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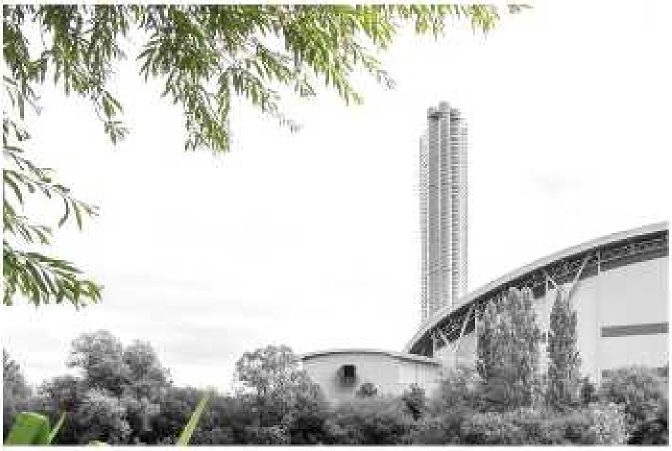

Margam Green Energy Plant

Margam Green Energy Limited

IC4 Validation Report

ENGINEERING – CONSULTING

Document approval

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Document revision record

Revision no	Date	Details of revisions	Prepared by	Checked by
0	03/10/2019	For Client	JGL	JRS

Contents

1 Introduction

An Environmental Permit (EP) (Ref: EPR/DP3137EG) for the operation of the Margam Green Energy Plant, (the Facility) (Ref: EPR/DP3137EG) was granted to Margam Green Energy Limited (MGEL) by Natural Resource Wales on 20th November 2014. Construction of the Facility was commenced on [MGEL to confirm date], commissioning was commenced on [MGEL to confirm date] and completed on 20th June 2019.

The EP includes several Pre-Operational and Improvement Conditions. IC4 requires the following:

> *"The Operator shall carry out checks to verify the residence time, minimum temperature and oxygen content of the exhaust gases in the furnace whilst operating under the anticipated most unfavourable operating conditions. The results shall be submitted in writing to Natural Resource Wales within 4 months of the completion of commissioning."*

Fichtner Consulting Engineers Ltd ("Fichtner") has been engaged by MGEL to provide a report which demonstrates that the relevant checks have been undertaken to verify the residence time, minimum temperature and oxygen content of the exhaust gases in the furnace.

1.1 Background

The residence time and minimum temperature conditions for waste incineration plant as stated in Article 50(2) of Chapter IV of the Industrial Emissions Directive (IED) are as follows:

> *"Waste incineration plants shall be designed, equipped, built and operated in such a way that the gas resulting from the incineration of waste is raised, after the last injection of combustion air, in a controlled and homogeneous fashion and even under the most unfavourable conditions, to a temperature of at least 850 °C for at least two seconds."*

In accordance with the requirements of Pre-operational Condition 08, Computational Fluid Dynamics (CFD) modelling was undertaken by Babcock & Wilcox Vølund (BWV) to demonstrate that design combustion conditions comply with the temperature and residence time requirements of the IED. [MGEL to confirm the date the CFD report was submitted to NRW]

The intention of this report is to verify that the design of the as-built boiler complies with the requirements of Article 50(2) of Chapter IV of the IED.

2 Conclusions

The initial CFD modelling undertaken by BWV indicate that the design of the boiler is sufficient for the flue gas temperature to be retained at a temperature above 850 °C for a period of more than 2 seconds.

To verify the results of the CFD modelling, a validation study was undertaken by TÜV SÜD. This study considered operation at 60 % and 100 % maximum continuous rating (MCR).

Sixteen measurements were carried out by TÜV SÜD on the furnace, measuring flue gas temperature. These performance measurements show that the furnace exceeds the requirements set out in the IED for compliance with the EP. The shortest residence time measured was 3.93 seconds at 60 % MCR. The furnace sustained temperatures above 850 °C in all the performed measurements.

3 Discussion

3.1 Validation tests

Residence time performance measurements were undertaken by TÜV SÜD Industrie Service between 28th February and 1st March 2019.

The residence time was measured using the time of flight method. This is a recognised method for verifying residence time as reported in the Environment Agency's guidance note titled '*Review of BAT for New Waste Incineration Issues: Part 2 Validation of Combustion Conditions*'.

Measurements were undertaken under the following operating conditions:

1. 60 % MCR (part load)
2. 100 % MCR (nominal load)

The lowest gas temperatures were measured on two planes using a multiple traverse method. The planes were located at the start and end of the secondary combustion zone. Temperature measurements were taken using suction pyrometers. In addition, monitoring for 1 hour was performed to check that the one-minute average temperature was above temperature requirements.

The following monitoring was undertaken:

- 6 grid measurements at 60 % load;
- 6 grid measurements at MCR;
- 2 lowest temperature measurements for one-hour at 60 % load; and
- 2 lowest temperature measurements for one-hour at MCR.

3.1.1 Results

The TÜV SÜD performance report is presented in Appendix B. The results from the study are summarised in Table 1 and Table 2:

Table 1: Performance at 60 % load

Measurement	Temperature after 2 seconds in the QSCZ (°C)			QSCZ Residence time (s)
	Mean	min	max	
1	955	863	1044	3.93
2	957	880	1048	3.97
3	960	871	1058	4.09
4	958	877	1047	4.06
5	965	871	1071	4.10
6	973	887	1065	4.25

Table 2: Performance at 100 % MCR

Measurement	Temperature after 2 seconds in the QSCZ (°C)			QSCZ Residence time (s)
	Mean	min	max	
1	1000	945	1050	4.14

Measurement	Temperature after 2 seconds in the QSCZ (°C)			QSCZ Residence time (s)
	Mean	min	max	
2	1005	950	1052	4.14
3	998	947	1041	4.13
4	1012	953	1067	4.18
5	1006	951	1049	4.19
6	1005	933	1057	4.19

At 60 % load the shortest gas residence time was in excess of the residence time requirement. The minimum temperature recorded after the gas spent 2 seconds in the QSCZ was 863 °C. Inside the secondary combustion zone the gas will have cooled. Therefore, if after 2 seconds it is above 850 °C then the required operating conditions have been achieved.

All four of the one-hour measurements had one-minute temperatures above 850 °C. These results validate the grid measurements since they were recorded at the point of lowest temperature in the measuring plane.

3.1.2 Load case summaries

The calculations for residence time were based on assuming plug-flow behaviour through the qualifying secondary combustion zone (QSCZ). The volume through which the incinerator gas flowed has a cross-sectional area of 59.25 m^2. The two measuring planes were assumed to be located at the start and end of the QSCZ. These two points were 6.10 m apart in height. For the measurements the QSCZ is 361.43 m^3.

The CFD study (Appendix A) considered the operational conditions presented in Table 3. Load point 2 was comparable to the MCR verification measurements. Also, load point 5 was comparable to the 60 % load verification measurements.

Table 3: CFD study load cases

Load point	Operational load	LCV [kJ/kg]	Fuel consumption [kg/h]	Flue gas flow [Nm^3/h]
1	100 % Thermal input Design Point	13100	34350	215667
2	100 % Thermal input Maximum Continuous Rating (MCR) Maximum flow of flue gas	10800	41670	213372
3	100 % Thermal input Hottest flue gas	15400	29220	206160
5 rev.1	60 % Thermal input Coldest flue gas in rev.1	15400	17532	147794
10 rev.1	60 % Thermal input Minimum flow of flue gas in rev.1	8400	32140	155814
6	45 % Thermal input Coldest flue gas in rev.0	15400	13150	111085

Load point	Operational load	LCV [kJ/kg]	Fuel consumption [kg/h]	Flue gas flow [Nm³/h]
9	45 % Thermal input Minimum flow of flue gas in rev.0	8400	24110	115668
Start-up	100 % burner	42870	7390	142376

The key parameters for IC4 from the CFD modelling are summarised in Table 4.

Table 4: CFD modelling data

Operational point	QSCZ entrance temperature (°C)	QSCZ exit temperature (°C)	Flue gas flow (Nm³/h)	Residence time (s)
60 % load	1011	851	147794	3.7
100 % MCR	1251	854	213372	4.4

The measured flue gas flow rates are given in Table 5 with plane 1 being the higher and plane 2 the lower measuring points.

Table 5: Volumetric flow through the QSCZ

Measurements	Volumetric flow (Nm³/h)	
	60 %	100 % MCR
1	132163	207548
2	132688	210965
3	132555	206638
4	132907	206607
5	135730	206825
6	134085	206977
Mean	**133355**	**207593**

TÜV SÜD also measured the oxygen concentration in the QSCZ. The measurements are summarised in Table 6.

Table 6: Measured flue gas oxygen concentrations

Measurement	Mean O_2 concentration (Vol. %)			
	60 % MCR		100 % MCR	
	Plane 1	Plane 2	Plane 1	Plane 2
1	3.4	3.3	3.4	3.4
2	3.3	3.5	3.2	3.2
3	3.2	3.1	3.6	3.6
4	3.4	3.3	3.2	3.2
5	3.2	3.1	3.2	3.0
6	2.9	2.8	3.3	3.1
Mean	**3.2**	**3.2**	**3.3**	**3.3**

3.2 Measurement uncertainties

The calculated uncertainties of the measured quantities are provided in Table 7. Full calculations for the measurement uncertainty are presented in Appendix B.

Table 7: Summary of uncertainties in measured values

Quantity	Calculated uncertainty
Minimum temperature	± 12.5 °C
Residence time	± 10 % of measured values

3.3 Boiler fouling

The Facility only commenced commissioning on 20th June 2019. Therefore, the boiler has not been subject to fouling.

Appendices

A CFD study

B Performance report

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