AIR DISPERSION MODELLING REPORT OF RELEASES FROM A BOILER AT WELSH WATER ORGANIC ENERGY, TREMORFA, CARDIFF

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ACRONYMS / TERMS USED IN THIS REPORT

AAD	Ambient Air Directive
ADMS	Atmospheric Dispersion Modelling System
AMS	Automatic Monitoring Site
APIS	Air Pollution Information System
AQAL	Air Quality Assessment Level
AQMA	Air Quality Management Area
AQO	Air Quality Objective
AQS	Air Quality Standard
AW	Ancient Woodland
CCC	City of Cardiff Council
CERC	Cambridge Environmental Research Consultants
CHP	Combined Heat and Power
CO	Carbon monoxide
cSAC	Candidate Special Area of Conservation
DEFRA	Department for Environment, Food and Rural Affairs
DT	Diffusion Tube
EA	Environment Agency
ECL	Environmental Compliance Ltd
ELV	Emission Limit Value
EPAQS	Expert Panel on Air Quality Standards
EPUK	Environmental Protection UK
GLC	Ground Level Concentration
IAQM	Institute of Air Quality Management
LNR	Local Nature Reserves
LWS	Local Wildlife Sites
MAGIC	Multi-Agency Geographic Information System for the Countryside
MCPD	Medium Combustion Plant Directive
Met data	Meteorological data
Met Office	Meteorological Office
Met year	Meteorological year
NNR	National Nature Reserves
NO_x	Oxides of nitrogen
NO_2	Nitrogen dioxide
NRW	Natural Resources Wales
PC	Process Contribution
PEC	Predicted Environmental Concentration
Ramsar	The Ramsar Convention on Wetlands of International Importance
SAC	Special Area of Conservation
SEPA	Scottish Environmental Protection Agency
SINC	Sites of Importance for Nature Conservation
SO_2	Sulphur Dioxide
SPA	Special Protection Area
SSSI	Site of Special Scientific Interest
The Site	Tremorfa Anaerobic Digestion Facility
Welsh Water	Welsh Water Organic Energy
WHO	World Health Organisation

1. INTRODUCTION

1.1. The Study

1.1.1. Environmental Compliance Ltd ("ECL") have been commissioned by Welsh Water Organic Energy ("Welsh Water") to undertake an air quality assessment of releases from a new boiler to their process (to be fuelled by biogas) at Tremorfa Anaerobic Digestion Facility, Cardiff ("the Site") as part of a Permit Variation to be submitted to Natural Resources Wales ("NRW").

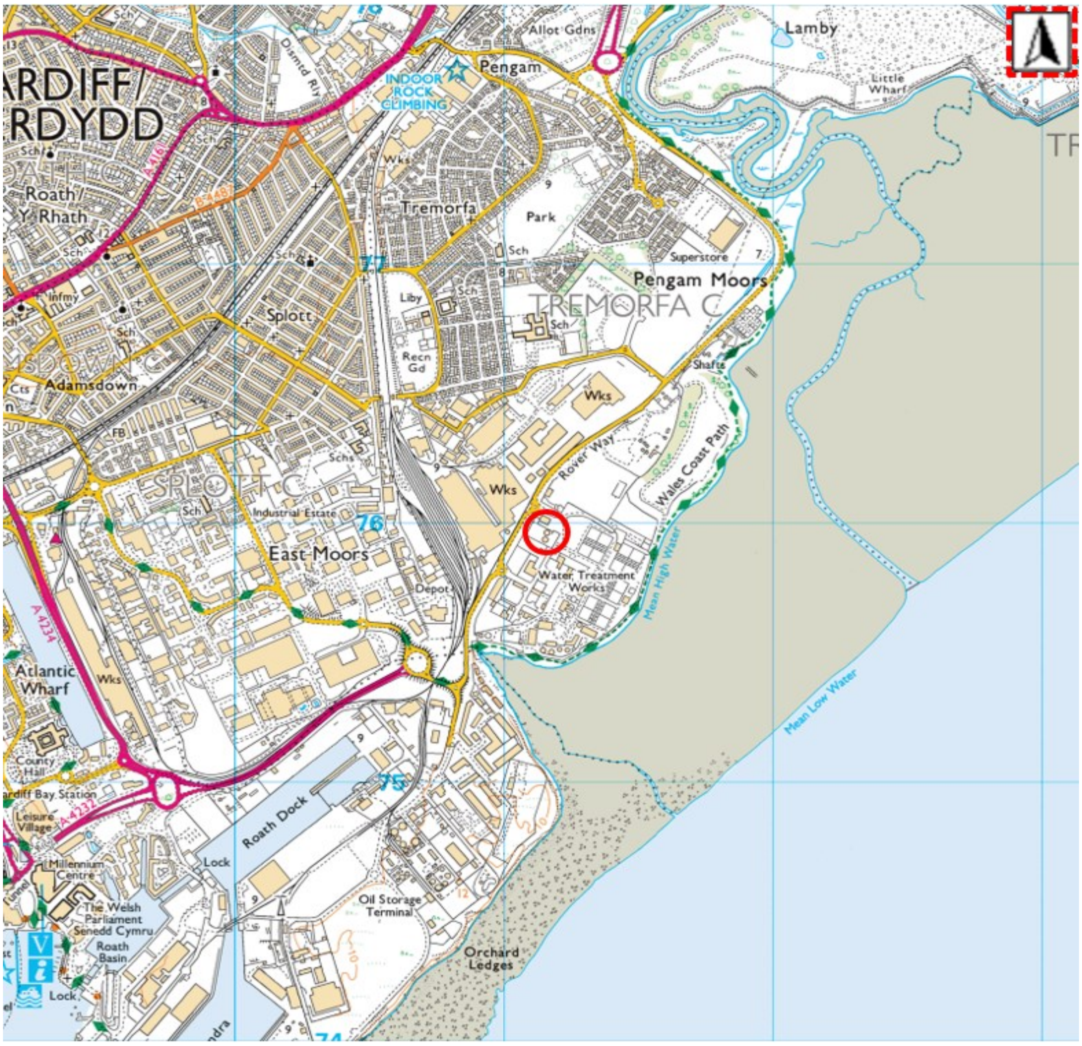
1.1.2. The study has been conducted to determine the impact of oxides of nitrogen ("NO_X") (as nitrogen dioxide ("NO_2")), sulphur dioxide ("SO_2") and carbon monoxide ("CO") on human health for receptors within a 2km radius of the Site. Specified environmental receptors within both a 10km and 2km radius of the discharge stacks have also been assessed, as outlined in the relevant guidance (see Section 2.4).

1.1.3. It should be noted that the proposed boiler is intended to be used a backup solely during periods of scheduled and unscheduled maintenance of the combined heat and power ("CHP") unit on-site - with the boiler's anticipated annual usage therefore not expected to exceed 500 hours.

1.1.4. The study was undertaken using the ADMS modelling package, which is one of the models recognised by NRW as being suitable for this type of study.

1.1.5. The location of the Site is circled in red and central on the Site Location Map which is presented as Figure 1.

Figure 1: Site Location Map



1.2. Objectives of the Study

1.2.1. The objectives of this study are as follows:

- to determine the maximum ground level concentrations ("GLCs") arising from the emission of NO_X as NO_2, SO_2 and CO from the boiler discharge stack. In the first instance, all pollutants are assumed to be released from the Site at their maximum permitted Emission Limit Value ("ELV"); and
- to assess the impact of emissions from the boiler on existing local air quality in relation to human health at a range of potentially sensitive human receptor locations by comparison with the relevant air quality standards ("AQSs").
- to assess the impact of emissions from the boiler discharge stack on potentially sensitive ecological receptors and compare these to the Critical Levels set for the protection of Ecosystems; and
- to predict deposition rates of nutrient nitrogen and acids from the modelled emissions and compare these with relevant Critical Loads at a range of sensitive habitat sites.

1.3. Scope of the Study

1.3.1. Modelling was carried out using the appropriate ELVs as specified in Medium Combustion Plant Directive ("MCPD"). The emission characteristics are explained in more detail in Tables 9 and 10 of Section 2.10.

1.3.2. The effects of prevailing meteorological conditions, building downwash effects, local terrain and existing ambient air quality were also taken into account.

1.3.3. This report spans a number of guidance documents. The EA online guidance[1] was used for assessing if process contributions ("PCs") are insignificant as approved by NRW. The Environmental Protection UK ("EPUK") and the Institute of Air Quality Management ("IAQM") guidance 2017[2] was used where applicable (i.e., where PCs exceeded the assessment criteria outlined in the EA online guidance).

1.3.4. The maximum predicted pollutant GLCs - also known as the process contributions ("PCs") - for releases were compared with the relevant AQSs.

1.3.5. The predicted environmental concentrations ("PECs") - the sum of the pollutant PC and the existing pollutant background concentration from other sources - were also compared to the relevant standards. Results are presented as the maximum predicted GLC and the maximum sensitive receptor GLC.

1.3.6. The maximum predicted pollutant GLCs at the specified potentially sensitive human receptor sites and ecological designations (refer to Tables 1 and 2 of Sections 2.3. and 2.4., respectively) were also compared to the relevant AQSs.

1.3.7. There are four Air Quality Management Areas ("AQMA)" in the City of Cardiff Council ("CCC"), namely:

- Cardiff City Centre AQMA (declared: 1st April 2013) - Former St Mary Street AQMA with the addition of Westgate Street in Cardiff City Centre;
- Stephenson Court AQMA (declared: 1st December 2010) - From NE and NW boundaries of Stephenson Court, NW boundary of Burgess Court, NW and SW boundaries of Four Elms Court, SW corner of Four Elms Court south across Newport road to the junction with Orbit street, West across Newport Road to the SE corner of Stephenson Court;
- Llandaff AQMA (declared: 1st April 2013) – Centre on Cardiff Road through Llandaff village; and
- Ely Bridge AQMA (declared: 1st December 2000 (amended 1st February 2007)) - A number of residential premises along the A48 Cowbridge Road West, Western Avenue and A4119 through Llandaff Village Cardiff Road.

1.3.8. NO_2 is the pollutant declared for all four AQMAs identified and is therefore relevant to this study.

[1] Available online via: https://www.gov.uk/guidance/environmental-permitting-air-dispersion-modelling-reports
[2] Available online via: http://www.iaqm.co.uk/text/guidance/air-quality-planning-guidance.pdf

1.3.9. Of the four AQMAs declared by CCC, Llandaff AQMA and Ely Bridge AQMA are both more than 6km west from the Site and, consequently, will not be considered further in this assessment.

1.3.10. The effect of the modelled emissions on Cardiff City Centre AQMA and Stephenson Court AQMA will be taken into account by including these AQMAs as potentially sensitive receptors. The approximate nearest grid coordinates of the boundary of both AQMAs, to the boiler's discharge stack (as a straight-line measurement), will be used as the location to be assessed.

1.3.11. Using ADMS, the rates of deposition for acids (nitrogen as kilo-equivalents) and nutrient nitrogen were also predicted for select habitat sites (outlined in Table 5). These rates were then compared to the appropriate critical loads for the type and location of each habitat.

2. METHOD STATEMENT

2.1. Choice of Model

2.1.1. The UK-ADMS model was developed jointly by Cambridge Environmental Research Consultants ("CERC"), Her Majesty's Inspectorate of Pollution (the EA's predecessor body), the Meteorological Office and National Power, with sponsorship from the UK Government and a number of commercial organisations. UK-ADMS is a computer-based model of dispersion from both point and non-point sources in the atmosphere, and is one of the modelling packages that are suitable for this type of study. The current version is ADMS 5.2.4.

2.1.2. ADMS 5.2.4 has been validated against a number of data sets in order to assess various configurations of the model such as flat or complex terrain, line/area/volume sources, buildings, dry deposition fluctuations and visible plumes. The model results have been compared to observational data or other model results if available.

2.1.3. ADMS 5.2.4 is a new generation Gaussian plume air dispersion model, which means that the atmospheric boundary layer properties are characterised by two parameters:

- the boundary layer depth, and
- the Monin-Obukhov length,

rather than in terms of the single parameter Pasquill-Gifford class.

2.1.4. Dispersion under convective meteorological conditions uses a skewed Gaussian concentration distribution (shown by validation studies to be a better representation than a symmetrical Gaussian expression).

2.1.5. ADMS 5.2.4 is therefore considered to be suitable for use in this assessment.

2.2. Key Assumptions

2.2.1. The study will be undertaken on the basis of a worst-case scenario. Consequently, the following assumptions have been made:

- the release concentrations of the pollutants will be at the permitted ELVs (or maximum expected concentration, in the case of CO) on a 24-hourly basis, 365 days of the year. In practice, when the plant is operating normally, the boiler will not be operational (with it being a back-up appliance for the purposes of scheduled and unscheduled maintenance for the CHP unit on-site). Consequently, as it is anticipated the boiler will not operate for more than circa 500 hours annually, the actual release concentrations are expected to be significantly lower.
- the highest predicted pollutant GLCs for the five years of meteorological data for each averaging period (annual mean, hourly, etc.) have been used;
- concentrations of NO_2 in the emissions have been calculated assuming a long-term 70% NOx to NO_2 conversion rate, and a short-term 35% NOx to NO_2);
- maximum predicted GLCs at any location, irrespective of whether a sensitive receptor is characteristic of public exposure, are compared against the relevant AQSs for each pollutant; in addition, the predicted maximum sensitive receptor GLC has also been assessed ; and

- the existing CHP at the site has been operational for the last few years and it is therefore assumed to be accounted for in the background air concentration. In addition, the CHP and boiler would not be operational at the same time and consequently has not been modelled in conjunction with the boiler.

2.3. Sensitive Human Receptors

2.3.1. In addition to predicting concentrations over a 4km by 4km grid, there are ten specified potentially sensitive human receptors and two AQMAs considered in the assessment. Details of these are provided in Table 1 and a visual representation provided as Figure 2. All receptors are assumed to be at ground level.

Table 1: Sensitive Human Receptors

ADMS Ref.	Location	Easting	Northing	Distance from Site[(a)] (m)	Heading (degrees)
HR1	Industrial activity off Martin Road	321119	175835	166	187
HR2	Properties off Willows Avenue	320906	176525	574	336
HR3	Properties off Moorland Road	320567	176196	604	289
HR4	Industrial units off Portmanmoor Road	320510	175845	647	256
HR5	Cloughmore Surgery / Splott Park	320648	176512	709	316
HR6	Moorland Primary School	320479	176294	722	294
HR7	Willows High School	321114	176741	741	358
HR8	Moorland Park	320328	176207	836	284
HR9	Industrial estate	320663	175211	921	211
HR10	Travellers' site	321862	176756	1047	44
AQMA1	Stephenson Court AQMA	319432	176981	1968	300
AQMA2	Cardiff City Centre AQMA	318399	175995	2739	270

Notes to Table 1

(a) The distance from Site is calculated as the crow flies from the boiler stack to the approximate nearest point of the potentially sensitive human receptor or AQMA location.

Figure 2: Location of the Potentially Sensitive Human Receptors & AQMAs Considered for the Assessment

Notes to Figure 2

The red circle is the approximate location of the boiler emission point (refer to Section 2.10., for further details); and

The neon green squares with the red outline and yellow highlighted annotations are the locations of the potentially sensitive human receptor locations and AQMAs specified in Table 1.

2.4. Sensitive Ecological Receptors

2.4.1. In accordance with EA guidance the impact of emissions to air on vegetation and ecosystems from the Site should be assessed for the following sensitive environmental receptors within 10km of the discharge stacks:

- Special Protection Areas ("SPAs") and potential SPAs designated under the EC Birds Directive;
- Special Areas of Conservation ("SACs") and candidate SACs ("cSACs") designated under the EC Habitats Directive; and
- Ramsar Sites designated under the Convention on Wetlands of International Importance.

2.4.2. In addition, the impact of emissions to air on vegetation and ecosystems from the Site should be assessed for the following sensitive environmental receptors within 2km of the discharge stacks:

- Sites of Special Scientific Interest ("SSSI") established by the 1981 Wildlife and Countryside Act; and
- local nature sites (ancient woodland ("AW"), local wildlife sites ("LWSs") (also referred to as Sites of Importance for Nature Conservation ("SINCs") and national and local nature reserves ("NNRs" and "LNRs")).

2.4.3. Habitat receptor designations that have been identified within the distance criteria are presented in Table 2, with a visual representation provided as Figure 3.

Table 2: Specific Sensitive Habitat Receptors Considered for the Assessment

ADMS Ref.	Name	Designation(s)	Easting	Northing	Distance from Site (m) [(b)]	Heading (degrees)
SE1	Severn Estuary [(c)]	Ramsar, SAC, SPA, SSSI	321630	176010	492	89
SE2			320901	175500	553	205
SE3			321840	176530	880	53
CBW1	Cardiff Beech Woods	SAC	314600	183220	9740	318
LWS1	Tidal Sidings	LWS [(d)]	320700	175500	665	221
LWS2	Ocean Park South		320500	175300	947	222
LWS3	Cardiff Heliport Fields		321100	175000	1001	182
LWS4	Pengam Moors		321600	176900	1012	27

Notes to Table 2

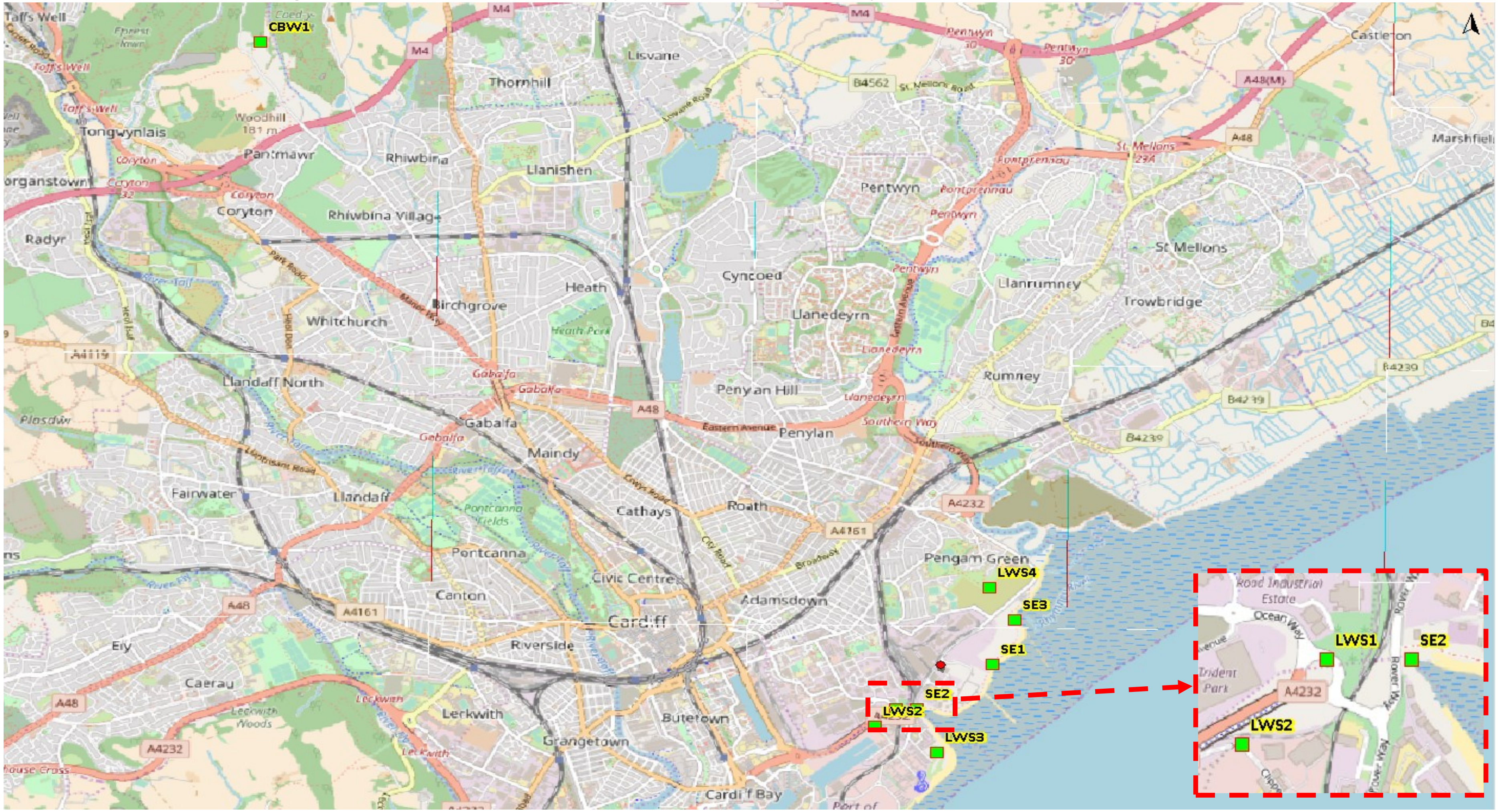
(a) The ecological sites included were identified using both the Multi-Agency Geographic Information System for the Countryside ("MAGIC") portal and the Lle Geo Portal.

(b) Distances are measured as the crow flies from the boiler stack to the approximate nearest point of the habitat receptor.

(c) As the Severn Estuary ecological site covers a large area and possesses many designations – to account for any variations to the predicted PCs with changing meteorological effects, multiple boundary points have been selected in numerous compass directions from the Site.

(d) For the LWS locations, these coordinates have been obtained from Section 2.5 of *Ecology and Biodiversity Technical Guidance Note*, November 2017, *Part 2 – The Cardiff Resource* (within *Cardiff Green Infrastructure SPG*), available online via: https://cardiff.moderngov.co.uk/documents/s18690/Item%209%20App%201%20SPG%20Green%20Infrastructure.pdf

Figure 3: Location of the Potentially Sensitive Ecological Receptors Considered for the Assessment



Notes to Figure 3

The red circle is the approximate location of the boiler emission point (refer to Section 2.10., for further details); and

The neon green squares with the red outline and yellow highlighted annotations are the ecological receptors detailed in Table 2.

2.5. Air Quality Standards for the Protection of Human Health

2.5.1. The Air Quality Strategy for England, Scotland, Wales and Northern Ireland (2007) details Air Quality Strategy Objectives for a range of pollutants, including a number that are directly relevant to this study. In addition, the Regulatory Authorities must ensure that the proposals do not exceed Ambient Air Directive ("AAD") limit values.

2.5.2. In this report, the generic term Air Quality Standard ("AQS") is used to refer to any of the above values. The various AQSs are intended to be used as guidelines for the protection of human health and the management of local air quality. The values relevant to this study are detailed in Table 3.

Table 3: Air Quality Standards for the Protection of Human Health

Pollutant	Averaging Period	AQS ($\mu g/m^3$)	Comments
Nitrogen Dioxide (NO_2)	annual	40	UK Air Quality Objective ("AQO") and Ambient Air Directive ("AAD") Limit
	1-hour	200	UK AQO and AAD Limit, not to be exceeded more than 18 times per annum, equivalent to the 99.79th percentile of 1-hour means
Sulphur Dioxide (SO_2)	24-hour	125	UK AQO, not to be exceeded more than 3 times per annum, equivalent to the 99.18th percentile of 24-hour means
	1-hour	350	UK AQO, not to be exceeded more than 24 times per annum, equivalent to the 99.73rd percentile of 1-hour means
	15-minute	266	UK AQO, not to be exceeded more than 35 times per annum, equivalent to the 99.90th percentile of 15-minute means
Carbon Monoxide (CO)	8-hour	10,000	UK AQO and AAD Limit

2.6. Air Quality Standards for the Protection of Sensitive Habitat Sites and Ecosystems

2.6.1. For dispersion modelling purposes, the specified habitat co-ordinates are a precautionary approach, and are those located at the boundary of the protected site approximately closest in proximity to the Site. The maximum predicted impact for each of the habitat sites has been identified for comparison with relevant assessment criteria.

Critical Levels

2.6.2. Critical levels are thresholds of airborne pollutant concentrations above which damage may be sustained to sensitive plants and animals. High concentrations of pollutants in ambient air directly cause harm to leaves and needles of forests and other plant communities. Oxidised nitrogen can have both a toxic effect on vegetation and an impact on nutrient nitrogen.

2.6.3. The 2008 Air Quality Directive set limit values for the protection of vegetation and ecosystems and these have been adopted by the Air Quality Strategy, but are not currently set in Regulations. The current objectives are summarised in Table 4.

Table 4: Assessment Criteria for the Protection of Sensitive Habitats and Ecosystems

Pollutant	Averaging Period	Critical Level ($\mu g/m^3$)	Comments
Nitrogen Oxides (as NO_2)	annual	30	Air Quality Objective
	daily	75	(a)
Sulphur Dioxide (SO_2)	annual	10	Sensitive lichen communities & bryophytes and ecosystems where lichens & bryophytes are an important part of the ecosystem's integrity (a)
	annual	20	Air Quality Objective
	winter mean	20	Air Quality Objective

Notes to Table 4
(a) WHO (2000) Air Quality Guidelines for Europe; 2nd Edition. WHO Regional Publications, European Series, No. 91.

Critical Loads

2.6.4. Critical Loads are defined as:

"a quantitative estimate of exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge"(3).

2.6.5. Critical loads for nutrient nitrogen are set under the Convention on Long-Range Transboundary Air Pollution based on empirical evidence, mainly observations from experiments and gradient studies. Critical loads (4) are assigned to habitat classes of the European Nature Information System (5) in units of kgN/ha/yr.

2.6.6. Predicted NO_x deposition rates in units of µg m^{-2} s^{-1} are converted to units of kg/ha/yr as nitrogen for direct comparison with critical loads as follows:

- kgN/ha/yr = µg/m^2/s × (14/46) (6) × 315.36(7) (which equates approximately to the conversion factor provided in the AQTAG06 guidance of 95.9).

2.6.7. Exceedance of critical loads for nitrogen deposition can result in significant terrestrial and freshwater impacts due to changes in species composition, reduction in species richness, increase in nitrate leaching, increases in plant production, changes in algal productivity and increases in the rate of succession (8).

2.6.8. In the UK, an empirical approach is applied to critical loads for acidity for non-woodland habitats; and the simple mass balance equation is applied to both managed and unmanaged woodland habitats. For freshwater ecosystems, national critical load maps are currently based on the First-order Acidity Balance model. All of these methods provide critical loads for systems at steady-state (4) in units of keq/ha/yr.

2.6.9. The unit kiloequivalent (keq) is the molar equivalent of potential acidity resulting from sulphur or oxidised and reduced nitrogen. Predicted acid deposition rates in units of µg/m^2/s are converted to units of keq/ha/yr) as hydrogen for direct comparison with critical loads as follows:

- nitrogen from NO_x (keq) =([NO_x]µg/m^2/s × (14/46) × 315.36) ÷ 14(9) (which equates approximately to the conversion factor provided in the AQTAG06 guidance of 6.86); and
- sulphur (keq) =([SO_2]µg/m^2/s × (32/64) × 315.36) ÷ 16 [10] (which equates approximately to the conversion factor provided in the AQTAG06 guidance of 9.86);

2.6.10. Exceedance of the critical loads for acid deposition can result in significant terrestrial and freshwater impacts due to leaching and subsequent increase in availability of potentially toxic metal ions.

(3) From http://www.unece.org/env/lrtap/WorkingGroups/wge/definitions.htm
(4) From http://www.apis.ac.uk/overview/issues/overview_Cloadslevels.htm
(5) See http://eunis.eea.europa.eu/ for details
(6) Ratio of atomic weight of nitrogen to molecular weight of nitrogen dioxide
(7) Conversion factor from ?g/m^2 to kg/ha.
(8) From http://www.apis.ac.uk/overview/issues/overview_Cloadslevels.htm#_Toc279788052
(9)14kg nitrogen/ha/yr = 1keq nitrogen/ha/yr
[10] 16kg sulphur/ha/yr= 1keq sulphur/ha/yr

2.6.11. Table 5 lists the site-specific critical loads for nutrient nitrogen deposition and acid deposition respectively. Features are as indicated on the Air Pollution Information System ("APIS") website for SACs, SPAs and SSSIs. Where a primary feature identified in the citation was not listed on the APIS website, an equivalent feature was used to derive critical loads as indicated in the Habitats Table on the APIS website [(11)].

([11]) http://www.apis.ac.uk/habitat_table.html

Table 5: Critical Loads for Deposition

Ref	Site Name	Habitat Interest	Habitat Feature	Nutrient Nitrogen Deposition		Acid Deposition		
				Lower Critical Load (kgN/ha/yr)	Upper Critical Load (kgN/ha/yr)	CL Min N (keq/ha/yr)	CL Max N (keq/ha/yr)	CL Max S (keq/ha/yr)
SE1 – SE3	Severn Estuary – Ramsar	Coastal Saltmarsh	Pioneer, low-mid, mid-upper saltmarshes	20	30	Not sensitive to acidification		
SE1 – SE3	Severn Estuary – SAC	Estuaries	Pioneer, low-mid, mid-upper saltmarshes	20	30	Not sensitive to acidification		
		Atlantic salt meadows	Pioneer, low-mid, mid-upper saltmarshes	20	30	Not sensitive to acidification		
		Sandbanks which are slightly covered by water all the time	None assigned	Not sensitive to eutrophication		Not sensitive to acidification		
		Mudflats and sandflats not covered be seawater at low tide		No comparable habitat with established critical load estimates available		Not sensitive to acidification		
		Reefs		Not sensitive to eutrophication		Not sensitive to acidification		
		Petromyzon marinus – Sea lamprey	Rivers and streams	No comparable habitat with established critical load estimates available		No critical loads available for this feature		
		Lampetra fluviatilis – River lamprey						
		Alosa fallax – Twaite Shad						

Table 5: Critical Loads for Deposition (cont.)

Ref	Site Name	Habitat Interest	Habitat Feature	Nutrient Nitrogen Deposition		Acid Deposition		
				Lower Critical Load (kgN/ha/yr)	Upper Critical Load (kgN/ha/yr)	CL Min N (keq/ha/yr)	CL Max N (keq/ha/yr)	CL Max S (keq/ha/yr)
SE1 – SE3	Severn Estuary – SPA	Common shelduck - Wintering	Littoral sediment	20	30	Not sensitive to acidification		
		Common redshank - Wintering						
		Greater white-fronted goose - Wintering						
		Tundra swan - Wintering	Improved grassland	Not sensitive to eutrophication		Not sensitive to acidification		
			Arable and horticulture					
			Standing open water and canals	No comparable habitat with established critical load estimates available		No expected negative impact on the species due to impacts on the species' broad habitat		
		Gadwall - Wintering	Standing open waters and canals	No comparable habitat with established critical load estimates available				
SE1 – SE3	Severn Estuary - SSSI	Fen, marsh and swamp	Rich Fens	15	30	Not sensitive to acidification		
		Neutral grassland	Low and medium altitude hay meadows	20	30	0.223	1.063	0.84
						0.856	4.856	4

Table 5: Critical Loads for Deposition (cont.)

Ref	Site Name	Habitat Interest	Habitat Feature	Nutrient Nitrogen Deposition		Acid Deposition		
				Lower Critical Load (kgN/ha/yr)	Upper Critical Load (kgN/ha/yr)	CL Min N (keq/ha/yr)	CL Max N (keq/ha/yr)	CL Max S (keq/ha/yr)
SE1 – SE3	Severn Estuary - SSSI (cont.)	Littoral sediment	Pioneer, low-mid, mid-upper saltmarshes	20	30	Not assessed for this feature		
		Vascular plant assemblage	No broad habitat assigned	No comparable habitat with established critical load estimates available		No Comparable Acidity Class		
		Ringed Plover	Littoral sediment	20	30	Not sensitive to acidification		
		Curlew						
		Grey Plover						
		Shelduck						
		Redshank						
		Non-breeding waterbirds	Bird – non-breeding; standing open waters and canals	No comparable habitat with established critical load estimates available		No values given via APIS		
		Allis Shad	Rivers and streams					

Table 5: Critical Loads for Deposition (cont.)

Ref	Site Name	Habitat Interest	Habitat Feature	Nutrient Nitrogen Deposition		Acid Deposition		
				Lower Critical Load (kgN/ha/yr)	Upper Critical Load (kgN/ha/yr)	CL Min N (keq/ha/yr)	CL Max N (keq/ha/yr)	CL Max S (keq/ha/yr)
SE1 – SE3	Severn Estuary - SSSI (cont.)	Twaite Shad	Rivers and streams	No comparable habitat with established critical load estimates available		No values given via APIS		
		River Lamprey						
		Sea Lamprey						
		Atlantic Salmon						
CBW1	Cardiff Beech Woods - SAC	Asperulo-Fagetum beech forests	Fagus woodland	10	20	0.142	1.428	1.286
		Tilio-Acerion forests of slopes, screes and ravines	Meso- and eutrophic Quercus woodland	15	20	0.142	1.428	1.286

2.7. Habitat Site Specific Baseline Concentrations and Deposition Rates

Airborne NO_X Concentrations

2.7.1. A summary of site-specific baseline concentrations of NO_X and SO_2, as provided by APIS, is presented in Table 6. Background concentrations for each ecological receptor have been obtained at the same point as listed in Table 2.

Table 6: Baseline Concentrations of NO_X and SO_2

ADMS Receptor Reference	Description & Designation	NO_X Background Concentration [a] (µg/m³)		SO_2 Background Concentration [a] (µg/m³)
		Annual Mean	24 Hour [b] Mean	Annual Mean
SE1	Severn Estuary – Ramsar, SAC, SPA, SSSI [c]	19.62	23.15	2.67
SE2		28.34	33.44	5.44
SE3		19.62	23.15	2.67
CBW1	Cardiff Beech Woods – SAC	12.12	14.30	1.39
LWS1	Tidal Sidings - LWS	28.34	33.44	5.44
LWS2	Ocean Park South - LWS	28.34	33.44	5.44
LWS3	Cardiff Heliport Fields - LWS	16.55	19.53	2.61
LWS4	Pengam Moors - LWS	19.62	23.15	2.67

Notes to Table 6

(a) Background concentrations for the relevant ecological habitats have been taken from the APIS website for the closest grid square to the site (data year: 2018 – 2020).

(b) The 24-hour mean baseline concentration is twice the annual mean multiplied by a factor of 0.59, in accordance with the H1 guidance.

(c) As the Severn Estuary ecological site covers a large area and possesses many designations – to account for any variations to the predicted PCs with changing meteorological effects, multiple boundary points have been selected in numerous compass directions from the Site.

Nutrient Nitrogen and Acid Deposition

2.7.2. A summary of site-specific baseline nutrient nitrogen and acid deposition rates, as provided by APIS, is presented in Table 7 for the relevant habitat sites. Again, the specific deposition rates for each ecological receptor have been obtained from the same point as listed in Table 2, i.e., the closest grid square to the point of the site used in the assessment.

Table 7: Background Nutrient Nitrogen and Acid Deposition Grid Averages

ADMS Receptor Reference	Description & Designation	Nutrient Nitrogen Background (kgN/ha/yr)	Acid Deposition Background (keq/ha/yr)		
			Total	Nitrogen	Sulphur
SE1	Severn Estuary – Ramsar, SAC, SPA, SSSI	8.68 [(a)]	1.33 [(b)]	1.12 [(b)]	0.27 [(b)]
SE2		8.68 [(a)]	1.33 [(b)]	1.12 [(b)]	0.27 [(b)]
SE3		8.68 [(a)]	1.33 [(b)]	1.12 [(b)]	0.27 [(b)]
CBW1	Cardiff Beech Woods – SAC	15.82 [(a)]	2.27 [(a)]	2.11 [(a)]	0.28 [(a)]

Notes to Table 7

(a) Background concentrations, for both nutrient nitrogen and acid deposition, for the relevant ecological habitats have been taken from the APIS website (data year: 2018-2020).

(b) With no information displayed via APIS for data year 2018 – 2020, background data taken from data year 2017 – 2019.

2.8. Deposition Parameters - Sensitive Habitats

2.8.1. Deposition of nitrogen and acids at the relevant designated habitats sites (i.e., SE1 – SE3 and CBW1) was also included in the assessment. This focused on sites within 10km of the Site as detailed in Section 2.4. The pollutant deposition rates are presented in Table 8. These parameters are detailed in AQTAG06. Since woodland sites have a greater surface area, higher deposition velocities are adopted for these sites.

2.8.2. In regard to the emitted pollutants from the Site's boiler - for the predicted nutrient nitrogen impacts, the deposition of oxides of nitrogen are considered. For the predicted acidification impacts, the deposition of oxides of nitrogen and sulphur dioxide are considered.

Table 8: Acid/Nitrogen Deposition Parameters [(12)]

Pollutant	Dry Deposition Velocity for Grassland (m/s)	Dry Deposition Velocity for Woodland (m/s)
Oxides of Nitrogen (as NO_2)	0.0015	0.003
Sulphur Dioxide	0.012	0.024

2.9. Background Air Quality

2.9.1. For the purposes of this assessment the most representative background concentration to the point being assessed (i.e., the maximum GLC or sensitive receptor location) will be used, where necessary, to calculate the PEC for long-term NO_2. The source, location and concentration of the background air quality data will be specified in the appropriate section.

[12] As detailed in AQTAG06.

2.10. Stack Emission Parameters and Emission Limit Values

2.10.1. The stack emission parameters used in the study are presented in Table 9.

Table 9: Stack Emission Parameters

Parameter		Boiler [(a)]
Rated Thermal Input (MWth)		1.53
Stack Height (m)		9
Stack Exit Diameter (m)		0.500
Stack Gas Discharge Velocity (actual) (m/s)		3.10
Stack Gas Discharge Temperature (°C)		82
Stack Centre Coordinates	Easting (X)	321138
	Northing (Y)	176000
Oxygen Concentration in Stack Emission (%)		3.17
Moisture Concentration in Stack Emission (%)		8.25
Normalised Volumetric Flowrate (Nm^3/s) [(b)]		0.425

Notes to Table 9
(a) Stack emission parameters either confirmed by Welsh Water or obtained from stack emissions monitoring data when the boiler was situated up in Wrexham (a copy of this emissions report may be found as Appendix I).
(b) Referenced to 273K, 1 atmosphere, 3% oxygen, dry.

2.10.2. The ELVs assumed for each pollutant and the pollutant mass emission rate for the study are presented in Table 10 for the boiler.

Table 10: Pollutant Emission Rates

Pollutant	ELV [(a)] (mg/Nm^3)	Boiler (g/s)
NO_X	200 [(b)]	0.0850
SO_2	100 [(c)]	0.0425
CO	1000 [(d)]	0.425

Notes to Table 10
(a) Concentrations are at reference conditions i.e., 273K, 1 atmosphere, 3% oxygen, dry.
(b) ELV as per Table 1 of Part 2 of Annex II of the MCPD (for gaseous fuels other than natural gas).
(c) ELV as per note (22) of Table 1 of Part 2 of Annex II of the MCPD (when running on biogas).
(d) Maximum anticipated concentration.

2.11. Meteorological (Met) Data

2.11.1. ADMS has a meteorological pre-processing capability, which calculates the required boundary layer parameters from a variety of data. Meteorological data (“met data”) can be utilised in its sequentially analysed form, which estimates the pattern of dispersion through 10 degree sectors from the source or as raw data.

2.11.2. The nearest suitable met data available from the Meteorological Office ("Met Office") is from St Athan. This site is located approximately 22km west-southwest of the Site.

2.11.3. The assessment utilises five years (2017 - 2021) of hourly sequentially analysed data in sectors of 10 degrees. Wind roses for the data are presented in Figure 4; these show that the prevailing winds are predominantly westerly, with a few easterly components.

2.11.4. Over the five years of meteorological data used (43,824 hours), ADMS reported that 1,076 hours contained inadequate data, 13 hours were calm and 420 hours were non-calm met data lines with a wind speed less than the minimum value (0.75 m/s). These represent 2.46%, 0.03% and 0.96% of the data respectively.

Figure 4: Wind Roses - Met Years 2017-2021

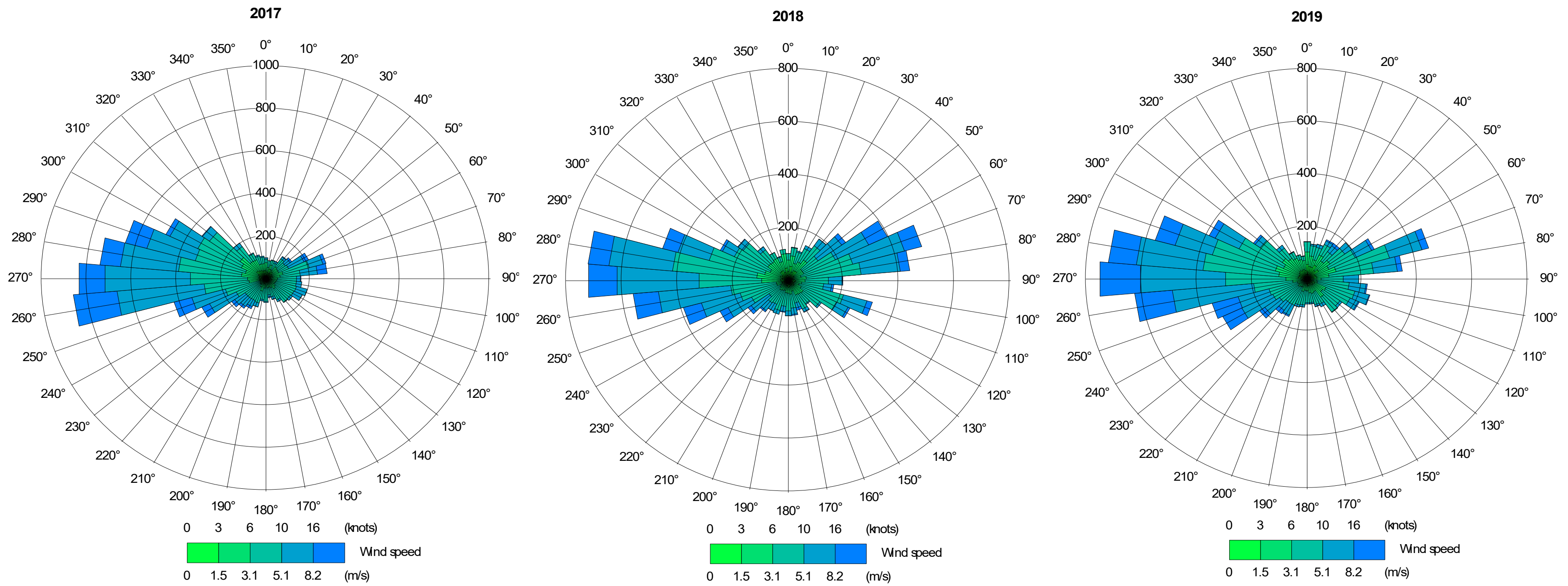
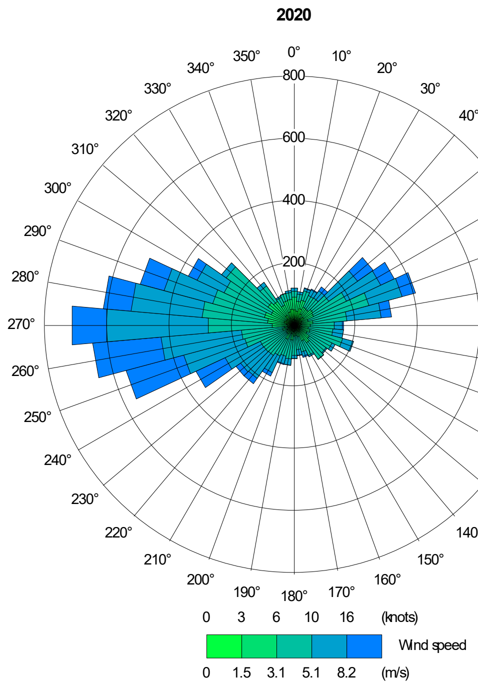
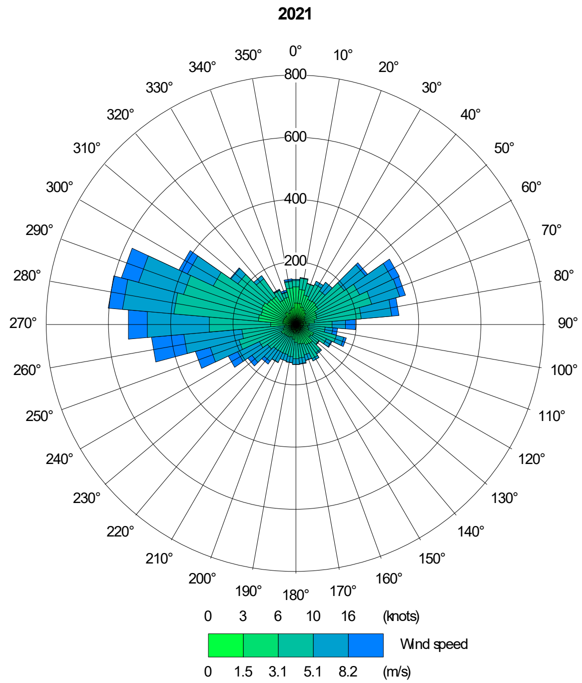


Figure 4: Wind Roses - Met Years 2017-2021 (cont.)





2.12. Surface Albedo

2.12.1. The surface albedo is the ratio of reflected to incident shortwave solar radiation at the surface of the earth[13]. ADMS allows the user to set this value between 0 and 1. A value of 0.40-0.95 would be considered representative of snow-covered ground where a large proportion of the light is reflected, soils from 0.05-0.40, agricultural crops 0.18-0.25, and grass would be 0.16 – 0.26 depending on length[14]. A value of 0.23 is an average value for non-snow-covered surfaces and is the default value used in the model. This value is considered appropriate for the setting of both the dispersion site and the met measurement site.

2.13. Priestley-Taylor Parameter

2.13.1. The Priestly Taylor parameter is a parameter representing the surface moisture available for evaporation[13]. This parameter must be set between 0 and 3 where 0 would be classed as dry bare earth, 0.45 as dry grassland, 1 as moist grassland and a value of 3 is suggested for a saturated forest surrounded by forest[15]. The default value of 1 was considered to be appropriate for the setting of the dispersion and the met measurement site and the surrounding areas.

2.14. Minimum Monin-Obukhov Length

2.14.1. The Monin-Obukhov length provides a measure of the stability of the atmosphere. For example, in urban areas the air is affected by heat generated from buildings and traffic which prevents the atmosphere from becoming stable. In rural areas the atmosphere would be more stable. The minimum Monin-Obukhov length can be set between 1 and 200m. Typical values would be[13]:

- large conurbations >1 million = 100m;
- cities and large towns = 30m;
- mixed urban/industrial = 30m;
- small towns <50,000 = 10m; and
- rural areas = 1m.

2.14.2. A value of 30m was used for the dispersion site as this value is considered appropriate for the combination of industrial and residential land use experienced in the vicinity of the site. A value of 10m was used for the met measurement site to reflect the presence of MOD Saint Athan and the surrounding villages and Llantwit Major town.

2.15. Building Parameters

2.15.1. The building parameters utilised for the study are detailed in Table 11 and a visual representation is provided as Figure 5.

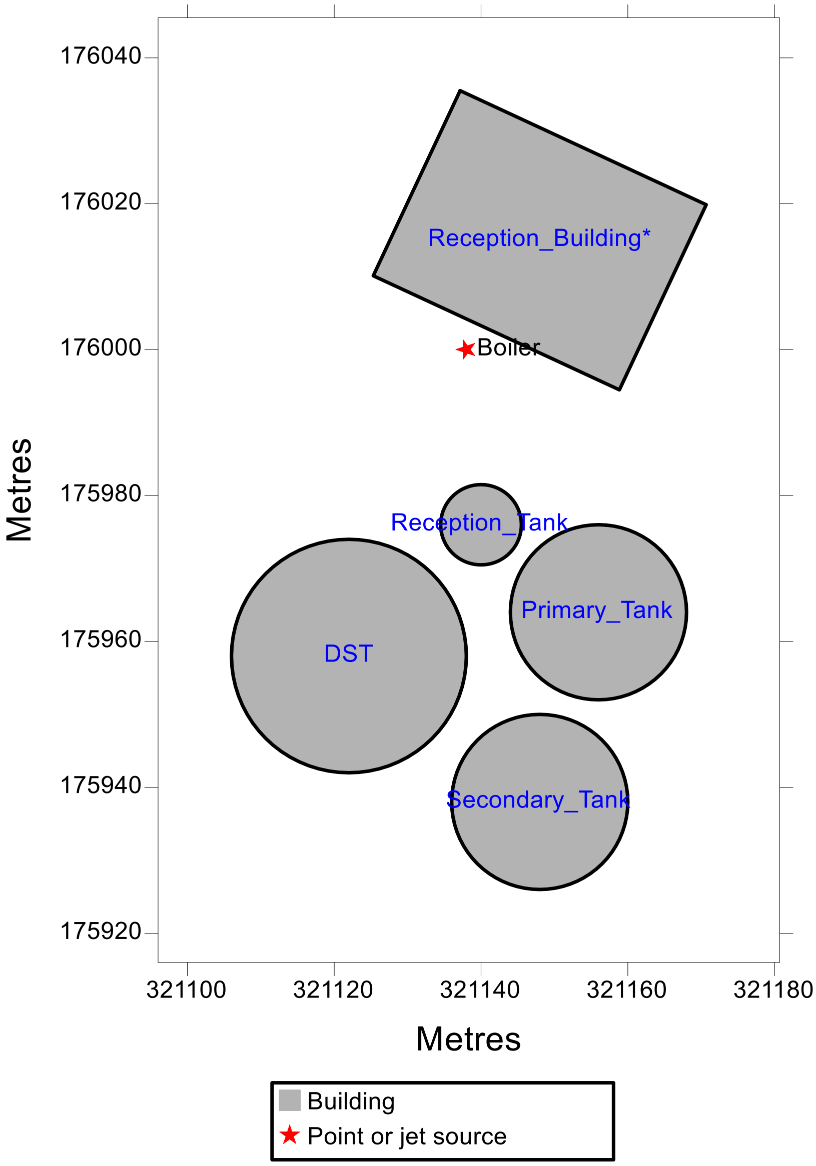
[13] ADMS5 User Guide, CERC, V5, Nov 2012
[14] TR Oke, Buondary Layer Climates, 2nd Edition 1987
[15] J P Lhomme, A Theorestivl Basis for the Priestley-Taylor Coefficient, February 1997.

Table 11: Building Parameters

Building	X [a]	Y [a]	Angle (º) [b]	Height (m) [c]	Length/ Diameter (m) [c]	Width (m) [c]
Reception Building	321148	176015	115	13.2	37	28
DST	321122	175958	N/A	9.9	32	N/A
Secondary Tank	321148	175938	N/A	8.4	24	N/A
Primary Tank	321156	175964	N/A	8.4	24	N/A
Reception Tank	321140	175976	N/A	7.4	11	N/A

Notes to Table 11
(a) X(m), Y(m) denote the grid reference coordinates of the centre of the building.
(b) Angle denotes the angle between north and the side designated as length in the ADMS model.
(c) Building dimensions provided or confirmed by Welsh Water.

Figure 5: Buildings Layout



2.16. Terrain Data

2.16.1. ADMS has a terrain pre-processing capability, which calculates the required boundary layer parameters from a variety of data.

2.16.2. Terrain data was used for an area of 400km^2 (20 km by 20 km), which is considerably larger than the output grid area. The terrain data used was of sufficient size to ensure that it would encompass all sensitive human receptors. The terrain file was created by compiling the data from the relevant Ordnance Survey tiles. The terrain data file was created using an ADMS terrain grid resolution of 64 x 64.

2.17. Roughness Length

2.17.1. The surface nature of the terrain is defined in terms of Roughness Length (Z_o). The roughness length is dependent on the type of terrain and its physical properties. The ADMS model gives values to various types of terrain, for example, sea areas are classed as 0.0001m, parkland and open suburbia is classed as 0.5m and cities and large urban areas are classed as 1.5m.

2.17.2. Given the nature of the surrounding land use and the presence of the Severn Estuary, a variable surface roughness file was created to account for these variations in surface roughness length.

2.17.3. This approach was discussed with CERC and was achieved by means of manually editing the terrain file created to assign areas (based on their coordinates) within the output extent with surface roughness values of:

- 0.0001m (indicative of sea) - for areas covered by the Severn Estuary;
- 0.2m (indicative of agricultural areas (min)) - for areas predominantly populated by open green space / farmers' fields; and
- 1.0m (indicative of cities and woodlands) - for land principally occupied by urban infrastructure and wooded areas.

2.18. Model Output Parameters

2.18.1. The ADMS model calculates the likely pollutant GLCs at locations within a definable grid system pre-determined by a user. Output grids may be determined in terms of a Cartesian or Polar co-ordinate system. For the purpose of this study the Cartesian system was used.

2.18.2. A Cartesian grid is constructed with reference to an initial origin, which is taken to be the bottom left corner of the grid. The lines of the grid are inserted at regular pre-defined increments in both northerly and easterly directions. Pollutant GLCs are calculated at the intersection of these grid lines; they are calculated in this manner primarily to aid in the generation of pollutant contours.

2.18.3. For assessing the maximum point of impact, a grid resolution of 4km x 4km was utilised in order to capture values of the predicted pollutant GLCs arising from the model. The grid co-ordinates were X = 319138 to 323138 and Y = 174000 to 178000, with 101 nodes along each axis i.e., a grid spacing of 40m.

2.18.4. For assessing the impact of emissions on human health and ecological sites, the grid references of each were included as specified points within the ADMS model.

2.19. Scenarios Modelled

2.19.1. The following scenarios were modelled from the emissions arising from the boiler:

- impact assessment at the maximum point of impact;
- impact assessment at the potentially sensitive human receptor locations and on the AQMAs; and
- impact assessment at the designated ecological sites relevant to the study (inclusive of deposition rates).

2.20. Assessment of Significance of Impact Guidelines – Maximum GLC and Human Receptors

2.20.1. Both the EA online guidance and IAQM guidance has been used for the purposes of significance assessment, and this guidance details the guidelines upon which the assessment of the significance of impact can be established.

2.20.2. In the first instance, the EA online guidance indicates that PCs can be considered insignificant if:

- the long-term PC is <1% of the long-term environmental standard; and
- the short-term PC is <10% of the short-term environmental standard.

2.20.3. As outlined in the EA online guidance, there are no criteria to determine whether:

- PCs are significant; and
- PECs are insignificant or significant.
- Consequently, significance will be judged based on the site-specific circumstances and on the EPUK and IAQM methodology as described in the following Sections.

Long-Term Impacts

2.20.4. If the PCs exceed the long-term criteria outlined in the EA online guidance, the potential long-term effects on human receptors from the operation of the existing and proposed boilers will be assessed in accordance with the latest guidance produced by EPUK and IAQM in January 2017.

2.20.5. The guidance provides a basis for a consistent approach that could be used by all parties to professionally judge the overall significance of the air quality effects based on the severity of air quality impacts.

2.20.6. The following rationale is used in determining the severity of the air quality impacts at individual human receptors:

- the effects are provided as a percentage of the AQAL;
- the absolute concentrations are also considered in terms of the AQAL and are divided into categories for long-term concentrations. The categories are based on the

sensitivity of the individual receptor in terms of harmful potential. The degree of potential to change increases as absolute concentrations are close to or above the AQAL;

- severity of the effect is described as qualitative descriptors; negligible, slight, moderate or substantial by taking into account in combination the harm potential and air quality effect. This means that a small increase at a receptor which is already close to or above the AQAL will have higher severity compared to a relatively large change at a receptor which is significantly below the AQAL, >75% AQAL;
- the effects can be adverse when the air quality concentration increases or beneficial when the concentration decreases as a result of development; and
- the judgement of overall significance of the effects is then based on severity of effects on all the individual receptors considered.

2.20.7. The impact descriptors for individual receptors are presented in Table 12.

Table 12: Impact Descriptors for Individual Receptors – Long-Term Concentrations

Long-term average concentration at receptor in assessment year	% Change in concentration relative to AQAL			
	1	2-5	6-10	>10
≤75% of AQAL	Negligible	Negligible	Slight	Moderate
76-94% of AQAL	Negligible	Slight	Moderate	Moderate
95-102% of AQAL	Slight	Moderate	Moderate	Substantial
103-109% of AQAL	Moderate	Moderate	Substantial	Substantial
≥ 110% of AQAL	Moderate	Substantial	Substantial	Substantial

Short-Term Impacts

2.20.8. As stated in EPUK / IAQM guidance, January 2017 (Land-Use Planning & Development Control: Planning for Air Quality') in Section 6.36, Page 27: *"For any point source, some consideration must also be given to the impacts resulting from short term, peak concentrations of those pollutants that can affect health through inhalation. The Environment Agency uses a threshold criterion of 10% of the short term AQAL as a screening criterion for the maximum short-term impact. This is a reasonable value to take and this guidance also adopts this as a basis for defining an impact that is sufficiently small in magnitude to be regarded as having an insignificant effect. Background concentrations are less important in determining the severity of impact for short term concentrations, not least because the peak concentrations attributable to the source and the background are not additive."*

2.20.9. Short-term concentrations in the context laid out in the IAQM guidance are those averaged over periods of an hour or less. These exposures would be regarded as acute and occur when a plume from an elevated source affects airborne concentrations experienced by a receptor over an hour or less.

2.20.10. The IAQM guidance offers the following severity of impact descriptors for peak short-term concentrations from an elevated source:

- 11-20% of the relevant AQAL – the magnitude can be regarded as 'small';

- 21-50% of the relevant AQAL – the magnitude can be regarded as 'medium'; and
- 51% or more of the relevant AQAL – the magnitude can be regarded as 'large'.
- It is argued that this approach is intended to be a streamlined and pragmatic assessment procedure that avoids undue complexity.

2.21. Assessment of Significance of Impact Guidelines – Ecological Receptors, Critical Levels and/or Loads

2.21.1. EA Operational Instruction 67_12 [16] states that a detailed assessment is required where modelling predicts that the long-term PC is greater than:

- 1% for European sites and SSSIs; or
- 100% for NNR, LNR, LWS and ancient woodlands.

And the PEC is greater than:

- 70% for European sites and SSSIs; or
- 100% for NNR, LNR, LWS and ancient woodlands.

2.21.2. For short-term emissions, modelling is required at European site and SSSI's where the PC is greater than 10% of the critical level, or 100% for NNR, LNR, LWS and ancient woodland.

2.21.3. Following detailed assessment, if the PEC is less than 100% of the appropriate environmental criterion, then it can be assumed there will be no adverse effect for European Sites and SSSI's.

2.21.4. For NNR, LNR, LWS or ancient woodland, if the PC is less than 100% of the appropriate environmental criterion, then it can be assumed there will be no significant pollution.

2.22. NO_x to NO_2 conversion Rates

2.22.1. EA online guidance states that emissions of NO_x should be recorded as NO_2 as follows:

- for the long-term PCs and PECs, assume 100% of the emissions of NO_x convert to NO_2; and
- for the short-term PCs and PECs assume 50% of the emissions of NO_x convert to NO_2.

2.22.2. However, further to detailed discussion with the EA and NRW on previous studies, a long-term 70% NO to NO_2 conversion rate, and a short-term 35% NO to NO_2 as required by guidance on NO_x and NO_2 Conversion Ratios as referenced in AQTAG06 *Technical guidance on detailed modelling approach for an appropriate assessment* (April 2010) should be used in all detailed modelling assessments. The conversion rates as provided in section 2.19.1. should only be used for screening assessment.

[16] EA Operational Instruction 67_12 Detailed assessment of the impact of aerial emissions from new or expanding IPPC regulated industry for impacts on nature conservation, V2, 27.3.15

3. ASSESSMENT OF AIR QUALITY IMPACTS

3.1. Human Health Impacts at Maximum GLCs

3.1.1. The predicted PCs for each of the pollutants considered in the assessment at the maximum point of impact for the boiler have been extracted and are presented in Table 13. The maximum predicted PCs are also compared to their respective AQSs.

3.1.2. Maximum concentrations are considered potentially significant if the long-term prediction is greater than 1% of the long-term AQS, and, for short-term predictions, a potentially significant concentration would be greater than 10% of the short-term AQS (see Section 2.20. of this document). In Table 13, any PCs that are above these significance criteria are indicated in bold type.

Table 13: Comparison of Maximum PCs with Air Quality Standards

Pollutant	WCMY* (2017 – 2021)	Max PC (µg/m³)	Location of Max PC		AQS (µg/m³)	PC as % of AQS
			Easting (X)	Northing (Y)		
NO_2 (annual)	2018	**50.83**	321138	176000	40	**127.07%**
NO_2 (1 hour, 99.79th percentile)	2017	**122.93**	321138	176000	200	**61.46%**
SO_2 (24 hour, 99.18th percentile)	2017	**93.18**	321138	176000	125	**74.54%**
SO_2 (1 hour, 99.73rd percentile)	2017	**173.09**	321138	176000	350	**49.45%**
SO_2 (15 min, 99.90th percentile)	2017	**178.42**	321138	176000	266	**67.08%**
CO (8 hour, 100th percentile)	2017	**1521.00**	321138	176000	10,000	**15.21%**

Notes to Table 13
*Worst Case Met Year (WCMY)

3.1.3. It can be seen from the data in Table 13 that all pollutants have predicted PCs which are potentially significant. Consequently, further assessments are required in order to categorise the long-term and short-term impacts in accordance with the significance criteria laid out in Section 2.20.

Long-Term NO_2

3.1.4. For the potentially significant long-term NO_2 PCs, PECs must be calculated. PECs are calculated by adding the long-term process contribution to the long-term ambient background concentration. CCC undertake automatic as well as non-automatic (passive) diffusion tube ("DT") monitoring for NO_2 throughout the county. The nearest automatic monitoring site ("AMS") and DT NO_2 data to the Site (i.e., observed data) are displayed in Table 14 for 2019 (the latest available data year).

Table 14: Nearest Monitoring Site Locations to Site [a]

Monitor Type	ID / Name	2019 Conc. (µg/m³)	Easting (X)	Northing (Y)	Distance from Source (m)[b]	Heading (°)
Automatic	AURN 2 Cardiff Newport Road	29	320095	177520	1843	326
DT	153 Magic Roundabout	25	319491	176183	1657	276

Notes to Table 14
(a) Information obtained online from CCC (*2020 Air Quality Progress Report for Cardiff Council*).
(b) Distances are measured as the crow flies from the monitoring site coordinates displayed in Table 14 to the 'Source'. The 'Source' is the collective term for the approximate halfway location between the two boiler stacks (320449 (X), 175704 (Y)).

3.1.5. Annual NO_2 data is also available from the Department for Environment, Food and Rural Affairs ("DEFRA"). Table 15 displays the locations of the nearest DEFRA modelled grid locations to Site and their annual NO_2 concentrations for the years 2019 and 2020.

Table 15: Nearest Background DEFRA Data to Site [a]

ECL Ref.	Pollutant	Annual Mean Conc. (µg/m³)		Easting (X)	Northing (Y)	Distance from Source (m)[b]	Heading (°)
		2019	2020				
NW	Annual NO_2	18.30	15.86	320500	176500	811	308
NE		14.64	13.18	321500	176500	617	36
SW		20.05	16.37	320500	175500	811	232
SE		12.90	10.95	321500	175500	617	144

Notes to Table 15
(a) Information obtained from the 2019 and 2020 DEFRA background pollution maps for annual NO_2.
Please note that, whilst it is good practise to make use of the latest available data, the 2020 concentrations are all lower when compared to the 2019 data. It is suspected this is due to reduced activity (particularly in regard to vehicle movements and their subsequent emissions) as a result of the lockdown restrictions and societal behavioural changes resulting from the Covid-19 pandemic. Consequently, in the interest of a conservative assessment, NO_2 concentrations from 2020 are regarded as anomalous and 2019 data will therefore be used for the purposes of PEC calculations.
(b) Distances are measured as the crow flies from the DEFRA coordinates displayed in Table 15 to the boiler stack.

3.1.6. It should be noted that the maximum GLC location, for all pollutants assessed, occurs in the immediate vicinity of the boiler stack centre coordinates. It is considered that this is most likely due to a combination of factors, inclusive of the meteorological conditions, the complex building layout surrounding the discharge stack and building downwash effects. CERC were consulted to query such an occurrence and it was suggested that the likely cause for this would be due to the output point falling within the cavity region created by the buildings in the vicinity of the emission point.

3.1.7. As the location of the maximum predicted PCs all occur on-site, and can therefore be excluded from the assessment, the location of the maximum predicted off-site PCs were also determined. Table 16 provides the assessment of impact for off-site PCs making use of both the EA and IAQM significance of impact guidelines (see Section 2.20).

Table 16: Comparison of Maximum Off-Site Long-Term NO_2 PCs and PECs with AQS

Pollutant	Location of Max PC		WCMY* (2017 – 2021)	Max PC (µg/m³)	AQS (µg/m³)	PC as % of AQS	2019 Annual Background NO_2 Concentration (µg/m³)	Max PEC (µg/m³)	PEC as % of AQS	Significance
	Easting (X)	Northing (Y)								
NO_2 (annual)	321218	176000	2017	**5.14**	40	**12.85%**	20.05 [(a)]	25.19	63%	**Moderate**

Notes to Table 16

*Worst Case Met Year (WCMY)

The most representative background source was considered to be DEFRA SW (2019 data) due to it possessing similar surrounding land use to the max GLC locations and also being closer in proximity (when compared to the observed data sources - which are suspected to possess more elevated concentrations due to their roadside locations). Refer to Tables 14 and 15 for further details on the background sources of air quality.

3.1.8. It can be seen from the data in Table 16, that the PECs of long-term NO_2 emissions arising from the boiler stack can be considered 'moderate' for the maximum off-site GLC. This categorisation of the impacts has been carried out in accordance with the impact descriptors outlined in the IAQM (2017) guidance.

3.1.9. It should be noted that, when using the EA online guidance for screening assessments for emissions to air, further detailed modelling is not required if PECs are less than 70% of the long-term AQS. Although not directly applicable to the detailed modelling stage, it is worth noting that the worst-case off-site PEC for long-term NO_2 would be considered not significant based on the screening criteria. Furthermore, and as previously discussed, it should also be noted that the boiler is only proposed to be used as a backup during periods of scheduled and unscheduled maintenance of the CHP unit on-site – with the annual operational hours of the boiler not expected to exceed 500 hours.

3.1.10. The modelled PC predictions for long-term NO_2, as presented in Tables 13 and 16, have been calculated assuming the boiler is operational twenty-four hours a day, 365 days of the year. Consequently, in accordance with EA guidance[17], long-term predictions can be scaled down based on the number of operational hours per year with a full year (i.e., 8,760 hours) operating envelope. Therefore, when assuming a more realistic worst-case operational scenario of 500 hours per year – when divided by 8,760, the factor to scale down the long-term PCs down by is 0.0571 (with 500 hours representing approximately 6% of the hours in a full year).

3.1.11. When taking the long-term PC reduction factor of 0.0571 into account, the maximum off-site long-term NO_2 PC would be 0.293 $\mu g/m^3$ (or 0.73% of the AQS). The PECs would therefore be 20.34 $\mu g/m^3$ (51% of the AQS – or an IAQM impact descriptor of 'negligible') for the off-site maximum long-term NO_2 GLCs. Consequently, it has been demonstrated that the long-term off-site NO_2 PECs are well within a level that is health protective (i.e., the AQS of 40 $\mu g/m^3$).

Short-Term NO_2, SO_2 and CO

3.1.12. Further to the results presented in Table 13, the pollutants with short-term impacts also need additional assessment.

3.1.13. Again, it should be noted that the maximum GLC location, for all short-term pollutants assessed, occurs in the immediate vicinity of the boiler stack centre coordinates. Consequently, only off-site GLCs will be considered.

3.1.14. Table 17 provides the off-site maximum GLCs. The impacts have been assessed making use of both the EA and IAQM significance of impact guidelines.

[17] Available online via: https://www.gov.uk/guidance/specified-generators-dispersion-modelling-assessment#results-and-impact-assessment

Table 17: Comparison of Maximum Off-Site Short-Term PCs with AQS

Pollutant	Location of Max PC		WCMY* (2017 – 2021)	Max PC (µg/m³)	AQS (µg/m³)	PC as % of AQS	IAQM Impact
	(X)	(Y)					
NO_2 (1 hour, 99.79th percentile)	321098	176040	2017	**94.41**	200	**47.20%**	Medium
SO_2 (24 hour, 99.18th percentile)	321098	176040	2017	**28.97**	125	**23.17%**	Medium
SO_2 (1 hour, 99.73rd percentile)	321098	176040	2019	**124.67**	350	**35.62%**	Medium
SO_2 (15 min, 99.90th percentile)	321098	176040	2017	**145.71**	266	**54.78%**	Large
CO (8 hour, 100th percentile)	321138	175920	2019	**1200.67**	10,000	**12.01%**	Small

Notes to Table 17
*Worst Case Met Year (WCMY)

3.1.15. It can be seen from the data in Table 17 that, when looking at the maximum off-site PCs, the impact descriptors (in accordance with the IAQM guidance outlined in Section 2.20.) are 'small' for 100th percentile CO, 'medium' for 99.79th percentile NO_2, 99.18th percentile SO_2 and 99.73rd percentile SO_2 and 'large' for 99.90th percentile SO_2.

3.1.16. The Scottish Environmental Protection Agency ("SEPA"), in their H1 guidance note[18], state that detailed assessment of short-term impacts is often complex and that the error of estimating short-term releases can also be a factor of 4 to 5. Consequently, whilst there is a range of impact descriptors assigned to the short-term pollutants assessed, both on-site and off-site maximum GLCs are all within a level that is health protective (i.e., their respective AQSs).

[18] Available online via: https://www.sepa.org.uk/media/61377/ippc-h1-environmental-assessment-and-appraisal-of-bat-updated-july-2003.pdf

3.2. Isopleths

3.2.1. The isopleths for NO_2 (long-term and short-term) SO_2 (all averaging periods) and CO are presented as Figures 6 to 11 for the worst case met years associated with the maximum GLC locations.

3.2.2. Please note that as the predicted GLCs all appear to occur in a concentrated area covering the Site and just beyond its boundary, it is difficult to differentiate between the pollutant concentrations. However, the isopleths are useful at demonstrating that, overall, the extent of the predicted GLCs is only very small in the context of the output grid modelled.

Figure 6: Isopleth for Long-Term NO_2, Met Year 2018

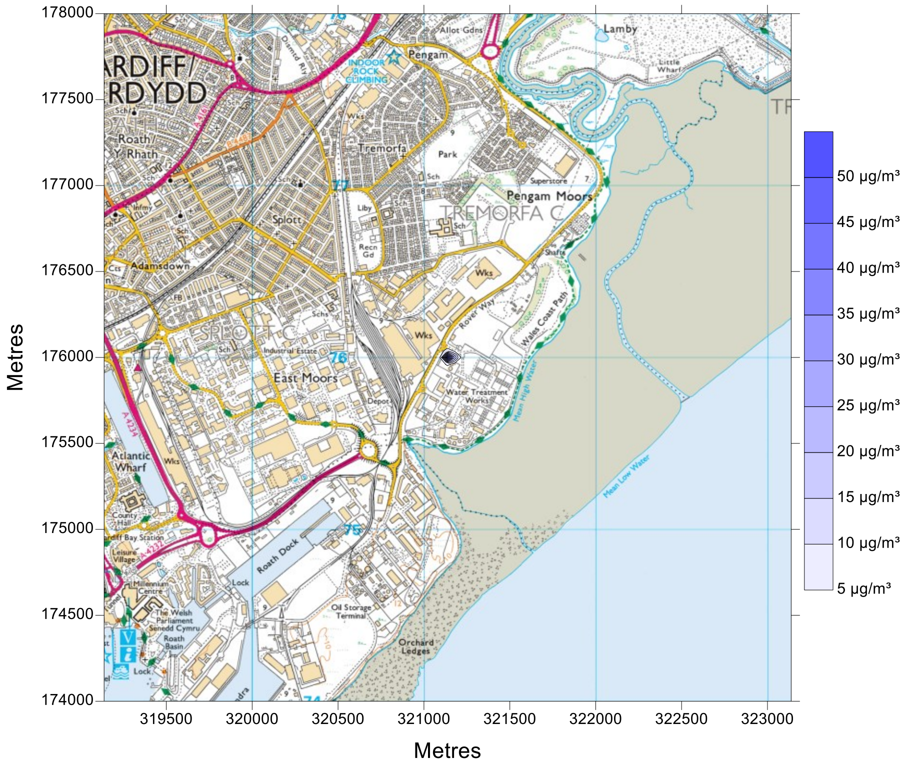


Figure 7: Isopleth for Short-Term (99.79th percentile) NO_2, Met Year 2017

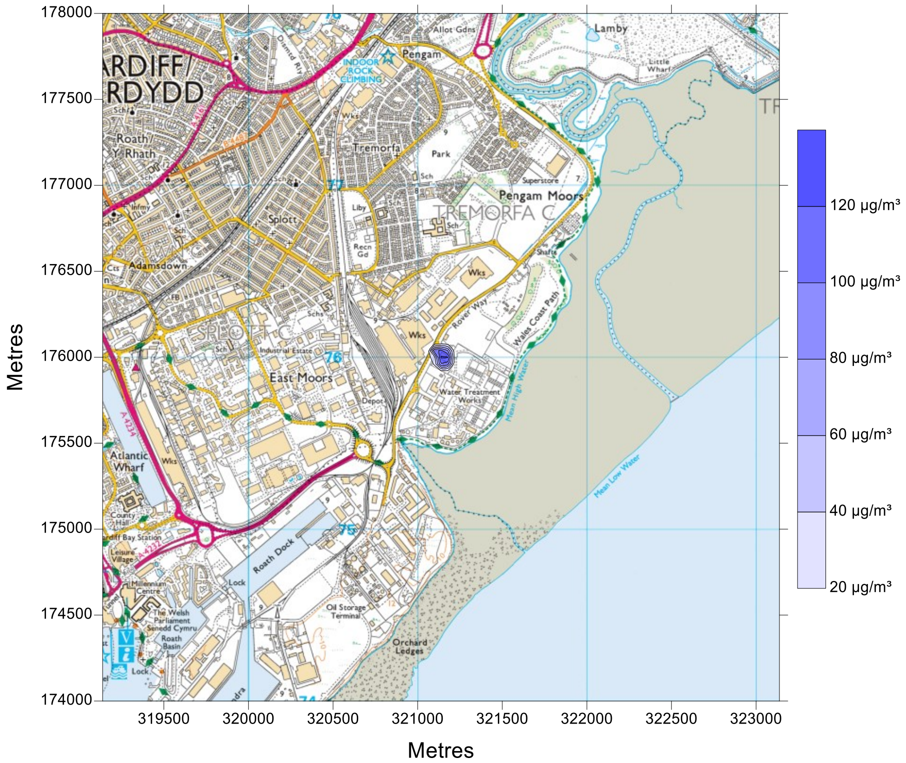


Figure 8: Isopleth for 24-hour (99.18th percentile) SO_2, Met Year 2017

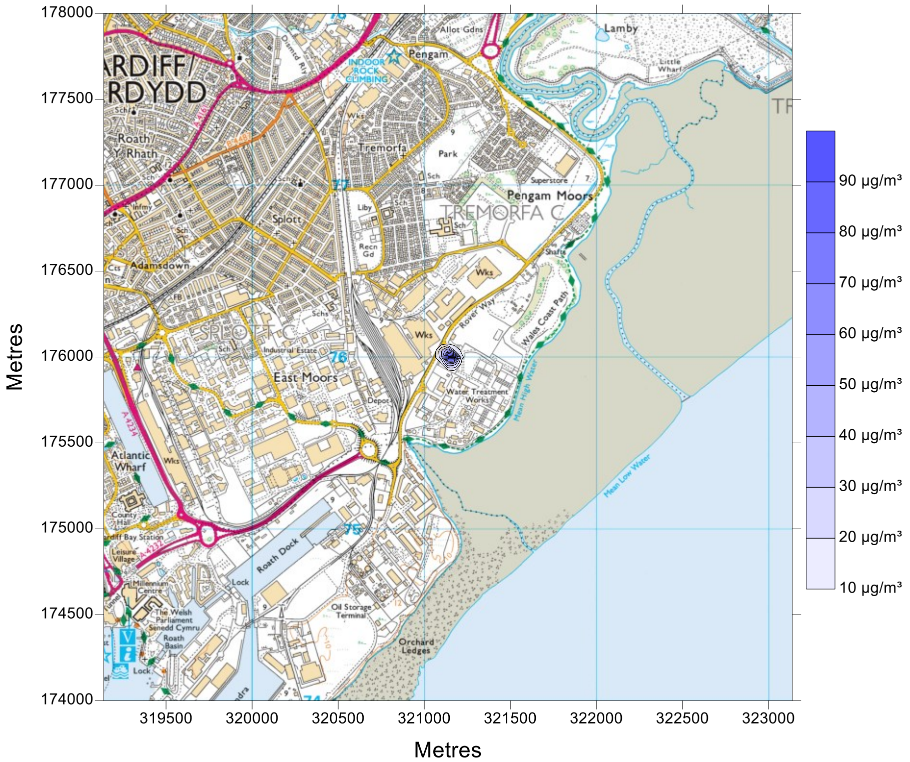


Figure 9: Isopleth for 1-hour (99.73rd percentile) SO_2, Met Year 2017

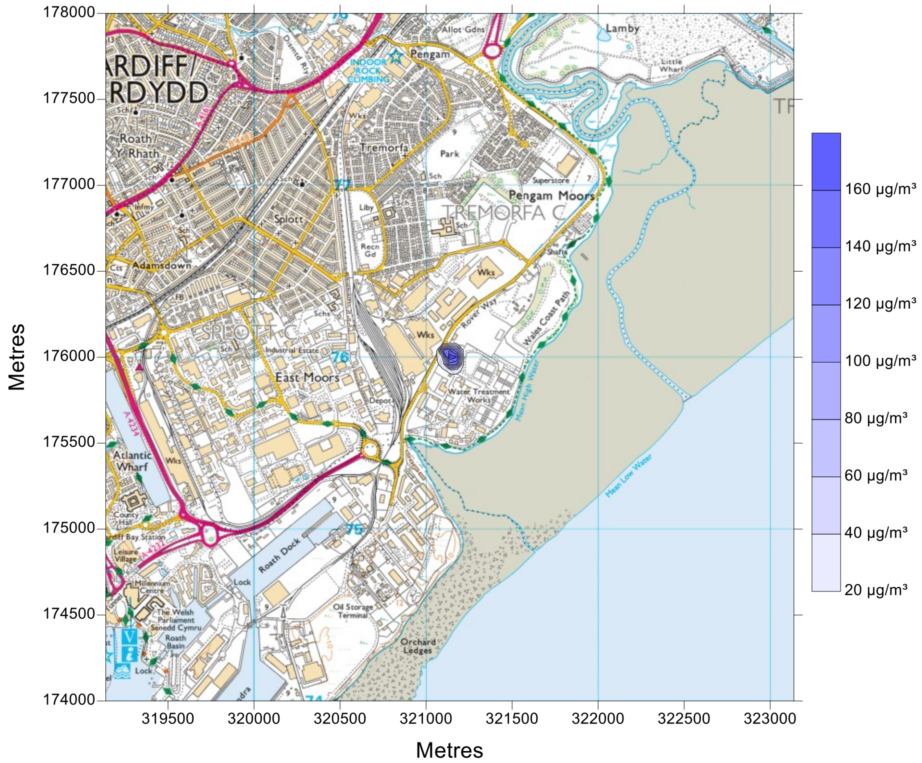


Figure 10: Isopleth for 15-minute (99.90th percentile) SO_2, Met Year 2017

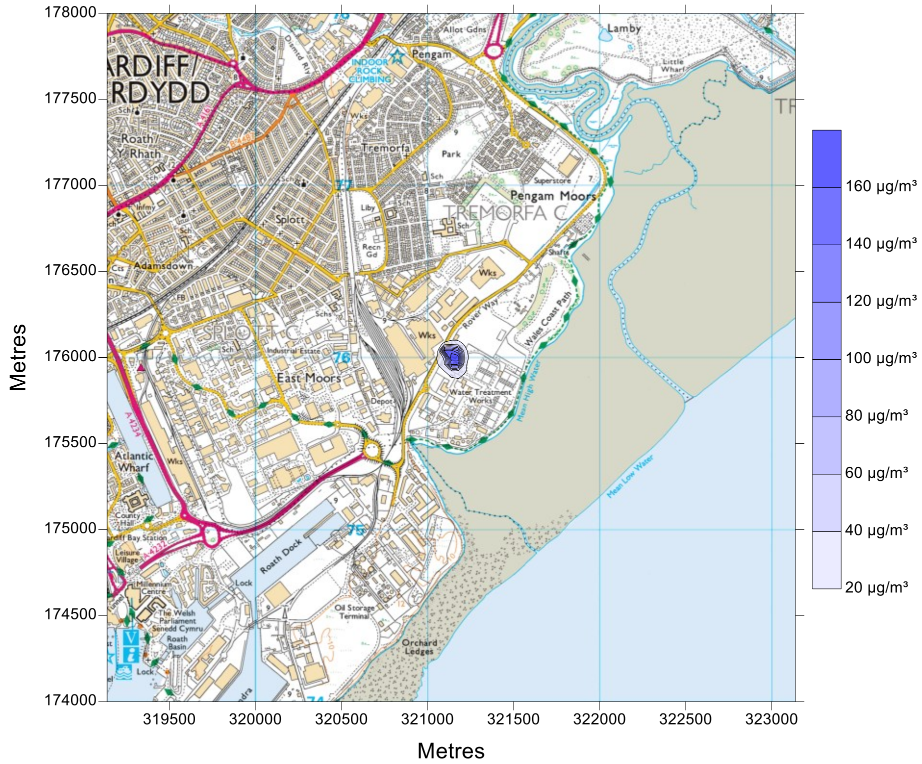
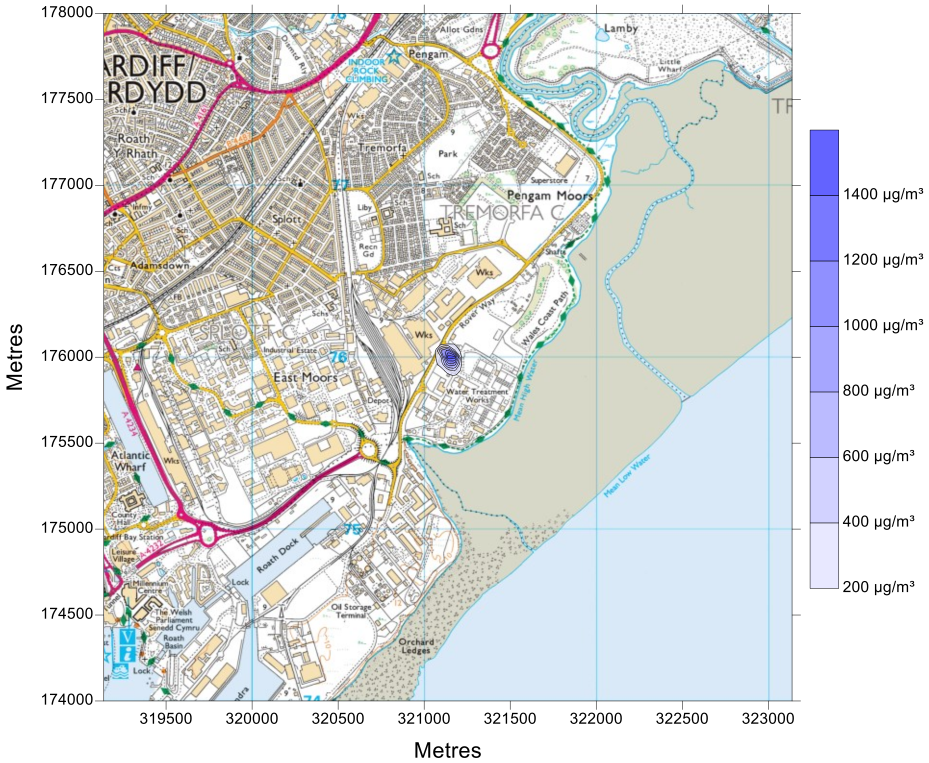


Figure 11: Isopleth for CO, Met Year 2017



4. ASSESSMENT OF AIR QUALITY IMPACTS AT POTENTIALLY SENSITIVE HUMAN RECEPTOR LOCATIONS

4.1. Human Health Impacts at the Specified Receptors

4.1.1. This part of the assessment considers emissions from the Site for emissions of NO_X as NO_2, SO_2 and CO at potentially sensitive human receptor and AQMA locations.

4.1.2. The PCs arising from the boiler's emission point, for each specified receptor considered and for the worst case met year for each pollutant and averaging period, are presented in Table 18. Any PCs that are above the significance criteria (outlined in Section 2.20.) are indicated in bold type.

Table 18: Comparison of Maximum PCs with AQS at Sensitive Receptor Locations

Pollutant		NO_2 (annual mean)	NO_2 (1 hour, 99.79th %ile)	SO_2 (24 hour, 99.18th %ile)	SO_2 (1 hour, 99.73rd %ile)	SO_2 (15 min, 99.90th %ile)	CO (8 hour, 100th %ile)
AQS (µg/m³)		40	200	125	350	266	10,000
Maximum PC (µg/m³)		**0.519**	6.71	3.24	9.49	12.8	74.8
Max PC as % of AQS		**1.30%**	3.36%	2.59%	2.71%	4.83%	0.75%
HR1	Industrial activity off Martin Road	**0.519**	6.71	3.24	9.49	12.8	74.8
HR2	Properties off Willows Avenue	0.0279	0.757	0.207	1.06	1.61	7.11
HR3	Properties off Moorland Road	0.0409	0.786	0.355	1.03	1.89	10.9
HR4	Industrial units off Portmanmoor Road	0.0558	0.712	0.336	1.00	1.45	7.54
HR5	Cloughmore Surgery / Splott Park	0.0265	0.637	0.183	0.876	1.34	6.74
HR6	Moorland Primary School	0.0339	0.714	0.299	0.949	1.81	6.81
HR7	Willows High School	0.0189	0.524	0.148	0.723	1.10	7.34
HR8	Moorland Park	0.0221	0.450	0.181	0.621	1.03	6.42
HR9	Industrial estate	0.0253	0.420	0.148	0.587	0.937	4.36
HR10	Travellers' site	0.0163	0.321	0.0961	0.437	0.803	4.76
AQMA1	Stephenson Court AQMA [(a)]	0.00732	0.189	0.0642	0.254	0.436	1.32
AQMA2	Cardiff City Centre AQMA [(a)]	0.00396	0.109	0.0298	0.143	0.246	0.906

Notes to Table 18

(a) Although the AQMAs considered have only been declared for NO_2, for completeness the predicted PCs have been calculated for all pollutants assessed.

4.1.3. It can be seen from the results in Table 18 that, with the exception of long-term NO_2 at HR1 (Industrial activity off Martin Road), the remaining specified potentially sensitive human receptor and AQMA locations screen out for all pollutants assessed (in accordance with the criteria outlined in Section 2.20.).

4.1.4. For HR1, when adding the relevant background concentration to calculate the PEC (i.e., a background concentration obtained from DEFRA SW (refer to Table 15 in Section 3.1.)) the PEC would be 20.57 µg/m^3 (or 51% of the AQS – with an IAQM impact descriptor of 'negligible'). Furthermore, it should also be reemphasised that the predicted PCs have been calculated assuming the boiler emits at its maximum ELVs twenty-four hours a day, 365 days of the year. When accounting for the more realistic annual operational hours (refer to Section 3.1.9. – 3.1.10.) the PC at HR1, when scaled down, would be 0.0296 µg/m^3 (or 0.07% of the AQS) and would therefore screen out as being insignificant. Consequently, no further assessments are required.

5. ASSESSMENT OF AIR QUALITY IMPACTS AT SENSITIVE ECOLOGICAL RECEPTOR LOCATIONS

5.1. Comparison of Maximum Predicted Ground Level Concentrations with Critical Levels for the Protection of Vegetation and Ecosystems - NO_x

5.1.1. This part of the assessment considers emissions from the Site for emissions of NO_X at the designated ecological receptors within the relevant search criteria (refer to Section 2.4).

5.1.2. The results of the maximum predicted GLCs of oxides of nitrogen, at the identified sensitive ecological sites, are presented in Table 19. In accordance with the H1 guidance (and as stated in Section 2.21.) the significance of the impacts has been determined using the 1% and 10% criteria for long and short-term predictions, respectively, for SPAs, SACs, Ramsar sites and SSSIs. As also outlined in Section 2.21., the 100% criteria for long and short-term predictions have been used for the local nature sites. Any potentially significant PCs have been indicated in bold type.

Table 19: Comparison of Maximum Predicted NO_x PCs with Critical Levels at Sensitive Ecological Sites

ADMS Ref. (a)	LT (Annual) PC (µg/m³)	LT CL (µg/m³)	LT PC as a % of the CL (µg/m³)	ST (24-hour mean) PC (µg/m³)	ST CL (µg/m³)	ST PC as a % of the CL (µg/m³)	WCMY for LT PC	WCMY for ST PC
SE1	**0.321**	30	**1.07%**	1.79	75	2.38%	2017	2019
SE2	0.0813		0.27%	0.919		1.23%	2021	2020
SE3	0.0361		0.12%	0.291		0.39%	2020	2020
CBW1	0.000543		0.002%	0.0179		0.02%	2019	2019
LWS1	0.0664		0.22%	0.675		0.90%	2021	2018
LWS2	0.0392		0.13%	0.415		0.55%	2021	2019
LWS3	0.0384		0.13%	0.478		0.64%	2021	2021
LWS4	0.0217		0.07%	0.333		0.44%	2017	2017

Notes to Table 19
LT = Long-term, ST = Short-term, CL = Critical Level and WCMY = Worst Case Met Year.
(a) Refer to Table 2 in Section 2.4. for receptor names and designations.

5.1.3. It can be seen from the data in Table 19 that, for the sites with one or all of the following designations: SAC, SPA, SSSI and Ramsar (i.e., SE1-SE3 and CBW1), the annual mean NO_X PCs are less than 1% of the critical level for all sites except SE1. Similarly, daily mean NO_X PCs are all less than 10% of the critical level at these sites and are therefore not significant (refer to Section 2.21.).

5.1.4. For the remaining sites (i.e., the local wildlife sites) the results in Table 19 show that the PCs are all less than 100% of the long-term and short-term critical levels (refer to Section 2.21.) and consequently no further assessment is required.

5.1.5. For the worst-case long-term NO_X PC on SE1, the impact is potentially significant, and the PEC will need to be calculated. As displayed in Table 6 of Section 2.7.1, based on a background NO_X concentration of 19.62 µg/m^3 – the PEC for SE1 would therefore be 19.94 µg/m^3 (or 66% of the critical level). It can therefore be assumed (with the PEC less than 100% of the appropriate environmental criterion) that there will be no adverse effect.

5.1.6. Furthermore, when applying the reduction factor of 0.0571 to account for the realistic annual operational hours (refer to Section 3.1.10.), the adjusted long-term NO_X PC at SE1 would be 0.0183 µg/m^3 (or 0.061% of the long-term critical level) and would therefore screen out at the first stage (i.e., with the PC less than 1% of the long-term critical level).

5.2. Comparison of Maximum Predicted PCs with Critical Levels for the Protection of Vegetation and Ecosystems – SO_2

5.2.1. This part of the assessment considers emissions from the Site for emissions of SO_2 at the designated ecological receptors within the relevant search criteria (Refer to Section 2.4).

5.2.2. A summary of the results of the maximum predicted GLCs of sulphur dioxide, at the identified sensitive ecological sites, are presented in Table 20. In accordance with the H1 guidance (and as stated in Section 2.21.) the significance of the impacts has been determined using the 1% criteria for the long-term predictions for SPAs, SACs, Ramsar sites and SSSIs. As also outlined in Section 2.21., the 100% criteria for the long-term predictions have been used for the local nature sites. Any potentially significant PCs have been indicated in bold type.

Table 20: Comparison of Maximum Predicted SO_2 PCs with Critical Levels at Sensitive Ecological Sites

ADMS Ref.[(a)]	LT PC (µg/m^3)	LT CL (µg/m^3)	LT PC as a % of the CL (µg/m^3)	WCMY for LT PC
SE1	**0.161**	10 [(b)]	**1.61%**	2017
SE2	0.0406		0.41%	2021
SE3	0.0181		0.18%	2020
CBW1	0.000272		0.00%	2019
LWS1	0.0332		0.33%	2021
LWS2	0.0196		0.20%	2021
LWS3	0.0192		0.19%	2021
LWS4	0.0109		0.11%	2017

Notes to Table 20

LT = Long-term, CL = Critical Level and WCMY = Worst Case Met Year.

(a) Refer to Table 2 in Section 2.4. for receptor names and designations.

(b) Without knowing whether lichens or bryophytes are present, the lower limit of 10 µg/m^3 has been selected in the interest of being conservative (refer to Table 4 in Section 2.6.2., for more information).

5.2.3. It can be seen from the data in Table 20 that, for the sites with one or all of the following designations: SAC, SPA, SSSI and Ramsar (i.e., SE1-SE3 and CBW1), the annual mean SO_2 PCs are less than 1% of the critical level for all sites except SE1.

5.2.4. For the remaining sites (i.e., the local wildlife sites) the results in Table 20 show that the annual SO_2 PCs are all less than 100% of the long-term critical level (refer to Section 2.21.) and consequently no further assessment is required.

5.2.5. For the worst-case long-term SO_2 PC on SE1 the impact is potentially significant, and the PEC will need to be calculated. As displayed in Table 6 of Section 2.7.1, based on a background SO_2 concentration of 2.67 µg/m3 – the PEC for SE1 would therefore be 2.83 µg/m3 (or 28% of the critical level). It can therefore be assumed (with the PEC less than 100% of the appropriate environmental criterion) that there will be no adverse effect.

5.2.6. Furthermore, when applying the reduction factor of 0.0571 to account for the realistic annual operational hours (refer to Section 3.1.10.), the adjusted long-term SO_2 PC at SE1 would be 0.00917 µg/m3 (or 0.092% of the long-term critical level) and would therefore screen out at the first stage (i.e., with the PC less than 1% of the long-term critical level).

6. ASSESSMENT OF AIR QUALITY IMPACTS - IMPACT ON HABITAT SITES – DEPOSITION

6.1. Comparison of Maximum Predicted Nutrient Nitrogen Deposition Rates with Critical Loads

6.1.1. A summary of maximum predicted nutrient nitrogen deposition rates at the identified habitat sites are presented in Table 21. It should be noted that due to the number of ecological sites and the number of habitats being considered, the habitat with the lowest lower critical load has been selected.

6.1.2. Where the nitrogen deposition rate is significant - i.e., greater than 1% of the maximum critical load, it is highlighted in bold.

Table 21: Comparison of Maximum Predicted Nutrient Nitrogen Deposition Rates with Critical Loads at Sensitive Habitat Sites – European Sites and SSSIs

ADMS Reference	Site Details	Deposition Rate Used	Critical Load (kgN/Ha/yr)		Nutrient Nitrogen Deposition Rate (kgN/Ha/yr) [(a)]	PC as % of Critical Load	
			Lower	Upper		Lower	Upper
SE1	Severn Estuary – Ramsar (Coastal saltmarsh / Estuaries)	Grassland	20	30	0.0308	0.15%	0.10%
SE2					0.00757	0.038%	0.025%
SE3					0.00354	0.018%	0.012%
SE1	Severn Estuary – SAC (Atlantic Salt Meadows / Estuaries)	Grassland	20	30	0.0308	0.15%	0.10%
SE2					0.00757	0.038%	0.025%
SE3					0.00354	0.018%	0.012%
SE1	Severn Estuary – SPA (Common Shelduck, Common Redshank, Greater White-Fronted Goose)	Grassland	20	30	0.0308	0.15%	0.10%
SE2					0.00757	0.038%	0.025%
SE3					0.00354	0.018%	0.01%
SE1	Severn Estuary – SSSI (Fen, Marsh and Swamp)	Grassland	15	30	0.0308	0.21%	0.10%
SE2					0.00757	0.050%	0.025%
SE3					0.00354	0.024%	0.012%
CBW1	Cardiff Beech Woods – SAC (Fagus Woodland)	Woodland	10	20	0.0000777	0.00078%	0.00039%

Note to Table 21

(a) Total PC is derived from the sum of the contribution from nitrogen deposition (dry deposition only).

6.1.3. It can be seen from the data in Table 21, that the maximum nutrient nitrogen deposition rates due to process emissions do not exceed 1% of the lower or upper critical load for all ecological sites considered. Consequently, no further assessment is required.

6.2. Comparison of Maximum Predicted Acid Deposition Rates with Critical Loads

6.2.1. A summary of maximum predicted acid deposition rates at the relevant identified habitat sites are presented in Table 22. It should be noted that due to the number of ecological sites and the number of habitats being considered, the habitat with the lowest maximum critical load has been selected.

6.2.2. Where the acid deposition rate is potentially significant (i.e., greater than 1% of the maximum critical load) it is highlighted in bold.

Table 22: Comparison of Maximum Predicted Acid Deposition Rates with the Maximum Critical Load at Sensitive Habitat Sites – European Sites and SSSIs

ADMS Ref. (a)	Site Details (a)	PC N	BG N	PC S	BG S	CL MinN	CLMaxN	CLMaxS	PEC N	PEC S	PC as % of CL
		(keq/Ha/yr)									
SE1 – SE3	Ramsar	Habitat not sensitive to acidification									
SE1 – SE3	SAC	Habitat not sensitive to acidification / or no critical loads set									
SE1 – SE3	SPA	Habitat not sensitive to acidification / no expected negative impact									
SE1	SSSI (b)	0.00220	1.12	0.0158	0.27	0.223	1.063	0.84	1.12	0.286	**1.69%**
SE2	SSSI (b)	0.000541	1.12	0.00338	0.27	0.223	1.063	0.84	1.12	0.273	0.37%
SE3	SSSI (b)	0.000253	1.12	0.00184	0.27	0.223	1.063	0.84	1.12	0.272	0.20%
CBW1	SAC (c)	0.00000555	2.11	0.0000290	0.28	0.142	1.428	1.286	2.11	0.280	0.0024%
SE1 (see note (d))	SSSI (b)	0.000126 (d)	1.12	0.000901 (d)	0.27	0.223	1.063	0.84	1.12	0.271	0.10%

Note to Table 22

(a) Refer to Table 2 in Section 2.4. for receptor names and designations.
(b) Grassland deposition rate used - refer to Table 8 in Section 2.8.2. for deposition parameters.
(c) Woodland deposition rate used – refer to Table 8 in Section 2.8.2. for deposition parameters.
(d) When PC reduction factor applied to account for maximum anticipated annual operational hours (refer to Section 3.1.9 – 3.1.10 and 6.2.4. below.).

PC N = Process contribution from Nitrogen (dry deposition only)
PC S = Process contribution from Sulphur (dry deposition)
BG = Background concentration (refer to Table 7 of Section 2.7.2. for the site-specific acid deposition background concentrations)
CL = Critical Load

6.2.3. The data in Table 22 shows that where the habitat is sensitive to acid deposition, with the exception of SE1 the maximum predicted acid deposition rate as a result of emissions from the boiler stack does not exceed 1% of the critical load function.

6.2.4. For SE1, when accounting for the more realistic annual operational hours of the boiler (i.e., applying the reduction factor of 0.0571 (refer to Section 3.1.10.) to the NO_X and SO_2 deposition rates), the PC to acid deposition at SE1 screens out as insignificant (as displayed by the results in the grey row in Table 22). Consequently, no further assessments are required.

7. CONCLUSION

7.1.1. Detailed air quality modelling using the ADMS dispersion model has been undertaken to predict the impacts associated with stack emissions from Welsh Water Organic Energy, Cardiff. This has been carried out for the Site's biogas fuelled boiler.

7.1.2. As a worst-case, in the first instance, emissions arising from the boiler have been assumed to emit to atmosphere twenty-four hours a day, 365 days of the year. This represents a highly conservative assessment of the impact since the maximum anticipated annual operational hours of the boiler is not expected to exceed 500.

7.1.3. Following further assessment at the point of maximum impact for long-term NO_2, the highest off-site GLC had an impact which could be regarded as 'moderate'. When applying a reduction factor, to account for the maximum anticipated annual operational hours of the boiler, the scaled down PC for long-term NO_2 could be regarded as 'negligible' for the maximum off-site GLC.

7.1.4. Following further assessment at the point of maximum impact for the short-term pollutants, the maximum off-site GLCs could be described as 'small' for 100th percentile CO, 'medium' for 99.79th percentile NO_2, 99.18th percentile SO_2 and 99.73rd percentile SO_2 and 'large' for 99.90th percentile SO_2. All worst-case short-term PCs were within a level that can be regarded as health protective (i.e., they did not breach their respective AQSs).

7.1.5. The assessment at the specified potentially sensitive human and AQMA receptor locations has demonstrated that, following further assessment where required (i.e., for long-term NO_2 at HR1), the impact of the predicted PCs can be considered insignificant.

7.1.6. For the potentially sensitive ecological sites, the assessment has demonstrated that the impact from the Site is either unlikely to result in a breach of the relevant Critical Levels or Critical Loads or is unlikely to have a detrimental effect on local habitat sites. Where further assessment was carried out (i.e., for SE1, Severn Estuary) it has been demonstrated that, when accounting for the reduced annual operational hours, the impact of the scaled down PCs could be considered insignificant.

7.1.7. In summary, therefore, it can be concluded that emissions arising from the new biogas fuelled boiler to Welsh Water Organic Energy's site in Cardiff, will not have a detrimental impact on local air quality, human health, sensitive ecological sites or on the AQMAs assessed.

APPENDIX I

ECL EMISSIONS REPORT: P3622 / R001

EMISSIONS MONITORING SURVEY

Prepared for:

Dwr Cymru Cyfyngedig.

Five Fords WwTW Gas to Grid Facility
Cefn Road
Abenbury
Wrexham
Clwyd
LL13 0PA

Permit Number	**: EPR/AP3139FT**
Variation Number	**: n/a**
Installation	**: Five Fords WwTW Gas to Grid Facility**
Visit Details	**: 2018 Annual Compliance**
Job Number	**: P3622**
Report Number	**: R001**
Report Issue Date	**: 13th August 2018**
Survey Dates	**: 26th & 27th June 2018**

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Report Issue:		**FINAL**	
Report Prepared by:		**Report Reviewed & Approved by** MCERTS Level Two Technical Endorsements TE1, TE2, TE3 & TE4	
Name:	Scott Hackett	***Name:***	Andy Barnes
		MCERTS No:	MM 03 235
		Signature:	[signature]
Date:	7th August 2018	***Date:***	13th August 2018

This report is not to be used for contractual or engineering purposes unless this approval sheet is signed where indicated by the approver and the report is designated "FINAL".

2499

Opinions and Interpretation expressed within this report are outside the scope of the UKAS accreditation.

MCERTS requirements mean that comparison of results with emissions limit values is not permitted within this report.

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PART 1 - EXECUTIVE SUMMARY

1 Monitoring Objectives

Environmental Compliance Ltd (ECL) was commissioned by **Dwr Cymru Cyfyngedig** to undertake an emission monitoring survey at their **Five Fords Facility**. This report presents the findings of the study.

The monitoring at this installation was carried out in accordance with our quotation & 2 year framework agreement, for compliance check monitoring of emissions to air. The substances requested for monitoring at each emissions point are listed below:

Substances to be monitored	Emission Point Identification		
	A1 CHP 1	**A2 CHP 2**	**A3 Standby Boiler**
Velocity / Flowrate	● U	● U	● U
Oxides of Nitrogen (as NO_2)	● U	● U	● U
Sulphur Dioxide	● U	● U	
Carbon Monoxide	● U	● U	● U
Oxygen	● U	● U	● U
Total Organic Carbon (TVOC)	● U	● U	
NMVOCs	● U	● U	

- ● Denotes the substances to be monitored.
- U **Denotes UKAS accreditation is held for monitoring that substance, but does not mean that it has been claimed which will depend on whether the testing could be completed in accordance with the Standard Reference Method.**

Special Requirements: *"During Normal Operation."*

1.1 Monitoring Results

Emission Point Reference	Substance to be Monitored	Emission Limit Value	Periodic Monitoring Result	Units	Uncertainty %	Reference Conditions 273 K, 101.3 kPa	Date of Sampling	Start and End Times	Monitoring Method Reference	Accreditation for use of Method	Tick if non-conforming test (see Sections 2 & 5)	Operating Status
A1 CHP No.1	Volumetric Flowrate	...	1.03830	m^3/sec	4	Stack Conditions	26/06/2018	12:45 – 12:57	BS EN 16911-1:2013 & MID	UKAS / MCERTS		Normal
	Volumetric Flowrate	...	0.40458	m^3/sec	7	Dry Gas & 5% Oxygen	26/06/2018	12:45 – 12:57	BS EN 16911-1:2013 & MID	UKAS / MCERTS		Normal
	TVOC as Carbon	1000	**1720.68**	mgC/m^3	2		26/06/2018	14:00 – 15:00	BS EN 12619:2013	UKAS / MCERTS		Normal
	NMVOC $	...	3.86	mg/m^3	19		26/06/2018	14:20 – 15:20	CEN/TS 13649:2014	NU	✓	Normal
	Sulphur Dioxide	...	0.72	mg/m^3	13		26/06/2018	13:00 – 14:00	BS EN 14791: 2017	UKAS / MCERTS		Normal
	Oxides of Nitrogen (as NO_2)	500	340.80	mg/m^3	3		26/06/2018	14:00 – 15:00	BS EN 14792: 2017	UKAS / MCERTS		Normal
	Carbon Monoxide	1400	847.81	mg/m^3	3		26/06/2018	14:00 – 15:00	BS EN 15058: 2017	UKAS / MCERTS		Normal
	Oxygen (Zirconia Cell)	...	8.68	%	2	Dry	26/06/2018	14:00 – 15:00	BS EN 14789: 2017	UKAS / MCERTS		Normal

Emission Point Reference	Substance to be Monitored	Emission Limit Value	Periodic Monitoring Result	Units	Uncertainty %	Reference Conditions 273 K, 101.3 kPa	Date of Sampling	Start and End Times	Monitoring Method Reference	Accreditation for use of Method	Tick if non-conforming test (see Sections 2 & 5)	Operating Status
A2 CHP No.2	Volumetric Flowrate	...	1.13149	m^3/sec	4	Stack Conditions	27/06/2018	11:25 – 11:39	BS EN 16911-1:2013 & MID	UKAS / MCERTS		Normal
	Volumetric Flowrate	...	0.45537	m^3/sec	7	Dry Gas & 5% Oxygen	27/06/2018	11:25 – 11:39	BS EN 16911-1:2013 & MID	UKAS / MCERTS		Normal
	TVOC as Carbon	1000	**1193.62**	mgC/m^3	3		27/06/2018	09:05 – 10:05	BS EN 12619:2013	UKAS / MCERTS		Normal
	NMVOC $	...	19.29	mg/m^3	22		27/06/2018	09:00 – 10:00	CEN/TS 13649:2014	NU	✓	Normal
	Sulphur Dioxide	...	7.88	mg/m^3	13		27/06/2018	10:20 – 11:20	BS EN 14791: 2017	UKAS / MCERTS		Normal
	Oxides of Nitrogen (as NO_2)	500	385.17	mg/m^3	3		27/06/2018	09:05 – 10:05	BS EN 14792: 2017	UKAS / MCERTS		Normal
	Carbon Monoxide	1400	761.65	mg/m^3	3		27/06/2018	09:05 – 10:05	BS EN 15058: 2017	UKAS / MCERTS		Normal
	Oxygen (Zirconia Cell)	...	8.11	%	4	Dry	27/06/2018	09:05 – 10:05	BS EN 14789: 2017	UKAS / MCERTS		Normal

Dwr Cymru Cyfyngedig
Permit No : EPR/AP3139FT
Variation No : n/a
Report Ref : P3622 : R001

Installation Name : Five Fords WwTW Gas to Grid Facility
Visit Details : 2018 Annual Compliance
Survey Dates : 26th & 27th June 2018
Report Issue Date : 13th August 2018

Emission Point Reference	Substance to be Monitored	Emission Limit Value	Periodic Monitoring Result	Units	Uncertainty %	Reference Conditions 273 K, 101.3 kPa	Date of Sampling	Start and End Times	Monitoring Method Reference	Accreditation for use of Method	Tick if non-conforming test (see Sections 2 & 5)	Operating Status
Standby Boiler A3	Volumetric Flowrate	...	0.60808	m^3/sec	7	Stack Conditions	27/06/2018	11:55 – 12:20	BS EN 16911-1:2013 & MID	UKAS / MCERTS		Normal
	Volumetric Flowrate	...	0.42547	m^3/sec	9	Dry Gas & 3% Oxygen	27/06/2018	11:55 – 12:20	BS EN 16911-1:2013 & MID	UKAS / MCERTS		Normal
	Oxides of Nitrogen (as NO_2)	...	133.17	mg/m^3	3		27/06/2018	12:45 – 13:45	BS EN 14792: 2017	UKAS / MCERTS		Normal
	Carbon Monoxide	...	0.75	mg/m^3	3		27/06/2018	12:45 – 13:45	BS EN 15058: 2017	UKAS / MCERTS		Normal
	Oxygen (Zirconia Cell)	...	3.17	%	4	Dry	27/06/2018	12:45 – 13:45	BS EN 14789: 2017	UKAS / MCERTS		Normal

The volumetric flowrate shown above is that from the initial pitot traverse.
Any other flow measurements made during isokinetic sampling and/ or repeat traverses are shown later in the tables section.

Notes

The uncertainty figures presented in Table 1.1 for NO_x, CO, O_2 & TVOC are “measurement uncertainty” figures, which do not take into account the variability of the measured sample values.
The “uncertainty of measurement results” figures, which do include this contribution, are presented in the appendices of the report for these determinands.

Emission Limit Value	The emission limit value is that stated in the permit and will be expressed as a concentration or a mass emission.
Periodic Monitoring Result	The result given is expressed in the same terms and units as the emission limit value.
Uncertainty	The uncertainty associated with the quoted result is at the 95% confidence interval. The Uncertainty results **DO NOT** take into account the effect of the sample location limitations.
Reference Conditions	All results are expressed at 273 K and 101.3kPa. The oxygen and moisture corrections are stated.
Monitoring Method Reference	The method stated is in accordance with the Environment Agency Technical Guidance Note M2, or other method approved by the Environment Agency.
Accreditation for use of Method	**The details indicate the accreditation for the use of the complete monitoring method, e.g. MCERTs, UKAS. If use of the method is not accredited " NA" is stated.**
Operating Status	The details indicate the feedstock and the loading rate of the plant during monitoring.
$	Chemical Analysis on sample reagents was performed by an External Laboratory as detailed in Section 4
NU	UKAS Accreditation Held but UKAS Accreditation cannot be claimed for the test as sampling did not comply with the Standard Reference Method (SRM), see section 2 & 5
NA	**Method is NOT UKAS Accredited.**

1.2 Operating Information

Emission Point Reference	Process Type	Process Duration	Fuel	Feedstock	Abatement	Load	Comparison of Operator CEMS and Periodic Monitoring Results					
							Parameter	Date	Time	CEMS Results	Periodic Monitoring Results	Units
CHP 1 (A1)	Continuous	Process on demand	Biogas	1.41MW CHP	None	Normal – 85%	…	…	…	NP	…	…
CHP 2 (A2)	Continuous	Process on demand	Biogas	1.41MW CHP	None	Normal – 75%	…	…	…	NP	…	…
Boiler (A3)	Batch	Process on demand	Natural Gas	N/A	None	Normal	…	…	…	NP	…	…

Notes:

Process Type	State whether the process is a continuous or batch process.
Process Duration	If a batch process, state the duration, frequency and details of the portion of the batch sampled. If continuous state "NA"
Fuel	If applicable, state the fuel type If not applicable state "NA"
Feedstock	State the feedstock type
Abatement	State the type and whether operational during monitoring. If not applicable state "NA"
Load	State the normal load, throughput or rating of the plant
CEMS Data	Enter this data for each CEM installed if it is has been provided by operator otherwise state “NP” (NOT PROVIDED)

2 Monitoring Deviations

The objective of the survey was to measure the concentrations of pollutants from the processes / locations as detailed in Section 1. This survey meets the requirements of the site's **PPC Permit Number: EPR/AP3139FT** where UKAS and MCERTS accreditation has and could be claimed for the testing in the monitoring results table.

There were no modifications to the sampling procedures (TPDs) listed in section 4.

There were no substance deviations from the original and agreed emissions monitoring schedule.

Non-conforming tests are as follows:-

- Due to the restrictions set out in CEN/TS 13649: 2014, UKAS/MCERTS accreditation can only be claimed when the target parameters are individual organic compounds. In addition, the analytical laboratory is not UKAS for the analysis of Total VOC (as NMVOC). Consequently, UKAS/MCERTS cannot be claimed for the NMVOC tests on A1 & A2.
- CEN/TS 13649: 2014 can only be used when the sample gas moisture content is low enough for no condensation occur upstream of the sorbent tube during sampling. As the stack temperature was >200C and moisture content >10% an empty knock-out pot was used to remove moisture before the sorbent tube. Consequently, the NMVOC tests on both A1 and A2 are non-conforming and UKAS/MCERTS cannot be claimed.

The Uncertainty of the reported concentrations for these pollutant results DOES NOT take into account the effect of non-conformities or sample location limitations.

Homogeneity tests have not been completed for pollutants at the following locations:

- A1, A2 & A3 – Such tests are not applicable to these locations as the duct area is <1m^2 and were not requested by the client.

PART 2 – SUPPORTING INFORMATION

3 SAMPLING STAFF DETAILS

Site Sampling Team

Names of Site Team	Dates on Site	MCERTS No.	LEVEL	Technical Endorsements
Jon Litterick	26th – 27th July 2018	MM 03 236	2	TE1, TE2, TE3, TE4
Steve Heginbotham		MM 03 169	1	…

Report Reviewer

Name	MCERTS No.	LEVEL	Technical Endorsements
Andy Barnes	MM 03 235	2	TE1, TE2, TE3, TE4

Technical Endorsement Key:-

TE1 – **Isokinetic** Particulates, Temperature & Velocity Profiles, Oxygen.
TE2 – **Isokinetic** Extractive Pollutants:- Metals, Dioxin & Furans, PAHs, PCBs, HCl, HF.
TE3 – **Non-Isokinetic** Extractive Pollutants:- Speciated VOCs, HF, HCl, Cyanide.
TE4 – **Continuous Analysers** (Combustion Gases):- TVOC, CO, NOx, SO2.

4 SAMPLING PROTOCOLS / METHODOLOGIES

Any required modifications to the Technical Procedure Documents (TPDs) specified below will be detailed in section 2 of this report.

Stand alone velocity measurements and those made to support isokinetic sampling are conducted using BS EN 16911-1:2013 & MID.

Pressure, Temperature and Velocity

Testing was carried out using a sampling system in accordance with **BS EN ISO 16911-1:2013 & MID** and In-house technical procedure **ECL/TPD/022A.**

Temperature was recorded using a thermocouple and digital temperature reader.

Velocity and pressure were recorded using an "S" type pitot and inclined manometer, data being recorded in mm H_2O.

Combustion Gases (NO_x, CO &O_2)

Measurements of combustion gases were carried out using an MCERTS Certified **Horiba PG 250** stack gas analyser. Continuous monitoring of emissions was undertaken over each test period recording minute averaged data (one measurement every 60 seconds). The measurement techniques for each determinand are as follows:

Determinand	Technique	SRM
• NO_x	Chemiluminescence	BS EN 14792: 2017
• CO	Non-dispersive infrared	BS EN 15058: 2017
• O_2	Galvanic / Zirconia	BS EN 14789: 2017

The analyser was set up with reference to the manufacturers operator handbook and the in-house technical procedure **ECL/TPD/033c**. The analyser was calibrated on site using certified gases which are traceable to ISO 17025. (with uncertainty <2%). Zero measurements were performed using Nitrogen. The analyser was calibrated directly into the sample inlet and then checked through the entire sampling system (including sampling probe, heated & unheated gas transport lines and gas drying/ conditioning system).

Data is presented graphically in the Figures Section, and the minute averaged data is given in the Tables Section.

TVOC as Carbon

Testing was carried out using an MCERTS Certified Signal 3030PM FID and heated gas sample line, with reference to the manufacturer's operation handbook, **BS EN 12619:2013** and in-house technical procedure **ECL/TPD/032A**.

The analyser was calibrated on site using certified propane span gases, (made up in synthetic air) which are traceable to ISO 17025 standard. (with uncertainty <2%).

Zero measurements were performed using synthetic air zero gas, with TVOC content less than 0.2 mg/m^3 (or purity greater than 99.998%).

The analyser was calibrated directly into the sample inlet and then checked through the entire sampling system (including sampling probe, heated filter and heated gas transport lines). Data was corrected by molecular weight to TVOCs as total carbon.

Data was recorded as minute averages over each test period. The data is presented in the Figures Section and the minute averaged data is detailed in the Tables Section.

Sulphur Dioxide

Testing was carried out non-isokinetically using a Universal Stack Sampling system in accordance with **BS EN 14791:2017** and In-house technical procedure **ECL/TPD/039**. Non-isokinetic sampling can only take place if there are no droplets present in the stack gas.

In this method the stack gases are filtered to remove particulate matter then the gases are passed through a series of impingers. The first three impingers each contain 140ml of 3% Hydrogen Peroxide (3% H_2O_2). The fourth impinger is left empty and the final impinger contains a measured quantity of silica gel.

The first three impingers containing the 3% Hydrogen Peroxide are analysed for concentrations of Sulphur Dioxide by IC (Ion Chromatography).

Concept Life Sciences Ltd (CLS) who are situated in Manchester carried out the analysis of the samples. **CLS** is UKAS accredited for this analysis. In addition to the survey samples, appropriate field blanks and efficiency checks are submitted as part of the technical procedure.

NMVOC

Non-continuous sampling for **NMVOC** was carried out in accordance with **CEN/TS 13649:2014** and In-house technical procedure **ECL/TPD/084.** In this method a metered volume of stack gas is extracted through a standard charcoal sorbent tube/ thermal desorption tube.

Concept Life Sciences Ltd (CLS) who are situated in Manchester carried out the analysis of the samples. **CLS are not UKAS** accredited for this analysis. In addition to the survey samples, appropriate field blanks and efficiency checks are submitted as part of the technical procedure.

Due to restrictions set out in CEN/TS 13649:2014, MCERTS/UKAS accreditation can only be claimed when the target parameters are organic compounds, the sorbent tube used is a standard charcoal tube/ thermal desorption tube and when laboratory analysis is UKAS accredited and carried out by GC. If other tubes are used, or if analysis is by other means than GC, then usually only UKAS accreditation can be claimed, as long as the laboratory analysis is UKAS accredited. (MCERTS accreditation may still be claimed if prior approval is given for the modifications by the Environment Agency – details will be given in section 2 of this report).

Laboratory analysis **cannot** be UKAS accredited for "Total VOC" or "TOP 10 compounds".

For the subcontract laboratory to claim UKAS accreditation for analysis, the internal recovery of a spiking compound (desorption efficiency from tube) needs to be above 80%. If it falls below 80% this will be noted on the analysis certificate.

If greater than 5% of the total amount of any of the target species is found in the back up portion of the sorbent tube, this will be noted on the analysis certificate.

Water Vapour

Testing was carried out using a Universal Stack Sampling system in accordance with **BS EN 14790:2017** and In-house technical procedure **ECL/TPD/082**.

In this method the stack gases are filtered (in-stack unheated filter or out-stack heated filter) to remove particulate matter. The gases are then passed through a **heated probe** and then to a cooled moisture trapping unit. All unheated parts of the sample train (outside the sample port) which come into contact with stack gas are weighed pre and post sampling in order to determine the weight gain.

After each test, a visual inspection of the last impinger is made to confirm that at least 50% of the silica gel column has not changed colour. This indicates satisfactory collection of water vapour.

5 SAMPLE POINT DESCRIPTIONS

The homogeneity test is applicable to combustion processes. This includes but is not restricted to, those regulated under the Waste Incineration Directive (**WID**) and the Large Combustion Plant Directive (**LCPD**).

Homogeneity testing has not been completed at these locations in accordance with the mandatory requirements of the regulatory authority.

The test is not usually required for stacks with sampling plane areas of $< 1m^2$ (below 1.13m in diameter for circular ducts).

The sample locations that were monitored are detailed below:-

CHP 1 (A1), CHP 2 (A2) and Standby Boiler (A3)

The sampling platform currently meets the requirements detailed in *Technical Guidance Note (Monitoring) M1"Sampling requirements for stack-emission monitoring" Environment Agency,* and BS EN 13284-1.

Access to the sampling location for CHP 1, CHP 2 & Standby Boiler is via permanent steps at a height approximately 3.0m from the sampling platform to ground floor. Sampling is undertaken from a single permanent platform in a section of straight vertical ducting that houses the stacks for CHP 1, CHP 2 & Standby Boiler.

The stack diameter for CHP 1 is 0.28m, for CHP 2 is 0.28m, and for Standby Boiler the stack diameter is 0.38m.

Two sample ports are located on each stack at 90 degrees to each other and are located on the same plane. These sample ports are located at a height of approximately 1.15m from the working sample platform on both sampling points. The sample platform width back from the sample ports is 2.1m.

The Uncertainty of the reported concentrations for these pollutant results DOES NOT take into account the effect of non-conformities or sample location limitations.

EQUIPMENT IDs
(Pre site checklist from SSP)

PRE SITE EQUIPMENT CHECKLIST/ EQUIPMENT USED

(Completed before departure to site and when on site in full)

Equipment	Equip. Type	ID No:	ID No:	ID No:	ID No:	ID No:	ID No:	ID No:	ID No:
MST console/pump	E001	U008							
MST Nozzle set									
MST "S" Type Pitot		668							
MST Probe		649							
MST Hot Box		400							
MST Impinger Arm		657							
Barometer		629							
Site Balance		1069							
Site Check weights		190							
		191							
Horiba	E002	096							
Heated Probe / Filter		1190							
Chiller		970							
Sonimix / MFC									
Heated Line		1090							
FID	E003	269							
Heated Line		1010							
Heated Probe / Filter		572							
Testo	E004								
FTIR	E005								
Heated Probe / Filter									
Heated Line									
Stackmite	E006								
"L" Type Pitot									
Digital Manometer									
Stack Thermocouple									
Thermocouple Reader									
Nozzle Set									
Workhorse Pumps	E007								
Low Flow Pumps									

Quantity of Ice Required / Used for Survey	4	Bags (2kg bags)

FIGURES

Figure 1

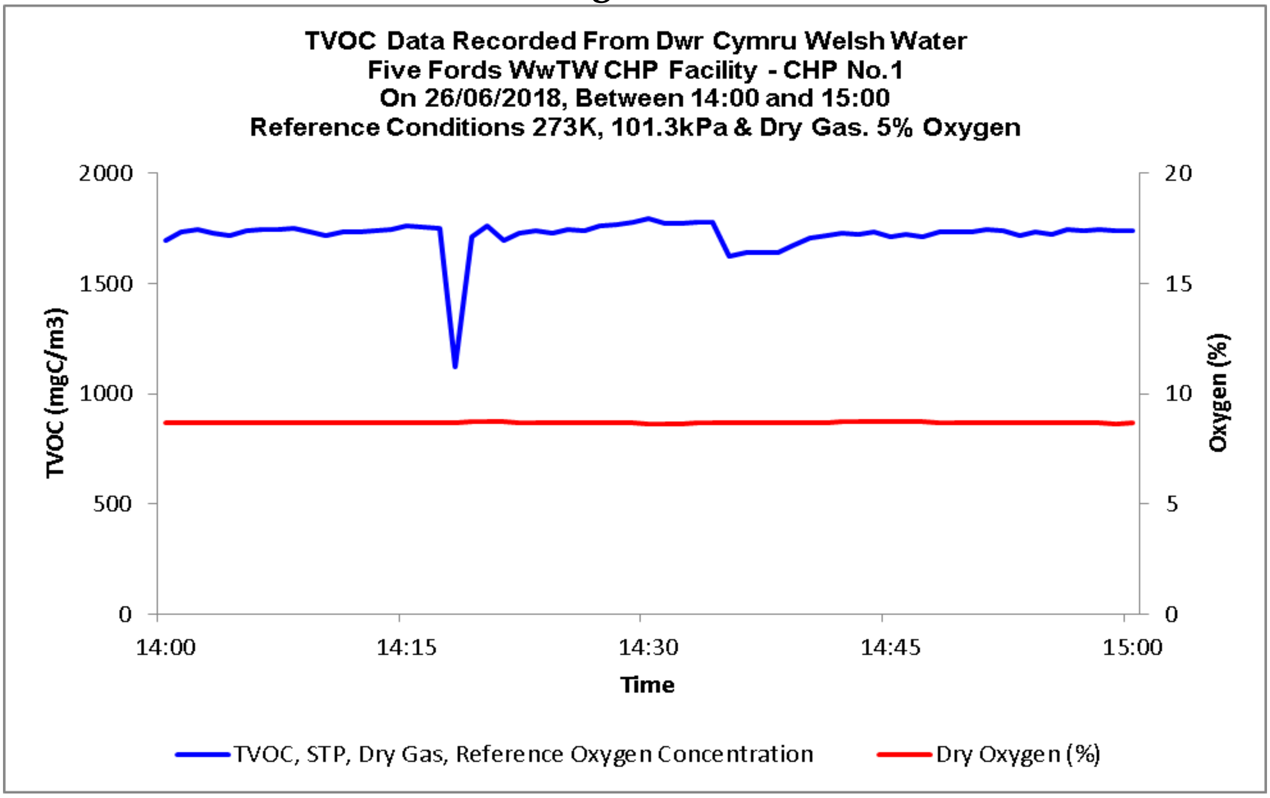


Figure 2

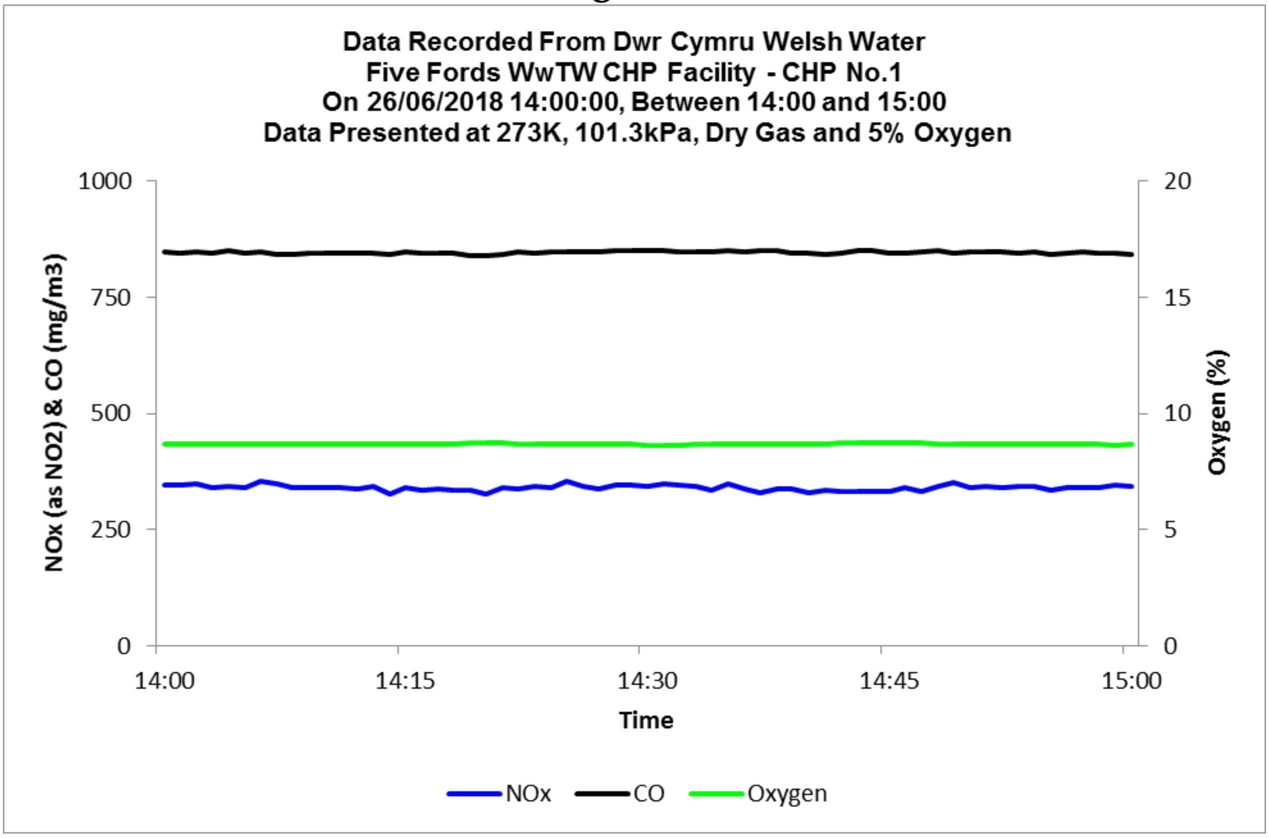


Figure 3

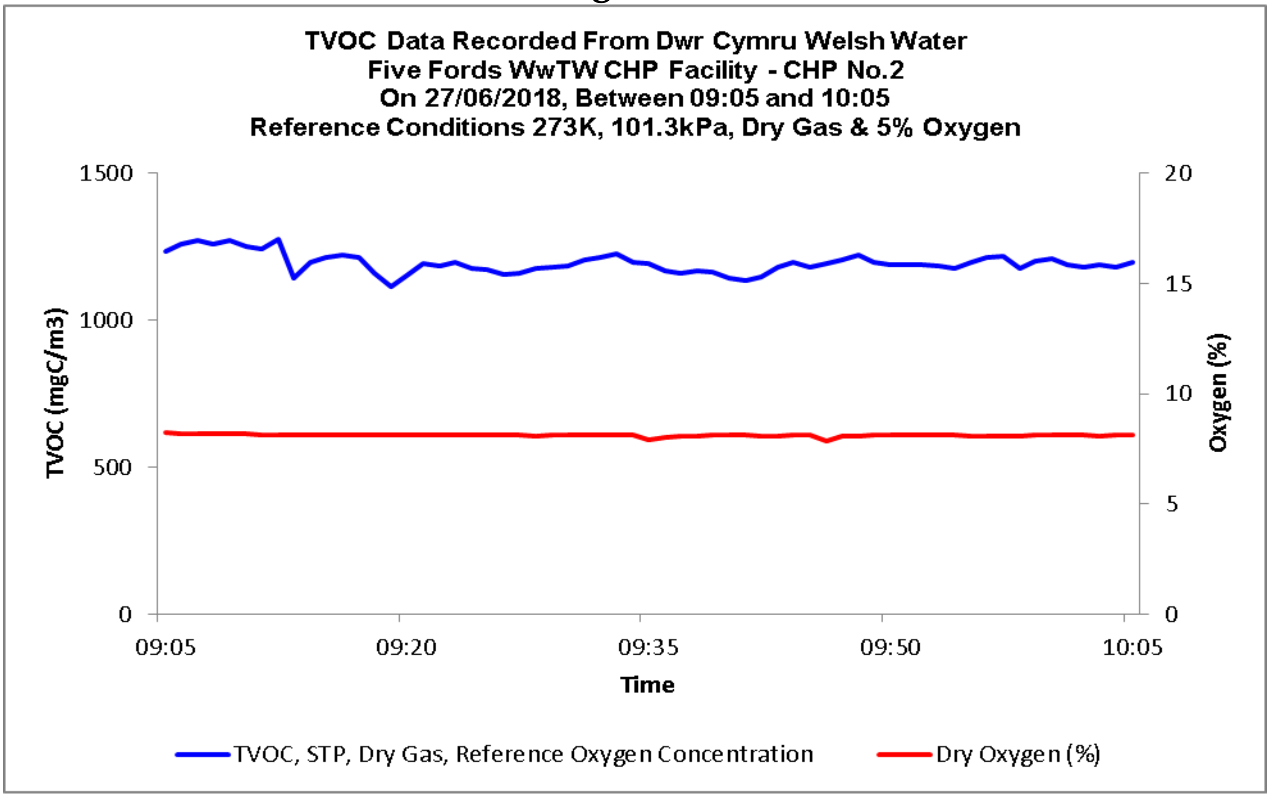


Figure 4

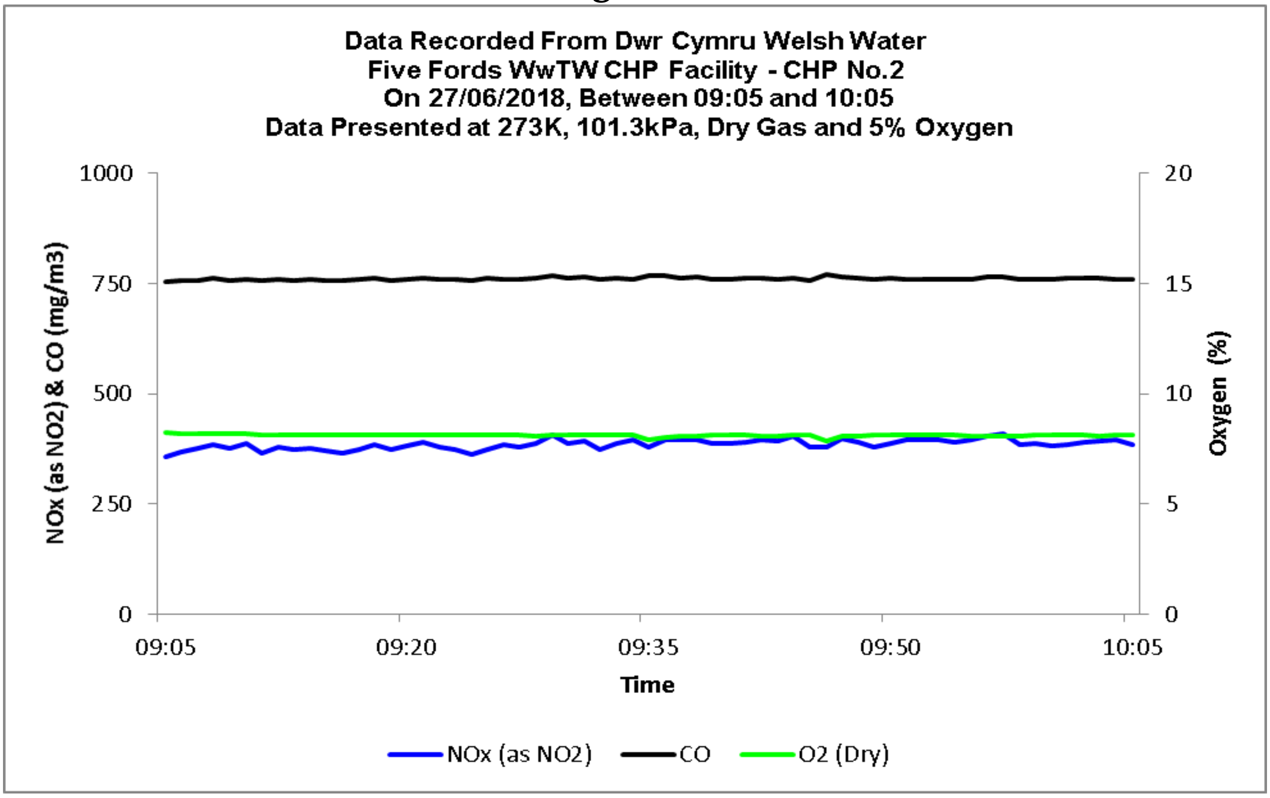
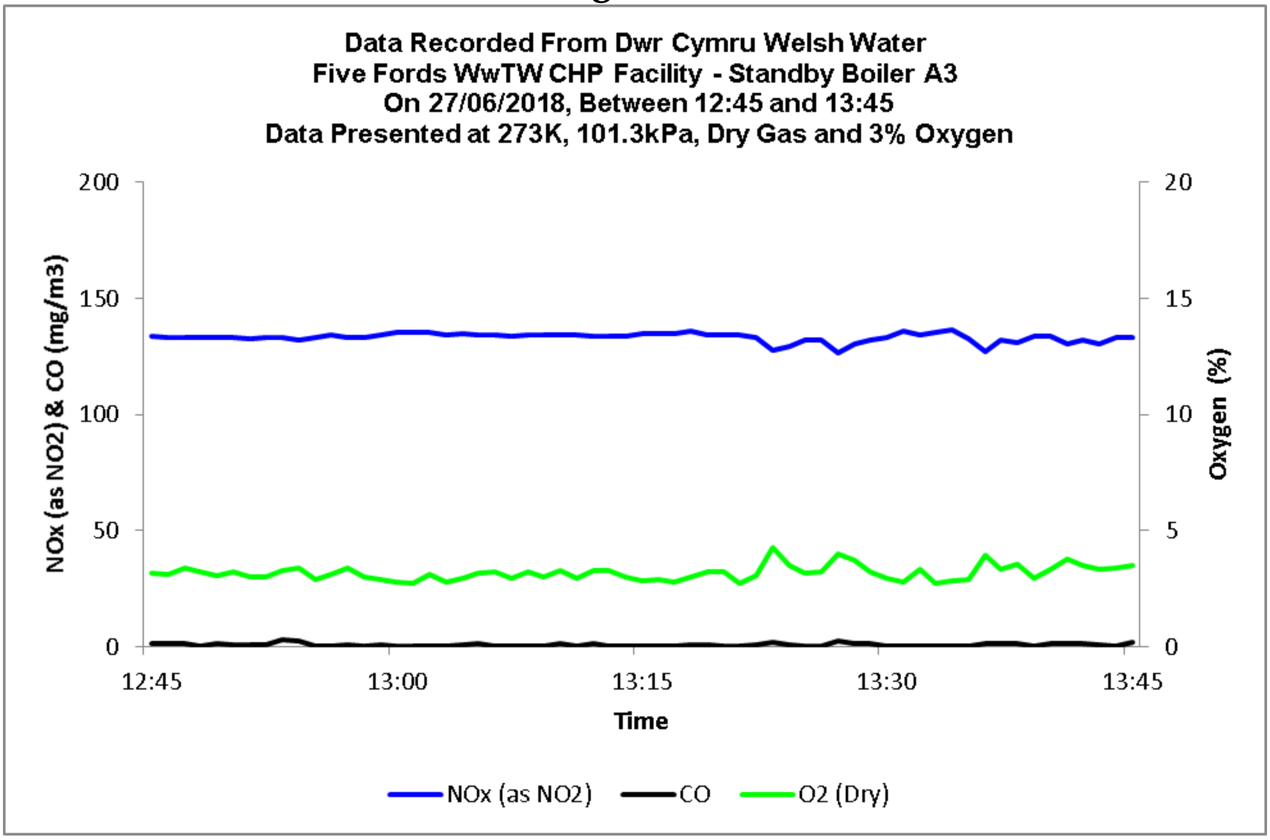


Figure 5


Data Recorded From Dwr Cymru Welsh Water
Five Fords WwTW CHP Facility - Standby Boiler A3
On 27/06/2018, Between 12:45 and 13:45
Data Presented at 273K, 101.3kPa, Dry Gas and 3% Oxygen
NOx (as NO2) & CO (mg/m3)
200
150
100
50
0
Oxygen (%)
20
15
10
5
0
12:45
13:00
13:15
13:30
13:45
Time
NOx (as NO2)
CO
O2 (Dry)

TABLES

Table 1

Data Recorded from A1 – CHP No.1

Sample Period: 14:00 – 15:00 on the 26th June 2018

Volumetric Flowrate (Reference Conditions) = 0.40458 **m^3/sec ***

	Average	Emission Rate
	mg/m^3	Kg/hr
TVOC (as carbon)*	1720.68	2.506

*** Reference Conditions (273K, 101.3 kPa, 5% Oxygen & Dry Gas)**

Table 2

Data Recorded from A1 – CHP No.1

Sample Period: 14:00 – 15:00 on the 26th June 2018

Volumetric Flowrate (Reference Conditions) = 0.40458 **m^3/sec ***

	Average	Emission Rate
	mg/m^3	Kg/hr
Oxides of Nitrogen (as NO2) *	340.80	0.496
Carbon Monoxide *	847.81	1.235
Oxygen (%)	8.68	…

*** Reference Conditions (273K, 101.3 kPa, 5% Oxygen & Dry Gas)**

Table 3

Data Recorded from A2 – CHP No.2

Sample Period: 09:05 – 10:05 on the 27th June 2018

Volumetric Flowrate (Reference Conditions) = 0.45537 m^3/sec *

	Average	Emission Rate
	mg/m^3	Kg/hr
TVOC (as carbon)*	1193.62	1.957

* Reference Conditions (273K, 101.3 kPa, 5% Oxygen & Dry Gas)

Table 4

Data Recorded from A2 – CHP No.2

Sample Period: 09:05 – 10:05 on the 27th June 2018

Volumetric Flowrate (Reference Conditions) = 0.45537 m^3/sec *

	Average	Emission Rate
	mg/m^3	Kg/hr
Oxides of Nitrogen (as NO2) *	385.17	0.631
Carbon Monoxide *	761.65	1.249
Oxygen (%)	8.11	...

* Reference Conditions (273K, 101.3 kPa, 5% Oxygen & Dry Gas)

Table 5

Data Recorded from A3 – Standby Boiler

Sample Period: 12:45 – 13:45 on the 27th June 2018

Volumetric Flowrate (Reference Conditions) = 0.42547 m^3/sec *

	Average	Emission Rate
	mg/m^3	Kg/hr
Oxides of Nitrogen (as NO2) *	133.17	0.204
Carbon Monoxide *	0.75	0.001
Oxygen (%)	3.17	...

*** Reference Conditions (273K, 101.3 kPa, 3% Oxygen & Dry Gas)**

Table 6 – Sulphur Dioxide

Data Recorded from CHP No.1 - CHP's

Emission Parameter	Units	SO2	Blank
Stack Diameter	metres	0.28	
Area of Sample Plane	m^2	0.062	
Moisture Content	%	9.73	
Oxygen Content	%	8.68	
Stack Temperature	^oC	217	
Gas Velocity (as Measured)	m/sec	16.86	
Gas Velocity (Reference Conditions)	m/sec*	6.57	
Volumetric Flowrate (as Measured)	m^3/sec	1.04	
Volumetric Flowrate (Reference Conditions)	m^3/sec*	0.40	
Dry Gas Molecular Weight	g/gmole	29.92651763	
Sample Date	...	26/06/2018	
Sample Period	...	13:00 - 14:00	
Sample Volume (reference Conditions)	m^3*	0.596	0.596
Sample Reference	ECL/18/	2984 & 2985	2986
Mass of Sulphur Dioxide Collected	mg	0.43	0.04
Concentration of Sulphur Dioxide	mg/m^3*	**0.72**	0.06
Emission Rate of Sulphur Dioxide	g/hr	1.05	...
Expanded Uncertainty (% Relative)	%	13	...
Impinger Collection Efficiency	%	87	...

*Reference Conditions (273K, 101.3kPa, 5% Oxygen, Dry Gas)

Impinger concentrations near to analytical limit of detection and so efficiency test is not required.

Table 7– NMVOC

Dwr Cymru Welsh Water

Five Fords WwTW CHP Facility CHP's CHP No.1

Emission Parameter	Units	Value		
Stack Diameter	mm	280		
Area of Sample Plane	m^2	0.062		
Moisture Content	%	9.71		
Expanded Uncertainty of Moisture (%Relative)	%	15.79		
Measured Oxygen (Dry)	%Vol	8.69		
Meter Temperature	°C	44.50		
StackTemperature	°C	216.17		
Sample Date	...	26/06/2018		
Sample Period	...	14:20 - 15:20		
Sample Volume (as Measured)	m^3	0.074		
Sample Volume (reference Conditions)	m^3*	0.049		
Sample Tube Results		NMVOC		Blank
Sample Reference ECL/18/2991	Units	Concentration*	Uncertainty	Concentration
Concentration of NMVOC	mg/m^3	3.86	19.39%	0.020

***Reference Conditions: 273 K, 101.3 kPa, 5% Oxygen & Dry Gas**

Table 8 – Sulphur Dioxide

Data Recorded from CHP No.2 - CHP's

Emission Parameter	Units	SO2	Blank
Stack Diameter	metres	0.28	
Area of Sample Plane	m^2	0.062	
Moisture Content	%	12.04	
Oxygen Content	%	8.09	
Stack Temperature	^oC	209	
Gas Velocity (as Measured)	m/sec	18.38	
Gas Velocity (Reference Conditions)	m/sec*	7.40	
Volumetric Flowrate (as Measured)	m^3/sec	1.13	
Volumetric Flowrate (Reference Conditions)	m^3/sec*	0.46	
Dry Gas Molecular Weight	g/gmole	29.92989008	
Sample Date	...	27/06/2018	
Sample Period	...	10:20 - 11:20	
Sample Volume (reference Conditions)	m^3*	0.617	0.617
Sample Reference	ECL/18/	2987 & 2988	2989
Mass of Sulphur Dioxide Collected	mg	4.86	0.02
Concentration of Sulphur Dioxide	mg/m^3*	**7.88**	0.04
Emission Rate of Sulphur Dioxide	g/hr	12.93	...
Expanded Uncertainty (% Relative)	%	13	...
Impinger Collection Efficiency	%	100	...

*Reference Conditions (273K, 101.3kPa, 5% Oxygen, Dry Gas)

Table 9 – NMVOC

Dwr Cymru Welsh Water

Five Fords WwTW CHP Facility CHP's CHP - No.2

Emission Parameter	Units	Value	
Stack Diameter	mm	280	
Area of Sample Plane	m^2	0.062	
Moisture Content	%	11.94	
Expanded Uncertainty of Moisture (%Relative)	%	13.82	
Measured Oxygen (Dry)	%Vol	8.11	
Meter Temperature	°C	28.00	
StackTemperature	°C	212.67	
Sample Date	...	27/06/2018	
Sample Period	...	09:00 - 10:00	
Sample Volume (as Measured)	m^3	0.092	
Sample Volume (reference Conditions)	m^3*	0.067	
Sample Tube Results		NMVOC		Blank
Sample Reference ECL/18/2992	Units	Concentration*	Uncertainty	Concentration
Concentration of NMVOC	mg/m^3	19.29	22.13%	0.015

***Reference Conditions: 273 K, 101.3 kPa, 5% Oxygen & Dry Gas**

Table 10 – Moisture

Data Recorded from A3 - Standby Boiler

Emission Parameter	Units	Moisture	Blank
Stack Diameter	metres	0.38	
Area of Sample Plane	m^2	0.113	
Moisture Content	%	8.25	
Oxygen Content	%	3.17	
Stack Temperature	^oC	82	
Gas Velocity (as Measured)	m/sec	5.36	
Gas Velocity (Reference Conditions)	m/sec*	4.13	
Volumetric Flowrate (as Measured)	m^3/sec	0.61	
Volumetric Flowrate (Reference Conditions)	m^3/sec*	0.47	
Dry Gas Molecular Weight	g/gmole	29.8276	
Sample Date	...	27/06/2018	
Sample Period	...	12:45 - 13:15	
Sample Volume (reference Conditions)	m^3*	0.416	0.416

*Reference Conditions (273K, 101.3kPa, Wet Gas)

VELOCITY TRAVERSE PROFILES

Environmental Compliance Limited

Dwr Cymru Cyfyngedig		**Installation Name**	**: Five Fords WwTW Gas to Grid Facility**
Permit No	**: EPR/AP3139FT**	**Visit Details**	**: 2018 Annual Compliance**
Variation No	**: n/a**	**Survey Dates**	**: 26th & 27th June 2018**
Report Ref	**: P3622 : R001**	**Report Issue Date**	**: 13th August 2018**

Environmental Compliance Limited	Traverse Data Profoma	Date of Measurement	26/06/2018

Company	Dwr Cymru Welsh Water	Stack Diameter Port A (mm)	280	Average Stack Diameter (mm)	280	Pitot tube coefficient	0.83
Site	Five Fords WwTW Facility	Stack Diameter Port B (mm)	280	Port Length (mm)	440	Pitot Id	668
Location	CHP's	Duct Length Port A (mm)		Average Duct Length (mm) L		Stack Thermocouple ID	650
Stack	CHP No.1	Duct Length Port B (mm)		Duct width (mm) B		Stack Temp Reader ID	387
Job No	P3622	Duct Length Port C (mm)		Barometric Pressure. (mb)	1020	Manometer ID	389
Operators	JL & Sheg	Duct Length Port D (mm)		Ave Static Press. (mm H_2O)	-9.00	Barometer ID	629

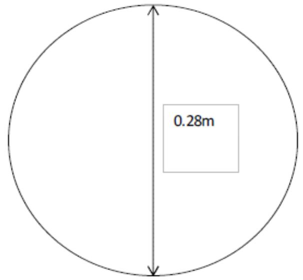
Pre - Traverse Checks Carried Out	Time	Pass/ Fail
Pre - Traverse PITOT Visual Inspection	12:45:00	Pass
Pre - Traverse PITOT Leak Check	12:46:00	Pass

Smooth Walls

Static Pressure Readings (mm H_2O)

Port A	Port B	Port C	Port D
-9.00			

Diagram/ Description of Cross Section of Stack/Duct



Port/ Point	Distance to Point (mm)	Time	Temperature Readings (°C) 1	2	3	(ΔP) Pitot Readings (mm H_2O) 1	2	3	Average Temp. (°C)	Average (ΔP) (mm H_2O)	Swirl Test ° From Reference
A1	140	12:49:00	216.0	216.0	216.0	15.60	15.20	15.20	216.0	15.33	5
									216.0	15.3	Total
Blockage Check @ A1 (L-Type Pitot Only)			Mean			Mean			216.0	15.3	Max
			Difference <5% from Initial ?			Difference <5% from Initial ?			216.0	15.3	Min
									216.0	15.3	Average

Notes

Including expected or actual deviations from procedures / non-conformities

Post - Traverse Checks Carried Out	Time	Pass/ Fail
Post - Traverse PITOT Visual Inspection	12:55:00	Pass
Post - Traverse PITOT Leak Check	12:57:00	Pass

Average temp (K)	489.000

Stagnation Check (S-type Pitot Only)	Time	Reading
Static Pressure Via Positive Leg (mm H_2O)	12:52:00	-9.00
Static Pressure Via Negative Leg (mm H_2O)	12:53:00	-9.00
Difference (Pa) < 1 mm H_2O ?		0.00

Suitability of Sampling Position	Actual Stack Conditions
Highest:lowest flow pressure ratio < 9:1?	1.02:1
Maximum deviation of flow from axis <15° ?	5
X-sectional area for stacks= πr2	0.06 m^2
X-sectional area for ducts = L x B	m^2
Suitability of Position for Sampling	OK

Compliance With Positional Requirements?

Height of sample ports from Platform	1.15m
Number of sample ports	2
Width of platform (port back to handrail)	2.1m

Stack Moisture	9.73	%	Gas Velocity (as Measured) Adjusted for Smooth Walls	16.86226	m/sec
Measured Oxygen	8.68	%	Gas Velocity (Reference Conditions) Adjusted for Smooth Walls	6.57056	m/sec*
Measured Carbon Dioxide	9.87	%	Volumetric Flowrate (as Measured) Adjusted for Smooth Walls	1.03830	m^3/sec
Dry Gas Molecular Weight	29.92640	g/g mole	Volumetric Flowrate (Ref Cond) Adjusted for Smooth Walls	0.40458	m^3/sec*

Nearest downstream disturbance	EXIT	>5m
Nearest upstream disturbance	BEND	1.9m
Disturbances are classed as bends, fans or diameter variations		

*Reference Conditions: 273K, 101.3kPa, 5% Oxygen, Dry Gas NOTE: Velocity / volume flowrate calculations exclude contributions from the measurement point(s) where swirl >15°

Environmental Compliance Limited

Dwr Cymru Cyfyngedig
Permit No : EPR/AP3139FT
Variation No : n/a
Report Ref : P3622 : R001

Installation Name : Five Fords WwTW Gas to Grid Facility
Visit Details : 2018 Annual Compliance
Survey Dates : 26th & 27th June 2018
Report Issue Date : 13th August 2018

Environmental Compliance Limited	Traverse Data Profoma	Date of Measurement	27/06/2018

Company	Dwr Cymru Welsh Water	Stack Diameter Port A (mm)	280	Average Stack Diameter (mm)	280	Pitot tube coefficient	0.83
Site	Five Fords WwTW Facility	Stack Diameter Port B (mm)	280	Port Length (mm)	440	Pitot Id	668
Location	CHP's	Duct Length Port A (mm)		Average Duct Length (mm) L		Stack Thermocouple ID	650
Stack	CHP No.2	Duct Length Port B (mm)		Duct width (mm) B		Stack Temp Reader ID	387
Job No	P3622	Duct Length Port C (mm)		Barometric Pressure. (mb)	1021	Manometer ID	389
Operators	JL & Sheg	Duct Length Port D (mm)		Ave Static Press. (mm H_2O)	-9.00	Barometer ID	629

Pre - Traverse Checks Carried Out	Time	Pass/ Fail
Pre - Traverse PITOT Visual Inspection	11:25:00	Pass
Pre - Traverse PITOT Leak Check	11:26:00	Pass

Smooth Walls

Static Pressure Readings (mm H_2O)			
Port A	Port B	Port C	Port D
-9.00			

Port/ Point	Distance to Point (mm)	Time	Temperature Readings (°C) 1	2	3	(ΔP) Pitot Readings (mm H_2O) 1	2	3	Average Temp. (°C)	Average (ΔP) (mm H_2O)	Swirl Test ° From Reference
A1	140	11:30:00	211.0	210.0	210.0	18.20	18.30	18.30	210.3	18.27	5
Blockage Check @ A1 (L-Type Pitot Only)									210.3	18.3	Total
			Mean			Mean			210.3	18.3	Max
			Difference <5% from Initial ?			Difference <5% from Initial ?			210.3	18.3	Min
									210.3	18.3	Average

Post - Traverse Checks Carried Out	Time	Pass/ Fail
Post - Traverse PITOT Visual Inspection	11:37:00	Pass
Post - Traverse PITOT Leak Check	11:38:00	Pass

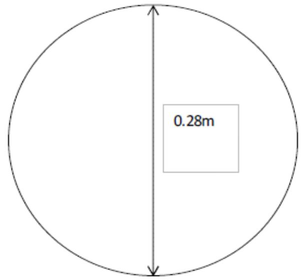
Average temp (K)	483.333

Stagnation Check (S-type Pitot Only)	Time	Reading
Static Pressure Via Positive Leg (mm H_2O)	11:34:00	-9.00
Static Pressure Via Negative Leg (mm H_2O)	11:35:00	-9.00
Difference (Pa) < 1 mm H_2O ?		0.00

Suitability of Sampling Position	Actual Stack Conditions
Highest:lowest flow pressure ratio < 9:1?	1:1
Maximum deviation of flow from axis < 15° ?	5
X-sectional area for stacks= πr2	0.06 m^2
X-sectional area for ducts = L x B	m^2
Suitability of Position for Sampling	OK

Stack Moisture	12.04	%	Gas Velocity (as Measured) Adjusted for Smooth Walls	18.37568	m/sec
Measured Oxygen	8.11	%	Gas Velocity (Reference Conditions) Adjusted for Smooth Walls	7.39535	m/sec*
Measured Carbon Dioxide	10.04	%	Volumetric Flowrate (as Measured) Adjusted for Smooth Walls	1.13149	m^3/sec
Dry Gas Molecular Weight	29.93080	g/g mole	Volumetric Flowrate (Ref Cond) Adjusted for Smooth Walls	0.45537	m^3/sec*

Diagram/ Description of Cross Section of Stack/Duct



Notes
Including expected or actual deviations from procedures / non-conformities

Compliance With Positional Requirements?

Height of sample ports from Platform	1.15m
Number of sample ports	2
Width of platform (port back to handrail)	2.1m

Nearest downstream disturbance	EXIT	> 5m
Nearest upstream disturbance	BEND	1.9m
Disturbances are classed as bends, fans or diameter variations		

*Reference Conditions: 273K, 101.3kPa, 5% Oxygen, Dry Gas NOTE: Velocity / volume flowrate calculations exclude contributions from the measurement point(s) where swirl > 15°

Environmental Compliance Limited

Dwr Cymru Cyfyngedig		Installation Name	: Five Fords WwTW Gas to Grid Facility
Permit No	: EPR/AP3139FT	Visit Details	: 2018 Annual Compliance
Variation No	: n/a	Survey Dates	: 26th & 27th June 2018
Report Ref	: P3622 : R001	Report Issue Date	: 13th August 2018

Environmental Compliance Limited	Traverse Data Profoma	Date of Measurement	27/06/2018

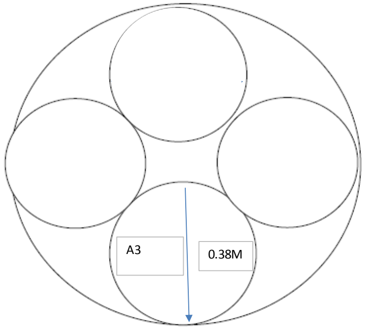
Company	Dwr Cymru Welsh Water	Stack Diameter Port A (mm)	380	Average Stack Diameter (mm)	380	Pitot tube coefficient	0.83
Site	Five Fords WwTW Facility	Stack Diameter Port B (mm)	380	Port Length (mm)	440	Pitot Id	668
Location	Standby Boiler	Duct Length Port A (mm)		Average Duct Length (mm) L		Stack Thermocouple ID	650
Stack	A3	Duct Length Port B (mm)		Duct width (mm) B		Stack Temp Reader ID	387
Job No	P3622	Duct Length Port C (mm)		Barometric Pressure. (mb)	1020	Manometer ID	389
Operators	JL & Sheg	Duct Length Port D (mm)		Ave Static Press. (mm H_2O)	-1.00	Barometer ID	629

Pre - Traverse Checks Carried Out	Time	Pass/ Fail
Pre - Traverse PITOT Visual Inspection	11:55:00	Pass
Pre - Traverse PITOT Leak Check	11:56:00	Pass

Smooth Walls

Static Pressure Readings (mm H_2O)			
Port A	Port B	Port C	Port D
-1.00			

Diagram/ Description of Cross Section of Stack/Duct



Port/ Point	Distance to Point (mm)	Time	Temperature Readings (°C) 1	2	3	(ΔP) Pitot Readings (mm H_2O) 1	2	3	Average Temp. (°C)	Average (ΔP) (mm H_2O)	Swirl Test ° From Reference
A1	56	12:00:00	83.0	83.0	83.0	2.00	2.00	2.00	83.0	2.00	5
A2	324	12:02:00	83.0	83.0	83.0	2.40	2.40	2.20	83.0	2.33	5
B1	56	12:07:00	85.0	85.0	85.0	2.20	2.00	2.20	85.0	2.13	5
B2	324	12:09:00	85.0	85.0	85.0	2.20	2.00	2.00	85.0	2.07	5
									336.0	8.5	Total
Blockage Check @ A1 (L-Type Pitot Only)			Mean			Mean			85.0	2.3	Max
			Difference <5% from Initial ?			Difference <5% from Initial ?			83.0	2.0	Min
									84.0	2.1	Average

Notes

Including expected or actual deviations from procedures / non-conformities

Post - Traverse Checks Carried Out	Time	Pass/ Fail
Post - Traverse PITOT Visual Inspection	12:18:00	Pass
Post - Traverse PITOT Leak Check	12:20:00	Pass

Average temp (K)	357.000

Stagnation Check (S-type Pitot Only)	Time	Reading
Static Pressure Via Positive Leg (mm H_2O)	12:15:00	-1.00
Static Pressure Via Negative Leg (mm H_2O)	12:16:00	-1.20
Difference (Pa) < 1 mm H_2O ?		-0.20

Suitability of Sampling Position	Actual Stack Conditions
Highest:lowest flow pressure ratio < 9:1?	1.2:1
Maximum deviation of flow from axis < 15° ?	5
X-sectional area for stacks = πr2	0.11 m^2
X-sectional area for ducts = L x B	m^2
Suitability of Position for Sampling	OK

Compliance With Positional Requirements?

Height of sample ports from Platform	1.15m
Number of sample ports	2
Width of platform (port back to handrail)	2.1m

Stack Moisture	8.25	%	Gas Velocity (as Measured) Adjusted for Smooth Walls	5.36173	m/sec
Measured Oxygen	3.17	%	Gas Velocity (Reference Conditions) Adjusted for Smooth Walls	3.75155	m/sec*
Measured Carbon Dioxide	10.63	%	Volumetric Flowrate (as Measured) Adjusted for Smooth Walls	0.60808	m^3/sec
Dry Gas Molecular Weight	29.82760	g/g mole	Volumetric Flowrate (Ref Cond) Adjusted for Smooth Walls	0.42547	m^3/sec*

Nearest downstream disturbance	EXIT	>5m
Nearest upstream disturbance	BEND	1.9m
Disturbances are classed as bends, fans or diameter variations		

*Reference Conditions: 273K, 101.3kPa, 3% Oxygen, Dry Gas   NOTE: Velocity / volume flowrate calculations exclude contributions from the measurement point(s) where swirl > 15°

FIELD CALIBRATION AND SAMPLING DATA

TVOC Calibration Site Log – 26/06/2018

TVOC - FIELD DATA SHEET

Client	Dwr Cymru Welsh Water	Barometric Pressure mb	1020	
Site	Five Fords WwTW CHP Faclitiy	Barometer ID	ECL/ID/ 629	
Date	26/06/2018	Analyser ID	ECL/ID/ 269	
Location	CHP's	Sonimix/ MFC ID	ECL/ID/ n/a	
Stack ID	CHP No.1	Heated Line/ Controller ID	ECL/ID/ 1010 & 1011	
Stack Temp °C	216C	Heated Line Set Temp °C	180	YES
Ambient Temp (sampling)	1=34 2=41 3=41	Heated Line Length	10	m
Ambient Temp (sampling)	4=43 5=44 6=44	Heated Probe Filter ID	ECL/ID/ 572	
Job No	P3622	Heated Filter Set Temp °C	180	YES
Operators	JL & SHEG	Logger ID	928	

Calibration Gas Details

Calibration Gas	Gas Bottle ID	Gas Value	Uncertainty of Gas (k=2)
Zero Gas (Synthetic Air)	Gas/ 1913	...	...
Hydrogen / Helium	Gas/ 1832	...	...
Propane (In Air)	Gas/ 1829	896.0 ppm	1%

	Analyser Range	Span Gas value used
Propane	4000 ppm	896.0 ppm

Analyser Range should be not less than the expected peak emissions.

Span Gas Values should be **either** *approximately the half-hourly ELV* **OR** ***50%*** *to* ***90%*** *of the Selected Analyser Range.*

	Direct Calibration (Rear of Analyser)					
	Zero Cal		Span Gas Cal		Zero Check	
	Start Time	End Time	Start Time	End Time	Start Time	End Time
ZERO /SPAN/ ZERO	12:20	12:25	12:26	12:31	12:32	12:37

NOTE: RESPONSE TIME

Response Time to be carried out at the same time as "Span Check" on system verification (via the sample probe)
Start Time = when gas turned on. 90% Time = when analyser displays 90% of span gas value used. Response must be within 200 seconds.

Pre-Cal Ambient Temp °C		PRE System Verification Check (Down Line)			
Max	Min	Zero Check		Span Check	
33	32	Start Time	End Time	Start Time	End Time
ZERO / SPAN		12:39	12:44	12:45	12:50

Response Time SYSTEM Span Gas Cal		
Start Time	90% Time	less than 200s (Y/N)
12:44:00	12:45	Y

	Start Time	End Time	Location	Production Details
Sample Period	12:50	15:20	CHP No.1	
Sample Period				
Sample Period				
Sample Period				
Sample Period				
Sample Period				

Post-Cal Ambient Temp °C		POST System Verification Check (Down Line)			
Max	Min	Zero Check		Span Check	
38	36	Start Time	End Time	Start Time	End Time
ZERO / SPAN		16:30	16:35	16:35	16:40

Process Details / Comments

TVOC Calibration Summary – 26/06/2018

		TVOC ppm
Analyser Range		4000
Repeatability at Zero		2
Span Gas Concentration Applied		896
Zero Gas Concentration Applied		0
Direct Cal	Zero	0.00
	Span	896.0
	Zero	-2.06
Difference (Zero)		2.0645
< 2 x Repeatability @ Zero?		YES
Pre Test (System)	Zero	-0.97
	Span	892.5
Difference (Zero)		0.9697
< 2% Relative to Direct Span		YES
Difference (Span)		3.5451
< 2% Relative to Direct Span		YES
Post Test (System)	Zero	-1.28
	Span	889.1
Difference (Zero)		0.3128
Zero Drift < 2% of Applied Span?		YES
Difference (Span)		3.3366
Span Drift < 2% of Applied Span?		YES
Zero and Span Drift < 5% of Applied Span?		YES

TVOC Calibration Site Log – 27/06/2018

TVOC - FIELD DATA SHEET

Client	Dwr Cymru Welsh Water	Barometric Pressure mb	1021	
Site	Five Fords WwTW CHP Faclitiy	Barometer ID	ECL/ID/ 629	
Date	27/06/2018	Analyser ID	ECL/ID/ 269	
Location	CHP's	Sonimix/ MFC ID	ECL/ID/ n/a	
Stack ID	CHP No.2	Heated Line/ Controller ID	ECL/ID/ 1010 & 1011	
Stack Temp °C	210C	Heated Line Set Temp °C	180	YES
Ambient Temp (sampling)	1 = 26 2 = 28 3 = 28	Heated Line Length	10	m
Ambient Temp (sampling)	4 = 29 5 = 29 6 = 29	Heated Probe Filter ID	ECL/ID/ 572	
Job No	P3622	Heated Filter Set Temp °C	180	YES
Operators	JL & SHEG	Logger ID	928	

Calibration Gas Details

Calibration Gas	Gas Bottle ID	Gas Value	Uncertainty of Gas (k=2)
Zero Gas (Synthetic Air)	Gas/ 1913	...	...
Hydrogen / Helium	Gas/ 1832	...	...
Propane (In Air)	Gas/ 1829	896.0 ppm	1%

	Analyser Range	Span Gas value used
Propane	4000 ppm	896.0 ppm

Analyser Range should be not less than the expected peak emissions.

Span Gas Values should be **either** *approximately the half-hourly ELV* **OR** ***50%*** *to* ***90%*** *of the Selected Analyser Range.*

	Direct Calibration (Rear of Analyser)					
	Zero Cal		Span Gas Cal		Zero Check	
	Start Time	End Time	Start Time	End Time	Start Time	End Time
ZERO /SPAN/ ZERO	08:39	08:44	08:45	08:49	08:49	08:53

NOTE: RESPONSE TIME

Response Time to be carried out at the same time as "Span Check" on system verification (via the sample probe)
Start Time = when gas turned on. 90% Time = when analyser displays 90% of span gas value used. Response must be within 200 seconds.

Pre-Cal Ambient Temp °C		PRE System Verification Check (Down Line)			
Max	Min	Zero Check		Span Check	
26	24	Start Time	End Time	Start Time	End Time
ZERO / SPAN		08:54	08:59	09:00	09:05

Response Time		
SYSTEM Span Gas Cal		
Start Time	90% Time	less than 200s (Y/N)
08:59:00	09:00:00	Y

	Start Time	End Time	Location	Production Details
Sample Period	09:05	11:22	CHP No.2	
Sample Period				
Sample Period				
Sample Period				
Sample Period				
Sample Period				

Post-Cal Ambient Temp °C		POST System Verification Check (Down Line)			
Max	Min	Zero Check		Span Check	
30	29	Start Time	End Time	Start Time	End Time
ZERO / SPAN		11:25	11:30	11:30	11:35

Process Details / Comments

TVOC Calibration Summary – 27/06/2018

		TVOC ppm
Analyser Range		4000
Repeatability at Zero		2
Span Gas Concentration Applied		896
Zero Gas Concentration Applied		0
Direct Cal	Zero	0.00
	Span	896.0
	Zero	0.00
Difference (Zero)		0.0000
< 2 x Repeatability @ Zero?		YES
Pre Test (System)	Zero	0.00
	Span	896.5
Difference (Zero)		0.0000
< 2% Relative to Direct Span		YES
Difference (Span)		0.5241
< 2% Relative to Direct Span		YES
Post Test (System)	Zero	2.10
	Span	884.6
Difference (Zero)		2.0964
Zero Drift < 2% of Applied Span?		YES
Difference (Span)		11.9495
Span Drift < 2% of Applied Span?		YES
Zero and Span Drift < 5% of Applied Span?		YES

Combustion Gases Calibration Summary 26/06/2018

	Horiba PG 250 Measurement Ranges:		
	NO as NO_2	CO	O_2
Units	1025 mg/m^3	2500 mg/m^3	25 %Vol
	Zero Values (Direct)		
Mean Initial Direct Zero	0.05	0.21	-0.02
Mean Confirmation Direct Zero	0.23	0.31	-0.04
Difference in Direct Zero	0.19	0.10	0.02
Repeatability at Zero	4.10	2.50	0.20
<2 x Repeatability at Zero?	YES	YES	YES
	Pre Zero Values (System)		
Mean Pre Test Zero	0.26	-0.14	0.01
% of Measurement Range?	0.03%	-0.01%	0.04%
Detection Limit (LOD)	0.10	0.43	0.20
	Applied Span:		
	NO	CO	O_2
Actual Applied Span Concentration	525.62	1251.25	15.15
	Pre Test System Zero Values		
Mean Pre Test System Zero	0.26	-0.14	0.01
Difference ≤ ± 2% of Span Value (5% for SO_2)?	0.05%	0.01%	0.06%
	Post Test Zero Values		
Mean Post Test Zero	0.00	-1.61	-0.04
% of Certified Range?	0.00%	-0.06%	-0.17%
Zero Drift ≤ ± 5% of Applied Span?	0.01%	0.15%	0.16%
	Pre Test System Span Values		
Mean Pre Test System Span	530.18	1234.48	15.13
Difference ≤ ± 2% of Span Value (5% for SO_2)?	0.87%	1.34%	0.12%
	Post Test Span Values		
Mean Post Test Span	535.36	1237.32	15.12
Span Drift ≤ ± 5% Span Value?	1.85%	1.11%	0.19%

Combustion Gases Calibration Summary
27/06/2018

	Horiba PG 250 Measurement Ranges:		
	NO as NO_2	CO	O_2
Units	**1025 mg/m^3**	**2500 mg/m^3**	**25 %Vol**
	Zero Values (Direct)		
Mean Initial Direct Zero	0.05	0.21	-0.02
Mean Confirmation Direct Zero	0.23	0.31	-0.04
Difference in Direct Zero	0.19	0.10	0.02
Repeatability at Zero	4.10	2.50	0.20
<2 x Repeatability at Zero?	YES	YES	YES
	Pre Zero Values (System)		
Mean Pre Test Zero	0.26	-0.14	0.01
% of Measurement Range?	0.03%	-0.01%	0.04%
Detection Limit (LOD)	0.10	0.43	0.20
	Applied Span:		
	NO	**CO**	**O_2**
Actual Applied Span Concentration	525.62	1251.25	15.15
	Pre Test System Zero Values		
Mean Pre Test System Zero	0.26	-0.14	0.01
Difference ≤ ± 2% of Span Value (5% for SO_2)?	0.05%	0.01%	0.06%
	Post Test Zero Values		
Mean Post Test Zero	0.41	-0.35	-0.07
% of Certified Range?	0.04%	-0.01%	-0.27%
Zero Drift ≤ ± 5% of Applied Span?	0.07%	0.04%	0.33%
	Pre Test System Span Values		
Mean Pre Test System Span	530.18	1234.48	15.13
Difference ≤ ± 2% of Span Value (5% for SO_2)?	0.87%	1.34%	0.12%
	Post Test Span Values		
Mean Post Test Span	522.31	1235.96	15.04
Span Drift ≤ ± 5% Span Value?	0.63%	1.22%	0.75%

Environmental Compliance Limited

Dwr Cymru Cyfyngedig			**Installation Name**	**: Five Fords WwTW Gas to Grid Facility**
Permit No	**: EPR/AP3139FT**		**Visit Details**	**: 2018 Annual Compliance**
Variation No	**: n/a**		**Survey Dates**	**: 26th & 27th June 2018**
Report Ref	**: P3622**	**: R001**	**Report Issue Date**	**: 13th August 2018**

CHP No.1 Sulphur Dioxide

Environmental Compliance Limited	NON ISOKINETIC SAMPLING PROFORMA	Date of Measurement	26/06/2018

If moisture was not measured see detailed notes below.

ECL/TPD/	039	Time taken to change Ports?	0	Start Time	13:00	End Time	14:00
				Test Duration	60 mins		

Client	Dwr Cymru Welsh Water	Stack Profile	Circular	Console id	U008	Barometer id	629
Site	Five Fords WwTW CHP Facilit	Stack Area (m^2)	0.06	Pump id	U008	Nozzle Id	n/a
Location	CHP's	Barometric Pressure (mb)	1020	Probe id	649	Nozzle size	n/a
Stack ID	CHP No.1	Static Pres. (mm H_20)	-9	DGM Yd	0.971	Filter Id	QMA
Test No.	SO2	Pitot coefficient	n/a	ΔH@	42.19	Pitot ID	n/a
Job No	P3622	Probe Heater Setting (^OC)	160	Impinger Id	657	Hot Box ID	400
ECL Site Staff	JL & Sheg	Hot Box Setting (^OC)	160	Balance Id	1069		

Required Sample Flowrate l/min	Suggested ΔH Entered Below
3	1
6	3
10	10
15	25
25	50
Initial ΔH	20
Reference Oxygen Percentage	5

	Sample	Leak 1	Leak 2	Leak 3	Leak 4	Leak 5	Total
Start Volume	3102694.8						
Final Volume	3103584.3						
Total Volume	889.5	0.0	0.0	0.0	0.0	0.0	889.5

Leak Check	First	Second	Third	Fourth	Fifth
Leak rate l/min	0.1	0			
Vaccum "Hg	-6	-5			
Time of Check	12:58	14:02			
Set Rate l/min	16	15			
Leak < 2%?	YES	YES			

Dry O_2 (☐ Atmospheric)	8.68
Dry Carbon Dioxide %	9.87
Dry Carbon Monoxide ppm	678.25

Traverse Point	CP	CP	CP	CP	CP	CP			Total
Time/Point (mins)	0 - 10	10 - 20	20 - 30	30 - 40	40 - 50	50 - 60			
ΔP (mm H20)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
K factor	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
ΔH (Orifice)	20.00	20.00	20.00	20.00	20.00	20.00			20.00
Meter (Tm in)	30.00	32.00	33.00	35.00	36.00	38.00			34.00
Meter (Tm out)	30.00	32.00	33.00	35.00	36.00	38.00			34.00
Stack Temp (Ts)	216.00	217.00	217.00	216.00	217.00	217.00			216.67
Impinger T Outlet	30.00	26.00	24.00	24.00	23.00	24.00			25.17
Vaccum (" Hg)	0.50	0.50	0.50	0.50	0.50	0.50			0.50

Traverse Point									Total
Time/Point(mins)									
ΔP (mm H20)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
K factor	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
ΔH (Orifice)									
Meter (Tm in)									
Meter (Tm out)									
Stack Temp (Ts)									
Impinger T Outlet									
Vaccum (" Hg)									

Traverse Point									Total
Time/Point(mins)									
ΔP (mm H20)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
K factor	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
ΔH (Orifice)									
Meter (Tm in)									
Meter (Tm out)									
Stack Temp (Ts)									
Impinger T Outlet									
Vaccum (" Hg)									

Traverse Point									Total
Time/Point(mins)									
ΔP (mm H20)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
K factor	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
ΔH (Orifice)									
Meter (Tm in)									
Meter (Tm out)									
Stack Temp (Ts)									
Impinger T Outlet									
Vaccum (" Hg)									

	Impinger 1	Impinger 2	Impinger3	Impinger 4	Impinger 5	Impinger 6	Impinger 7	Impinger 8
Contents	3% H2O2	3% H2O2	3% H2O2	Empty	Silica			
SOL/	3472	3472	3472					
Start Weight (g)	657.9	643.7	621.8	467.4	905.7			
End Weight (g)	679.1	678.5	622.7	469.9	913.4			
Total weight (g)	21.2	34.8	0.9	2.5	7.7	0	0	0

Total (g)	67.10
Silica < 50% used at End of Test? Y/N	YES

Rinse Solutions used	
Solution	SOL NO
DI Water	3471
Acetone	

Additional Moisture Weighings

	1	2	3	4	5	6	7	8	9	10
Item Name										
Start Weight (g)										
End Weight (g)										
Total weight (g)	0	0	0	0	0	0	0	0	0	0

If moisture was not measured and gas was dried before entering the gas meter, impinger weights must be included to produce the moisture concentration used in the isokinetic calculations. If the gas was not dried before it entered the gas meter then impinger weights may be included to produce a nominal 0.1% moisture value.

CHP No.1 NMVOC

Environmental Compliance Limited	SAMPLE TUBE DATA SAMPLING PROFORMA

Client	Dwr Cymru Welsh Water	◉ Circular ○ectangular E○pse		Pump ID	U008
Site	Five Fords WwTW CHP Facility	Stack Diameter (mm)	280	Meter ID	U008
Location	CHP's			MST Probe ID	649
Stack ID	CHP No.1	Stack Area (m^2)	0.062	MST Probe Heating Temp (C)	160
Test No	NMVOC	Barometric Pressure (mb)	1020	DGM Yd or ml/count	0.971
Job No	P3622	Stack Thermocouple ID	650	MST Hot Box ID	400
ECL Site Staff	JL & SHEG	Tube Thermocouple ID	1040	MST Hot Box Heating Temp (C)	160
Barometer ID	629	Meter Thermocouple ID	387	Workhorse Set Sample Rate (%)	n/a
		In-Stack Sinter Used (Y/N)	N	MST Delta H Sampling Rate	42.19

Date of Test	26/06/2018
Sample Start Time	14:20
Sample End Time	15:20
Duration	60
Measured O2	8.69
O2 Uncertainty %Vol	0.52

Meter Units ○ ml ◉ litres

	Sample	Leak 1	Time (start/ end) (minimum 1 minute)	Leak 2	Time (start/ end) (minimum 1 minute)	Total
Start Volume	3103655.0	3103650.3	14:16:00	31037351.0	15:25:00	
Final Volume	3103732.4	3103650.3	14:17:00	31037351.0	15:26:00	
Total Volume	76.2	0.0		0.0		76.2
Sample Train Internal Volume	1.217381694	Litres				

Sample Point	CP	CP	CP	CP
Time/ point (mins)	0-10	10-20	20-30	30-40
Tube Temp ^OC	30	30	30	30
Stack Temp ^OC	217	215	216	217
Meter Temp In ^OC	41	42	44	45
Meter Temp Out ^OC	41	42	44	45

Sample Point	CP	CP		
Time/ point (mins)	40-50	50-60		
Tube Temp ^OC	29	29		
Stack Temp ^OC	216	216		
Meter Temp In ^OC	47	48		
Meter Temp Out ^OC	47	48		

Sample Point				
Time/ point (mins)				
Tube Temp ^OC				
Stack Temp ^OC				
Meter Temp In ^OC				
Meter Temp Out ^OC				

	Impinger 1	Impinger 2	Impinger3
Contents	Empty	Silica	
Start Weight (g)	501.1	785	
End Weight (g)	502.6	789.2	
Total weight (g)	1.5	4.2	0

Silica	(IF USED)
<50% Spent at end Y/N?	Yes
Sample train upstream of sorbent tube condensation free for entire sample (Y/N)	NO

CHP No.2 Sulphur Dioxide

Environmental Compliance Limited	NON ISOKINETIC SAMPLING PROFORMA	Date of Measurement	27/06/2018

ECL/TPD/	039	Time taken to change Ports?	0	Start Time	10:20	End Time	11:20
				Test Duration	60 mins		

Client	Dwr Cymru Welsh Water	Stack Profile	Circular	Console id	U008	Barometer id	629
Site	Five Fords WwTW CHP Facilit	Stack Area (m^2)	0.06	Pump id	U008	Nozzle Id	n/a
Location	CHP's	Barometric Pressure (mb)	1020	Probe id	649	Nozzle size	n/a
Stack ID	CHP No.2	Static Pres. (mm H_20)	-9	DGM Yd	0.971	Filter Id	QMA
Test No.	SO2	Pitot coefficient	n/a	ΔH@	42.19	Pitot ID	n/a
Job No	P3622	Probe Heater Setting (^OC)	160	Impinger Id	657	Hot Box ID	400
ECL Site Staff	JL & Sheg	Hot Box Setting (^OC)	160	Balance Id	1069		

	Sample	Leak 1	Leak 2	Leak 3	Leak 4	Leak 5	Total
Start Volume	3104046.1						
Final Volume	3104920.3						
Total Volume	874.2	0.0	0.0	0.0	0.0	0.0	874.2

Leak Check	First	Second	Third	Fourth	Fifth
Leak rate l/min	0	0			
Vaccum "Hg	-10	-8			
Time of Check	10:16	11:24			
Set Rate l/min	16	15			
Leak < 2%?	YES	YES			

Dry O_2 (☐ Atmospheric)	8.09
Dry Carbon Dioxide %	10.04
Dry Carbon Monoxide ppm	609.32

Required Sample Flowrate l/min	Suggested ΔH Entered Below
3	1
6	3
10	10
15	25
25	50
Initial ΔH	20
Reference Oxygen Percentage	5

Traverse Point	CP	CP	CP	CP	CP	CP			Total
Time/Point (mins)	0 - 10	10 - 20	20 - 30	30 - 40	40 - 50	50 - 60			
ΔP (mm H20)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
K factor	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
ΔH (Orifice)	20.00	20.00	20.00	20.00	20.00	20.00			20.00
Meter (Tm in)	30.00	31.00	33.00	33.00	34.00	35.00			32.67
Meter (Tm out)	30.00	31.00	33.00	33.00	34.00	35.00			32.67
Stack Temp (Ts)	211.00	210.00	209.00	209.00	209.00	208.00			209.33
Impinger T Outlet	38.00	27.00	28.00	29.00	30.00	31.00			30.50
Vaccum (" Hg)	0.50	0.50	0.50	0.50	0.50	0.50			0.50

Traverse Point									Total
Time/Point(mins)									
ΔP (mm H20)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
K factor	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
ΔH (Orifice)									
Meter (Tm in)									
Meter (Tm out)									
Stack Temp (Ts)									
Impinger T Outlet									
Vaccum (" Hg)									

Traverse Point									Total
Time/Point(mins)									
ΔP (mm H20)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
K factor	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
ΔH (Orifice)									
Meter (Tm in)									
Meter (Tm out)									
Stack Temp (Ts)									
Impinger T Outlet									
Vaccum (" Hg)									

Traverse Point									Total
Time/Point(mins)									
ΔP (mm H20)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
K factor	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
ΔH (Orifice)									
Meter (Tm in)									
Meter (Tm out)									
Stack Temp (Ts)									
Impinger T Outlet									
Vaccum (" Hg)									

	Impinger 1	Impinger 2	Impinger3	Impinger 4	Impinger 5	Impinger 6	Impinger 7	Impinger 8
	3% H2O2	3% H2O2	3% H2O2	Empty	Silica			
SOL/	3472	3472	3472					
Start Weight (g)	666.4	640.3	632.5	470.1	915.5			
End Weight (g)	691.2	680	634.6	470.7	932.4			
Total weight (g)	24.8	39.7	2.1	0.6	16.9	0	0	0

Total (g)	84.10
Silica < 50% used at End of Test? Y/N	YES

Rinse Solutions used	
Solution	SOL NO
DI Water	3471
Acetone	

If moisture was not measured see detailed notes below.

Additional Moisture Weighings

	1	2	3	4	5	6	7	8	9	10
Item Name										
Start Weight (g)										
End Weight (g)										
Total weight (g)	0	0	0	0	0	0	0	0	0	0

If moisture was not measured and gas was dried before entering the gas meter, impinger weights must be included to produce the moisture concentration used in the isokinetic calculations. If the gas was not dried before it entered the gas meter then impinger weights may be included to produce a nominal 0.1% moisture value.

CHP No.2 NMVOC

Environmental Compliance Limited	SAMPLE TUBE DATA SAMPLING PROFORMA

Client	Dwr Cymru Welsh Water	◉ Circular ○ectangular E○pse		Pump ID	U008
Site	Five Fords WwTW CHP Facility	Stack Diameter (mm)	280	Meter ID	U008
Location	CHP's			MST Probe ID	649
Stack ID	CHP - No.2	Stack Area (m^2)	0.062	MST Probe Heating Temp (C)	160
Test No	NMVOC	Barometric Pressure (mb)	1020	DGM Yd or ml/count	0.971
Job No	P3622	Stack Thermocouple ID	650	MST Hot Box ID	400
ECL Site Staff	JL & Sheg	Tube Thermocouple ID	1040	MST Hot Box Heating Temp (C)	160
Barometer ID	629	Meter Thermocouple ID	387	Workhorse Set Sample Rate (%)	n/a
		In-Stack Sinter Used (Y/N)	N	MST Delta H Sampling Rate	42.19

Date of Test	27/06/2018
Sample Start Time	09:00
Sample End Time	10:00
Duration	60
Measured O2	8.11
O2 Uncertainty %Vol	0.49

Meter Units ○ ml ◉ litres

	Sample	Leak 1	Time (start/ end) (minimum 1 minute)	Leak 2	Time (start/ end) (minimum 1 minute)	Total
Start Volume	3103850.3	3103845.9	08:41:00	3103950.1	10:02:00	
Final Volume	3103946.0	3103845.9	08:42:00	3103950.1	10:03:00	
Total Volume	94.5	0.0		0.0		94.5
Sample Train Internal Volume	1.217381694	Litres				

Sample Point	CP	CP	CP	CP
Time/ point (mins)	0-10	10-20	20-30	30-40
Tube Temp ^OC	27	27	28	28
Stack Temp ^OC	214	214	212	212
Meter Temp In ^OC	26	27	27	28
Meter Temp Out ^OC	26	27	27	28

Sample Point	CP	CP		
Time/ point (mins)	40-50	50-60		
Tube Temp ^OC	30	30		
Stack Temp ^OC	212	212		
Meter Temp In ^OC	30	30		
Meter Temp Out ^OC	30	30		

Sample Point				
Time/ point (mins)				
Tube Temp ^OC				
Stack Temp ^OC				
Meter Temp In ^OC				
Meter Temp Out ^OC				

Impinger 1	Empty
Start Weight (g)	502.1
End Weight (g)	502.9
Total weight (g)	0.8

Impinger 2	Silica
Start Weight (g)	789.5
End Weight (g)	798.1
Total weight (g)	8.6

Impinger3	
Start Weight (g)	
End Weight (g)	
Total weight (g)	0

Silica	(IF USED)
< 50% Spent at end Y/N?	Yes
Sample train upstream of sorbent tube condensation free for entire sample (Y/N)	NO

A3 Standby Boiler Moisture

Environmental Compliance Limited	NON ISOKINETIC SAMPLING PROFORMA	Date of Measurement	27/06/2018

ECL/TPD/	082	Time taken to change Ports?	0	Start Time	12:45
				Test Duration	30 mins
				End Time	13:15

Client	Dwr Cymru Welsh Water	Stack Profile	Circular	Console id	U008	Barometer id	629
Site	Five Fords WwTW CHP Facilit	Stack Area (m^2)	0.11	Pump id	U008	Nozzle Id	n/a
Location	Standby Boiler	Barometric Pressure (mb)	1020	Probe id	649	Nozzle size	n/a
Stack ID	A3	Static Pres. (mm $H_2$0)	-1	DGM Yd	0.971	Filter Id	...
Test No.	Moisture	Pitot coefficient	n/a	ΔH@	42.19	Pitot ID	n/a
Job No	P3622	Probe Heater Setting (^{O}C)	160	Impinger Id	657	Hot Box ID	400
ECL Site Staff	JL & SHEG	Hot Box Setting (^{O}C)	160	Balance Id	1069		

	Sample	Leak 1	Leak 2	Leak 3	Leak 4	Leak 5	Total
Start Volume	3105474.6						
Final Volume	3105916.2						
Total Volume	441.6	0.0	0.0	0.0	0.0	0.0	441.6

Required Sample Flowrate l/min	Suggested ΔH Entered Below
3	1
6	3
10	10
15	25
25	50
Initial ΔH	20
Reference Oxygen Percentage	n/a

Leak Check	First	Second	Third	Fourth	Fifth
Leak rate l/min	0	0			
Vaccum "Hg	-8	-8			
Time of Check	11:55	13:18			
Set Rate l/min	16	15			
Leak < 2%?	YES	YES			

Dry O_2 ☐ Atmospheric)	3.17
Dry Carbon Dioxide %	10.63
Dry Carbon Monoxide ppm	0

Traverse Point	CP	CP	CP						Total
Time/Point (mins)	0 - 10	10 - 20	20 - 30						
ΔP (mm H20)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
K factor	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
ΔH (Orifice)	20.00	20.00	20.00						20.00
Meter (Tm in)	35.00	36.00	37.00						36.00
Meter (Tm out)	35.00	36.00	37.00						36.00
Stack Temp (Ts)	82.00	82.00	82.00						82.00
Impinger T Outlet	29.00	30.00	31.00						30.00
Vaccum (" Hg)	1.00	1.00	1.00						1.00

Traverse Point									Total
Time/Point(mins)									
ΔP (mm H20)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
K factor	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
ΔH (Orifice)									
Meter (Tm in)									
Meter (Tm out)									
Stack Temp (Ts)									
Impinger T Outlet									
Vaccum (" Hg)									

Traverse Point									Total
Time/Point(mins)									
ΔP (mm H20)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
K factor	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
ΔH (Orifice)									
Meter (Tm in)									
Meter (Tm out)									
Stack Temp (Ts)									
Impinger T Outlet									
Vaccum (" Hg)									

Traverse Point									Total
Time/Point(mins)									
ΔP (mm H20)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
K factor	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
ΔH (Orifice)									
Meter (Tm in)									
Meter (Tm out)									
Stack Temp (Ts)									
Impinger T Outlet									
Vaccum (" Hg)									

	Impinger 1	Impinger 2	Impinger3	Impinger 4	Impinger 5	Impinger 6	Impinger 7	Impinger 8
	H2O	H2O	H2O	Empty	Silica			
SOL/	...	...	...					
Start Weight (g)	660.1	729.7	545.6	470.7	932.4			
End Weight (g)	571.2	766.6	610.6	472.5	945.2			
Total weight (g)	-88.9	36.9	65	1.8	12.8	0	0	0

Total (g)	27.60
Silica < 50% used at End of Test? Y/N	YES

Rinse Solutions used	
Solution	SOL NO
DI Water	
Acetone	

If moisture was not measured see detailed notes below.

Additional Moisture Weighings	
Item Name	
Start Weight (g)	
End Weight (g)	
Total weight (g)	0
Item Name	
Start Weight (g)	
End Weight (g)	
Total weight (g)	0
Item Name	
Start Weight (g)	
End Weight (g)	
Total weight (g)	0
Item Name	
Start Weight (g)	
End Weight (g)	
Total weight (g)	0
Item Name	
Start Weight (g)	
End Weight (g)	
Total weight (g)	0
Item Name	
Start Weight (g)	
End Weight (g)	
Total weight (g)	0
Item Name	
Start Weight (g)	
End Weight (g)	
Total weight (g)	0
Item Name	
Start Weight (g)	
End Weight (g)	
Total weight (g)	0
Item Name	
Start Weight (g)	
End Weight (g)	
Total weight (g)	0
Item Name	
Start Weight (g)	
End Weight (g)	
Total weight (g)	0

If moisture was not measured and gas was dried before entering the gas meter, impinger weights must be included to produce the moisture concentration used in the isokinetic calculations. If the gas was not dried before it entered the gas meter then impinger weights may be included to produce a nominal 0.1% moisture value.

LABORATORY ANALYSIS RESULTS

CONCEPT LIFE SCIENCES
DELIVERING SCIENCE

Concept Life Sciences is a trading name of Concept Life Sciences Analytical & Development Services Limited registered in England and Wales (No 2514788)

Concept Life Sciences

Certificate of Analysis

Hadfield House
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Report Number: 748359-1

Date of Report: 10-Jul-2018

Customer: Environmental Compliance Ltd
Unit G1
Main Avenue
Treforest Industrial Estate
Pontypridd
CF37 5BF

Customer Contact: Mr John Litterick

Customer Job Reference: P3622
Customer Purchase Order: E8085
Date Job Received at Concept: 29-Jun-2018
Date Analysis Started: 03-Jul-2018
Date Analysis Completed: 06-Jul-2018

The results reported relate to samples received in the laboratory and may not be representative of a whole batch.

Opinions and interpretations expressed herein are outside the scope of UKAS accreditation

This report should not be reproduced except in full without the written approval of the laboratory

Tests covered by this certificate were conducted in accordance with Concept Life Sciences SOPs

All results have been reviewed in accordance with Section 25 of the Concept Life Sciences, Analytical Services Quality Manual

UKAS TESTING 1549

Report checked
and authorised by :
Kathryn Gleaves
Customer Service Advisor

Issued by :
Kathryn Gleaves
Customer Service Advisor

Concept Reference: 748359
Customer Reference: P3622

Impinger(peroxide) Analysed as Impinger(peroxide)
Sulphur Dioxide

					Concept Reference	748359 001	748359 002	748359 003	748359 004	748359 005
					Customer Sample Reference	ECL/18/2984	ECL/18/2985	ECL/18/2986	ECL/18/2987	ECL/18/2988
					Test Sample	AR	AR	AR	AR	AR
					Date Sampled	26-JUN-2018	26-JUN-2018	26-JUN-2018	27-JUN-2018	27-JUN-2018
Determinand	**Method**	**LOD**	**Units**	**Symbol**						
Sulphur Dioxide	IC	0.05	mg/l	U		(13) 0.92	(13) 0.26	(13) 0.08	(13) 11	(13) 0.11
Volume	Vol	1	ml	U		410	210	450	440	210

Concept Reference: 748359
Customer Reference: P3622

Impinger(peroxide) Analysed as Impinger(peroxide)
Sulphur Dioxide

					Concept Reference	748359 006
					Customer Sample Reference	ECL/18/2989
					Test Sample	AR
					Date Sampled	27-JUN-2018
Determinand	**Method**	**LOD**	**Units**	**Symbol**		
Sulphur Dioxide	IC	0.05	mg/l	U		(13) <0.05
Volume	Vol	1	ml	U		450

Concept Reference: 748359
Customer Reference: P3622

Tube (Charcoal 226-09) Analysed as Tube (Charcoal 226-09)
Volatile Organic Compounds (Total)

					Concept Reference	748359 008	748359 009	748359 010	748359 011
					Customer Sample Reference	ECL/18/2991	ECL/18/2992	ECL/18/2993	ECL/18/2994
					Test Sample	AR	AR	AR	AR
					Date Sampled	26-JUN-2018	27-JUN-2018	26-JUN-2018	27-JUN-2018
Determinand	**Method**	**LOD**	**Units**	**Symbol**					
Volatile Organic Compounds (Total)	GC/MS	1	µg	N		190	(37) 1300	<1	<1

Index to symbols used in 748359-1

Value	Description
AR	As Received
37	There was >10% found on the back section of the tube
13	Results have been blank corrected.
U	Analysis is UKAS accredited
N	Analysis is not UKAS accredited

UNCERTAINTY CALCULATIONS

TVOC Measurement Uncertainty – CHP No.1

CHP No.1 - TVOC - Measurement Uncertainty - Uncertainty Calculations Table 1

Performance Characteristics	Standard Uncertainty (% of Range)	Distribution	Min Certified Ranges TVOC 0 - 15 mgC/m³
Lack of fit[1]	u_{lof}	Rectangular (Divisor = √3)	0.73
Span drift[2]	$u_{d,s}$	Rectangular (Divisor = √3)	0.35
Repeatability Standard Deviation (span)[3]	u_r	Normal (Divisor = 1)	32.85
Losses / leakage in the sample system[4]	u_{loss}	Rectangular (Divisor = √3)	23.63
Temperature dependant span drift[5]	u_t	Rectangular (Divisor = √3)	0.30
Interferents[1]	u_i	Rectangular (Divisor = √3)	4.39
Uncertainty of Reference Gas[6]	u_{ref}	Rectangular (Divisor = √3)	24.94

Note:

$$when\ \left|(x_{i,\max} - x_{i,adj})\right| = \left|(x_{i,\min} - x_{i,adj})\right|, then\ u(x_i) = \frac{\Delta x_i}{\sqrt{3}}$$

1 Expressed as a percentage of the certified range
2 Expressed as maximum drift per 24hr period as percentage of the certified range
3 Expressed as a percentage of the certified range
4 Expressed as a percentage of the certified range
5 Expressed as a percentage of the certified range per one degree centigrade
6 Expressed as standard uncertainty in units of measurement i.e. mg/m³ / %Vol taking account of an additional uncertainty of 2% for gas blending
7 Expressed as a percentage of the certified range

CHP No.1 - TVOC - Measurement Uncertainty - Uncertainty Calculations Table 2

Performance Characteristics	Uncertainty	Value of Standard Uncertainty	*TVOC 0 - 15 mgC/m³
Lack of fit	u_{lof}	$u(x_i) = \frac{u_{lof} \times R_i}{\sqrt{3}} =$	0.064
Span drift	$u_{d,s}$	$u(x_i) = \frac{u_{d,s} \times R_i}{\sqrt{3}} =$	0.031
Repeatability Standard Deviation (span)	u_r	$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}} =$	4.93
Losses / leakage in the sample system	u_{loss}	$u(x_i) = \frac{u_{loss} \times R_i}{\sqrt{3}} =$	2.05
Temperature dependant span drift	u_t	$u(x_i) = \frac{u_t}{100} \times R_i \times \sqrt{\frac{(x_{i,max}-x_{adj})^2 + (x_{i,min}-x_{adj})(x_{i,max}-x_{adj}) + (x_{i,min}-x_{adj})^2}{3}}$	0.078
Interferents	u_i	$u(x_i) = \frac{u_i \times R_i}{\sqrt{3}} =$	0.38
Uncertainty of Reference Gas	u_{ref}	$u(x_i) = \frac{u_{ref}}{\sqrt{3}} =$	14.40
Combined Standard Uncertainty		$u_c = \sqrt{u_{lof}^2 + u_{d,s}^2 + u_r^2 + u_{loss}^2 + u_t^2 + u_i^2 + u_{ref}^2}$	15.37
Expanded measurement uncertainty (at 95% confidence)		$U_{EXP} = 2 \times u_c$	30.73
Applied Span Concentration			1439.87
Measured Span Concentration, STP Dry Gas			1434.29
Expanded measurement uncertainty as % of Applied Span			2 %

* **Signal 3030 FID**

TVOC Uncertainty of Measurement Results – CHP No.1

CHP No.1 - TVOC - Uncertainty of Measurement Results - Calculations Part 1

Performance Characteristics	Standard Uncertainty (% of Range)	Distribution	Divisor	Min Certified Range O_2 0 - 25 %Vol	Min Certified Range TVOC 0 - 15 mgC/m^3
Lack of fit(1)	u_{lof}	Rectangular	$\sqrt{3}$	0.13	0.73
Span drift(2)	$u_{d,s}$			0.029	0.35
Losses / leakage in the sample system(4)	u_{loss}			1.00	0.40
Temperature dependant span drift(5)	u_t			0.070	0.30
Interferents(1)	u_i			0.56	4.39
Effect of Voltage Fluctuation(7)	u_v			...	1.80
Effect of Oxygen Synergism(7)	u_{syn}			...	

Notes:

For rectangular distributions, $u(x_i) = \frac{u \times R_i}{\sqrt{3}}$

For $u(x_i) = \Delta x_i \sqrt{\frac{(x_{i,\max} - x_{i,adj})^2 + (x_{i,\min} - x_{i,adj})(x_{i,\max} - x_{i,adj}) + (x_{i,\min} - x_{i,adj})^2}{3}}$, when $|(x_{i,\max} - x_{i,adj})| = |(x_{i,\min} - x_{i,adj})|$, then $u(x_i) = \frac{\Delta x_i}{\sqrt{3}}$

Where $u(x_i) = \frac{\sigma}{\sqrt{n}}$ (See note 6 below), $\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}}$

Performance Characteristics	Uncertainty (Units of final measurement)	Distribution	Divisor	O_2 0 - 25 %Vol	TVOC 0 - 15 mgC/m^3
Lack of fit	u_{lof}	Rectangular	$\sqrt{3}$	0.019	0.064
Span drift	$u_{d,s}$			0.0041	0.031
Temperature dependant span drift	u_t			0.086	0.22
Interferents	u_i			0.081	0.38
Effect of Voltage Fluctuation (See Note)	u_v			...	0.16

CHP No.1 - TVOC - Uncertainty of Measurement Results - Calculations Part 2

Performance Characteristics	Uncertainty (Units of final measurement)	Date & Time	O_2 0 - 25 %Vol	TVOC 0 - 15 mgC/m^3
Losses / leakage in the sample system	u_{loss}	26/06/18 14:00 - 15:00	0.087	6.81
Standard Error of Measured Value	u_{SE}	26/06/18 14:00 - 15:00	0.0024	7.52
Uncertainty due to Moisture Correction(6)	u_{H2O}	26/06/18 14:00 - 15:00	0.10	18.55

Effect on Uncertainty Caused by Oxygen

$$uCorr^{n}_{o_2} = \frac{20.9\% - O_{2,ref}}{(20.9\% - O_{2,measured})x(20.9\% - O_{2,measured})} \text{ x Uncertainty of } O_2 \text{ Meas} =$$

0.03

$$f_{o_2} = \frac{20.9\% - O_{2,ref}}{20.9\% - O_{2,measured}} = \quad 1.3014$$

$$uf_{o_2} = \frac{uCorr^{n}_{o_2}}{f_{o_2}} x100 = \quad 2.46 \quad \%$$

The effect of oxygen on the overall uncertainties (below) is incorporated using the following equation:-

$$u_{combined} = \sqrt{\sum (uf_{o_2})^2 + (Uncertainty\ of\ Measurement\ of\ Determinand)^2}$$

Where oxygen or moisture correction is required, uncertainty based on the standard error of the measured peripheral value is converted to units of final measurement using a sensitivity coefficient C,

$\therefore u(x_i) = C_i u_i$ where $C_i = \frac{\partial f}{\partial x_i}$

CHP No.1 - TVOC - Uncertainty of Measurement Results - Calculations Part 3

Uncertainty	Date & Time	O_2 0 - 25 %Vol	*TVOC 0 - 15 mgC/m^3
Measured Concentration	26/06/18 14:00 - 15:00	8.68	1720.68
Expanded Uncertainty as Percentage of Measured Concentration		4 %	3 %

Combined Standard Uncertainty $u_c = \sqrt{u_{lof}^2 + u_{d,s}^2 + u_r^2 + u_{loss}^2 + u_t^2 + u_i^2 + u_{ref}^2 + u_v^2 + u_{syn}^2}$

Expanded uncertainty (at 95% confidence) $U_{Exp} = 2 \times u_c$

1 Expressed as a percentage of the certified range
2 Expressed as a percentage of the certified range as maximum drift per 24hr period
3 Expressed as a percentage of the certified range
4 Expressed as a percentage of the applied span concentration
5 Expressed as a percentage of the certified range per one degree centigrade
6 Where the uncertainty of moisture is taken from the manual extract test calculations.
7 Expressed as a percentage of the certified range
8 Where no uncertainty is presented above, the uncertainty is > 100%

TVOC Measurement Uncertainty – CHP No.2

CHP No.2 - TVOC - Measurement Uncertainty - Uncertainty Calculations Table 1

Performance Characteristics	Standard Uncertainty (% of Range)	Distribution	Min Certified Ranges TVOC 0 - 15 mgC/m³
Lack of fit[1]	u_{lof}	Rectangular (Divisor = √3)	0.73
Span drift[2]	$u_{d,s}$	Rectangular (Divisor = √3)	0.35
Repeatability Standard Deviation (span)[3]	u_r	Normal (Divisor = 1)	75.54
Losses / leakage in the sample system[4]	u_{loss}	Rectangular (Divisor = √3)	3.49
Temperature dependant span drift[5]	u_t	Rectangular (Divisor = √3)	0.30
Interferents[1]	u_i	Rectangular (Divisor = √3)	4.39
Uncertainty of Reference Gas[6]	u_{ref}	Rectangular (Divisor = √3)	24.94

Note:

$$when\ \left|(x_{i,\max} - x_{i,adj})\right| = \left|(x_{i,\min} - x_{i,adj})\right|, then\ u(x_i) = \frac{\Delta x_i}{\sqrt{3}}$$

1 Expressed as a percentage of the certified range
2 Expressed as maximum drift per 24hr period as percentage of the certified range
3 Expressed as a percentage of the certified range
4 Expressed as a percentage of the certified range
5 Expressed as a percentage of the certified range per one degree centigrade
6 Expressed as standard uncertainty in units of measurement i.e. mg/m³ / %Vol taking account of an additional uncertainty of 2% for gas blending
7 Expressed as a percentage of the certified range

CHP No.2 - TVOC - Measurement Uncertainty - Uncertainty Calculations Table 2

Performance Characteristics	Uncertainty	Value of Standard Uncertainty	*TVOC 0 - 15 mgC/m³
Lack of fit	u_{lof}	$u(x_i) = \frac{u_{lof} \times R_i}{\sqrt{3}} =$	0.064
Span drift	$u_{d,s}$	$u(x_i) = \frac{u_{d,s} \times R_i}{\sqrt{3}} =$	0.031
Repeatability Standard Deviation (span)	u_r	$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}} =$	11.33
Losses / leakage in the sample system	u_{loss}	$u(x_i) = \frac{u_{loss} \times R_i}{\sqrt{3}} =$	0.30
Temperature dependant span drift	u_t	$u(x_i)=\frac{u_t}{100}\times R_i\times\sqrt{\frac{(x_{i,max}-x_{adj})^2+(x_{i,min}-x_{adj})(x_{i,max}-x_{adj})+(x_{i,min}-x_{adj})^2}{3}}$	0.078
Interferents	u_i	$u(x_i) = \frac{u_i \times R_i}{\sqrt{3}} =$	0.38
Uncertainty of Reference Gas	u_{ref}	$u(x_i) = \frac{u_{ref}}{\sqrt{3}} =$	14.40
Combined Standard Uncertainty		$u_c = \sqrt{u_{lof}^2 + u_{d,s}^2 + u_r^2 + u_{loss}^2 + u_t^2 + u_i^2 + u_{ref}^2}$	18.33
Expanded measurement uncertainty (at 95% confidence)		$U_{EXP} = 2 \times u_c$	36.67
Applied Span Concentration			1439.87
Measured Span Concentration, STP Dry Gas			1431.90
Expanded measurement uncertainty as % of Applied Span			3 %

* **Signal 3030 FID**

TVOC Uncertainty of Measurement Results – CHP No.2

CHP No.2 - TVOC - Uncertainty of Measurement Results - Calculations Part 1

Performance Characteristics	Standard Uncertainty (% of Range)	Distribution	Divisor	Min Certified Range: O_2 0 - 25 %Vol	Min Certified Range: TVOC 0 - 15 mgC/m^3
Lack of fit[1]	u_{lof}	Rectangular	$\sqrt{3}$	0.13	0.73
Span drift[2]	$u_{d,s}$			0.029	0.35
Losses / leakage in the sample system[4]	u_{loss}			1.00	0.058
Temperature dependant span drift[5]	u_t			0.070	0.30
Interferents[1]	u_i			0.56	4.39
Effect of Voltage Fluctuation[7]	u_v			...	1.80
Effect of Oxygen Synergism[7]	u_{syn}			...	

Notes:

For rectangular distributions, $u(x_i) = \frac{u \times R_i}{\sqrt{3}}$

For $u(x_i) = \Delta x_i \sqrt{\frac{(x_{i,\max} - x_{i,adj})^2 + (x_{i,\min} - x_{i,adj})(x_{i,\max} - x_{i,adj}) + (x_{i,\min} - x_{i,adj})^2}{3}}$, when $|(x_{i,\max} - x_{i,adj})| = |(x_{i,\min} - x_{i,adj})|$, then $u(x_i) = \frac{\Delta x_i}{\sqrt{3}}$

Where $u(x_i) = \frac{\sigma}{\sqrt{n}}$ (See note 6 below), $\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}}$

Performance Characteristics	Uncertainty (Units of final measurement)	Distribution	Divisor	O_2 0 - 25 %Vol	TVOC 0 - 15 mgC/m^3
Lack of fit	u_{lof}	Rectangular	$\sqrt{3}$	0.019	0.064
Span drift	$u_{d,s}$			0.0041	0.031
Temperature dependant span drift	u_t			0.018	0.045
Interferents	u_i			0.081	0.38
Effect of Voltage Fluctuation (See Note)	u_v			...	0.16

CHP No.2 - TVOC - Uncertainty of Measurement Results - Calculations Part 2

Performance Characteristics	Uncertainty (Units of final measurement)	Date & Time	O_2 0 - 25 %Vol	TVOC 0 - 15 mgC/m^3
Losses / leakage in the sample system	u_{loss}	27/06/18 09:05 - 10:05	0.081	0.70
Standard Error of Measured Value	u_{SE}	27/06/18 09:05 - 10:05	0.0067	3.05
Uncertainty due to Moisture Correction[6]	u_{H2O}	27/06/18 09:05 - 10:05	0.13	16.34

Effect on Uncertainty Caused by Oxygen

$$uCorr^{n}_{o_2} = \frac{20.9\% - O_{2,ref}}{(20.9\% - O_{2,measured})x(20.9\% - O_{2,measured})} \text{ x Uncertainty of } O_2 \text{ Meas} =$$

0.03

$$f_{o_2} = \frac{20.9\% - O_{2,ref}}{20.9\% - O_{2,measured}} = \quad 1.2429$$

$$uf_{o_2} = \frac{uCorr^{n}_{o_2}}{f_{o_2}} x100 = \quad 2.35 \quad \%$$

The effect of oxygen on the overall uncertainties (below) is incorporated using the following equation:-

$$u_{combined} = \sqrt{\sum (uf_{o_2})^2 + (Uncertainty\ of\ Measurement\ of\ Determinand)^2}$$

Where oxygen or moisture correction is required, uncertainty based on the standard error of the measured peripheral value is converted to units of final measurement using a sensitivity coefficient C,

$\therefore u(x_i) = C_i u_i$ where $C_i = \frac{\partial f}{\partial x_i}$

CHP No.2 - TVOC - Uncertainty of Measurement Results - Calculations Part 3

Uncertainty	Date & Time	O_2 0 - 25 %Vol	*TVOC 0 - 15 mgC/m^3
Measured Concentration	27/06/18 09:05 - 10:05	8.11	1193.62
Expanded Uncertainty as Percentage of Measured Concentration		4 %	4 %

Combined Standard Uncertainty $u_c = \sqrt{u_{lof}^2 + u_{d,s}^2 + u_r^2 + u_{loss}^2 + u_t^2 + u_i^2 + u_{ref}^2 + u_v^2 + u_{syn}^2}$

Expanded uncertainty (at 95% confidence) $U_{Exp} = 2 \times u_c$

1 Expressed as a percentage of the certified range
2 Expressed as a percentage of the certified range as maximum drift per 24hr period
3 Expressed as a percentage of the certified range
4 Expressed as a percentage of the applied span concentration
5 Expressed as a percentage of the certified range per one degree centigrade
6 Where the uncertainty of moisture is taken from the manual extract test calculations.
7 Expressed as a percentage of the certified range
8 Where no uncertainty is presented above, the uncertainty is > 100%

Combustion Gases Measurement Uncertainty – CHP No.1

Measurement Uncertainty Calculations Part 1

Horiba PG 250 Performance Characteristics	Standard Uncertainty (% of Range)	Distributiuon	Minimum Certified Range (R_i) NO 0 - 125 mg/m³	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Lack of fit(1)	u_{lof}	Rectangular (Divisor = √3)	0.40	0.40	0.13
Span drift(2)	$u_{d,s}$	Rectangular (Divisor = √3)	0.27	0.29	0.029
Repeatability Standard Deviation (span)(3)	u_r	Normal (Divisor = 1)	2.93	2.91	0.11
Losses / leakage in the sample system(4)	u_{loss}	Rectangular (Divisor = √3)	3.65	17.65	0.07
Temperature dependant span drift(5)	u_t	Rectangular (Divisor = √3)	0.18	0.050	0.070
Interferents(1)	u_i	Rectangular (Divisor = √3)	1.20	2.90	0.56
Uncertainty of Reference Gas(6)	u_{ref}	Rectangular (Divisor = √3)	9.10	21.67	0.15

Note:

$$when \left|(x_{i,\max} - x_{i,adj})\right| = \left|(x_{i,\min} - x_{i,adj})\right|, then\ u(x_i) = \frac{\Delta x_i}{\sqrt{3}}$$

1 Expressed as a percentage of the certified range
2 Expressed as a percentage of the certified range as maximum drift per 24hr period
3 Expressed as a percentage of the certified range
4 Expressed as a percentage of the certified range
5 Expressed as a percentage of the certified range per one degree centigrade
6 Expressed as standard uncertainty in units of measurement i.e. mg/m³ / %Vol inc additional uncertainty of 2% for gas blending
7 Data not available so not included

Measurement Uncertainty Calculations Part 2

Horiba PG 250 Performance Characteristics	Uncertainty	Value of Standard Uncertainty	NO 0 - 125 mg/m³	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Lack of fit	u_{lof}	$u(x_i) = \frac{u_{lof} \times R_i}{\sqrt{3}} =$	0.29	0.22	0.019
Span drift	$u_{d,s}$	$u(x_i) = \frac{u_{d,s} \times R_i}{\sqrt{3}} =$	0.20	0.16	0.0041
Repeatability Standard Deviation (span)	u_r	$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}} =$	2.93	2.91	0.11
Losses / leakage in the sample system	u_{loss}	$u(x_i) = \frac{u_{loss} \times R_i}{\sqrt{3}} =$	2.635	9.68	0.011
Temperature dependant span drift	u_t	$u(x_i) = \frac{u_t}{100} \times R_i \times \sqrt{\frac{(x_{i,max} - x_{adj})^2 + (x_{i,min} - x_{adj})(x_{i,max} - x_{adj}) + (x_{i,min} - x_{adj})^2}{3}}$	0.06	0.014	0.005
Interferents	u_i	$u(x_i) = \frac{u_i \times R_i}{\sqrt{3}} =$	0.87	1.59	0.081
Uncertainty of Reference Gas	u_{ref}	$u(x_i) = \frac{u_{ref}}{\sqrt{3}} =$	5.26	12.51	0.087
Combined Standard Uncertainty		$u_c = \sqrt{u_{lof}^2 + u_{d,s}^2 + u_r^2 + u_{loss}^2 + u_t^2 + u_i^2 + u_{ref}^2}$	6.64	16.17	0.16
Expanded measurement uncertainty (at 95% confidence)		$U_{EXP} = 2 \times u_c$	13.27	32.33	0.32
Applied Span Concentration			525.62	1251.25	15.15
Measured Span Concentration, STP Dry Gas			533.01	1235.90	15.13
Expanded measurement uncertainty as % of Applied Span			3%	3%	2%

Combustion Gases Uncertainty of Measurement Results – CHP No.1

Uncertainty of Measurement Results - Calculations Part 1

Horiba PG 250 Performance Characteristics	Standard Uncertainty (% of Range)	Distribution	Divisor	Minimum Certified Range (R_i) NO 0 - 125 mg/m³	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Lack of fit[1]	u_{lof}	Rectangular	$\sqrt{3}$	0.40	0.40	0.13
Span drift[2]	$u_{d,s}$			0.27	0.29	0.029
Losses / leakage in the sample system[4]	u_{loss}			3.65	17.65	0.073
Temperature dependant span drift[5]	u_t			0.18	0.050	0.070

Notes:

For rectangular distributions, $u(x_i) = \frac{u \times R_i}{\sqrt{3}}$

For $u(x_i) = \Delta x_i \sqrt{\frac{(x_{i,\max} - x_{i,adj})^2 + (x_{i,\min} - x_{i,adj})(x_{i,\max} - x_{i,adj}) + (x_{i,\min} - x_{i,adj})^2}{3}}$, when $|(x_{i,\max} - x_{i,adj})| = |(x_{i,\min} - x_{i,adj})|$, then $u(x_i) = \frac{\Delta x_i}{\sqrt{3}}$

Where $u(x_i) = \frac{\sigma}{\sqrt{n}}$ (See note 6 below), $\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}}$

Horiba PG 250 Performance Characteristics	Uncertainty (Units of final measurement)	Distribution	Divisor	NO 0 - 125 mg/m³	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Lack of fit	u_{lof}	Rectangular	$\sqrt{3}$	0.29	0.22	0.019
Span drift	$u_{d,s}$			0.20	0.16	0.0041
Temperature dependant span drift	u_t			3.45	0.73	0.27
Interferents	u_i			0.87	1.59	0.081

Uncertainty of Measurement Results - Calculations Part 2

Horiba PG 250 Performance Characteristics	Uncertainty (Units of final measurement)	Date & Time	NO 0 - 125 mg/m³	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Losses / leakage in the sample system	u_{loss}	26/06/18 14:00 - 15:00	12.45	149.67	0.0064
Standard Error of Measured Value	u_{SE}	26/06/18 14:00 - 15:00	0.59	0.26	0.0024

Effect on Uncertainty Caused by Oxygen

$$uCorr^n_{O_2} = \frac{20.9\% - O_{2,ref}}{(20.9\% - O_{2,measured})x(20.9\% - O_{2,measured})} x\,Uncertainty\ of\ O_2\ Measurement = 0.032$$

$$f_{O_2} = \frac{20.9\% - O_{2,ref}}{20.9\% - O_{2,measured}} = 1.8312 \qquad uf_{O_2} = \frac{uCorr^n_{O_2}}{f_{O_2}} x100 = 1.75\ \%$$

The effect of oxygen on the overall uncertainties (below) is incorporated using the following equation:-

$$u_{combined} = \sqrt{\sum (uf_{O_2})^2 + (Uncertainty\ of\ Measurement\ of\ Determinand)^2}$$

Where oxygen or moisture correction is required, uncertainty based on the standard error of the measured peripheral value is converted to units of final measurement using a sensitivity coefficient C,

$\therefore\ u(x_i) = C_i u_i$ where $C_i = \frac{\partial f}{\partial x_i}$

Uncertainty of Measurement Results - Calculations Part 3

Horiba PG 250 Uncertainty	Date & Time	NOx (as NO2) 0 - 125 mg/m³	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Measured Concentration	26/06/18 14:00 - 15:00	340.80	847.81	8.68
Expanded Uncertainty as Percentage of Measured Concentration		8%	35%	7%

Combined Standard Uncertainty $u_c = \sqrt{u_{lof}^2 + u_{d,s}^2 + u_r^2 + u_{loss}^2 + u_t^2 + u_i^2 + u_{ref}^2 + u_v^2 + u_{syn}^2}$

Expanded uncertainty (at 95% confidence) $U_{Exp} = 2 \times u_c$

1 Expressed as a percentage of the certified range
2 Expressed as a percentage of the certified range as maximum drift per 24hr period
3 Expressed as a percentage of the certified range
4 Expressed as a percentage of the certified range
5 Expressed as a percentage of the certified range per one degree centigrade
6 Where the uncertainty of Moisture is taken as the standard error of the time averaged value used to correct to Dry Conditions
7 If no value for uncertainty is presented above, the uncertainty is considered to be > 100%

Combustion Gases Measurement Uncertainty – CHP No.2 & A3 Boiler

Measurement Uncertainty Calculations Part 1

Horiba PG 250 Performance Characteristics	Standard Uncertainty (% of Range)	Distributiuon	Minimum Certified Range (R_i) NO 0 - 125 mg/m^3	CO 0 - 95 mg/m^3	O_2 0 - 25 %Vol
Lack of fit[1]	u_{lof}	Rectangular (Divisor = √3)	0.40	0.40	0.13
Span drift[2]	$u_{d,s}$	Rectangular (Divisor = √3)	0.27	0.29	0.029
Repeatability Standard Deviation (span)[3]	u_r	Normal (Divisor = 1)	3.83	2.72	0.22
Losses / leakage in the sample system[4]	u_{loss}	Rectangular (Divisor = √3)	3.65	17.65	0.07
Temperature dependant span drift[5]	u_t	Rectangular (Divisor = √3)	0.18	0.050	0.070
Interferents[1]	u_i	Rectangular (Divisor = √3)	1.20	2.90	0.56
Uncertainty of Reference Gas[6]	u_{ref}	Rectangular (Divisor = √3)	9.10	21.67	0.15

Note:

$$when \left|(x_{i,\max} - x_{i,adj})\right| = \left|(x_{i,\min} - x_{i,adj})\right|, then\ u(x_i) = \frac{\Delta x_i}{\sqrt{3}}$$

1 Expressed as a percentage of the certified range
2 Expressed as a percentage of the certified range as maximum drift per 24hr period
3 Expressed as a percentage of the certified range
4 Expressed as a percentage of the certified range
5 Expressed as a percentage of the certified range per one degree centigrade
6 Expressed as standard uncertainty in units of measurement i.e. mg/m^3 / %Vol inc additional uncertainty of 2% for gas blending
7 Data not available so not included

Measurement Uncertainty Calculations Part 2

Horiba PG 250 Performance Characteristics	Uncertainty	Value of Standard Uncertainty	NO 0 - 125 mg/m^3	CO 0 - 95 mg/m^3	O_2 0 - 25 %Vol
Lack of fit	u_{lof}	$u(x_i) = \frac{u_{lof} \times R_i}{\sqrt{3}} =$	0.29	0.22	0.019
Span drift	$u_{d,s}$	$u(x_i) = \frac{u_{d,s} \times R_i}{\sqrt{3}} =$	0.20	0.16	0.0041
Repeatability Standard Deviation (span)	u_r	$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}} =$	3.83	2.72	0.22
Losses / leakage in the sample system	u_{loss}	$u(x_i) = \frac{u_{loss} \times R_i}{\sqrt{3}} =$	2.635	9.68	0.011
Temperature dependant span drift	u_t	$u(x_i) = \frac{u_t}{100} \times R_i \times \sqrt{\frac{(x_{i,max} - x_{adj})^2 + (x_{i,min} - x_{adj})(x_{i,max} - x_{adj}) + (x_{i,min} - x_{adj})^2}{3}}$	0.97	0.206	0.076
Interferents	u_i	$u(x_i) = \frac{u_i \times R_i}{\sqrt{3}} =$	0.87	1.59	0.081
Uncertainty of Reference Gas	u_{ref}	$u(x_i) = \frac{u_{ref}}{\sqrt{3}} =$	5.26	12.51	0.087
Combined Standard Uncertainty		$u_c = \sqrt{u_{lof}^2 + u_{d,s}^2 + u_r^2 + u_{loss}^2 + u_t^2 + u_i^2 + u_{ref}^2}$	7.15	16.14	0.27
Expanded measurement uncertainty (at 95% confidence)		$U_{EXP} = 2 \times u_c$	14.29	32.27	0.53
Applied Span Concentration			525.62	1251.25	15.15
Measured Span Concentration, STP Dry Gas			526.68	1235.30	15.08
Expanded measurement uncertainty as % of Applied Span			3%	3%	4%

Combustion Gases Uncertainty of Measurement Results – CHP No.2

Uncertainty of Measurement Results - Calculations Part 1

Horiba PG 250 Performance Characteristics	Standard Uncertainty (% of Range)	Distribution	Divisor	Minimum Certified Range (R_i) NO 0 - 125 mg/m^3	CO 0 - 95 mg/m^3	O_2 0 - 25 %Vol
Lack of fit[(1)]	u_{lof}	Rectangular	$\sqrt{3}$	0.40	0.40	0.13
Span drift[(2)]	$u_{d,s}$			0.27	0.29	0.029
Losses / leakage in the sample system[(4)]	u_{loss}			3.65	17.65	0.073
Temperature dependant span drift[(5)]	u_t			0.18	0.050	0.070

Notes:

For rectangular distributions, $u(x_i) = \frac{u \times R_i}{\sqrt{3}}$

For $u(x_i) = \Delta x_i \sqrt{\frac{(x_{i,\max} - x_{i,adj})^2 + (x_{i,\min} - x_{i,adj})(x_{i,\max} - x_{i,adj}) + (x_{i,\min} - x_{i,adj})^2}{3}}$, when $|(x_{i,\max} - x_{i,adj})| = |(x_{i,\min} - x_{i,adj})|$, then $u(x_i) = \frac{\Delta x_i}{\sqrt{3}}$

Where $u(x_i) = \frac{\sigma}{\sqrt{n}}$ (See note 6 below), $\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}}$

Horiba PG 250 Performance Characteristics	Uncertainty (Units of final measurement)	Distribution	Divisor	NO 0 - 125 mg/m^3	CO 0 - 95 mg/m^3	O_2 0 - 25 %Vol
Lack of fit	u_{lof}	Rectangular	$\sqrt{3}$	0.29	0.22	0.019
Span drift	$u_{d,s}$			0.20	0.16	0.0041
Temperature dependant span drift	u_t			0.70	0.15	0.055
Interferents	u_i			0.87	1.59	0.081

Uncertainty of Measurement Results - Calculations Part 2

Horiba PG 250 Performance Characteristics	Uncertainty (Units of final measurement)	Date & Time	NO 0 - 125 mg/m^3	CO 0 - 95 mg/m^3	O_2 0 - 25 %Vol
Losses / leakage in the sample system	u_{loss}	27/06/18 09:05 - 10:05	14.07	134.46	0.0059
Standard Error of Measured Value	u_{SE}	27/06/18 09:05 - 10:05	1.14	0.32	0.0067

Effect on Uncertainty Caused by Oxygen $uCorr^{n}_{o_2} = \frac{20.9\% - O_{2,ref}}{(20.9\% - O_{2,measured})x(20.9\% - O_{2,measured})} x Uncertainty\ of\ O_2\ Measurement =$ 0.029

$f_{o_2} = \frac{20.9\% - O_{2,ref}}{20.9\% - O_{2,measured}} =$ 1.9611 $uf_{o_2} = \frac{uCorr^{n}_{o_2}}{f_{o_2}} x100 =$ 1.49 %

The effect of oxygen on the overall uncertainties (below) is incorporated using the following equation:-

$$u_{combined} = \sqrt{\sum (uf_{o_2})^2 + (Uncertainty\ of\ Measurement\ of\ Determinand)^2}$$

Where oxygen or moisture correction is required, uncertainty based on the standard error of the measured peripheral value is converted to units of final measurement using a sensitivity coefficient C,

$\therefore u(x_i) = C_i u_i$ where $C_i = \frac{\partial f}{\partial x_i}$

Uncertainty of Measurement Results - Calculations Part 3

Horiba PG 250 Uncertainty	Date & Time	NOx (as NO2) 0 - 125 mg/m^3	CO 0 - 95 mg/m^3	O_2 0 - 25 %Vol
Measured Concentration	27/06/18 09:05 - 10:05	385.17	761.65	8.11
Expanded Uncertainty as Percentage of Measured Concentration		8%	35%	3%

Combined Standard Uncertainty $u_c = \sqrt{u_{lof}^2 + u_{d,s}^2 + u_r^2 + u_{loss}^2 + u_t^2 + u_i^2 + u_{ref}^2 + u_v^2 + u_{syn}^2}$

Expanded uncertainty (at 95% confidence) $U_{Exp} = 2 \times u_c$

1 Expressed as a percentage of the certified range
2 Expressed as a percentage of the certified range as maximum drift per 24hr period
3 Expressed as a percentage of the certified range
4 Expressed as a percentage of the certified range
5 Expressed as a percentage of the certified range per one degree centigrade
6 Where the uncertainty of Moisture is taken as the standard error of the time averaged value used to correct to Dry Conditions
7 If no value for uncertainty is presented above, the uncertainty is considered to be > 100%

Combustion Gases Uncertainty of Measurement Results – Standby Boiler A3

Uncertainty of Measurement Results - Calculations Part 1

Horiba PG 250 Performance Characteristics	Standard Uncertainty (% of Range)	Distribution	Divisor	Minimum Certified Range (R_i) NO 0 - 125 mg/m³	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Lack of fit[(1)]	u_{lof}	Rectangular	$\sqrt{3}$	0.40	0.40	0.13
Span drift[(2)]	$u_{d,s}$			0.27	0.29	0.029
Losses / leakage in the sample system[(4)]	u_{loss}			3.65	17.65	0.073
Temperature dependant span drift[(5)]	u_t			0.18	0.050	0.070

Notes:

For rectangular distributions, $u(x_i) = \frac{u \times R_i}{\sqrt{3}}$

For $u(x_i) = \Delta x_i \sqrt{\frac{(x_{i,\max} - x_{i,adj})^2 + (x_{i,\min} - x_{i,adj})(x_{i,\max} - x_{i,adj}) + (x_{i,\min} - x_{i,adj})^2}{3}}$, when $|(x_{i,\max} - x_{i,adj})| = |(x_{i,\min} - x_{i,adj})|$, then $u(x_i) = \frac{\Delta x_i}{\sqrt{3}}$

Where $u(x_i) = \frac{\sigma}{\sqrt{n}}$ (See note 6 below), $\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}}$

Horiba PG 250 Performance Characteristics	Uncertainty (Units of final measurement)	Distribution	Divisor	NO 0 - 125 mg/m³	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Lack of fit	u_{lof}	Rectangular	$\sqrt{3}$	0.29	0.22	0.019
Span drift	$u_{d,s}$			0.20	0.16	0.0041
Temperature dependant span drift	u_t			0.70	0.15	0.055
Interferents	u_i			0.87	1.59	0.081

Uncertainty of Measurement Results - Calculations Part 2

Horiba PG 250 Performance Characteristics	Uncertainty (Units of final measurement)	Date & Time	NO 0 - 125 mg/m³	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Losses / leakage in the sample system	u_{loss}	27/06/18 12:45 - 13:45	4.86	0.13	0.0023
Standard Error of Measured Value	u_{SE}	27/06/18 12:45 - 13:45	0.25	0.084	0.041

Effect on Uncertainty Caused by Oxygen $uCorr^{n}_{O_2} = \frac{20.9\% - O_{2,ref}}{(20.9\% - O_{2,measured})x(20.9\% - O_{2,measured})} x Uncertainty\ of\ O_2\ Measurement =$ 0.010

$f_{O_2} = \frac{20.9\% - O_{2,ref}}{20.9\% - O_{2,measured}} =$ 5.6420 $uf_{O_2} = \frac{uCorr^{n}_{O_2}}{f_{O_2}} x100 =$ 0.18 %

The effect of oxygen on the overall uncertainties (below) is incorporated using the following equation:-

$$u_{combined} = \sqrt{\sum (uf_{O_2})^2 + (Uncertainty\ of\ Measurement\ of\ Determinand)^2}$$

Where oxygen or moisture correction is required, uncertainty based on the standard error of the measured peripheral value is converted to units of final measurement using a sensitivity coefficient C,

$\therefore u(x_i) = C_i u_i$ where $C_i = \frac{\partial f}{\partial x_i}$

Uncertainty of Measurement Results - Calculations Part 3

Horiba PG 250 Uncertainty	Date & Time	NOx (as NO2) 0 - 125 mg/m³	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Measured Concentration	27/06/18 12:45 - 13:45	133.17	0.75	3.17
Expanded Uncertainty as Percentage of Measured Concentration		8%	>100%	7%

Combined Standard Uncertainty $u_c = \sqrt{u_{lof}^2 + u_{d,s}^2 + u_r^2 + u_{loss}^2 + u_t^2 + u_i^2 + u_{ref}^2 + u_v^2 + u_{syn}^2}$

Expanded uncertainty (at 95% confidence) $U_{Exp} = 2 \times u_c$

1 Expressed as a percentage of the certified range
2 Expressed as a percentage of the certified range as maximum drift per 24hr period
3 Expressed as a percentage of the certified range
4 Expressed as a percentage of the certified range
5 Expressed as a percentage of the certified range per one degree centigrade
6 Where the uncertainty of Moisture is taken as the standard error of the time averaged value used to correct to Dry Conditions
7 If no value for uncertainty is presented above, the uncertainty is considered to be >100%

CHP No.1 SO2 Measurement Uncertainty

Site: Five Fords WwTW CHP Facility
Location: CHP No.1

$$u_{mass} = \sqrt{\sum (u_{filter})^2 + (u_{solution})^2}$$

Determinand	Filter mg	Solution mg	Recovered Mass mg	LAB Method Uncert (%) K=2 Filter mg	LAB Method Uncert (%) K=2 Solution mg	Standard Uncertainty Filter mg	Standard Uncertainty Solution mg	Combined Uncertainty mg
				SO2				
...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...
Sulphur Dioxide	...	0.43	0.43	...	0.0561	...	0.0281	0.0281
...	...	...	...	...	...	...	...	...
				...				
...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...

	SO2		Standard Uncertainty @ 95%			
Sampled Volume (V_m)	0.89	m^3	uV_m	0.001	m^3	
Meter Correction Factor (Yd)	0.97	...		...	...	
Meter Temperature (T_m)	307.00	k	uT_m	1.5	k	
Average Differential Pressure (ΔH)	20.00	mmH_2O	uΔH	0.25	mmH_2O	
Barometric Pressure (ρ_b)	765.06	mmHg	$u\rho_b$	3.8	mmHg	
ΔH + ρs (ρ_m)	102.20	kPa		...	...	
Oxygen content ($O_{2,m}$)	8.68	% by volume	$uO_{2,m} = \sigma/\sqrt{n}$	0.00215		% by volume
Moisture Content (H_2O)	9.73	% by volume	uH_2O	0.31		% by volume

Note: In the following calculations, the sensitivity coefficient (C) is estimated using: $C_i = \frac{\partial f}{\partial x_i}$

For each factor, uncertainty is then calculated by $C_i u_i$ where C is the sensitivity coefficient, u is the standard uncertainty and i is the index identifying the contributing factor e.g. $i = uV_m$, uT_m etc.

Where results are required at wet conditions, the following correction factor is used to convert the data from the dry gas meter:

SO2:

$$f_{s,wet} = \frac{100}{(100 - H_2O)} = \quad 1.00$$

Uncertainty in correction factor to STP due to measured ΔH uncertainty component (uΔH), measured stack pressure uncertainty component ($u\rho_s$) & measured temperature of dry gas uncertainty component ($uT_{m\,Dry}$)

SO2:

$$f_s = \frac{273}{760} \times \frac{P_b + \frac{\Delta H}{13.6}}{T_m} \times Y_d = \quad 0.871$$

	Maximum	Minimum	Sensitivity	ufstp
uΔH	0.87	0.87	0.0000835	0.0000209
$u\rho_b$	0.88	0.87	0.00114	0.00426
uT_m	0.88	0.87	0.00284	0.00426
H_2O	...	...	...	...

$$\frac{uf_s}{f_s} = \sqrt{\left(\frac{\sqrt{(u\Delta H)^2 + (uP_s)^2}}{(P_m/101.3)}\right)^2 + \left(\frac{uT_m}{(T_m/273.15)}\right)^2 + \left(\frac{uH_2O}{100/(100 - H_2O)}\right)^2} = \quad 0.00494$$

Uncertainty in volume @ STP due to volume correction factor uncertainty component (uV_{std}) & volume uncertainty component (uV_m)

SO2:

$$V_{std} = V_{measured} \times f_s = \quad 0.775$$

	Maximum m^3	Minimum m^3	Sensitivity	Standard Uncertainty (m^3)
Effect of uV_{std}	0.78	0.77	0.89	0.00439
Effect of uV_m	0.78	0.77	0.87	0.000871

Combined Standard Uncertainty

$$\frac{uV_{std}}{V_{std}} = \sqrt{\left(\frac{uV_{std}}{f_s}\right)^2 + \left(\frac{uV_m}{V_m}\right)^2} = \quad 0.00398$$

Uncertainty of Oxygen Correction Factor (%):-

SO2:

$$f_{o_2} = \frac{20.9\% - O_{2,ref}}{20.9\% - O_{2,measured}} = \quad 1.30$$

$$uCorr^{n}_{o_2} = \frac{20.9\% - O_{2,ref}}{(20.9\% - O_{2,measured})x(20.9\% - O_{2,measured})} x\,Uncertainty\,of\;O_2\;Measurement = \quad 0.0320$$

$$uf_{o_2} = \frac{uCorr^{n}_{o_2}}{f_{o_2}} x100 = \quad 2.46\ \%$$

Uncertainty in final measurement @ reference conditions due to mass uncertainty component (uM)

Determinand	SO2:			
	Maximum mg/Nm^3	Minimum mg/Nm^3	Sensitivity	uM mg/Nm^3
...	...	...	...	...
...	...	...	...	...
Sulphur Dioxide	0.77	0.68	1.68	0.0472
...	...	...	...	...

Uncertainty in final measurement @ reference conditions due to uncertainty component arrising from leak and/or loss (assumed 2% max) in the sample system (uL)

Determinand	SO2: uL mg/Nm^3
...	...
...	...
Sulphur Dioxide	0.00838
...	...

Uncertainty in final measurement @ Reference Conditions due to uVstp

Determinand	SO2:			
	Maximum mg/Nm^3	Minimum mg/Nm^3	Sensitivity	uVstp mg/Nm^3
...	...	...	...	...
...	...	...	...	...
Sulphur Dioxide	0.73	0.72	0.94	0.00373
...	...	...	...	...

Combined Uncertainty excluding oxygen contribution

$$u_{combined} = \sqrt{\sum (u_M)^2 + (u_L)^2 + (uV_{stp})^2}$$

Determinand	SO2:			
	Combined Uncertainty mg/Nm^3	Expanded Uncertainty mg/Nm^3	Measured Concentration mg/Nm^3	Percent of Measured Concentration
...	...	...	...	...
...	...	...	...	...
Sulphur Dioxide	0.0480	0.0961	0.73	13.24
...	...	...	...	...

Combined Uncertainty including oxygen contribution

$$u_{combined} = \sqrt{\sum (uf_{o_2})^2 + (Uncertainty\ of\ Measurement\ of\ Determinand)^2}$$

Determinand	Measurement Uncertainty of Determinand	Measurement Uncertainty of Oxygen Corrn Factor	Overall Measurement Uncertainty inc O_2 Corr^n factor (Ucombined)
...	...	...	...
...	...	...	...
Sulphur Dioxide	13.24	2.46	13.47
...	...	...	...

CHP No.1 NMVOC Measurement Uncertainty

Note:
Results based on Charcoal Tubes Only!

Site: Dwr Cymru Welsh Water, Five Fords WwTW CHP Facility
Location: CHP's, Stack ID:CHP No.1

				Standard Uncertainty @ 95%		
Sampled Volume	V_m	0.07618	m^3	uV_m	0.000	m^3
Meter Correction Factor or ml/count	Yd	0.971	...	...	...	...
Meter Temperature	T_m	317.50	k	uT_m	1.5	k
Barometric Pressure	ρ_b	1020.00	mBar		10.0	mBar
Oxygen content	$O_{2,m}$	8.69	%Vol	$uO_{2,m}$	0.52	%Vol
Moisture	H_2O	9.71	%Vol	uH_2O	1.53	%Vol

Tubes						
Determinand	Recovered Mass		Standard Uncertainty			
NMVOC	190.00	μg	uM	19.00	μg	

Note: In the following calculations, the sensitivity coefficient (C) is estimated using: $C_i = \frac{\partial f}{\partial x_i}$

For each factor, uncertainty is then calculated by $C_i u_i$ where *C* is the sensitivity coefficient, *u* is the standard uncertainty and *i* is the index identifying the contributing factor e.g. i = uV_m, uT_m etc.

Where results are required at wet conditions, the following correction factor is used to convert the data from the dry gas meter:

$$f_{s,wet} = \frac{100}{(100 - H_2O)} = 1.00$$

Uncertainty in correction factor to STP due to measured barometric pressure uncertainty component (upb), measured temperature of dry gas uncertainty component (uT_m) & measured moisture (uH_2O) where required

$$f_s = \frac{273}{T_m} \times \frac{\rho}{101.3} = 0.87$$

	Maximum	Minimum	Sensitivity	ufstp
$u\rho_b$	0.47	0.46	0.000456	0.00456
uT_m	0.87	0.86	0.00273	0.00409
uH_2O	...	...	...	...

$$\frac{uf_s}{f_s} = \sqrt{\left(\frac{uP_b}{(P_b/101.3)}\right)^2 + \left(\frac{uT_m}{(T_m/273.15)}\right)^2 + \left(\frac{uH_2O}{100/(100-H_2O)}\right)^2} = 0.00497$$

Uncertainty in volume @ STP due to volume correction factor uncertainty component (uVstd) & volume uncertainty component (uVm)

$$V_{std} = V_{measured} \times f_s = 0.0640$$

	Maximum m^3	Minimum m^3	Sensitivity	Standard Uncertainty m^3
Effect of uf_s	0.0644	0.0637	0.0740	0.000368
Effect of uV_m	0.0641	0.0640	0.84	8.407E-06

$$\frac{uV_{std}}{V_{std}} = \sqrt{\left(\frac{uf_s}{f_s}\right)^2 + \left(\frac{uV_m}{V_m}\right)^2} = 0.00474$$

Uncertainty of correction factor to reference conditions (excluding oxygen contribution) & Uncertainty in final measurement @ reference conditions due to uncertainty component arrising from leak and/or loss (assumed 2% max) in the sample system (uL)

$$uL = \frac{Conc \times \frac{2}{100}}{\sqrt{3}}$$

	Tubes uL mg/Nm^3	Condensate uL mg/Nm^3
NMVOC	0.0343	...

$$Conc = \frac{M_{Recovered}}{V_m \times f_s \times f_{O_2}}$$

Uncertainty in final measurement @ Reference Conditions due to $uM_{Recovered}$

Charcoal Tube Results	Maximum mg/Nm^3	Minimum mg/Nm^3	Sensitivity	Standard Uncertainty mg/Nm^3
NMVOC	3.26	2.67	15.61	0.30

Condensate Results	Maximum mg/Nm^3	Minimum mg/Nm^3	Sensitivity	Standard Uncertainty mg/Nm^3
NMVOC				

Uncertainty in final measurement @ Reference Conditions due to uV_{STD}

Charcoal Tube Results	Maximum mg/Nm^3	Minimum mg/Nm^3	Sensitivity	Standard Uncertainty mg/Nm^3
NMVOC	3.20	2.76	46.58	0.22

Combined Uncertainty (excluding Oxygen contribution)

$$u_{combined} = \sqrt{\sum (u_M)^2 + (u_L)^2 + (uV_{stp})^2}$$

Charcoal Tubes: Determinand	Combined Uncertainty mg/Nm^3	Expanded Uncertainty mg/Nm^3	Measured Concentration mg/Nm^3	Percent of Measured Concentration
NMVOC	0.37	0.74	3.86	19.23

CHP No.2 SO2 Measurement Uncertainty

Site: Five Fords WwTW CHP Facility
Location: CHP No.2

$$u_{mass} = \sqrt{\sum (u_{filter})^2 + (u_{solution})^2}$$

Determinand	Filter mg	Solution mg	Recovered Mass mg	LAB Method Uncert (%) K= 2 Filter mg	LAB Method Uncert (%) K= 2 Solution mg	Standard Uncertainty Filter mg	Standard Uncertainty Solution mg	Combined Uncertainty mg
			SO2					
...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...
Sulphur Dioxide	...	4.86	4.86	...	0.63	...	0.32	0.32
...	...	...	...	...	...	...	...	...
			...					
...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...

	SO2		Standard Uncertainty @ 95%			
Sampled Volume (V_m)	0.87	m^3	uV_m	0.001	m^3	
Meter Correction Factor (Yd)	0.97	...		...	...	
Meter Temperature (T_m)	305.67	k	uT_m	1.5	k	
Average Differential Pressure (ΔH)	20.00	mmH_2O	uΔH	0.25	mmH_2O	
Barometric Pressure (ρ_b)	765.06	mmHg	$u\rho_b$	3.8	mmHg	
ΔH + ρs (ρ_m)	102.20	kPa		...	...	
Oxygen content ($O_{2,m}$)	8.09	% by volume	$uO_{2,m} = \sigma/\sqrt{n}$	0.00341		% by volume
Moisture Content (H_2O)	12.04	% by volume	uH_2O	0.36		% by volume

Note: In the following calculations, the sensitivity coefficient (C) is estimated using: $C_i = \frac{\partial f}{\partial x_i}$

For each factor, uncertainty is then calculated by $C_i u_i$ where C is the sensitivity coefficient, u is the standard uncertainty and i is the index identifying the contributing factor e.g. $i = uV_m$, uT_m etc.

Where results are required at wet conditions, the following correction factor is used to convert the data from the dry gas meter:

SO2:

$$f_{s,wet} = \frac{100}{(100 - H_2O)} = \quad 1.00$$

Uncertainty in correction factor to STP due to measured ΔH uncertainty component (uΔH), measured stack pressure uncertainty component (up_s) & measured temperature of dry gas uncertainty component ($uT_{m\,Dry}$)

SO2:

$$f_s = \frac{273}{760} \times \frac{P_b + \frac{\Delta H}{13.6}}{T_m} \times Y_d = \quad 0.875$$

	Maximum	Minimum	Sensitivity	ufstp
uΔH	0.87	0.87	0.0000839	0.0000210
$u\rho_b$	0.88	0.87	0.00114	0.00428
uT_m	0.88	0.87	0.00286	0.00429
H_2O	...	...	...	...

$$\frac{uf_s}{f_s} = \sqrt{\left(\frac{\sqrt{(u\Delta H)^2 + (uP_s)^2}}{(P_m/101.3)}\right)^2 + \left(\frac{uT_m}{(T_m/273.15)}\right)^2 + \left(\frac{uH_2O}{100/(100 - H_2O)}\right)^2} = \quad 0.00500$$

Uncertainty in volume @ STP due to volume correction factor uncertainty component (uV_{std}) & volume uncertainty component (uV_m)

SO2:

$$V_{std} = V_{measured} \times f_s = \quad 0.765$$

	Maximum m^3	Minimum m^3	Sensitivity	Standard Uncertainty (m^3)
Effect of uV_{std}	0.77	0.76	0.87	0.00437
Effect of uV_m	0.77	0.76	0.87	0.000875

Combined Standard Uncertainty

$$\frac{uV_{std}}{V_{std}} = \sqrt{\left(\frac{uV_{std}}{f_s}\right)^2 + \left(\frac{uV_m}{V_m}\right)^2} = \quad 0.00390$$

Uncertainty of Oxygen Correction Factor (%):-

SO2:

$$f_{o_2} = \frac{20.9\% - O_{2,ref}}{20.9\% - O_{2,measured}} = \quad 1.24$$

$$uCorr^{n}{}_{o_2} = \frac{20.9\% - O_{2,ref}}{(20.9\% - O_{2,measured})x(20.9\% - O_{2,measured})} x\,Uncertainty\ of\ O_2\ Measurement = \quad 0.0291$$

$$uf_{o_2} = \frac{uCorr^{n}{}_{o_2}}{f_{o_2}} x100 = \quad 2.34\ \%$$

Uncertainty in final measurement @ reference conditions due to mass uncertainty component (uM)

Determinand	SO2:			
	Maximum mg/Nm^3	Minimum mg/Nm^3	Sensitivity	uM mg/Nm^3
...	...	...	...	...
...	...	...	...	...
Sulphur Dioxide	8.41	7.38	1.62	0.51
...	...	...	...	...

Uncertainty in final measurement @ reference conditions due to uncertainty component arrising from leak and/or loss (assumed 2% max) in the sample system (uL)

Determinand	SO2: uL mg/Nm^3
...	...
...	...
Sulphur Dioxide	0.0911
...	...

Uncertainty in final measurement @ Reference Conditions due to uVstp

Determinand	SO2:			
	Maximum mg/Nm^3	Minimum mg/Nm^3	Sensitivity	uVstp mg/Nm^3
...	...	...	...	...
...	...	...	...	...
Sulphur Dioxide	7.93	7.85	10.32	0.0402
...	...	...	...	...

Combined Uncertainty excluding oxygen contribution

$$u_{combined} = \sqrt{\sum (u_M)^2 + (u_L)^2 + (uV_{stp})^2}$$

Determinand	SO2:			
	Combined Uncertainty mg/Nm^3	Expanded Uncertainty mg/Nm^3	Measured Concentration mg/Nm^3	Percent of Measured Concentration
...	...	...	...	...
...	...	...	...	...
Sulphur Dioxide	0.52	1.05	7.89	13.24
...	...	...	...	...

Combined Uncertainty including oxygen contribution

$$u_{combined} = \sqrt{\sum (uf_{o_2})^2 + (Uncertainty\ of\ Measurement\ of\ Determinand)^2}$$

Determinand	Measurement Uncertainty of Determinand	Measurement Uncertainty of Oxygen Corrn Factor	Overall Measurement Uncertainty inc O_2 Corr^n factor (Ucombined)
...	...	...	...
...	...	...	...
Sulphur Dioxide	13.24	2.34	13.45
...	...	...	...

CHP No.2 NMVOC Measurement Uncertainty

Note:
Results based on Charcoal Tubes Only!

Site: Dwr Cymru Welsh Water, Five Fords WwTW CHP Facility
Location: CHP's, Stack ID:CHP - No.2

				Standard Uncertainty @ 95%		
Sampled Volume	V_m	0.09448	m^3	uV_m	0.000	m^3
Meter Correction Factor or ml/count	Yd	0.971	...	...	...	...
Meter Temperature	T_m	301.00	k	uT_m	1.5	k
Barometric Pressure	ρ_b	1020.00	mBar		10.0	mBar
Oxygen content	$O_{2,m}$	8.11	%Vol	$uO_{2,m}$	0.49	%Vol
Moisture	H_2O	11.94	%Vol	uH_2O	1.65	%Vol

Determinand	Tubes Recovered Mass		Standard Uncertainty		
NMVOC	1300.00	μg	uM	130.00	μg

Note: In the following calculations, the sensitivity coefficient (C) is estimated using: $C_i = \frac{\partial f}{\partial x_i}$

For each factor, uncertainty is then calculated by $C_i u_i$ **where** ***C*** **is the sensitivity coefficient,** ***u*** **is the standard uncertainty and** ***i*** **is the index identifying the contributing factor e.g. i = uV_m, uT_m etc.**

Where results are required at wet conditions, the following correction factor is used to convert the data from the dry gas meter:

$$f_{s,wet} = \frac{100}{(100 - H_2O)} = 1.00$$

Uncertainty in correction factor to STP due to measured barometric pressure uncertainty component (upb), measured temperature of dry gas uncertainty component (uT_m) & measured moisture (uH_2O) where required

$$f_s = \frac{273}{T_m} \times \frac{\rho}{101.3} = 0.91$$

	Maximum	Minimum	Sensitivity	ufstp
$u\rho_b$	0.48	0.47	0.000470	0.00470
uT_m	0.92	0.91	0.00303	0.00455
uH_2O	...	...	...	...

$$\frac{uf_s}{f_s} = \sqrt{\left(\frac{uP_b}{(P_b/101.3)}\right)^2 + \left(\frac{uT_m}{(T_m/273.15)}\right)^2 + \left(\frac{uH_2O}{100/(100-H_2O)}\right)^2} = 0.00569$$

Uncertainty in volume @ STP due to volume correction factor uncertainty component (uVstd) & volume uncertainty component (uVm)

$$V_{std} = V_{measured} \times f_s = 0.0838$$

	Maximum m^3	Minimum m^3	Sensitivity	Standard Uncertainty m^3
Effect of uf_s	0.0843	0.0833	0.0917	0.000522
Effect of uV_m	0.0838	0.0838	0.89	8.868E-06

$$\frac{uV_{std}}{V_{std}} = \sqrt{\left(\frac{uf_s}{f_s}\right)^2 + \left(\frac{uV_m}{V_m}\right)^2} = 0.00769$$

Uncertainty of correction factor to reference conditions (excluding oxygen contribution) & Uncertainty in final measurement @ reference conditions due to uncertainty component arrising from leak and/or loss (assumed 2% max) in the sample system (uL)

$$uL = \frac{Conc \times \frac{2}{100}}{\sqrt{3}}$$

	Tubes uL mg/Nm³	Condensate uL mg/Nm³
NMVOC	0.18	...

$$Conc = \frac{M_{Recovered}}{V_m \times f_s \times f_{O_2}}$$

Uncertainty in final measurement @ Reference Conditions due to $uM_{Recovered}$

Charcoal Tube Results	Maximum mg/Nm³	Minimum mg/Nm³	Sensitivity	Standard Uncertainty mg/Nm³
NMVOC	17.07	13.96	11.94	1.55

Condensate Results	Maximum mg/Nm³	Minimum mg/Nm³	Sensitivity	Standard Uncertainty mg/Nm³
NMVOC				

Uncertainty in final measurement @ Reference Conditions due to uV_{STD}

Charcoal Tube Results	Maximum mg/Nm³	Minimum mg/Nm³	Sensitivity	Standard Uncertainty mg/Nm³
NMVOC	17.08	14.21	186.77	1.44

Combined Uncertainty (excluding Oxygen contribution)

$$u_{combined} = \sqrt{\sum (u_M)^2 + (u_L)^2 + (uV_{stp})^2}$$

Charcoal Tubes: Determinand	Combined Uncertainty mg/Nm³	Expanded Uncertainty mg/Nm³	Measured Concentration mg/Nm³	Percent of Measured Concentration
NMVOC	2.12	4.24	19.29	22.00

Stack Reference CHP No.1

Measurement Uncertainty Calculations - Velocity at Stack Conditions

Contribution From	Standard u/c (mm H_2O)	
Pitot Calibration Uncertainty Contribution	0.077	A
Manometer Calibration Uncertainty Contribution	0.077	B
Variation in Actual Pitot reading at sample points	0.20	C
Combined u/c (mm H_2O) =	**Combined u/c (mm H_2O)**	
SQRT $(A/\sqrt{3})^2 + (B/\sqrt{3})^2 + (C/\sqrt{3})^2)$	0.13	
Expanded Uncertainty of Flow Measurements (mm H_2O)	**0.26**	
	Standard u/c (K)	
Temperature Calibration (K)	2.45	D
Variation in Actual Temp reading at sample points	0.00	E
Combined u/c of Temp (K)	**Combined u/c (K)**	
SQRT $((D/\sqrt{3}^2) + (E/\sqrt{3})^2)$	1.41	
Expanded Uncertainty of Temp Measurements (K)	**2.82**	
Measured Average Velocity (m/s) at Stack Conds	16.95	
Maximum Average Velocity (m/s) at Stack Conds	17.14	
Standard Uncertainty Velocity at Stack Conditions (%)	1.14	
Expanded Uncertainty Velocity (at Stack Conditions)	**2.29**	**(%)**

Measurement Uncertainty Calculations - Flowrate at Stack Conditions

Contribution From	Standard u/c (m^2)	
Area (m2)	0.00062	
Measured Average Flowrate (m^3/s) at Stack Conds	1.04	
Maximum Average Flowrate (m^3/s) at Stack Conds	1.07	
Standard Uncertainty Flowrate (m^3/s) at Stack Conditions (%)	2.16	
Expanded Uncertainty Flowrate (m^3/s) at Stack Conditions	**4.31**	**(%)**

Measurement Uncertainty Calculations - Flowrate at STP & Wet Gas

Contribution From	Standard u/c (%)	
Temperature Calibration (K)	0.5	
Barometer Calibration	0.5	
Measured Average Flowrate (m^3/s) at STP Wet	0.59	
Maximum Average Flowrate (m^3/s) at STP Wet	0.60	
Standard Uncertainty Flowrate (m^3/s) at STP Wet	2.44	
Expanded Uncertainty Flowrate (m^3/s) at STP Wet	**4.88**	**(%)**

Measurement Uncertainty Calculations - Flowrate at STP & Dry Gas

Contribution From	Standard u/c (%)	
Moisture Uncertainty (% v/v)	0.16	
Measured Average Flowrate (m^3/s) at STP Dry	0.53	
Maximum Average Flowrate (m^3/s) at STP Dry	0.54	
Standard Uncertainty Flowrate (m^3/s) at STP Dry	2.62	
Expanded Uncertainty Flowrate (m^3/s) at STP Dry	**5.23**	**(%)**

Measurement Uncertainty Calculations - Flowrate at STP, Dry Gas & Ref Oxygen

Contribution From	Standard u/c (%)	
Oxygen Uncertainty (% v/v)	0.087	
Measured Average Flowrate (m^3/s) at STP Dry & Ref Oxygen	0.41	
Maximum Average Flowrate (m^3/s) at STP Dry & Ref Oxygen	0.42	
Standard Uncertainty Flowrate (m^3/s) at STP Dry & Ref Oxygen	3.34	
Expanded Uncertainty Flowrate (m^3/s) at STP Dry & Ref O_2	**6.68**	**(%)**

Stack Reference CHP No.2

Measurement Uncertainty Calculations - Velocity at Stack Conditions

Contribution From	**Standard u/c (mm H_2O)**	
Pitot Calibration Uncertainty Contribution	0.091	A
Manometer Calibration Uncertainty Contribution	0.091	B
Variation in Actual Pitot reading at sample points	0.05	C
Combined u/c (mm H_2O) =	**Combined u/c (mm H_2O)**	
SQRT $(A/\sqrt{3})^2 + (B/\sqrt{3})^2 + (C/\sqrt{3})^2)$	0.08	
Expanded Uncertainty of Flow Measurements (mm H_2O)	**0.16**	
	Standard u/c (K)	
Temperature Calibration (K)	2.42	D
Variation in Actual Temp reading at sample points	0.50	E
Combined u/c of Temp (K)	**Combined u/c (K)**	
SQRT $((D/\sqrt{3}^2) + (E/\sqrt{3})^2)$	1.42	
Expanded Uncertainty of Temp Measurements (K)	**2.85**	
Measured Average Velocity (m/s) at Stack Conds	18.47	
Maximum Average Velocity (m/s) at Stack Conds	18.60	
Standard Uncertainty Velocity at Stack Conditions (%)	0.73	
Expanded Uncertainty Velocity (at Stack Conditions)	**1.46**	**(%)**

Measurement Uncertainty Calculations - Flowrate at Stack Conditions

Contribution From	**Standard u/c (m^2)**	
Area (m2)	0.00062	
Measured Average Flowrate (m^3/s) at Stack Conds	1.14	
Maximum Average Flowrate (m^3/s) at Stack Conds	1.16	
Standard Uncertainty Flowrate (m^3/s) at Stack Conditions (%)	1.74	
Expanded Uncertainty Flowrate (m^3/s) at Stack Conditions	**3.48**	**(%)**

Measurement Uncertainty Calculations - Flowrate at STP & Wet Gas

Contribution From	**Standard u/c (%)**	
Temperature Calibration (K)	0.5	
Barometer Calibration	0.5	
Measured Average Flowrate (m^3/s) at STP Wet	0.65	
Maximum Average Flowrate (m^3/s) at STP Wet	0.66	
Standard Uncertainty Flowrate (m^3/s) at STP Wet	2.03	
Expanded Uncertainty Flowrate (m^3/s) at STP Wet	**4.05**	**(%)**

Measurement Uncertainty Calculations - Flowrate at STP & Dry Gas

Contribution From	**Standard u/c (%)**	
Moisture Uncertainty (% v/v)	0.18	
Measured Average Flowrate (m^3/s) at STP Dry	0.57	
Maximum Average Flowrate (m^3/s) at STP Dry	0.58	
Standard Uncertainty Flowrate (m^3/s) at STP Dry	2.24	
Expanded Uncertainty Flowrate (m^3/s) at STP Dry	**4.47**	**(%)**

Measurement Uncertainty Calculations - Flowrate at STP, Dry Gas & Ref Oxygen

Contribution From	**Standard u/c (%)**	
Oxygen Uncertainty (% v/v)	0.162	
Measured Average Flowrate (m^3/s) at STP Dry & Ref Oxygen	0.46	
Maximum Average Flowrate (m^3/s) at STP Dry & Ref Oxygen	0.47	
Standard Uncertainty Flowrate (m^3/s) at STP Dry & Ref Oxygen	3.52	
Expanded Uncertainty Flowrate (m^3/s) at STP Dry & Ref O_2	**7.04**	**(%)**

Stack Reference A3

Measurement Uncertainty Calculations - Velocity at Stack Conditions

Contribution From	**Standard u/c (mm H_2O)**	
Pitot Calibration Uncertainty Contribution	0.011	A
Manometer Calibration Uncertainty Contribution	0.011	B
Variation in Actual Pitot reading at sample points	0.08	C
Combined u/c (mm H_2O) =	**Combined u/c (mm H_2O)**	
SQRT $(A/\sqrt{3})^2 + (B/\sqrt{3})^2 + (C/\sqrt{3})^2)$	0.04	
Expanded Uncertainty of Flow Measurements (mm H_2O)	**0.09**	
	Standard u/c (K)	
Temperature Calibration (K)	1.79	D
Variation in Actual Temp reading at sample points	0.00	E
Combined u/c of Temp (K)	**Combined u/c (K)**	
SQRT $((D/\sqrt{3}^2) + (E/\sqrt{3})^2)$	1.03	
Expanded Uncertainty of Temp Measurements (K)	**2.06**	
Measured Average Velocity (m/s) at Stack Conds	5.39	
Maximum Average Velocity (m/s) at Stack Conds	5.51	
Standard Uncertainty Velocity at Stack Conditions (%)	2.34	
Expanded Uncertainty Velocity (at Stack Conditions)	**4.69**	**(%)**

Measurement Uncertainty Calculations - Flowrate at Stack Conditions

Contribution From	**Standard u/c (m^2)**	
Area (m2)	0.00113	
Measured Average Flowrate (m^3/s) at Stack Conds	0.61	
Maximum Average Flowrate (m^3/s) at Stack Conds	0.63	
Standard Uncertainty Flowrate (m^3/s) at Stack Conditions (%)	3.37	
Expanded Uncertainty Flowrate (m^3/s) at Stack Conditions	**6.73**	**(%)**

Measurement Uncertainty Calculations - Flowrate at STP & Wet Gas

Contribution From	**Standard u/c (%)**	
Temperature Calibration (K)	0.5	
Barometer Calibration	0.5	
Measured Average Flowrate (m^3/s) at STP Wet	0.47	
Maximum Average Flowrate (m^3/s) at STP Wet	0.49	
Standard Uncertainty Flowrate (m^3/s) at STP Wet	3.76	
Expanded Uncertainty Flowrate (m^3/s) at STP Wet	**7.52**	**(%)**

Measurement Uncertainty Calculations - Flowrate at STP & Dry Gas

Contribution From	**Standard u/c (%)**	
Moisture Uncertainty (% v/v)	0.21	
Measured Average Flowrate (m^3/s) at STP Dry	0.43	
Maximum Average Flowrate (m^3/s) at STP Dry	0.45	
Standard Uncertainty Flowrate (m^3/s) at STP Dry	4.00	
Expanded Uncertainty Flowrate (m^3/s) at STP Dry	**8.00**	**(%)**

Measurement Uncertainty Calculations - Flowrate at STP, Dry Gas & Ref Oxygen

Contribution From	**Standard u/c (%)**	
Oxygen Uncertainty (% v/v)	0.063	
Measured Average Flowrate (m^3/s) at STP Dry & Ref Oxygen	0.43	
Maximum Average Flowrate (m^3/s) at STP Dry & Ref Oxygen	0.45	
Standard Uncertainty Flowrate (m^3/s) at STP Dry & Ref Oxygen	4.37	
Expanded Uncertainty Flowrate (m^3/s) at STP Dry & Ref O_2	**8.74**	**(%)**