STACK EMISSIONS MONITORING REPORT

Units C&D Bankside Trade Park
2 Wilkinson Road
Cirencester
GL7 1YT
Tel: 01283 554 540

Your contact at ESG
Mike Davies Business Manager - South Tel: 01283 554 540 Email: mike.davies@esg.co.uk

Operator & Address:
IQE Europe Limited Cypress Driver St. Mellons Cardiff CF3 0EG

Permit:
EPR Permit: KP3235SS

Release Point:
Reactor North 1

Sampling Date(s):
18th June 2015

ESG Job Number:	LSO 150512
Report Date:	7th July 2015
Version:	1
Report By:	Catherine Elsey
MCERTS Number:	MM 08 996
MCERTS Level:	MCERTS Level 2 - Team Leader
Technical Endorsements:	1, 2, 3 & 4
Report Approved By:	David May
MCERTS Number:	MM 07 862
Business Title:	MCERTS Level 2 - Team Leader
Technical Endorsements:	1, 2, 3 & 4
Signature:	

1015

CONTENTS

EXECUTIVE SUMMARY

Stack Emissions Monitoring Objectives
- Plant
- Operator
- Stack Emissions Monitoring Test House

Emissions Summary
Monitoring Times
Process Details
Monitoring Methods
Analytical Methods
- Sampling Methods with Subsequent Analysis
- On-Site Testing

Sampling Location
- Sampling Plane Validation Criteria
- Duct Characteristics
- Sampling Lines & Sample Points
- Sampling Platform
- Sampling Location / Platform Improvement Recommendations

Sampling and Analytical Method Deviations

APPENDICES

APPENDIX 1 - Monitoring Schedule, Calibration Checklist & Monitoring Team
APPENDIX 2 - Summaries, Calculations, Raw Data and Charts
APPENDIX 3 - Measurement Uncertainty Budget Calculations

EXECUTIVE SUMMARY

MONITORING OBJECTIVES

IQE Europe Limited operates a epitaxis process at St Mellons which is subject to EPR Permit KP3235SS, under the Environmental Permitting Regulations 2010.

Environmental Scientifics Group Limited were commissioned by ESP Environmental to carry out stack emissions monitoring to determine the release of prescribed pollutants from the following Plant under normal operating conditions.

The results of these tests shall be used to demonstrate compliance with a set of emission limit values for prescribed pollutants as specified in the Plant's EPR Permit, KP3235SS.

Plant

Reactor North 1

Operator

IQE Europe Limited
Cypress Driver
St. Mellons
Cardiff
CF3 0EG

EPR Permit: KP3235SS

Stack Emissions Monitoring Test House

Environmental Scientifics Group Limited - Cirencester Laboratory
Units C&D Bankside Trade Park
2 Wilkinson Road
Cirencester
GL7 1YT
UKAS and MCERTS Accreditation Number: 1015

Opinions and interpretations expressed herein are outside the scope of UKAS accreditation.
MCERTS accredited results will only be claimed where both the sampling and analytical stages are UKAS accredited.
This test report shall not be reproduced, except in full, without written approval of Environmental Scientifics Group Limited.

EXECUTIVE SUMMARY

EMISSIONS SUMMARY					
Parameter	**Units**	**Result**	**Calculated Uncertainty +/-**	**Limit**	**MCERTS accredited result**
Hydrogen Chloride	mg/m³	0.27	0.032	10	✓
Hydrogen Chloride Emission Rate	g/hr	0.03	0.004	-	
Moisture	%	0.7	0.07	-	✓
Stack Gas Temperature	°C	21	-	-	
Stack Gas Velocity	m/s	4.0	0.15	-	
Gas Volumetric Flow Rate (Actual)	m³/hr	138	6.2	-	✓
Gas Volumetric Flow Rate (STP, Wet)	m³/hr	129	5.8	-	
Gas Volumetric Flow Rate (STP, Dry)	m³/hr	128	5.8	-	
Gas Volumetric Flow Rate at Reference Conditions	m³/hr	129	5.8	-	

ND = None Detected,
Results at or below the limit of detection are highlighted by bold italic text.
The above volumetric flow rate is calculated using data from the preliminary survey. Mass emissions for non isokinetic tests are calculated using these values. For all isokinetic testing the mass emission is calculated using test specific flow data and not the above values.

Reference conditions are 273K, 101.3kPa without correction for water vapour

EXECUTIVE SUMMARY

MONITORING TIMES			
Parameter	**Sampling Date(s)**	**Sampling Times**	**Sampling Duration**
Hydrogen Chloride Run 1	18 June 2015	11:30 - 12:10	40 minutes
Stack Gas Flow Rate & Temperature Run 1	18 June 2015	11:30 - 12:10	-

EXECUTIVE SUMMARY

PROCESS DETAILS

Parameter	Process Details
Description of process	Epitaxis
Continuous or batch	Batch
Product Details	Silicon Wafer
Part of batch to be monitored (if applicable)	3 micron DCS Intrinsic
Normal load, throughput or continuous rating	Normal
Fuel used during monitoring	N/A
Abatement	Wet Scrubber & Dry Bed Scrubber
Plume Appearance	None Visible

EXECUTIVE SUMMARY

Monitoring Methods

The selection of standard reference / alternative methods employed by Environmental Scientifics Group Limited is determined, wherever possible by the hierarchy of method selection outlined in Environment Agency Technical Guidance Note (Monitoring) M2. i.e. CEN, ISO, BS, US EPA etc.

MONITORING METHODS						
Species	**Method** Standard Reference Method / Alternative Method	**ESG Technical Procedure**	**UKAS Lab Number**	**MCERTS Accredited Method**	**Limit of Detection (LOD)**	**Calculated MU +/- %**
Hydrogen Chloride	SRM - BS EN 1911	AE 111	1015	Yes	0 mg/m³	12 %
H_2O	SRM - BS EN 14790	AE 105	1015	Yes	0.03%	10.00%
Velocity	SRM - BS EN ISO 16911-1	AE 154	1015	Yes	5 Pa	3.8 %
Volumetric Flow Rate	SRM - BS EN ISO 16911-1	AE 154	1015	Yes	-	4.5 %

BS EN 14790 has been validated over a range of 4 - 40%. It is however the prefered method of the Environment Agency for concentrations below 4%

EXECUTIVE SUMMARY

Analytical Methods

The following tables list the analytical methods employed together with the custody and archiving details:

SAMPLING METHODS WITH SUBSEQUENT ANALYSIS							
Species	**Analytical Technique**	**Analytical Procedure**	**UKAS Lab Number**	**UKAS Accredited Lab Analysis**	**Analysis Lab (ESG or Subcontract)**	**Sample Archive Location**	**Archive Period**
Hydrogen Chloride	Ion Chromatography	ASC/SOP/110/107	1015	Yes	ESG Bretby	ESG Bretby	3 months

ON-SITE TESTING							
Species	**Analytical Technique**	**Analytical Procedure**	**UKAS Lab Number**	**MCERTS Accredited Analysis**	**Laboratory**	**Data Archive Location**	**Archive Period**
H_2O	Gravimetric	AE 105	1015	Yes	ESG - Cirencester	-	-

EXECUTIVE SUMMARY

SAMPLING LOCATION					
Sampling Plane Validation Criteria	**Value**	**Units**	**Requirement**	**Compliant**	**Method**
Lowest Differential Pressure	10	Pa	>= 5 Pa	Yes	BS EN 16911-1
Lowest Gas Velocity	4.04	m/s	-	-	-
Highest Gas Velocity	4.04	m/s	-	-	-
Ratio of Gas Velocities	1.00	: 1	< 3 : 1	Yes	BS EN 16911-1
Mean Velocity	4.04	m/s	-	-	-
Maximum angle of flow with regard to duct axis	<15	^{o}	< 15^{o}	Yes	BS EN 16911-1
No local negative flow	Yes	-	-	Yes	BS EN 16911-1
Highly homogeneous flow stream / gas velocity	Yes	-	-	Yes	BS EN 16911-1

DUCT CHARACTERISTICS		
	Value	**Units**
Shape	Circular	-
Depth	0.11	m
Width	-	m
Area	0.01	m^2
Port Depth	85	mm

SAMPLING LINES & POINTS			
	Isokinetic (CEN Methods)	**Isokinetic** (ISO Methods)	**Non-Iso & Gases**
Sample port size	-	48mm	-
Number of lines used	-	1	-
Number of points / line	-	1	-
Duct orientation	-	Horizontal	-

SAMPLING PLATFORM	
General Platform Information	
Permanent / Temporary Platform / Ground level / Floor Level / Roof	Floor Level
Inside / Outside	Inside

M1 Platform requirements	
Is there a sufficient working area so work can be performed in a compliant manner	N/A
Platform has 2 levels of handrails (approximately 0.5 m & 1.0 m high)	N/A
Platform has vertical base boards (approximately 0.25 m high)	N/A
Platform has removable chains / self closing gates at the top of ladders	N/A
Handrail / obstructions do not hamper insertion of sampling equipment	N/A
Depth of Platform = >Stack depth / diameter + wall and port thickness + 1.5m	No

Sampling Platform Improvement Recommendations (if applicable)

The sampling location should meet all the requirements as specified in EA Guidance Note M1.

EXECUTIVE SUMMARY

Sampling & Analytical Method Deviations

Flow Traverse

Due to the nature of the process it is not possible to perform a preliminary flow traverse. A single point flow measurement was obtained during the course of the sampling instead

APPENDICES

CONTENTS

APPENDIX 1 - Monitoring Schedule, Calibration Checklist & Monitoring Team

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

APPENDIX 3 - Measurement Uncertainty Budget Calculations

APPENDIX 1 - Monitoring Schedule, Calibration Checklist & Monitoring Team

MONITORING SCHEDULE					
Species	**Method** Standard Reference Method / Alternative Method	**ESG Technical Procedure**	**UKAS Lab Number**	**MCERTS Accredited Method**	**Number of Samples**
Hydrogen Chloride	SRM - BS EN 1911	AE 111	1015	Yes	1
H_2O	SRM - BS EN 14790	AE 105	1015	Yes	1
Velocity	SRM - BS EN ISO 16911-1	AE 154	1015	Yes	1

APPENDIX 1 - Monitoring Schedule, Calibration Checklist & Monitoring Team

CALIBRATEABLE EQUIPMENT CHECKLIST

Extractive Sampling		Instrumental Analyser/s		Miscellaneous	
Equipment	**Equipment I.D.**	**Equipment**	**Equipment I.D.**	**Equipment**	**Equipment I.D.**
Control Box DGM	P1298	Horiba PG-250 Analyser	-	Laboratory Balance Mitcheldean	-
Box Thermocouples	P1298	FT-IR	-	Laboratory Balance Stockport	-
Meter In Thermocouple	P1298	FT-IR Oven Box	-	Laboratory Balance Stockport	-
Meter Out Thermocouple	P1298	Bernath 3006 FID	-	Tape Measure	P1300
Control Box Timer	P1298	Signal 3030 FID	-	Stopwatch	-
Oven Box	-	Servomex	-	Barometer	P2366
Probe	-	JCT Heated Head Filter	-	Digital Temperature Meter	P1746
Probe Thermocouple	-	Thermo FID	-	Stack Thermocouple	P1855
Probe	-	Stackmaster	-	Digital Manometer	P1909
Probe Thermocouple	-	FTIR Heater Box for Heated Line	-	MFC Display module	-
S-Pitot	-	Anemometer	-	1m Heated Line (1)	-
L-Pitot	P1384	Ecophysics NOx Analyser	-	1m Heated Line (2)	-
Site Balance	P1774	Chiller (JCT/MAK 10)	-	1m Heated Line (3)	-
Last Impinger Arm	P1714	Heated Line Controller (1)	Kit no. 5114	5m Heated Line (1)	P2409
Dioxins Cond. Thermocouple	-	Heated Line Controller (2)	-	10m Heated Line (1)	-
Callipers	-	Site temperature Logger	P2210	10m Heated Line (2)	-
Small DGM	-		-	15m Heated Line (1)	-
Heater Controller	-		-	20m Heated Line (1)	-
Inclinometer (Swirl Device)	-		-	20m Heated Line (2)	-

NOTE: If the equipment I.D is represented by a dash (-), then this piece of equipment has not been used for this test.

CALIBRATION GASES

Gas (traceable to ISO 17025)	Cylinder I.D Number	Supplier	ppm	%	Analytical Tolerance +/- %
-	-	-	-	-	-

STACK EMISSIONS MONITORING TEAM

MONITORING TEAM							
Personnel	**MCERTS Number**	**MCERTS Qualification**	**TE / H&S Qualifications and Expiry Date**				
			TE1	**TE2**	**TE3**	**TE4**	**H&S**
Jonathan Ward	MM 02 080	MCERTS Level 2 - Team Leader	Mar-18	Jun-18	Aug-16	Mar-16	Sep-17
Catherine Elsey	MM 08 996	MCERTS Level 2 - Team Leader	Dec-15	Dec-20	Feb-19	Mar-17	Nov-18

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

HYDROGEN CHLORIDE SUMMARY					
Test	**Sampling Times**	**Concentration mg/m³**	**LOD mg/m³**	**Limit mg/m³**	**Emission Rate g/hr**
Run 1	11:30 - 12:10 18 June 2015	0.27	0.00	10	0.03
Field Blank	-	0.02	-	-	-

Reference conditions are 273K, 101.3kPa without correction for water vapour

HYDROGEN CHLORIDE QUALITY ASSURANCE CHECKLIST

Leak Test Results	Mean Sampling Rate l/min	Pre sampling leak rate l/min	Post sampling leak rate l/min	Acceptable leak rate l/min	Leak Tests Acceptable?
Run 1	14.2	0.10	0.10	0.28	Yes

	Filter Material	Filter Size mm	Max. Filtration Temp. °C	Max. Storage / Transit Temp. °C	Type of Absorbers	Absorption Solutions
Run 1	QF	7	N/A	15	Glass	HPLC Water

GF = Glass Fibre

QF = Quartz Fibre

HYDROGEN CHLORIDE ABSORPTION EFFICIENCY

Parameter	**Total ug**	**IMP C ug**	**Absorption Efficiency %**	**Acceptable Absorption Efficiency %**	**Absorption Efficiency Acceptable ?**
Run 1	153.3	16.5	89	95	N/A- < 1mg/m³

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

MOISTURE CALCULATIONS

Moisture Determination - Non Isokinetic							
Test Number	Sampling Time and Date	Start Weight kg	End Weight kg	Total gain kg	Concentration %	LOD %	Uncertainty %
Run 1	11:30 - 12:10 18 June 2015	4.6344	4.6368	0.0024	0.7	0.027	10.0

Moisture Quality Assurance							
Test Number	Sampling Duration mins	Total Volume Sampled l	Sampling Rate l/min	Start Leak Rate l/min	End Leak Rate l/min	Acceptable Leak Rate l/min	Leak Tests Acceptable?
Run 1	32	455	14.2	0.1000	0.1000	0.2844	Yes

PRELIMINARY STACK SURVEY

Stack Characteristics		
Stack Diameter / Depth, D	0.11	m
Stack Width, W	-	m
Stack Area, A	0.01	m^2
Average stack gas temperature	21	^oC
Stack static pressure	0.005	kPa
Barometric Pressure	101.8	kPa
Pitot tube calibration coefficient, K_{pt}	1.00	-

Stack Gas Composition & Molecular Weights								
Component	Molar Mass M	Density kg/m^3 p	Conc Dry % Vol	Dry Volume Fraction r	Dry Conc kg/m^3 pi	Conc Wet % Vol	Wet Volume Fraction r	Wet Conc kg/m^3 pi
CO_2	44	1.963059	0.030000	0.000300	0.000589	0.029804	0.000298	0.000585
O_2	32	1.427679	20.900000	0.209000	0.298385	20.763544	0.207635	0.296437
N_2	28	1.249219	79.070000	0.790700	0.987758	78.553753	0.785538	0.981309
H_2O	18	0.803070	-	-	-	0.652899	0.006529	0.005243

Where: p = M / 22.41 pi = r x p

Calculation of Stack Gas Densities		
Determinand	Result	Units
Dry Density (STP), P_{STD}	1.2867	kg/m^3
Wet Density (STP), P_{STW}	1.2836	kg/m^3
Dry Density (Actual), P_{Actual}	1.2008	kg/m^3
Average Wet Density (Actual), $P_{ActualW}$	1.198	kg/m^3

Where:

P_{STD} = sum of component concentrations, kg/m^3 (not including water vapour)

P_{STW} = (P_{STD} + pi of H_2O) / (1 + (pi of H_2O / 0.8036))

$P_{Actual} = P_{STD}$ x (Ts / Ps) x (Pa / Ta)

$P_{ActualW} = P_{STW}$ x (Ts / Ps) x (Pa / Ta)

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

PRELIMINARY STACK SURVEY

TRAVERSE 1

Date of Survey	18 June 2015
Time of Survey	11:30 - 12:10
Velocity Measurement Device:	L-Type Pitot

Sampling Line A

Traverse Point	Distance into duct (m)	ΔP pt mmH_2O (average of 3)	ΔP pt Pa (average of 3)	Temp °C	Velocity m/s	Volumetric Flow Rate (actual) m^3/s	O_2 % Vol	Angle of Swirl °
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
1	0.04	1.0	10	21	4.04	0.04	-	<15
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
Mean	-	1.0	10	21	4.04	0.04	-	

Sampling Line B

Traverse Point	Distance into duct (m)	ΔP pt mmH_2O (average of 3)	ΔP pt Pa (average of 3)	Temp °C	Velocity m/s	Volumetric Flow Rate (actual) m^3/s	O_2 % Vol	Angle of Swirl °
1	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-
Mean	-	-	-	-	-	-	-	

PRELIMINARY STACK SURVEY QUALITY ASSURRANCE CHECKLIST

PITOT LEAK CHECK								
Run	Pre Traverse Leak Rate				Post Traverse Leak Rate			
	Start Value mmH_2O	End Value mmH_2O	Difference %	Outcome	Start Value mmH_2O	End Value mmH_2O	Difference %	Outcome
Run 1	83.0	84.0	-1.2	Pass	88.00	86	2.3	Pass

To complete a compliant pitot leak check a pressure of over 80mmH_2O is applied and the pressure drop monitored over 5 mins. A drop of less than 5% must be observed.

L-Type Pitot Blockage Test				
Run	Final Reading (Pa)	Reading After Purge	Difference (%)	Outcome
Run 1	42	41	-1	Pass

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

PRELIMINARY STACK SURVEY (CONTINUED)

Sampling Plane Validation Criteria				
EA Technical Guidance Note (Monitoring) M1	Result	Units	Requirement	Compliant
Lowest Differential Pressure	9.8	Pa	>= 5 Pa	Yes
Lowest Gas Velocity	4.04	m/s	-	-
Highest Gas Velocity	4.04	m/s	-	-
Ratio of Gas Velocities	1.00	-	< 3 : 1	Yes
Maximum angle of flow with regard to duct axis	0	^{o}	< 15^{o}	Yes
No local negative flow	Yes	-	-	Yes

Calculation of Stack Gas Velocity, V		
Velocity at Traverse Point, V = K_{pt} x (1-ε) * √(2 * ΔP_{pt} / $P_{ActualW}$)		
Where: K_{pt} = Pitot tube calibration coefficient (1-ε) = Compressibility correction factor, assumed at a constant 0.998		
Average Stack Gas Velocity, Va	**4.04**	m/s

Calculation of Stack Gas Volumetric Flowrate, Q			
Duct gas flow conditions	Actual	Reference	Units
Temperature	21	0	^{o}C
Total Pressure	101.805	101.3	kPa
Oxygen	21.0	21	%
Moisture	0.65	0.65	%

Gas Volumetric Flowrate	Result	Units
Average Stack Gas Velocity (Va)	4.04	m/s
Stack Area (A)	0.01	m^2
Gas Volumetric Flowrate (Actual), Q_{Actual}	138	m^3/hr
Gas Volumetric Flowrate (STP, Wet), Q_{STP}	129	m^3/hr
Gas Volumetric Flowrate (STP, Dry), $Q_{STP,Dry}$	128	m^3/hr
Gas Volumetric Flowrate (REF), Q_{Ref}	129	m^3/hr

Where:

Q_{Actual} = Va x A x 3600

Q_{STP} = Q (Actual) x (Ts / Ta) x (Pa / Ps) x 3600

$Q_{STP,Dry}$ = Q (STP) / (100 - (100 / Ma)) x 3600

Q_{Ref} = Q (STP) x ((100 - Ma) / (100 - Ms)) x ((20.9 - O_2a) / (20.9 - O_2s))

Nomenclature:

Ts = Absolute Temperature, Standard Conditions, 273 K

Ps = Absolute Pressure, Standard Conditions, 101.3 kPa

Ta = Absolute Temperature, Actual Conditions, K

Pa = Absolute Pressure, Actual Conditions, kPa

Ma = Water vapour, Actual Conditions, % Vol

Ms = Water vapour, Reference Conditions, % Vol

O_2a = Oxygen, Actual Conditions, % Vol

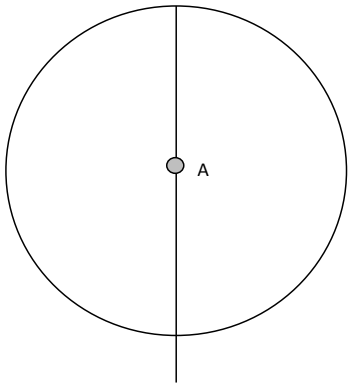
O_2s = Oxygen, Reference Conditions, % Vol

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

STACK DIAGRAM

	Value	Units
Stack Depth	0.11	m
Stack Width	-	m
Area	0.01	m^2

Non-Isokinetic/Gases Sampling			
Sampling Point	Distance (% of Depth)	Distance into Stack	Units
A	50	0.06	m



Sampling Line

Isokinetic Sampling CEN Methods			
Sampling Point	Distance (% of Depth)	Distance into Stack (m)	Swirl °
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-

○ Isokinetic sampling point
● Isokinetic sampling points not used
● Non Isokinetic/Gases sampling point

SAMPLING LOCATION



APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - NON-ISOKINETIC HYDROGEN CHLORIDE

Run	Sampled Volume	Sampled Gas Temp	Sampled Gas Pressure	Sampled Gas Humidity	Oxygen Content	Concentration in impinger	Limit of Detection	Leak
	m^3	K	kPa	% by volume	% by volume	mg	% by mass	%
MU required	**<=2%**	**<2.5 k**	**<=1%**	**<=1%**	**<=5%**	**<5%**	**≤ 5% of ELV**	**<=2%**
Run 1	0.000	2.000	0.500	1.000	0.100	0.006	0.005	-
as a %	0.050	0.678	0.491	1.000	-	3.000	3.003	0.703
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**	**Yes**	**Yes**

Run	Volume (STP)	Mass of Hydrogen Chloride	O2 Correction	Leak	Lab Uncertainty	Combined uncertainty
	m^3	mg	-	mg/m^3	mg	
Run 1	0.5325	0.1533	-	0.0011	-	-
MU as mg/m^3	0.0035	0.0080	-	0.0011	0.0134	**0.0160**
MU as %	1.3053	3.0033	-	0.4060	5.0	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.03**	**mg/m^3**	**11.98**	**%**

(k is a coverage factor which gives a 95% confidence in the quoted figures)
Developed for the STA by R Robinson, NPL

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - MOISTURE

Run	Sampled Volume m³	Sampled Gas Temp K	Sampled Gas Pressure kPa	Sampled Gas Humidity % by volume	Oxygen Content % by volume	Leak %
MU required	**≤ 2%**	**≤ 2%**	**≤ 1%**	**≤ 1%**	**≤ 10%**	**≤ 2%**
Run 1	0.000	2	0.5	1	N/A	-
as a %	0.06	0.68	0.49	1.00	N/A	0.70
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**

Run	Volume (STP) m³	Mass Gained mg	O2 Correction -	Leak mg/m³	Uncollected Mass mg	Combined uncertainty
Run 1	0.4	2400.0	1.00	21.4	57.7	-
MU as % v/v	0.01	0.03	-	0.00	0.02	**0.03**
MU as %	1.3	4.2	-	0.4	2.4	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.07**	**% v/v**	**10.00**	**%**

Developed for the STA by R Robinson, NPL

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - VELOCITY & VOLUMETRIC FLOW RATE

Measured Velocity at Actual Conditions	4.0	m/s
Measured Volumetric Flow rate at Actual Conditions	138	m³/hr

Performance Characteristics & Source of Value	Units	Values	Requirement	Compliant
Uncertainty of Local Gas Velocity Determination				
Uncertainty of pitot tube coefficient	-	0.010		
Uncertainty of mean local dynamic pressures	-	0.33		
Factor loading, function of the number of measurements.	3 readings	0.591	minimum 3	Yes
Range of measurment device	pa	1000		
Resolution	pa	1.00		
Calibration uncertainty	pa	0.21	<1% of Value or 20 Pa whichever is greater	No
Drift	% range	0.10		
Linearity	% range	0.06	<2% of value	Yes
Uncertainty of gas density determination				
Uncertainty of molar mass determination	kg/mol	0.00003		
Uncertainty of temperature measurement	K	1.50	<1% of value	No
Uncertainty of absolute pressure in the duct	pa	519		
Uncertainty associated with the estimate of density	-	0.007		
Uncertainty associated with the measurement of local velocity	-	0.0001		
Uncertainty associated with the measurement of mean velocity	-	0.0004		

Measurement Uncertainty - Velocity	m/s
Combined uncertainty	0.08
Expanded uncertainty at a 95% Confidence Interval	0.15

Note - The expanded uncertainty uses a coverage factor of k = 2.

Expanded Measurement Uncertainty of Velocity at a 95% Confidence Interval	%
Expressed as a % of the Measured Concentration	1.95
Expanded uncertainty at a 95% Confidence Interval	3.81

Measurement Uncertainty Volumetric Flow Rate	m³/hr
Combined uncertainty	3.19
Expanded uncertainty at a 95% Confidence Interval	6.26

Note - The expanded uncertainty uses a coverage factor of k = 2.

Expanded Measurement Uncertainty of Volumetric Flow Rate at a 95% Confidence Interval	%
Expressed as a % of the Measured Concentration	2.31
Expanded uncertainty at a 95% Confidence Interval	4.53

END OF REPORT