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Stack Emissions Testing Report Commissioned by
Brierley British Crystal

Installation Name & Address
Brierley British Crystal
Unit 14
Pedmore Road Industrial Estate
Brierley Hill
West Midlands
DY5 1TJ

PPC Permit: PB 98 Variation 200839393

Stack Reference
Acid Fume Scrubber

Dates of the Monitoring Campaign
23rd January 2019

Job Reference Number
CAT-4637

Report Written by
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Report Date
18th February 2019

Version
Version 1

Signature of Report Approver

TITLE PAGE

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Executive Summary

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MONITORING OBJECTIVES

Brierley British Crystal, Brierley Hill
Acid Fume Scrubber
23rd January 2019

Overall Aim of the Monitoring Campaign

Exova Catalyst were commissioned by Brierley British Crystal 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

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MONITORING RESULTS

Brierley British Crystal, Brierley Hill

Acid Fume Scrubber

23rd January 2019

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	< 0.07	0.005	5	g/hr	< 0.37	0.03	-
Water Vapour	% v/v	0.51	0.13					
Stack Gas Temperature	°C	5.0						
Stack Gas Velocity	m/s	8.3	0.20					
Volumetric Flow Rate (ACTUAL)	m ³ /hr	5416	277					
Volumetric Flow Rate (REF)	¹ m ³ /hr	5170	265					

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.

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MONITORING DATE(S) & TIMES

Brierley British Crystal, Brierley Hill
 Acid Fume Scrubber
 23rd January 2019

Parameter	Units	Concentration	Units	Mass Emission	Sampling Date(s)	Sampling Times	Duration mins
Hydrogen Fluoride	R1 mg/m ³	< 0.07	g/hr	< 0.37	23/01/2019	11:08 - 11:38	30
Velocity Traverse	R1				23/01/2019	10.50 - 10:58	

All results are expressed at the respective reference conditions.

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PROCESS DETAILS

Brierley British Crystal, Brierley Hill
 Acid Fume Scrubber
 23rd January 2019

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

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MONITORING & ANALYTICAL METHODS

Brierley British Crystal, Brierley Hill

Acid Fume Scrubber

23rd January 2019

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	0.072 mg/m ³
Water Vapour	EN 14790	CAT-TP-05	Yes	CAT	CAT-TP-05	Gravimetric	Yes	CAT	Yes	0.1 % 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
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SUMMARY OF SAMPLING DEVIATIONS

Parameter	Run	Deviation
Hydrogen Fluoride	All Runs	The measurement uncertainty for water vapour was greater than 20%. This was due to the low level of water vapour which was found to be present in the stack.

Executive Summary

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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
Number of Ports	-	1
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	No
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

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	44.0	> 5 Pa	Yes
Mean Velocity	m/s	8.31	-	-
Lowest Gas Velocity	m/s	7.09	-	-
Highest Gas Velocity	m/s	9.74	-	-
Ratio of Above	: 1	1.37	< 3 : 1	Yes
Maximum Angle of Swirl	°	NM	NM	NM
No Local Negative Flow	-	Yes	-	Yes

Where NM = Not Measured as no Isokinetic sampling was performed.

Executive Summary

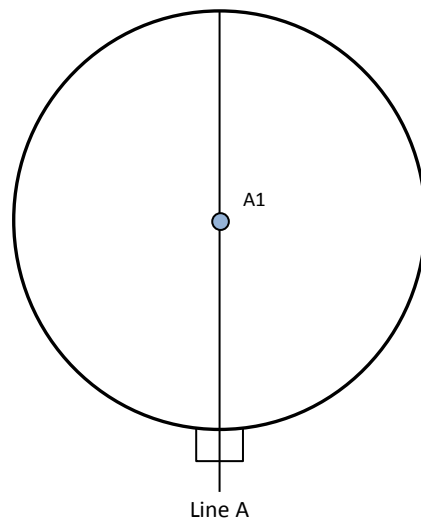
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PLANT PHOTOS

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
Technician	Lee Heaton	MCERTS Level 1	MM 17 1433	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)	-	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)	-	Servomex 4900	-	Digital Temperature Meter	-
Box Thermocouples (2)	-	Eco Physics CLD 822Mh	-	Stopwatch	CAT 14.84
Umbilical (1)	-	ABB AO2020-URAS26	-	Barometer	CAT 13.40
Umbilical (2)	-	Testo 350 XL	-	Stack Thermocouple (1)	CAT 4.1034
Oven Box (1)	-	Ankersmid APS 313	-	Stack Thermocouple (2)	CAT 4.1048
Oven Box (2)	-	Gasmet DX4000	-	Stack Thermocouple (3)	CAT 4.1135
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.110	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 17.33 a & b	Hioki 5043 (V)	-	Dual Channel Heater Controller	-
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	5.0
Average Stack Gas Pressure	Pa	61.3
Average Stack Static Pressure, P _{static}	kPa	0.072
Average Barometric Pressure, P _b	kPa	98.4
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	0.00118
O ₂ (Estimated)	-	20.80	20.69	0.2080	32.00	1.4277	0.29696
N ₂	-	79.14	78.74	0.7914	28.01	1.2498	0.98913
Moisture (H ₂ O)	-	-	0.51	0.0051	18.02	0.8037	0.00408

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	1.285
Dry Density (Actual), P _{Actual}	kg/m ³	1.229
Average Wet Density (Actual), P _{ActualW}	kg/m ³	1.226

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	5.0	0.0
Total Pressure	kPa	98.5	101.3
Moisture	%	0.51	0.51

Gas Volumetric Flowrate (from Traverse)	Units	Result
Gas Volumetric Flowrate (Actual)	m ³ /hr	5416
Gas Volumetric Flowrate (STP, Wet)	m ³ /hr	5170
Gas Volumetric Flowrate (STP, Dry)	m ³ /hr	5144
Gas Volumetric Flowrate REF ¹	m ³ /hr	5170

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

(1 of 1)

Parameter	Units	Value
Date of Survey	-	23/01/2019
Time of Survey	-	10.50 - 10:58
Atmospheric Pressure	kPa	98.4
Average Stack Static Pressure	Pa	72
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 °
STATIC (Units: Pa)		72.0				
Mean		61.3	5.0	1.226	8.31	
1	0.03	83.0	5.0	1.226	9.74	
2	0.12	63.0	5.0	1.226	8.49	
3	0.36	55.0	5.0	1.226	7.93	
4	0.45	44.0	5.0	1.226	7.09	

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	$u(\Delta p_i)$	1.250	Pa
- Resolution	$u(res)$	0.00087	
- Calibration	$u(cal)$	0.391	
- Drift	$u(drift)$	0.083	
- Lack of Fit	$u(fit)$	0.089	
- Overall corrections to dynamic measurements	$u(Cf)$	0.563	
Standard uncertainty associated with the molar mass of the gas	$u(M)$	0.00003	-
- $\varphi_{O_2,w}$	-	20.694	
- $\varphi_{CO_2,w}$	-	0.060	
- Oxygen, dry	$u(\phi_{O_2,d})$	0.637	
- Carbon Dioxide, dry	$u(\phi_{CO_2,d})$	0.002	
- Water Vapour	$u(\phi_{H_2O})$	0.026	
- Oxygen, wet	$u(\phi_{O_2,w})$	0.634	
- Carbon Dioxide, wet	$u(\phi_{CO_2,w})$	0.002	
Standard uncertainty associated with the stack temperature	$u(T_c)$	1.418	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	$u(p_{stat})$	1.250	
Standard uncertainty associated with the density in the duct	$u(\rho)$	0.00663	-
Standard uncertainty associated with the local velocities	$u(v_i)$	0.127	Pa
Standard uncertainty associated with the mean velocity	$u(\underline{v})$	0.101	m/s
Standard uncertainty associated with the mean velocity (95% Confidence)	$U_c(v)$	0.198	m/s
Standard uncertainty associated with the mean velocity (95% Confidence), relative	$U_{c,rel}(v)$	2.39	%
Standard uncertainty associated with the volume flow rate (95% Confidence)	$U_c(qV,w)$	277.1	m ³ /hr
- $u^2(a)/a^2$	-	0.00053	
- $u^2(qV,w)/q^2V,w$	-	0.00068	
- $u^2(qV,w)$	-	19988	
- $u(qV,w)$	-	141.4	
Standard uncertainty associated with the volume flow rate (95% Confidence), relative	$U_{c,rel}(qV,w)$	5.12	%

HYDROGEN FLUORIDE: RESULTS SUMMARY

Brierley British Crystal, Brierley Hill
Acid Fume Scrubber

Sample Runs

Parameter	Units	Run 1	Mean
Concentration	mg/m ³	< 0.07	< 0.07
Uncertainty	±mg/m ³	0.005	0.005
Mass Emission	g/hr	< 0.37	< 0.37
Uncertainty	±g/hr	0.03	0.03

Parameter	Units	Run 1	Mean
Water Vapour	% v/v	0.51	0.51
Uncertainty	±% v/v	0.13	0.13

Blank Runs

Parameter	Units	Blank 1	Maximum
Concentration	mg/m ³	< 0.07	< 0.07

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	29/01/2019
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	-	11:08 - 11:38
Sampling Dates	-	23/01/2019
Sampling Device	-	MFC / MV
Duration	mins	30
Volume Sampled (STP, Dry)	m ³	0.2200
Volume Sampled (STP, Wet)	m ³	0.2211
Volume Sampled (REF)	m ³	0.2211
Sample Flow Rate	l/min	7.33
Laboratory Result for Front Impingers	µg/ml	< 0.05
Laboratory Result for Back Impinger	µg/ml	< 0.05
Volume in Front Impingers	ml	210.1
Volume in Back Impinger	ml	110.3
Mass in Front Impingers	µg	< 10.5
Mass in Back Impinger	µg	< 5.5
Total Mass Collected	µg	< 16.0
Calculated Concentration	mg/m ³	< 0.07
Liquid Trap Start Mass	g	1247.0
Liquid Trap End Mass	g	1246.8
Silica Trap Start Mass	g	1431.8
Silica Trap End Mass	g	1432.9
Total Mass Of Water Vapour	g	0.9
Calculated Water Vapour	% v/v	0.51

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

Blank Runs

Parameter	Units	Blank 1
Blank Dates	-	23/01/2019
Average Volume Sampled (REF)	m ³	0.2211
Laboratory Result for Impingers	µg/ml	< 0.05
Volume in Impingers	ml	308.1
Total Mass Collected	µg	< 15.4
Calculated Concentration	mg/m ³	< 0.07

HYDROGEN FLUORIDE: QUALITY ASSURANCE

Sample Runs

Leak Test Results	Units	Run 1
Mean Sampling Rate	l/min	7.3
Pre-Sampling Leak Rate	l/min	0.01
Post-Sampling Leak Rate	l/min	0.01
Allowable Leak Rate	l/min	0.15
Leak Test Acceptable	-	Yes

Absorption Efficiency	Units	Run 1
Absorption Efficiency	%	100.0
Allowable Absorption Efficiency	%	N/A ²
Absorption Efficiency Acceptable	-	Yes 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)	%	26.4
Allowable MU	%	20.0
MU Acceptable	%	No

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	7.0
Pre-Sampling Leak Rate	l/min	0.01
Post-Sampling Leak Rate	l/min	0.01
Allowable Leak Rate	l/min	0.14
Leak Test Acceptable	-	Yes

Validity of Blank vs ELV	Units	Blank 1
Allowable Blank	mg/m ³	0.5
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
The measurement uncertainty for water vapour was greater than 20%. This was due to the low level of water vapour which was found to be present in the stack.	wx

HYDROGEN FLUORIDE: MEASUREMENT UNCERTAINTY CALCULATIONS

Measured Quantities	Value		Standard uncertainty		
	Symbol	Run 1	Symbol	Units	Run 1
Sampled Volume (STP)	V _m	0.2200	uV _m	m ³	0.0044
Leak	L	0.14	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	%	0.14	≤2%
Laboratory Result	%	2.65	No Requirement

Measured Quantities	Uncertainty in Measurement Units			Sensitivity Coefficient
	Symbol	Units	Run 1	
Sampled Volume (STP)	V _m	m ³	0.2200	0.33
Leak	L	mg/m ³	0.000	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	0.001
Leak	mg/m ³	0.0001
Laboratory Result	mg/m ³	0.0019

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	0.00
Expanded uncertainty (95% confidence), without Oxygen Correction	mg/m ³	0.00
Expanded uncertainty (95% confidence), with Oxygen Correction	mg/m ³	N/A
Expanded uncertainty (95% confidence), estimated with Method Deviations	mg/m ³	0.00
Reported Uncertainty	mg/m ³	0.00
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