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Stack Emissions Testing Report Commissioned by
Dow Corning

Installation Name & Address
Dow Corning
Cardiff Road
Barry
Vale Of Glamorgan
CF63 2YL

EPR Permit: BR96851X

Stack Reference
ERU

Dates of the Monitoring Campaign
22nd May

Job Reference Number
CSW-3258

Report Written by
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25th June 2018

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Signature of Report Approver


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Executive Summary

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MONITORING OBJECTIVES

Dow Corning, Barry

ERU

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Overall Aim of the Monitoring Campaign

Exova Catalyst were commissioned by Dow Corning to carry out stack emissions testing on the ERU at Barry.

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

Dioxins & Furans

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MONITORING RESULTS

Dow Corning, Barry

ERU

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where MU = Measurement Uncertainty associated with the Result

Parameter	Concentration				Mass Emission			
	Units	Result	MU +/-	Limit	Units	Result	MU +/-	Limit
Dioxins & Furans Upper Limit (worst case where <LOD = LOD)								
Dioxins & Furans (NATO I-TEQ)	¹ ng/m ³	0.163	0.037	0.1	µg/hr	1.38	0.40	-
Dioxins & Furans (WHO TEQ Humans / Mammals)	¹ ng/m ³	0.131	0.030	-	µg/hr	1.11	0.32	-
Dioxins & Furans (WHO TEQ Fish)	¹ ng/m ³	0.130	0.030	-	µg/hr	1.10	0.32	-
Dioxins & Furans (WHO TEQ Birds)	¹ ng/m ³	0.846	0.192	-	µg/hr	7.17	2.09	-
Dioxins & Furans Lower Limit (best case where <LOD = 0)								
Dioxins & Furans (NATO I-TEQ)	¹ ng/m ³	0.160	0.036	-	µg/hr	1.36	0.40	-
Dioxins & Furans (WHO TEQ Humans / Mammals)	¹ ng/m ³	0.128	0.029	-	µg/hr	1.09	0.32	-
Dioxins & Furans (WHO TEQ Fish)	¹ ng/m ³	0.127	0.029	-	µg/hr	1.07	0.31	-
Dioxins & Furans (WHO TEQ Birds)	¹ ng/m ³	0.843	0.191	-	µg/hr	7.15	2.08	-
Oxygen	% v/v	Wet 8.04	Dry 8.6	0.4				
Water Vapour	% v/v	6.9	0.5					
Stack Gas Temperature	°C	46						
Stack Gas Velocity	m/s	7.2	1.28					
Volumetric Flow Rate (ACTUAL)	m ³ /hr	9996	1824					
Volumetric Flow Rate (REF)	¹ m ³ /hr	8485	1548					

NOTE: VOLUMETRIC FLOW RATE & VELOCITY DATA TAKEN FROM AN AVERAGE OF ALL OF THE ISOKINETIC RUNS.

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

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MONITORING DATE(S) & TIMES

Dow Corning, Barry

ERU

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Parameter		Units	Concentration	Units	Mass Emission	Sampling Date(s)	Sampling Times	Duration mins
Dioxins & Furans (NATO)	R1	ng/m ³	0.163	µg/hr	1.4	25/05/2018	10:17 - 14:17	240
Oxygen	R1	% v/v	8.3			25/05/2018	10:17 - 14:17	240
Velocity Traverse	R1					25/05/2018	09:30 - 09:35	

All results are expressed at the respective reference conditions.

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PROCESS DETAILS

Dow Corning, Barry

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Standard Operating Conditions

Parameter	Value
Process Status	Operational
Capacity (of 100%) and Tonnes / Hour	N/A
Continuous or Batch Process	Continuous
Feedstock (if applicable)	N/A
Abatement System	Scrubber
Abatement System Running Status	Operational
Fuel	N/A
Plume Appearance	Visible

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MONITORING & ANALYTICAL METHODS

Dow Corning, Barry

ERU

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Parameter	Monitoring				Analysis				MCERTS Testing	LOD (Average)
	Standard	Technical Procedure	ISO 17025 Testing	Testing Lab	Analytical Procedure	Analytical Technique	ISO 17025 Analysis	Analysis Lab		
Dioxins & Furans	EN 1948	CAT-TP-07	Yes	CAT	WI 1122	GC-HRMS	Yes	CAT	Yes	0.0042 ng/m ³
Water Vapour	EN 14790	CAT-TP-05	Yes	CAT	CAT-TP-05	Gravimetric	Yes	CAT	Yes	0.1 % v/v
Oxygen	EN 14789	CAT-TP-33	Yes	CAT	Dry Paramagnetic Cell by Servomex 5200MP				Yes	0.1 %
Velocity & Vol. Flow Rate	EN 16911-1 (MID)	CAT-TP-41	Yes	CAT	Pitot Tube and Thermocouple				Yes	1.8 m/s

ANALYSIS LABORATORIES

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

Exova Catalyst (CAT)	ISO 17025 Accreditation Number: 4279
Marchwood Scientific Services Ltd (MAR)	ISO 17025 Accreditation Number: 1668

SUMMARY OF SAMPLING DEVIATIONS

Parameter	Run	Deviation
All	1	One out of two sampling lines was used due to sampling location restrictions, however the number of sample points used on the available line were increased to the minimum required by the Standard

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SUITABILITY OF SAMPLING LOCATION

Duct Characteristics

Parameter	Units	Value
Type	-	Circular
Depth	m	0.70
Width	m	-
Area	m ²	0.38
Port Depth	cm	8
Orientation of Duct	-	Vertical
Number of Ports	-	2
Sample Port Size	-	4" BSP

Location of Sampling Platform

General Platform Information	Value
Permanent / Temporary Platform	Permanent
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	Yes
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	No
Safe Access Available	Yes
Easy Access Available	Yes

Sampling Location / Platform Improvement Recommendations

Obstructions prevented access to both sampling lines, and in an ideal world, the obstruction would be removed to allow sampling to be performed from all the sampling lines.

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	29.4	> 5 Pa	Yes
Mean Velocity	m/s	8.07	-	-
Lowest Gas Velocity	m/s	6.20	-	-
Highest Gas Velocity	m/s	9.47	-	-
Ratio of Above	: 1	1.53	< 3 : 1	Yes
Maximum Angle of Swirl	°	0	< 15°	Yes
No Local Negative Flow	-	Yes	-	Yes

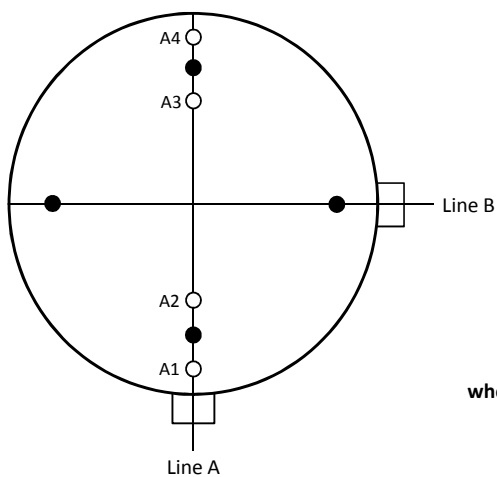
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PLANT PHOTOS

No Photo's Allowed

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	Darren Price	MCERTS Level 2	MM 03 176	TE1 TE2 TE3 TE4
Team Leader	Craig Harley	MCERTS Level 2	MM 05 670	TE1 TE2 TE3 TE4

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 7.18	Horiba PG-250	-	Digital Manometer (1)	-
Control Box DGM (2)	-	Horiba PG-250 SRM	-	Digital Manometer (2)	-
Box Thermocouples (1)	CAT 3.38	Servomex 4900	-	Digital Temperature Meter	-
Box Thermocouples (2)	-	Eco Physics CLD 822Mh	-	Stopwatch	-
Umbilical (1)	CAT 3.38	ABB AO2020-URAS26	-	Barometer	CAT 13.17
Umbilical (2)	-	Testo 350 XL	-	Stack Thermocouple (1)	CAT 4.481
Oven Box (1)	CAT 12.79	JCT JCC P1 Cooler	-	Stack Thermocouple (2)	-
Oven Box (2)	-	Gasmet DX4000	-	Stack Thermocouple (3)	-
Heated Probe (1)	CAT 5.45	Gasmet Sampling System	-	1m Heated Line (1)	-
Heated Probe (2)	-	Bernath 3006 FID	CAT 8.13	1m Heated Line (2)	-
Heated Probe (3)	-	M&C PSS	-	1m Heated Line (3)	-
S-Pitot (1)	CAT 21P.115	Mass Flow Controller (1)	CAT 6.34	5m Heated Line (1)	-
S-Pitot (2)	-	Mass Flow Controller (2)	CAT 6.35	15m Heated Line (1)	-
L-Pitot	-	Mass View (1)	CAT 25.13	20m Heated Line (1)	CAT 20.63
Site Balance	CAT 17.14	Mass View (2)	CAT 25.14	20m Heated Line (2)	-
500g / 1Kg Check Weights	CAT 17.14	Hioki 5043 (V)	-	Dual Channel Heater Controller	-
Last Impinger Arm	CAT 4.646	Easylogger EN-EL-12 Bit	-	Single Channel Heater Controller	CAT 20.63
Callipers	CAT 23.50	Bioaerosols Temperature Logger	-	Laboratory Balance	-
Tubes Kit Thermocouple	-	Electronic Refrigerator	-	Tape Measure	CAT 16.22

METHODS & TECHNICAL PROCEDURES USED

Parameter	Standard	Technical Procedure
Dioxins & Furans	EN 1948	CAT-TP-07
Water Vapour	EN 14790	CAT-TP-05
Oxygen	EN 14789	CAT-TP-33
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	0.70
Stack Width, W	m	-
Stack Area, A	m ²	0.38
Average Stack Gas Temperature, T _a	°C	44.0
Average Stack Gas Pressure	mmH ₂ O	5.3
Average Stack Static Pressure, P _{static}	kPa	0.050
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 p	Conc kg/m ³ p _i
CO ₂ (Estimated)	-	0.06	0.06	0.0006	44.01	1.9635	0.00118
O ₂ (Estimated)	-	20.08	18.69	0.2008	32.00	1.4277	0.28668
N ₂	-	79.86	74.35	0.7986	28.01	1.2498	0.99813
Moisture (H ₂ O)	-	-	6.90	0.0690	18.02	0.8037	0.05549

Where: $p = M / 22.41$

$p_i = r \times p$

Calculation of Stack Gas Densities

Determinand	Units	Result
Dry Density (STP), P _{STD}	kg/m ³	1.286
Wet Density (STP), P _{STW}	kg/m ³	1.253
Dry Density (Actual), P _{Actual}	kg/m ³	1.105
Average Wet Density (Actual), P _{ActualW}	kg/m ³	1.076

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	44.0	0.0
Total Pressure	kPa	101.1	101.3
Moisture	%	6.90	6.90

Gas Volumetric Flowrate (from Traverse)	Units	Result
Gas Volumetric Flowrate (Actual)	m ³ /hr	11187
Gas Volumetric Flowrate (STP, Wet)	m ³ /hr	9610
Gas Volumetric Flowrate (STP, Dry)	m ³ /hr	8947
Gas Volumetric Flowrate REF ¹	m ³ /hr	9610

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

(1 of 1)

Parameter	Units	Value
Date of Survey	-	25/05/2018
Time of Survey	-	09:30 - 09:35
Atmospheric Pressure	kPa	101.0
Average Stack Static Pressure	Pa	50
Result of Pitot Stagnation Test	-	Pass
Are Water Droplets Present?	-	No
Device Used	S-Type Pitot with Liquid Incline Manometer	

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 mmH ₂ O	Temp °C	Wet Density kg/m ³	Velocity m/s	Swirl °
STATIC (Units: Pa)		50.0				
Mean		5.3	44.0	1.076	8.07	
1	0.05	3.0	44.0	1.076	6.20	0.0
2	0.18	4.0	44.0	1.076	7.16	0.0
3	0.53	7.0	44.0	1.076	9.47	0.0
4	0.65	7.0	44.0	1.076	9.47	0.0

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	$u(\Delta p_i)$	1.739	Pa
- Resolution	$u(res)$	0.52154	
- Calibration	$u(cal)$	0.276	
- Drift	$u(drift)$	1.096	
- Lack of Fit	$u(fit)$	0.132	
- Overall corrections to dynamic measurements	$u(C_f)$	2.026	
Standard uncertainty associated with the molar mass of the gas	$u(M)$	0.00004	-
- $\varphi O_2, w$	-	18.694	
- $\varphi CO_2, w$	-	0.056	
- Oxygen, dry	$u(\phi O_2, d)$	0.615	
- Carbon Dioxide, dry	$u(\phi CO_2, d)$	0.002	
- Water Vapour	$u(\phi H_2O)$	0.352	
- Oxygen, wet	$u(\phi O_2, w)$	0.577	
- Carbon Dioxide, wet	$u(\phi CO_2, w)$	0.002	
Standard uncertainty associated with the stack temperature	$u(T_c)$	1.617	K
Standard uncertainty associated with the absolute pressure in the duct	$u(p_c)$	175.701	Pa
- Atmospheric Pressure	$u(p_{atm})$	175.692	
- Static Pressure	$u(p_{stat})$	1.739	
Standard uncertainty associated with the density in the duct	$u(\rho)$	0.00580	-
Standard uncertainty associated with the local velocities	$u(v_i)$	1.428	Pa
Standard uncertainty associated with the mean velocity	$u(\bar{v})$	0.728	m/s
Standard uncertainty associated with the mean velocity (95% Confidence)	$U_c(v)$	1.427	m/s
Standard uncertainty associated with the mean velocity (95% Confidence), relative	$U_{c,rel}(v)$	17.68	%
Standard uncertainty associated with the volume flow rate (95% Confidence)	$U_c(qV, w)$	2041.2	m ³ /hr
- $u^2(a)/a^2$	-	0.00053	
- $u^2(qV, w)/q^2V, w$	-	0.00867	
- $u^2(qV, w)$	-	1084625	
- $u(qV, w)$	-	1041.5	
Standard uncertainty associated with the volume flow rate (95% Confidence), relative	$U_{c,rel}(qV, w)$	18.25	%

DIOXINS & FURANS: RESULTS SUMMARY

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TEQ1 - UPPER LIMITS (worst case where <LOD = LOD)

Sample Runs (UPPER NATO I-TEQ)

Parameter	Units	Run 1		Mean
Concentration	ng/m ³	0.163		0.163
Uncertainty	±ng/m ³	0.037		0.037
Mass Emission	µg/hr	1.38		1.38
Uncertainty	±µg/hr	0.40		0.40

Sample Runs (UPPER WHO TEQ Humans / Mammals)

Parameter	Units	Run 1		Mean
Concentration	ng/m ³	0.131		0.131
Uncertainty	±ng/m ³	0.030		0.030
Mass Emission	µg/hr	1.11		1.11
Uncertainty	±µg/hr	0.32		0.32

Sample Runs (UPPER WHO TEQ Fish)

Parameter	Units	Run 1		Mean
Concentration	ng/m ³	0.130		0.130
Uncertainty	±ng/m ³	0.030		0.030
Mass Emission	µg/hr	1.10		1.10
Uncertainty	±µg/hr	0.32		0.32

Sample Runs (UPPER WHO TEQ Birds)

Parameter	Units	Run 1		Mean
Concentration	ng/m ³	0.846		0.846
Uncertainty	±ng/m ³	0.192		0.192
Mass Emission	µg/hr	7.17		7.17
Uncertainty	±µg/hr	2.09		2.09

DIOXINS & FURANS: RESULTS SUMMARY

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TEQ2 - LOWER LIMITS (best case where <LOD = 0)

Sample Runs (LOWER NATO I-TEQ)

Parameter	Units	Run 1		Mean
Concentration	ng/m ³	0.160		0.160
Uncertainty	±ng/m ³	0.036		0.036
Mass Emission	µg/hr	1.36		1.36
Uncertainty	±µg/hr	0.40		0.40

Sample Runs (LOWER WHO TEQ Humans / Mammals)

Parameter	Units	Run 1		Mean
Concentration	ng/m ³	0.128		0.128
Uncertainty	±ng/m ³	0.029		0.029
Mass Emission	µg/hr	1.09		1.09
Uncertainty	±µg/hr	0.32		0.32

Sample Runs (LOWER WHO TEQ Fish)

Parameter	Units	Run 1		Mean
Concentration	ng/m ³	0.127		0.127
Uncertainty	±ng/m ³	0.029		0.029
Mass Emission	µg/hr	1.07		1.07
Uncertainty	±µg/hr	0.31		0.31

Sample Runs (LOWER WHO TEQ Birds)

Parameter	Units	Run 1		Mean
Concentration	ng/m ³	0.843		0.843
Uncertainty	±ng/m ³	0.191		0.191
Mass Emission	µg/hr	7.15		7.15
Uncertainty	±µg/hr	2.08		2.08

DIOXINS & FURANS: RESULTS SUMMARY

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TEQ1 - UPPER LIMITS (worst case where <LOD = LOD)

Blank Runs (UPPER NATO I-TEQ)

Parameter	Units	Blank 1		Maximum
Concentration	ng/m ³	0.0023		0.0023

Blank Runs (UPPER WHO TEQ Humans / Mammals)

Parameter	Units	Blank 1		Maximum
Concentration	ng/m ³	0.0028		0.0028

Blank Runs (UPPER WHO TEQ Fish)

Parameter	Units	Blank 1		Maximum
Concentration	ng/m ³	0.0030		0.0030

Blank Runs (UPPER WHO TEQ Birds)

Parameter	Units	Blank 1		Maximum
Concentration	ng/m ³	0.0033		0.0033

TEQ2 - LOWER LIMITS (best case where <LOD = 0)

Blank Runs (LOWER NATO I-TEQ)

Parameter	Units	Blank 1		Maximum
Concentration	ng/m ³	0.0000		0.0000

Blank Runs (LOWER WHO TEQ Humans / Mammals)

Parameter	Units	Blank 1		Maximum
Concentration	ng/m ³	0.0000		0.0000

Blank Runs (LOWER WHO TEQ Fish)

Parameter	Units	Blank 1		Maximum
Concentration	ng/m ³	0.0000		0.0000

Blank Runs (LOWER WHO TEQ Birds)

Parameter	Units	Blank 1		Maximum
Concentration	ng/m ³	0.0000		0.0000

DIOXINS & FURANS: RESULTS SUMMARY

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Parameter	Units	Run 1		Mean
Water Vapour	% v/v	6.90		6.90
Uncertainty	±% v/v	0.49		0.49

General Sampling Information

Parameter	Value	
Standard	EN 1948	
Technical Procedure	CAT-TP-07	
Name of Analytical Laboratory	CAT	
Analytical Laboratory's Procedure	WI 1122	
ISO 17025 Accredited Analysis?	Yes	
Date of Sample Analysis	13/06/2018	
Probe Material	Titanium	
Filter Housing Material	Titanium	
Glassware Material	Borosilicate Glass	
Absorption Material	XAD-2	
Positioning of Filter	Out Stack	
Filter Size and Material	47mm Quartz Fibre	
Number of Sampling Lines Used	1 / 2	FORMAT: Number Used / Number Required
Number of Sampling Points Used	4 / 4	FORMAT: Number Used / Number Required
Sample Point I.D.'s	A1 - A4	

Reference Conditions

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

DIOXINS & FURANS: ISOKINETIC SAMPLING CALCULATIONS

Test	Units	Run 1	
Absolute pressure of stack gas, P_s			
Barometric pressure, P_b	mmHg	752.3	
Stack static pressure, P_{static}	mmH ₂ O	5.1	
$P_s = (P_b + (P_{static} / 13.6))$	mmHg	752.6	
Volume of water vapour collected, V_{wstd}			
Total mass collected in impingers (liquid trap)	g	132.7	
Total mass collected in impingers (silica trap)	g	9.8	
Total mass of liquid collected, V_{lc}	g	142.5	
$V_{wstd} = (0.001246)(V_{lc})$	m ³	0.1776	
Volume of gas metered dry, V_{mstd}			
Volume of gas sample through gas meter, V_m	m ³	2.7914	
Gas meter correction factor, Y_d	-	0.9310	
Average dry gas meter temperature, T_m	°C	20.7	
Average pressure drop across orifice, ΔH	mmH ₂ O	15.2	
$V_{mstd} = ((0.3592)(V_m)(P_b + (\Delta H/13.6))(Y_d)) / (T_m + 273)$	m ³	2.3943	
Moisture content, B_{wo} & R_{wv}			
$B_{wo} = V_{wstd} / (V_{mstd} + V_{wstd})$	m ³	0.0690	
B_{wo} as a percentage	% v/v	6.90	
Reported Water Vapour, checked with Tables in EN 14790, R_{wv}	% v/v	6.90	
Volume of gas metered wet, V_{mstw}			
$V_{mstw} = (V_{mstd})(100/(100 - R_{wv}))$	m ³	2.5718	
Volume of gas metered at Oxygen Reference Conditions, $V_{mstd@X\%O_2}$ & $V_{mstw@X\%O_2}$			
IED & Incinerates Hazardous Material? (Yes = no positive O ₂ correction)	-	No	
% wet oxygen measured in gas stream, ACT%O _{2w}	% v/v	N/A	
% dry oxygen measured in gas stream, ACT%O _{2d}	% v/v	N/A	
% oxygen reference condition, REF%O ₂	% v/v	N/A	
O ₂ Reference Factor wet ($O_{2REFw} = (21 - REF\%O_2) / (21 - ACT\%O_{2w})$)	-	N/A	
O ₂ Reference Factor dry ($O_{2REFd} = (21 - REF\%O_2) / (21 - ACT\%O_{2d})$)	-	N/A	
$V_{mstw@X\%oxygen} = (V_{mstw}) / (O_{2REFw})$	m ³	N/A	
$V_{mstd@X\%oxygen} = (V_{mstd}) / (O_{2REFd})$	m ³	N/A	
Molecular weight of dry gas stream, M_d			
CO ₂ (Estimated)	% v/v	3.00	
O ₂ (Estimated)	% v/v	8.33	
Total	% v/v	11.33	
N ₂	% v/v	88.67	
$M_d = 0.44(\%CO_2) + 0.32(\%O_2) + 0.28(\%N_2)$	g/gmol	28.81	
Molecular weight of stack gas (wet), M_s			
$M_s = M_d(1 - (R_{wv}/100)) + 18(R_{wv}/100)$	g/gmol	28.07	
Velocity of stack gas, V_s			
Pitot tube velocity constant, K_p	-	34.97	
Velocity pressure coefficient, C_p	-	0.84	
Average of velocity heads, ΔP_{avg}	mmH ₂ O	4.00	
Average square root of velocity heads, $\sqrt{\Delta P}$	√mmH ₂ O	2.00	
Average stack gas temperature, T_s	°C	45.5	
$V_s = ((K_p)(C_p)(\sqrt{\Delta P})(\sqrt{T_s + 273})) / (\sqrt{M_s})(P_s))$	m/s	7.21	
Total flow of stack gas: Actual (Q_a), Wet (Q_{stw}), Dry (Q_{std}), Wet@O_{2REF} (Q_{stwO_2}), Dry@O_{2REF} (Q_{stdO_2})			
Area of stack, A_s	m ²	0.38	
$Q_a = (60)(A_s)(V_s)$	m ³ /min	166.6	
Conversion factor (K/mm.Hg), C_f	-	0.3592	
$Q_{stw} = ((Q_a)(P_s)(C_f)) / ((T_s) + 273)$	m ³ /min	141.4	
$Q_{std} = ((Q_a)(P_s)(C_f)(1 - (R_{wv}/100))) / ((T_s) + 273)$	m ³ /min	131.6	
$Q_{stwO_2} = ((Q_a)(P_s)(C_f)) / ((T_s) + 273) / (O_{2REFw})$	m ³ /min	N/A	
$Q_{stdO_2} = ((Q_a)(P_s)(C_f)(1 - (R_{wv}/100))) / ((T_s) + 273) / (O_{2REFd})$	m ³ /min	N/A	
Percent isokinetic, %I			
Nozzle diameter, D_n	mm	6.18	
Nozzle area, A_n	mm ²	30.03	
Total sampling time, q	min	240	
$\%I = (4.6398E^6)(T_s + 273)(V_{mstd}) / (P_s)(V_s)(A_n)(q)(1 - (R_{wv}/100))$	%	97.1	

DIOXINS & FURANS: SAMPLING DETAILS

RUN 1

Parameter	Units	Value
Sampling Times	-	10:17 - 14:17
Sampling Dates	-	25/05/2018
Sampling Device	-	ISO
Volume Sampled (REF)	m ³	2.5718

Where: ISO stands for Manual Isokinetic Sampling Train

Parameter	Units	Result	DL	NATO I-TEQ		WHO Humans / Mammals		WHO Fish		WHO Birds		% Rec
				TEQ1	TEQ2	TEQ1	TEQ2	TEQ1	TEQ2	TEQ1	TEQ2	
2378-TCDD	ng	ND	0.0033	0.0033	0.0000	0.0033	0.0000	0.0033	0.0000	0.0033	0.0000	101
12378-PeCDD	ng	ND	0.0035	0.0018	0.0000	0.0035	0.0000	0.0035	0.0000	0.0035	0.0000	99
123478-HxCDD	ng	ND	0.0039	0.0004	0.0000	0.0004	0.0000	0.0020	0.0000	0.0002	0.0000	97
123678-HxCDD	ng	0.0055	0.0042	0.0005	0.0005	0.0005	0.0005	0.0001	0.0001	0.0001	0.0001	90
123789-HxCDD	ng	ND	0.0050	0.0005	0.0000	0.0005	0.0000	0.0001	0.0000	0.0005	0.0000	-
1234678-HPeCDD	ng	0.0175	0.0036	0.0002	0.0002	0.0002	0.0002	0.0000	0.0000	0.0000	0.0000	97
OCDD	ng	0.0166	0.0053	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	99
Total Dioxins	ng	0.0396	-	0.0067	0.0007	0.0084	0.0007	0.0089	0.0001	0.0076	0.0001	-
2378-TCDF	ng	1.7200	0.0037	0.1720	0.1720	0.1720	0.1720	0.0860	0.0860	1.7200	1.7200	89
12378-PeCDF	ng	0.7290	0.0041	0.0365	0.0365	0.0219	0.0219	0.0365	0.0365	0.0729	0.0729	89
23478-PeCDF	ng	0.3420	0.0046	0.1710	0.1710	0.1026	0.1026	0.1710	0.1710	0.3420	0.3420	98
123478-HxCDF	ng	0.2130	0.0033	0.0213	0.0213	0.0213	0.0213	0.0213	0.0213	0.0213	0.0213	90
123678-HxCDF	ng	0.0757	0.0034	0.0076	0.0076	0.0076	0.0076	0.0076	0.0076	0.0076	0.0076	88
234678-HxCDF	ng	0.0219	0.0037	0.0022	0.0022	0.0022	0.0022	0.0022	0.0022	0.0022	0.0022	87
123789-HxCDF	ng	0.0087	0.0050	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	109
1234678-HPeCDF	ng	0.0250	0.0025	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	93
1234789-HPeCDF	ng	0.0065	0.0035	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	102
OCDF	ng	0.0093	0.0042	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	95
Total Furans	ng	3.1511	-	0.4117	0.4117	0.3287	0.3287	0.3257	0.3257	2.1671	2.1671	-
Totals	ng	3.1907	-	0.4184	0.4124	0.3371	0.3294	0.3346	0.3258	2.1747	2.1672	-
Total Concentration	ng/m ³	-	-	0.1627	0.1604	0.1311	0.1281	0.1301	0.1267	0.8456	0.8427	-
Limit of Detection	ng/m ³	-	-	0.0042	-	0.0045	-	0.0051	-	0.0069	-	-

Where: ND stands for Non Detected

DL stands for Analytical Detection Limit

TEQ1 refers to Non Detected Congeners at the Detection Limit

TEQ2 refers to Non Detected Congeners at Zero

% Rec stands for the Recovery Percentage of the Sample

DIOXINS & FURANS: SAMPLING DETAILS

(Continued)

BLANK 1

Parameter	Units	Value
Sampling Dates	-	25/05/2018
Sampling Device	-	ISO
Average Volume Sampled (REF)	m ³	2.5718

Where: ISO stands for Manual Isokinetic Sampling Train

Parameter	Units	Result	DL	NATO I-TEQ		WHO Humans / Mammals		WHO Fish		WHO Birds		% Rec
				TEQ1	TEQ2	TEQ1	TEQ2	TEQ1	TEQ2	TEQ1	TEQ2	
2378-TCDD	ng	ND	0.0020	0.0020	0.0000	0.0020	0.0000	0.0020	0.0000	0.0020	0.0000	105
12378-PeCDD	ng	ND	0.0027	0.0014	0.0000	0.0027	0.0000	0.0027	0.0000	0.0027	0.0000	98
123478-HxCDD	ng	ND	0.0034	0.0003	0.0000	0.0003	0.0000	0.0017	0.0000	0.0002	0.0000	93
123678-HxCDD	ng	ND	0.0038	0.0004	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000	91
123789-HxCDD	ng	ND	0.0045	0.0005	0.0000	0.0005	0.0000	0.0000	0.0000	0.0005	0.0000	-
1234678-HPeCDD	ng	ND	0.0034	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	105
OCDD	ng	ND	0.0054	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	103
Total Dioxins	ng	0.0000	-	0.0046	0.0000	0.0059	0.0000	0.0065	0.0000	0.0054	0.0000	-
2378-TCDF	ng	ND	0.0012	0.0001	0.0000	0.0001	0.0000	0.0001	0.0000	0.0012	0.0000	89
12378-PeCDF	ng	ND	0.0010	0.0001	0.0000	0.0000	0.0000	0.0001	0.0000	0.0001	0.0000	92
23478-PeCDF	ng	ND	0.0011	0.0006	0.0000	0.0003	0.0000	0.0006	0.0000	0.0011	0.0000	91
123478-HxCDF	ng	ND	0.0014	0.0001	0.0000	0.0001	0.0000	0.0001	0.0000	0.0001	0.0000	87
123678-HxCDF	ng	ND	0.0014	0.0001	0.0000	0.0001	0.0000	0.0001	0.0000	0.0001	0.0000	86
234678-HxCDF	ng	ND	0.0016	0.0002	0.0000	0.0002	0.0000	0.0002	0.0000	0.0002	0.0000	88
123789-HxCDF	ng	ND	0.0022	0.0002	0.0000	0.0002	0.0000	0.0002	0.0000	0.0002	0.0000	103
1234678-HPeCDF	ng	0.0014	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	100
1234789-HPeCDF	ng	ND	0.0019	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	92
OCDF	ng	ND	0.0039	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	101
Total Furans	ng	0.0014	-	0.0014	0.0000	0.0012	0.0000	0.0014	0.0000	0.0031	0.0000	-
Totals	ng	0.0014	-	0.0060	0.0000	0.0071	0.0000	0.0078	0.0000	0.0085	0.0000	-
Total Concentration	ng/m ³	-	-	0.0023	0.0000	0.0028	0.0000	0.0030	0.0000	0.0033	0.0000	-

Where: ND stands for Non Detected
DL stands for Analytical Detection Limit
TEQ1 refers to Non Detected Congeners at the Detection Limit
TEQ2 refers to Non Detected Congeners at Zero
% Rec stands for the Recovery Percentage of the Sample

DIOXINS & FURANS: QUALITY ASSURANCE

(PAGE 1 OF 2)

Sample Runs

Leak Test Results	Units	Run 1	
Mean Sampling Rate	l/min	10.83	
Pre-Sampling Leak Rate	l/min	0.14	
Post-Sampling Leak Rate	l/min	0.35	
Allowable Leak Rate	l/min	0.54	
Leak Test Acceptable	-	Yes	
Water Droplets	Units	Run 1	
Are Water Droplets Present	-	No	
MU (Concurrent Water Vapour)	Units	Run 1	
Measurement Uncertainty (MU)	%	7.1	
Allowable MU	%	20	
MU Acceptable	-	Yes	
Silica Gel (Concurrent Water Vapour)	Units	Run 1	
Less than 50% Faded	%	Yes	
Isokinetic Criterion Compliance	Units	Run 1	
Isokinetic Variation	%	97.1	
Allowable Isokinetic Range	%	95 - 115	
Isokineticity Acceptable	-	Yes	
Filter Temperatures	Units	Run 1	
Maximum Filter Temperature	°C	119	
Maximum Allowable Temperature	°C	125	
Temperature Acceptable	-	Yes	
Condenser Exit Temperature	Units	Run 1	
Maximum Temperature Recorded	°C	15	
Maximum Allowable Temperature	°C	20	
Exit Temperature Acceptable	-	Yes	
Test Conditions	Units	Run 1	
Ambient Temperature Recorded?	-	Yes	

DIOXINS & FURANS: QUALITY ASSURANCE

(PAGE 2 OF 2)

Blank Runs

Leak Test Results	Units	Blank 1	
Expected Sampling Rate	l/min	15.00	
Sampling Leak Rate	l/min	0.12	
Allowable Leak Rate	l/min	0.75	
Leak Test Acceptable	-	Yes	

Validity of NATO I-TEQ Blank vs ELV	Units	Blank 1	
Allowable Blank	ng/m ³	0.0100	
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	
One out of two sampling lines was used due to sampling location restrictions, however the number of sample points used on the available line were increased to the minimum required by the Standard	wx	

DIOXINS & FURANS (NATO I-TEQ): MEASUREMENT UNCERTAINTY CALCULATIONS

Measured Quantities	Value			Standard uncertainty			
	Symbol	Run 1		Symbol	Units	Run 1	
Sampled Volume (Actual)	V _m	2.7914		uV _m	m ³	0.0558	
Sampled Gas Temperature	T _m	293.7		uT _m	K	2.0	
Sampled Gas Pressure	p _m	100.4		up _m	kPa	0.5	
Sampled Gas Humidity	H _m	0.0		uH _m	% v/v	1.0	
Leak	L	3.23		uL	%	-	
Laboratory Result	L _r	10.00		uL _r	%	-	

Measured Quantities	Uncertainty as a Percentage			Requirement of Standard
	Units	Run 1		
Sampled Volume (Actual)	%	2.00		≤2%
Sampled Gas Temperature	%	0.68		≤1%
Sampled Gas Pressure	%	0.50		≤1%
Sampled Gas Humidity	%	1.00		≤1%
Leak	%	3.23		≤5%
Laboratory Result	%	10.00		No Requirement

Measured Quantities	Uncertainty in Measurement Units				Sensitivity Coefficient	
	Symbol	Units	Run 1		Run 1	
Sampled Volume (STP)	V _m	m ³	2.3943		0.07	
Leak	L	ng/m ³	0.0030		1.00	
Laboratory Result	L _r	ng/m ³	0.0163		1.00	

Measured Quantities	Uncertainty in Result		
	Units	Run 1	
Sampled Volume (STP)	ng/m ³	0.0043	
Leak	ng/m ³	0.0030	
Laboratory Result	ng/m ³	0.0163	

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	ng/m ³	0.0171	
Expanded uncertainty (95% confidence), without Oxygen Correction	ng/m ³	0.0335	
Expanded uncertainty (95% confidence), with Oxygen Correction	ng/m ³	N/A	
Expanded uncertainty (95% confidence), estimated with Method Deviations	ng/m ³	0.0369	
Reported Uncertainty	ng/m ³	0.0369	
Expanded uncertainty (95% confidence), without Oxygen Correction	%	20.6	
Expanded uncertainty (95% confidence), with Oxygen Correction	%	N/A	
Expanded uncertainty (95% confidence), estimated with Method Deviations	%	22.7	
Reported Uncertainty	%	22.7	

OXYGEN: RESULTS SUMMARY

Dow Corning, Barry
ERU

Sample Runs

Parameter	Units	Run 1		Mean
Concentration	% v/v	8.33		8.33
Uncertainty	±% v/v	0.35		0.35

General Sampling Information

Parameter	Value
Standard	EN 14789
Technical Procedure	CAT-TP-33
Probe Material	Titanium
Filtration Type / Size	0.1µm Glass Fibre
Heated Head Filter Used	N/A
Heated Line Temperature	Orsat Used
Span Gas Type	Synthetic Air (5 Grade)
Span Gas Reference Number	11.0332
Span Gas Expiry Date	08/03/2022
Span Gas Start Pressure (bar)	100
Gas Cylinder Concentration (% v/v)	21.03
Span Gas Uncertainty (%)	2
Zero Gas Type	Nitrogen (5 Grade)
Number of Sampling Lines Used	1 / 1
Number of Sampling Points Used	4 / 4
Sample Point I.D.'s	A1-A4

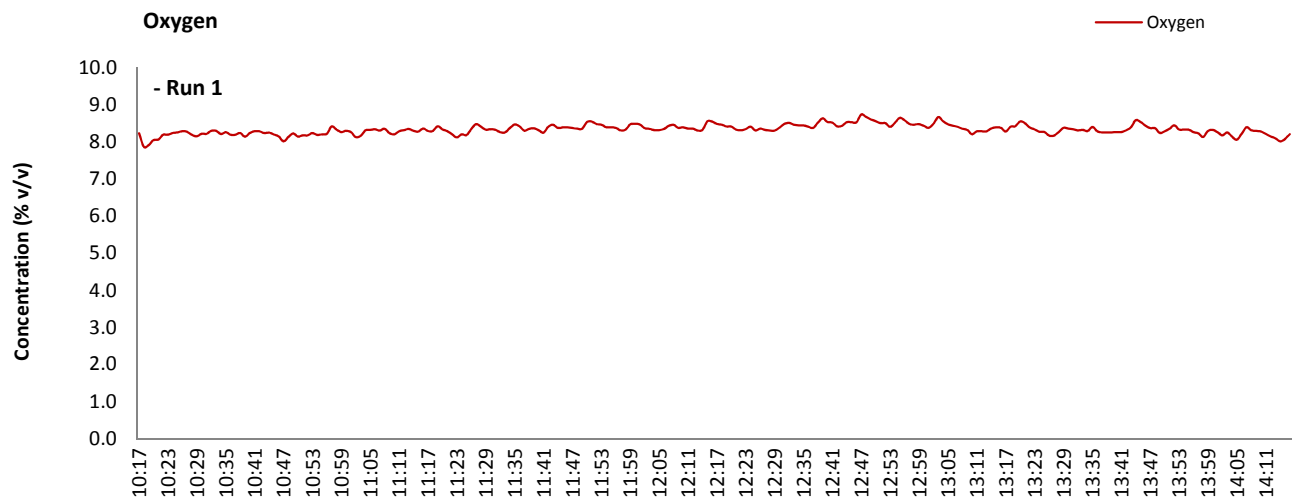
NOTE: Dilution performed to achieve correct span value

FORMAT: Number Used / Number Required

FORMAT: Number Used / Number Required

OXYGEN: DATA TREND

Graphical Trend of Data



OXYGEN: SAMPLING DETAILS & QUALITY ASSURANCE

Sampling Details

Parameter	Units	Run 1	
Sampling Times	-	10:17 - 14:17	
Sampling Dates	-	25/05/2018	
Instrument Range	% v/v	25	
Span Gas Value	% v/v	8.00	

Quality Assurance

Conditioning Unit Temperature	Units	Run 1	
Average Temperature	°C	N/A	
Allowable Temperature	< °C	N/A	
Temperature Acceptable	-	N/A	

Zero Drift	Units	Run 1	
CAL 1	Zero at Analyser (Pre)	% v/v	0.00
	Zero at Analyser (Post)	% v/v	0.10
	Zero Drift	% v/v	0.10
CAL 2	Zero at Analyser (Pre)	% v/v	
	Zero at Analyser (Post)	% v/v	
	Zero Drift	% v/v	
CAL 3	Zero at Analyser (Pre)	% v/v	
	Zero at Analyser (Post)	% v/v	
	Zero Drift	% v/v	
Allowable Zero Drift		± % v/v	0.40
Zero Drift Acceptable		-	Yes

Span Drift	Units	Run 1	
CAL 1	Span at Analyser (Pre)	% v/v	8.00
	Span at Analyser (Post)	% v/v	8.30
	Span Drift	% v/v	0.30
CAL 2	Span at Analyser (Pre)	% v/v	
	Span at Analyser (Post)	% v/v	
	Span Drift	% v/v	
CAL 3	Span at Analyser (Pre)	% v/v	
	Span at Analyser (Post)	% v/v	
	Span Drift	% v/v	
Allowable Span Drift		± % v/v	0.40
Span Drift Acceptable		-	Yes

Test Conditions	Units	Run 1	
Run Ambient Temperature Range	°C	15	

Method Deviations

Nature of Deviation	Run Number
(x = deviation applies to the associated run)	1
There are no deviations associated with the sampling employed.	x

OXYGEN: MEASUREMENT UNCERTAINTY CALCULATIONS

Performance characteristics	RUN 1		Units
Limit value	N/A		%vol
TGN M2 Allowable MU	6.0		%
Measured concentration	8.95		%vol
Range Used	25.0		%vol
Cal gas conc.	21.0		%vol

Performance characteristics	RUN 1		Units
Response time	70		seconds
Number of readings in measurement	240		-
Repeatability at zero	0.01		% full scale
Repeatability at span level	0.01		% full scale
Deviation from linearity	0.00		% of value
Zero drift	1.25		% full scale
Span drift	0.00		% full scale
Volume or pressure flow dependence	-0.04		% of full scale
Atmospheric pressure dependence	-0.40		% of value/kPa
Ambient temperature dependence	0.11		% full scale/10K
Combined interference	0.20		% range
Dependence on voltage	0.01		% full scale/10V
Losses in the line (leak)	0.00		% of value
Uncertainty of calibration gas	2.00		% of value

Performance characteristic	RUN 1		Units
Standard deviation of repeatability at zero	use rep at span		%vol
Standard deviation of repeatability at span level	0.00		%vol
Lack of fit	0.00		%vol
Drift	0.15		%vol
Volume or pressure flow dependence	0.00		%vol
Atmospheric pressure dependence	-0.03		%vol
Ambient temperature dependence	0.02		%vol
Combined interference (from MCERTS Certificate)	0.03		%vol
Dependence on voltage	0.00		%vol
Losses in the line (leak)	0.00		%vol
Uncertainty of calibration gas	0.10		%vol

		RUN 1		Units
Measurement uncertainty	Result	8.95		%vol
Combined uncertainty		0.19		%vol
Expanded uncertainty	k = 1.96	0.37		%vol

	RUN 1		Units
Expanded uncertainty (no O ₂) - at 95% Confidence	4.18		% of Value
Result of Compliance with Uncertainty Requirement in M2	COMPLIANT		-

Requirement for SRM is that Uncertainty should be 0.5%vol absolute or 6% relative whichever is the lower, on a dry gas basis. Ref EA TGN M2.