REC Environmental Monitoring

Client **Staffordshire Crystal Ltd.**
Unit 14 Pedmore Road Ind. Estate
Brierly Hill
West Midlands
DY5 1TJ

Part 1: Executive Summary

Report for the Periodic Monitoring of Emissions to Air.

Site	**Brierly Hill**
Plant	**Acid Fume Scrubber**
Sampling Date	**14th October 2014**
Report Date	**25th November 2014**
Job Number	**2p71962**
Permit Number	**PB/98 Variation 200839393**

Report Prepared by: ***Print*** **Graham Rowley**

MCERTS No. **MM 03 148** **Level 2 TE: 1,2,3,4**

Report Approved by: ***Sign*** 

Print **Emily Buffam**

MCERTS No. **MM 04 502** **Level 2 TE: 1,2,3,4**

1783

REC Environmental Monitoring Ltd
10 Broad Lane
Moldgreen
Huddersfield
HD5 9BX

Tel: 0845 676 9303
Company Registration No 08343822

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Contents

Monitoring Objectives

The monitoring was undertaken to check compliance with authorised emission limits.

All monitoring procedures were carried out to the MCERTS requirements under the REC Environmental Monitoring quality system to ISO 17025: 2005.

Monitoring was undertaken for the listed emissions from the following sampling positions:

Sampling Location	Emission
Acid Fume Scrubber	**Hydrogen fluoride**

Special Monitoring Requirements

There were no special requirements for this monitoring campaign.

Summary Of Methods

Emission	Method number	Method standard
Gas velocity	TPM/01	BS EN 13284 : 2002
Water vapour	TPM/37	BS EN 14790 : 2005
Hydrogen fluoride	TPM/38	BS ISO 15713 : 2006

Summary Of Results

The table presents the atmospheric emissions from the tests undertaken on behalf of **Staffordshire Crystal Ltd.** The results were measured from the sample positions downstream of the arrestment plant.

Emission at Brierly Hill Acid Fume Scrubber	Sampling Time			Emission Result	Authorised Limit	Uncertainty +/-	Detection Limit	Mass Emission
	Date	Start	End	mg/m^3*	mg/m^3*	mg/m^3*	mg/m^3*	g/h
s Hydrogen fluoride	14/10/14	13:09	13:49	ND	5	0.02	0.17	0.66

* at reference conditions	Stack Gas Weight	0 °C	Without correction for moisture
	29.00 Kg/kmol	101.3 kPa	Oxygen No Correction %

Where applicable Oxides of nitrogen results are expressed as nitrogen dioxide
TOC results are expressed as total carbon

Throughout Report:
* Reference conditions (see above)
** Analysis not required
ND Non detectable
s - Subcontracted laboratory analysis
Nm^3 273 K, 101.3 kPa
- UKAS accredited only
- Not Accredited
N/A Not applicable

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor k=2, providing a 95% confidence level. The uncertainty evaluation has been carried out in accordance with UKAS requirements.

Operating Information

The tables below shows details of the operating information on each sampling date for: **Acid Fume Scrubber**

Date	Process type	Process duration	Fuel	Feedstock	Abatement	Load
14/10/2014	Acid Fume Scrubber	Continuous	-	Glass	Wet Scrubber	Normal operation

There are no CEMs currently installed on this process for the determinands being monitored.

Comments & Monitoring Deviations

A waste gas homogeneity test to BS EN 15259:2007 (MID) is not required:-
The homogeneity test is not applicable to non-combustion processes.
The homogeneity test is not applicable to duct areas less than $1m^2$.

All monitoring was performed in accordance with the relevant procedures.

The velocity and temperature profile at the sampling location met the requirements of BS EN 13284-1: 2002.

The impinger efficiency check for hydrogen fluoride was not performed because the measured emission was less than 30% of the emission limit value.

When the results are expressed as non-detected the mass emissions are calculated from the detection limit and therefore they are worst case results.

REC Environmental Monitoring

Part 2: Supporting Information

Report for the Periodic Monitoring of Emissions to Air.

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Report Prepared by:	***Print***	**Graham Rowley**	
	MCERTS No.	**MM 03 148**	**Level 2 TE: 1,2,3,4**
Report Approved by:	***Sign***	EBuffam	
	Print	**Emily Buffam**	
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APPENDIX 1

Emission Monitoring Procedures And Instrumentation

Gas velocity and temperature

Documented in-house procedure TPM/01 to the main procedural requirements of BS EN 13284:2002. Velocity and temperature measurements are performed using a calibrated Pitot tube, as described in BS ISO 10780:1994 and a calibrated thermocouple. Velocity and possible flow deviation measurements are carried out at selected, representative points in the gas stream.

Water vapour

Documented in-house procedure TPM/37 to the main procedural requirements of BS EN 14790:2005. A measured volume of gas is extracted from the gas stream through a moisture trapping unit. The mass gain of moisture trapped is divided by the volume of gas sampled to determine the mass concentration of water vapour. For water saturated stacks the temperature of the gas stream is measured and the water vapour concentration is determined using liquid-gas equilibrium tables. Sampling points are selected in accordance with the findings of any BS EN 15259 assessment.

Hydrogen fluoride

Documented in-house procedure TPM/38 to the main procedural requirements of BS ISO 15713:2006- substantial metered volume of gas extracted through a dedicated heated probe, filter, sample line and chilled multi-impinger train containing sodium hydroxide solution, and subsequent Ion Chromatography analysis. Sampling points are selected in accordance with the findings of any BS EN 15259 assessment.

Sampling Project Personnel Competency And Expiry Dates

		MCERTS No	Level 1	Level 2	TE1	TE2	TE3	TE4
Report prepared by:	Graham Rowley	MM 03 148	-	30/11/2018	30/11/2018	31/03/2015	31/10/2019	31/03/2020
Report authorised by:	Emily Buffam	MM 04 502	-	30/06/2016	30/06/2016	31/08/2016	31/08/2016	31/08/2016
Team leader:	Graham Rowley	MM 03 148	-	30/11/2018	30/11/2018	31/03/2015	31/10/2019	31/03/2020
Technician:	Tom Clarkson	MM 02 120	31/12/2018	-	-	-	-	-

Equipment References

Equipment	Reference Number
Probe	**P52**
Probe Thermocouple	**TP52**
Stack Thermocouple	**TS52**
Control Box	**CU13**
Timer / Stopwatch	**CU13/8**
Barometer	**WS04**
Pitot	**PT113**
Callipers	**CV17**
Hot Box	**HB23**
Impinger Thermocouple	**TV34**
Sample Rate Calculation Equipment	**Laptop**
Balance	**BL19**
Weights	**W35, W36**

Subcontracted Analysis

REC Environmental Monitoring has, with your approval, used the following sub-contracted laboratories for the laboratory analyses referenced below:

Laboratory:	Scientific Analysis Laboratories
Parameters:	Acid Gases - Internal method IC
Accreditation:	UKAS Accredited testing laboratory number 1549

APPENDIX 2

Date	14/10/2014
Time	13:20
Pitot Cp	0.85

Barometric pressure	98.9	kPa
Duct static pressure	0.06	kPa
Stack Area	0.181	m^2

Stack Diameter (circular)	0.48	m

Traverse Point	Traverse Line	Depth cm	ΔP mmH_2O	T ^oC	Angle ^{o}	velocity m/s	Traverse Line	Depth cm	ΔP mmH_2O	T ^oC	Angle ^{o}	velocity m/s
1	A	5.0	3.0	14	<15	5.9	B	5.0				
2	A	5.0	3.5	14	<15	6.4	B	5.0				
3	A	5.7	4.0	14	<15	6.9	B	5.7				
4	A	8.5	4.0	14	<15	6.9	B	8.5				
5	A	12.0	4.5	14	<15	7.3	B	12.0				
6	A	17.1	3.5	14	<15	6.4	B	17.1				
7	A	30.9	3.5	14	<15	6.4	B	30.9				
8	A	36.0	5.0	14	<15	7.7	B	36.0				
9	A	39.5	4.5	14	<15	7.3	B	39.5				
10	A	42.3	5.5	14	<15	8.1	B	42.3				
11	A	43.0	5.5	14	<15	8.1	B	43.0				
12	A	43.0	5.0	14	<15	7.7	B	43.0				

Average Pitot DP	4.25	mmH_2O
Average Temperature	287.2	K
Average Velocity	7.1	m/s
Average volumetric flow rate	1.28	m^3/s at stack conditions
Average volumetric flow rate	1.19	m^3/s (wet STP)
Average volumetric flow rate	1.16	m^3/s (dry STP)
Average volumetric flow rate	N/A	m^3/s (dry, STP, reference oxygen concentraion)

Sampling plane requirements Re: BS EN 13284-1:2001 5.2

a	Angel of gas flow less than 15^o with regard to duct axis	YES
b	No local negative flow	YES
c	Minimum pitot greater than 5Pa	YES
d	Ratio of highest to lowest local gas velocity less than 3:1	YES
	Minimum local gas velocity	5.9
	Maximum local gas velocity	8.1
	Ratio of highest to lowest local gas velocity	1.35

Moisture Determination BS EN 14790:2005

	Volume m^3	Temp ^oC	Pressure mbar
Meter start	5.141	12	989
Meter end	5.249	13	989
Meter Yd	1.013		
Gas volume	0.102		

Impinger	1	2	3	4	5
Mass start (g)	338.9	332.5	227.8	945.5	
Mass End (g)	339.6	332.6	228.0	947.0	
Total Mass collected (g)		2.5			

Water vapour content (% v/v)	3.0

If water droplets are present in the gas, the water vapour content is calculated using BS EN 14790 Annex A N/A % v/v

Preliminary Velocity Traverse & Moisture Data

Probe/Pitot ID No		P52/PT113	Nozzle Diameter (d)	mm	-
Pitot Calibration Factor (Cp)		0.85	In-stack Filtration	Y/N	N
Gas Calibration Factor (Y)		1.013	Leak check OK	Y/N	Y
Barometric Pressure	kPa	98.9	Meter ID No		CU13
Duct static Pressure	kPa	0.06	Initial Gas Meter Reading	m³	5.141
Date		14/10/2014	Final Gas Meter Reading	m³	5.249
Start Time	hh:min	13:09	Sampled Vol, Dry at Meter	m³	0.108
End Time	hh:min	13:49	Sampled Vol, Dry STP	Nm³	0.102
Sampling Duration	hh:min	00:40	Moisture content of stack gas	% v/v	3.0

Impinger	1	2	3	4
Initial mass (g)	338.9	332.5	227.8	945.5
Final mass (g)	339.6	332.6	228.0	947.0

Sample Point Number	Line	Sampling Time	Pitot Reading	Temperatures			Orifice Pressure
				Sample Gas Temperature	Filter Temperature	Meter Temperature	
		hh:min	(h) mm w.g	(Ts) °C	°C	(Tm) °C	(Dh) mm w.g
Centre	Point	00:00	3.5	14	160	12	1.5
		00:05	3.5	14	160	12	1.5
		00:10	3.5	14	160	12	1.5
		00:15	3.5	14	160	12	1.5
		00:20	3.5	14	160	13	1.5
		00:25	3.5	14	160	13	1.5
		00:30	3.5	14	160	13	1.5
		00:35	3.5	14	160	13	1.5
		00:40					
		Averages	3.5	14.0	160.0	12.5	1.5

Average velocity	**6.42**	**m/s**
Average flow rate	**1.16**	**m³/s**
Average flow rate	**1.08**	**m³/s***

Hydrogen Fluoride - Sampling Data

Date	14/10/2014
Start time	13:09
Finish time	13:49

	UNITS	Impinger 1	Impinger 2	Impinger 3 (Drop Out)	Impinger 4 (Silica Gel)
Start mass	g	338.9	332.5	227.8	945.5
Finish mass	g	339.6	332.6	228.0	947.0
Impingers 1 & wash mass	g	186.5			
Impingers 2,3 & wash mass	g	172.3			
Field blank mass	g	197.9			
Sample gas volume	Nm^3	0.102			

Acid Gases	UNITS	Impinger 1 & wash conc. 2p71962/02	Impinger 2&3 & wash conc. 2p71962/03	Field Blank conc. 2p71962/01
Hydrogen fluoride	mg/l	**0.05**	**0.05**	**0.05**

		Impinger 1 Emission	Impinger 2 Emission	Detection Limit	Field Blank Emission	Total Emission	Impinger Efficiency %
Hydrogen fluoride	mg/m^{3*}	0.09	0.08	0.17	0.09	0.17	N/A

Numbers in bold indicate detection limits

Laboratory	SAL	
Method N^o & Accreditation Status	IC	UKAS
Date of analysis	29/10/2014	

Oxygen content of gas	%	N/A
Moisture content of gas	% v/v	3.0

Hydrogen Fluoride - Emission Results

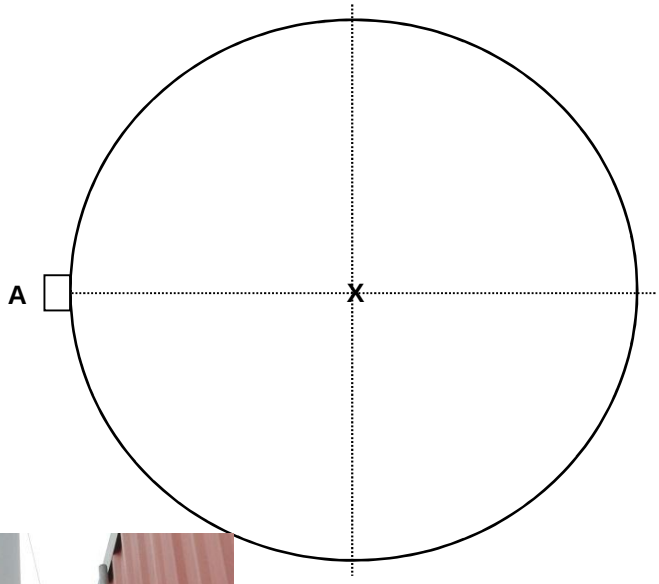
APPENDIX 3

Diagram Of The Sampling Location

Diagram of sampling points across the cross section of the duct (not to scale).

Traverse length = 0.48 m

Point	% of D	Location cm
1	50.0	24.0



General Calculations

Stack area:

$$Area\,of\ a\,circle = \frac{\pi.D^2}{4}$$

D = Diameter (m)
π = 3.142

Pressure conversion:

1mmH2O = 0.00980665 kPa
1mmH2O = 9.80665 Pa
1 mar = 0.1 kPa

Water vapour concentration:
From reference calculations (taken from BS EN 14790):

$$V_{WC(\%)} = \frac{\frac{m_{WC}.V_{mol(std)}}{M_W}}{\frac{m_{WC}.V_{mol(std)}}{M_W} + V_{m(std)}} \times 100$$

VWC (%) = Water vapour content on wet basis, in volume % (m^3 of water vapour in m^3 of wet gas)
Vm(std) = Dry gas volume measured, corrected to standard conditions (m^3)
mWC = Mass of water collected in the impingers (g)
Mw = Molecular weight of water, 18.01534 rounded to 18 (g/mol)
Vmol(std) = Molar volume of water at standard conditions = 0.0224 (m3/mol)

Gas meter volume at standard conditions (STP)
From reference calculations (taken from BS EN 14790):

$$V_{m(std)} = y_d \times (V_2 - V_1) \times \frac{T_{std}}{T_m} \times \frac{p_m}{p_{std}}$$

Vm(std) = Dry gas meter volume at standard conditions (m^3)
yd = Gas meter calibration coefficient
(V2-V1) = Dry gas meter volume at actual conditions (m^3)
Tm = Actual Temperature (K)
Tstd = Standard temperature (273 K)
pm = Absolute pressure at the gas meter (kPa)
pstd = Standard gas pressure (101.3 kPa)

Isokenetic Ratio (%):
From reference calculations (taken from EA TGN M2):

$$IsokineticRatio(\%) = \frac{Velocity\ at\ the\ sampling\ nozzle}{Velocity\ of\ the\ stack\ gas} \times 100$$

Estimating Measurment Uncertainty
Uncertainty estimates are calculated using the general rule of uncertainty propagation. Guidance is taken from publications including UKAS document M3003 and ISO 20988:2007.

Flow Calculations

Velocity:
From reference calculations (taken from ISO 10780):

$$\bar{v} = KC\sqrt{\frac{T_s \, \Delta\bar{p}}{p_e \, M_s}}$$

$\bar{v}$ = Average velocity (m/s)
C = velocity calculation constant = 129
Ts = Average stack temperature (K)
Ms = Molar mass of gas; assume 29 kg/kmol unless the molar mass is < 27 kg/kmol or > 31 g/kmol
K = Pitot calibration coefficient
Pe = Absolute gas pressure (kPa)
$\Delta\bar{p}$ = Average pitot tube pressure differencial (kPa)

Volume flow rate
From reference calculations (taken from ISO 10780):

$$q_{va} = \bar{v}A$$

qva = Average flow rate (m^3/s)
$\bar{v}$ = Average velocity (m/s)
A = Stack cross-sectional area (m^2)

Volume flow rate corrected for moisture
From reference calculations (taken from BS ISO 9096):

$$q_m = q_{va}\frac{(100 - H_a)}{(100 - H_m)}$$

qm = Corrected volume flowrate (m^3/s)
qva = Volume flow rate at actual conditions (m^3/s)
Ha = Moisture at actual conditions (%volume)
Hm = Reference moisture (%volume)

Volume flow rate corrected for temperature and pressure
From reference calculations (taken from BS ISO 9096):

$$q_m = q_{va}\frac{(T_m \; p_a)}{(T_a \; p_m)}$$

qm = Corrected volume flowrate (m^3/s)
qva = Volume flow rate at actual conditions (m^3/s)
Ta = Temperature at actual conditions (K)
Tm = Reference Temperatue (K)
pa = Absolute gas pressure at actual conditions (kPa)
pm = Reference pressure (kPa)

Volume flow rate corrected for oxygen
From reference calculations (taken from BS ISO 9096):

$$q_m = q_{va}\frac{(20.9 - O_{2,ref})}{(20.9 - O_{2,m})}$$

qm = Corrected volume flowrate (m^3/s)
qva = Volume flow rate at actual conditions (m^3/s)
O2,m = Actual oxygen concentration (%)
O2,ref = Reference oxygen concentration (%)

Concentration Calculations

Concentration:
From reference calculations (taken from BS EN 13284-1):

$$c = \frac{m}{V}$$

c = Concentration
m = Mass of substane
V = Volume sampled

Mass Emission

$$Mass\ emission = c \times q_m$$

c = Concentration
q = Volume flow rate

Concentration corrected for oxygen:
From reference calculations (taken from BS ISO 9096):

$$c_m = c_a \times \frac{20.9 - O_{2,ref}}{20.9 - O_{2,a}}$$

cm = Concentration at reference conditions
ca = Actual concentration
O2, ref = Reference oxygen (%)
O2, a= Actual Oxygen (%)

Concentration corrected for moisture:
From reference calculations (taken from BS ISO 9096):

Convert wet gas to dry gas

$$c_{dry} = c_{wet} \times \frac{100}{100 - H_a}$$

Convert dry gas to wet gas

$$c_{wet} = c_{dry} \times \frac{100 - H_a}{100}$$

cwet = Concentration wet gas
cdry = Concentration dry gas
Ha = Water vapour content (%vol)

Conversion of parts per million (ppm) to mg/m^3
From reference calculations (taken from EA TGN M2):

$$Concentration(mg/m^3) = \frac{Concentration(ppm) \times molecular\ weight(g)}{molar\ volume(l)\ at\ a\ given\ temperature}$$

molar volume at 273K = 22.4 litres

When Converting TOC

$$Concentration(mg/m^3) = \frac{Concentration(ppm) \times molecular\ weight\ of\ carbon\ in\ span\ gas(g)}{molar\ volume(l)\ at\ a\ given\ temperature}$$

molar volume at 273K = 22.4 litres

Calculation of Uncertainty Estimates - Manual Monitoring Techniques

$$C_m = \frac{Q_m}{V_{std}}$$

$$V_{std} = V_{T.p} \times \frac{T_{std}}{T} \times \frac{p}{P_{std}}$$

Where:

C_m	=	the measured concentration	in	mg/m^3
Q_m	=	mass concentration collected in absorber solution and filter	in	mg
v_s	=	the volume of the sample solution	in	l
V_{std}	=	volume sampled at standard conditions	in	m^3
T_m	=	mean temperature of gas meter	in	K
T_{std}	=	standard temperature	=	273K
p=prel+Patm	=	absolute pressure = gas meter pressure + atmospheric pressure	in	kPa
P_{std}	=	standard pressure	=	101.325 kPa
$V_{T.p}$	=	volume sampled as indicated by the gas meter	in	m^3

Expression for calculation of the combined uncertainty of the measured concentration

$$\frac{u^2(C_m)}{(C_m)^2} = \frac{u^2(Q_m)}{(Q_m)^2} + \frac{u^2(v_s)}{(v_s)^2} + \frac{u^2(V_{std})}{(V_{std})^2}$$

Expression for calculation of the combined uncertainty of the gas volume

$$V_{std} = V_{T.p} \times \frac{T_{std}}{T_m} \times \frac{p}{P_{std}}$$

Assuming that uncertainties associated with the standard quantities T_{std} and P_{std} are negliable
Expression for calculation of the combined uncertainty of the measured concentration

$$\frac{u^2(C_m)}{(C_m)^2} = \frac{u^2(Q_m)}{(Q_m)^2} + \frac{u^2(v_s)}{(v_s)^2} + \frac{u^2(V_{T.p})}{(V_{T.p})^2} + \frac{u^2(T)}{(T)^2} + \frac{u^2(p_{rel})}{(p)^2} + \frac{u^2(p_{atm})}{(p)^2}$$

$$u(C_m) = \sqrt{\left(\frac{u^2(Q_m)}{(Q_m)^2} + \frac{u^2(v_s)}{(v_s)^2} + \frac{u^2(V_{T.p})}{(V_{T.p})^2} + \frac{u^2(T)}{(T)^2} + \frac{u^2(p_{rel})}{(p)^2} + \frac{u^2(p_{atm})}{(p)^2}\right) \times (C_m)^2}$$

Overall expanded uncertainty (k = 2)

$$U(C_m) = u(C_m) \times k$$

Uncertainty of the measured concentration at oxygen reference concentration

$$u\left(C_{m,O_{2,ref}}\right) = \sqrt{\left(\frac{u^2(Q_m)}{(Q_m)^2} + \frac{u^2(v_s)}{(v_s)^2} + \frac{u^2(V_{T.p})}{(V_{T.p})^2} + \frac{u^2(T)}{(T)^2} + \frac{u^2(p_{rel})}{(p)^2} + \frac{u^2(p_{atm})}{(p)^2} + \frac{u^2(O_{2,meas,dry})}{(21-O_{2,meas,dry})^2}\right) \times \left(C_{m,O_2,ref}\right)^2}$$

Where:

u(Cm,$O_{2,ref}$)	=	uncertainty associated with the mass concentration at O_2 reference concentration	in	mg/m^3
Cm,$O_{2,ref}$	=	mass concentration at O_2 reference concentration	in	mg/m^3
$O_{2,meas}$	=	O_2 measured concentration	in	% volume
u(($O_{2,meas)dry}$)	=	uncertainty associated to the measured O_2 concentration	in	% (relative to $O_{2\ meas}$)

APPENDIX 4

Uncertainty Estimate For The Measurement Of Hydrogen Fluoride ISO 15713

Mass Concentration Of Hydrogen Fluoride

Symbol	Mass concentration of HF	Units
Cm	0.18	mg/m^3
Cm at O2 ref	N/A	mg/m^3

Symbol	Daily emission limit value	Units
DELV	5.0	mg/m^3

Reference Oxygen

O_2,*ref*	0.0	%	(0 = No Correction)

Symbol	Source of Uncertainty	Value	Units	Probability Distribution	Divisor	*ci*	*Ui*
$u(Q_m)$	Analytical Uncertainty	7.0	%	Normal (k=2)	1	1	7
Q_m	Concentration in absorption solution	0.10	mg/l	Normal	-	1	0.0070
$u(Q_m)/Q_m$	Relatve		-	Normal	-	-	0.0700
						$u(Q_m)^2/Q_m^2$	0.0049

Volume of sampled gas

Symbol	Source of Uncertainty	Value	Units	Probability Distribution	Divisor	*ci*	*Ui*
$u(calV_{T,p})$	Calibration	0.0005	m^3	Normal	2	1	0.0003
$u(repV_{T,p})$	Repeatability	0.0001	m^3	Normal	1	1	0.0001
$u(driftV_{T,p})$	Drift	0.0003	m^3	Rectangular	$\sqrt{3}$	1	0.0002
$u(resV_{T,p})$	Resolution	0.0002	m^3	Rectangular	$\sqrt{3}$	1	0.0001
$u(V_{T,p})$	Combined Uncertainty	-	-	Normal	-	-	0.0003
$u(V_{T,p})/V_{T,p}$	Relatve	0.102	m^3	-	-	-	0.0034
						$u(Vm)^2/Vm^2$	0.000011

Temperature of the DGM

Symbol	Source of Uncertainty	Value	Units	Probability Distribution	Divisor	*ci*	*Ui*
$u(calTi_m)$	Calibration	1.00	K	Normal	2	1	0.5000
$u(calTc_m)$	Calibration	1.0	K	2.00	2	1	0.5000
$u(resT_m)$	Resolution	0.1	K	Rectangular	$\sqrt{3}$	1	0.0577
$u(driftT_m)$	Drift	1.0	K	Rectangular	$\sqrt{3}$	1	0.5774
$u(T_m)$	Combined Uncertainty	-	-	Normal	-	-	0.9147
$u(T_m)$/Tm	Relatve	285.5	K	Normal	-	-	0.0032
						$u(Tm)^2/Tm^2$	0.000010

Atmospheric Pressure

Symbol	Source of Uncertainty	Value	Units	Probability Distribution	Divisor	*ci*	*Ui*
$u(P_{atm})$	Metrological Office	300	Pa	Normal	$\sqrt{3}$	1	173
$u(P_{atm})$	Combined Uncertainty	-	-	Normal	-	-	173
$u(P_{atm})$/P	Relatve	98900	-	Normal	-	-	0.00
						$u(P_{atm})^2/P^2$	0.00

Relative DGM Pressure

Symbol	Source of Uncertainty	Value	Units	Probability Distribution	Divisor	*ci*	*Ui*
$u(P_{rel})$	DGM Pressure	40	Pa	Normal	1	1	40
$u(P_{rel})$	Combined Uncertainty	-	-	Normal	-	-	40
$u(P_{rel})$/P	Relative	98915	-	Normal	-	-	0.0004
						$u(Prel)^2/P^2$	0.0000002

Volume (mass) of Absorption Solution

Symbol	Source of Uncertainty	Value	Units	Probability Distribution	Divisor	*ci*	*Ui*
u (repvs)	Repeatability	0.13	g (ml)	Normal	1	1	0.13
u (calvs)	Calibration (Tare)	0.10	g (ml)	Rectangular	1	1	0.10
u (drvs)	Drift	0.10	g (ml)	Rectangular	1	1	0.10
u (resvs)	Resolution	0.05	g (ml)	Rectangular	$\sqrt{3}$	1	0.03
u (vs)	Combined Uncertainty	-	-				0.19
u (vs)/vs	Relative	186.5	-	Normal	-	-	0.0010
						$u(vs)^2/vs^2$	0.0000011

Oxygen reference concentration

Symbol	Source of Uncertainty	Value	Units	Probability Distribution	Divisor	*ci*	*Ui*
$u((O_2,meas)dry)rel$	Measurement of oxygen	N/A	%	Normal	1	1	N/A
	Uncertainty of oxygen correction	-	-	-	-	-	N/A
	Measured Oxygen	N/A	%			$u(Orel)^2/O^2$	N/A

Measurement uncertainty

u(Cm)	Combined Standard Uncertainty			±	0.01	mg/m^3
u(Cm) at ref O_2	Combined Standard Uncertainty			±	N/A	mg/m^3

Expanded uncertainty expressed with a level of confidence of 95%, k=2

U(Cm)	Expanded Combined Uncertainty	*k = 2*		±	0.02	mg/m^3
U(Cm,rel)	Expanded Combined Uncertainty	*k = 2*		±	14.0	%
U(Cm,rel,ELV)	Expanded Combined Uncertainty	*k = 2*		±	0.5	%

Expanded uncertainty at oxygen reference conditions expressed with a level of confidence of 95%, k=2

U(Cm) at ref O_2	Expanded Combined Uncertainty	*k = 2*		±	N/A	mg/m^3
$U(Cm_{rel})$ at ref O_2	Expanded Combined Uncertainty	*k = 2*		±	N/A	%
U(Cm,rel,ELV) at ref	Expanded Combined Uncertainty	*k = 2*		±	N/A	%

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor (k = 2), providing a level of confidence of approximately 95%
The uncertainty evaluation has been carried out in accordance with UKAS requirements.