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Stack Emissions Testing Report Commissioned by
Barrow Borough Council

Installation Name & Address

Thornccliffe Crematorium
Devonshire Road
Barrow-In Furness
Cumbria
LA14 5PD

PPC Permit: PPC/B/10

Stack Reference

Combined Cremator Exhaust

Dates of the Monitoring Campaign

6th January 2022

Job Reference Number

EMT02361

Report Written by

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Team Leader
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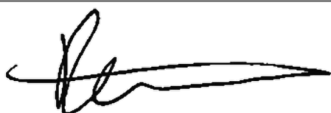
Report Date

3rd February 2022

Version

Version 1

Signature of Report Approver



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Executive Summary

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MONITORING OBJECTIVES

Thornccliffe Crematorium, Barrow-in-Furness
Combined Cremator Exhaust
6th January 2022

Overall Aim of the Monitoring Campaign

Element were commissioned by Barrow Borough Council to carry out stack emissions testing for Thornccliffe Crematorium on the Combined Cremator Exhaust at Barrow-in-Furness.

The aim of the monitoring campaign was to demonstrate compliance with a set of emission limit values (ELVs) as specified in the Site's Permit.

Special Requirements

There were no special requirements.

Target Parameters

Total Particulate Matter, Hydrogen Chloride, Mercury, Total VOCs (as Carbon), Carbon Monoxide

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MONITORING RESULTS

Thornccliffe Crematorium, Barrow-in-Furness

Combined Cremator Exhaust

6th January 2022

where MU = Measurement Uncertainty associated with the Result

Parameter		Concentration				Mass Emission			
		Units	Result	MU +/-	Limit	Units	Result	MU +/-	Limit
Total Particulate Matter	¹	mg/m ³	1.9	0.6	20	g/hr	3.7	1.4	-
Hydrogen Chloride	¹	mg/m ³	3.7	0.4	30	g/hr	7.1	1.8	-
Mercury	¹	mg/m ³	0.013	0.003	0.05	g/hr	0.025	0.008	-
Total VOCs (as Carbon)	¹	mg/m ³	8.4	0.7	20	g/hr	16.3	4.0	-
Carbon Monoxide	¹	mg/m ³	21.5	1.8	100	g/hr	41.8	10.1	-
Oxygen		% v/v	Dry 13.41	0.44					
Water Vapour		% v/v	8.5	0.4					
Stack Gas Temperature		°C	112.1						
Stack Gas Velocity		m/s	7.6	1.71					
Volumetric Flow Rate (ACTUAL)		m ³ /hr	3979	910					
Volumetric Flow Rate (REF)	¹	m ³ /hr	1941	444					

NOTE: VOLUMETRIC FLOW RATE & VELOCITY DATA TAKEN FROM AN AVERAGE OF ALL OF THE ISOKINETIC RUNS.

¹ Reference Conditions (REF) are: 273K, 101.3kPa, dry gas, 11% oxygen.

† Unless stated otherwise in the respective Permit, as per PG5/2(12), these emission limits are applicable '...for 95% of cremations'.

‡ Unless stated otherwise in the respective Permit, as per PG5/2(12), these emission limits are applicable '...for all cremations'.

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MONITORING DATE(S) & TIMES

Thornccliffe Crematorium, Barrow-in-Furness

Combined Cremator Exhaust

6th January 2022

Parameter		Units	Concentration	Units	Mass Emission	Sampling Date(s)	Sampling Times	Duration mins
Total Particulate Matter	R1	mg/m ³	1.9	g/hr	3.7	06/01/2022	12:34 - 13:34	60
Hydrogen Chloride	R1	mg/m ³	3.7	g/hr	7.1	06/01/2022	12:34 - 13:34	60
Mercury	R1	mg/m ³	0.013	g/hr	0.025	06/01/2022	14:18 - 14:53 , 14:55 - 15:20	60
Total VOCs (as Carbon)	R1	mg/m ³	8.4	g/hr	16.3	06/01/2022	12:34 - 13:34	60
Carbon Monoxide	R1	mg/m ³	21.5	g/hr	41.8	06/01/2022	12:34 - 13:34	60
Oxygen	R1	% v/v	13.4			06/01/2022	12:34 - 13:34	60
Velocity Traverse	R1					06/01/2022	12:15 - 12:22	

All results are expressed at the respective reference conditions.

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PROCESS DETAILS

Thornccliffe Crematorium, Barrow-in-Furness

Combined Cremator Exhaust

6th January 2022

Standard Operating Conditions

Parameter	Value
Process Status	Normal Operation
Capacity (of 100%) and Tonnes / Hour	N/A
Continuous or Batch Process	Batch
Feedstock (if applicable)	N/A
Abatement System	Carbon & Particulate Filtration
Abatement System Running Status	On
Fuel	Natural Gas
Plume Appearance	No Visible Plume

Site Specific Operating Conditions

Parameter	Status
Cremator Number	Cremator 2 / Cremator 2
Load Time	12:30 / 14:17
Coffin Type	Standard / Standard
Sex	Female / Male
Temperature in Primary Chamber	886 / 890
Temperature in Secondary Chamber	888 / 888
Cremation Number	51364 / 51366
Size	Medium / medium

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MONITORING & ANALYTICAL METHODS

Thornccliffe Crematorium, Barrow-in-Furness

Combined Cremator Exhaust

6th January 2022

Parameter	Monitoring				Analysis				Overall Status	LOD (Average)
	Standard	Technical Procedure	Sampling Status	Testing Lab	Analytical Procedure	Analytical Technique	Analysis Status	Analysis Lab		
Total Particulate Matter	EN 13284-1	CAT-TP-01	MCERTS	EET	CAT-TP-03	Gravimetric	MCERTS	EET	MCERTS	0.28 mg/m ³
Hydrogen Chloride	EN 1911	CAT-TP-11	MCERTS	EET	CAT-AP-01	IC	MCERTS	EET	MCERTS	0.022 mg/m ³
Mercury	EN 13211	CAT-TP-06	MCERTS	EET	CAT-AP-08	ICP-MS	MCERTS	EET	MCERTS	0 mg/m ³
Water Vapour	EN 14790	CAT-TP-05	MCERTS	EET	CAT-TP-05	Gravimetric	MCERTS	EET	MCERTS	0.10 % v/v
Total VOCs (as Carbon)	EN 12619:2013	CAT-TP-20	MCERTS	EET	Flame Ionisation Detection by Sick 3006 FID				MCERTS	0.32 mg/m ³
Carbon Monoxide	EN 15058	CAT-TP-21	MCERTS	EET	NDIR by Horiba PG-250				MCERTS	0.25 mg/m ³
Oxygen	EN 14789	CAT-TP-21	MCERTS	EET	Dry Zirconia Cell by Horiba PG-250				MCERTS	0.1 %
Velocity & Vol. Flow Rate	EN 16911-1 (MID)	CAT-TP-41	MCERTS	EET	Pitot Tube and Thermocouple				MCERTS	1.8 m/s

ANALYSIS LABORATORIES

(with short name reference as appears in the table above)

Element (Stockport Lab - EET)	ISO 17025 Accreditation Number: 4279
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SUMMARY OF SAMPLING DEVIATIONS

Parameter	Run	Deviation
Total Particulate Matter & Mercury	1	One out of two sampling lines was used due to sampling location restrictions, however the number of sample points used on the available line were increased to the minimum required by the Standard

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SUITABILITY OF SAMPLING LOCATION

Duct Characteristics

Parameter	Units	Value
Type	-	Circular
Depth	m	0.43
Width	m	-
Area	m ²	0.15
Port Depth	cm	13
Orientation of Duct	-	Horizontal
Number of Ports	-	2
Sample Port Size	-	5" Flange

Location of Sampling Platform

General Platform Information	Value
Permanent / Temporary Platform	On Roof
Inside / Outside	Outside

Platform Details

EA Technical Guidance Note M1 / EN 15259 Platform Requirements	Value
Sufficient working area to manipulate probe and operate the measuring instruments	Yes
Platform has 2 levels of handrails (approx. 0.5m & 1.0m high)	Yes
Platform has vertical base boards (approx. 0.25m high)	Yes
Platform has chains / self closing gates at top of ladders	Yes
There are no obstructions present which hamper insertion of sampling equipment	Yes
Safe Access Available	Yes
Easy Access Available	No

Sampling Location / Platform Improvement Recommendations

All platforms should be designed in accordance with the requirements in the Environment Agency's Technical Guidance Note M1 and EN 15259.

EN 15259 Homogeneity Test Requirements

There is no requirement to perform a EN 15259 Homogeneity Test on this Stack.

Sampling Plane Validation Criteria (from EN 15259)

Criteria in EN 15259	Units	Traverse 1	Required	Compliant
Lowest Differential Pressure	Pa	33.3	> 5 Pa	Yes
Mean Velocity	m/s	7.52	-	-
Lowest Gas Velocity	m/s	7.21	-	-
Highest Gas Velocity	m/s	7.82	-	-
Ratio of Above	: 1	1.08	< 3 : 1	Yes
Maximum Angle of Swirl	°	5.00	< 15°	Yes
No Local Negative Flow	-	Yes	-	Yes

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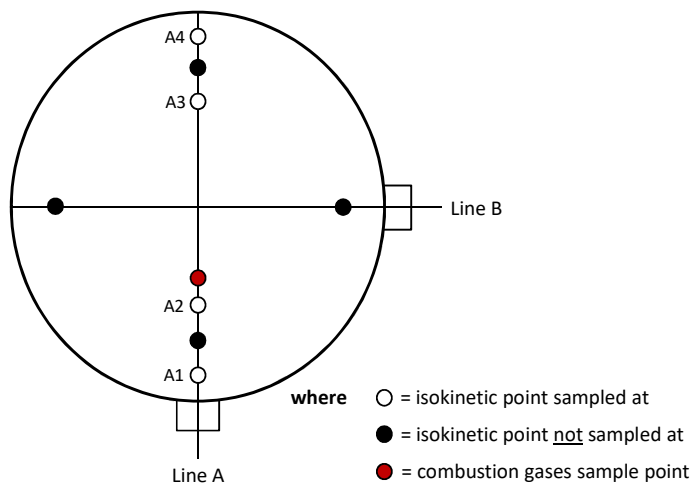
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PLANT PHOTOS

Photo 1



SAMPLE POINTS



APPENDICES

APPENDIX CONTENTS

APPENDIX 1 - Stack Emissions Monitoring Personnel, List of Equipment & Methods and Technical Procedures Used

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

APPENDIX 1

STACK EMISSIONS MONITORING PERSONNEL

Position	Name	MCERTS Accreditation	MCERTS Number	Technical Endorsements
Team Leader	Sean Egan	MCERTS Level 2	MM 17 1416	TE1 TE2 TE3 TE4
Technician	Chris Whiteley	MCERTS Level 1	MM 19 1543	None

LIST OF EQUIPMENT

Extractive Sampling		Instrumental Analysers		Miscellaneous Items	
Equipment Type	Equipment I.D.	Equipment Type	Equipment I.D.	Equipment Type	Equipment I.D.
Control Box DGM (1)	CAT 7.60	Horiba PG-250	CAT 9.2	Digital Manometer (1)	CAT 3.272
Control Box DGM (2)	-	Horiba PG-350E	-	Digital Manometer (2)	CAT 3.273
Box Thermocouples (1)	CAT 3.159	Servomex 4900	-	Digital Temperature Meter	CAT 3.272 / 3.273
Box Thermocouples (2)	-	Eco Physics CLD 822Mh	-	Stopwatch	CAT 14.53
Umbilical (1)	CAT 3.159	ABB AO2020-URAS26	-	Barometer	CAT 13.43
Umbilical (2)	-	Testo 350 XL	-	Stack Thermocouple (1)	CAT 4.1562
Oven Box (1)	CAT 12.113	JCT JCC P1 Cooler	CAT 4.0109	Stack Thermocouple (2)	CAT 4.1376
Oven Box (2)	-	Gasmet DX4000	-	Stack Thermocouple (3)	CAT 4.1497
Heated Probe (1)	CAT 5.135	Gasmet Sampling System	-	1m Heated Line (1)	-
Heated Probe (2)	CAT 5.136	Sick 3006 FID	CAT 8.10	1m Heated Line (2)	-
Heated Probe (3)	CAT 5.137	M&C PSS	CAT 12.112	1m Heated Line (3)	-
S-Pitot (1)	CAT 21S.59	Mass Flow Controller (1)	CAT 6.15	5m Heated Line (1)	CAT 20.1
S-Pitot (2)	CAT 21P.181	Mass Flow Controller (2)	CAT 6.16	10m Heated Line (1)	CAT 20.122
L-Pitot	CAT 21L.13	Mass View (1)	CAT 25.57	20m Heated Line (1)	CAT 20.123
Site Balance	CAT 17.52	Mass View (2)	CAT 25.58	20m Heated Line (2)	-
500g / 1Kg Check Weights	CAT 17.52	Hioki 5043 (V)	CAT 11.73	Dual Channel Heater Controller	CAT 3.160
Last Impinger Arm	CAT 4.930	Hioki 5043 (V)	-	Single Channel Heater Controller	-
Callipers	CAT 23.42	Bioaerosols Temperature Logger	-	Laboratory Balance	CAT 1.18, 1.18a, 1.18b
Tubes Kit Thermocouple	CAT 4.1222	Electronic Refrigerator	-	Tape Measure	CAT 16.03

METHODS & TECHNICAL PROCEDURES USED

Parameter	Standard	Technical Procedure
Total Particulate Matter	EN 13284-1	CAT-TP-01
Hydrogen Chloride	EN 1911	CAT-TP-11
Mercury	EN 13211	CAT-TP-06
Water Vapour	EN 14790	CAT-TP-05
Total VOCs (as Carbon)	EN 12619:2013	CAT-TP-20
Carbon Monoxide	EN 15058	CAT-TP-21
Oxygen	EN 14789	CAT-TP-21
Velocity & Vol. Flow Rate	EN 16911-1 (MID)	CAT-TP-41

PRELIMINARY STACK SURVEY: CALCULATIONS

General Stack Details

Stack Details (from Traverse)	Units	Value
Stack Diameter / Depth, D	m	0.43
Stack Width, W	m	-
Stack Area, A	m ²	0.15
Average Stack Gas Temperature, T _a	°C	94.3
Average Stack Gas Pressure	mmH ₂ O	3.7
Average Stack Static Pressure, P _{static}	kPa	0.012
Average Barometric Pressure, P _b	kPa	100.5
Average Pitot Tube Calibration Coefficient, C _p	-	0.85

Stack Gas Composition & Molecular Weights

Component	Conc ppm	Conc Dry % v/v	Conc Wet % v/v	Volume Fraction r	Molar Mass M	Density kg/m ³ p	Conc kg/m ³ p _i
CO ₂ (Estimated)	-	3.00	2.74	0.0300	44.01	1.9635	0.05891
O ₂	-	13.41	12.26	0.1341	32.00	1.4277	0.19139
N ₂	-	83.59	76.47	0.8359	28.01	1.2498	1.04480
Moisture (H ₂ O)	-	-	8.52	0.0852	18.02	0.8037	0.06849

Where: $p = M / 22.41$

$p_i = r \times p$

Calculation of Stack Gas Densities

Determinand	Units	Result
Dry Density (STP), P _{STD}	kg/m ³	1.295
Wet Density (STP), P _{STW}	kg/m ³	1.253
Dry Density (Actual), P _{Actual}	kg/m ³	0.955
Average Wet Density (Actual), P _{ActualW}	kg/m ³	0.924

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

P_{STW} = sum of all wet concentrations / 100 x density, kg/m³ (including water vapour)

$P_{Actual} = P_{STD} \times (T_{STP} / (P_{STP})) \times ((P_{static} + P_b) / T_a)$

$P_{ActualW}$ (at each sampling point) = P_{STW} x (T_s / P_s) x (P_a / T_a)

Calculation of Stack Gas Volumetric Flowrate, Q

Duct gas flow conditions	Units	Actual	REF ¹
Temperature	°C	94.3	0.0
Total Pressure	kPa	100.5	101.3
Moisture	%	8.52	0.00
Oxygen (Dry)	%	13.4	11.0

Gas Volumetric Flowrate (from Traverse)	Units	Result
Gas Volumetric Flowrate (Actual)	m ³ /hr	3933
Gas Volumetric Flowrate (STP, Wet)	m ³ /hr	2901
Gas Volumetric Flowrate (STP, Dry)	m ³ /hr	2654
Gas Volumetric Flowrate REF ¹	m ³ /hr	2015

PRELIMINARY STACK SURVEY: VELOCITY TRAVERSE TO EN 16911-1 (MID)

(1 of 1)

Parameter	Units	Value
Date of Survey	-	06/01/2022
Time of Survey	-	12:15 - 12:22
Atmospheric Pressure	kPa	100.5
Average Stack Static Pressure	Pa	12
Result of Pitot Stagnation Test	-	Pass
Are Water Droplets Present?	-	Yes
Device Used	S-Type Pitot with Liquid Incline Manometer	

Parameter	Units	Value
Initial Pitot Leak Check	-	Pass
Final Pitot Leak Check	-	Pass
Orientation of Duct	-	Horizontal
Pitot Tube, C _p	-	0.85
Number of Lines Available	-	2
Number of Lines Used	-	1

Sampling Line A						
Traverse Point	Depth m	ΔP mmH ₂ O	Temp °C	Wet Density kg/m ³	Velocity m/s	Swirl °
STATIC (Units: Pa)		12.0				
Mean		3.7	94.3	0.924	7.52	
1	0.03	4.0	94.0	0.925	7.82	5.0
2	0.11	3.6	94.0	0.925	7.42	4.0
3	0.32	3.4	94.0	0.925	7.21	4.0
4	0.40	3.8	95.0	0.922	7.63	3.0

Sampling Line B - Restricted Access				
ΔP	Temp °C	Wet Density kg/m ³	Velocity m/s	Swirl °

PRELIMINARY STACK SURVEY: VELOCITY TRAVERSE TO EN 16911-1 (MID) - MEASUREMENT UNCERTAINTY

(1 of 1)

Performance characteristics (Uncertainty Components)	Uncertainty	Value	Units
Standard Uncertainty on the coefficient of the Pitot Tube	$u(k)$	0.005	-
Standard Uncertainty associated with the mean local dynamic pressures	$u(\Delta p_i)$	1.679	Pa
- Resolution	$u(res)$	0.52154	
- Calibration	$u(cal)$	0.137	
- Drift	$u(drift)$	1.096	
- Lack of Fit	$u(fit)$	0.066	
- Overall corrections to dynamic measurements	$u(C_f)$	1.820	
Standard uncertainty associated with the molar mass of the gas	$u(M)$	0.00005	-
- $\varphi_{O_2,w}$	-	12.263	
- $\varphi_{CO_2,w}$	-	2.744	
- Oxygen, dry	$u(\phi_{O_2,d})$	0.410	
- Carbon Dioxide, dry	$u(\phi_{CO_2,d})$	0.092	
- Water Vapour	$u(\phi_{H_2O})$	0.435	
- Oxygen, wet	$u(\phi_{O_2,w})$	0.380	
- Carbon Dioxide, wet	$u(\phi_{CO_2,w})$	0.085	
Standard uncertainty associated with the stack temperature	$u(T_c)$	1.874	K
Standard uncertainty associated with the absolute pressure in the duct	$u(p_c)$	175.700	Pa
- Atmospheric Pressure	$u(p_{atm})$	175.692	
- Static Pressure	$u(p_{stat})$	1.679	
Standard uncertainty associated with the density in the duct	$u(\rho)$	0.00499	-
Standard uncertainty associated with the local velocities	$u(v_i)$	1.713	Pa
Standard uncertainty associated with the mean velocity	$u(\bar{v})$	0.860	m/s
Standard uncertainty associated with the mean velocity (95% Confidence)	$U_c(v)$	1.686	m/s
Standard uncertainty associated with the mean velocity (95% Confidence), relative	$U_{c,rel}(v)$	22.42	%
Standard uncertainty associated with the volume flow rate (95% Confidence)	$U_c(qV,w)$	899.5	m ³ /hr
- $u^2(a)/a^2$	-	0.00053	
- $u^2(qV,w)/q^2V,w$	-	0.01362	
- $u^2(qV,w)$	-	210600	
- $u(qV,w)$	-	458.9	
Standard uncertainty associated with the volume flow rate (95% Confidence), relative	$U_{c,rel}(qV,w)$	22.87	%

TOTAL PARTICULATE MATTER: RESULTS SUMMARY

Thornccliffe Crematorium, Barrow-in-Furness
Combined Cremator Exhaust

Sample Runs

Parameter	Units	Run 1		Mean
Concentration	mg/m ³	1.9		1.9
Uncertainty	±mg/m ³	0.6		0.6
Mass Emission	g/hr	3.7		3.7
Uncertainty	±g/hr	1.4		1.4

Parameter	Units	Run 1		Mean
Water Vapour	% v/v	8.0		8.0
Uncertainty	±% v/v	0.4		0.4

Blank Runs

Parameter	Units	Blank 1		Maximum
Concentration	mg/m ³	0.28		0.28

NOTE: Where the Balance Uncertainty / Limit of Detection is higher than the Blank concentration, the Balance Uncertainty / Limit of Detection concentration has been reported.

General Sampling Information

Parameter	Value	
Standard	EN 13284-1	
Technical Procedure	CAT-TP-01	
Probe Material	Titanium	
Filter Housing Material	Titanium	
Positioning of Filter	In Stack	
Filter Size and Material	47mm Glass Fibre	
Number of Sampling Lines Used	1 / 2	FORMAT: Number Used / Number Required
Number of Sampling Points Used	4 / 4	FORMAT: Number Used / Number Required
Sample Point I.D.'s	B1 - B4	

Reference Conditions

Reference Conditions are: 273K, 101.3kPa, dry gas, 11% oxygen.

TOTAL PARTICULATE MATTER: ISOKINETIC SAMPLING CALCULATIONS

Test	Units	Run 1	
Absolute pressure of stack gas, P_s			
Barometric pressure, P_b	mmHg	753.8	
Stack static pressure, P_{static}	mmH ₂ O	1.2	
$P_s = (P_b + (P_{static} / 13.6))$	mmHg	753.9	
Volume of water vapour collected, V_{wstd}			
Total mass collected in impingers (liquid trap)	g	73.7	
Total mass collected in impingers (silica trap)	g	7.1	
Total mass of liquid collected, V_{lc}	g	80.8	
$V_{wstd} = (0.001246)(V_{lc})$	m ³	0.1007	
Volume of gas metered dry, V_{mstd}			
Volume of gas sample through gas meter, V_m	m ³	1.2590	
Gas meter correction factor, Y_d	-	0.9760	
Average dry gas meter temperature, T_m	°C	13.9	
Average pressure drop across orifice, ΔH	mmH ₂ O	47.1	
$V_{mstd} = ((0.3592)(V_m)(P_b + (\Delta H/13.6))(Y_d)) / (T_m + 273)$	m ³	1.1650	
Moisture content, B_{wo} & R_{wv}			
$B_{wo} = V_{wstd} / (V_{mstd} + V_{wstd})$	m ³	0.0795	
B_{wo} as a percentage	% v/v	7.95	
Reported Water Vapour, checked with Tables in EN 14790, R_{wv}	% v/v	7.95	
Volume of gas metered wet, V_{mstw}			
$V_{mstw} = (V_{mstd})(100/(100 - R_{wv}))$	m ³	1.2657	
Volume of gas metered at Oxygen Reference Conditions, $V_{mstd@X\%O_2}$ & $V_{mstw@X\%O_2}$			
IED & Incinerates Hazardous Material? (Yes = no positive O ₂ correction)	-	No	
% wet oxygen measured in gas stream, ACT%O _{2w}	% v/v	12.13	
% dry oxygen measured in gas stream, ACT%O _{2d}	% v/v	13.36	
% oxygen reference condition, REF%O ₂	% v/v	11.00	
O ₂ Reference Factor wet ($O_{2REFw} = (21 - REF\%O_2) / (21 - ACT\%O_{2w})$)	-	1.13	
O ₂ Reference Factor dry ($O_{2REFd} = (21 - REF\%O_2) / (21 - ACT\%O_{2d})$)	-	1.31	
$V_{mstw@X\%oxygen} = (V_{mstw}) / (O_{2REFw})$	m ³	1.1232	
$V_{mstd@X\%oxygen} = (V_{mstd}) / (O_{2REFd})$	m ³	0.8902	
Molecular weight of dry gas stream, M_d			
CO ₂ (Estimated)	% v/v	3.00	
O ₂	% v/v	13.36	
Total	% v/v	16.36	
N ₂	% v/v	83.64	
$M_d = 0.44(\%CO_2) + 0.32(\%O_2) + 0.28(\%N_2)$	g/gmol	29.01	
Molecular weight of stack gas (wet), M_s			
$M_s = M_d(1 - (R_{wv}/100)) + 18(R_{wv}/100)$	g/gmol	28.14	
Velocity of stack gas, V_s			
Pitot tube velocity constant, K_p	-	34.97	
Velocity pressure coefficient, C_p	-	0.85	
Average of velocity heads, ΔP_{avg}	mmH ₂ O	3.76	
Average square root of velocity heads, $\sqrt{\Delta P}$	√mmH ₂ O	1.94	
Average stack gas temperature, T_s	°C	111.5	
$V_s = ((K_p)(C_p)(\sqrt{\Delta P})(T_s + 273)) / (\sqrt{M_s}(P_s))$	m/s	7.77	
Total flow of stack gas: Actual (Q_a), Wet (Q_{stw}), Dry (Q_{std}), Wet@O_{2REF} (Q_{stwO_2}), Dry@O_{2REF} (Q_{stdO_2})			
Area of stack, A_s	m ²	0.15	
$Q_a = (60)(A_s)(V_s)$	m ³ /min	67.7	
Conversion factor (K/mm.Hg), C_f	-	0.3592	
$Q_{stw} = ((Q_a)(P_s)(C_f)) / ((T_s) + 273)$	m ³ /min	47.7	
$Q_{std} = ((Q_a)(P_s)(C_f)(1 - (R_{wv}/100))) / ((T_s) + 273)$	m ³ /min	43.9	
$Q_{stwO_2} = ((Q_a)(P_s)(C_f)) / ((T_s) + 273) / (O_{2REFw})$	m ³ /min	42.3	
$Q_{stdO_2} = ((Q_a)(P_s)(C_f)(1 - (R_{wv}/100))) / ((T_s) + 273) / (O_{2REFd})$	m ³ /min	33.6	
Percent isokinetic, %I			
Nozzle diameter, D_n	mm	8.91	
Nozzle area, A_n	mm ²	62.36	
Total sampling time, q	min	60	
$\%I = (4.6398E^9)(T_s+273)(V_{mstd}) / (P_s)(V_s)(A_n)(q)(1 - (R_{wv}/100))$	%	103.0	

TOTAL PARTICULATE MATTER: SAMPLING DETAILS

Sample Runs

Parameter	Units	Run 1
Sampling Times	-	12:34 - 13:34
Sampling Dates	-	06/01/2022
Sampling Device	-	ISO
Volume Sampled (REF)	m ³	0.8902
Filter I.D. Number	-	47-87239
Start Filter Mass	g	0.14707
End Filter Mass	g	0.14866
Total Mass on Filter	g	0.00159
Probe Rinse I.D. Number	-	PR-47-87239
Start Probe Rinse Mass	g	2.88926
End Probe Rinse Mass	g	2.88936
Total Mass in Probe Rinse	g	0.00010
Total Mass Collected	mg	1.69
Calculated Concentration	mg/m ³	1.90
Balance Uncertainty / LOD	mg/m ³	0.28

Where: ISO stands for Manual Isokinetic Sampling Train

Blank Runs

Parameter	Units	Blank 1
Blank Dates	-	06/01/2022
Average Volume Sampled (REF)	m ³	0.8902
Filter I.D. Number	-	47-87238
Start Filter Mass	g	0.14896
End Filter Mass	g	0.14891
Total Mass on Filter	g	-0.00005
Probe Rinse I.D. Number	-	PR-47-87238
Start Probe Rinse Mass	g	2.75618
End Probe Rinse Mass	g	2.75608
Total Mass in Probe Rinse	g	-0.00010
Total Mass Collected	mg	-0.15
Calculated Concentration	mg/m ³	-0.17
Balance Uncertainty / LOD	mg/m ³	0.28

TOTAL PARTICULATE MATTER: QUALITY ASSURANCE

(PAGE 1 OF 2)

Sample Runs

Leak Test Results	Units	Run 1	
Mean Sampling Rate	l/min	20.5	
Pre-Sampling Leak Rate	l/min	0.15	
Allowable Leak Rate	l/min	0.41	
Leak Test Acceptable	-	Yes	
Water Droplets	Units	Run 1	
Are Water Droplets Present	-	No	
MU (Concurrent Water Vapour)	Units	Run 1	
Measurement Uncertainty (MU)	%	5.1	
Allowable MU	%	20.0	
MU Acceptable	%	Yes	
Silica Gel (Concurrent Water Vapour)	Units	Run 1	
Less than 50% Faded	%	Yes	
Isokinetic Criterion Compliance	Units	Run 1	
Isokinetic Variation	%	103.0	
Allowable Isokinetic Range	%	95 - 115	
Isokineticity Acceptable	-	Yes	
Weighing Uncertainty Criteria	Units	Run 1	
Overall Weighing Uncertainty	± mg	0.50	
Overall Weighing Uncertainty	± mg/m ³	0.56	
ELV [Daily ELV for IED]	mg/m ³	20.00	
Allowable Weighing Uncertainty	mg/m ³	1.00	
Weighing Uncertainty Acceptable	-	Yes	
Filter Temperatures	Units	Run 1	
Pre-Conditioning Temperature	°C	180	
Post-Conditioning Temperature	°C	160	
Maximum Filter Temperature	°C	118	
Test Conditions	Units	Run 1	
Ambient Temperature Recorded?	-	Yes	

TOTAL PARTICULATE MATTER: QUALITY ASSURANCE

(PAGE 2 OF 2)

Blank Runs

Leak Test Results	Units	Blank 1	
Expected Sampling Rate	l/min	20.0	
Pre-Sampling Leak Rate	l/min	0.10	
Allowable Leak Rate	l/min	0.40	
Leak Test Acceptable	-	Yes	

Validity of Blank vs ELV	Units	Blank 1	
Allowable Blank	mg/m ³	2.0	
Blank Acceptable	-	Yes	

Acetone / Water Rinse Blank	Units	Blank
Acetone / Water Rinse Value	mg/l	2.7
Allowable Blank	mg/l	10
Blank Acceptable	-	Yes

Method Deviations

Nature of Deviation	Run Number
(x = deviation applies to the associated run, wx = deviation also applies to the concurrent water vapour run)	1
One out of two sampling lines was used due to sampling location restrictions, however the number of sample points used on the available line were increased to the minimum required by the Standard	wx

TOTAL PARTICULATE MATTER: MEASUREMENT UNCERTAINTY CALCULATIONS

Measured Quantities	Value		Standard uncertainty		
	Symbol	Run 1	Symbol	Units	Run 1
Sampled Volume (Actual)	V _m	1.2590	uV _m	m ³	0.0252
Sampled Gas Temperature	T _m	286.9	uT _m	K	2.00
Sampled Gas Pressure	p _m	100.5	up _m	kPa	0.50
Sampled Gas Humidity	H _m	0.00	uH _m	% v/v	1.00
Leak	L	0.73	uL	%	-
Mass of Particulate	m	1.69	um	mg	0.25
Uncollected Mass	UCM	-0.15	uUCM	mg	-

Measured Quantities	Uncertainty as a Percentage		Requirement of Standard
	Units	Run 1	
Sampled Volume (Actual)	%	2.00	≤2%
Sampled Gas Temperature	%	0.70	≤1%
Sampled Gas Pressure	%	0.50	≤1%
Sampled Gas Humidity	%	1.00	≤1%
Leak	%	0.73	≤2%
Mass of Particulate	%	1.40	<5% of ELV
Uncollected Mass	%	-	-

Measured Quantities	Uncertainty in Measurement Units			Sensitivity Coefficient
	Symbol	Units	Run 1	
Sampled Volume (STP)	V _m	m ³	1.1650	1.63
Leak	L	mg/m ³	0.008	1.00
Mass of Particulate	L _r	mg	1.690	1.12
Uncollected Mass	UCM	mg	-0.09	1.12

Measured Quantities	Uncertainty in Result	
	Units	Run 1
Sampled Volume (STP)	mg/m ³	0.048
Leak	mg/m ³	0.0080
Mass of Particulate	mg/m ³	0.2808
Uncollected Mass	mg/m ³	-0.0973

Measured Quantities	Oxygen Correction Part of MU Budget	
	Units	Run 1
O ₂ Correction Factor	-	1.31
Stack Gas O ₂ Content	% v/v	13.36
MU for O ₂ Correction	-	0.09
Overall MU For O ₂ Measurement	%	6.54

Parameter	Units	Run 1
Combined uncertainty	mg/m ³	0.30
Expanded uncertainty (95% confidence), without Oxygen Correction	mg/m ³	0.59
Expanded uncertainty (95% confidence), with Oxygen Correction	mg/m ³	0.60
Expanded uncertainty (95% confidence), estimated with Method Deviations	mg/m ³	0.60
Reported Uncertainty	mg/m ³	0.60
Expanded uncertainty (95% confidence), without Oxygen Correction	%	31.1
Expanded uncertainty (95% confidence), with Oxygen Correction	%	31.8
Expanded uncertainty (95% confidence), estimated with Method Deviations	%	31.8
Reported Uncertainty	%	31.8

HYDROGEN CHLORIDE: RESULTS SUMMARY

Thornccliffe Crematorium, Barrow-in-Furness
Combined Cremator Exhaust

Sample Runs

Parameter	Units	Run 1	Mean
Concentration	mg/m ³	3.7	3.7
Uncertainty	±mg/m ³	0.4	0.4
Mass Emission	g/hr	7.1	7.1
Uncertainty	±g/hr	1.8	1.8

Parameter	Units	Run 1	Mean
Water Vapour	% v/v	8.0	8.0
Uncertainty	±% v/v	0.4	0.4

Blank Runs

Parameter	Units	Blank 1	Maximum
Concentration	mg/m ³	< 0.017	< 0.017

General Sampling Information

Parameter	Value
Standard	EN 1911
Technical Procedure	CAT-TP-11
Name of Analytical Laboratory	EET
Analytical Laboratory's Procedure	CAT-AP-01
ISO 17025 Accredited Analysis?	MCERTS
Date of Sample Analysis	11/01/2022
Probe Material	Titanium
Filter Housing Material	Titanium
Impinger Material	Polyethylene
Absorption Solution	HPLC Grade Water
Positioning of Filter	In Stack
Filter Size and Material	47mm Glass Fibre
Number of Sampling Lines Used	1 / 2
Number of Sampling Points Used	4 / 4
Sample Point I.D.'s	B1 - B4

FORMAT: Number Used / Number Required

FORMAT: Number Used / Number Required

Reference Conditions

Reference Conditions are: 273K, 101.3kPa, dry gas, 11% oxygen.

HYDROGEN CHLORIDE: ISOKINETIC SAMPLING CALCULATIONS

Test	Units	Run 1	
Absolute pressure of stack gas, P_s			
Barometric pressure, P_b	mmHg	753.8	
Stack static pressure, P_{static}	mmH ₂ O	1.2	
$P_s = (P_b + (P_{static} / 13.6))$	mmHg	753.9	
Volume of water vapour collected, V_{wstd}			
Total mass collected in impingers (liquid trap)	g	73.7	
Total mass collected in impingers (silica trap)	g	7.1	
Total mass of liquid collected, V_{lc}	g	80.8	
$V_{wstd} = (0.001246)(V_{lc})$	m ³	0.1007	
Volume of gas metered dry, V_{mstd}			
Volume of gas sample through gas meter, V_m	m ³	1.2590	
Gas meter correction factor, V_d	-	0.9760	
Average dry gas meter temperature, T_m	°C	13.9	
Average pressure drop across orifice, ΔH	mmH ₂ O	47.1	
$V_{mstd} = ((0.3592)(V_m)(P_b + (\Delta H/13.6))(V_d)) / (T_m + 273)$	m ³	1.1650	
Moisture content, B_{wo} & R_{wv}			
$B_{wo} = V_{wstd} / (V_{mstd} + V_{wstd})$	m ³	0.0795	
B_{wo} as a percentage	% v/v	7.95	
Reported Water Vapour, checked with Tables in EN 14790, R_{wv}	% v/v	7.95	
Volume of gas metered wet, V_{mstw}			
$V_{mstw} = (V_{mstd})(100/(100 - R_{wv}))$	m ³	1.2657	
Volume of gas metered at Oxygen Reference Conditions, $V_{mstd@X\%O_2}$ & $V_{mstw@X\%O_2}$			
IED & Incinerates Hazardous Material? (Yes = no positive O ₂ correction)	-	No	
% wet oxygen measured in gas stream, ACT%O _{2w}	% v/v	12.13	
% dry oxygen measured in gas stream, ACT%O _{2d}	% v/v	13.36	
% oxygen reference condition, REF%O ₂	% v/v	11.00	
O ₂ Reference Factor wet ($O_{2REFw} = (21 - REF\%O_2) / (21 - ACT\%O_{2w})$)	-	1.13	
O ₂ Reference Factor dry ($O_{2REFd} = (21 - REF\%O_2) / (21 - ACT\%O_{2d})$)	-	1.31	
$V_{mstw@X\%oxygen} = (V_{mstw}) / (O_{2REFw})$	m ³	1.1232	
$V_{mstd@X\%oxygen} = (V_{mstd}) / (O_{2REFd})$	m ³	0.8902	
Molecular weight of dry gas stream, M_d			
CO ₂ (Estimated)	% v/v	3.00	
O ₂	% v/v	13.36	
Total	% v/v	16.36	
N ₂	% v/v	83.64	
$M_d = 0.44(\%CO_2) + 0.32(\%O_2) + 0.28(\%N_2)$	g/gmol	29.01	
Molecular weight of stack gas (wet), M_s			
$M_s = M_d(1 - (R_{wv}/100)) + 18(R_{wv}/100)$	g/gmol	28.14	
Velocity of stack gas, V_s			
Pitot tube velocity constant, K_p	-	34.97	
Velocity pressure coefficient, C_p	-	0.85	
Average of velocity heads, ΔP_{avg}	mmH ₂ O	3.76	
Average square root of velocity heads, $\sqrt{\Delta P}$	√mmH ₂ O	1.94	
Average stack gas temperature, T_s	°C	111.5	
$V_s = ((K_p)(C_p)(\sqrt{\Delta P})(T_s + 273)) / (\sqrt{M_s}(P_s))$	m/s	7.77	
Total flow of stack gas: Actual (Q_a), Wet (Q_{stw}), Dry (Q_{std}), Wet@O_{2REF} (Q_{stwO_2}), Dry@O_{2REF} (Q_{stdO_2})			
Area of stack, A_s	m ²	0.15	
$Q_a = (60)(A_s)(V_s)$	m ³ /min	67.7	
Conversion factor (K/mm.Hg), C_f	-	0.3592	
$Q_{stw} = ((Q_a)(P_s)(C_f)) / ((T_s) + 273)$	m ³ /min	47.7	
$Q_{std} = ((Q_a)(P_s)(C_f)(1 - (R_{wv}/100))) / ((T_s) + 273)$	m ³ /min	43.9	
$Q_{stwO_2} = ((Q_a)(P_s)(C_f)) / ((T_s) + 273) / (O_{2REFw})$	m ³ /min	42.3	
$Q_{stdO_2} = ((Q_a)(P_s)(C_f)(1 - (R_{wv}/100))) / ((T_s) + 273) / (O_{2REFd})$	m ³ /min	33.6	
Percent isokinetic, %I			
Nozzle diameter, D_n	mm	8.91	
Nozzle area, A_n	mm ²	62.36	
Total sampling time, q	min	60	
$\%I = (4.6398E^6)(T_s+273)(V_{mstd}) / (P_s)(V_s)(A_n)(q)(1 - (R_{wv}/100))$	%	103.0	

HYDROGEN CHLORIDE: SAMPLING DETAILS

Sample Runs

Parameter	Units	Run 1
Sampling Times	-	12:34 - 13:34
Sampling Dates	-	06/01/2022
Sampling Device	-	ISO
Volume Sampled (REF)	m ³	0.8902
Laboratory Result for Front Impingers	µg/ml	11.57
Laboratory Result for Back Impinger	µg/ml	0.12
Volume in Front Impingers	ml	280.5
Volume in Back Impinger	ml	110.3
Mass in Front Impingers	µg	3244.7
Mass in Back Impinger	µg	13.0
Total Mass Collected	µg	3257.7
Calculated Concentration	mg/m ³	3.66

Where: ISO stands for Manual Isokinetic Sampling Train

Blank Runs

Parameter	Units	Blank 1
Blank Dates	-	06/01/2022
Average Volume Sampled (REF)	m ³	0.8902
Laboratory Result for Impingers	µg/ml	< 0.05
Volume in Impingers	ml	304.3
Total Mass Collected	µg	< 15.2
Calculated Concentration	mg/m ³	< 0.02

HYDROGEN CHLORIDE: QUALITY ASSURANCE

(PAGE 1 OF 2)

Sample Runs

Leak Test Results	Units	Run 1	
Mean Sampling Rate	l/min	20.5	
Pre-Sampling Leak Rate	l/min	0.15	
Allowable Leak Rate	l/min	0.41	
Leak Test Acceptable	-	Yes	
Absorption Efficiency	Units	Run 1	
Absorption Efficiency	%	99.6	
Allowable Absorption Efficiency	%	N/A ¹	
Absorption Efficiency Acceptable	-	Yes ¹	
¹ The concentration in the last absorber was less than 5 times the analytical detection limit.			
Water Droplets	Units	Run 1	
Are Water Droplets Present	-	No	
MU (Concurrent Water Vapour)	Units	Run 1	
Measurement Uncertainty (MU)	%	5.1	
Allowable MU	%	20.0	
MU Acceptable	%	Yes	
Silica Gel (Concurrent Water Vapour)	Units	Run 1	
Less than 50% Faded	%	Yes	
Isokinetic Criterion Compliance	Units	Run 1	
Isokinetic Variation	%	103.0	
Allowable Isokinetic Range	%	95 - 115	
Isokineticity Acceptable	-	Yes	
Filter Temperatures	Units	Run 1	
Maximum Filter Temperature	°C	111	
Test Conditions	Units	Run 1	
Ambient Temperature Recorded?	-	Yes	

APPENDIX 2

HYDROGEN CHLORIDE: QUALITY ASSURANCE

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Blank Runs

Leak Test Results	Units	Blank 1	
Expected Sampling Rate	l/min	20.0	
Pre-Sampling Leak Rate	l/min	0.10	
Allowable Leak Rate	l/min	0.40	
Leak Test Acceptable	-	Yes	
Validity of Blank vs ELV	Units	Blank 1	
Allowable Blank	mg/m ³	3.0	
Blank Acceptable	-	Yes	

Method Deviations

Nature of Deviation	Run Number
(x = deviation applies to the associated run, wx = deviation also applies to the concurrent water vapour run)	1
One out of two sampling lines was used due to sampling location restrictions, however the number of sample points used on the available line were increased to the minimum required by the Standard	wx

HYDROGEN CHLORIDE: MEASUREMENT UNCERTAINTY CALCULATIONS

Measured Quantities	Value		Standard uncertainty		
	Symbol	Run 1	Symbol	Units	Run 1
Sampled Volume (Actual)	V_m	1.2590	uV_m	m ³	0.0252
Sampled Gas Temperature	T_m	286.9	uT_m	K	2.00
Sampled Gas Pressure	p_m	100.5	up_m	kPa	0.50
Sampled Gas Humidity	H_m	0.00	uH_m	% v/v	1.00
Leak	L	0.73	uL	%	-
Laboratory Result	L_r	2.50	uL_r	%	-

Measured Quantities	Uncertainty as a Percentage		Requirement of Standard
	Units	Run 1	
Sampled Volume (Actual)	%	2.00	≤2%
Sampled Gas Temperature	%	0.70	≤1%
Sampled Gas Pressure	%	0.50	≤1%
Sampled Gas Humidity	%	1.00	≤1%
Leak	%	0.73	≤2%
Laboratory Result	%	2.50	No Requirement

Measured Quantities	Uncertainty in Measurement Units			Sensitivity Coefficient
	Symbol	Units	Run 1	
Sampled Volume (STP)	V_m	m ³	1.1650	3.14
Leak	L	mg/m ³	0.015	1.00
Laboratory Result	L_r	mg/m ³	0.091	1.00

Measured Quantities	Uncertainty in Result	
	Units	Run 1
Sampled Volume (STP)	mg/m ³	0.093
Leak	mg/m ³	0.0155
Laboratory Result	mg/m ³	0.0915

Measured Quantities	Oxygen Correction Part of MU Budget	
	Units	Run 1
O ₂ Correction Factor	-	1.31
Stack Gas O ₂ Content	% v/v	13.36
MU for O ₂ Correction	-	0.09
Overall MU For O ₂ Measurement	%	6.54

Parameter	Units	Run 1
Combined uncertainty	mg/m ³	0.13
Expanded uncertainty (95% confidence), without Oxygen Correction	mg/m ³	0.26
Expanded uncertainty (95% confidence), with Oxygen Correction	mg/m ³	0.35
Expanded uncertainty (95% confidence), estimated with Method Deviations	mg/m ³	0.35
Reported Uncertainty	mg/m ³	0.35
Expanded uncertainty (95% confidence), without Oxygen Correction	%	7.0
Expanded uncertainty (95% confidence), with Oxygen Correction	%	9.6
Expanded uncertainty (95% confidence), estimated with Method Deviations	%	9.6
Reported Uncertainty	%	9.6

MERCURY: RESULTS SUMMARY

Thorncliffe Crematorium, Barrow-in-Furness
Combined Cremator Exhaust

Sample Runs

Parameter	Units	Run 1	Mean
Concentration	mg/m ³	0.013	0.013
Uncertainty	±mg/m ³	0.003	0.003
Mass Emission	g/hr	0.025	0.025
Uncertainty	±g/hr	0.008	0.008

Parameter	Units	Run 1	Mean
Water Vapour	% v/v	9.7	9.7
Uncertainty	±% v/v	0.5	0.5

Blank Runs

Parameter	Units	Blank 1	Maximum
Concentration	mg/m ³	< 0.00022	< 0.00022

General Sampling Information

Parameter	Value
Standard	EN 13211
Technical Procedure	CAT-TP-06
Name of Analytical Laboratory	EET
Analytical Laboratory's Procedure	CAT-AP-08
ISO 17025 Accredited Analysis?	MCERTS
Date of Sample Analysis	13/01/2022
Probe Material	Titanium
Filter Housing Material	Borosilicate Glass
Impinger Material	Borosilicate Glass
Absorption Solution	Nitric Peroxide & Potassium Dichromate
Positioning of Filter	Out Stack
Filter Size and Material	47mm Quartz Fibre
Number of Sampling Lines Used	1 / 2
Number of Sampling Points Used	4 / 4
Sample Point I.D.'s	B1 - B4

FORMAT: Number Used / Number Required

FORMAT: Number Used / Number Required

Reference Conditions

Reference Conditions are: 273K, 101.3kPa, dry gas, 11% oxygen.

MERCURY: ISOKINETIC SAMPLING CALCULATIONS

Test	Units	Run 1	
Absolute pressure of stack gas, P_s			
Barometric pressure, P_b	mmHg	753.8	
Stack static pressure, P_{static}	mmH ₂ O	1.2	
$P_s = (P_b + (P_{static} / 13.6))$	mmHg	753.9	
Volume of water vapour collected, V_{wstd}			
Total mass collected in impingers (liquid trap)	g	90.9	
Total mass collected in impingers (silica trap)	g	10.5	
Total mass of liquid collected, V_{lc}	g	101.4	
$V_{wstd} = (0.001246)(V_{lc})$	m ³	0.1263	
Volume of gas metered dry, V_{mstd}			
Volume of gas sample through gas meter, V_m	m ³	1.2910	
Gas meter correction factor, V_d	-	0.9760	
Average dry gas meter temperature, T_m	°C	16.7	
Average pressure drop across orifice, ΔH	mmH ₂ O	41.1	
$V_{mstd} = ((0.3592)(V_m)(P_b + (\Delta H/13.6))(Y_d)) / (T_m + 273)$	m ³	1.1824	
Moisture content, B_{wo} & R_{wv}			
$B_{wo} = V_{wstd} / (V_{mstd} + V_{wstd})$	m ³	0.0965	
B_{wo} as a percentage	% v/v	9.65	
Reported Water Vapour, checked with Tables in EN 14790, R_{wv}	% v/v	9.65	
Volume of gas metered wet, V_{mstw}			
$V_{mstw} = (V_{mstd})(100/(100 - R_{wv}))$	m ³	1.3087	
Volume of gas metered at Oxygen Reference Conditions, $V_{mstd@X\%O_2}$ & $V_{mstw@X\%O_2}$			
IED & Incinerates Hazardous Material? (Yes = no positive O ₂ correction)	-	No	
% wet oxygen measured in gas stream, ACT%O _{2w}	% v/v	12.30	
% dry oxygen measured in gas stream, ACT%O _{2d}	% v/v	13.55	
% oxygen reference condition, REF%O ₂	% v/v	11.00	
O ₂ Reference Factor wet ($O_{2REFw} = (21 - REF\%O_2) / (21 - ACT\%O_{2w})$)	-	1.15	
O ₂ Reference Factor dry ($O_{2REFd} = (21 - REF\%O_2) / (21 - ACT\%O_{2d})$)	-	1.34	
$V_{mstw@X\%oxygen} = (V_{mstw}) / (O_{2REFw})$	m ³	1.1390	
$V_{mstd@X\%oxygen} = (V_{mstd}) / (O_{2REFd})$	m ³	0.8813	
Molecular weight of dry gas stream, M_d			
CO ₂ (Estimated)	% v/v	3.00	
O ₂	% v/v	13.55	
Total	% v/v	16.55	
N ₂	% v/v	83.45	
$M_d = 0.44(\%CO_2) + 0.32(\%O_2) + 0.28(\%N_2)$	g/gmol	29.02	
Molecular weight of stack gas (wet), M_s			
$M_s = M_d(1 - (R_{wv}/100)) + 18(R_{wv}/100)$	g/gmol	27.96	
Velocity of stack gas, V_s			
Pitot tube velocity constant, K_p	-	34.97	
Velocity pressure coefficient, C_p	-	0.85	
Average of velocity heads, ΔP_{avg}	mmH ₂ O	3.27	
Average square root of velocity heads, $\sqrt{\Delta P}$	√mmH ₂ O	1.81	
Average stack gas temperature, T_s	°C	113.5	
$V_s = ((K_p)(C_p)(\sqrt{\Delta P})(T_s + 273)) / (\sqrt{M_s}(P_s))$	m/s	7.28	
Total flow of stack gas: Actual (Q_a), Wet (Q_{stw}), Dry (Q_{std}), Wet@O_{2REF} (Q_{stwO_2}), Dry@O_{2REF} (Q_{stdO_2})			
Area of stack, A_s	m ²	0.15	
$Q_a = (60)(A_s)(V_s)$	m ³ /min	63.5	
Conversion factor (K/mm.Hg), C_f	-	0.3592	
$Q_{stw} = ((Q_a)(P_s)(C_f)) / ((T_s) + 273)$	m ³ /min	44.5	
$Q_{std} = ((Q_a)(P_s)(C_f)(1 - (R_{wv}/100))) / ((T_s) + 273)$	m ³ /min	40.2	
$Q_{stwO_2} = ((Q_a)(P_s)(C_f)) / ((T_s) + 273) / (O_{2REFw})$	m ³ /min	38.7	
$Q_{stdO_2} = ((Q_a)(P_s)(C_f)(1 - (R_{wv}/100))) / ((T_s) + 273) / (O_{2REFd})$	m ³ /min	29.9	
Percent isokinetic, %I			
Nozzle diameter, D_n	mm	8.91	
Nozzle area, A_n	mm ²	62.36	
Total sampling time, q	min	60	
$\%I = (4.6398E^6)(T_s+273)(V_{mstd}) / (P_s)(V_s)(A_n)(q)(1 - (R_{wv}/100))$	%	114.2	

MERCURY: SAMPLING DETAILS

Sample Runs

Parameter	Units	Run 1
Sampling Times	-	14:18 - 14:53 , 14:55 - 15:20
Sampling Dates	-	06/01/2022
Sampling Device	-	ISO
Volume Sampled (REF)	m ³	0.8813
Mass on Filter / in Rinse	µg	4.34
Mass in Front Impingers	µg	4.99
Mass in Back Impinger	µg	2.19
Total Mass Collected	µg	11.52
Calculated Concentration	mg/m ³	0.0131
Reported Concentration	mg/m ³	0.0131

Where: ISO stands for Manual Isokinetic Sampling Train

Blank Runs

Parameter	Units	Blank 1
Blank Dates	-	06/01/2022
Average Volume Sampled (REF)	m ³	0.8813
Mass on Filter / in Rinse	µg	< 0.03
Mass in Front Impingers	µg	< 0.10
Mass in Back Impinger	µg	< 0.06
Total Mass Collected	µg	< 0.19
Calculated Concentration	mg/m ³	< 0.0002
Reported Concentration	mg/m ³	< 0.0002

MERCURY: QUALITY ASSURANCE

(PAGE 1 OF 2)

Sample Runs

Leak Test Results	Units	Run 1	
Mean Sampling Rate	l/min	21.0	
Pre-Sampling Leak Rate	l/min	0.15	
Allowable Leak Rate	l/min	0.40	
Leak Test Acceptable	-	Yes	
Absorption Efficiency	Units	Run 1	
Absorption Efficiency	%	81.0	
Allowable Absorption Efficiency	%	N/A	
Absorption Efficiency Acceptable	-	Yes	
Where the emissions are < 30% of the ELV, MID 14385 does not require the absorption efficiency requirement to be applied			
Concentration in Final Impinger	Units	Run 1	
Concentration in Final Impinger	µg/m ³	2.5	
Allowable Concentration	µg/m ³	N/A	
Concentration Acceptable	-	Yes	
Water Droplets	Units	Run 1	
Are Water Droplets Present	-	No	
MU (Concurrent Water Vapour)	Units	Run 1	
Measurement Uncertainty (MU)	%	5.2	
Allowable MU	%	20.0	
MU Acceptable	%	Yes	
Silica Gel (Concurrent Water Vapour)	Units	Run 1	
Less than 50% Faded	%	Yes	
Isokinetic Criterion Compliance	Units	Run 1	
Isokinetic Variation	%	114.2	
Allowable Isokinetic Range	%	95 - 115	
Isokineticity Acceptable	-	Yes	
Filter Temperatures	Units	Run 1	
Maximum Filter Temperature	°C	180	
Impingers Exit Temperature	Units	Run 1	
Maximum Temperature Recorded	°C	5	
Maximum Allowable Temperature	°C	30	
Exit Temperature Acceptable	-	Yes	
Test Conditions	Units	Run 1	
Ambient Temperature Recorded?	-	Yes	

APPENDIX 2

MERCURY: QUALITY ASSURANCE

(PAGE 2 OF 2)

Blank Runs

Leak Test Results	Units	Blank 1	
Expected Sampling Rate	l/min	20.0	
Pre-Sampling Leak Rate	l/min	0.20	
Allowable Leak Rate	l/min	0.40	
Leak Test Acceptable	-	Yes	

Validity of Blank vs ELV	Units	Blank 1	
Allowable Blank	mg/m ³	0.005	
Blank Acceptable	-	Yes	

Method Deviations

Nature of Deviation	Run Number
(x = deviation applies to the associated run, wx = deviation also applies to the concurrent water vapour run)	1
Due to the restricted access, it was not possible to sample at all of the sample points on the available sampling lines.	wx

MERCURY: MEASUREMENT UNCERTAINTY CALCULATIONS

Measured Quantities	Value		Standard uncertainty		
	Symbol	Run 1	Symbol	Units	Run 1
Sampled Volume (Actual)	V _m	1.2910	uV _m	m ³	0.0258
Sampled Gas Temperature	T _m	289.7	uT _m	K	2.00
Sampled Gas Pressure	p _m	100.5	up _m	kPa	0.50
Sampled Gas Humidity	H _m	0.0	uH _m	% v/v	1.00
Leak	L	0.71	uL	%	-
Laboratory Result	L _r	11.50	uL _r	%	-

Measured Quantities	Uncertainty as a Percentage		Requirement of Standard
	Units	Run 1	
Sampled Volume (Actual)	%	2.00	≤2%
Sampled Gas Temperature	%	0.69	≤1%
Sampled Gas Pressure	%	0.50	≤1%
Sampled Gas Humidity	%	1.00	≤1%
Leak	%	0.71	≤2%
Laboratory Result	%	11.50	No Requirement

Measured Quantities	Uncertainty in Measurement Units			Sensitivity Coefficient
	Symbol	Units	Run 1	
Sampled Volume (STP)	V _m	m ³	1.1824	0.01
Leak	L	mg/m ³	0.0001	1.00
Laboratory Result	L _r	mg/m ³	0.0015	1.00

Measured Quantities	Uncertainty in Result	
	Units	Run 1
Sampled Volume (STP)	mg/m ³	0.0003
Leak	mg/m ³	0.0001
Laboratory Result	mg/m ³	0.0015

Measured Quantities	Oxygen Correction Part of MU Budget	
	Units	Run 1
O ₂ Correction Factor	-	1.34
Stack Gas O ₂ Content	% v/v	13.55
MU for O ₂ Correction	%	0.09
Overall MU For O ₂ Measurement	%	6.71

Parameter	Units	Run 1
Combined uncertainty	mg/m ³	0.0015
Expanded uncertainty (95% confidence), without Oxygen Correction	mg/m ³	0.0030
Expanded uncertainty (95% confidence), with Oxygen Correction	mg/m ³	0.0031
Expanded uncertainty (95% confidence), estimated with Method Deviations	mg/m ³	0.0031
Reported Uncertainty	mg/m ³	0.0031
Expanded uncertainty (95% confidence), without Oxygen Correction	%	23.1
Expanded uncertainty (95% confidence), with Oxygen Correction	%	24.1
Expanded uncertainty (95% confidence), estimated with Method Deviations	%	24.1
Reported Uncertainty	%	24.1

TOTAL VOCs (as CARBON): RESULTS SUMMARY

Thornccliffe Crematorium, Barrow-in-Furness
Combined Cremator Exhaust

Sample Runs

Parameter	Units	Run 1	Mean
Concentration	mg/m ³	8.4	8.4
Uncertainty	±mg/m ³	0.7	0.7
Mass Emission	g/hr	16.3	16.3
Uncertainty	±g/hr	4.0	4.0

General Sampling Information

Parameter	Value
Standard	EN 12619:2013
Technical Procedure	CAT-TP-20
Probe Material	Stainless Steel
Filtration Type / Size	0.1µm Glass Fibre
Heated Head Filter Used	Yes
Heated Line Temperature	180°C
Span Gas Type	Propane in 12% O ₂ in N ₂ (5 Grade)
Span Gas Reference Number	CYL 12.0356 in N ₂ CYL 1.0447a in AIR
Span Gas Expiry Date	05/06/2023 12/05/2026
Span Gas Start Pressure (bar)	50 40
Gas Cylinder Concentration (ppm)	81.73 80.3
Span Gas Set Point (ppm)	80.91
Span Gas Uncertainty (%)	2 2
Zero Gas Type	12% O ₂ in N ₂ (5 Grade)
Number of Sampling Lines Used	1 / 1
Number of Sampling Points Used	1 / 1
Sample Point I.D.'s	A3

This is the blended concentration of both propane cylinders

FORMAT: Number Used / Number Required

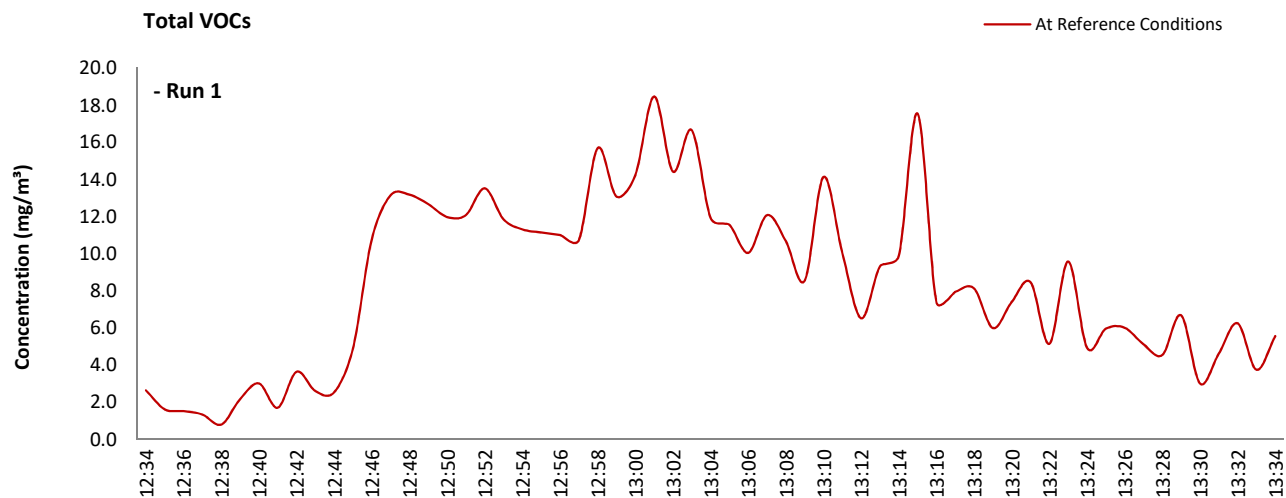
FORMAT: Number Used / Number Required

Reference Conditions

Reference Conditions are: 273K, 101.3kPa, dry gas, 11% oxygen.

TOTAL VOCs (as CARBON): DATA TREND

Graphical Trend of Data



TOTAL VOCs (as CARBON): SAMPLING DETAILS & QUALITY ASSURANCE

Sampling Details

Parameter	Units	Run 1	
Sampling Times	-	12:34 - 13:34	
Sampling Dates	-	06/01/2022	
Instrument Range	ppm	100	
Span Gas Value	ppm	80.9	

Quality Assurance

	Zero Drift	Units	Run 1	
CAL 1	Zero Down Sampling Line (Pre)	ppm	0.10	
	Zero Down Sampling Line (Post)	ppm	-0.40	
	Zero Drift	ppm	-0.50	
	Allowable Zero Drift	± ppm	4.05	
	Zero Drift Acceptable	-	Yes	

	Span Drift	Units	Run 1	
CAL 1	Span Down Sampling Line (Pre)	ppm	79.90	
	Span Down Sampling Line (Post)	ppm	78.60	
	Span Drift	ppm	-1.30	
	Allowable Span Drift	± ppm	4.05	
	Span Drift Acceptable	-	Yes	

Test Conditions	Units	Run 1	
Run Ambient Temperature Range	°C	12 - 13	

Method Deviations

Nature of Deviation	Run Number
(x = deviation applies to the associated run)	1
There are no deviations associated with the sampling employed.	x

TOTAL VOCs (as CARBON): MEASUREMENT UNCERTAINTY CALCULATIONS

Performance characteristics	RUN 1	Units
Limit value	20.0	mg/m ³ (REF)
Allowable MU	15.0	%
Measured concentration	6.42	mg/m ³ (STP, dry)
Range Used	100.0	ppm
Range Used [A]	160.6	mg/m ³
Cal gas conc.	80.9	ppm
Conversion	1.61	ppm to mg/m ³
MCERTS Range [B]	15.0	mg/m ³
Lower of [A] or [B]	15.0	mg/m ³
Cal gas conc.	130.0	mg/m ³

Performance characteristics	RUN 1	Units
Response time	45	seconds
Number of readings in measurement	60	-
Repeatability at zero	2.00	% full scale
Repeatability at span level	0.00	% full scale
Deviation from linearity	0.14	% of value
Zero drift	-0.63	% full scale
Span drift	-1.63	% full scale
Volume or pressure flow dependence	1.60	% of full scale
Atmospheric pressure dependence	0.30	% of value/kPa
Ambient temperature dependence	1.40	% full scale/10K
Combined interference	0.45	% range
Dependence on voltage	0.50	% full scale/10V
Losses in the line (leak)	1.24	% of value
Uncertainty of calibration gas	2.83	% of value

Performance characteristic	RUN 1	Units
Standard deviation of repeatability at zero	use rep at span	mg/m ³
Standard deviation of repeatability at span level	0.00	mg/m ³
Lack of fit	0.01	mg/m ³
Drift	0.00	mg/m ³
Volume or pressure flow dependence	0.00	mg/m ³
Atmospheric pressure dependence	0.01	mg/m ³
Ambient temperature dependence	0.20	mg/m ³
Combined interference (from MCERTS Certificate)	0.04	mg/m ³
Dependence on voltage	0.06	mg/m ³
Losses in the line (leak)	0.05	mg/m ³
Uncertainty of calibration gas	0.10	mg/m ³

Measurement uncertainty	Result	RUN 1	Units
Combined uncertainty		6.42	mg/m ³
Expanded uncertainty	k =	0.25	mg/m ³
Expanded uncertainty	1.96	0.48	mg/m ³
Uncertainty corrected to std conds. (O ₂)		0.63	mg/m ³ (REF)

	RUN 1	Units
Expanded uncertainty (no O ₂) - at 95% Confidence	7.51	% of Value
Expanded uncertainty (no O ₂) - at 95% Confidence	2.41	% at ELV
Overall Allowable uncertainty (no O ₂) - at 95% Confidence	15.0	% at ELV
Result of Compliance with Uncertainty Requirement	N/A	-

	RUN 1	Units
Expanded uncertainty (with O ₂) - at 95% Confidence	8.20	% of Value
Expanded uncertainty (with O ₂) - at 95% Confidence	4.55	% at ELV
Overall Allowable uncertainty (with O ₂) - at 95% Confidence	15.4	% at ELV
Result of Compliance with Uncertainty Requirement	COMPLIANT	-

Requirement for SRM is that Uncertainty should be <15% of the value at the ELV, on a dry gas basis, or if O₂ correction is applied less than 15% + the uncertainty associated with the O₂ correction (using sqrt of sum squares to add uncertainty components).

CARBON MONOXIDE: RESULTS SUMMARY

Thorncliffe Crematorium, Barrow-in-Furness
Combined Cremator Exhaust

Sample Runs

Parameter	Units	Run 1	Mean
Concentration	mg/m ³	21.5	21.5
Uncertainty	±mg/m ³	1.8	1.8
Mass Emission	g/hr	41.8	41.8
Uncertainty	±g/hr	10.1	10.1

General Sampling Information

Parameter	Value
Standard	EN 15058
Technical Procedure	CAT-TP-21
Probe Material	Stainless Steel
Filtration Type / Size	0.1µm Glass Fibre
Heated Head Filter Used	Yes
Heated Line Temperature	180°C
Span Gas Type	Carbon Monoxide
Span Gas Reference Number	CYL 12.0356
Span Gas Expiry Date	05/06/2023
Span Gas Start Pressure (bar)	50
Gas Cylinder Concentration (ppm)	396
Span Gas Uncertainty (%)	2
Zero Gas Type	Nitrogen (5 Grade)
Number of Sampling Lines Used	1 / 1
Number of Sampling Points Used	1 / 1
Sample Point I.D.'s	A3

NOTE: Dilution performed to achieve correct span value

FORMAT: Number Used / Number Required

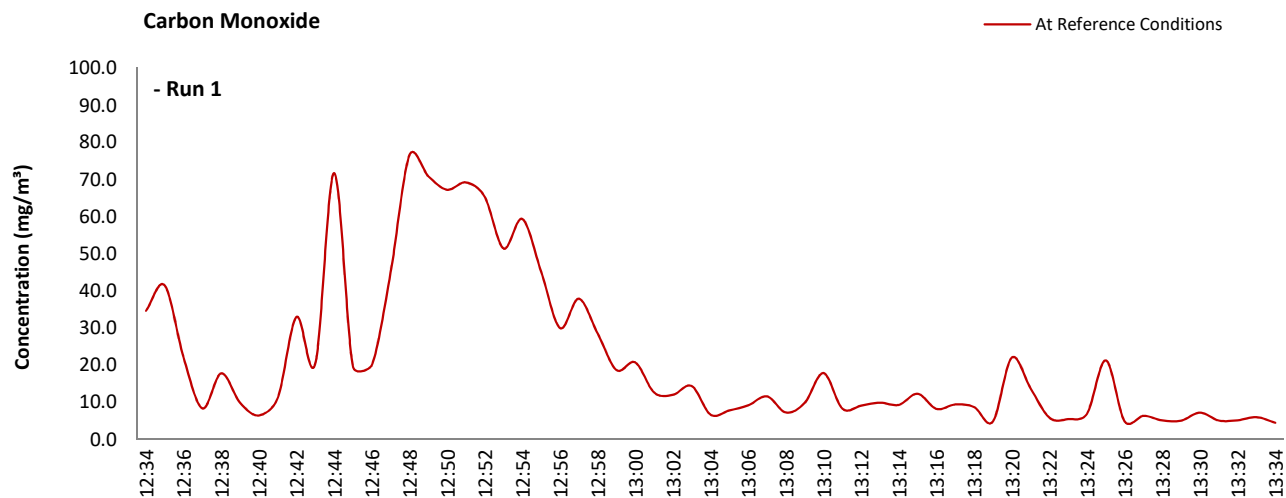
FORMAT: Number Used / Number Required

Reference Conditions

Reference Conditions are: 273K, 101.3kPa, dry gas, 11% oxygen.

CARBON MONOXIDE: DATA TREND

Graphical Trend of Data



APPENDIX 2

CARBON MONOXIDE: SAMPLING DETAILS & QUALITY ASSURANCE

Sampling Details

Parameter	Units	Run 1
Sampling Times	-	12:34 - 13:34
Sampling Dates	-	06/01/2022
Instrument Range	ppm	500
Span Gas Value	ppm	80.1

Quality Assurance

Conditioning Unit Temperature	Units	Run 1
Average Temperature	°C	2.5
Allowable Temperature	< °C	4.0
Temperature Acceptable	-	Yes

Zero Drift	Units	Run 1
Zero at Analyser (Pre)	ppm	0.00
Zero at Analyser (Post)	ppm	0.90
Zero Drift	ppm	0.90
Zero Drift	%	1.12
Drift Correction Applied	2-5%	No
Allowable Zero Drift	± %	5.00
Zero Drift Acceptable	-	Yes

Span Drift	Units	Run 1
Span at Analyser (Pre)	ppm	80.10
Span at Analyser (Post)	ppm	79.90
Span Drift	ppm	-0.20
Zero Adj. Span Drift	%	1.37
Drift Correction Applied	2-5%	No
Allowable Span Drift	± %	5.00
Span Drift Acceptable	-	Yes

Test Conditions	Units	Run 1
Run Ambient Temperature Range	°C	12 - 13

Method Deviations

Nature of Deviation	Run Number
(x = deviation applies to the associated run)	1
There are no deviations associated with the sampling employed.	x

CARBON MONOXIDE: MEASUREMENT UNCERTAINTY CALCULATIONS

Performance characteristics	RUN 1	Units
Limit value	100.0	mg/m ³ (REF)
Allowable MU	6.0	%
Measured concentration	16.44	mg/m ³ (STP, dry)
Range Used	500.0	ppm
Range Used [A]	624.6	mg/m ³
Cal gas conc.	80.1	ppm
Conversion	1.25	ppm to mg/m ³
MCERTS Range [B]	95.0	mg/m ³
Lower of [A] or [B]	95.0	mg/m ³
Cal gas conc.	100.0	mg/m ³

Performance characteristics	RUN 1	Units
Response time	60	seconds
Number of readings in measurement	60	-
Repeatability at zero	0.40	% full scale
Repeatability at span level	0.40	% full scale
Deviation from linearity	0.20	% of value
Zero drift	1.12	% full scale
Span drift	-1.37	% full scale
Volume or pressure flow dependence	0.40	% of full scale
Atmospheric pressure dependence	0.30	% of value/kPa
Ambient temperature dependence	0.05	% full scale/10K
Combined interference	0.73	% range
Dependence on voltage	0.40	% full scale/10V
Losses in the line (leak)	0.00	% of value
Uncertainty of calibration gas blending	1.40	% of value
Uncertainty of calibration gas	2.00	% of value

Performance characteristic	RUN 1	Units
Standard deviation of repeatability at zero	use rep at span	mg/m ³
Standard deviation of repeatability at span level	0.05	mg/m ³
Lack of fit	0.11	mg/m ³
Drift	0.00	mg/m ³
Volume or pressure flow dependence	0.00	mg/m ³
Atmospheric pressure dependence	0.08	mg/m ³
Ambient temperature dependence	0.01	mg/m ³
Combined interference (from MCERTS Certificate)	0.40	mg/m ³
Dependence on voltage	0.05	mg/m ³
Losses in the line (leak)	0.00	mg/m ³
Uncertainty of calibration gas blending	0.13	mg/m ³
Uncertainty of calibration gas	0.19	mg/m ³

Measurement uncertainty	Result	RUN 1	Units
Combined uncertainty		16.44	mg/m ³
Expanded uncertainty	k = 1.96	0.63	mg/m ³
Expanded uncertainty		1.23	mg/m ³
Uncertainty corrected to std conds. (O ₂)		1.61	mg/m ³ (REF)

	RUN 1	Units
Expanded uncertainty (no O ₂) - at 95% Confidence	7.48	% of Value
Expanded uncertainty (no O ₂) - at 95% Confidence	1.23	% at ELV
Overall Allowable uncertainty (no O ₂) - at 95% Confidence	6.0	% at ELV
Result of Compliance with Uncertainty Requirement	N/A	-

	RUN 1	Units
Expanded uncertainty (with O ₂) - at 95% Confidence	8.17	% of Value
Expanded uncertainty (with O ₂) - at 95% Confidence	3.65	% at ELV
Overall Allowable uncertainty (with O ₂) - at 95% Confidence	6.8	% at ELV
Result of Compliance with Uncertainty Requirement	COMPLIANT	-

Requirement for SRM is that Uncertainty should be <6% of the value at the ELV, on a dry gas basis, or if O₂ correction is applied less than 6% + the uncertainty associated with the O₂ correction (using sqrt of sum squares to add uncertainty components).

APPENDIX 2

OXYGEN: RESULTS SUMMARY

Thornccliffe Crematorium, Barrow-in-Furness
Combined Cremator Exhaust

Sample Runs

Parameter	Units	Run 1	Mean
Concentration	% v/v	13.4	13.4
Uncertainty	±% v/v	0.4	0.4

General Sampling Information

Parameter	Value
Standard	EN 14789
Technical Procedure	CAT-TP-21
Probe Material	Stainless Steel
Filtration Type / Size	0.1µm Glass Fibre
Heated Head Filter Used	Yes
Heated Line Temperature	180°C
Span Gas Type	Synthetic Air (5 Grade)
Span Gas Reference Number	CYL 11.0489
Span Gas Expiry Date	06/08/2026
Span Gas Start Pressure (bar)	50
Gas Cylinder Concentration (% v/v)	20.8
Span Gas Uncertainty (%)	2
Zero Gas Type	Nitrogen (5 Grade)
Number of Sampling Lines Used	1 / 1
Number of Sampling Points Used	1 / 1
Sample Point I.D.'s	A3

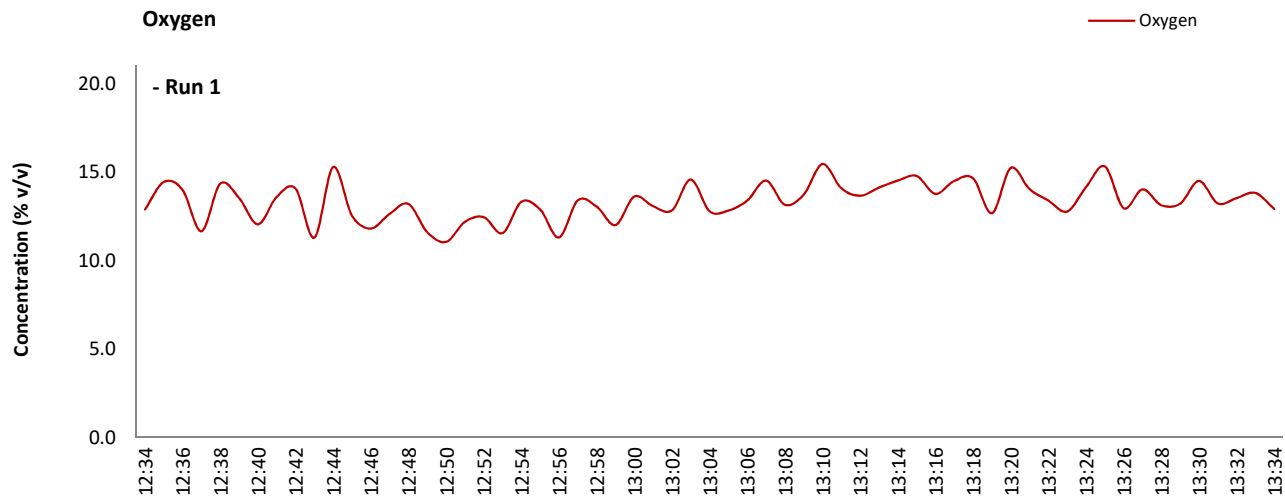
NOTE: Dilution performed to achieve correct span value

FORMAT: Number Used / Number Required

FORMAT: Number Used / Number Required

OXYGEN: DATA TREND

Graphical Trend of Data



APPENDIX 2

OXYGEN: SAMPLING DETAILS & QUALITY ASSURANCE

Sampling Details

Parameter	Units	Run 1
Sampling Times	-	12:34 - 13:34
Sampling Dates	-	06/01/2022
Instrument Range	% v/v	25.0
Span Gas Value	% v/v	12.0

Quality Assurance

Conditioning Unit Temperature	Units	Run 1
Average Temperature	°C	2.5
Allowable Temperature	< °C	4.0
Temperature Acceptable	-	Yes

Zero Drift	Units	Run 1
Zero at Analyser (Pre)	% v/v	0.00
Zero at Analyser (Post)	% v/v	0.05
Zero Drift	% v/v	0.05
Zero Drift	%	0.43
Drift Correction Applied	2-5%	No
Allowable Zero Drift	± %	5.00
Zero Drift Acceptable	-	Yes

Span Drift	Units	Run 1
Span at Analyser (Pre)	% v/v	11.65
Span at Analyser (Post)	% v/v	11.85
Span Drift	% v/v	0.20
Zero Adj. Span Drift	%	1.25
Drift Correction Applied	2-5%	No
Allowable Span Drift	± %	5.00
Span Drift Acceptable	-	Yes

Test Conditions	Units	Run 1
Run Ambient Temperature Range	°C	12 - 13

Method Deviations

Nature of Deviation	Run Number
(x = deviation applies to the associated run)	1
There are no deviations associated with the sampling employed.	x

APPENDIX 2

OXYGEN: MEASUREMENT UNCERTAINTY CALCULATIONS

Performance characteristics	RUN 1		Units
Limit value	N/A		%vol
Allowable MU	6.0		%
Measured concentration	13.36		%vol
Range Used	25.0		%vol
Cal gas conc.	20.8		%vol

Performance characteristics	RUN 1		Units
Response time	60		seconds
Number of readings in measurement	60		-
Repeatability at zero	0.04		% full scale
Repeatability at span level	0.04		% full scale
Deviation from linearity	0.13		% of value
Zero drift	0.43		% full scale
Span drift	1.25		% full scale
Volume or pressure flow dependence	0.20		% of full scale
Atmospheric pressure dependence	0.30		% of value/kPa
Ambient temperature dependence	-0.07		% full scale/10K
Combined interference	0.56		% range
Dependence on voltage	0.02		% full scale/10V
Losses in the line (leak)	1.42		% of value
Uncertainty of calibration gas	2.00		% of value

Performance characteristic	RUN 1		Units
Standard deviation of repeatability at zero	use rep at span		%vol
Standard deviation of repeatability at span level	0.01		%vol
Lack of fit	0.02		%vol
Drift	0.00		%vol
Volume or pressure flow dependence	0.00		%vol
Atmospheric pressure dependence	0.02		%vol
Ambient temperature dependence	-0.01		%vol
Combined interference (from MCERTS Certificate)	0.08		%vol
Dependence on voltage	0.00		%vol
Losses in the line (leak)	0.11		%vol
Uncertainty of calibration gas	0.15		%vol

		RUN 1		Units
Measurement uncertainty	Result	13.36		%vol
Combined uncertainty		0.22		%vol
Expanded uncertainty	k = 1.96	0.44		%vol

	RUN 1		Units
Expanded uncertainty (no O ₂) - at 95% Confidence	3.27		% of Value
Result of Compliance with Uncertainty Requirement	COMPLIANT		-

Requirement for SRM is that Uncertainty should be 0.3% vol absolute or 6% relative whichever is the lower, on a dry gas basis. Source, EN 14789.

Version Number	Record of changes made within this version of the document
V1	The original document issued to the client