SAPUTO DAIRY UK

DAVIDSTOW

Biomass Boiler Derating Report

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Rev: B

Date: 28 June 2024

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Revision History

Key changes from the last revision:

Revision	Date	Author	Details of Change	Reviewed
A	2024-06-02	NR Horton	None	S Carhart
B	2024-06-28	NR Horton	Title changed and details or software changes added.	

Contents

Abbreviations

CEA	Combustion Engineering Association
CIBSE	Chartered Institution of Building Services Engineers
CO	Carbon monoxide
EPR	The Environmental Permitting (England and Wales) Regulations
FD	Forced Draught
ID	Induced Draught
MCPD	Medium Combustion Plant Directive

Executive Summary

Tests were carried out on Boiler 5 in order to calibrate the wood pellet feeder thus providing an algorithm to determine the net heat input into the boiler for display on the Operating screen and enable a net heat input limit of 5 MW into the control system. Algorithms were also produced to enable the system to accommodate fuel changes. An outline of how the wood pellet feeder speed can be limited to ensure that the net heat input limit of 5 MW is not exceeded and also how an audit trail to verify this can be provided.
Combustion trials also took place to demonstrate a biomass boiler could be productively operate with a maximum heat input of 5 MW.
Emission testing was carried out as part of the combustion trails and demonstrated that the requirements of the Environmental Permit can be achieved for NO_X, SO_2 and particulate emissions on the trial boiler, despite reduced cyclone efficiency due to significant air in-leakage caused by erosion of the outer cyclone casing.

1. Introduction

The Environmental Permitting (England and Wales) Regulations 2018 (EPR) provide a consolidated regime of environmental permitting in England and Wales and transposes the EU's Medium Combustion Plant Directive (MCPD), which lays down rules to control emissions of sulphur dioxide (SO2), nitrogen oxides (NOx) and dust from MCPs. Although new plant must comply with the Emmissioin Limit Values from commencement of operation, the date required for compliance of existing plant is dependant upon the plant's net heat input (not aggregated), these dates are:

Net Heat Input / MW	Permit required	Compliance with ELVs
$1 < Q \leq 5$	1st January 2029	1st January 2030
$5< Q \leq 50$	1st January 2024	1st January 2025

Due to the age and technology of the biomass fired (wood pellet) boilers, they are not capable of meeting the particulate ELV specified in the EPR in their current configuration and require significant additional clean-up equipment to meet

compliance. Due to the age of the biomass fired boilers, the uncertainty over energy provision, a proposal has been made to operate the biomass boilers at less than 5 MW net thermal heat input, which will provide Saputo Ltd and Veolia time to assess future options. This testing programme was carried out to demonstrate the viability of such an operating regime and be able to assist in demonstrating the scheme to the satisfaction of the Environment Agency.

2. Legislative Normative and Informative documents

The following documents have been used for guidance in investigating best practice for the boiler systems.

2.1. Standards

BS EN ISO 17225-4: Solid biofuels. Fuel specifications and classes. Graded wood chips.

3. Fuel Biomass System

3.1. Design and operating parameters

The parameters for the testing of the wood chip feeders and the combustion trails was to determine the performance of the biomass boilers when operating with a net heat input less than or equal to 5 MW, approximately 1000 kg/h of wood pellets.
The wood pellet feeder speed testing was carried out over the range 19 % to 50 %, as this is the minimum to maximum range that the biomass boiler has operated over.

4. Methodology

4.1. Test Parameters

The testing of the wood pellet feeder was carried out on Boiler 5.
The calibration of the biomass feeder and testing of the boiler emissions was carried out using the current biomass pellet supplied by AMP and sourced in Germany.
For each test three runs were carried out, the average being reported, if a value was obtained that did not seem consistent then that test was repeated.

5. Test Equipment

The weighing of the collected wood pellet was carried out using a crane hook.
Manufacturer: Crane Scale
Model: OCS-1-S
Accuracy +/- 0.5 kg
Resolution 0.5 kg

All other equipment on the boiler was used in its standard operating condition and parameters.

6. Feeder Calibration Test Results

6.1. Test Data

The test data results are provided in Appendix 6

- Feeder speed tests - Table A6.1
- Wood pellet feed rate tests - Table A6.2

6.2. Test Calculations

A summary of their key parameters for the current wood pellets are provided in Section 7.
The results to show the feeder speed (min-1) for percentage speed signal is provided in Table A6.3

6.2.1. Wood pellet feed rate

From the test data shown in Appendix 6, the wood pellet flowrates are as follows:

Feeder motor speed / %	Mass flowrate / kg/h	Volume flowrate / m^3/h
19	510.0	0.761
30	813.0	1.213
38	1023.0	1.527
50	1353.0	2.019

Table 1 Relationship of Wood Pellet Flowrates to Feeder Speed.

Note: Mass flowrate specific to test pellet, whilst volume flowrate is valid for any pellet of similar size and bulk density.

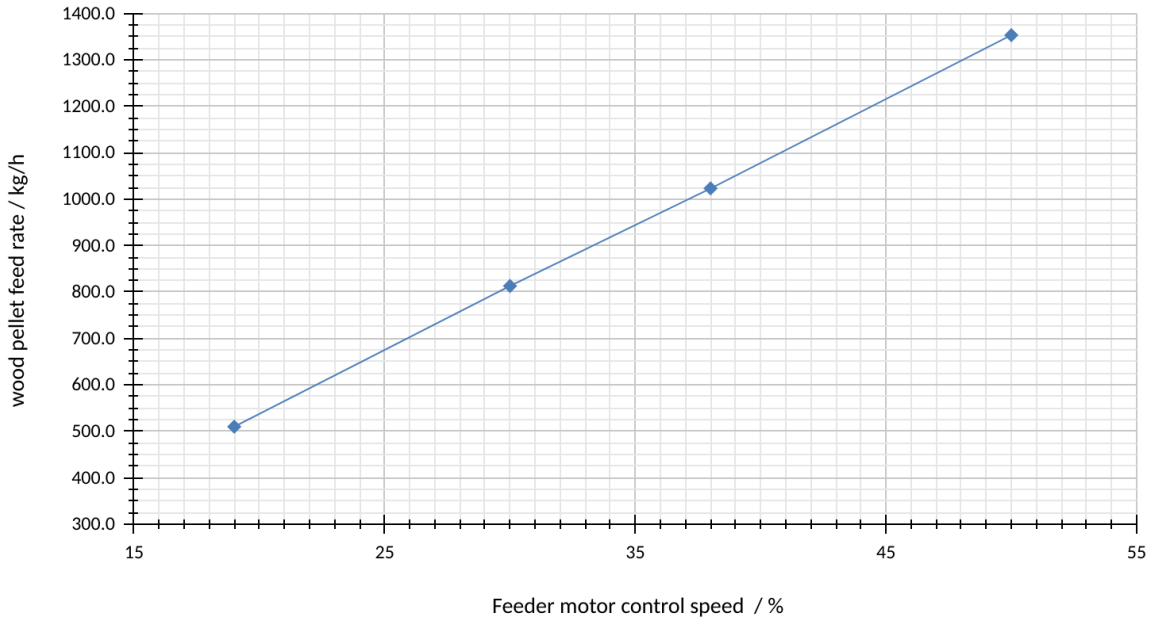

Figure 1 Relationship of Wood Pellet Mass Feedrate against Feeder Speed

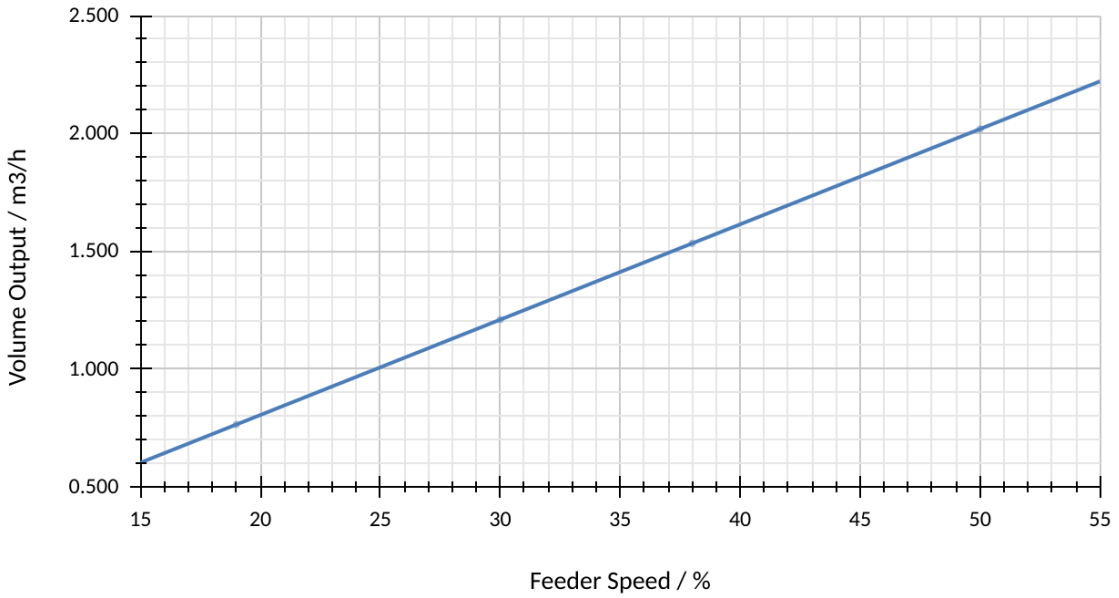

Figure 2 Wood Pellet Volume Feedrate against Feeder Speed

6.2.2. Boiler net heat input

Feeder motor speed / %	Net heat input / MW
19	2.47
30	3.93
38	4.95
50	6.55

Table 2 Relationship of Boiler Wood Pellet Net Heat Input to Feeder Speed.

Note: The above values are valid for the wood pellet being tested, i.e., bulk density 670 kg/m3 and a Net Calorific Value of 17.42 MW/kg.

6.3. Feeder Modelling

In order to use this data to accommodate variations in calorific value and bulk density and be able to integrate the data within the SCADA and eSight systems, the above relationships need to be modelled. As can be seen from the above graphs the relationships between flowrates and feeder speed are linear, therefore the relationship used shall take the general form:

Y = m.x + c
Where:
X = independent variable, e.g. feeder speed
M and c = constants
Y = dependent variable, e.g., mass flowrate.

Two relationships shall be defined, these are:

- Current wood pellet heat input for feeder speed input
- Volumetric wood pellet throughput for feeder speed input

6.3.1. Current wood pellet heat input for feeder speed input

From Table 5, and using Linear Regression (Lineest) in Google Sheets, the required constants are:

m1 = 0.13130
c1 = -0.02230

wood pellet net heat input (MW) = 0.13160 x Feeder speed (%) - 0.02235

Error check on model.

Feeder motor speed / %	Test Net heat input / MW	Calculated Net heat input / MW	Error / %
19	2.468	2.517	1.99
30	3.934	3.961	0.69

38	4.950	5.012	1.22
50	6.547	6.587	0.62

Table 3 Modelled Net Heat Input for Feeder Control Speed

7. Wood Pellet Specification

The following table is a comparison of key parameters from the current wood pellet and the trial wood pellets.

Status		Current	Trial	Trial
Supplier		AMP	AMP	Peltrade
Source		Germany	Belgium	Estonia
Reference		Anmare	Peak Bergen	Test Report: EEESTJ23001868-1
			Testing w/c 8 Apr -22 Apr 2024	Testing w/c 3 June - 16th June
Net Calorific Value (AR)	MJ/kg	17.42 +/- 5 %	17.46 +/- 5 %	17.68
Bulk density	kg/m^3	670 +/- 10	670 +/- 10	700
Ash (dry)	%	0.61 +/- 0.02 %	0.35 +/- 0.02 %	0.43
Fines <3.1 mm (dry)	%	1.02 +/- 004 %	0.43 +/- 002 %	2.5
Moisture (mAR)	%	7.3 +/- 0.2 %	6.8 +/- 0.2 %	5.47
Pellet diameter	mm	6.1 +/- 0.1	6.0 +/- 0.1	Nominal 6

Table 7 Wood Pellet Property Comparison

8. Combustions Trials

The combustion trials took place on boiler 5 during 9th May 2024. The primary objective being to determine the particulate emissions during operation of the biomass boilers with a net heat input less than 5 MW. Boiler 5 being chosen as it tends to have higher particulate emission rates than boiler 4.

The test setpoints were based on the combustion trials carried out in March 2023 and the biomass feeder testing carried out earlier in May 2024.

8.1. Combustion Test Conditions

Three tests were completed with the boiler set points as shown below in Table 7

Parameter	Test 1	Test 2	Test 3
Feeder speed / %	37	36	37
Grate speed / %	70	68	68
Forced draft / %	48	48	47
Secondary draft / %	50	45	40
Draft control / Pa	45	40	40

Table 8 Combustion trial boiler control set points

The associated boiler operating conditions being:

Boiler Conditions	Test 1	Test 2	Test 3
Actual draft / Pa	42.1	35.6	37.4
Steam flow meter / t/h	7.1	6.8	6.8
Steam header pressure / barg	21.43	21.43	21.35
ID fan speed / %	88.19	87.25	86.21
Stack temperature / °C	180.9	180.8	179.6
Econ outlet temperature / °C	223.1	223.7	222.5
Feedwater temperature Econ inlet / °C	103.6	100.9	101.7
Feedwater temperature Econ outlet / °C	123.7	119.8	116.9
Arch temperature / °C	86.2	92.5	88.4
Boiler steam pressure / barg	21.33	21.25	21.14
O2 at furnace exit / % wet	9.7	9.2	8.2
O2 at economiser outlet / % wet			9.9
O2 in stack (Anchem) / % dry	10.9	10.8	10.2

Table 9 Boiler Operating Conditions during Combustion Trials

8.2. Combustion Test Results

These settings resulted in the following boiler heat inputs

	Test 1	Test 2	Test 3
Net heat input / MW	4.85	4.70	4.85

Table 10 Combustion trial boiler control set points

The particulate emission rates and associated parameters were determined by Anchem Ltd., the results being provided in Table 10.

Parameter	Test 1	Test 2	Test 3
Particulate matter / mg/Nm3	208.65	196.07	209.82
Measurement Uncertainty / mg/m3	7.90	7.05	7.74
Flue gas flowrate / m3/h	6715	6274	6797
Oxygen / % dry	10.8	10.7	10.2
Carbon monoxide / mg/Nm^3	Approx 400	Approx 500	Approx 1200
Oxides of nitrogen / mg/Nm^3	195 to 229		

Table 11 Emission Test Results

Note: Reference conditions for Table 10 are: 273 K, 101.3 kPa, 6 % O_2 and dry

The values of the carbon monoxide, oxides of nitrogen and oxygen for the overall testing period are shown in Table 11.

The emission values for NOx and sulphur dioxide (referenced to 273 K, 101.3 kPa, 6 % O_2 and dry) for all three tests are below the current permit Emission Limit Values (ELV) and those

required by The Environmental Permitting (England and Wales) Regulations 2018 for existing plant.

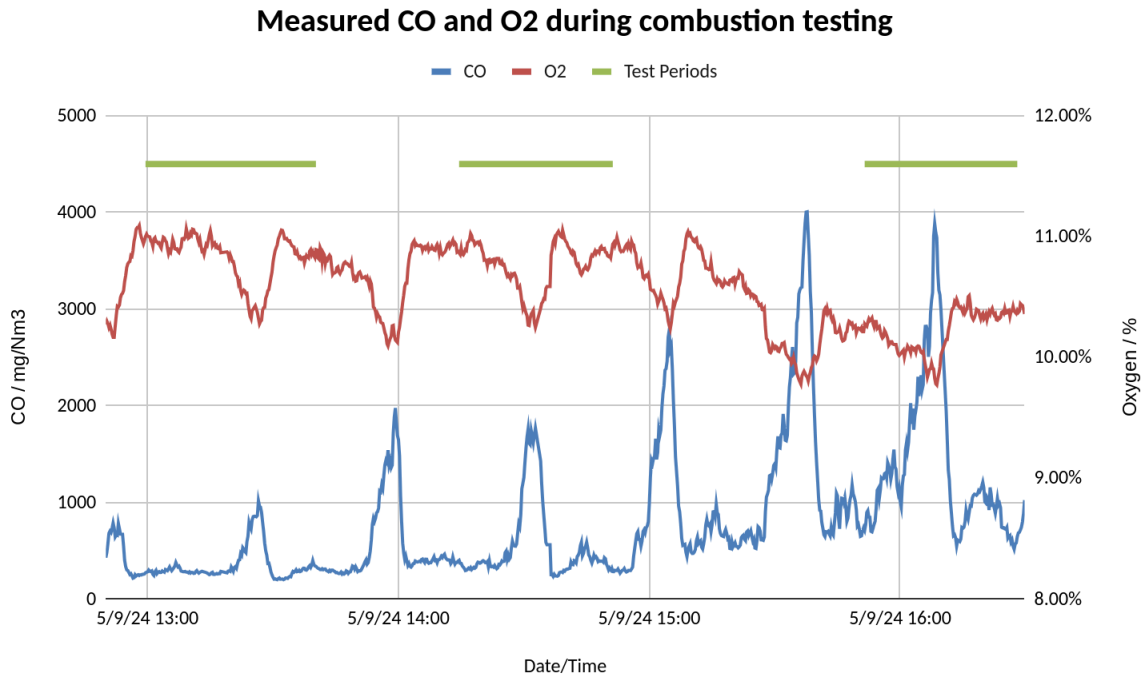

Figure 3 Measured CO and O_2 during Combustion Testing

9. Proposed Control System Modifications

Currently the maximum percentage speed of the wood pellet feeder is set manually via the Allen Bradly 600 menus, see Appendix 7 Figure A7-2.

This capability will be removed and replaced by having a maximum net heat input value in the system and using the algorithm derived from the testing in section 6.3.1, this will calculate the maximum pellet feeder speed and this will replace the current manually input value. The speed limit will then be restricted as per the current system. The algorithm's 'm' and 'c' values will be able to be input into the system, which will enable the calibration to be altered should the wood pellet type be changed. Access to these parameters will only be via

a managers/admin password. The PLC will then calculate the boiler net heat input from the actual feeder speed.

This heat input will be displayed on the remote SCADA screens in the area indicated in Figure A7-3. The heat input will also be exported into the Veolia eSight system, that will provide an audit trail to demonstrate that the heat input has not been greater than the limit of 5 MW.

10. Discussion

The results from the biomass pellet feed rates provided good correlation with the weight quantities, with the maximum error being approximately 2 % at the minimum required firing rate.

From the testing, in order to ensure that the net heat input is less than 5 MW , the feeder speed required is between 36 %, equivalent to 4.72 MW and 37 %,equivalent to 4.85 MW.

Boiler 5 consistently has higher particulate emissions, although the wood pellet feed system appears to distribute the fuel equally to both boilers, Boiler 5 appears to receive more dust.

This may be due to when the screw feeder loads the conveyor with the wood pellet at the silo does seem to favour the side that will feed Boiler 5. A diverter/baffle may reduce this occurrence.

There is also more dust deposited around the FD fan area on Boiler 5, this is shown in Figure A5. These do not show large quantities, however based on the testing a particulate concentration reduction of approximately 20 mg/m3, equates to roughly 100 g/h of dust

This depositing of the dust is demonstrated by the long term plot of CO and oxygen levels taken during the testing in May 2024, shown in Figure 3. The cycle frequency appears to coincide with feeding of the wood pellets. They do not coincide with changes to operating conditions made for the testing. This reduction in oxygen equates to approximately 35 kg/h of wood pellet.

Also in order to reduce the dust lifting off the grate the ID fan suction should be reduced as far as practical with preventing egress into the boilerhouse, it is suggested a value of 40 to 45 Pa should be used.

It was noted during test 3 that the grate combustion did not appear as clean and bright, it is thought this was due to the secondary air setting being low, this observation being confirmed as the particulate emissions being higher for this test.

A major factor in the particulate emission concentration is the efficiency of the cyclone. This was visually inspected and there were a number of areas where the steel of the cyclone had

been eroded and the integrity had been branched; this would have had a significant impact on the efficiency of the cyclone and thus the level of particulate passing to the chimney. The cyclones have already been repaired and thus replacement is required.

Previous repair and test work carried out in 2014 (Reference 1) on Boiler 5 cyclone demonstrated that with full cyclone efficiency restored and boiler combustion optimised the particulate emissions were reduced from 348 mg/m^3 to 115 mg/m^3 (referenced to 273 K, 101.3 kPa, 6 % O_2 and dry).

Based on the particulate emissions results from Anchem the measurement uncertainty was approximately 7 mg/m3, using the actual results in terms of compliance the values would have been:

Test 1: 200.75 mg/m^3

Test 2: 189.02 mg/m^3

Test 3: 202.08 mg/m^3

Thus only test 2 would not have been considered a breach of the permit.

11. Conclusions and Recommendations

11.1. Conclusions

The feeder calibration was successful and good calibration curves were obtained for use with the control system.
Successful combustion trials and testing were completed in terms of steady controllable operation and steam output and despite the wear to the cyclones, severely impacting their efficiency compliant or near compliant particulate concentrations were obtained.

11.2. Recommendations

1. In order to maintain some operating margin below the 5 MW net heat input, then a minimum 3 % margin could be adopted, this equates to 4.85 MW.
This is shown in the Figure 4 below:

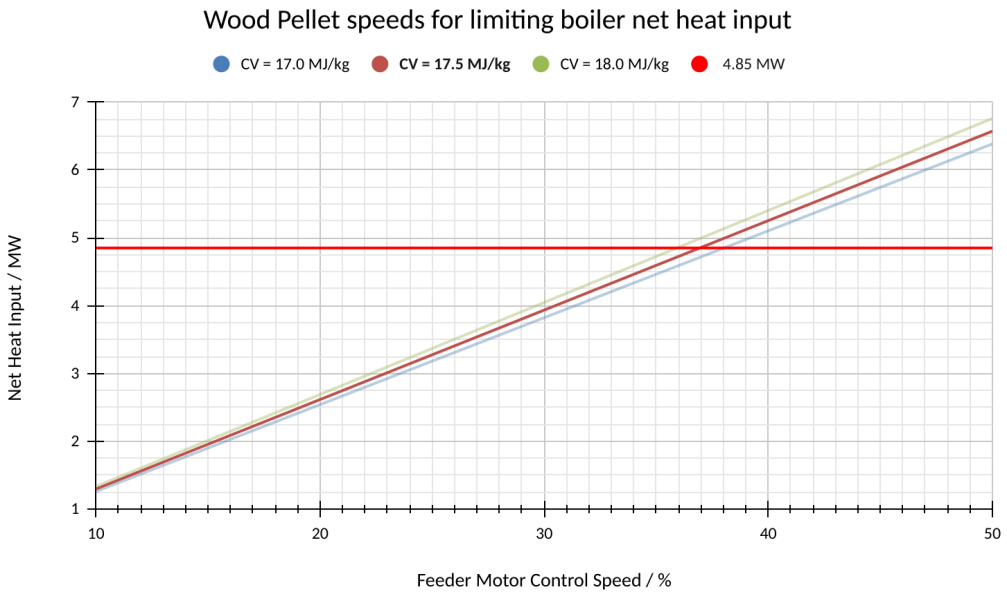

Figure 4 Relationship of Boiler Net Heat Input and Wood Pellet Feeder Speed

This results in a maximum wood pellet feeder speed of 37 %, however to allow for operational variances and to obtain a data history, it is recommended that initially the maximum heat input is set to operate at 4.75 MW, this equates to a with a maximum feeder speed of approximately 36 %, this provides a margin of 5.0 %.

2. The net heat input-feeder speed correlation is required to be installed into the control system software and displayed on the SCADA system. The net heat input shall also be recorded on the Veolia eSight system to provide an audit trail. The algorithm constants should be able to be changed without the need for software engineering. It is recommended that this is carried out by the use of a separate password protected input screen and any changes recorded within the monitoring system. It is proposed that the proposed changes are carried out on one of the biomass boilers as a trial to be able to demonstrate this to the Environment Agency and allow time to prove the system and its security.

3. The current cyclones are to be replaced with new cyclones as the existing units have already been repaired on a number of occasions. In terms of materials, stainless steel provides a greater resistance to erosion, however currently there appears to be a significant price premium for this and the extended life may not justify the additional cost over carbon steel.

References

1. Dalkia 2014, DCGA1-SMJ, Grit Arrestor Investigation

Appendices

Appendix 1 - Wood pellet specification - current

INDEPENDENT TRANSPORT AND CARGO SURVEYORS
No.2, Katrinas street, office 5
Riga, Latvia, LV-1045
Latvian Chamber of Commerce and Industry Reg. № 3755
LVS EN ISO 9001:2015 Bureau Veritas issued Cert. Nr. LV007066

Ref. m/v Anmare / 02.01.2023

COPY

CERTIFICATE OF ANALYSIS No.1-1020/23Q-1

Material/Packing : Wood Pellets in bulk. Representative sample, weight 5,0 kg. Packing- single tight plastic locked bag, seals n/a.
Sample marking : m/v ANMARE dated 02-01-2023. Quantity- 2463,480 MT. From: Flushing, NL To: Groveport, UK.
Shipment details : TLR International laboratories BV. Handelsweg 66 Ridderkerk, NL. TNT Con No.294604649. Pickup Date: 09-Jan-2023.

Date of receipt : 10-th of January, 2023.

This to certify that as per instruction received from Applicant, inspectors of Independent Survey agency "SKS-F" Ltd received mentioned material, prepared according to EN ISO 18135:2017 standard represent specimen tightly packed at double plastic bags. Such specimen locked by seal was send to local certified laboratory for quality analyses as per LVS EN ISO TS International Standards.
Obtained test results for the next parameters:

No.	Characteristics Verification	Unit	Standard	Actual result	Uncertainty
1.	Total Moisture content, Mar	%	LVS EN ISO 18134-1	7,3	+/- 0,2
2.	Ash content, dry material, 550 °C	%	LVS EN ISO 18122	0,61	+/- 0,02
3.	Gross Calorific value at constant volume Q gr as received V=const.	MJ/kg Kcal/kg MWh/t	EN ISO 18125:2017	18,85 4502 5,24	+/- 0,5%
4.	Net Calorific value at constant pressure Q net as received P=const.	MJ/kg Kcal/kg MWh/t	EN ISO 18125;2017	17,42 4160 4,84	+/- 0,5%
5.	Bulk density, BD	Kg/m3	LVS EN ISO17828	670	+/- 10
6.	Chlorine content for dry material, Cl	%	LVS EN ISO 16994	0,0023	+/- 0,0008
7.	Nitrogen content for dry material, N	%	LVS EN ISO 16948	0,16	+/- 0,02
8.	Sulphur content for dry material, S	%	LVS EN ISO 16994	0,008	+/- 0,002
9.	Mechanical Durability, at moisture content, a.r.b	%	LVS EN ISO17831-1	99,4	+/- 0,1
10.	Fines content (Dry sieve test) basis < 3,15 mm	%	LVS EN ISO 18846	1,02	+/- 0,04
11.	Average Diameter of pellets	mm	LVS EN ISO 17829	6,1	+/- 0,1
12.	Length of pellets /Fraction/ ≤ 50 mm	%	LVS EN ISO 17829:2016	100,0	+/- 0,1
13.	Length of pellets /Fraction/ ≤ 45 mm	%		100,0	
14.	Length of pellets /Fraction/ ≤ 40 mm			100,0	
15.	Ash melting behaviour oxidising atmosphere (t°) - Deformation temperature, DT - Hemisphere temperature, HT - Flow temperature, FT	°C	LVS EN ISO 21404:2020 /Fuse process phenomena/	 1390 1500 >1500	+/- 10
16.	**Chemical elements content in the dry material**	(db)		**Concentration**	+/-
	- Arsenic (Arsenicum), As	mg/kg	ISO TS 16996 ISO 16968 LVS EN 15309	≤ 0,1	-
	- Cadmium, Cd	mg/kg		≤ 0,1	-
	- Chromium (Cromium), Cr	mg/kg		≤0,3	+/-0,1
	- Copper (Cuprum), Cu	mg/kg		1,4	0,1
	- Mercury (Hydrargyrum), Hg	mg/kg		≤ 0,1	-
	- Nickel (Niccolum), Ni	mg/kg		0,5	0,1
	- Lead (Plumbum), Pb	mg/kg		0,2	0,1
	- Zink (Zincum), Zn	mg/kg		11,5	0,8

Represented specimen marked as m/v ANMARE dated 02-01-2023 has been tested at the local laboratory in the period of 10.01÷12.01.2023. Remain of representative sample one bag to be retained for minimum of 1 week unless written instructions was received to the contrary. Certificate is issued amenably the Virsma, Testesanas Parskats/ test reports No.1-024.1-23-1 dated 12.01.2023 of the laboratory accredited in accordance with LVS ISO 17025 standard, at Riga Latvia.

This inspection performed in accordance with the Principals instructions. This Certificate is issued to the best of our ability and knowledge for the time and place of inspection and within the limitation of instructions received but without prejudice and without releasing Shippers and/or other parties involved from their contractual obligations.

Issued and dated at Riga.
13-th of January, 2023

FOR AND ON BEHALF OF SKS-F
SKS-F
FOR CERTIFICATES
Independent Surveyors

SKS-F Ltd
INDEPENDENT TRANSPORT & CARGO SURVEYORS
Ph: +371-67321009; Fax:+371-6732337; mail: sks@apollo.lv ; sks_r@inbox.lv

Appendix 2 - Calibration testing photographs


DOOSAN


BYWORTH
BOILERS
Boiler 4

Appendix 3 - May 2024 Boiler 5 testing particulate emission results

Emission Point	Boiler 5		
Sample Number	107366/1	107366/2	107366/3
Substance to be Monitored	Particulate		
Emission Limit Value	200		
Periodic Monitoring Result	208.65	196.07	209.82
Uncertainty	±7.90	±7.05	±7.74
Units	mg/Nm^3		
Reference Conditions	273K, 101.3kPa, 6% oxygen & dry gas		
Date of Sampling	09/05/2024		
Start/End Time	13:00 – 13:35	14:14 – 14:51	15:52 – 16:28
Average Volumetric flow @ reference conditions / m^3/hr	6595		
Standard Reference Method	BS EN 13284-1		
Technical Procedure Reference	ANC/S/6		
Accreditation Status	MCERTS		
Process Status (Load/Feedstock)	See Process Status (page 6)		

Monitoring results continued

Emission Point	Boiler 5			
Sample Number	107366/4			
Substance to be Monitored	Sulphur Dioxide	Oxides of Nitrogen	Carbon Monoxide	Oxygen
Emission Limit Value	300	1000	N/A	N/A
Periodic Monitoring Result	3.8	206.7	1158.2	10.6
Uncertainty	±0.7	±4.8	±42.4	±0.1
Units	mg/Nm^3			
Reference Conditions	273K, 101.3kPa, 6% oxygen & dry gas			
Date of Sampling	09/05/2024			
Start/End Time	12:50 – 16:29			
Average Volumetric flow @ reference conditions / m^3/hr	6595			
Standard Reference Method	CEN/TS 17021	BS EN 14792	BS EN 15058	BS EN 14791

Appendix 4 - March 2023 Boiler 5 testing particulate emission results

Test Report ALL104087/23/PR-1

Monitoring results continued

Emission Point	Boiler 5		
Sample Number	104087/5	104087/6	104087/7
Substance to be Monitored	Particulate		
Emission Limit Value	200		
Periodic Monitoring Result	169.43	190.72	186.21
Uncertainty	±5.76	±6.38	±6.01
Units	mg/Nm^3		
Reference Conditions	273K, 101.3kPa, 6% oxygen & dry gas		
Date of Sampling	07/03/2023		
Start/End Time	12:33 – 13:08	14:47 – 15:23	16:01 – 16:35
Average Volumetric flow @ reference conditions / m^3/hr	5969.3		
Standard Reference Method	BS EN 13284-1		
Technical Procedure Reference	ANC/S/6		
Accreditation Status	MCERTS		
Process Status (Load/Feedstock)	See Process Status (page 9)		

Appendix 5 - FD fan dust levels

Figure A5 - dust levels on FD fan shortly after clean (boiler 5 on left, boiler 4 on right)

Appendix 6 - Feeder Calibration Test Results

A6.1. Test Data

The following table is a summary of the test results.

A6.1.1. Feeder speed tests

Test	Feeder motor speed / %	Feeder motor speed / Hz	Feeder Shaft revolutions	Test duration / mins
1.1	38	19.3	7	15
1.2	36	18.29	6.6	15
1.3	34	17.28	6.2	15
1.4	32	16.26	5.8	15

Table A6.1 Relationship of Wood Pellet Feeder Setpoint to Rotational Speed

A6.1.2. Wood pellet feed rate tests

Test	Feeder motor speed / %	Average mass / kg	Test duration / minutes
2.1	19	85.0	10
2.2	30	135.5	10
2.3	38	170.5	10
2.4	50	225.5	10

Table A5.2 Mass of Wood Pellets Collected for Different Feeder Speeds

A6.2. Test Calculations

A6.2.1. Feeder speed

Feeder motor speed / %	Feeder shaft speed / min^{-1}
32	0.387
34	0.413
36	0.440
38	0.467

Table A6.3 Relationship of Wood Pellet Shaft Speed to Feeder Control Speed.

A6.3. Feeder Modelling

A6.3.1. Wood pellet feeder shaft speed for feeder speed input

From Table 3, and using Linear Regression (Lineest) in Google Sheets, the required constants are:

m2 = 0.01335
c2 = -0.0405

Therefore:

wood pellet feeder shaft speed (min-1) = 0.01335 x Feeder Speed (%) - 0.0405

A6.3.2. Volumetric wood pellet throughput for feeder speed input

From Table 4, and using Linear Regression (Lineest) in Google Sheets, the required constants are:

m3 = 0.04050
c3 = -0.00688

Therefore:

Volumetric wood pellet feed rate (m3/h) = 0.04050 x Feeder speed (%) - 0.00688

Appendix 7 - Biomass Boiler Control System Images

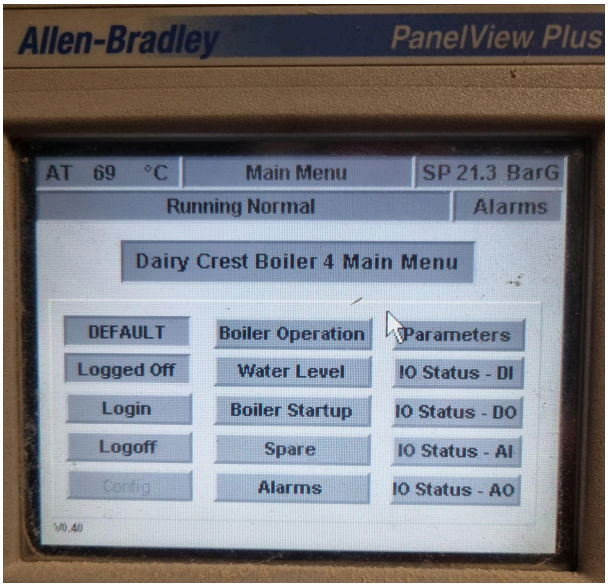

Figure A7-1 Login and Parameter Change Menu

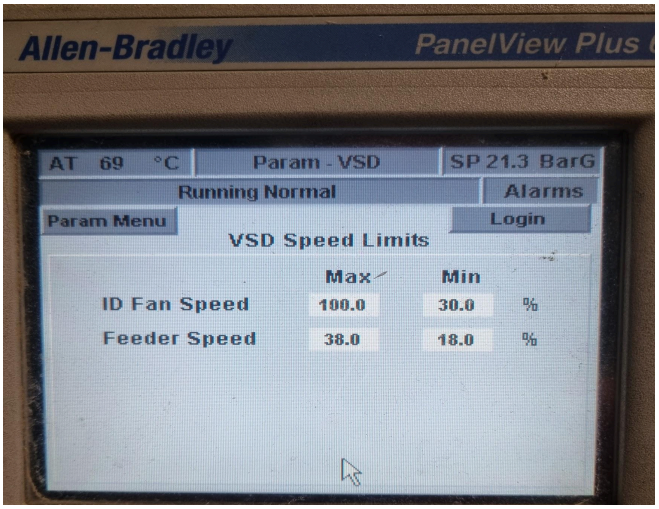

Figure A7-2 Maximum and Minimum Feeder Speeder Menu

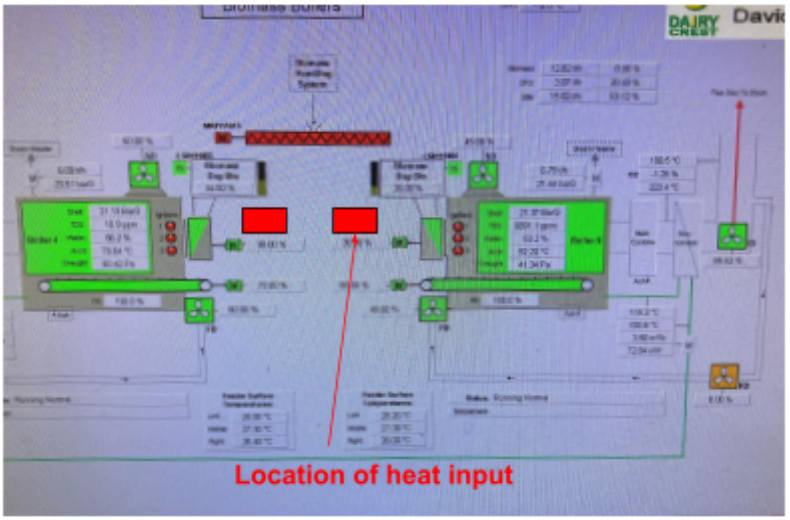

Figure A7-3 SCADA Boiler Status Display Screen