

**MONITORING OF EMISSIONS FROM
THE FURNACE, ACID SCRUBBER
& WET ARRESTOR PROCESSES**

13 November 2013

Prepared for Staffordshire Crystal Ltd

REC Report 71621p1r0

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EXECUTIVE SUMMARY

Resource & Environmental Consultants (REC) Ltd was commissioned by Staffordshire Crystal Ltd to monitor emissions of pollutants released from the Furnace, Acid Scrubber and Wet Arrestor processes at their site in Brierley Hill.

In accordance with the requirements of their site permit, monitoring has been undertaken for the following pollutants:-

- Oxygen
- Total Particulate Matter
- Hydrogen Fluoride
- Lead.

The following results were obtained from the monitoring survey and are compared with the current permit limit:-

Emission Source & Species		Emission Concentration mg/Nm ³	Emission Concentration mg/m ³ @ ref O ₂	Mass Emission Value (g/hr)	Permit Limit	
					mg/m ³	g/hr
Furnace	Particulates run 1	6.2	39.1	374	20	500
	Particulates run 2	3.6	22.1	211		
	Lead run 1	0.8	5.1	48.7	5	25
	Lead run 2	0.7	4.0	38.2		

NOTE 1: Furnace Emission Data expressed in mg/Nm³ at 273K, 101.3kPa, on a dry gas basis and corrected to 8% oxygen content unless otherwise stated. Mass emission rates are expressed in g/hr.

Emission Source & Species		Emission Concentration (mg/Nm ³)	Permit Limit (mg/Nm ³)
Wet Arrestor	Particulates run 1	1.3	20
	Particulates run 2	3.4	
	Lead run 1	0.1	5
	Lead run 2	0.1	

NOTE 1: Wet Arrestor Emission data expressed in mg/m³ at 273K, 101.3kPa, on a wet gas basis without correction for oxygen content.

Emission Source	Species	Emission Concentration (mg/m ³)	Permit Limit (mg/m ³)
Acid Scrubber Run 1	Hydrogen Fluoride	19.2	5

Note 1: Acid Scrubber Emission data expressed in mg/m³ at 273K, 101.3kPa, without correction for moisture and oxygen content.

INTRODUCTION

1.1 Background

Staffordshire Crystal Ltd commissioned REC Ltd to conduct an emission monitoring survey on the Furnace, Wet Arrestor and Acid scrubber processes at their site in Brierley Hill.

The Furnace melts down solid pieces of glass cullet in to a molten state ready for Blowing & casting. The furnace operates at approximately 1300 degrees centigrade and is fuelled by natural gas. There was no abatement present on the furnace.

The Wet Arrestor process involves the extraction of glass cuttings from the cutting lathe areas by local exhaust fans. The waste cuttings pass through a water trough which acts as abatement before being discharged to the atmosphere.

The Acid Fume Scrubbing Unit process collects the exhaust gases arising from the glass cleaning process which pass through a wet scrubber before being discharged to the atmosphere.

1.2 Scope of the Survey

An emission monitoring survey was required to determine the release concentrations of various pollutants from the aforementioned processes. Concentrations of the following pollutants were quantified during the survey:

- Oxygen
- Hydrogen Fluoride
- Lead
- Particulate matter

Ancillary measurements of stack dimensions, temperature and velocity were also made.

The results for the Furnace are reported at 273K, 101.3kPa, dry gas and corrected to 8% oxygen content.

The results for the Wet Arrestor are reported at 273K, 101.3kPa, dry gas without correction for oxygen content.

The results for the Acid Fume Scrubbing Unit are reported at 273K, 101.3kPa, without correction for moisture and oxygen content

1.3 Sampling Personnel

Monitoring was conducted by the following REC Ltd permanent staff:-

- Aidan Wryne - Team Leader, MM08 921, MCERTS Level 2, TE 1,3 &4
- Craig MacDonald - Assistant, MM11 1130, MCERTS Trainee

2. METHODOLOGY

2.1 Species & Techniques

The following table shows the reference methods used for the emission monitoring survey:

Species	Method	Uncertainty (±%)	Limit of Detection
Moisture	In house method MM0010 based on BS EN 14790	20	0.1%vol
Particulate Matter	In house method MM0004 based on BS 3405	25	1 mg/m ³
Hydrogen Fluoride	In house method MM0013 based on BS ISO 15713	20	0.1 mg/m ³
Lead	In house method MM0007 based on US EPA M29	15	0.01 – 0.1 mg/m ³
Oxygen	In house method MM0002 based on ISO 12039	10	0.1%vol

2.2 Sampling & Analytical Methodology

Total Particulate Matter

To determine the concentration of particulate matter in emissions, non isokinetic stack sampling equipment satisfying the requirements of BS 3405 was utilised and in-house method MM0004 followed.

This standard describes methodology for measuring particulate matter under defined conditions and at discrete locations in the duct. If all the procedural requirements of the test are complied with, the accuracy of the test results can be quoted as ± 25%.

The sampling train consisted of a stainless steel nozzle and probe connected to a filter holder containing a 37mm quartz filter.

This was connected to a calibrated dry gas meter and a sampling pump. Isokinetic sampling could not be maintained due to the high flow rate in the stack.

Hydrogen Fluoride

To determine the concentration of HF in emissions, non isokinetic stack sampling equipment based on the requirements of BS ISO 15713 was utilised and in-house method MM00013 followed.

A sample of the exhaust stream was removed from the stack via a PTFE probe.

On leaving the probe, the sampled exhaust gas was passed into a series of Impingers. The first two Impingers encountered by the gas stream contained dilute Sodium Hydroxide (0.1M) to capture and absorb the volatile fluoride (F^-) ions. The third Impinger was empty and the fourth contained anhydrous silica gel which was used to dry the gas stream before passing it through a dry gas meter (DGM) to measure the volume of gas sampled.

Upon completion of sampling, the contents of the first two Impingers were transferred to a sealed, labelled container, which was subsequently analysed for F^- via an ion chromatographic technique.

Lead

To determine the concentration of Lead in emissions, stack sampling equipment satisfying the requirements of US EPA Method 29 was utilised and in-house method MM0007 followed.

The Standard describes the methodology for measuring heavy metals under defined conditions and at discrete locations in the duct.

A sample of the exhaust stream was removed from the stack via a stainless steel nozzle and probe. It was then passed through a quartz filter. On leaving the filter, the sampled exhaust gas was passed into a series of Impingers. The first two Impingers encountered by the gas stream contained H_2O_2 / HNO_3 mix to absorb volatile heavy metals. The third impinger was empty and the fourth Impinger contained anhydrous silica gel which was used to dry the gas stream before passing it through a dry gas meter (DGM) to measure the volume of gas sampled.

Upon completion of sampling, the filter was transferred to a clean, labelled Petri dish and sealed for transport back to the laboratory. The contents of the Impingers were transferred to two clean, labelled containers which were sealed for transport back to the laboratory. The filter and the Impinger solutions were analysed for Lead, via an ICP-OES technique.

Oxygen

To determine the concentration of Oxygen in emissions, a Testotherm Model 350XL multigas analyser was used. The analyser incorporates a gas conditioner to enable the gas stream to be presented to the electrochemical cells on a dry gas basis. In house method MM0002 was followed.

The analyser satisfies the requirements of the following Standards:-

O₂ - ISO 12039

For Oxygen the measured value (m.v.) and accuracy associated with this type of measurement using the Testo 350XL is:

O₂ ± 0.8% of full scale deflection

The analyser would be calibrated against traceable test gases prior to the survey.

The Standards describe the methodology for measuring the combustion gases listed above under defined conditions in the duct. Sampling is carried out under anisokinetic sampling conditions as it is assumed that the gas is homogenous across the sample plane.

Stack Temperature and Velocity

To determine the stack temperature, a calibrated thermocouple and digital indicator were employed. The exhaust gas velocity was investigated using a pitot static probe (to MM0004) and digital manometer.

3. SAMPLING AND OPERATIONAL DETAILS

3.1 Process Description

The operations at Staffordshire Crystal are authorised under a Part B permit issued by the Local Authority under the Environmental Permitting Regulations, 2010.

The process is therefore under Local Authority regulation and must demonstrate compliance with the emission limits stipulated in the site permit: PB/98/CP1

The Furnace process uses natural gas as a fuel to operate at temperatures of approximately 1300 degrees centigrade in order to melt down solid cullet in to a molten state. The process operates on a batch basis. No abatement was present on the Furnace. The loading during testing consisted of a batch of 750kg of solid cullet which is melted over a 24 hour period.

The Wet Arrestor process collects all the waste cuttings from the Glass cutting lathes via a local exhaust ventilation system. The LEV system then discharges the gas stream in to a water trough which acts as abatement before the process gases are discharged to the atmosphere. The loading during testing was normal.

The Acid Fume Scrubbing Unit utilises a wet scrubber in order to minimise hydrogen fluoride emissions which are collected from the acid polishing process inside the factory. The loading during testing was normal.

3.2 Sampling Positions

On the Furnace 1 x 4 inch Hole was installed in a vertical section of ducting which was located greater than five hydraulic diameters away from potential flow disturbances both upstream and downstream. The velocity profile conducted along the sampling plane complies with the sampling plane requirements stipulated in the EA technical guidance note M1. The size of the port does not comply with the EA Technical guidance note M1.

On the Wet Arrestor stack sampling was carried out on a diagonal section of ducting leaving the water trough. One 10mm hole was provided which does not comply with the EA technical guidance note M1. The sampling plane was located less than five hydraulic diameters away from potential flow disturbances both upstream and downstream. The velocity profile was however compliant with EA technical guidance note M1.

On the Acid Fume Scrubbing Unit a 1 x 1 inch hole was installed in a vertical section of ducting. The sampling plane was greater than five hydraulic diameters both upstream and downstream away from potential flow disturbances. The size of the port does not comply with the requirements specified in the EA technical guidance note M1. The velocity profile conducted along sampling plane complies with the requirements of the EA technical guidance not M1.

3.3 Uncertainty

On the Furnace and Wet Arrestor stacks only one sampling port was installed and due to access restrictions isokinetic sampling equipment could not be used. Consequently this will increase the uncertainty associated with the particulate tests and the particulate phase of the lead tests above the standard 25% and 15 % respectively.

On the Acid Fume Scrubbing Unit only one port was installed, however this will not affect the standard uncertainty associated with the HF testing as the HF was sampled in the gaseous phase and so it is assumed to be homogenous across the sample plane. Consequently standard uncertainties apply.

3.4 Emission Monitoring Survey Details

The emission monitoring survey was carried out on at Staffordshire Crystal Ltd on the 13th of November 2013. The table below summarises the actual sampling periods.

SAMPLING PERIODS

Stack	Parameter	Sample Time (& Date)
Furnace	Particulates, Lead Run 1	11:36 - 12:16 (13/11/13)
	Particulates, Lead Run 2	12:58 - 13:38 (13/11/13)
Wet Arrestor	Particulates, Lead Run 1	14:11 -14:51 (13/11/13)
	Particulates, Lead Run 2	15:05 - 15:45 (13/11/13)
Acid Fume Scrubbing Unit	Hydrogen Fluoride Run 1	13:09 - 13:49 (13/11/13)

4. RESULTS AND DISCUSSION

4.1 Initial Velocity and Temperature Traverse

An initial pitot-static pressure and temperature traverse was carried out. From these data stack velocity, expressed in metres per second (m/s), and volumetric flowrates expressed in cubic metre per hour (m³/hr) have been calculated.

The results are reported at actual stack conditions and the volumetric flowrate is further expressed at the standard reference conditions of 273K, 101.3kPa i.e. standard temperature and pressure (STP). The results are summarised in Table 1.

4.2 Particulate Matter

The results of the particulate sampling runs are summarised in Tables 2 - 5. From the mass of particulate matter on the filter and in the acetone/water wash residue and volume sampled an emission concentration was calculated.

The results for the Furnace are expressed in mg/m³ at 273K, 101.3kPa, on a dry gas basis and corrected to 8% O₂ content. They are also expressed as mass emission rates in grams per hour.

The results for the Wet Arrestor particulate tests are expressed in mg/m³ at 273K, 101.3kPa, on a dry gas basis without correction for oxygen content.

4.3 Hydrogen Fluoride

The results of the volatile fluoride sampling run is summarised in Table 6. From the concentration of F⁻ and the measured volume of absorbing solution a total mass of HF in microgram (µg) was determined. From the respective molecular weight, equivalent weights of HF were then calculated. From the measured sample volume, an emission concentration was calculated.

The results are expressed in mg/m³ at 273K, 101.3kPa, without correction for water vapour and oxygen content.

4.4 Lead

The results of the lead sampling runs are summarised in Tables 2 - 5. The total mass of Lead in µg was calculated from the filter and Impinger solution contributions.

The lead results for the Furnace are expressed in mg/m³ at 273K, 101.3kPa, on a dry gas basis and corrected to 8% oxygen content. The lead results for the furnace are also expressed as mass emission rates in grams per hour.

The lead results for the Wet Arrestor unit are expressed in mg/m³ at 273K, 101.3kPa, on a wet gas basis without correction for oxygen content.

4.5 Oxygen

The results of the oxygen gas monitoring tests are summarised in Table 7. The table presents the average of concentrations measured throughout each of the sample periods.

Concentrations are expressed as a percentage at 101.3kPa .

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TABLES

TABLE 1
FLOW DATA

Stack Ref.	Stack Temp	Av Pitot ΔP	Duct Diam	X-Sect. Area	Velocity (actual)	Volume Flow (m ³ /hr)	
	(°C)	(Pa)	(cm)	(m ²)	(m/s)	(actual)	(@ ntp)
Furnace	32	258	40	0.126	21.1	9,556	8,559
Wet arrestor	16	142	40	0.126	15.3	6,906	6,518
Acid Scrubber	22	101	50	0.196	13.0	9,162	8,490

TABLE 2

PARTICULATE / LEAD EMISSION DATA SUMMARY - FURNACE – RUN 1 – 13/11/13

Sampling Data	Run 1
Start Time/Date	11:36, 13/11/13
End Time/Date	12:16, 13/11/13
Sampling Period (min)	40
DGM start (dry m ³)	5938.285
DGM end (dry m ³)	5938.499
Volume Sampled (dry m ³)	0.214
Ambient Temp (°C)	17
Ambient Press (kPa)	101.2
Wt of Water (g)	0
Volume Water (m ³)	0.000
Volume Sampled, 273K, 101.3kPa (dry m ³)	0.201
Volume Sampled, 273K, 101.3kPa (wet m ³)	0.201
Volume Impingers (ml)	190
Measured O ₂ (%vol)	18.9
Reference O ₂ (%vol)	8.0
Analytical Data	
Pb Blank (ug/l)	0.3
Pb Imp (ug/l)	9.90
Pb Imp (µg)	2
Pb on filter (µg)	160.00
Total Pb (ug)	162
Filter weight gain (mg)	0.1
Acetone wash weight gain (mg)	1.2
Total Particulate (mg)	1.3
Emission Concentration Data	
Moisture (%vol)	0.0
Pb (mg/m ³)	0.8
Pb (mg/m ³ @ ref O ₂)	5.1
Pb Measurement Uncertainty (± mg/m ³)	0.1
Particulate matter (mg/m ³)	6.2
Particulate matter (mg/m ³ @ ref O ₂)	39.1

TABLE 3

**PARTICULATE / LEAD EMISSION DATA SUMMARY – FURNACE RUN 2 –
13/11/13**

Sampling Data	Run 2
Start Time/Date	12:58, 13/11/13
End Time/Date	13:38, 13/11/13
Sampling Period (min)	40
DGM start (dry m ³)	5938.532
DGM end (dry m ³)	5938.755
Volume Sampled (dry m ³)	0.223
Ambient Temp (°C)	18.5
Ambient Press (kPa)	101.2
Wt of Water (g)	10.7
Volume Water (m ³)	0.013
Volume Sampled, 273K, 101.3kPa (dry m ³)	0.209
Volume Sampled, 273K, 101.3kPa (wet m ³)	0.222
Volume Impingers (ml)	300
Measured O ₂ (%vol)	18.8
Reference O ₂ (%vol)	8.0
Analytical Data	
Pb Blank (ug/l)	0.3
Pb Imp (ug/l)	19.00
Pb Imp (µg)	6
Pb on filter (µg)	130.00
Total Pb (ug)	136
Filter weight gain (mg)	0.1
Acetone wash weight gain (mg)	0.7
Total Particulate (mg)	0.8
Emission Concentration Data	
Moisture (%vol)	6.0
Pb (mg/m ³)	0.7
Pb (mg/m ³ @ ref O ₂)	4.0
Pb Measurement Uncertainty (± mg/m ³)	0.1
Particulate matter (mg/m ³)	3.6
Particulate matter (mg/m ³ @ ref O ₂)	22.1

TABLE 4

**PARTICULATE / LEAD EMISSION DATA SUMMARY – WET ARRESTOR – RUN
1 – 13/11/13**

Sampling Data	Run 1
Start Time/Date	14:11, 13/11/13
End Time/Date	14:51, 13/11/13
Sampling Period (min)	40
DGM start (dry m ³)	50.195
DGM end (dry m ³)	50.617
Volume Sampled (dry m ³)	0.422
Ambient Temp (°C)	10
Ambient Press (kPa)	101.2
Wt of Water (g)	6.4
Volume Water (m ³)	0.008
Volume Sampled, 273K, 101.3kPa (dry m ³)	0.407
Volume Sampled, 273K, 101.3kPa (wet m ³)	0.415
Volume Impingers (ml)	190
Analytical Data	
Pb Blank (ug/l)	0.3
Pb Imp (ug/l)	14.00
Pb Imp (µg)	3
Pb on filter (µg)	34.00
Total Pb (ug)	37
Filter weight gain (mg)	0.1
Acetone wash weight gain (mg)	0.5
Total Particulate (mg)	0.6
Emission Concentration Data	
Moisture (%vol)	1.9
Pb (mg/m ³)	0.1
Pb Measurement Uncertainty (± mg/m ³)	0.2
Particulate matter (mg/m ³)	1.3

TABLE 5

PARTICULATE / LEAD EMISSION DATA SUMMARY- WET ARRESTOR – RUN 2
– 13/11/13

Sampling Data	Run 2
Start Time/Date	15:05, 13/11/13
End Time/Date	15:45, 13/11/13
Sampling Period (min)	40
DGM start (dry m ³)	50.617
DGM end (dry m ³)	51.050
Volume Sampled (dry m ³)	0.433
Ambient Temp (°C)	9
Ambient Press (kPa)	101.2
Wt of Water (g)	2.2
Volume Water (m ³)	0.003
Volume Sampled, 273K, 101.3kPa (dry m ³)	0.419
Volume Sampled, 273K, 101.3kPa (wet m ³)	0.422
Volume Impingers (ml)	180
Analytical Data	
Pb Blank (ug/l)	0.3
Pb Imp (ug/l)	75.00
Pb Imp (µg)	14
Pb on filter (µg)	48.00
Total Pb (ug)	62
Filter weight gain (mg)	0.5
Acetone wash weight gain (mg)	1.0
Total Particulate (mg)	1.5
Emission Concentration Data	
Moisture (%vol)	0.6
Pb (mg/m ³)	0.1
Pb Measurement Uncertainty (± mg/m ³)	0.3
Particulate matter (mg/m ³)	3.4

TABLE 6

**HYDROGEN FLUORIDE EMISSION DATA SUMMARY– ACID SCRUBBER-
13/11/13**

Sampling Data	Run 1
Start Time/Date	13:09, 13/11/13
End Time/Date	13:49, 13/11/13
Sampling Period (min)	40
DGM start (dry m ³)	49.883
DGM end (dry m ³)	50.195
Volume Sampled (dry m ³)	0.312
Ambient Temp (°C)	12
Ambient Press (kPa)	101.2
Wt of Water (g)	2.4
Volume Water (m ³)	0.003
Volume Sampled, 273K, 101.3kPa (dry m ³)	0.299
Volume Sampled, 273K, 101.3kPa (wet m ³)	0.302
Volume NaOH Impingers (ml)	340
Analytical Data	
HF Blank (mg/l)	0.05
HF in NaOH Imps (mg/l)	17.00
HF (µg)	5780
Emission Concentration Data	
Moisture (%vol)	1.0
HF (mg/m ³)	19.2
HF Measurement Uncertainty (± mg/m ³)	2.9

TABLE 7

**OXYGEN EMISSION DATA SUMMARY – FURNACE – RUNS 1 & 2 -
13/11/13**

EMISSION SOURCE	OXYGEN %
Furnace run 1	18.85
Furnace run 2	18.80

APPENDIX 1

Calculations

Conversion Factors

ppm @ mg/Nm³ (at 273K, 101.3kPa: STP)

CO	x	1.25	
SO ₂	x	2.86	
VOC's	x	1.61	(ppm as C ₃ H ₈ to mg/Nm ³ as C)
NO _x	x	2.05	(ppm NO + NO ₂ to mg/m ³ as NO ₂)

Oxygen Correction to Reference Value

Concentration at (STP) -> Concentration at 273K, 101.3kPa, reference O₂ and Dry Gas, i.e.

Concentration X ((20.9-O₂ ref)/(20.9-O₂ measured)) = Concentration at ref Oxygen state.

Example Calculation

SO ₂ concentration at STP	=	170.7 mg/Nm ³
Oxygen percentage in gas stream	=	13.8%
Reference Oxygen	=	11%
SO ₂ concentration at reference O ₂ conditions	=	170.7 ((20.9-11)/(20.9-13.8))
	=	238 mg/Nm ³ at 273K, 101.3kPa, 11% O ₂ and Dry Gas

Moisture Correction (Wet to Dry)

Concentration of Gas Dry = Concentration of x 100/100-Bws Gas Wet

Concentration of Gas Wet = Concentration of x 100-Bws/100 Gas Dry

Where Bws = moisture content of gas stream in percent (Vol/Vol).

Example

VOC concentration	=	25 mg/Nm ³ (Wet)
Moisture Content	=	27.1%
Concentration of VOC	=	25 (100/(100-27.1))

Carbon (C) to Trichloethylene (TCE)

ppm TCE = ppm C x 0.6715

TCE in mg/m³ = TCE ppm x 5.864 (Mol Wt/22.4)