AIR DISPERSION MODELLING REPORT OF RELEASES FROM TWO PACKAGE BOILERS AT PRINCES, PORTMANMOOR ROAD, CARDIFF

Princes Limited,
Unit 69, Portmanmoor Road,
Cardiff.
CF24 5HB

ECL Ref: ECL.046.01.01/ADM
March 2022
Issue: 2

LIST OF AMENDMENTS SINCE ISSUE 1(a)

The following amendments to the previous modelling study and report (ECL.046.01.01/ADM Issue 1(a) – August 2020) have been made in response to NRW's notice (dated 21/03/2022) for additional information:

- Update to Table 2 of Section 2.4, to revise the modelled coordinates used for SE1;
- Update to Tables 6 and 7 of Section 2.7, to provide the latest APIS background concentrations;
- Revision to Section 2.18 to reflect the Environment Agency's Operational Instruction 67_12;
- Update to Section 2.4 to include the latest available background NO_2 concentrations;
- Update to Table 19 of Section 6 and Tables 20 and 21 of Section 7 (to account for the revised coordinates and NO_X calculations);
- Updated Conclusions (Section 8) to capture the revised assessments for SE1; and
- Inclusion of Appendix I (Emissions Monitoring Survey report).

For ease of reference, revised sections and updates have been highlighted in grey throughout the report.

AIR DISPERSION MODELLING REPORT OF RELEASES FROM TWO PACKAGE BOILERS AT PRINCES, CARDIFF

TABLE OF CONTENTS

TABLE OF CONTENTS (cont.)

LIST OF TABLES

LIST OF FIGURES

APPENDICES

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
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
LPA	Local Planning Authority
LWS	Local Wildlife Sites
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
Princes	Princes Limited
Ramsar	The Ramsar Convention on Wetlands of International Importance
SAC	Special Area of Conservation
SINC	Sites of Importance for Nature Conservation
SPA	Special Protection Area
SSSI	Site of Special Scientific Interest
The Site	Princes Limited, Cardiff
WHO	World Health Organisation

1. INTRODUCTION

1.1. The Study

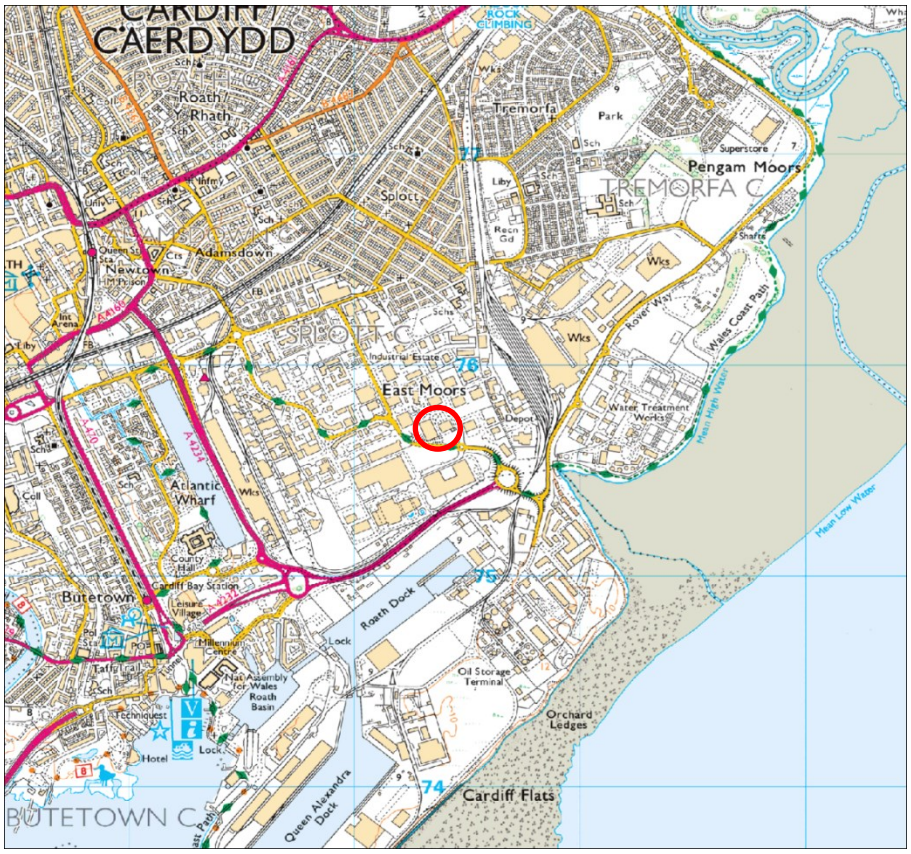
1.1.1. Environmental Compliance Ltd ("ECL") have been commissioned by Princes Limited ("Princes") to undertake an air quality assessment of releases from one existing boiler and one proposed boiler operating simultaneously at Princes Limited, Cardiff ("the Site") as part of a Permit Variation to be submitted to Natural Resources Wales ("NRW") and a Planning Application to be submitted to the Local Planning Authority ("LPA").

1.1.2. The study has been conducted to determine the impact of oxides of nitrogen ("NOx") (as nitrogen dioxide ("NO_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. The study was undertaken using the ADMS modelling package, which is one of the models recognised by the Local Planning Authority and Natural Resources Wales as Regulators as being suitable for this type of study.

1.1.4. 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 suitable heights for the one existing and one proposed boiler stacks;
- to determine the maximum ground level concentrations ("GLCs") arising from the emission of NOx as NO_2 and CO from the two boilers' (one existing and one proposed) discharge stacks; and
- to assess the impact of emissions from the boilers (one existing and one proposed) on existing local air quality in relation to human and environmental health at a range of potentially sensitive receptors by comparison with relevant air quality standards ("AQSs"). All pollutants are assumed to be released from the Site at their maximum permitted Emission Limit Value ("ELV").

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;

[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

- 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.

1.3.9. Of the four AQMAs declared by CCC, Llandaff AQMA and Ely Bridge AQMA are both more than 5km 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 assessing maximum predicted GLCs against the relevant AQSs.

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 on a 24-hourly basis, 365 days of the year; in practice, when the plant is operating, the release concentrations will be below the ELVs; furthermore, taking shutdowns for planned maintenance into account, the plant will not operate for 365 days;
- 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); and
- 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.

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.

Table 1: Sensitive Human Receptors

ADMS Ref.	Location	Easting	Northing	Distance from Site[(a)] (m)	Heading (degrees)
HSR1	Industrial estate	320663	175211	537	157
HSR2	Mary Price Court	320222	176234	577	337
HSR3	Moorland Primary School	320456	176290	586	1
HSR4	Industrial estate	321203	175788	759	84
HSR5	Youth club and sporting grounds	319702	175920	778	286
HSR6	Apartments, Bute East Dock	319518	175137	1090	239
HSR7	Holiday Inn	319250	175462	1223	259
HSR8	Willows High School	321114	176741	1232	33
HSR9	St Cuthbert's School	319033	175475	1434	261
HSR10	Travellers' site	321862	176756	1762	53
AQMA1	Stephenson Court AQMA	319432	176981	1632	321
AQMA2	Cardiff City Centre AQMA	318399	175995	2071	278

Notes to Table 1

(a) The distance from Site is calculated as the crow flies from the coordinates between the two boiler stacks (320449 (X), 175704 (Y)) to the approximate nearest point of the potentially sensitive human receptor or AQMA location.

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. The various ecological sites each cover a large area, consequently grid references for the ecological sites have been taken as the point of the ecological site closest to the Site (with the exception of the LWSs – refer to the notes to Table 2 for details).

Table 2: Specific Sensitive Habitat Receptors Considered for the Assessment

ADMS Ref.	Name	Designation(s)	Easting	Northing	Distance from Site (m)	Heading (degrees)
SE1	Severn Estuary	Ramsar, SAC, SPA, SSSI	320901	175500	496	114
SE2			320709	174131	1594	171
SE3			321854	176572	1651	58
CBW1	Cardiff Beech Woods	SAC	314346	183183	9653	321
LNR1	Cardiff Bay Wetlands and Hamadryad Park	LNR	318902	174259	2117	227
LWS1	Tidal Sidings	LWS	320700	175500	323	129
LWS2	Ocean Park South		320500	175300	407	173
LWS3	Cardiff Heliport Fields		321100	175000	959	137
LWS4	Pengam Moors		321600	176900	1660	44
LWS5	Beach Sidings		320500	174000	1705	178
LWS6	Cardiff Bay Wetland Reserve		318800	174000	2371	224

Notes to Table 2
The distance from Site is calculated as the crow flies from the coordinates between the two boiler stacks (320449 (X), 175704 (Y)) to the approximate nearest point of the habitat receptor.
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
Please note, that as the Site's permitted boundary spans a larger area, the distance between the 'Source' and the site boundary has been taken into consideration in the interest of being conservative. Therefore, sites that appear to exceed the 2km search criteria are either close to or just within the relevant search radii.

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, i.e., NO_2 and CO. 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
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.

2.6.2. **Critical Levels**

2.6.3. 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.

2.6.4. 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)

Notes to Table 4

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

2.6.5. Critical Loads

2.6.5.1. 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].

2.6.5.2. 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.

2.6.5.3. 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]

2.6.5.4. 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].

2.6.5.5. 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.

2.6.5.6. 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 6.84);

2.6.5.7. Dry and wet deposition were modelled using ADMS. For modelling wet deposition, washout coefficients are required. The default parameters for NO_x (as NO_2) were used in the model (i.e., values of 0.0001 for parameter A and 0.64 for parameter B).

2.6.5.8. 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

2.6.5.9. 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 [10].

([10]) 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		
		Dunlin	Bird – non-breeding; littoral sediment	20	30	Not sensitive to acidification		
		Ringed Plover						
		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

2.7.1. Airborne NO_X Concentrations

2.7.1.1. A summary of site-specific baseline concentrations of NO_X, 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 i.e., the closest grid square to the point of the site used in the assessment.

Table 6: Baseline Concentrations of NO_X

ADMS Receptor Reference	Description & Designation	NO_X Background Concentration [(a)] ($\mu g/m^3$)	
		Annual Mean	24 Hour [(b)] Mean
SE1	Severn Estuary – Ramsar, SAC, SPA, SSSI	31.17	36.78
SE2		23.12	27.28
SE3		21.62	25.51
CBW1	Cardiff Beech Woods – SAC	13.69	16.15
LNR1	Cardiff Bay Wetlands and Hamadryad Park – LNR	22.97	27.10
LWS1	Tidal Sidings - LWS	31.17	36.78
LWS2	Ocean Park South - LWS	31.17	36.78
LWS3	Cardiff Heliport Fields - LWS	18.34	21.64
LWS4	Pengam Moors - LWS	21.62	25.51
LWS5	Beach Sidings - LWS	23.12	27.28
LWS6	Cardiff Bay Wetland Reserve - LWS	22.97	27.10

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: 2017 – 2019).

(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.

2.7.2. Nutrient Nitrogen and Acid Deposition

2.7.2.1. A summary of site-specific baseline nutrient nitrogen and acid deposition rates, as provided by APIS, is presented in Table 7. 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

ADMS Receptor Reference	Description & Designation	Nutrient Nitrogen Background (kgN/ha/yr)	Acid Deposition Background (keq/ha/yr)	
			Nitrogen	Sulphur
SE1	Severn Estuary – Ramsar, SAC, SPA, SSSI	15.68	1.12	0.27
SE2		0	0	0.25
SE3		15.68	1.12	0.27
CBW1	Cardiff Beech Woods – SAC	25.76	1.84	0.27
LNR1	Cardiff Bay Wetlands and Hamadryad Park – LNR	12.74	0.91	0.22
LWS1	Tidal Sidings - LWS	15.68	1.12	0.27
LWS2	Ocean Park South - LWS	15.68	1.12	0.27
LWS3	Cardiff Heliport Fields - LWS	15.68	1.12	0.27
LWS4	Pengam Moors - LWS	15.68	1.12	0.27
LWS5	Beach Sidings - LWS	0	0	0.25
LWS6	Cardiff Bay Wetland Reserve - LWS	12.74	0.91	0.22

Notes to Table 7
Background concentrations, for both nutrient nitrogen and acid deposition, for the relevant ecological habitats have been taken from the APIS website (data year: 2017-2019).

2.8. Deposition Parameters - Sensitive Habitats

2.8.1. Deposition of nitrogen and acids at designated habitats sites was also included in the assessment. This focused on sites within 10km of the Site as detailed in Section 2.4.3. 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. For both nutrient nitrogen and acidification impacts, the deposition of oxides of nitrogen are considered.

Table 8: Acid/Nitrogen Deposition Parameters [11]

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

Note to Table 8
(a) As detailed in AQTAG06.

[11] As detailed in AQTAG06.

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.

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		Existing Boiler[(a)]	Proposed Boiler[(a)]
Rated Thermal Input (MWth)		4.02	4.02
Stack Height (m)		TBC	TBC
Stack Exit Diameter (m)		0.504	0.430
Stack Gas Discharge Velocity (actual) (m/s)		9.52	12.74
Stack Gas Discharge Temperature (°C)		149	127
Stack Centre Coordinates	Easting (X)	320446	320451
	Northing (Y)	175703	175705
Oxygen Concentration in Stack Emission (%)		3.7	2.54
Moisture Concentration in Stack Emission (%)		10.63	10.80
Normalised Volumetric Flowrate (Nm^3/s) [(b)]		1.05	1.16

Notes to Table 9
(a) Stack emission parameters provided by Princes
(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 one existing and one proposed boiler. These are the assumed daily ELVs used for the main modelling assessment.

Table 10: Pollutant Emission Rates

Pollutant	ELV [(a)] (mg/Nm^3)	Existing Boiler (g/s)	Proposed Boiler (g/s)
Nitrogen dioxide	250 [(b)]	0.26	n/a
	100 [(c)]	n/a	0.12
Carbon monoxide	1000	1.05	1.16

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 1 of Annex II of the Medium Combustion Plant Directive
(c) ELV as per Table 1 of Part 2 of Annex II of the Medium Combustion Plant Directive

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 (2015 - 2019) of hourly sequentially analysed data in sectors of 10 degrees. Wind roses for the data are presented in Figure 2; 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 709 hours contained inadequate data, 13 hours were calm and 380 hours were non-calm met data lines with a wind speed less than the minimum value (0.75 m/s). These represent 1.62%, 0.03% and 0.87% of the data respectively.

Figure 2: Wind Roses - Met Years 2015-2019

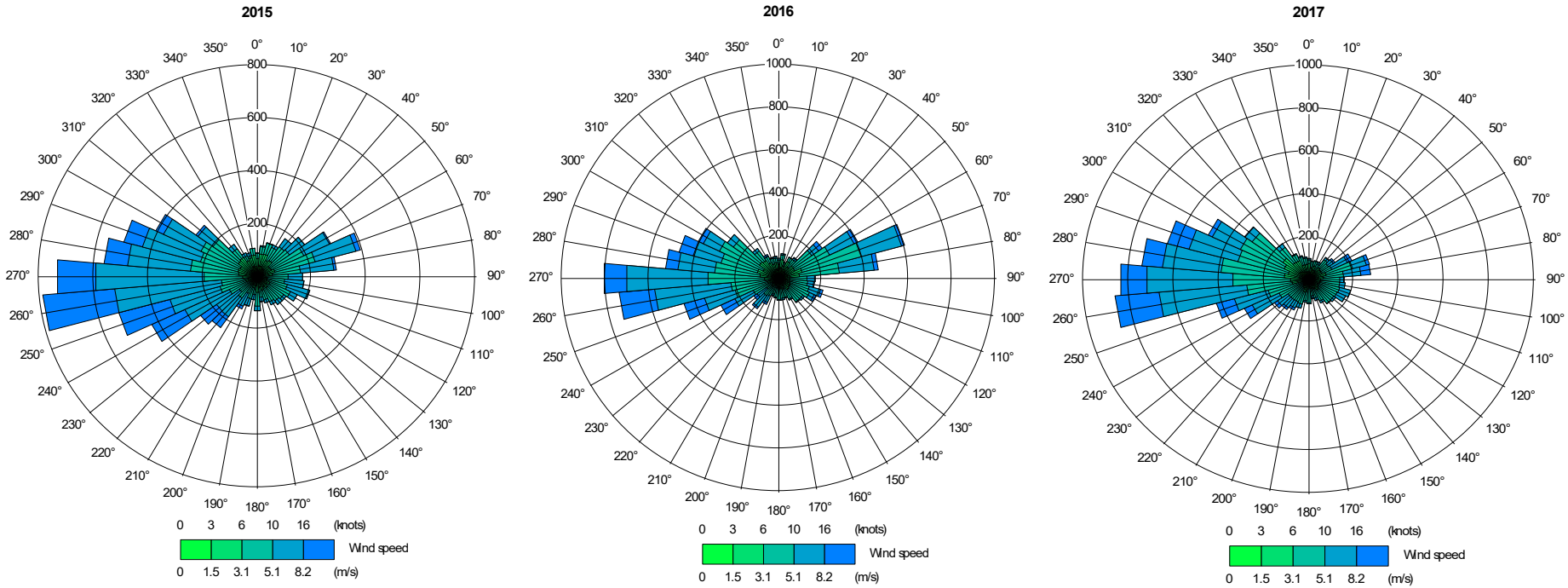
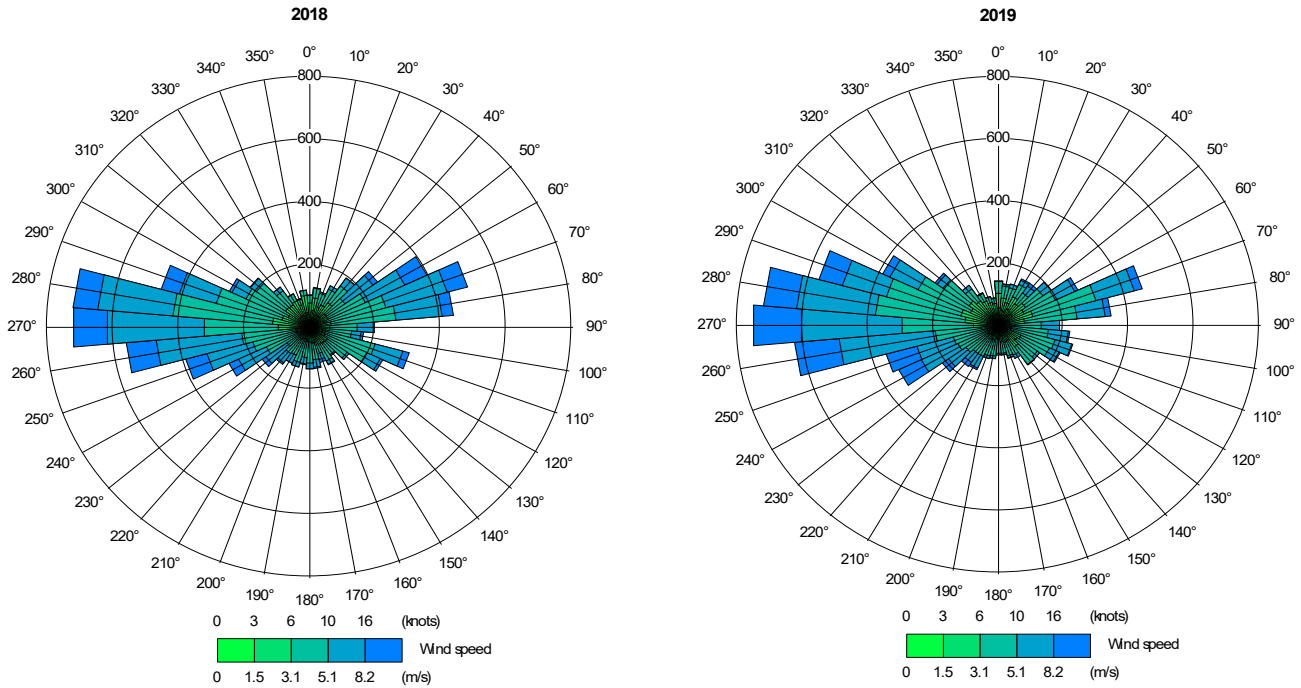


Figure 2: Wind Roses - Met Years 2015-2019 (cont.)



2.12. Building Parameters

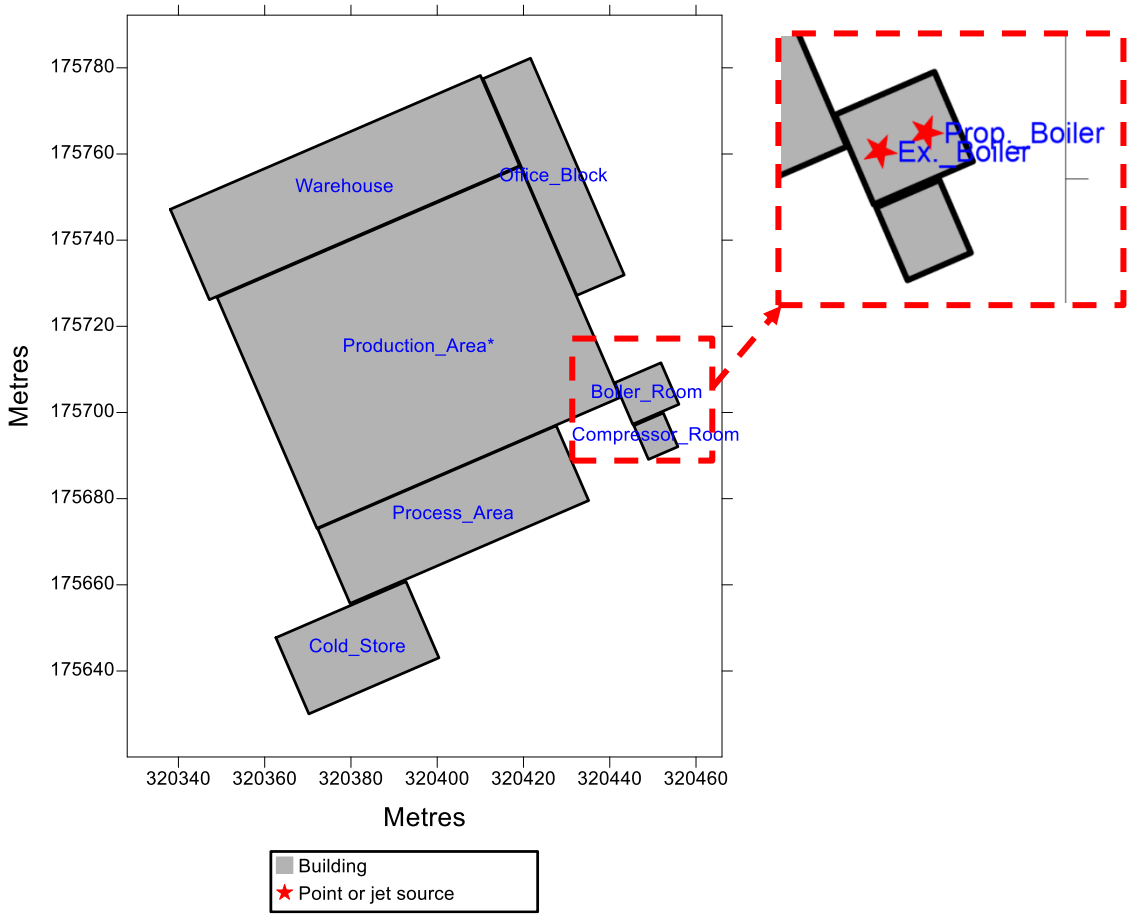
The building parameters utilised for the study are detailed in Table 11 and a visual representation is provided as Figure 3.

Table 11: On-Site and nearest Off-site Building Parameters

Building	X[(a)]	Y[(a)]	Angle (°)[(b)]	Height (m)[(c)]	Length/ Diameter (m)[(c)]	Width (m)[(c)]
Production Area	320396	175715	66.64	10.32	76.62	58.38
Process Area	320404	175676	66.64	10.20	60.25	18.92
Warehouse	320379	175752	66.64	12.49	78.32	22.85
Office Block	320427	175755	66.64	13.86	11.98	54.79
Boiler Room	320449	175704	66.64	5.13	11.67	10.50
Compressor Room	320451	175695	66.64	3.70	7.44	8.53
Cold Store	320382	175645	66.64	12.90	32.86	19.27

Notes to Table 11
(a) X(m), Y(m) denote the grid reference co-ordinates 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 confirmed by Princes Limited.

Figure 3: Buildings Layout



2.13. Terrain Data

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

2.13.2. 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.

2.14. Roughness Length

2.14.1. 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.

2.14.2. 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.

2.14.3. 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.

2.15. Model Output Parameters

2.15.1. 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.

2.15.2. 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.

2.15.3. 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 = 318449 to 322449 and Y = 173704 to 177704, with 101 nodes along each axis i.e., a grid spacing of 40m.

2.15.4. 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.

2.16. Scenarios Modelled

2.16.1. A stack height screening study has been undertaken for the two boilers (one existing and one proposed) utilising the emission parameter values and emission rates shown in Tables 9 and 10, with modelled stack heights ranging from 10m - 24m.

2.16.2. The optimum stack height is determined by assessment of the following averaging periods: the annual mean of hourly averages (NO_2), the 99.79th percentile of 1 hour means (NO_2) and the 100th percentile of 8 hour-rolling means (CO).

2.16.3. The screening assessment considers the maximum ground level concentration of pollutants only. Following this, an assessment of significance has been undertaken for all stack heights. The significance criteria used in accordance with the EA Online Guidance is provided in Section 2.17.

2.16.4. The following scenarios were modelled:

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

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

2.17.1. 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.

2.17.2. 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.

2.17.3. 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 Sections 2.17.4 and 2.17.5.

2.17.4. **Long-Term Impacts**

2.17.4.1. 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.

2.17.4.2. 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.

2.17.4.3. 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.

2.17.4.4. 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

2.17.5. **Short-Term Impacts**

2.17.5.1. 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."

2.17.5.2. 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.

2.17.5.3. 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.

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

2.18.1. EA Operational Instruction 67_12 [12] 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.

2.18.2. 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.

2.18.3. 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.

2.18.4. 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.

[12] 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

2.19. NO_x to NO_2 conversion Rates

2.19.1. 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.

2.19.2. 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.

3. IDENTIFICATION OF APPROPRIATE STACK HEIGHT

3.1. Building Screening Assessment

3.1.1. Due to the number of buildings on-site, a building screening assessment was undertaken for the three largest buildings (i.e., in terms of building height or floor area covered) in proximity to the one existing and one proposed boiler. Consequently, the Production Area, Process Area and Office Block (refer to Table 11 and Figure 3 in Section 2.12. for details) buildings were screened to determine which building, when defined as the 'Main' building, was associated with the highest (i.e., worst case) modelled long-term NO_2 PCs arising from the emission points considered, for all five met years assessed. The results from the building screening assessment are presented in Table 13, with the highest PC for each height highlighted bold.

Table 13: Building Screening Assessment

Pollutant	Stack Height (m)	Main Building	Worst Case Met Year (2015-2019)	Max PC (µg/m³)	AQS (µg/m³)	PC as % of AQS
NO_2 (annual)	10m	Production Area	2017	**23.78**	40	59.46%
		Process Area	2017	19.73		49.33%
		Office Block	2017	13.93		34.82%
	12m	Production Area	2017	**15.58**		38.94%
		Process Area	2017	9.38		23.44%
		Office Block	2017	8.00		20.01%
	14m	Production Area	2017	**9.78**		24.46%
		Process Area	2017	6.20		15.49%
		Office Block	2017	5.55		13.87%
	16m	Production Area	2017	**7.72**		19.30%
		Process Area	2017	4.21		10.53%
		Office Block	2017	3.61		9.02%
	18m	Production Area	2017	**6.30**		15.75%
		Process Area	2017	3.13		7.83%
		Office Block	2017	2.86		7.15%
	20m	Production Area	2017	**4.91**		12.28%
		Process Area	2017	2.49		6.21%
		Office Block	2017	2.20		5.50%
	22m	Production Area	2017	**3.43**		8.58%
		Process Area	2017	1.92		4.80%
		Office Block	2017	1.81		4.52%
	24m	Production Area	2017	**2.70**		6.75%
		Process Area	2017	1.58		3.94%
		Office Block	2017	1.46		3.66%

3.1.2. It can be seen from the results in Table 13 that the highest (and therefore the worst case) long-term NO_2 PCs are associated with the Production Area as the 'Main' building. Consequently, the Production Area will be defined as the 'Main' building for all scenarios modelled (refer to Section 2.16. for details).

3.2. Effect of Stack Height on Ground Level Concentrations

3.2.1. This assessment considered the effect of stack height on the annual mean and the 99.79th percentile of 1 hour means of NO_2 and the 100th percentile of 8-hour rolling means of CO. The results of this assessment, for each met year considered (2015-2019) for the one existing and one proposed boiler are shown in Figures 4-8.

Figure 4: Effect of Stack Height on Ground Level Concentrations, Met Year 2015

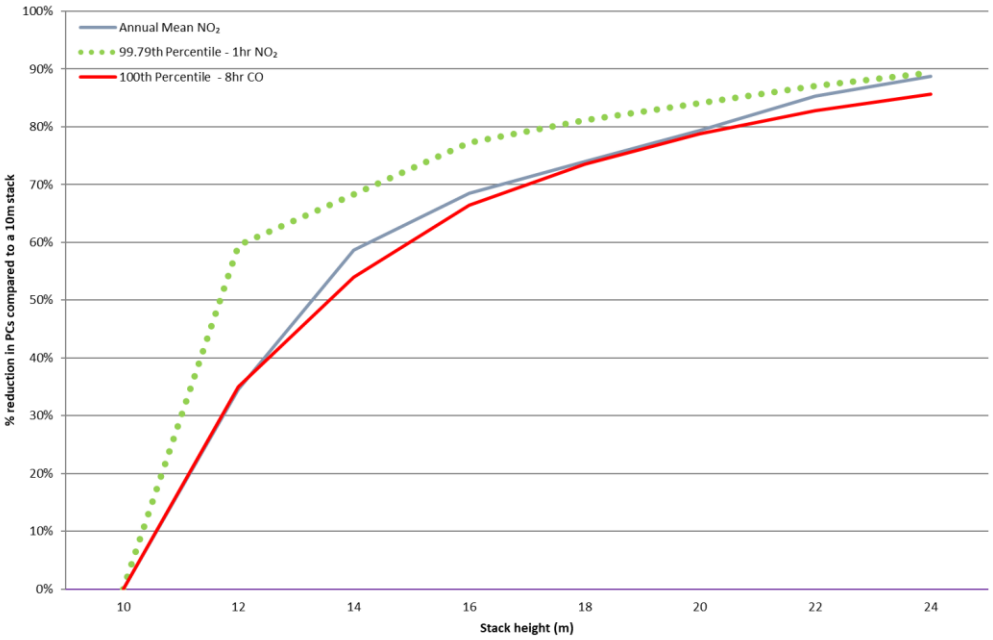


Figure 5: Effect of Stack Height on Ground Level Concentrations, Met Year 2016

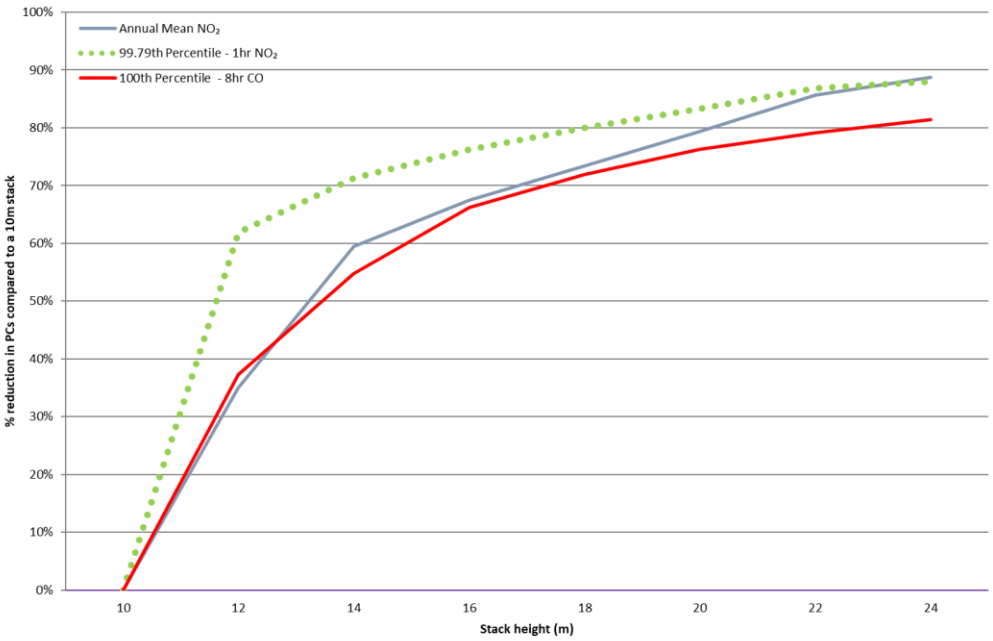


Figure 6: Effect of Stack Height on Ground Level Concentrations, Met Year 2017

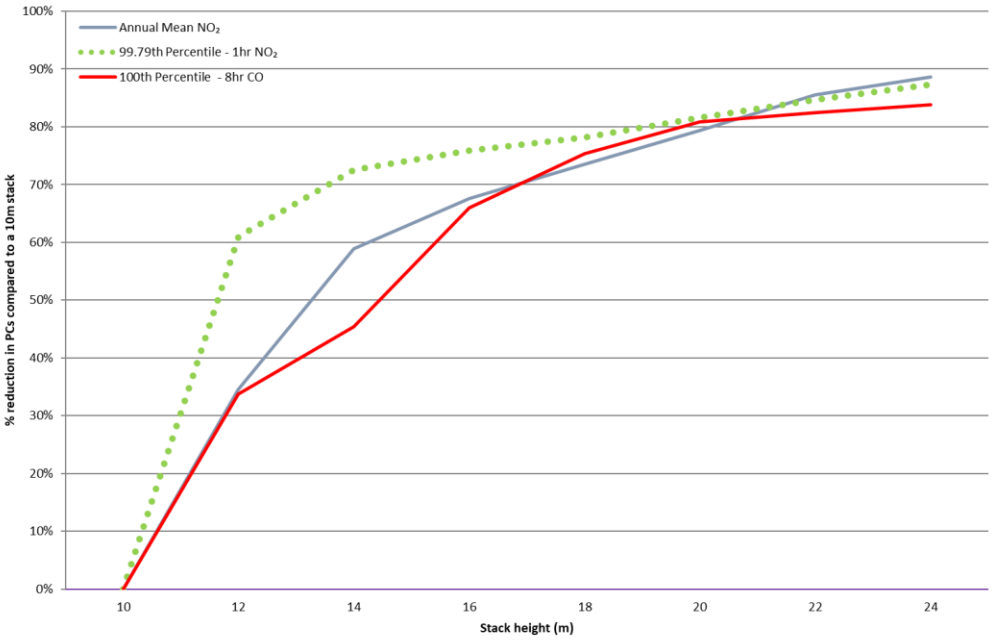


Figure 7: Effect of Stack Height on Ground Level Concentrations, Met Year 2018

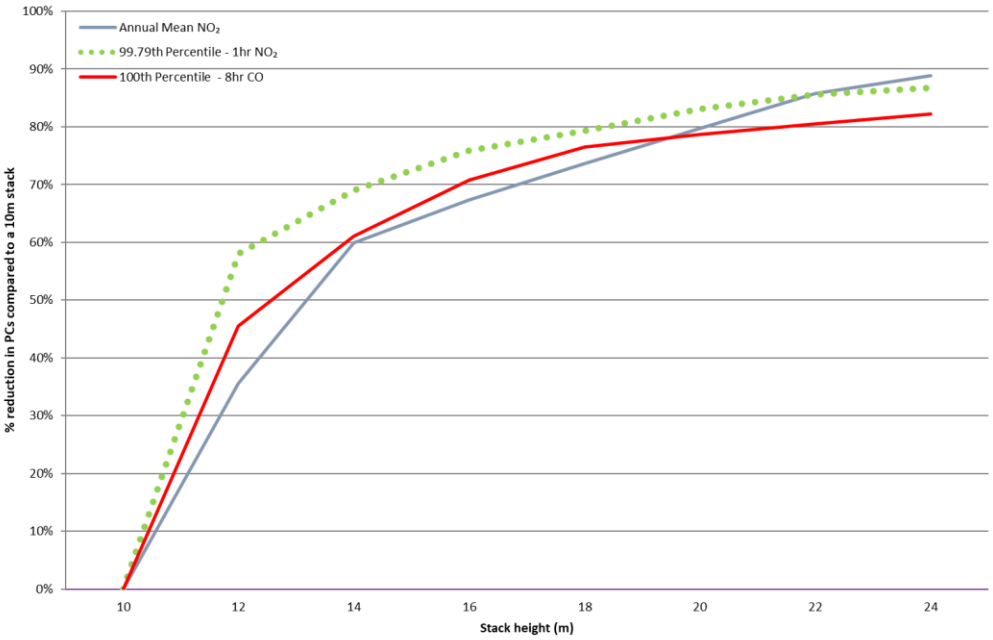
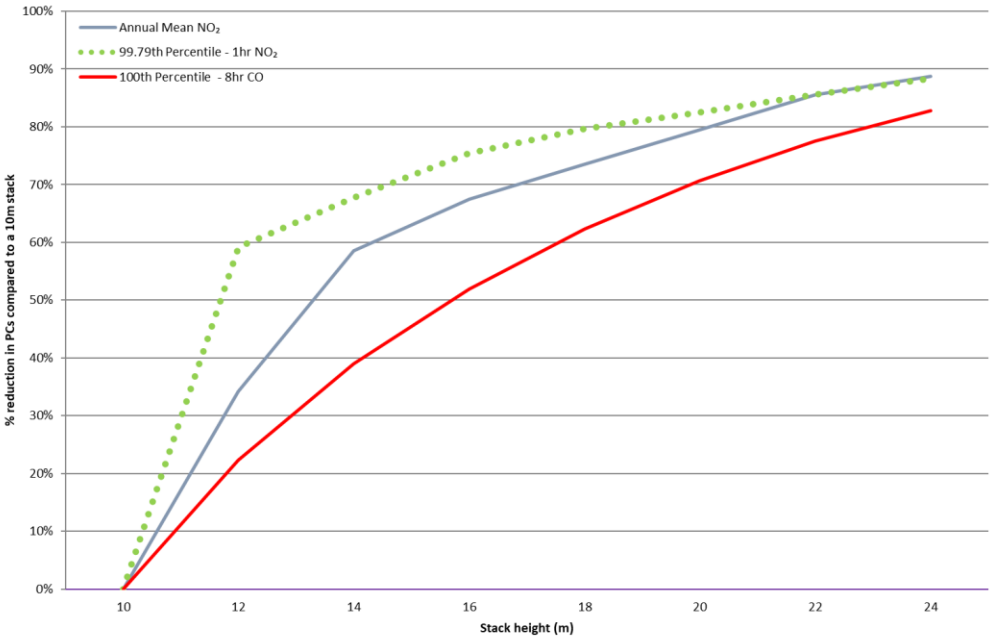


Figure 8: Effect of Stack Height on Ground Level Concentrations, Met Year 2019



3.2.2. Figures 4-8 indicate that increasing the stack heights of the two boilers (i.e., the one existing and the one proposed boiler), from 10m to 24m, has the effect of decreasing the modelled maximum ground level PC. The purpose of Figures 4-8 is to help determine an 'optimum' stack height by identifying a compromise between the required mitigation on impacts from air quality and the increased negative impacts of extending the stack height.

3.2.3. There would appear to be points of inflection at boiler stack heights of 12m (for all pollutants and met years assessed, with the exception of met year 2019 for CO) and at boiler stack heights of 14m (all met years for long-term NO_2 and met year 2017 in particular for short-term NO_2 and CO). These points of inflection help to demonstrate, for the relevant pollutants, the point at which continuing to increase the stack height much further would not result in a significant improvement in terms of aiding plume dispersion and lowering the predicted GLCs.

3.2.4. However, in order to determine the optimum stack height for the emission points considered, and the impact of emissions on the environment, all modelled stack heights will be assessed for impact at the maximum GLC. This will help to further assess the significance of the emissions arising from the existing boiler and the proposed boiler in accordance with the criteria (see Section 2.17.)

4. ASSESSMENT OF AIR QUALITY IMPACTS

4.1. Human Health Impacts at Maximum GLCs

4.1.1. The predicted PCs for each of the pollutants considered in the assessment at the maximum point of impact for the one existing and the one proposed boiler have been extracted and are presented in Table 14. The maximum predicted PCs are also compared to their respective AQSs.

4.1.2. 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 2.17. of this document). In Table 14, any PCs that are above these significance criteria are indicated in bold type.

Table 14: Comparison of Maximum PCs with Air Quality Standards

Pollutant	Stack Height (m)	WCMY* (2015-2019)	Max PC (µg/m³)	Location of Max PC		AQS (µg/m³)	PC as % of AQS
				X Coord.	Y Coord.		
NO_2 (annual)	10	2017	**23.78**	320489	175704	40	**59.46%**
	12	2017	**15.58**	320489	175704		**38.94%**
	14	2017	**9.78**	320489	175704		**24.46%**
	16	2017	**7.72**	320529	175704		**19.30%**
	18	2017	**6.30**	320529	175704		**15.75%**
	20	2017	**4.91**	320529	175704		**12.28%**
	22	2017	**3.43**	320529	175704		**8.58%**
	24	2017	**2.70**	320569	175704		**6.75%**
NO_2 (1 hour, 99.79th percentile)	10	2017	**79.19**	320449	175664	200	**39.60%**
	12	2018	**31.85**	320489	175704		**15.93%**
	14	2019	**24.50**	320489	175704		**12.25%**
	16	2017	19.08	320489	175664		9.54%
	18	2017	17.28	320489	175664		8.64%
	20	2017	14.61	320489	175664		7.31%
	22	2017	12.14	320489	175664		6.07%
	24	2018	10.03	320489	175664		5.02%
CO (8 hour, 100th percentile)	10	2019	**1042.20**	320449	175664	10,000	**10.42%**
	12	2019	809.56	320449	175664		8.10%
	14	2019	636.33	320449	175664		6.36%
	16	2019	501.07	320449	175664		5.01%
	18	2019	392.67	320449	175664		3.93%
	20	2019	305.32	320449	175664		3.05%
	22	2019	233.99	320449	175664		2.34%
	24	2019	179.24	320449	175664		1.79%

Notes to Table 14

*Worst Case Met Year (WCMY)

Refer to Figure 9 for a visual representation of the location of the maximum PCs for long-term NO_2 (that correspond with the colour coded coordinates in Table 14).

4.1.3. It can be seen from the data in Table 14 that, with the exception of 99.79th percentile NO_2 at stack heights of 16m and taller and CO at stack heights of 12m and taller, the impacts of the

PCs for the remaining pollutants and stack heights (i.e., the PCs in bold type) are potentially significant. Consequently, further assessments are required for the PCs that have not screened out.

4.1.4. 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 15 for 2019 (the latest available data year).

Table 15: Nearest Monitoring Site Locations to Site [(a)]

Monitor Type	ID / Name & Pollutant Monitored	2019 Conc. (µg/m³)	Easting Coord. (X)	Northing Coord. (Y)	Distance from Source (m)[(b)]	Heading (°)
Automatic	AMS1 – Cardiff Centre AURN	29	318416	176525	2193	292
DT	153 – Magic Roundabout	25	319491	176183	1071	297

Notes to Table 15

(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 15 to the 'Source'. The 'Source' is the collective term for the approximate halfway location between the two boiler stacks (320449 (X), 175704 (Y)).

4.1.5. Annual NO_2 data is also available from the Department for Environment, Food and Rural Affairs ("DEFRA"). Table 16 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 16: Nearest Background DEFRA Data to Site [(a)]

Ref.	Pollutant	Annual Mean Conc. (µg/m³)		Easting Coordinate (X)	Northing Coordinate (Y)	Distance from Source (m)[(b)]	Heading (°)
		2019	2020				
BN1 – NW	Annual NO_2	21.17	16.22	319500	176500	1239	310
BN2 – NE		18.30	15.86	320500	176500	798	4
BN3 – SE		21.48	16.83	320500	175500	210	166
BN4 – SW		20.05	16.37	319500	175500	971	258

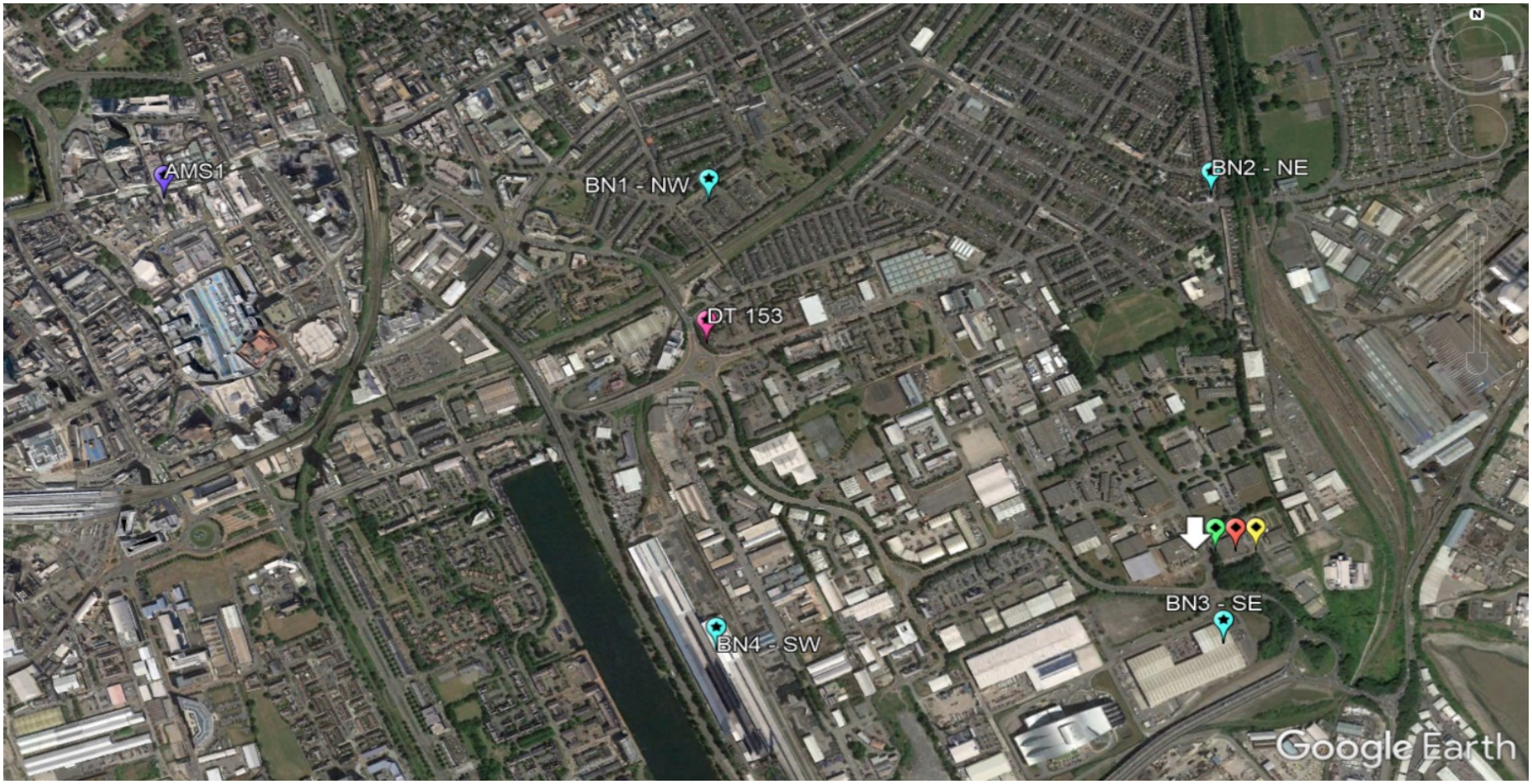
Notes to Table 16

(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 16 to the 'Source'. The 'Source' is the collective term for the approximate halfway location between the two boiler stacks (320449 (X), 175704 (Y)).

4.1.6. When calculating PECs, it is important to consider the location of the maximum GLC in order to assign an appropriate background concentration. The location of the maximum GLCs (PCs) for all met years for long-term NO_2 are displayed in Table 14. Figure 9 demonstrates the location of the nearest background sources (as outlined in Tables 15 and 16) in relation to the maximum long-term NO_2 PCs for the worst case met year, for each stack height assessed.

Figure 9: Nearest Background Sources of NO_2 in Relation to the Maximum PC Locations for Long-Term NO_2



Notes to Figure 9

The greed, red and yellow pins represent the locations of the maximum long-term NO_2 PCs for the stack heights assessed for the worst case met years (refer to Table 14 for further details – the colour coded coordinates in Table 14, for long-term NO_2, correspond to the colour coded icons displayed in Figure 9);

The white arrow is the approximate location of where the existing and proposed boiler stacks are situated (two in total); and

The blue, pink and purple annotated icons represent the locations of the nearest sources of background NO_2 concentrations (refer to Tables 15 and 16 for details).

4.1.7. It can be seen from Figure 9 that the maximum PCs, for all stack heights assessed (for the worst case met years) are all closest in proximity to the DEFRA modelled background location BN3 - SE (refer to Table 16 for further details). This site had a 2019 annual NO_2 concentration of 21.48 $\mu g/m^3$ (or 54% of the AQS).

4.1.8. Consequently, for the purposes of calculating the PECs for long-term NO_2, at the maximum point of impact, the DEFRA modelled background location, BN3 – SE, will be used as the source of the background concentration. The PEC assessment for long-term NO_2 is provided in Table 17. The PECs calculated have been compared with the relevant long-term AQS and the significance categorised adopting the IAQM guidance and impact descriptors shown in Table 12 of Section 2.17.4.4.

Table 17: Comparison of Maximum PCs and Maximum PECs with AQS

Pollutant	Stack Height (m)	WCMY* (2015 – 2019)	Max PC (µg/m³)	AQS (µg/m³)	PC as % of AQS	Location of Max PC		2019 Annual Background NO_2 Concentration (µg/m³)	Max PEC (µg/m³)	PEC as % of AQS	Significance
						X Coord.	Y Coord.				
NO_2 (annual)	10	2017	**23.78**	40	**59.46%**	320489	175704	21.48	45.26	113.16%	**Substantial**
	12	2017	**15.58**		**38.94%**	320489	175704		37.06	92.64%	**Moderate**
	14	2017	**9.78**		**24.46%**	320489	175704		31.26	78.16%	**Moderate**
	16	2017	**7.72**		**19.30%**	320529	175704		29.20	73.00%	**Moderate**
	18	2017	**6.30**		**15.75%**	320529	175704		27.78	69.45%	**Moderate**
	20	2017	**4.91**		**12.28%**	320529	175704		26.39	65.98%	**Moderate**
	22	2017	**3.43**		**8.58%**	320529	175704		24.91	62.28%	Slight
	24	2017	**2.70**		**6.75%**	320569	175704		24.18	60.45%	Slight

Notes to Table 17
*Worst Case Met Year (WCMY)
Background source – DEFRA BN3 - SE (2019 data). Refer to Table 16 in Section 4.1.5. for further details.

4.1.9. It can be seen from the data in Table 17, that the PECs of long-term NO_2 emissions arising from the one existing and the one proposed boiler can be considered 'Substantial' for stack heights of 10m, 'Moderate' for stack heights of 12m to 20m (inclusive) and 'Slight' for stack heights of 22m and 24m. This categorisation of the impacts has been carried out in accordance with the impact descriptors outlined in the IAQM (2017) guidance (refer to Table 12 of Section 2.17.4.4. for details).

4.1.10. 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. Based on that guidance, the PECs of long-term NO_2 for stack heights of 18m and taller (for the existing and proposed boiler flues) would be considered not significant.

4.1.11. Following discussions with Princes in August 2020, it is anticipated that a further package boiler (identical to the current proposed boiler considered in this assessment) could potentially be installed in the future to allow for expansion and operational flexibility on-site. Subsequently, an investigatory scenario was modelled to ascertain the maximum GLCs associated with three emission points (i.e., the one existing boiler and two identical proposed boilers) operating simultaneously. As part of this investigation a building screening and a stack height screening assessment was undertaken. The results of the investigatory modelled runs demonstrated that the recommended minimum stack heights to adopt, for all three flues, should be at least 20m.

4.1.12. It is considered that opting for 20m high stacks, over 18m stacks, for this investigation (i.e., the one existing and the one proposed boiler) should also help to future proof the suitability of these flue heights in the event that one further emission point is proposed (which would subsequently require additional air quality assessments to be undertaken).

4.1.13. Consequently, as the nearest tallest building to the existing and the proposed boiler is approximately 14m high (refer to Section 2.12. for further details on the Site's building layout and dimensions), the long-term NO_2 PECs are less than 70% of the AQS at stack heights of 18m and taller and stack heights of 20m and taller are also suitable when modelling three boilers concurrently (when taking existing ambient air quality data into consideration) - stack heights of 20m can be considered appropriate for the existing and proposed boiler flues.

4.1.14. The significance of the impact of the potentially significant short-term NO_2 and CO PCs (as shown in Table 14) therefore screen out as being insignificant at modelled boiler stack heights of 20m (i.e., the PCs are less than 10% of the relevant AQS).

4.1.15. Based on the results of the significance assessment of the worst-case PCs, at the maximum point of impact, boiler stack heights of 20m will be used from this point forward for the impact assessment at the potentially sensitive human receptor locations and at the ecological sites (as outlined in Tables 1 and 2 of Sections 2.3. and 2.4., respectively).

4.2. Isopleths

4.2.1. The isopleths for long-term and short-term NO_2 and CO, at stack heights of 20m, are presented as Figures 10 to 13 for the worst case met years (2017, 2017 and 2019, respectively).

Figure 10: Isopleth for Long-Term NO_2, Met Year 2017

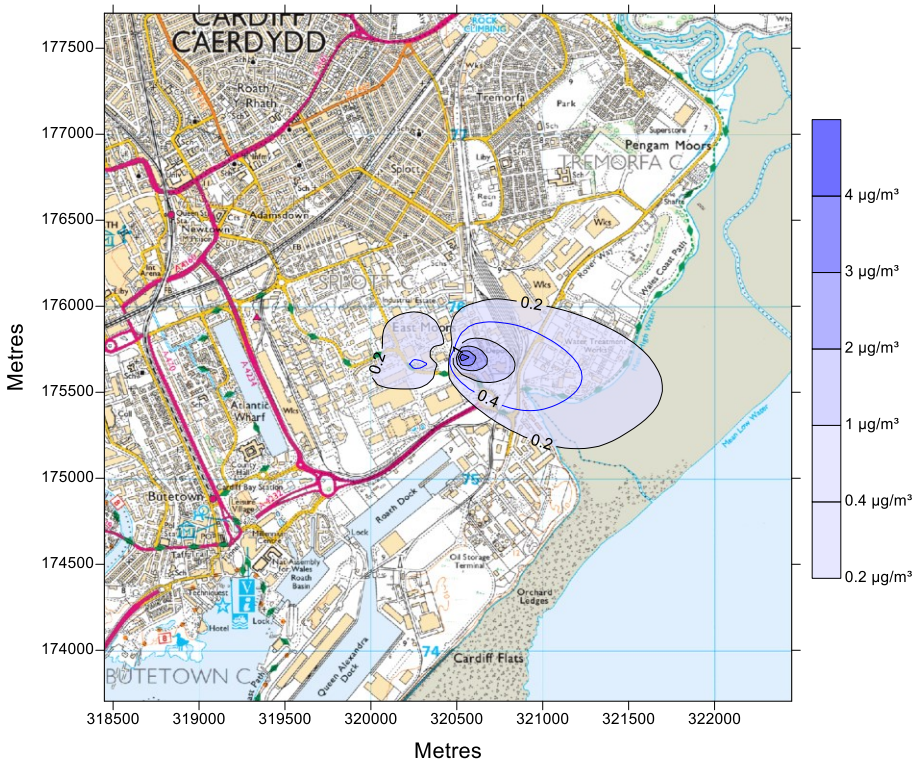


Figure 11: Isopleth for Short-Term NO_2, Met Year 2017

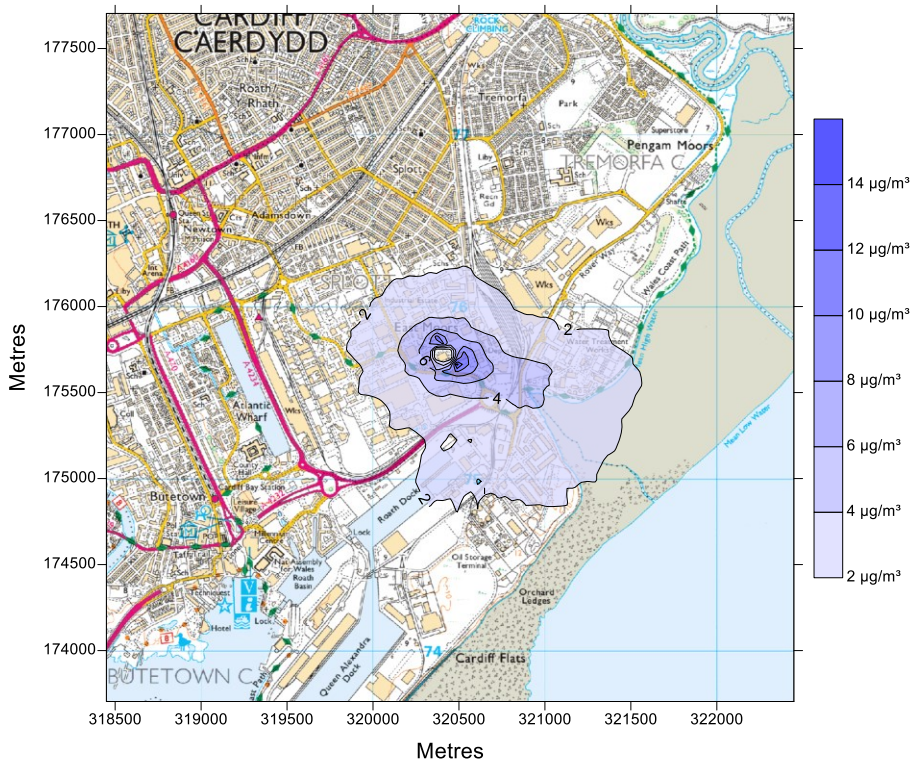
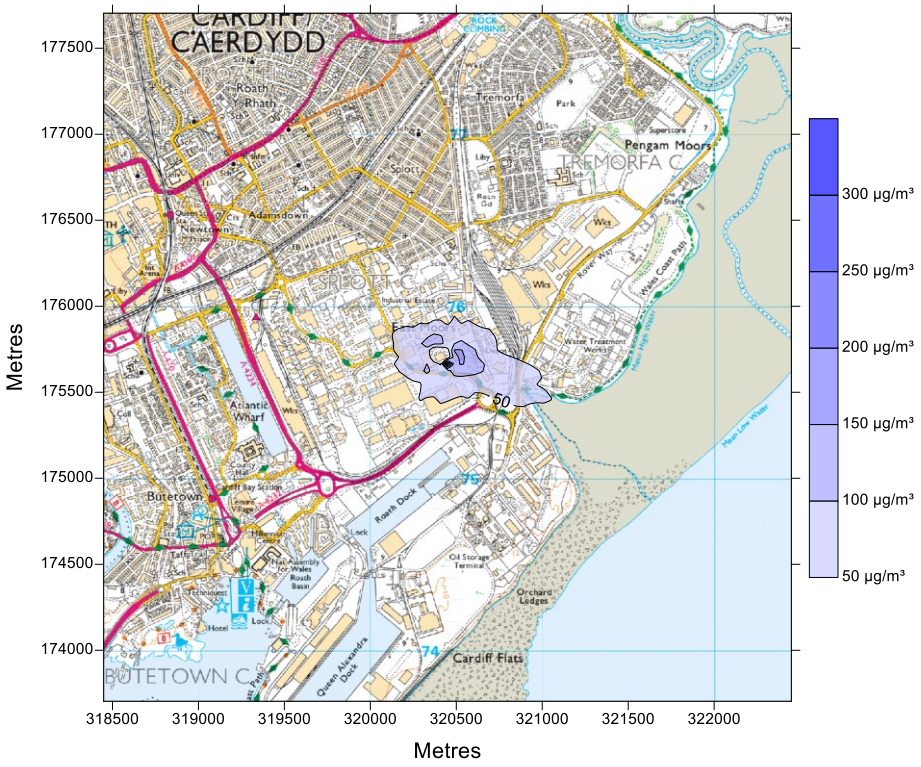


Figure 12: Isopleth for CO, Met Year 2019



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

5.1. Human Health Impacts at the Specified Receptors

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

5.1.2. The PCs from the one existing and the one proposed boiler for each sensitive receptor considered, for the worst case met year for each pollutant and averaging period, are presented in Table 18.

5.1.3. In Table 18, any PCs that are above the significance criteria (outlined in Section 2.17.) are indicated in bold type.

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

Pollutant		NO_2 (annual mean)	NO_2 (99.79th %ile)	CO (8hour)
AQS (µg/m^3)		40	200	10,000
Maximum PC (µg/m^3)		0.316	2.51	37.8
Max PC as % of AQS		0.79%	1.25%	0.38%
HSR1	Industrial estate	0.107	2.51	37.8
HSR2	Mary Price Court	0.0789	1.76	25.9
HSR3	Moorland Primary School	0.0840	1.80	21.0
HSR4	Industrial estate	0.316	2.35	29.3
HSR5	Youth club and sporting grounds	0.0954	1.58	21.4
HSR6	Apartments, Bute East Dock	0.108	1.14	20.3
HSR7	Holiday Inn	0.102	1.03	12.4
HSR8	Willows High School	0.0448	0.904	10.8
HSR9	St Cuthbert's School	0.0746	0.859	9.70
HSR10	Travellers' site	0.0339	0.642	6.89
AQMA1	Stephenson Court AQMA	0.0269	0.736	8.58
AQMA2	Cardiff City Centre AQMA	0.0219	0.538	7.48

5.1.4. It can be seen from the results in Table 18 that all pollutants screen out (in accordance with the criteria outlined in Section 2.17.) for both the specified potentially sensitive human receptors and the AQMA locations considered. Consequently, no further assessments are required.

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

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

6.1.1. 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.

6.1.2. A summary of 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 2.18.1) 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 outlined in Section 2.18.2., 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.	Long Term (Annual) PC (µg/m³)	Long Term Critical Level (CL) (µg/m³)	Long Term PC as a % of the CL (µg/m³)	Short Term (24-hour mean) PC (µg/m³)	Short Term Critical Level (CL) (µg/m³)	Short Term PC as a % of the CL (µg/m³)	Worst Case Met Year for Long-Term PCs	Worst Case Met Year for Short-Term PCs
SE1	**0.861**	30	**2.87%**	5.19	75	6.92%	2017	2019
SE2	0.0575		0.19%	0.916		1.22%	2018	2018
SE3	0.0601		0.20%	0.491		0.65%	2015	2015
CBW1	0.00239		0.01%	0.0698		0.09%	2019	2019
LNR1	0.0514		0.17%	0.709		0.95%	2018	2019
LWS1	0.887		2.96%	6.12		8.16%	2017	2019
LWS2	0.139		0.46%	3.21		4.28%	2019	2019
LWS3	0.167		0.56%	1.97		2.62%	2017	2015
LWS4	0.0464		0.15%	0.590		0.79%	2017	2016
LWS5	0.0562		0.19%	0.885		1.18%	2018	2018
LWS6	0.0442		0.15%	0.582		0.78%	2018	2019

6.1.3. 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 oxides of nitrogen PCs are less than 1% of the critical level for all sites except SE1. Similarly, daily mean oxides of nitrogen PCs are all less than 10% of the critical level at these sites and are therefore not significant (refer to Section 2.18.).

6.1.4. 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 2.18.) and consequently no further assessment is required.

6.1.5. For the worst-case long-term PC on SE1, the impact is potentially significant. Consequently, for this ecological site, the PEC will need to be calculated. As displayed in Table 6 of Section 2.7.1, the background NO_X concentration at SE1 is 31.17 µg/m^3 – the PEC would therefore be 32.03 µg/m^3 (or 107% of the critical level), consequently it cannot be assumed there will be no adverse effect and therefore further assessment is required.

6.1.6. Firstly, it is worth noting that the background concentration alone, at SE1, exceeds the long-term NO_X critical level (with a background concentration of 104%) in the absence of the Site's predicted PCs from A1 and A2 being added. Furthermore, as a worst-case scenario, emissions from the Site's two boilers have been assumed to be released at the maximum ELVs twenty-four hours a day, 365 days of the year. This represents a highly conservative assessment of the impact since the actual emissions from the Site are likely to be significantly lower during normal operation (as demonstrated by the Emissions Monitoring Survey undertaken for the A1 and A2 boilers in July 2021 – a copy of this report (P5003, R001) may be found as Appendix I).

6.1.7. Consequently, when carrying out further assessment making use of measured emissions data (i.e., as shown in Appendix I), the Site's predicted long-term (annual) NO_X PCs on SE1 for the worst-case met year (2017) would be 0.177 µg/m^3 (or 0.59% of the long-term critical level).

6.1.8. It can therefore be considered that, during normal operation, the predicted long-term NO_X PCs from Site on SE1 can be considered insignificant in accordance with the significance criteria (i.e., at less than 1% of the long-term critical level).

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

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

7.1.1. A summary of maximum predicted total (wet and dry) nutrient nitrogen deposition rates at the identified habitat sites are presented in Table 20. 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.

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

Table 20: Comparison of Maximum Predicted Nutrient Nitrogen Deposition Rates with Critical Loads at Sensitive Habitat Sites

ADMS Ref.	Description	Habitat Type	Deposition Rate Used	Critical Load (kgN/Ha/yr)[j]		Nutrient Nitrogen Deposition Rate (kgN/Ha/yr) [(a)]	Percentage of Critical Load (%)	
				Lower	Upper		Lower	Upper
SE1	Severn Estuary - Ramsar	Coastal saltmarsh / Estuaries	Grassland	20	30	0.120	0.60%	0.40%
SE2						0.00778	0.039%	0.026%
SE3						0.00856	0.043%	0.029%
SE1	Severn Estuary - SAC	Atlantic Salt Meadows / Estuaries	Grassland	20	30	0.120	0.60%	0.40%
SE2						0.00778	0.039%	0.026%
SE3						0.00856	0.043%	0.029%
SE1	Severn Estuary – SPA	Common Shelduck, Common Redshank, Greater White-Fronted Goose	Grassland	20	30	0.120	0.60%	0.40%
SE2						0.00778	0.039%	0.026%
SE3						0.00856	0.043%	0.03%
SE1	Severn Estuary - SSSI	Fed, Marsh and Swamp	Grassland	15	30	0.120	0.80%	0.40%
SE2						0.00778	0.052%	0.026%
SE3						0.00856	0.057%	0.029%
CBW1	Cardiff Beech Woods - SAC	Fagus Woodland	Woodland	10	20	0.000543	0.0054%	0.0027%

Note to Table 20

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

7.1.3. It can be seen from the data in Table 20, 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.

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

7.2.1. A summary of maximum predicted acid deposition rates at the relevant 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 maximum critical load has been selected.

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

Table 21: Comparison of Maximum Predicted Acid Deposition Rates with the Maximum Critical Load at Sensitive Habitat Sites

Habitat Ref. [a]	Deposition Rate Used [b]	Acid Deposition (kEq/ha/yr)	CL Min N (kEq/ha/yr)	CL Max N (kEq/ha/yr)	CL Max S (kEq/ha/yr)	PEC N (kEq/ha/yr) [c]	Total PC as a Percentage of the Critical Load Function [d]
		PC N					
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	Grassland	0.00859	0.223	1.063	0.84	1.13	0.81%
SE2- SSSI		0.000556				1.12	0.052%
SE3- SSSI		0.000612				1.12	0.058%
CBW1 - SAC	Forest	0.0000388	0.142	1.428	1.286	1.84	0.0027%

Note to Table 21

(a) Refer to Table 2 in Section 2.4. for receptor names and designations.
(b) Refer to Table 8 in Section 2.8.2. for deposition parameters.
(c) Refer to Table 7 in Section 2.7.2. for the site-specific acid deposition background concentrations.
(d) Total PC to acid deposition is derived from the sum of PC N (where PC N is the sum of NO_2 deposition (dry deposition only)).

7.2.3. The data is Table 21 shows, that where the habitat is sensitive to acid deposition, the maximum predicted acid deposition rate, as a result of emissions from the two boiler stacks at the Site (i.e., the one existing and the one proposed boiler), does not exceed 1% of the critical load function. Consequently, no further assessments are required.

8. CONCLUSIONS

8.1.1. Detailed air quality modelling using the ADMS dispersion model has been undertaken to predict the impacts associated with stack emissions from Princes Cardiff. This has been carried out for both the one existing boiler and the one proposed boiler operating simultaneously.

8.1.2. A detailed screening assessment has been carried out to derive conservative assumptions for the assessment and to determine the optimum discharge stack heights for the existing and the proposed boiler flues. It has been considered that 20m high stacks for both boiler flues (i.e., for the one existing and the one proposed boiler) will facilitate both adequate dispersion of the combustion emissions as well as affording a level of future-proofing of the proposed stack heights, should Princes look to add one additional emission point (i.e., another identical boiler to the one currently proposed) in the vicinity of the boiler house (it is anticipated that, in such an event, the impact of the cumulative emissions would need to be investigated via means of further air quality assessments).

8.1.3. The assessment at maximum predicted GLCs (PCs), at boiler stack heights of 20m, showed that the long-term NO_2 PC would see the impact regarded as 'Moderate' and that the short-term NO_2 and CO PCs could be considered insignificant.

8.1.4. The assessment at the potentially sensitive human receptor locations has demonstrated that the impact of the predicted PCs can be considered insignificant for all the pollutants considered at all of the human receptors and AQMA sites assessed.

8.1.5. For the potentially sensitive ecological sites, the assessment has demonstrated that the impact from the Site is unlikely to result in a breach of the relevant Critical Levels or Critical Loads or 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 the impact could be considered insignificant when making use of actual emissions data.

8.1.6. It should be emphasised that, unless specified otherwise, the emissions rates have been calculated at a worst-case scenario basis of being emitted from the two boiler stacks twenty-four hours a day, 365 days of the year. This represents a conservative assessment which assumes both emission points assessed will release to atmosphere at the maximum proposed ELVs continuously throughout the year.

8.1.7. In reality during normal operation, and when scheduled and unscheduled maintenance is taken into account, it is considered the predicted mean pollutant concentrations for each pollutant assessed would be smaller. Consequently, during normal day to day operation, maximum GLCs are likely to be less and the significance of the impact lower as a result.

8.1.8. In summary, therefore, it can be concluded that emissions arising from the existing and the proposed boiler flues at Princes, Cardiff, will not have a detrimental impact on local air quality, human health, sensitive habitat sites or on the AQMAs assessed.

APPENDIX I

ECL REPORT: P5003 / R001

(EMISSIONS MONITORING SURVEY: JULY 2021)

ECL Ref: ECL.046.01.01/ADM
March 2022
Issue: 2

EMISSIONS MONITORING SURVEY

Prepared for:

Princes Limited.
Unit 69 East Moors Trading Estate
Portmanmoor Road
East Moors
Cardiff
CF24 5HB

Permit Number	**: EPR/BX8289IW**
Variation Number	**: V003**
Installation	**: A1 Boiler 2 (Old Boiler) & A2 Boiler 1 (New Boiler)**
Visit Details	**: Compliance – July 2021**
Job Number	**: P5003**
Report Number	**: R001**
Report Issue Date	**: 24th August 2021**
Survey Dates	**: 15th July 2021**

Prepared by:

Environmental Compliance Limited
Unit G1
Main Avenue
Treforest Industrial Estate
Pontypridd
CF37 5BF.

Tel: 01443 841760
Fax: 01443 841761

Report Issue:		**FINAL**	
Report Prepared by:		**Report Reviewed & Approved by** **MCERTS Level Two** **Technical Endorsements TE1, TE2, TE3 & TE4**	
Name:	Paul Jones	***Name:***	Andy Barnes
		MCERTS No:	MM 03 235
		Signature:	
Date:	13/08/2021	***Date:***	24/08/2021

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".

mCERTS THE ENVIRONMENT AGENCY'S MONITORING CERTIFICATION SCHEME

UKAS TESTING
2499

This report has been prepared by Environmental Compliance Limited (ECL) in their professional capacity as Environmental Consultants. The contents of the report reflect the conditions that prevailed and the information available or supplied at the time of its preparation. The report, and the information contained therein, is provided by ECL solely for use and reliance by the Client in performance of ECLs duties and liabilities under its contract with the Client. Until ECL has received payment in full as detailed in the quotation or contract the contents of this report remain the legal property of ECL. The contents of the report do not, in any way, purport to include any manner of legal advice or opinion.

Any operating information and CEMS data used in this report has been supplied by the client.

This report should not be reproduced, (except in full) without the written approval of the laboratory.

Should the Client wish to release this report to a Third Party for the party's reliance, Environmental Compliance Ltd may, at its discretion, agree to such release provided that:

- Environmental Compliance Ltd gives written agreement prior to such release and ECL has received payment in full for all works/services undertaken;
- By release of the report to the Third Party, that Third Party does not acquire any rights, contractual or otherwise, whatsoever against Environmental Compliance Ltd and, accordingly, Environmental Compliance Ltd assume no duties, liabilities or obligations to that Third Party;
- Environmental Compliance Ltd accepts no responsibility for any loss or damage incurred by the Client or for any conflict of Environmental Compliance Ltd interests arising out of the Clients' release of this report to the Third Party.

In the event that a report is revised and re-issued, the client shall ensure that any earlier versions of the report, and any copies thereof, are void and such copies should be marked with the words "superseded and revised".

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.

TABLE OF CONTENTS

PART 1 - EXECUTIVE SUMMARY

1 Monitoring Objectives

Environmental Compliance Ltd (ECL) was commissioned by **Princes Limited** to undertake an emission monitoring survey at their **Cardiff Soft Drinks Plant**. This report presents the findings of the study.

The monitoring at this installation was carried out in accordance with our quotation reference **DHFB/P5003/Q001**, 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	**A2**
	Boiler 2 (Old Boiler)	Boiler 1 (New Boiler)
Velocity / Flowrate	● U	● U
Oxides of Nitrogen (as NO_2)	● U	● U
Carbon Monoxide	● U	● U
Oxygen	● 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: *"Normal firing 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 Claimed For Test Result	Tick if non-conforming test (see Section 2	Operating Status
A1 – Boiler 2 (Old Boiler)	Volumetric Flowrate	…	0.83145	m^3/sec	5	Stack Conditions	15/07/2021	12:45 – 13:22	BS EN 16911-1:2013 & MID	UKAS / MCERTS	✓	Normal
	Volumetric Flowrate	…	0.42324	m^3/sec	7	Dry & 3% O_2	15/07/2021	12:45 – 13:22	BS EN 16911-1:2013 & MID	UKAS / MCERTS	✓	
	Oxides of Nitrogen (as NO_2)	250*	81.82	mg/m^3	3	Dry & 3% O_2	15/07/2021	13:31 – 14:31	BS EN 14792: 2017	UKAS / MCERTS		
	Carbon Monoxide	…	3.15	mg/m^3	3	Dry & 3% O_2	15/07/2021	13:31 – 14:31	BS EN 15058: 2017	UKAS / MCERTS		
	Oxygen (Paramagnetic)	…	4.48	%	4	& Dry Gas	15/07/2021	13:31 – 14:31	BS EN 14789: 2017	UKAS / MCERTS		

The volumetric flowrate shown above is that from the initial pitot traverse.

*** This limit is not stated in the current version of the permit, but is expected to be included in the next revision of the permit, based on Table 1 of Part 1 of Annex II of the MCPD.**

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 Claimed For Test Result	Tick if non-conforming test (see Section 2	Operating Status
A2 – Boiler 1 (New Boiler)	Volumetric Flowrate	…	0.77773	m^3/sec	8	Stack Conditions	15/07/2021	11:00 – 11:32	BS EN 16911-1:2013 & MID	UKAS / MCERTS	✓	Normal
	Volumetric Flowrate	…	0.45200	m^3/sec	10	Dry & 3% O_2	15/07/2021	11:00 – 11:32	BS EN 16911-1:2013 & MID	UKAS / MCERTS	✓	
	Oxides of Nitrogen (as NO_2)	100#	78.07	mg/m^3	3	Dry & 3% O_2	15/07/2021	11:29 – 12:29	BS EN 14792: 2017	UKAS / MCERTS		
	Carbon Monoxide	…	3.54	mg/m^3	3	Dry & 3% O_2	15/07/2021	11:29 – 12:29	BS EN 15058: 2017	UKAS / MCERTS		
	Oxygen (Paramagnetic)	…	3.81	%	4	& Dry Gas	15/07/2021	11:29 – 12:29	BS EN 14789: 2017	UKAS / MCERTS		

The volumetric flowrate shown above is that from the initial pitot traverse.

 # This limit is not stated in the current version of the permit, but is expected to be included in the next revision of the permit, based on Table 1 of Part 2 of Annex II of the MCPD.

Princes Limited		**Installation Name**	**: A1 Boiler 2 (Old Boiler) & A2 Boiler 1 (New Boiler)**
Permit No	**: EPR/BX8289IW**	**Visit Details**	**: Compliance – July 2021**
Variation No	**: V003**	**Survey Dates**	**: 15th July 2021**
Report Ref	**: P5003 : R001**	**Report Issue Date.**	**: 24th August 2021**

Notes

The uncertainty figures presented in Table 1.1 for NO_x, CO, & O_2 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

Any operating information and CEMS data below has been supplied by the client.

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
A1 – Boiler 2 (Old Boiler)	Continuous	As required	Gas	NA	None	Normal*	…	…	…	NP	…	…
A2 – Boiler 1 (New Boiler)	Continuous	As required	Gas	NA	None	Normal*	…	…	…	NP	…	…

* Each boiler was set to "lead" during the period that it was being sampled.

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/BX8289IW BX8289IW/V003** 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, as follows.

There were non-conforming tests, as follows**.**

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

Flowrate tests are non-conforming, as there is only one sampling port available in each case, rather than two as required by the sampling standards. In order to maintain the UKAS/MCERTS accreditation status of the tests, extra sample points were used on the one available sample line.

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

- A1 Boiler 2 (Old Boiler): Such tests are not applicable to this location (as the duct area is $<1m^2$) were not requested by the client.
- A2 Boiler 1 (New Boiler): Such tests are not applicable to this location (as the duct area is $<1m^2$) 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
Paul Jones	15/07/21	MM 02 021	2	TE1, TE2, TE3, TE4
Tyrone Morris	15/07/21	MM 21 1639	Trainee	

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

Details of the substances monitored, the standard methods used and the Environmental Compliance Limited Technical Procedures used during this survey are shown in the table below. Detailed sampling protocols are included in a separate document which will be sent with the report.

In all cases, where analysis of collected samples was required, the analysis was by a subcontract laboratory. Details of the sub-contract laboratory are shown on the analysis certificates in this report. The UKAS/MCERTs accreditation status of the analysis is also indicated on the certificates.

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

Determinand	External Reference Method	ECL Technical Procedure Number
Velocity and Flowrate	BS EN 16911-1:2013 & MID	ECL/ TPD/ 022A
Oxygen (PG350)	BS EN 14789: 2017	ECL / TPD / 033D
Carbon Monoxide (PG350)	BS EN 15058: 2017	ECL / TPD / 033D
Oxides of Nitrogen (PG350)	BS EN 14792: 2017	ECL / TPD / 033D
Carbon Dioxide (PG350)	ISO 12039	ECL / TPD / 033D
Moisture	BS EN 14790: 2017	ECL / TPD / 082

5 SAMPLE POINT DESCRIPTIONS

The homogeneity test is applicable to combustion processes, but may also be requested by the regulator for non-combustion processes.

Homogeneity testing has not been completed at these locations.

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

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

The sample locations that were monitored are detailed below:-

A1 Boiler 2 (Old Boiler)

The stack diameter is 0.38m and the sample platform width back from the sample port is 1.2m.

One 3″ BSP sample port is located on the stack on the horizontal. This sample port is located at a height of approximately 0.4m from the working sample platform.

Access to the sample platform was attained by means of scaffold accessed from inside the Boiler House building.

A2 Boiler 1 (New Boiler)

The stack diameter is 0.38m and the sample platform width back from the sample port is 1.2m.

One 3″ BSP sample port is located on the stack on the horizontal. This sample port is located at a height of approximately 0.6m from the working sample platform.

Access to the sample platform was attained by means of scaffold accessed from inside the Boiler House building.

EQUIPMENT IDs
(Pre site checklist from SSP)

Princes Limited		Installation Name	: A1 Boiler 2 (Old Boiler) & A2 Boiler 1 (New Boiler)
Permit No	: EPR/BX8289IW	Visit Details	: Compliance – July 2021
Variation No	: V003	Survey Dates	: 15th July 2021
Report Ref	: P5003 : R001	Report Issue Date.	: 24th August 2021

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	U002							
MST Nozzle set									
MST "S" Type Pitot		635							
MST Probe		135							
MST Hot Box		400							
MST Impinger Arm		656							
Barometer		204							
Site Balance		1069							
Site Check weights		190							
		191							
Horiba	E002	1264							
Heated Probe / Filter		572							
Chiller		1092							
MFC		1180	1181						
Heated Line		1090	1091						
FID	E003								
Heated Line									
Heated Probe / Filter									
Testo	E004								
FTIR	E005								
Heated Probe / Filter									
Heated Line									
Stackmite	E006								
"L" Type Pitot									
Digital Manometer									
Stack Thermocouple		860							
Thermocouple Reader									
Nozzle Set									
Workhorse Pumps	E007								
Stack Thermocouple									
Tube Thermocouple									
Meter Thermocouple									
High Vac Gauge									
Dioxin Thermocouple									

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

FIGURES

Figure 1

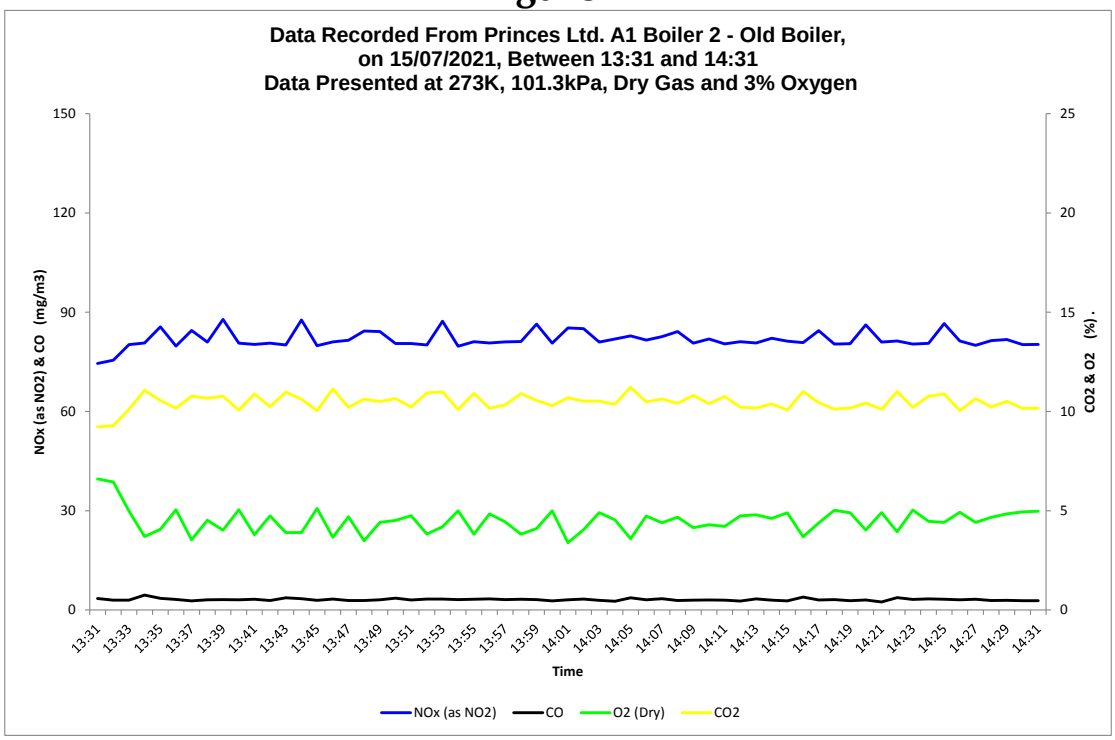
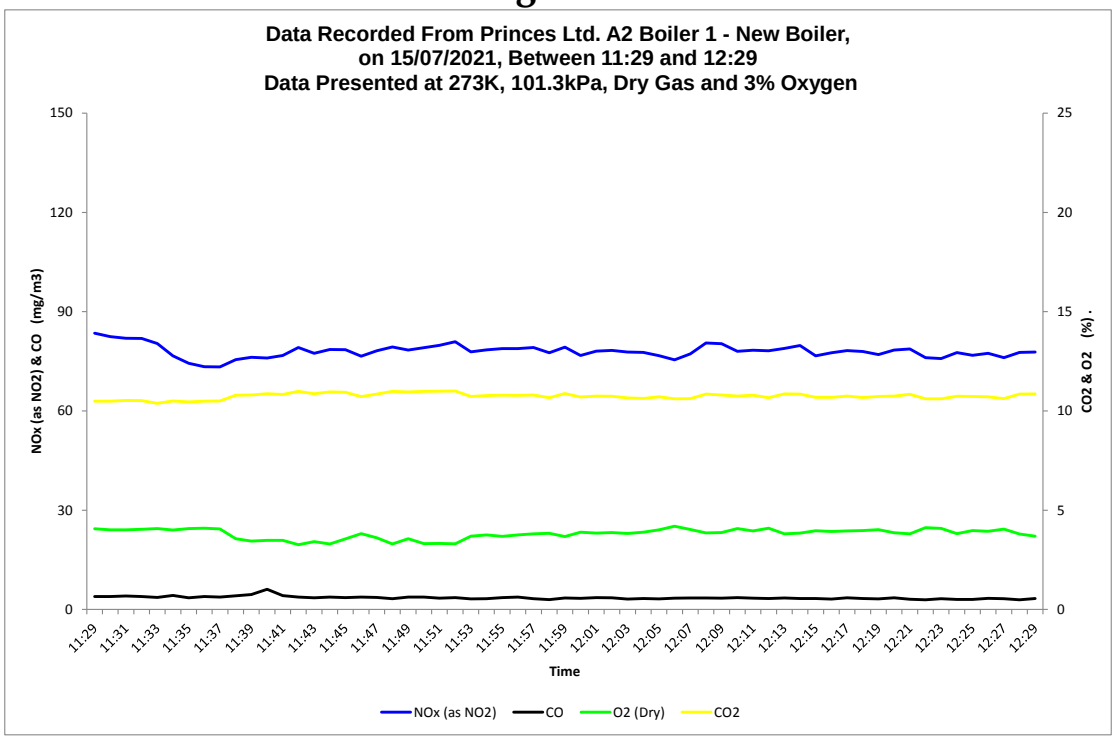


Figure 2



TABLES

Table 1

Data Recorded from A1 – Boiler 2 (Old Boiler)

Sample Period: 13:31 – 14:31 on the 15th July 2021

Volumetric Flowrate (Reference Conditions) = 0.42324 **m^3/sec ***

	Average	Emission Rate
	mg/m^3	**Kg/hr**
Oxides of Nitrogen (as NO_2) *	**81.82**	**0.1247**
Carbon Monoxide *	**3.15**	**0.0048**
Oxygen (%)	**4.48**	**...**

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

Table 2

Data Recorded from A2 – Boiler 1 (New Boiler)

Sample Period: 11:29 – 12:29 on the 15th July 2021

Volumetric Flowrate (Reference Conditions) = 0.45200 **m^3/sec ***

	Average	Emission Rate
	mg/m^3	**Kg/hr**
Oxides of Nitrogen (as NO_2) *	**78.07**	**0.1270**
Carbon Monoxide *	**3.54**	**0.0058**
Oxygen (%)	**3.81**	**...**

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

VELOCITY TRAVERSE PROFILES

Environmental Compliance Limited

Princes Limited		**Installation Name**	**: A1 Boiler 2 (Old Boiler) & A2 Boiler 1 (New Boiler)**
Permit No	**: EPR/BX8289IW**	**Visit Details**	**: Compliance – July 2021**
Variation No	**: V003**	**Survey Dates**	**: 15th July 2021**
Report Ref	**: P5003 : R001**	**Report Issue Date.**	**: 24th August 2021**

Environmental Compliance Limited	Traverse Data Profoma	Date of Measurement	15/07/2021

Company	Princes Ltd.	Stack Diameter Port A (mm)	380	Average Stack Diameter (mm)	380	Pitot tube coefficient	0.84
Site	Cardiff	Stack Diameter Port B (mm)		Port Length (mm)	60	Pitot Id	635
Location	Boiler House	Duct Length Port A (mm)		Average Duct Length (mm) L		Stack Thermocouple ID	860
Stack	A1 Boiler 2 (Old Boiler)	Duct Length Port B (mm)		Duct width (mm) B		Stack Temp Reader ID	116
Job No	P5003	Duct Length Port C (mm)		Barometric Pressure. (mb)	1023	Manometer ID	113
Operators	PJ/TM	Duct Length Port D (mm)		Ave Static Press. (mm $H_2$0)	5.00	Barometer ID	204

Pre - Traverse Checks Carried Out	Time	Pass/ Fail
Pre - Traverse PITOT Visual Inspection	12:45:00	Pass
Pre - Traverse PITOT Leak Check	12:47:00	Pass

Smooth Walls

Static Pressure Readings (mm H_2O)			
Port A	Port B	Port C	Port D
5.00			

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 ^{O} From Reference
A1	25	13:00:00	180.0	180.0	180.0	2.50	2.50	2.50	180.0	2.50	9
A2	95	13:02:00	180.0	180.0	180.0	3.50	3.50	3.00	180.0	3.33	9
A3	285	13:04:00	181.0	180.0	181.0	3.50	3.50	3.50	180.7	3.50	9
A4	355	13:06:00	180.0	180.0	180.0	3.00	3.00	3.00	180.0	3.00	9
Blockage Check @ A1 (L-Type Pitot Only)									720.7	12.3	Total
			Mean			Mean			180.7	3.5	Max
			Difference <5% from Initial ?			Difference <5% from Initial ?			180.0	2.5	Min
									180.2	3.1	Average

Stagnation Check (S-type Pitot Only)	Time	Reading
Static Pressure Via Positive Leg (mm H_2O)	13:08:00	4.50
Static Pressure Via Negative Leg (mm H_2O)	13:10:00	4.00
Difference (Pa) < 1 mm $H_2$0 ?		-0.50

Post - Traverse Checks Carried Out	Time	Pass/ Fail
Post - Traverse PITOT Visual Inspection	13:20:00	Pass
Post - Traverse PITOT Leak Check	13:22:00	Pass

Average temp (K)	453.167

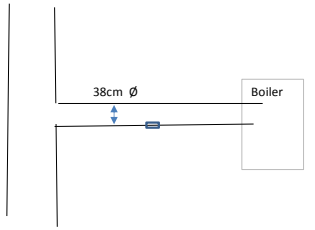
Suitability of Sampling Position	Actual Stack Conditions
Highest:lowest flow pressure ratio < 9:1?	1.4:1
Maximum deviation of flow from axis < 15^O ?	9
X-sectional area for stacks = πr2	0.11 m^2
X-sectional area for ducts = L x B	m^2
Suitability of Position for Sampling	OK

Stack Moisture	8.83	%	Gas Velocity (as Measured) Adjusted for Smooth Walls	7.33124	m/sec
Measured Oxygen	4.48	%	Gas Velocity (Reference Conditions) Adjusted for Smooth Walls	3.73189	m/sec*
Measured Carbon Dioxide	10.47	%	Volumetric Flowrate (as Measured) Adjusted for Smooth Walls	0.83145	m^3/sec
Dry Gas Molecular Weight	29.85440	g/g mole	Volumetric Flowrate (Ref Cond) Adjusted for Smooth Walls	0.42324	m^3/sec*

*Reference Conditions: 273K, 101.3kPa, 3% Oxygen, Dry Gas

NOTE: Velocity / volume flowrate calculations exclude contributions from the measurement point(s) where swirl >15°

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	0.4m
Number of sample ports	1
Width of platform (port back to handrail)	1.2m

Nearest downstream disturbance	Bend	1.30m
Nearest upstream disturbance	Bend	0.87m

Disturbances are classed as bends, fans or diameter variations

Environmental Compliance Limited

Princes Limited		Installation Name	: A1 Boiler 2 (Old Boiler) & A2 Boiler 1 (New Boiler)
Permit No	: EPR/BX8289IW	Visit Details	: Compliance – July 2021
Variation No	: V003	Survey Dates	: 15th July 2021
Report Ref	: P5003 : R001	Report Issue Date.	: 24th August 2021

Environmental Compliance Limited	Traverse Data Profoma	Date of Measurement	15/07/2021

Company	Princes Ltd.	Stack Diameter Port A (mm)	380	Average Stack Diameter (mm)	380	Pitot tube coefficient	0.84
Site	Cardiff	Stack Diameter Port B (mm)		Port Length (mm)	60	Pitot Id	635
Location	Boiler House	Duct Length Port A (mm)		Average Duct Length (mm) L		Stack Thermocouple ID	860
Stack	A2 Boiler 1 (New Boiler)	Duct Length Port B (mm)		Duct width (mm) B		Stack Temp Reader ID	116
Job No	P5003	Duct Length Port C (mm)		Barometric Pressure. (mb)	1023	Manometer ID	113
Operators	PJ/TM	Duct Length Port D (mm)		Ave Static Press. (mm $H_2$0)	4.50	Barometer ID	204

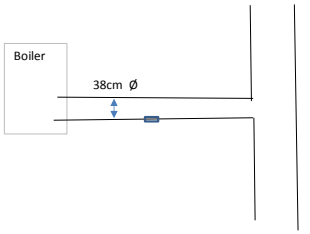
Pre - Traverse Checks Carried Out	Time	Pass/ Fail
Pre - Traverse PITOT Visual Inspection	11:00:00	Pass
Pre - Traverse PITOT Leak Check	11:02:00	Pass

Smooth Walls

Static Pressure Readings (mm H_2O)

Port A	Port B	Port C	Port D
4.50			

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	25	11:18:00	139.0	139.0	140.0	2.50	2.50	2.50	139.3	2.50	8
A2	95	11:20:00	140.0	140.0	140.0	3.00	3.00	3.50	140.0	3.17	8
A3	285	11:22:00	141.0	142.0	142.0	3.50	3.50	3.50	141.7	3.50	9
A4	355	11:24:00	143.0	143.0	143.0	3.00	2.50	2.50	143.0	2.67	9
Blockage Check @ A1 (L-Type Pitot Only)									564.0	11.8	Total
			Mean			Mean			143.0	3.5	Max
			Difference <5% from Initial ?			Difference <5% from Initial ?			139.3	2.5	Min
									141.0	3.0	Average

Stagnation Check (S-type Pitot Only)	Time	Reading
Static Pressure Via Positive Leg (mm H_2O)	11:26:00	4.50
Static Pressure Via Negative Leg (mm H_2O)	11:28:00	4.00
Difference (Pa) < 1 mm $H_2$0 ?		-0.50

Post - Traverse Checks Carried Out	Time	Pass/ Fail
Post - Traverse PITOT Visual Inspection	11:30:00	Pass
Post - Traverse PITOT Leak Check	11:32:00	Pass

Average temp (K)	414.000

Suitability of Sampling Position	Actual Stack Conditions
Highest:lowest flow pressure ratio < 9:1?	1.4:1
Maximum deviation of flow from axis < 15°?	9
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

Stack Moisture	8.63	%	Gas Velocity (as Measured) Adjusted for Smooth Walls	6.85762	m/sec
Measured Oxygen	3.81	%	Gas Velocity (Reference Conditions) Adjusted for Smooth Walls	3.98549	m/sec*
Measured Carbon Dioxide	10.74	%	Volumetric Flowrate (as Measured) Adjusted for Smooth Walls	0.77773	m^3/sec
Dry Gas Molecular Weight	29.87080	g/g mole	Volumetric Flowrate (Ref Cond) Adjusted for Smooth Walls	0.45200	m^3/sec*

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

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

Compliance With Positional Requirements?

Height of sample ports from Platform	0.6m
Number of sample ports	1
Width of platform (port back to handrail)	1.2m

Nearest downstream disturbance	Bend	1.30m
Nearest upstream disturbance	Bend	0.87m

Disturbances are classed as bends, fans or diameter variations

FIELD CALIBRATION AND SAMPLING DATA

Environmental Compliance Limited

Princes Limited			**Installation Name**	: A1 Boiler 2 (Old Boiler) & A2 Boiler 1 (New Boiler)
Permit No	: EPR/BX8289IW		**Visit Details**	: Compliance – July 2021
Variation No	: V003		**Survey Dates**	: 15th July 2021
Report Ref	: P5003	: R001	**Report Issue Date.**	: 24th August 2021

Proforma 1

Environmental Compliance Limited	NON ISOKINETIC SAMPLING PROFORMA	Date of Measurement	15/07/2021

If moisture was not measured see detailed notes below.

ECL/TPD/	82	Time taken to change Ports?	0	Start Time	14:00	End Time	14:30
				Test Duration	30 mins		

Client	Princes Ltd	Stack Profile	Circular	Console id	U002	Barometer id	204
Site	Cardiff	Stack Area (m^2)	0.11	Pump id	U002	Nozzle Id	n/a
Location	Boiler House	Barometric Pressure (mb)	1023	Probe id	135	Nozzle size	n/a
Stack ID	Boiler 2 (Old Boiler)	Static Pres. (mm H_20)	5	DGM Yd	0.9851	Filter Id	uwqma
Test No.	Moisture 1	Pitot coefficient	n/a	ΔH@	47.18	Pitot ID	n/a
Job No	P5003	Probe Heater Setting (°C)	180	Impinger Id	656	Hot Box ID	400
ECL Site Staff	PJ / TM	Hot Box Setting (°C)	180	Balance Id	1069		

FOR HF ONLY - A leak check MUST be performed at the end of the test (and when moving between sample ports if any disconnections are required).

	Sample	Leak 1	Leak 2	Leak 3	Leak 4	Leak 5	Total
Start Volume	8298.3						
Final Volume	8601.2						
Total Volume	302.9	0.0	0.0	0.0	0.0	0.0	302.9
Leak Check	First	Second	Third	Fourth	Fifth		
Leak rate l/min	0						
Vaccum "Hg	4						
Time of Check	13:45						
Set Rate l/min	10						
Leak <2%?	YES						

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

Dry O_2 (Atmospheric)	4.48
Dry Carbon Dioxide %	10.47
Dry Carbon Monoxide ppm	2.31

FOR OTHER Determinands, no further leak checks are required (but are allowed) after the sample has started.

Traverse Point	A1	A1	A1						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)	10.00	10.00	10.00						10.00
Meter (Tm in)	28.00	31.00	32.00						30.33
Meter (Tm out)	28.00	28.00	28.00						28.00
Stack Temp (Ts)	183.00	180.00	170.00						177.67
Impinger T Outlet	9.00	10.00	13.00						10.67
Vaccum (" Hg)	2.00	2.00	2.00						2.00

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	SOL/	Start Weight (g)	End Weight (g)	Total weight (g)
Impinger 1: DI Water	4318	744.6	757.5	12.9
Impinger 2: DI Water	4318	665.7	671	5.3
Impinger3: Empty		592.7	593.7	1
Impinger 4: Silica		913	915	2
Impinger 5				0
Impinger 6				0
Impinger 7				0
Impinger 8				0
Total (g)				21.20

Silica <50% used at End of Test? Y/N	YES

Rinse Solutions used	
Solution	SOL NO
DI Water	4138
Acetone	NA

Additional Moisture Weighings

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.

Proforma 2

Environmental Compliance Limited	NON ISOKINETIC SAMPLING PROFORMA	Date of Measurement	15/07/2021

If moisture was not measured see detailed notes below.

ECL/TPD/	82	Time taken to change Ports?	0	Start Time	11:55	End Time	12:25
				Test Duration	30 mins		

Client	Princes Ltd	Stack Profile	Circular	Console id	U002	Barometer id	204
Site	Cardiff	Stack Area (m^2)	0.11	Pump id	U002	Nozzle Id	n/a
Location	Boiler House	Barometric Pressure (mb)	1023	Probe id	135	Nozzle size	n/a
Stack ID	A2 Boiler 1 (Newer Boiler)	Static Pres. (mm H_20)	4.5	DGM Yd	0.9851	Filter Id	uwqma
Test No.	Moisture 1	Pitot coefficient	n/a	ΔH@	47.18	Pitot ID	n/a
Job No	P5003	Probe Heater Setting (°C)	180	Impinger Id	656	Hot Box ID	400
ECL Site Staff	PJ / TM	Hot Box Setting (°C)	180	Balance Id	1069		

FOR HF ONLY - A leak check MUST be performed at the end of the test (and when moving between sample ports if any disconnections are required).

	Sample	Leak 1	Leak 2	Leak 3	Leak 4	Leak 5	Total
Start Volume	7800.7						
Final Volume	8274.1						
Total Volume	473.4	0.0	0.0	0.0	0.0	0.0	473.4
Leak Check	First	Second	Third	Fourth	Fifth		
Leak rate l/min	0						
Vaccum "Hg	4						
Time of Check	11:50						
Set Rate l/min	15						
Leak <2%?	YES						

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

Dry O_2 (Atmospheric)	3.81
Dry Carbon Dioxide %	10.74
Dry Carbon Monoxide ppm	3.38

FOR OTHER Determinands, no further leak checks are required (but are allowed) after the sample has started.

Traverse Point	A1	A1	A1						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)	25.00	25.00	25.00						25.00
Meter (Tm in)	25.00	27.00	30.00						27.33
Meter (Tm out)	25.00	25.00	25.00						25.00
Stack Temp (Ts)	133.00	137.00	107.00						125.67
Impinger T Outlet	15.00	17.00	19.00						17.00
Vaccum (" Hg)	2.00	2.00	2.00						2.00

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	SOL/	Start Weight (g)	End Weight (g)	Total weight (g)
Impinger 1: DI Water	4318	711.1	730.6	19.5
Impinger 2: DI Water	4318	658.6	665.7	7.1
Impinger3: Empty		591.5	592.7	1.2
Impinger 4: Silica		908.1	913	4.9
Impinger 5				0
Impinger 6				0
Impinger 7				0
Impinger 8				0
Total (g)				32.70

Silica <50% used at End of Test? Y/N	YES

Rinse Solutions used	
Solution	SOL NO
DI Water	4138
Acetone	NA

Additional Moisture Weighings

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.

Princes Limited		Installation Name	: A1 Boiler 2 (Old Boiler) & A2 Boiler 1 (New Boiler)
Permit No	: EPR/BX8289IW	Visit Details	: Compliance – July 2021
Variation No	: V003	Survey Dates	: 15th July 2021
Report Ref	: P5003 : R001	Report Issue Date.	: 24th August 2021

Horiba (Combustion Gases) – Calibration Summary

	Horiba PG 350 Measurement Ranges:			
	NO as NO_2	CO	O_2	CO_2
	512.5	250	25	20
Units	mg/m^3	mg/m^3	%Vol	%Vol
Zero Values (Direct)				
Mean Initial Direct Zero	0.16	0.08	0.03	0.10
Mean Confirmation Direct Zero	0.04	-0.24	0.13	0.13
Difference in Direct Zero	0.12	0.31	0.10	0.03
Repeatability at Zero	4.10	2.50	0.20	0.20
<2 x Repeatability at Zero?	YES	YES	YES	YES
Pre Zero Values (System)				
Mean Pre Test Zero	0.14	0.12	0.13	0.14
% of Measurement Range?	0.03%	0.05%	0.53%	0.71%
Detection Limit (LOD)	0.16	0.01	0.20	0.01
Applied Span:				
	NO	CO	O_2	CO_2
Actual Applied Span Concentration	320.42	197.88	15.16	17.90
Pre Test System Zero Values				
Mean Pre Test System Zero	0.14	0.12	0.13	0.14
Difference ≤ ± 2% of Span Value?	0.04%	0.06%	0.87%	0.80%
Post Test Direct Zero Values				
Mean Post Test Direct Zero	0.15	-0.06	0.11	0.23
% of Certified Range?	0.03%	-0.03%	0.44%	1.17%
Zero Drift ≤ ± 5% of Applied Span?	0.00%	0.07%	0.53%	0.73%
Pre Test System Span Values				
Mean Pre Test System Span	319.18	197.51	15.07	17.93
Difference ≤ ± 2% of Span Value ?	0.39%	0.19%	0.57%	0.19%
Post Test Direct Span Values				
Mean Post Test Direct Span	320.79	198.47	15.18	18.00
Span Drift ≤ ± 5% Span Value?	0.12%	0.30%	0.13%	0.56%

UNCERTAINTY CALCULATIONS

Princes Limited		Installation Name	: A1 Boiler 2 (Old Boiler) & A2 Boiler 1 (New Boiler)
Permit No	: EPR/BX8289IW	Visit Details	: Compliance – July 2021
Variation No	: V003	Survey Dates	: 15th July 2021
Report Ref	: P5003 : R001	Report Issue Date.	: 24th August 2021

Stack Reference A1 Boiler 2 (Old Boiler)

Measurement Uncertainty Calculations - Velocity at Stack Conditions

Contribution From	Standard u/c (mm H_2O)	
Pitot Calibration Uncertainty Contribution	0.015	A
Manometer Calibration Uncertainty Contribution	0.015	B
Variation in Actual Pitot reading at sample points	0.06	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)	**0.08**	
	Standard u/c (K)	
Temperature Calibration (K)	2.27	D
Variation in Actual Temp reading at sample points	0.13	E
Combined u/c of Temp (K)	**Combined u/c (K)**	
SQRT $((D/\sqrt{3^2}) + (E/\sqrt{3})^2)$	1.31	
Expanded Uncertainty of Temp Measurements (K)	**2.62**	
Measured Average Velocity (m/s) at Stack Conds	7.37	
Maximum Average Velocity (m/s) at Stack Conds	7.48	
Standard Uncertainty Velocity at Stack Conditions (%)	1.52	
Expanded Uncertainty Velocity (at Stack Conditions)	**3.05 (%)**	

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	0.84
Maximum Average Flowrate (m^3/s) at Stack Conds	0.86
Standard Uncertainty Flowrate (m^3/s) at Stack Conditions (%)	2.54
Expanded Uncertainty Flowrate (m^3/s) at Stack Conditions	**5.08 (%)**

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	0.51
Maximum Average Flowrate (m^3/s) at STP Wet	0.52
Standard Uncertainty Flowrate (m^3/s) at STP Wet	2.85
Expanded Uncertainty Flowrate (m^3/s) at STP Wet	**5.70 (%)**

Measurement Uncertainty Calculations - Flowrate at STP & Dry Gas

Contribution From	Standard u/c (%)
Moisture Uncertainty (% v/v)	0.28
Measured Average Flowrate (m^3/s) at STP Dry	0.46
Maximum Average Flowrate (m^3/s) at STP Dry	0.48
Standard Uncertainty Flowrate (m^3/s) at STP Dry	3.16
Expanded Uncertainty Flowrate (m^3/s) at STP Dry	**6.33 (%)**

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

Contribution From	Standard u/c (%)
Oxygen Uncertainty (% v/v)	0.090
Measured Average Flowrate (m^3/s) at STP Dry & Ref Oxygen	0.43
Maximum Average Flowrate (m^3/s) at STP Dry & Ref Oxygen	0.44
Standard Uncertainty Flowrate (m^3/s) at STP Dry & Ref Oxygen	3.72
Expanded Uncertainty Flowrate (m^3/s) at STP Dry & Ref O_2	**7.45 (%)**

Princes Limited		Installation Name	: A1 Boiler 2 (Old Boiler) & A2 Boiler 1 (New Boiler)
Permit No	: EPR/BX8289IW	Visit Details	: Compliance – July 2021
Variation No	: V003	Survey Dates	: 15th July 2021
Report Ref	: P5003 : R001	Report Issue Date.	: 24th August 2021

Stack Reference A2 Boiler 1 (New Boiler)

Measurement Uncertainty Calculations - Velocity at Stack Conditions

Contribution From	Standard u/c (mm H_2O)	
Pitot Calibration Uncertainty Contribution	0.015	A
Manometer Calibration Uncertainty Contribution	0.015	B
Variation in Actual Pitot reading at sample points	0.13	C
Combined u/c (mm H_2O) =	**Combined u/c (mm H_2O)**	
SQRT $(A/\sqrt{3})^2 + (B/\sqrt{3})^2 + (C/\sqrt{3})^2$	0.07	
Expanded Uncertainty of Flow Measurements (mm H_2O)	**0.15**	
	Standard u/c (K)	
Temperature Calibration (K)	2.07	D
Variation in Actual Temp reading at sample points	0.25	E
Combined u/c of Temp (K)	**Combined u/c (K)**	
SQRT $((D/\sqrt{3^2}) + (E/\sqrt{3})^2)$	1.20	
Expanded Uncertainty of Temp Measurements (K)	**2.41**	
Measured Average Velocity (m/s) at Stack Conds	6.89	
Maximum Average Velocity (m/s) at Stack Conds	7.08	
Standard Uncertainty Velocity at Stack Conditions (%)	2.74	
Expanded Uncertainty Velocity (at Stack Conditions)	**5.48 (%)**	

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	0.78
Maximum Average Flowrate (m^3/s) at Stack Conds	0.81
Standard Uncertainty Flowrate (m^3/s) at Stack Conditions (%)	3.77
Expanded Uncertainty Flowrate (m^3/s) at Stack Conditions	**7.54 (%)**

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	0.52
Maximum Average Flowrate (m^3/s) at STP Wet	0.54
Standard Uncertainty Flowrate (m^3/s) at STP Wet	4.11
Expanded Uncertainty Flowrate (m^3/s) at STP Wet	**8.22 (%)**

Measurement Uncertainty Calculations - Flowrate at STP & Dry Gas

Contribution From	Standard u/c (%)
Moisture Uncertainty (% v/v)	0.20
Measured Average Flowrate (m^3/s) at STP Dry	0.48
Maximum Average Flowrate (m^3/s) at STP Dry	0.50
Standard Uncertainty Flowrate (m^3/s) at STP Dry	4.34
Expanded Uncertainty Flowrate (m^3/s) at STP Dry	**8.68 (%)**

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

Contribution From	Standard u/c (%)
Oxygen Uncertainty (% v/v)	0.076
Measured Average Flowrate (m^3/s) at STP Dry & Ref Oxygen	0.45
Maximum Average Flowrate (m^3/s) at STP Dry & Ref Oxygen	0.48
Standard Uncertainty Flowrate (m^3/s) at STP Dry & Ref Oxygen	4.80
Expanded Uncertainty Flowrate (m^3/s) at STP Dry & Ref O_2	**9.60 (%)**

Princes Limited		**Installation Name**	**: A1 Boiler 2 (Old Boiler) & A2 Boiler 1 (New Boiler)**
Permit No	**: EPR/BX8289IW**	**Visit Details**	**: Compliance – July 2021**
Variation No	**: V003**	**Survey Dates**	**: 15th July 2021**
Report Ref	**: P5003 : R001**	**Report Issue Date.**	**: 24th August 2021**

A1 & A2 Combustion Gases Measurement Uncertainty

Measurement Uncertainty Calculations Part 1

Horiba PG 350 Performance Characteristics	Standard Uncertainty (% of Range)	Distributiuon	Minimum Certified Range (R_i) NO 0 - 134 mg/m³	CO 0 - 75 mg/m³	O_2 0 - 25 %Vol	CO_2 0 - 20 %Vol
Lack of fit[1]	u_{lof}	Rectangular (Divisor = √3)	0.75	0.61	0.10	1.00
Span drift[2]	$u_{d,s}$	Rectangular (Divisor = √3)	0.094	0.056	0.0057	0.074
Repeatability Standard Deviation (span)[3]	u_r	Normal (Divisor = 1)	0.67	1.03	0.24	0.26
Losses / leakage in the sample system[4]	u_{loss}	Rectangular (Divisor = √3)	0.92	0.49	0.35	0.17
Temperature dependant span drift[5]	u_t	Rectangular (Divisor = √3)	1.80	2.00	0.15	1.00
Interferents[1]	u_i	Rectangular (Divisor = √3)	0.52	0.87		0.55
Uncertainty of Reference Gas[6]	u_{ref}	Rectangular (Divisor = √3)	5.55	3.43	0.15	0.31
Effect of Voltage Fluctuation[7]	u_v	Rectangular (Divisor = √3)	0.40	0.50	0.020	0.40
Effect of Sample Gas Flow/ Pressure[7]	u_{sg}	Rectangular (Divisor = √3)	0.10	0.10	0.10	0.10

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 Expressed as a percentage of the certified range

Measurement Uncertainty Calculations Part 2

Horiba PG 350 Performance Characteristics	Uncertainty	Value of Standard Uncertainty	NO 0 - 134 mg/m³	CO 0 - 75 mg/m³	O_2 0 - 25 %Vol	CO_2 0 - 20 %Vol
Lack of fit	u_{lof}	$u(x_i) = \frac{u_{lof} \times R_i}{\sqrt{3}} =$	0.58	0.26	0.014	0.12
Span drift	$u_{d,s}$	$u(x_i) = \frac{u_{d,s} \times R_i}{\sqrt{3}} =$	0.073	0.024	0.00082	0.0085
Repeatability Standard Deviation (span)	u_r	$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}} =$	0.67	1.03	0.24	0.26
Losses / leakage in the sample system	u_{loss}	$u(x_i) = \frac{u_{loss} \times R_i}{\sqrt{3}} =$	0.71	0.21	0.050	0.02
Temperature dependant span drift	u_t	$u(x_i) = \frac{u_t}{100} \times R_i \times \sqrt{\frac{(x_{i,max} - x_{adj})^2 + (x_{i,min} - x_{adj})(x_{i,max} - x_{adj}) + (x_{i,min} - x_{adj})^2}{3}}$	3.48	2.17	0.054	0.289
Interferents	u_i	$u(x_i) = \frac{u_i \times R_i}{\sqrt{3}} =$	0.40	0.38		0.55
Uncertainty of Reference Gas	u_{ref}	$u(x_i) = \frac{u_{ref}}{\sqrt{3}} =$	3.20	1.98	0.088	0.18
Effect of Voltage Fluctuation [7]	u_v	$u(x_i) = \frac{u_v \times R_i}{\sqrt{3}} =$	0.23	0.29	0.012	0.23
Effect of Sample Gas Flow / Pressure [7]	u_{sg}	$u(x_i) = \frac{usg \times R_i}{\sqrt{3}} =$	0.058	0.058	0.058	0.06
Combined Standard Uncertainty		$u_c = \sqrt{u_{lof}^2 + u_{d,s}^2 + u_r^2 + u_{loss}^2 + u_t^2 + u_i^2 + u_{ref}^2} + u2v + u2sg$	4.89	3.16	0.27	0.50
Expanded measurement uncertainty (at 95% confidence)		$U_{EXP} = 2 \times u_c$	9.78	6.32	0.54	1.00
Applied Span Concentration			320.42	197.88	15.16	17.90
Measured Span Concentration, STP Dry Gas			319.99	197.99	15.13	17.97
Expanded measurement uncertainty as % of Applied Span			3%	3%	4%	6%

Princes Limited		**Installation Name**	**: A1 Boiler 2 (Old Boiler) & A2 Boiler 1 (New Boiler)**
Permit No	**: EPR/BX8289IW**	**Visit Details**	**: Compliance – July 2021**
Variation No	**: V003**	**Survey Dates**	**: 15th July 2021**
Report Ref	**: P5003 : R001**	**Report Issue Date.**	**: 24th August 2021**

A1 Combustion Gases Uncertainty of Measurement Results

Uncertainty of Measurement Results - Calculations Part 1

Horiba PG 350 Performance Characteristics	Standard Uncertainty (% of Range)	Distribution	Divisor	Minimum Certified Range (R_i) NO 0 - 134 mg/m³	CO 0 - 75 mg/m³	O_2 0 - 25 %Vol	CO_2 0 - 20 %Vol
Lack of fit[1]	u_{lof}	Rectangular	$\sqrt{3}$	0.75	0.61	0.10	1.00
Span drift[2]	$u_{d,s}$			0.094	0.056	0.0057	0.074
Losses / leakage in the sample system[4]	u_{loss}			0.92	0.49	0.35	0.17
Temperature dependant span drift[5]	u_t			1.80	2.00	0.15	1.00

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 350 Performance Characteristics	Uncertainty (Units of final measurement)	Distribution	Divisor	NO 0 - 134 mg/m³	CO 0 - 75 mg/m³	O_2 0 - 25 %Vol	CO_2 0 - 20 %Vol
Lack of fit	u_{lof}	Rectangular	$\sqrt{3}$	0.58	0.26	0.014	0.12
Span drift	$u_{d,s}$			0.073	0.024	0.00082	0.0085
Temperature dependant span drift	u_t			3.04	1.89	0.047	0.23
Interferents	u_i			0.40	0.38		...

Uncertainty of Measurement Results - Calculations Part 2

Horiba PG 350 Performance Characteristics	Uncertainty (Units of final measurement)	Date & Time	NO 0 - 134 mg/m³	CO 0 - 75 mg/m³	O_2 0 - 25 %Vol	CO_2 0 - 20 %Vol
Losses / leakage in the sample system	u_{loss}	15/07/21 13:31 - 14:31	0.75	0.015	0.016	0.017
Standard Error of Measured Value	u_{SE}	15/07/21 13:31 - 14:31	0.30	0.039	0.079	0.050

Effect on Uncertainty Caused by Oxygen $uCorr^n_{o_2} = \frac{20.9\% - O_{2,ref}}{(20.9\% - O_{2,measured})x(20.9\% - O_{2,measured})} x\, Uncertainty\ of\ O_2\ Measurement =$ 0.012

$f_{o_2} = \frac{20.9\% - O_{2,ref}}{20.9\% - O_{2,measured}} =$ 3.9913 $uf_{o_2} = \frac{uCorr^n_{o_2}}{f_{o_2}} x100 =$ 0.30 %

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 350 Uncertainty	Date & Time	NOx (as NO2) 0 - 134 mg/m³	CO 0 - 75 mg/m³	O_2 0 - 25 %Vol	CO_2 0 - 20 %Vol
Measured Concentration	15/07/21 13:31 - 14:31	81.82	3.15	4.48	10.47
Expanded Uncertainty as Percentage of Measured Concentration		8%	>100%	4%	5%

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

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%

Princes Limited		**Installation Name**	**: A1 Boiler 2 (Old Boiler) & A2 Boiler 1 (New Boiler)**
Permit No	**: EPR/BX8289IW**	**Visit Details**	**: Compliance – July 2021**
Variation No	**: V003**	**Survey Dates**	**: 15th July 2021**
Report Ref	**: P5003 : R001**	**Report Issue Date.**	**: 24th August 2021**

A2 Combustion Gases Uncertainty of Measurement Results

Uncertainty of Measurement Results - Calculations Part 1

Horiba PG 350 Performance Characteristics	Standard Uncertainty (% of Range)	Distribution	Divisor	Minimum Certified Range (R_i) NO 0 - 134 mg/m³	CO 0 - 75 mg/m³	O_2 0 - 25 %Vol	CO_2 0 - 20 %Vol
Lack of fit[1]	u_{lof}	Rectangular	$\sqrt{3}$	0.75	0.61	0.10	1.00
Span drift[2]	$u_{d,S}$			0.094	0.056	0.0057	0.074
Losses / leakage in the sample system[4]	u_{loss}			0.92	0.49	0.35	0.17
Temperature dependant span drift[5]	u_t			1.80	2.00	0.15	1.00

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 350 Performance Characteristics	Uncertainty (Units of final measurement)	Distribution	Divisor	NO 0 - 134 mg/m³	CO 0 - 75 mg/m³	O_2 0 - 25 %Vol	CO_2 0 - 20 %Vol
Lack of fit	u_{lof}	Rectangular	$\sqrt{3}$	0.58	0.26	0.014	0.12
Span drift	$u_{d,s}$			0.073	0.024	0.00082	0.0085
Temperature dependant span drift	u_t			3.04	1.89	0.047	0.23
Interferents	u_i			0.40	0.38		...

Uncertainty of Measurement Results - Calculations Part 2

Horiba PG 350 Performance Characteristics	Uncertainty (Units of final measurement)	Date & Time	NO 0 - 134 mg/m³	CO 0 - 75 mg/m³	O_2 0 - 25 %Vol	CO_2 0 - 20 %Vol
Losses / leakage in the sample system	u_{loss}	15/07/21 11:29 - 12:29	0.72	0.017	0.013	0.018
Standard Error of Measured Value	u_{SE}	15/07/21 11:29 - 12:29	0.24	0.058	0.032	0.019

Effect on Uncertainty Caused by Oxygen $uCorr^n_{o_2} = \frac{20.9\% - O_{2,ref}}{(20.9\% - O_{2,measured})(20.9\% - O_{2,measured})} x\, Uncertainty\ of\ O_2\ Measurement =$ 0.011

$f_{o_2} = \frac{20.9\% - O_{2,ref}}{20.9\% - O_{2,measured}} =$ 4.6974 $uf_{o_2} = \frac{uCorr^n_{o_2}}{f_{o_2}} x100 =$ 0.23 %

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 350 Uncertainty	Date & Time	NOx (as NO2) 0 - 134 mg/m³	CO 0 - 75 mg/m³	O_2 0 - 25 %Vol	CO_2 0 - 20 %Vol
Measured Concentration	15/07/21 11:29 - 12:29	78.07	3.54	3.81	10.74
Expanded Uncertainty as Percentage of Measured Concentration		8%	> 100%	3%	5%

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

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%