



Exova Catalyst, Unit C6, Emery Court, The Embankment Business Park, Heaton Mersey, Stockport, SK4 3GL

T: 0800 328 1821 (or + 44 161 432 3286 from overseas)

E: toby.campbell@exova.com

Your Exova Catalyst Contact: Toby Campbell (07825 130 074)

Stack Emissions Testing Report Commissioned by

British Crystal Ltd

Installation Name & Address

British Crystal Ltd

Unit 14

Pedmore Road Industrial Estate

Brierley Hill

West Midlands

DY5 1TJ

PPC Permit: PB 98

Stack Reference

Acid Fume Scrubber

Dates of the Monitoring Campaign

6th September 2016

Job Reference Number

CAT-2917

Report Written by
Harpreet Badwal Team Leader MCERTS Level 2 MM 03 149 TE1 TE2 TE3 TE4

Report Approved by
Matthew Pendlebury Team Leader MCERTS Level 2 MM 04 535 TE1 TE2 TE3 TE4

Report Date
3rd October 2016

Version
Version 1

Signature of Report Approver

CONTENTS

TITLE PAGE

CONTENTS

Summary of Sampling Deviations 2

EXECUTIVE SUMMARY

Monitoring Objectives 3

Monitoring Results 4

Monitoring Dates & Times 5

Process Details 6

Monitoring & Analytical Methods 7

Sampling Location 8

Plant Photos / Sample Points 9

APPENDIX 1 - Monitoring Personnel & List of Equipment

APPENDIX 2 - Raw Data, Sampling Equations & Charts

Opinions and interpretations expressed herein are outside the scope of Exova Catalyst's ISO 17025 accreditation.

This test report shall not be reproduced, except in full, without the written approval of Exova Catalyst.



Executive Summary

(Page 1 of 7)

MONITORING OBJECTIVES

British Crystal Ltd, Brierley Hill
Acid Fume Scrubber
6th September 2016

Overall Aim of the Monitoring Campaign

Exova Catalyst were commissioned by British Crystal Ltd to carry out stack emissions testing on the Acid Fume Scrubber at Brierley Hill.

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

Hydrogen Fluoride |

Executive Summary

(Page 2 of 7)

MONITORING RESULTS

British Crystal Ltd, Brierley Hill

Acid Fume Scrubber

6th September 2016

where MU = Measurement Uncertainty associated with the Result

Parameter	Concentration				Mass Emission			
	Units	Result	MU +/-	Limit	Units	Result	MU +/-	Limit
Hydrogen Fluoride ¹	mg/m ³	< 0.06	0.004	5	g/hr	< 0.30	0.02	-
Water Vapour	% v/v	0.92	0.09					
Stack Gas Temperature	°C	21.6						
Stack Gas Velocity	m/s	7.9	0.18					
Volumetric Flow Rate (ACTUAL)	m ³ /hr	5174	262					
Volumetric Flow Rate (REF) ¹	m ³ /hr	4784	242					

NOTE: VOLUMETRIC FLOW RATE & VELOCITY DATA TAKEN FROM THE PRELIMINARY VELOCITY TRAVERSE.

¹ Reference Conditions (REF) are: 273K, 101.3kPa, without correction for water vapour content.

Executive Summary

(Page 3 of 7)

MONITORING DATE(S) & TIMES

British Crystal Ltd, Brierley Hill
 Acid Fume Scrubber
 6th September 2016

Parameter	Units	Concentration	Units	Mass Emission	Sampling Date(s)	Sampling Times	Duration mins
Hydrogen Fluoride	R1 mg/m ³	< 0.06	g/hr	< 0.30	06/09/2016	10:32 - 11:02	30
Velocity & Volumetric Flow Rate	R1				06/09/2016	10:04 - 10:09	

All results are expressed at the respective reference conditions.

Executive Summary

(Page 4 of 7)

PROCESS DETAILS

British Crystal Ltd, Brierley Hill

Acid Fume Scrubber

6th September 2016

Standard Operating Conditions

Parameter	Value
Process Status	Normal Operation
Capacity (of 100%) and Tonnes / Hour	Full Extraction
Continuous or Batch Process	Continuous
Feedstock (if applicable)	Acid Fume
Abatement System	Wet Scrubber
Abatement System Running Status	On
Fuel	N/A
Plume Appearance	None Visible

Executive Summary

(Page 5 of 7)

MONITORING & ANALYTICAL METHODS

British Crystal Ltd, Brierley Hill

Acid Fume Scrubber

6th September 2016

Parameter	Monitoring				Analysis				MCERTS Testing	LOD (Average)
	Standard	Technical Procedure	ISO 17025 Testing	Testing Lab	Analytical Procedure	Analytical Technique	ISO 17025 Analysis	Analysis Lab		
Hydrogen Fluoride	ISO 15713	CAT-TP-10	Yes	CAT	CAT-AP-01	IC	Yes	CAT	Yes	0.06 mg/m ³
Water Vapour	EN 14790	CAT-TP-05	Yes	CAT	CAT-TP-05	Gravimetric	Yes	CAT	Yes	0.10 % v/v
Velocity & Vol. Flow Rate	EN 16911-1 (MID)	CAT-TP-41	Yes	CAT	Pitot Tube and Thermocouple				Yes	1.2 m/s

ANALYSIS LABORATORIES

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

Exova Catalyst (CAT)	ISO 17025 Accreditation Number: 4279
----------------------	--------------------------------------

SUMMARY OF SAMPLING DEVIATIONS

Parameter	Run	Deviation
All Parameters	All Runs	There are no deviations associated with the sampling employed.

Executive Summary

(Page 6 of 7)

SUITABILITY OF SAMPLING LOCATION

Duct Characteristics

Parameter	Units	Value
Type	-	Circular
Depth	m	0.48
Width	m	-
Area	m ²	0.18
Port Depth	cm	0
Orientation of Duct	-	Vertical
Sample Port Size	-	4" Hole

Location of Sampling Platform

General Platform Information	Value
Permanent / Temporary Platform	Temporary
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	No
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	Yes

Sampling Location / Platform Improvement Recommendations

The sampling location meets all the requirements specified in EA Guidance Note M1 and EN 15259, and therefore there are no improvement recommendations.

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	31.0	> 5 Pa	Yes
Mean Velocity	m/s	7.94	-	-
Lowest Gas Velocity	m/s	6.05	-	-
Highest Gas Velocity	m/s	9.79	-	-
Ratio of Above	: 1	1.62	< 3 : 1	Yes
Maximum Angle of Swirl	°	3	< 15°	Yes
No Local Negative Flow	-	Yes	-	Yes

Executive Summary

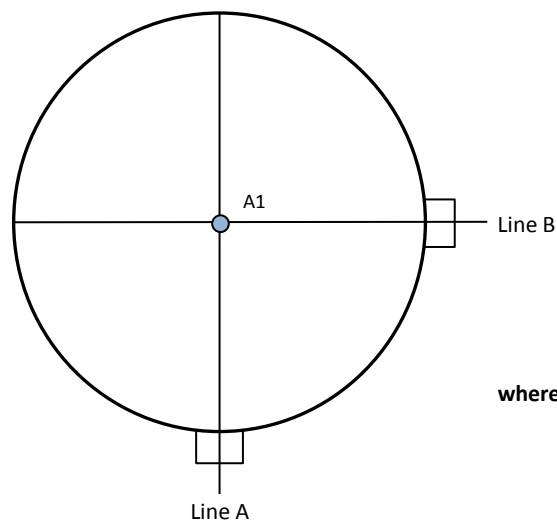
(Page 7 of 7)

PLANT PHOTOS

Photo 1



SAMPLE POINTS



- where**
- = isokinetic point sampled at
 - = isokinetic point not sampled at
 - = combustion gases sample point
 - = non-isokinetic sample point



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

STACK EMISSIONS MONITORING PERSONNEL

Position	Name	MCERTS Accreditation	MCERTS Number	Technical Endorsements
Team Leader	Harpreet Badwal	MCERTS Level 2	MM 03 149	TE1 TE2 TE3 TE4
Trainee	Aaron Nagha	MCERTS Trainee	MM 16 1392	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 7.57	Horiba PG-350E	-	Digital Manometer (1)	CAT 3.142
Control Box DGM (2)	-	Horiba PG-250	-	Digital Manometer (2)	CAT 3.144
Box Thermocouples (1)	CAT 3.146	Servomex 4900	-	Digital Temperature Meter	-
Box Thermocouples (2)	-	Eco Physics CLD 822Mh	-	Stopwatch	CAT 14.84
Umbilical (1)	CAT 3.146	ABB AO2020-URAS26	-	Barometer	CAT 13.40
Umbilical (2)	-	Servomex 5200MP	-	Stack Thermocouple (1)	CAT 4.844
Oven Box (1)	-	Ankersmid APS 313	-	Stack Thermocouple (2)	CAT 4.789
Oven Box (2)	-	Gasmet DX4000	-	Stack Thermocouple (3)	CAT 4.013
Heated Probe (1)	CAT 5.126	Gasmet Sampling System	-	1m Heated Line (1)	-
Heated Probe (2)	CAT 5.127	Bernath 3006 FID	-	1m Heated Line (2)	-
Heated Probe (3)	CAT 5.128	M&C PSS	-	1m Heated Line (3)	-
S-Pitot (1)	CAT 21S.57	Mass Flow Controller (1)	-	5m Heated Line (1)	-
S-Pitot (2)	CAT 21P.38	Mass Flow Controller (2)	-	15m Heated Line (1)	-
L-Pitot	-	Mass View (1)	CAT 25.59	20m Heated Line (1)	-
Site Balance	CAT 17.33	Mass View (2)	CAT 25.60	20m Heated Line (2)	-
500g / 1Kg Check Weights	CAT 17.33a & b	Hioki 5043 (V)	-	Dual Channel Heater Controller	CAT 3.151
Last Impinger Arm	-	Easylogger EN-EL-12 Bit	-	Single Channel Heater Controller	-
Callipers	-	Bioaerosols Temperature Logger	-	Laboratory Balance	-
Tubes Kit Thermocouple	-	Electronic Refrigerator	-	Tape Measure	CAT 16.45

METHODS & TECHNICAL PROCEDURES USED

Parameter	Standard	Technical Procedure
Hydrogen Fluoride	ISO 15713	CAT-TP-10
Water Vapour	EN 14790	CAT-TP-05
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	0.48
Stack Width, W	m	-
Stack Area, A	m ²	0.18
Average Stack Gas Temperature, T _a	°C	21.6
Average Stack Gas Pressure	Pa	54.5
Average Stack Static Pressure, P _{static}	kPa	0.08
Average Barometric Pressure, P _b	kPa	101.0
Average Pitot Tube Calibration Coefficient, C _p	-	0.84

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 ρ	Conc kg/m ³ ρ _i
CO ₂ (Estimated)	-	0.06	0.06	0.0006	44.01	1.9635	0.0012
O ₂ (Estimated)	-	20.80	20.61	0.2080	32.00	1.4277	0.2970
N ₂	-	79.14	78.42	0.7914	28.01	1.2498	0.9891
Moisture (H ₂ O)	-	-	0.92	0.0092	18.02	0.8037	0.0074

Where: $\rho = M / 22.41$

$\rho_i = r \times \rho$

Calculation of Stack Gas Densities

Determinand	Units	Result
Dry Density (STP), P _{STD}	kg/m ³	1.287
Wet Density (STP), P _{STW}	kg/m ³	1.283
Dry Density (Actual), P _{Actual}	kg/m ³	1.190
Average Wet Density (Actual), P _{ActualW}	kg/m ³	1.186

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)

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

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

Calculation of Stack Gas Volumetric Flowrate, Q

Duct gas flow conditions	Units	Actual	REF ¹
Temperature	°C	21.6	0.00
Total Pressure	kPa	101.1	101.3
Moisture	%	0.92	0.92

Gas Volumetric Flowrate (from Traverse)	Units	Result
Gas Volumetric Flowrate (Actual)	m ³ /hr	5174
Gas Volumetric Flowrate (STP, Wet)	m ³ /hr	4784
Gas Volumetric Flowrate (STP, Dry)	m ³ /hr	4740
Gas Volumetric Flowrate REF ¹	m ³ /hr	4784

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

(1 of 1)

Parameter	Units	Value
Date of Survey	-	06/09/2016
Time of Survey	-	10:04 - 10:09
Atmospheric Pressure	kPa	101.0
Average Stack Static Pressure	Pa	77
Result of Pitot Stagnation Test	-	Pass
Are Water Droplets Present?	-	No
Device Used	S-Type Pitot with KIMO MP 210 (500Pa)	

Parameter	Units	Value
Initial Pitot Leak Check	-	Pass
Final Pitot Leak Check	-	Pass
Orientation of Duct	-	Vertical
Pitot Tube, C _p	-	0.84
Number of Lines Available	-	1
Number of Lines Used	-	1

Sampling Line A						
Traverse Point	Depth m	ΔP Pa	Temp °C	Wet Density kg/m ³	Velocity m/s	Swirl °
<i>STATIC (Units: Pa)</i>		77.0				
Mean		54.5	21.6	1.186	7.94	
1	0.01	81.0	21.7	1.186	9.79	2.0
2	0.04	73.0	21.6	1.186	9.29	2.0
3	0.07	65.0	21.6	1.186	8.77	2.0
4	0.11	58.0	21.5	1.187	8.28	1.0
5	0.16	62.0	21.7	1.186	8.56	3.0
6	0.32	53.0	21.6	1.186	7.92	2.0
7	0.37	47.0	21.6	1.186	7.45	3.0
8	0.41	40.0	21.7	1.186	6.88	3.0
9	0.44	35.0	21.7	1.186	6.43	2.0
10	0.47	31.0	21.7	1.186	6.05	2.0

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	$u(\Delta p_i)$	1.210	Pa
- Resolution	$u(res)$	0.00087	
- Calibration	$u(cal)$	0.309	
- Drift	$u(drift)$	0.083	
- Lack of Fit	$u(fit)$	0.070	
- Overall corrections to dynamic measurements	$u(C_f)$	0.464	
Standard uncertainty associated with the molar mass of the gas	$u(M)$	0.00003	-
- $\phi_{O_2,w}$	-	20.610	
- $\phi_{CO_2,w}$	-	0.059	
- Oxygen, dry	$u(\phi_{O_2,d})$	0.637	
- Carbon Dioxide, dry	$u(\phi_{CO_2,d})$	0.002	
- Water Vapour	$u(\phi_{H_2O})$	0.047	
- Oxygen, wet	$u(\phi_{O_2,w})$	0.631	
- Carbon Dioxide, wet	$u(\phi_{CO_2,w})$	0.002	
Standard uncertainty associated with the stack temperature	$u(T_c)$	1.503	K
Standard uncertainty associated with the absolute pressure in the duct	$u(p_c)$	175.696	Pa
- Atmospheric Pressure	$u(p_{atm})$	175.692	
- Static Pressure	$u(p_{stat})$	1.210	
Standard uncertainty associated with the density in the duct	$u(\rho)$	0.00639	-
Standard uncertainty associated with the local velocities	$u(v_i)$	0.128	Pa
Standard uncertainty associated with the mean velocity	$u(\bar{v})$	0.092	m/s
Standard uncertainty associated with the mean velocity (95% Confidence)	$U_c(v)$	0.180	m/s
Standard uncertainty associated with the mean velocity (95% Confidence), relative	$U_{c,rel}(v)$	2.27	%
Standard uncertainty associated with the volume flow rate (95% Confidence)	$U_c(qV,w)$	262.0	m ³ /hr
- $u^2(a)/a^2$	-	0.00053	
- $u^2(qV,w)/q^2V,w$	-	0.00067	
- $u^2(qV,w)$	-	17868	
- $u(qV,w)$	-	133.7	
Standard uncertainty associated with the volume flow rate (95% Confidence), relative	$U_{c,rel}(qV,w)$	5.06	%

HYDROGEN FLUORIDE: RESULTS SUMMARY

British Crystal Ltd, Brierley Hill
Acid Fume Scrubber

Sample Runs

Parameter	Units	Run 1	Mean
Concentration	mg/m ³	< 0.06	< 0.06
Uncertainty	±mg/m ³	0.004	0.004
Mass Emission	g/hr	< 0.30	< 0.30
Uncertainty	±g/hr	0.02	0.02

Parameter	Units	Run 1	Mean
Water Vapour	% v/v	0.92	0.92
Uncertainty	±% v/v	0.09	0.09

Blank Runs

Parameter	Units	Blank 1	Maximum
Concentration	mg/m ³	< 0.05	< 0.05

General Sampling Information

Parameter	Value
Standard	ISO 15713
Technical Procedure	CAT-TP-10
Name of Analytical Laboratory	CAT
Analytical Laboratory's Procedure	CAT-AP-01
ISO 17025 Accredited Analysis?	Yes
Date of Sample Analysis	16/09/2016
Probe Material	Monel
Filter Housing Material	Monel
Impinger Material	Polyethylene
Absorption Solution	0.1 mol/l Sodium Hydroxide
Positioning of Filter	In Stack
Filter Size and Material	47mm Quartz Fibre
Number of Sampling Lines Used	1 / 1
Number of Sampling Points Used	1 / 1
Sample Point I.D.'s	A1

FORMAT: Number Used / Number Required
FORMAT: Number Used / Number Required

Reference Conditions

Reference Conditions are: 273K, 101.3kPa, without correction for water vapour content.

HYDROGEN FLUORIDE: SAMPLING DETAILS

Sample Runs

Parameter	Units	Run 1	
Sampling Times	-	10:32 - 11:02	
Sampling Dates	-	06/09/2016	
Sampling Device	-	MFC / MV	
Duration	mins	30	
Volume Sampled (STP, Dry)	m ³	0.3372	
Volume Sampled (STP, Wet)	m ³	0.3403	
Volume Sampled (REF)	m ³	0.3403	
Sample Flow Rate	l/min	11.24	
Laboratory Result for Front Impingers	µg/ml	< 0.05	
Laboratory Result for Back Impinger	µg/ml	< 0.05	
Volume in Front Impingers	ml	266.7	
Volume in Back Impinger	ml	155.2	
Mass in Front Impingers	µg	< 13.3	
Mass in Back Impinger	µg	< 7.8	
Total Mass Collected	µg	< 21.1	
Calculated Concentration	mg/m ³	< 0.06	
Liquid Trap Start Mass	g	1152.3	
Liquid Trap End Mass	g	1152.8	
Silica Trap Start Mass	g	1580.4	
Silica Trap End Mass	g	1582.4	
Total Mass Of Water Vapour	g	2.5	
Calculated Water Vapour	% v/v	0.92	

Where: MFC stands for Mass Flow Controller, MV stands for Mass View Flowmeter

Blank Runs

Parameter	Units	Blank 1	
Blank Dates	-	06/09/2016	
Average Volume Sampled (REF)	m ³	0.3403	
Laboratory Result for Impingers	µg/ml	< 0.05	
Volume in Impingers	ml	334.6	
Total Mass Collected	µg	< 16.7	
Calculated Concentration	mg/m ³	< 0.05	

HYDROGEN FLUORIDE: QUALITY ASSURANCE

Sample Runs

Leak Test Results	Units	Run 1	
Mean Sampling Rate	l/min	11.2	
Pre-Sampling Leak Rate	l/min	0.04	
Post-Sampling Leak Rate	l/min	0.04	
Allowable Leak Rate	l/min	0.22	
Leak Test Acceptable	-	Yes	

Absorption Efficiency	Units	Run 1	
Absorption Efficiency	%	100.0	
Allowable Absorption Efficiency	%	N/A ²	
Absorption Efficiency Acceptable	-	N/A ²	

² The concentration is less than 30% of the ELV, therefore no assessment against an allowable efficiency is required.

Water Droplets	Units	Run 1	
Are Water Droplets Present	-	No	

MU (Concurrent Water Vapour)	Units	Run 1	
Measurement Uncertainty (MU)	%	9.5	
Allowable MU	%	20	
MU Acceptable	%	Yes	

Silica Gel (Concurrent Water Vapour)	Units	Run 1	
Less than 50% Faded	%	Yes	

Test Conditions	Units	Run 1	
Ambient Temperature Recorded?	-	Yes	

Blank Runs

Leak Test Results	Units	Blank 1	
Expected Sampling Rate	l/min	9.50	
Pre-Sampling Leak Rate	l/min	0.03	
Post-Sampling Leak Rate	l/min	0.04	
Allowable Leak Rate	l/min	0.19	
Leak Test Acceptable	-	Yes	

Validity of Blank vs ELV	Units	Blank 1	
Allowable Blank	mg/m ³	0.50	
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
There are no deviations associated with the sampling employed.	wx	

HYDROGEN FLUORIDE: MEASUREMENT UNCERTAINTY CALCULATIONS

Measured Quantities	Value			Standard uncertainty			
	Symbol	Run 1		Symbol	Units	Run 1	
Sampled Volume (STP)	V _m	0.34		uV _m	m ³	0.007	
Leak	L	0.36		uL	%	-	
Laboratory Result	L _r	2.65		uL _r	%	-	

Measured Quantities	Uncertainty as a Percentage			Requirement of Standard
	Units	Run 1		
Sampled Volume (STP)	%	2.00		≤2%
Leak	%	0.36		≤2%
Laboratory Result	%	2.65		No Requirement

Measured Quantities	Uncertainty in Measurement Units				Sensitivity Coefficient	
	Symbol	Units	Run 1		Run 1	
Sampled Volume (STP)	V _m	m ³	0.34		0.18	
Leak	L	mg/m ³	0.0001		1.00	
Laboratory Result	L _r	mg/m ³	0.002		1.00	

Measured Quantities	Uncertainty in Result		
	Units	Run 1	
Sampled Volume (STP)	mg/m ³	0.0012	
Leak	mg/m ³	0.0001	
Laboratory Result	mg/m ³	0.002	

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

Parameter	Units	Run 1	
Combined uncertainty	mg/m ³	0.002	
Expanded uncertainty (95% confidence), without Oxygen Correction	mg/m ³	0.004	
Expanded uncertainty (95% confidence), with Oxygen Correction	mg/m ³	N/A	
Expanded uncertainty (95% confidence), estimated with Method Deviations	mg/m ³	0.004	
Reported Uncertainty	mg/m ³	0.004	
Expanded uncertainty (95% confidence), without Oxygen Correction	%	6.5	
Expanded uncertainty (95% confidence), with Oxygen Correction	%	N/A	
Expanded uncertainty (95% confidence), estimated with Method Deviations	%	6.5	
Reported Uncertainty	%	6.5	