STACK EMISSIONS MONITORING REPORT

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Operator & Address:
Celtic Recycling 29-31 Clearwater Road Queensway Meadows Newport Gwent NP19 4ST

Permit Reference:
EPR Permit: EPR/YP3135TE

Release Point:
A1 Shredder

Sampling Date(s):
14th December 2018

SOCOTEC UK Job Number:	LSO 181204
Report Date:	8th January 2019
Version:	1
Report By:	Stephen Huntley
MCERTS Number:	MM 02 081
MCERTS Level:	MCERTS Level 2 - Team Leader
Technical Endorsements:	1, 2, 3 & 4
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MCERTS Number:	MM 07 862
Business Title:	MCERTS Level 2 - Operations Manager (LSO)
Technical Endorsements:	1, 2, 3 & 4
Signature:	

1015

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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 UK 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
Gwent
NP19 4ST

EPR Permit: EPR/YP3135TE

Stack Emissions Monitoring Test House

SOCOTEC UK - 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 +/-**	**Limit**	**MCERTS accredited result**
Total Particulate Matter	mg/m³	1.58	0.63	10	✓
Particulate Emission Rate	g/hr	20.56	8.25	-	
Oil Mist	mg/m³	0.25	0.14	-	×
Oil Mist Emission Rate	g/hr	3.35	1.81	-	
Moisture	%	2.4	0.07	-	✓
Stack Gas Temperature	°C	17	-	-	✓
Stack Gas Velocity	m/s	25.2	0.61	-	
Gas Volumetric Flow Rate (Actual)	m³/hr	14423	742	-	
Gas Volumetric Flow Rate (STP, Wet)	m³/hr	13491	694	-	
Gas Volumetric Flow Rate (STP, Dry)	m³/hr	13160	677	-	
Gas Volumetric Flow Rate at Reference Conditions	m³/hr	13491	694	-	

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	14 December 2018	09:25 - 10:25	60 minutes
Oil Mist Run 1	14 December 2018	09:25 - 10:25	60 minutes
Preliminary Stack Traverse	14 December 2018	x	-

EXECUTIVE SUMMARY

PROCESS DETAILS

Parameter	Process Details
Description of process	Shredding papered covered copper
Continuous or batch	Batch
Product Details	Shredded clean copper
Part of batch to be monitored (if applicable)	Representative 1 Hr 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 UK 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 UK Technical Procedure**	**UKAS Lab Number**	**MCERTS Accredited Method**	**Limit of Detection (LOD)**	**Calculated MU +/- %**
TPM	SRM - BS EN 13284-1	AE 104	1015	Yes	0.32 mg/m³	40.1%
Oil Mist	SRM - BS EN 13284-1 / MDHS 84	AE 061	1015	No	0.007 mg/m³	53.9%
H_2O	SRM - BS EN 14790	AE 105	1015	Yes	0.01%	2.92%
Velocity	SRM - BS EN ISO 16911-1	AE 154	1015	Yes	5 Pa	2.44%
Volumetric Flow Rate	SRM - BS EN ISO 16911-1	AE 154	1015	Yes	-	5.14%

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 and archiving details:

SAMPLING METHODS WITH SUBSEQUENT ANALYSIS							
Species	Analytical Technique	Analytical Procedure	UKAS Lab Number	UKAS Accredited Lab Analysis	Analysis Lab	Sample Archive Location	Archive Period
TPM	Gravimetric	AE 106	1015	Yes	SOCOTEC UK - (Cirencester)	SOCOTEC UK - (Cirencester)	8 Weeks
Oil Mist	GC/FID	SOP	N/A	No	SAL	SAL	8 Weeks

Please note, at least one of the metals analysed fall outside of the labs UKAS accreditation. For an individual breakdown please refer to the metals summary in appendix 2

ON-SITE TESTING							
Species	Analytical Technique	Analytical Procedure	UKAS Lab Number	MCERTS Accredited Analysis	Laboratory	Data Archive Location	Archive Period
H_2O	Gravimetric	AE 105	1015	Yes	SOCOTEC UK - (Cirencester)	-	-

EXECUTIVE SUMMARY

SAMPLING LOCATION					
Sampling Plane Validation Criteria	**Value**	**Units**	**Requirement**	**Compliant**	**Method**
Lowest Differential Pressure	471	Pa	>= 5 Pa	Yes	BS EN 15259
Lowest Gas Velocity	23.5	m/s	-	-	-
Highest Gas Velocity	26.5	m/s	-	-	-
Ratio of Gas Velocities	1.1	: 1	< 3 : 1	Yes	BS EN 15259
Mean Velocity	25.2	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	0.45	m
Width	-	m
Area	0.16	m^2
Port Depth	90	mm

SAMPLING LINES & POINTS		
	Isokinetic	**Non-Iso & Gases**
Sample port size	3"	-
Number of lines used	1	-
Number of points / line	4	-
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	No
Handrail / obstructions do not hamper insertion of sampling equipment	No
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

Single port

Only one line available for sampling, however the number of sampling points were doubled in line with the standard reference method.

APPENDICES

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APPENDIX 1 - Monitoring Schedule, Calibration Checklist & Monitoring Team

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 UK Technical Procedure**	**UKAS Lab Number**	**MCERTS Accredited Method**	**Number of Samples**
TPM	SRM - BS EN 13284-1	AE 104	1015	Yes	1
Oil Mist	SRM - BS EN 13284-1 / MDHS 84	AE 061	1015	No	1
H_2O	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	P1959	Horiba PG-250 Analyser	-	Laboratory Balance	P66
Box Thermocouples	P1959	FT-IR Gasmet	-	Tape Measure	P1256
Meter In Thermocouple	P1959	FT-IR Oven Box	-	Stopwatch	P2674
Meter Out Thermocouple	P1959	Bernath 3006 FID	-	Protractor	-
Control Box Timer	-	Signal 3030 FID	-	Barometer	P1313
Oven Box	-	Servomex	-	Digital Micromanometer	P2868
Probe	P1972	JCT Heated Head Filter	-	Digital Temperature Meter	P1475
Probe Thermocouple	P2137	Thermo FID	-	Stack Thermocouple	P1711
Probe	-	Stackmaster	-	Mass Flow Controller	-
Probe Thermocouple	-	FTIR Heater Box for Heated Line	-	MFC Display module	-
S-Pitot	P2712 (0.84)	Anemometer	-	1m Heated Line (1)	-
L-Pitot	-	Ecophysics NOx Analyser	-	1m Heated Line (2)	-
Site Balance	P2770	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)	P2191		-	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
John Norvell	MM 02 126	MCERTS Level 2	Sep-22	Jun-18	Jun-18	Mar-19	Dec-18	Sep-22
Stephen Huntley	MM 02 081	MCERTS Level 2	Sep-22	Mar-22	Mar-22	Mar-22	Nov-18	Sep-22

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

TOTAL PARTICULATE MATTER SUMMARY					
Parameter	**Sampling Times**	**Concentration mg/m³**	**Uncertainty mg/m³**	**Limit mg/m³**	**Emission Rate g/hr**
Run 1	09:25 - 10:25 14 December 2018	1.58	0.63	10	21
Blank	-	0.32	-	-	-

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	311275	0.14410	0.14420	0.00010	68.72550	68.72790	0.00240	0.00250

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	311274	0.14360	0.14360	0.00000	68.24730	68.24760	0.00030	0.00050

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	mm Hg	753.76
Stack static pressure, P_{static}	mm H_2O	15.81
$P_s = P_b + \frac{(P_{static})}{13.6}$	mm Hg	754.92
Vol. of water vapour collected, V_{wstd}		
Moisture trap weight increase,Vlc	g	31.1
$V_{wstd} = (0.001246)(V_{lc})$	m^3	0.0387506
Volume of gas metered dry, V_{mstd}		
Volume of gas sample through gas meter, V_m		1.495
Gas meter correction factor, Y_d		1.085
Mean dry gas meter temperature, T_m		14.000
Mean pressure drop across orifice, DH	mmH_2O	85.418
$V_{mstd} = \frac{(0.3592)(V_m)(P_b+(DH/13.6))(Y_d)}{T_m + 273}$		1.543
Volume of gas metered wet, V_{mstw}		
$V_{mstw} = V_{mstd} + V_{wstd}$	m^3	1.5820
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		20.9
% oxygen reference condition		21
O_2 Reference Factor: O_2 Ref = 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}		
$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}}$		0.0245
	%	2.45
Moisture by FTIR	%	-
Velocity of stack gas, V_s		
Pitot tube velocity constant, K_p		34.97
Velocity pressure coefficient, C_p		0.84
Mean of velocity heads, DP_{avg}	mm H_2O	50.92
Mean square root of velocity heads, ÖDP		7.14
Mean stack gas temperature, T_s	°C	17
$V_s = \frac{(K_p)(C_p)(ÖDP)(Ö(T_s + 273))}{(M_s)(P_s)}$	m/s	24.30

Molecular weight of dry gas, M_d		
CO_2	%	0.03
O_2	%	20.90
Total	%	20.93
N_2 (100 -Total)	%	79.07
$M_d = 0.44(\%CO_2)+0.32(\%O_2)+0.28(\%N_2)$		28.84
Molecular weight of wet gas, M_s		
$M_s = M_d(1 - B_{wo}) + 18(B_{wo})$	g/gmol	28.58
Actual flow of stack gas, Q_a		
Area of stack, A_s	m^2	0.16
$Q_a = (60)(A_s)(V_s)$	m³/min	231.9
Total flow of stack gas, Q		
Conversion factor (K/mm.Hg)		0.3592
$Q_{std} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})}{(T_s)+273}$	Dry	211.6
$Q_{stdO2} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})(O_2REF)}{(T_s)+273}$	@O_2ref	No O2 Ref
$Q_{stw} = \frac{(Q_a)P_s(0.3592)}{(T_s)+273}$	Wet	216.88
Percent isokinetic, %I		
Nozzle diameter, D_n	mm	5.03
Nozzle area, A_n	mm^2	19.87
Total sampling time, q	min	60
$\%I = \frac{(4.6398E6)(T_s+273)(V_{mstd})}{(P_s)(V_s)(A_n)(q)(1-B_{wo})}$	%	97.3
Acceptable isokinetic range 95% to 115%		Yes
Particulate Concentration, C		
Mass collected on filter, M_f	g	0.00010
Mass collected in probe, M_p	g	0.00240
Total mass collected, M_n	g	0.00250
$C_{wet} = \frac{M_n}{V_{mstw}}$	mg/m³	1.580
$C_{dry} = \frac{M_n}{V_{mstd}}$	mg/m³	1.620
$C_{dry@X\%O2} = \frac{M_n}{V_{mstd@X\%oxygen}}$	mg/m³	No O2 Ref
Particulate Emission Rates, E		
$E = [(C_{wet})(Q_{stw})(60)] / 1000$		20.56

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	27.04	0.24	0.24	-381	0.54	Yes

ISOKINETICITY		
Run	Isokinetic Variation %	Acceptable Isokineticity
Run 1	97.30	Yes

Acceptable isokinetic range 95% to 115%

WEIGHING BALANCE UNCERTAINTY			
Run	Result mg/m³	5% ELV mg/m³	LOD < 5% ELV
Run 1	0.32	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	0.32	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	17	180	160

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

OIL MIST SUMMARY

OIL MIST					
Test	Sampling Times	Concentration mg/m³	LOD mg/m³	Limit mg/m³	Emission Rate g/hr
Run 1	09:25 - 10:25 14 December 2018	0.2538	0.007	-	3.35
Field Blank	-	0.0634	-	-	-

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

OIL MIST	PARTICULATE PHASE			VAPOUR PHASE		
	Stack LOD mg/m³	Laboratory Result ug	Concentration mg/m³	Stack LOD mg/m³	Laboratory Result ug	Concentration mg/m³
Oil Mist	0.06344	400	0.25378	-	-	-
Volume Sampled m^3		1.5762			-	

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

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

ISOKINETIC SAMPLING EQUATIONS RUN 1 — OIL MIST

Absolute pressure of stack gas, P_s		
Barometric pressure, P_b	mm Hg	753.8
Stack static pressure, P_{static}	mm H_2O	15.8
$P_s = P_b + (P_{static})$ / 13.6	mm Hg	754.9
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		1.495
Gas meter correction factor, Y_d		1.0852
Mean dry gas meter temperature, T_m		14.00
Mean pressure drop across orifice, DH	mm	47.28
$V_{mstd} = (0.3592)(V_m)(P_b+(DH/13.6))(Y_d) / T_m + 273$		1.54
Volume of gas metered wet, V_{mstw}		
$V_{mstw} = V_{mstd} + V_{wstd}$	m^3	1.5762
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		20.9
% oxygen reference condition		21
O_2 Reference Factor: 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}		
$B_{wo} = V_{wstd} / (V_{mstd} + V_{wstd})$		0.0245
	%	2.45
Moisture by FTIR	%	-

Molecular weight of dry gas, M_d		
CO_2	%	0.03
O_2	%	20.90
Total	%	20.93
N_2 (100 -Total)	%	79.07
$M_d = 0.44(\%CO_2)+0.32(\%O_2)+0.28(\%N_2)$		28.84
Molecular weight of wet gas, M_s		
$M_s = M_d(1 - B_{wo}) + 18(B_{wo})$	g/gmol	28.58
Velocity of stack gas, V_s		
Pitot tube velocity constant, K_p		34.97
Velocity pressure coefficient, C_p		0.84
Mean of velocity heads, DP_{avg}	mm H_2O	50.92
Mean square root of velocity heads, ÖDP		7.14
Mean stack gas temperature, T_s	°C	9
$V_s = (K_p)(C_p)(ÖDP)(Ö(T_s + 273)) / (M_s)(P_s)$	m/s	23.97
Actual flow of stack gas, Q_a		
Area of stack, A_s	m^2	0.16
$Q_a = (60)(A_s)(V_s)$	m^3/min	228.7
Total flow of stack gas, Q		
Conversion factor (K/mm.Hg)		0.3592
$Q_{std} = (Q_a)P_s(0.3592)(1-B_{wo}) / (T_s) +273$	Dry	214.5
$Q_{stdO2} = (Q_a)P_s(0.3592)(1-B_{wo})(O_2REF) / (T_s) +273$	@O2ref	No O2 Ref
$Q_{stw} = (Q_a)P_s(0.3592) / (T_s) +273$	Wet	219.9
Percent isokinetic, %I		
Nozzle diameter, D_n	mm	5.03
Nozzle area, A_n	mm^2	19.87
Total sampling time, q	min	60
$\%I = (4.6398E6)(T_s+273)(V_{mstd}) / (P_s)(V_s)(A_n)(q)(1-B_{wo})$	%	95.6
Acceptable isokinetic range 95% to 115%		Yes

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

OIL MIST QA CHECKLIST

Leak Test Results	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 litre/min
Run 1	27.0	0.24	0.24	-381	0.54	Yes

Isokinetic Criterion Compliance	Isokinetic Variation %	Acceptable Isokineticity
Run 1	95.6	Yes

Filtration / Temp	Filter Material	Filter Size mm	Maximum Filtration Temperature °C	Maximum storage / transit Temperature °C
Run 1	Quartz Fibre	47	10	15

Metals	Type of Absorbers - Metals	Absorption Solutions - Metals
Run 1	Quartz Filter	None

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	09:25 - 10:25 14 December 2018	3.0882	3.1193	0.0311	2.4	0.0	2.9

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	60	1582	27.0	0.240	0.240	0.541	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	17	^oC
Stack static pressure	0.155	kPa
Barometric Pressure	100.5	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	0.028571	0.000286	0.000561	0.027872	0.000279	0.000547
O_2	32	1.427679	20.900000	0.209000	0.298385	20.388066	0.203881	0.291076
N_2	28	1.249219	79.071429	0.790714	0.987775	77.134619	0.771346	0.963581
H_2O	18	0.803070	-	-	-	2.449443	0.024494	0.019671

Where: p = M / 22.41 pi = r x p

Calculation of Stack Gas Densities		
Determinand	Result	Units
Dry Density (STP), P_{STD}	1.2867	kg/m^3
Wet Density (STP), P_{STW}	1.2749	kg/m^3
Dry Density (Actual), P_{Actual}	1.2036	kg/m^3
Average Wet Density (Actual), $P_{ActualW}$	1.192	kg/m^3

Where:

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

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

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

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

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

PRELIMINARY STACK SURVEY

TRAVERSE 1

Date of Survey	14 December 2018
Time of Survey	x
Velocity Measurement Device:	S-Type Pitot

Sampling Line A								
Traverse Point	Distance into duct (m)	DP pt mmH_2O (average of 3 readings)	DP pt Pa (average of 3 readings)	Temp °C	Velocity m/s	Volumetric Flow Rate (actual) m^3/s	O_2 % Vol	Angle of Swirl °
1	0.01	48.0	470	17	23.5	3.7	20.9	<15
2	0.04	51.0	500	17	24.2	3.9	-	<15
3	0.07	51.0	500	17	24.2	3.9	-	<15
4	0.10	55.0	539	17	25.1	4.0	-	<15
5	0.15	57.7	565	17	25.7	4.1	-	<15
6	0.30	61.0	598	17	26.5	4.2	-	<15
7	0.35	61.0	598	17	26.5	4.2	-	<15
8	0.38	57.0	559	17	25.6	4.1	-	<15
9	0.41	57.0	559	17	25.6	4.1	-	<15
10	0.44	54.0	529	17	24.9	4.0	-	<15
Mean	-	55.3	542	17	25.2	4.0	20.9	-

PRELIMINARY STACK SURVEY QUALITY ASSURANCE CHECKLIST

PITOT LEAK CHECK								
Run	Pre Traverse Leak Rate				Post Traverse Leak Rate			
	Start Value Pa	End Value Pa	Difference %	Outcome	Start Value Pa	End Value Pa	Difference %	Outcome
Run 1	92	91	1.1	Pass	93	93	0.0	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	138	138.5	-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	470	Pa	>= 5 Pa	Yes
Lowest Gas Velocity	23.5	m/s	-	-
Highest Gas Velocity	26.5	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, $V = K_{pt} \times (1\text{-}e) * \sqrt{(2 * DP_{pt} / P_{ActualW})}$		
Where:		
K_{pt} = Pitot tube calibration coefficient		
(1-e) = Compressibility correction factor, assumed at a constant 0.998		
Average Stack Gas Velocity, Va	**25.2**	m/s

Calculation of Stack Gas Volumetric Flowrate, Q			
Duct gas flow conditions	Actual	Reference	Units
Temperature	17	0	°C
Total Pressure	100.655	101.3	kPa
Oxygen	20.9	21	%
Moisture	2.45	2.45	%
Pitot tube calibration coefficient, K_{pt}	0.84		

Gas Volumetric Flowrate	Result	Units
Average Stack Gas Velocity (Va)	25.19	m/s
Stack Area (A)	0.16	m^2
Gas Volumetric Flowrate (Actual), Q_{Actual}	14423	m^3/hr
Gas Volumetric Flowrate (STP, Wet), Q_{STP}	13491	m^3/hr
Gas Volumetric Flowrate (STP, Dry), $Q_{STP,Dry}$	13160	m^3/hr
Gas Volumetric Flowrate (REF), Q_{Ref}	13491	m^3/hr

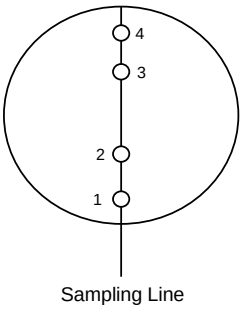
Where:
Q_{Actual} = Va x A x 3600
Q_{STP} = Q (Actual) x (Ts / Ta) x (Pa / Ps) x 3600
$Q_{STP,Dry}$ = Q (STP) / (100 - (100 / Ma)) x 3600
Q_{Ref} = Q (STP) x ((100 - Ma) / (100 - Ms)) x ((20.9 - O_2a) / (20.9 - O_2s))

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	0.45	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
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-

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	0.5000	-	-
as a %	0.06	0.69	0.50	1.0	N/A	3.16052	0.89	0.005
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**	**Yes**	**Yes**

Run	Volume (STP)	Mass of particulate	O_2 Correction	Leak	Uncollected Mass	Combined uncertainty
	m^3	mg	-	mg/m^3	mg	
Run 1	1.44	2.5000	1.0	0.008	0.0003	-
MU as mg/m^3	0.02	0.3161	-	0.008	0.0002	**0.32**
MU as %	1.31	20.0000	-	0.512	0.0115	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.63**	**mg/m³**	**40.10**	**%**

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

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - OIL MIST

Run	Sampled Volume	Sampled Gas Temp	Sampled Gas Pressure	Sampled Gas Humidity	Oxygen Content	Concentration in impinger	Leak
	m^3	K	kPa	% by volume	% by volume	mg	%
MU required	**<=2%**	**<2.5 k**	**<=1%**	**<=1%**	**<=5%**	**<5%**	**<=2%**
Run 1	0.001	2.0	0.50	1.0	0.10	-	-
as a %	0.06	0.73	0.49	1.0	-	-	0.89
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**No**	**Yes**

Run	Volume (STP)	O2 Correction	Mass of Heavy Metals	Leak	Lab Uncertainty	Combined uncertainty
	m^3	-	mg	mg/m^3	mg	
Run 1	1.5878	-	400.0000	0.0013	-	-
MU as mg/m^3	0.0034	-	0.0634	0.0013	0.02538	**0.0684**
MU as %	1.3344	-	25.0000	0.5124	10.00000	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.14**	**mg/m^3**	**53.93**	**%**

(k is a coverage factor which gives a 95% confidence in the quoted figures)
Reference – SOCOTEC UK 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	0.69	0.50	1.0	N/A	0.89
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	1.44	31100	1.0	103.27	58	-
MU as % v/v	0.03	0.01	-	0.01	0.005	**0.04**
MU as %	1.31	0.32	-	0.51	0.19	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.07**	**% v/v**	**2.92**	**%**

MEASUREMENT UNCERTAINTY BUDGET - VELOCITY & VOLUMETRIC FLOW RATE

Measured Velocity at Actual Conditions	25.2	m/s
Measured Volumetric Flow rate at Actual Conditions	14423	m^3/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	-	0.60		
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	9.92	<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	1.48	<1% of value	Yes
Uncertainty of absolute pressure in the duct	pa	514		
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	0.31
Expanded uncertainty at a 95% Confidence Interval	0.61

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	378
Expanded uncertainty at a 95% Confidence Interval	742

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 UK Technical Procedure AE150 Estimation of Uncertainty of Measurement

END OF REPORT

Thank you for choosing SOCOTEC UK 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