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Pre-normative research on solid biofuels for improved European standards

SPECIFIC TARGETED RESEARCH OR INNOVATION PROJECT

PRIORITY [6-1] – Sustainable energy systems

Task IV – Supply chain based properties

Pellet combustion tests

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List of Abbreviations

P	Particle size of fuel, D and L, mm
D	Diameter, mm
L	Length, mm
M	M_{ar} =Moisture content, ar = as received, w-%
A	ash content, dry basis, w-%
$q_{net, d}$	Net calorific value, dry basis
Q	$q_{net, ar}$ =Net calorific value, as received, MJ/kg or kWh/kg (1 kWh/kg = 3.6 MJ/kg) used in quality tables of prEN 14961
BD	Bulk density, kg/m ³
DU	Mechanical durability of pellets, w-%
E_{ar}	Energy density, kWh/m ³ E used in the quality tables of prEN 14961
F	Fines, (< 3,15 mm)
S	Sulphur, dry basis, w-%
N	Nitrogen, dry basis, w-%
Cl	Chlorine, dry basis, w-%
CO, %	carbon monoxide, reported at 10% oxygen content (%)
OGC	organic gaseous compounds, reported at 10% oxygen content, mg/Nm ³
Dust	particles, reported at 10% oxygen content, mg/Nm ³

1 The aim of the combustion tests

The general aim of the combustion boiler tests was addressed to analyze the fuel properties that affect emissions and efficiency during a domestic boiler combustion supplied by different types of pellets. In this report 6 different combustion tests on 3 different types of pellets are carried out using a typical boiler produced by a Latvian manufacturer with a nominal power of 15 kW. The main normative EN 303-5 about testing of heating boilers for solids fuels was taken into account for all measurements.

2 The appliance used in the tests

The boiler tested in the framework of the BioNorm II project has a nominal power of 15 kW and it is produced by a Latvian manufacturer (see Figure 2.1).

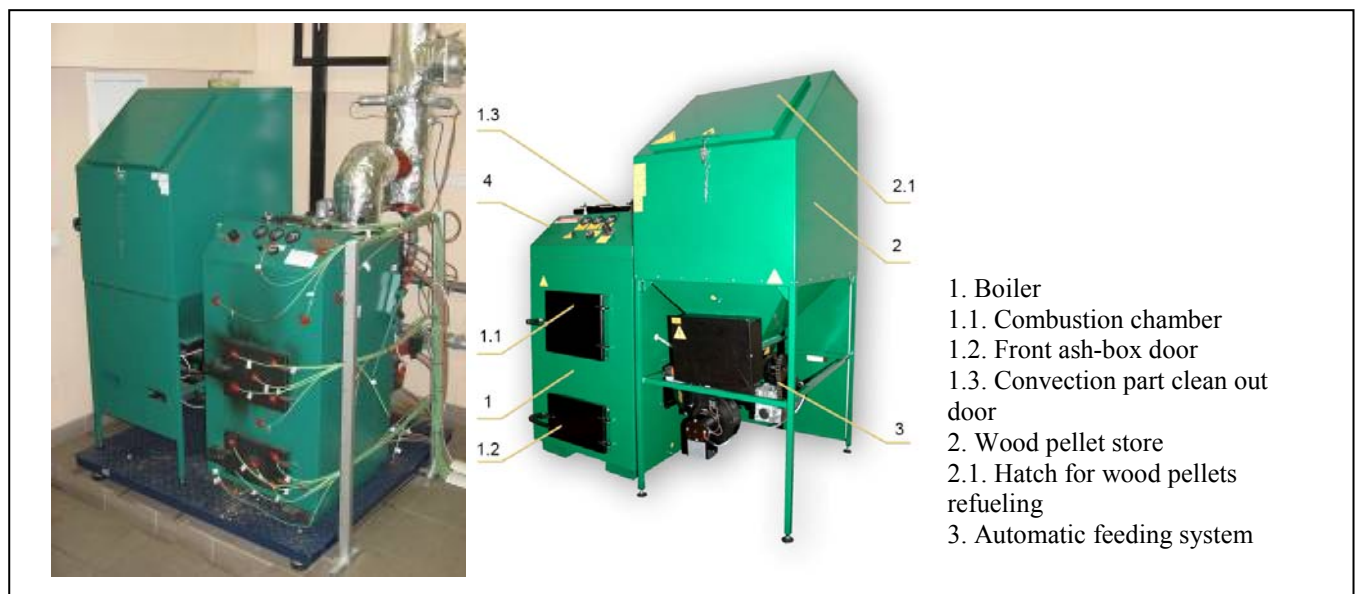


Figure 2.1. Latvian pellet boiler used in the tests as installed in the tests rig.

The boiler has a semiautomatic operational system; the user manually ignites the fuel in the furnace and regularly has to clean the boiler from ashes.

After the manual ignition, once the fuel has a stable combustion, the burning process is switched to automatic regime, where the boiler automatically supplies pellets and control on/off sequences in function of the water temperature in the boiler.

When the boiler reaches the maximum set temperature, it switches off: the air fan and fuel feeding system are switched off and the pellets remain in the burner in a no-air environment. Then, when the temperature goes below a minimum set temperature, the combustion starts again. If the time between an off phase and an on phase are very long it may happen that the combustion process is completely extinguished and consequently the user should ignite the fuel again. A modulation of the heating power is not possible.

Fuel feeding from the pellet storage of the boiler is carried out with a fixed supply screw. The boiler has a bottom fed burner and is equipped with an alarm system that warns when the pellet store is empty.

The boiler has an internal circulation pump and is equipped with a three-way valve for regulation the supply water temperature to the heating system.

The main technical parameters are summarized in the Table 2.1.

Table 2.1. Technical parameters of the tested pellet boiler

Parameter	Value	Unit
Nominal heat capacity	15	kW
Maximal working temperature	95	°C
Rated efficiency	80 - 90	%
Nominal work pressure	1	bar
Maximal work pressure	2.5	bar
Minimal work pressure at water $t = 95^{\circ}\text{C}$	0.5	bar
Maximal supply water temperature	95	°C
Minimal return water temperature	50	°C
Nominal water consumption at $\Delta t = 20^{\circ}\text{C}$	0.6	m^3/h
Minimal water consumption	50	% of nominal
Minimal temperature of flue gases	110	°C
Consumption of wood pellets	3.5	kg/h

In order to ensure burning of the wood pellet fuel material at the highest quality, the cylindric wood pellet burner is designed as a high-temperature combustion chamber, shaped by the burner-cone that is mounted on top of it (see Figure 2.2). With that, the burning intensity of wood pellets is increased by concentrating the burning process in limited space. The heat radiation generated in the firebox due to the cone promotes more intensive vaporization of evaporable substances and more qualitative burning. The cone also prevents yet unburned particles of wood to be thrown out of the burner by the air-flow within it, hence ensuring a more complete and effective burning process.

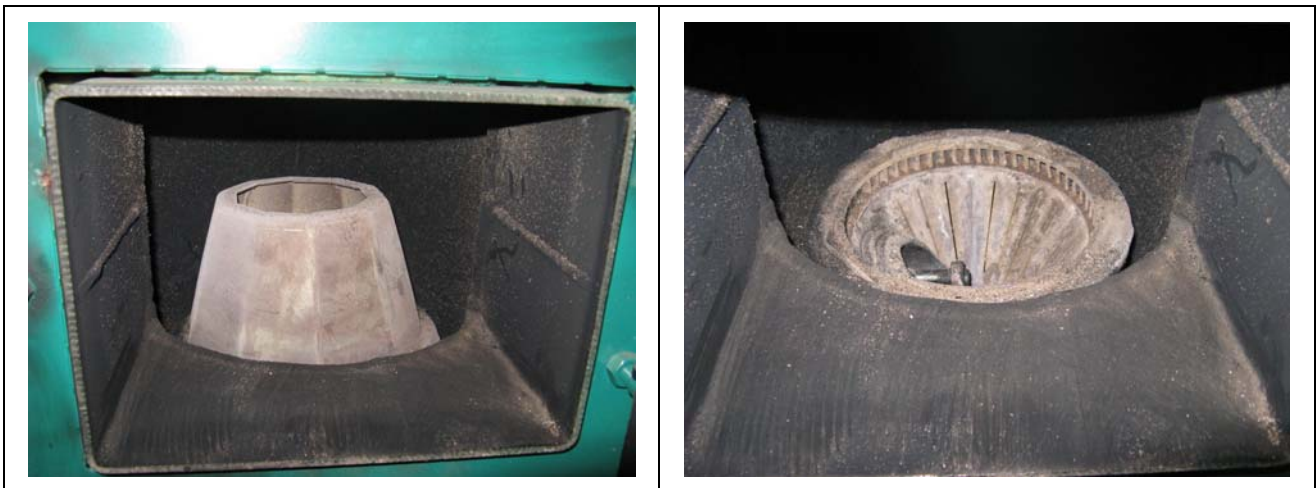


Figure 2.2. view of the combustion chamber and bottom fed burner with the burner-cone (left) and without burner cone (right)

In order to ease up the maintenance of the wood pellet burner, there is a sealable opening in the center of its base: via this opening, the slag remaining in the burner can be removed. Apart from

that, a ring-shaped sealing cover is there in the base of the burner, which can be removed to clean the air-feed space from ash and slag that is accumulated over longer time periods due to particles falling down via the slanting turbulence air-feed outlets on the top of the burner.

3 Test procedure

In the initial procedure was expected to use two different pellet samples and to provide for each kind of pellet two tests at boiler nominal capacity and one test at reduced capacity for a total sum of six tests. The control system of the experimental boiler works only using an on/off principle; during the boiler operation a constant amount of fuel and oxygen is provided to the furnace, hence it is not possibility for an ordinary operator to regulate boiler capacity. As a consequence only tests at nominal capacity were executed using three different types of pellets guarantying always a total sum of six tests.

For the boiler tests three different qualities of pellets were used with a nominal diameter equal to 8.0 mm. The moisture content for all types was included in the range between 6 w-% and 9 w-%. During the experiments the return water temperature was approximately equal to 50 °C, water flow through the system was approximately equal to 0.6 m³/h and draught inside chimney was in the range of 0.2 mbar. The boiler temperature in the internal circulation loop is set up by the manufacturer 80°C with a deadband of +5 °C. The duration of each test was at least 6 hours long. All types and main properties of pellets used for tests are summarized on the Table 5.21.

4 Measuring equipment

The solar and biomass laboratory of RTU-IESE has been equipped with a test facility for testing small scale biomass boilers (under 50 kW). The facility allows the measurements of the following parameters:

- Flow rate through the boiler
- Water inlet temperature to boiler
- Water outlet temperature from boiler
- Boiler water temperature
- Flue gas temperature at outlet of boiler
- Flue gas temperature at the position of flue gas flow sensor
- Room ambient temperature at 4 different heights
- Combustion temperature in the furnace
- Surface temperature of hot surfaces of the boiler
- Oxygen concentration in flue gas
- Carbon dioxide concentration in flue gases
- Carbon monoxide concentration in flue gases
- NO concentration in flue gases
- SO₂ concentration in flue gases
- Small particles in flue gases
- Dynamic pressure in chimney
- Weight of pellet store and boiler for dynamic measurements of pellet consumption
- Voltage and current to the screw motor
- Voltage and current to the fan motor
- Voltage and current to boiler pump

The data are centrally collected with a programmable datalogger. A schematic view of the test rig is given in Figure 4.1.

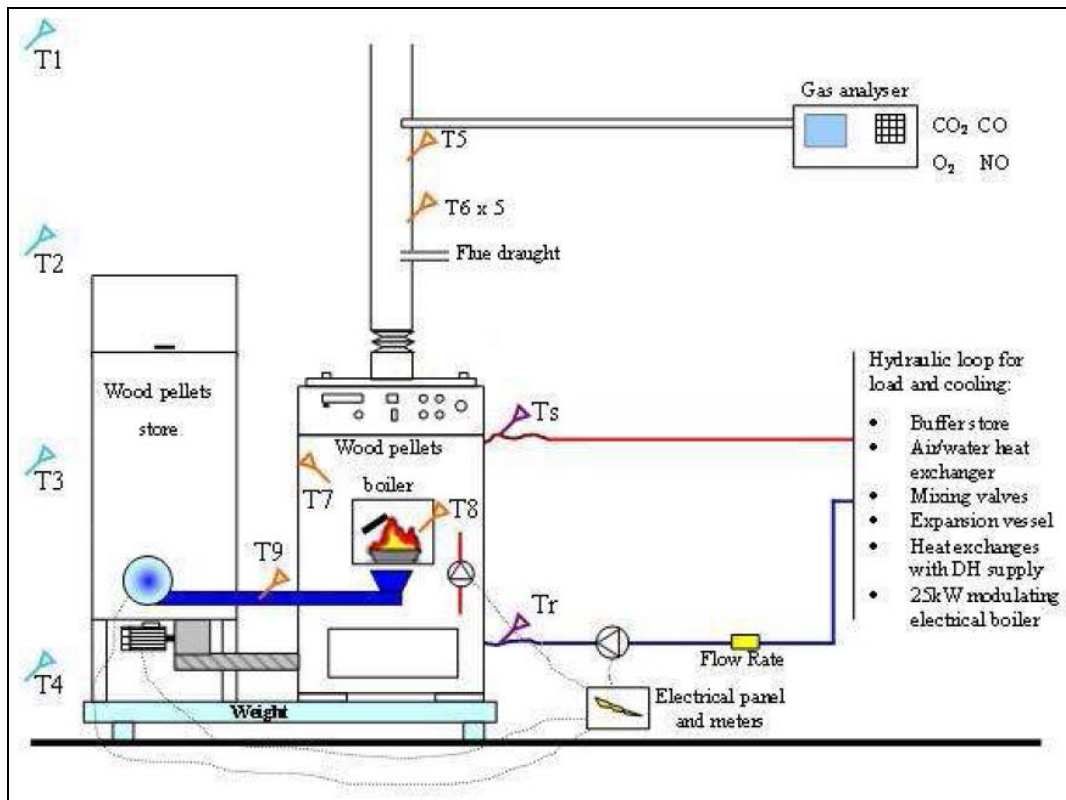


Figure 4.1. Scheme of the test rig used for the Latvian pellet boiler tests

The connection of the boiler to the chimney is assured with a flexible flange to ensure that temperature expansion does not affect weight measurements. Also flexible pipes are used for connecting the boilers to the hydraulic loop in order not to influence the scale due to temperature or pressure. Flue gas draught was adjusted using mechanical valve placed in chimney above measuring area.

In Table 4.1 is given an overview of the measurement instruments used for the BioNorm tests

Table 4.1. Measurement instrument used for the boiler tests

Name	Type	Model	Measurement range	Output signal range
Ambient temperature	Thermocouple type T	Exposed – soldered	-45 to 75 °C	±2,5mV
Flue gas temperature probe	Thermocouple Type K	KH-08516-71	-250 to 620°C	±25mV
Water inlet and outlet temperatures	Thermocouple type T	Exposed – soldered	-270 to 180°C	±7,5mV
Flue gas analyzer CO concentration CO ₂ concentration NO concentration	Continuous non-dispersive infrared absorption	Uras 14	0 - 3000 ppm 0 - 2500 ppm 0 - 25 %	4-20 mA 4-20 mA 4-20 mA
Flue gas analyzer O ₂ concentration	Magneto mechanical oxygen continuous analyzer	Magnos 106	0 - 100%	4-20 mA
Draught	Pressure Transducer	EW-68075-32	-14.7 to 15 psig	4-20 mA
Flow meter	Electromagnetic flow meter	9EVL-MP115	0-3 m ³ /h	10 l/pulse
Fuel consumption	Weighting platform	HCPS-4	0-500kg	4-20 mA

In the following paragraphs a brief overview of the installed equipments is given.

4.1 Mass measurements

The electronic weight used for calculating the mass of pellets is the electronic weighting platform (Svenska Vag HCPS-4) with an electronic weight indicator unit (Svenska Vag AB MODEL LD5204-06).

The load cells have been fixed to a steel platform, where afterward is possible to install and connect the pellet boiler and the pellet store (or just the pellet store) for testing.

The electronic weight indicator unit has an analogue output of 4...20 mA. This output is recorded at the data logger using an analogue differential voltage channel with a current shunt module that consist of a high accuracy resistor of 100Ω with tolerance at 25°C of ± 0.01% and power rating of 0.25W at 70°C.

The instrument has an accuracy of ± 0.05kg.

4.2 Temperature measurements

For temperature measurements are used thermocouple cable and probes type K and type T, measured at the data logger with differential voltage channels.

In particular type T thermocouple are used to measure the following temperatures:

- Water inlet temperature to boiler in the voltage range of $\pm 7.5\text{mV}$
- Water outlet temperature from boiler in the voltage range of $\pm 7.5\text{mV}$
- Boiler water temperature in the voltage range of $\pm 7.5\text{mV}$
- Room ambient temperature at 4 different heights in the voltage range of $\pm 2.5\text{mV}$

Then type K thermocouples are used for measuring the following temperatures:

- Flue gas temperature at outlet of boiler in the voltage range of 250mV
- Flue gas temperature at the standard position in the flue gas chimney in the voltage range of 25mV
- Combustion temperature in the furnace in the voltage range of 250mV
- Surface temperature of hot surfaces of the boiler in the voltage range of 25mV

As reference temperature for the thermocouples is used the internal thermistor of the data logger.

4.3 Flow rate measurements

For measuring the flow rate is used an electromagnetic flow meter, which is part of a heat meter (Kamstrup 9EVL, MP115). The heat meter has a digital pulse output, which is measured at the data logger with a pulse counter channel.

The main parameters of the meter are shown in Table 4.2.

Table 4.2. Technical parameters of heat meter Kamstrup 9EVL

Parameter	Value	Unit
Maximal water flow	3	m ³ /h
Nominal water flow	1.5	m ³ /h
Minimal water flow	0.015	m ³ /h
Readings of heat energy values	0.001	MWh
Readings of water flow	0.01	m ³

4.4 Flue gas analyses

In the main flue gas chimney of the test facility there are 3 slots for connecting 3 gas analyzer lines.

The first line is used for the ABB AO2000 analyzer, which includes an electronic module, an URAS 14 module and a MAGNOS 106 module. The URAS 14 module is a continuous non-dispersive infrared absorption gas analyzer in the $\lambda = 2.5\text{--}8\ \mu\text{m}$ wave length range for measuring carbon dioxide, carbon monoxide and nitrogen oxides. The MAGNOS 106 module is a magneto mechanical oxygen continuous analyzer based on the paramagnetic behavior of oxygen principle. The analyzer set up includes flue gas pump, heat connecting line, filters and condensing unit for collection and preparation of gas samples.

The Electronic module of the ABB AO2000 gas analyzer used from measuring CO₂, CO, O₂ and NO has 4 output channels, one for each gas, with analogue output of 4...20mA. The analogue output is recorder at the data logger with a voltage differential channel using a current shunt module that consist of a high accuracy resistor with tolerance at 25°C of $\pm 0.01\%$ and power rating of 0.25W at 70°C for each channel.

The second line is used for the Isokinetic analyzer for measuring small particles, in particular the PM10. This instrument allows as well as measurements of dynamic pressure in the chimney.

The third line is used for the TESTO 350XL analyzer. This analyzer is used for measuring SO₂ using a electrochemical cell sensor. The analyzer allows as well as the measuring of oxygen, carbon monoxide and nitrogen oxides with electrochemical cells. Furthermore it has an infrared absorption cell for measuring carbon dioxide. The analyzer is equipped with pump, filters and condensation unit for collection and preparation of gas samples. However this analyzer is designed and typically used for spot or short term measurement.

5 Fuels

Fuels were provided inside the typical plastic selling envelope in order to guarantee as much as possible the real moisture content and the quality of the pellets. The moisture content of the as received pellet was analyzed together and also ash content, net calorific value, bulk density and % of fines was investigated how specific norms was required. Pictures of pellets used are reported in Figure 5.1 and all the main results and the norms used for the analysis are reported in the Tables 5.1a, 5.1b, 5.1c and 5.2.



Figure 5.1. Pictures of the sample of pellets used for boiler tests

Table 5.1a. Measurement and reporting of fuel properties according prEN 14961 Table 4 – pellet I_201208_001

Property	Standard for measurement	EN 14961-1 category (N164)	Actual measured value
According prEN 14961-1, Table 4 (Latest document N164)			
Origin	According Table 1	1.1.4.4	
Length (L), mm	10 random sample of pellets, report also the amount (w-%) of pellets which are longer than 40mm	D08 (0% longer than 40mm)	14,8
Diameter (D), mm	According the die size, measurement of 10 random samples	D08	8,4
Moisture of whole fuel batch, M, w-%	CEN/TS 14774	M10	See table 5.2
Ash, A, w-% of dry basis	CEN/TS 14755	A0.5	See table 5.2
Mechanical durability, DU, w-% of pellets after testing	CEN/TS 15210-1	DU96.5	See table 5.2
Amount of fine (w-%, < 3,15 mm)	CEN/TS 15149-1 (manual sieving can be used, sieve to ISO 3310-1)	F1.0	See table 5.2
Additives, w-%	Type and amount (w-%) from manufacturer	-	-
Sulphur, S, w-% of dry basis	CEN/TS 15289	S0.02	
Nitrogen, N, w-% of dry basis	CEN/TS 15104	0.18	
Additional properties required in EN-303-5			
Carbon content	CEN/TS 15104		See table 5.2
Net calorific value, dry and as received (formula in prEN14961-1)	CEN/TS 14918		See table 5.2

Table 5.1b. Measurement and reporting of fuel properties according prEN 14961 Table 4 – pellet F_281208_002

Property	Standard for measurement	EN 14961-1 category (N164)	Actual measured value
According prEN 14961-1, Table 4			
Origin	According Table 1	1.1.4.4	
Length (L), mm	10 random sample of pellets, report also the amount (w-%) of pellets which are longer than 40mm	D08 (0% longer than 40mm)	21,24
Diameter (D), mm	According the die size, measurement of 10 random samples	D08	8,32
Moisture of whole fuel batch, M, w-%	CEN/TS 14774	M10	See table 5.2
Ash, A, w-% of dry basis	CEN/TS 14755	A0.7	See table 5.2
Mechanical durability, DU, w-% of pellets after testing	CEN/TS 15210-1	DU96.5	See table 5.2
Amount of fine (w-%, < 3,15 mm)	CEN/TS 15149-1 (manual sieving can be used, sieve to ISO 3310-1)	F1.0	See table 5.2
Additives, w-%	Type and amount (w-%) from manufacturer	-	-
Sulphur, S, w-% of dry basis	CEN/TS 15289	S0.02	
Nitrogen, N, w-% of dry basis	CEN/TS 15104	0.20	
Additional properties required in EN-303-5			
Carbon content	CEN/TS 15104		See table 5.2
Net calorific value, dry and as received (formula in prEN14961-1)	CEN/TS 14918		See table 5.2

Table 5.1c. Measurement and reporting of fuel properties according prEN 14961 Table 4 – pellet V_030109_003

Property	Standard for measurement	EN 14961-1 category (N164)	Actual measured value
According prEN 14961-1, Table 4			
Origin	According Table 1	1.1.3.3	
Length (L), mm	10 random sample of pellets, report also the amount (w-%) of pellets which are longer than 40mm	D08 (0% longer than 40mm)	18,14
Diameter (D), mm	According the die size, measurement of 10 random samples	D08	8,32
Moisture of whole fuel batch, M, w-%	CEN/TS 14774		See table 5.2
Ash, A, w-% of dry basis	CEN/TS 14755		See table 5.2
Mechanical durability, DU, w-% of pellets after testing	CEN/TS 15210-1	DU97.5	See table 5.2
Amount of fine (w-%, < 3,15 mm)	CEN/TS 15149-1 (manual sieving can be used, sieve to ISO 3310-1)	F2.0	See table 5.2
Additives, w-%	Type and amount (w-%) from manufacturer	-	-
Sulphur, S, w-% of dry basis	CEN/TS 15289	S0.02	
Nitrogen, N, w-% of dry basis	CEN/TS 15104	0.16	
Additional properties required in EN-303-5			
Carbon content	CEN/TS 15104		See table 5.2
Net calorific value, dry and as received (formula in prEN14961-1)	CEN/TS 14918		See table 5.2

Table 5.2. results of pellet analysis

Analysis	Result	Unit	Method
Pellet I_201208_001			
Total moisture	6.3	w-%	CEN/TS 14774-3
Bulk density (CEN)	688	kg/m ³	CEN/TS 15103
Ash content (550°)	0.4	w-%, dry matter	CEN/TS 14775
Mechanical durability (CEN)	97.6	w-%	CEN/TS 15210-1
Sulphur content	<0.02	w-%, dry matter	CEN/TS 15289
Net calorific value	17.46	MJ/kg, dry matter	CEN/TS 14918
Fines (<3.15mm)	0.66	w-%	CEN/TS 15149-1
Carbon	51.7	w-%, dry matter	CEN/TS 15104
Hydrogen	5.7	w-%, dry matter	CEN/TS 15104
Nitrogen	0.18	w-%, dry matter	CEN/TS 15104
Pellet F_281208_002			
Total moisture	6.1	w-%	CEN/TS 14774-3
Bulk density (CEN)	633	kg/m ³	CEN/TS 15103
Ash content (550°)	0.6	w-%, dry matter	CEN/TS 14775
Mechanical durability (CEN)	97.4	w-%	CEN/TS 15210-1
Sulphur content	0.02	w-%, dry matter	CEN/TS 15289
Net calorific value	17.39	MJ/kg, dry matter	CEN/TS 14918
Fines (<3.15mm)	0.37	w-%	CEN/TS 15149-1
Carbon	51.5	w-%, dry matter	CEN/TS 15104
Hydrogen	5.7	w-%, dry matter	CEN/TS 15104
Nitrogen	0.20	w-%, dry matter	CEN/TS 15104
Pellet V_030109_003			
Total moisture	8.8	w-%	CEN/TS 14774-3
Bulk density (CEN)	670	kg/m ³	CEN/TS 15103
Ash content (550°)	0.4	w-%, dry matter	CEN/TS 14775
Mechanical durability (CEN)	99.1	w-%	CEN/TS 15210-1
Sulphur content	<0.02	w-%, dry matter	CEN/TS 15289
Net calorific value	17.01	MJ/kg, dry matter	CEN/TS 14918
Fines (<3.15mm)	1.23	w-%	CEN/TS 15149-1
Carbon	50.9	w-%, dry matter	CEN/TS 15104
Hydrogen	6.0	w-%, dry matter	CEN/TS 15104
Nitrogen	0.16	w-%, dry matter	CEN/TS 15104

6 Results of combustion tests

The results from the combustion tests are given in table 6.1 according to the EN 303-5; while in Figures 6.1, 6.2, 6.3 and 6.4 emissions of CO, CO₂, NO and calculated boiler efficiency for the different types of pellets are shown for comparison. Other comparisons are as well as reported in Appendix 6.

Table 6.1. Results from the combustion tests according to EN 303-5

TEST	SAMPLE	O ₂ %			CO ₂ %			CO % at 10% O ₂			NO Mg/Nm ³ at 10% O ₂		
		min	aver.	max	min	aver.	max	min	aver.	max	min	aver.	max
1.1	I_201208_001	3.89	6.13	8.25	11.98	13.91	15.91	0.009	0.044	0.202	66.62	75.77	84.79
1.2	I_201208_001	4.20	6.80	9.06	11.31	13.34	15.75	0.011	0.041	0.201	64.31	75.75	87.13
2.1	F_281208_002	5.08	7.04	9.28	11.54	13.74	15.58	0.009	0.025	0.211	83.50	97.02	108.70
2.2	F_281208_002	5.08	7.54	9.44	11.16	12.99	15.27	0.007	0.021	0.094	80.84	96.03	109.80
3.1	V_201208_003	10.6	11.77	12.98	7.53	8.67	9.84	0.032	0.054	0.085	45.52	67.04	87.97
3.2	V_201208_003	8.68	10.16	12.18	8.38	10.14	11.51	0.014	0.026	0.047	35.58	67.39	87.08

TEST	SAMPLE	Flue gas temperature °C			Inlet water temperature °C			Outlet water temperature °C			Eff. %	Draught mbar	Time of test min.
		min	aver.	max	min	aver.	max	min	aver.	max			
1.1	I_201208_001	93.2	94.71	96.3	49.0	49.8	50.5	67.1	69.5	71.3	86.3	0.19	391
1.2	I_201208_001	87.5	92.64	95.3	47.6	50.0	51.0	66.6	69.4	71.7	86.4	0.18	374
2.1	F_281208_002	90.8	94.63	96.0	48.7	49.8	50.8	67.3	69.2	71.2	84.7	0.21	371
2.2	F_281208_002	92.6	96.09	97.9	49.2	50.2	50.8	67.4	69.2	70.7	83.9	0.20	361
3.1	V_201208_003	83.5	85.59	86.9	49.0	50.1	50.8	63.8	65.2	66.5	84.1	0.18	383
3.2	V_201208_003	80.3	84.03	85.3	49.2	50.1	50.8	63.6	65.7	67.1	84.7	0.19	372

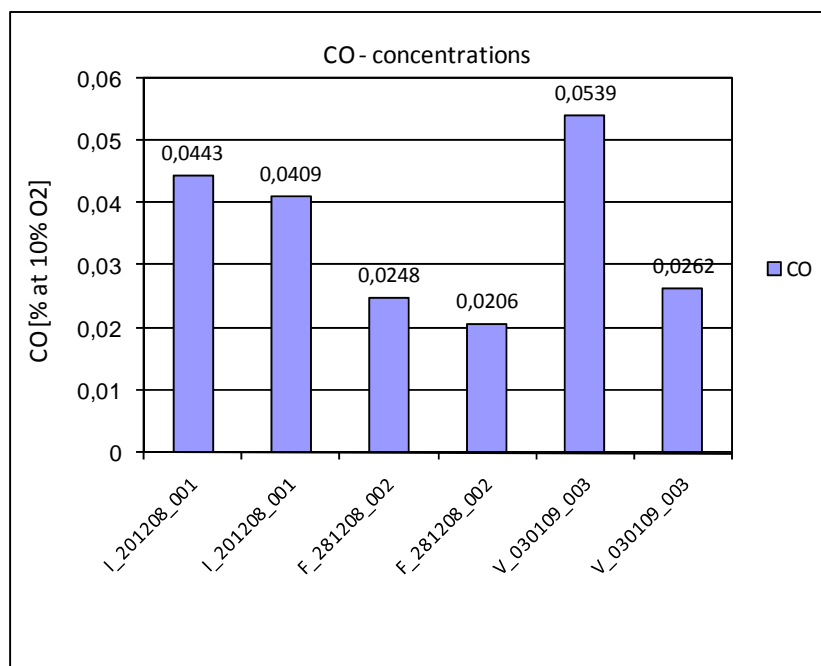


Figure 6.1. Comparison of CO-concentrations recalculated at 10% of O₂

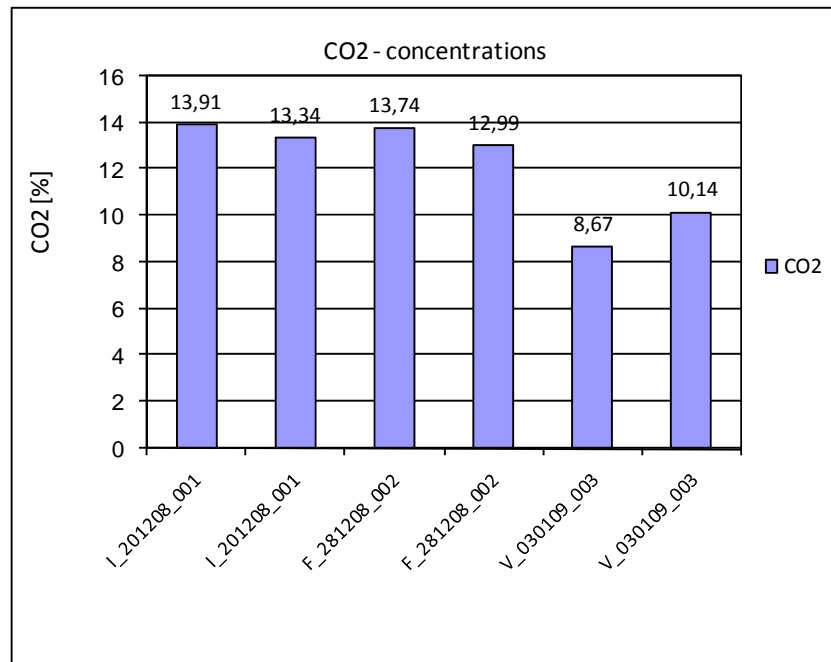


Figure 6.2. Comparison of CO₂-concentrations

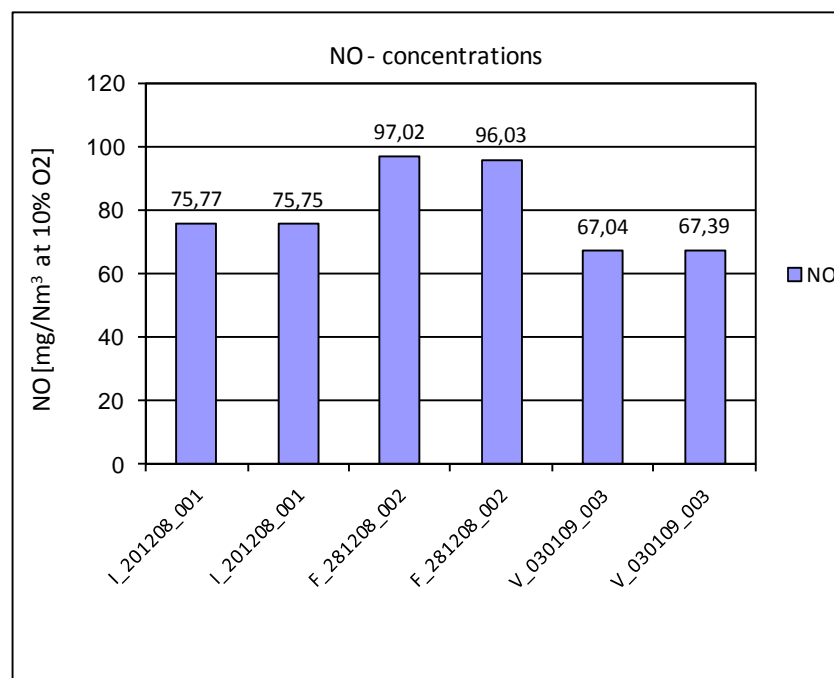


Figure 6.3. Comparison of NO-concentrations recalculated at 10% of O₂

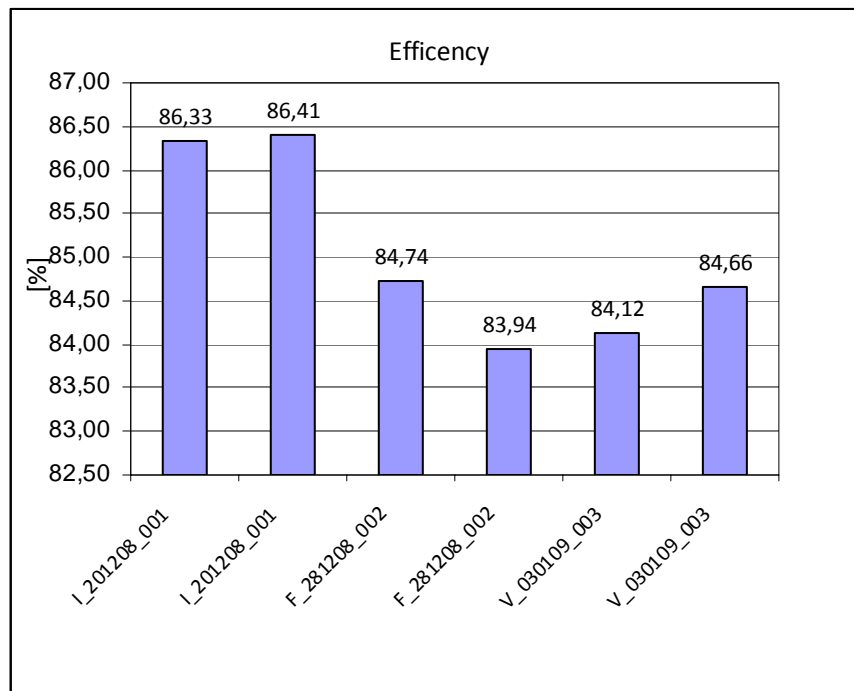


Figure 6.4. Comparison of efficiency

7 Conclusions

1. The boiler used for tests is produced by a Latvian manufacturer and it represent a classic model easily available on the Latvian market. Close cooperation with boiler producers allowed improving combustion efficiency during testing of boiler.
2. Boiler efficiency varies in a range between 83.9% and 86.4%. Difference in boiler efficiency values is connected with both parameters of boiler operation conditions (different oxygen content in furnace, temperature of flues gases) and the different types of pellets.
3. The 3 different pellet qualities used in the test were rather close to each other in terms of pellet quality parameters and therefore the separate effect of pellet quality parameters on boiler efficiency is not clearly detectable. For example ash content of pellets in range of 0,39 – 0,55 % does not affect boiler efficiency.
4. Emission level of nitrogen oxides in flue gases depends on temperature level. Some features are observed which need additional testing and research. For example lower NO_x emissions have been measured for the pellet sample with higher moisture content (sample V_201208_003 with total moisture 8.75 w-% compared to 633 w-% and 6.28 w-% of sample . F_281208_002 and I_201208_001 respectively). However from laboratory test the pellet F_281208_002 shows an higher content of Nitrogen (0.20 w-%, dry matter) compared to the other pellet samples; this could be in relation to the higher concentration of NO in the boiler tests executed with this kind of pellet.
5. Two of the samples used in these tests have very similar durability values (sample I_201208_001 at 97.6 w-% and sample F_281208_002 at 97.4 w-%) while the third one had an higher value (V_201208_003 at 99.1 w-%). From this few data it was not possible to

make relevant conclusion on the effect of mechanical durability on boiler efficiency and emission level.

Some interesting features of formation of boiler efficiency and emissions were observed during testing of combustion process, which could be discussed with other partners in this project. Continuation of testing will be implemented after end of project.

1. Ash content of pellets in range of 0,39 – 0,55 % does not affect combustion efficiency. Therefore higher ash content has to be tested to find influence to boiler efficiency.
2. Emission levels of NO_x should be further analyzed in particular in relation to Nitrogen content in the pellet sample and moisture content of the pellets.
3. The effect of pellet mechanical durability should be further investigated in particular for understanding the effect of pellet mechanical durability on flue gas emissions.
4. Moisture content of pellets may influence level of emissions of nitrogen oxides. Testing has to be continued to confirm dependence in different combustion conditions.

8 Recommendations to prEN14961-2

In connection to the prEN14961-2, regarding specifications for wood pellets for non-industrial use, the following recommendations have been carried out during the period of the project:

1. It is not enough clearly specified the sizes of the “smaller commercial boiler situations” for which the Standard is referred,
2. It not enough clear which is the real way to characterized which is the non-industrial and the industrial situation where the standard can be applied. This problem became evident when we have a situation such as some small public building (e.g. kinder garden, small hospital ...) that can be in the middle of the two categories. Idea is that the classification can be done in relation to the capacity of the systems and this should be well described in the standard.

9 Recommendations to EN 303-5

The following short recommendations were carried out in connection to the European Standard for boiler tests EN 303-5:

1. There is no method found on how to calculate or determine all boiler heat losses (q_a, q_u, q_s, q_b) for indirect boiler efficiency calculation method.
2. In future, the standard should be divided in two separate parts – first, that refers to boiler testing in laboratory, second, that refers only to boiler manufacturers.
3. The classification should be revised according to the performance of modern boilers. The classification should be separated for different boiler types and used fuels.

APPENDICES

App. 1 Fuel Analyses

App. 2 CO₂ and CO concentrations versus test time

App. 3 O₂ concentrations versus test time

App. 4 NO concentrations versus test time

**App. 5 Temperature of flue gases, inlet boiler water, outlet boiler water versus
test time**

App. 6 Test comparisons

App. 7 Heating power

APPENDICE 1

Fuel Analyses



Riga Technical University
 Institute of Energy Systems and Environment
 Environmental Laboratory

ANALYSIS CERTIFICATE n. 120109_001_RTU

ANALYSIS CERTIFICATE
 n. 120109_001_RTU

Date: 12/01/2009

Analysis from: Institute of Energy Systems and Environment
 Environmental Laboratory

Sample data:

Name: I_201208_001

Order number LV159-X151208_10132
 (invoice number):
 Sample taken: 2012_002

Pellet info: Nominal pellet diameter = 8 mm

Analysis	Result	Unit	Method
Total moisture	6.28	wt%	CEN/TS 14774-3
Bulk density (CEN)	688.44	kg/m ³	CEN/TS 15103
Ash content (550 °C)	0.43	wt%,d	CEN/TS 14775
Mechanical durability (CEN)	97.63	wt%,	CEN/TS 15210-1
Net calorific value as received	17.46	MJ/kg	CEN/TS 14918
Fines (<3.15 mm)	0.66	wt%	CEN/TS 15149-1
Sulphur content	<0.02	wt%,d	CEN/TS 15289
C	51.66	wt%,d	CEN/TS 15104
H	5.70	wt%,d	CEN/TS 15104
N	0.18	wt%,d	CEN/TS 15104

Analysis responsible: Aivars Žandeckis

Net calorific value calculated from det. values/or
 According to prEN14961-1:2008.5 ANNEX B table B.3

Analysis result applies only to the sample examined. Copying the document partly is not allowed

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 Institute of Energy Systems and Environment
 Environmental Laboratory

ANALYSIS CERTIFICATE n. 130109_002_RTU

ANALYSIS CERTIFICATE
 n. 130109_002_RTU

Date: 13/01/2009

Analysis from: Institute of Energy Systems and Environment
 Environmental Laboratory

Sample data: F_281208_002

Order number LV200_X101208_15280
 (invoice number):
 Sample taken: 2818_004

Pellet info: Nominal pellet diameter = 8 mm

Analysis	Result	Unit	Method
Total moisture	6.14	wt%	CEN/TS 14774-3
Bulk density (CEN)	633.27	kg/m ³	CEN/TS 15103
Ash content (550 °C)	0.56	wt%,d	CEN/TS 14775
Mechanical durability (CEN)	97.42	wt%,	CEN/TS 15210-1
Net calorific value as received	17.39	MJ/kg	CEN/TS 14918
Fines (<3.15 mm)	0.37	wt%	CEN/TS 15149-1
Sulphur content	0.02	wt%,d	CEN/TS 15289
C	51.50	wt%,d	CEN/TS 15104
H	5.70	wt%,d	CEN/TS 15104
N	0.20	wt%,d	CEN/TS 15104

Analysis responsible: Aivars Žandeckis

Net calorific value calculated from det. values/or
 According to prEN14961-1:2008.5 ANNEX B table B.3

Analysis result applies only to the sample examined. Copying the document partly is not allowed

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ANALYSIS CERTIFICATE n. 140109_003_RTU

ANALYSIS CERTIFICATE
 n. 140109_003_RTU

Date: 14/01/2009

Analysis from: Institute of Energy Systems and Environment
 Environmental Laboratory

Sample data:

Name: V_030109_003

Order number: LV130_X181208_20300
 (invoice number):
 Sample taken: 0301_005

Pellet info: Nominal pellet diameter = 8 mm

Analysis	Result	Unit	Method
Total moisture	8.75	wt%	CEN/TS 14774-3
Bulk density (CEN)	669.55	kg/m ³	CEN/TS 15103
Ash content (550 °C)	0.39	wt%,d	CEN/TS 14775
Mechanical durability (CEN)	99.14	wt%,	CEN/TS 15210-1
Net calorific value as received	17.01	MJ/kg	CEN/TS 14918
Fines (<3.15 mm)	1.23	wt%	CEN/TS 15149-1
Sulphur content	<0.02	wt%,d	CEN/TS 15289
C	50.88	wt%,d	CEN/TS 15104
H	6.00	wt%,d	CEN/TS 15104
N	0.16	wt%,d	CEN/TS 15104

Analysis responsible: Aivars Žandeckis

Net calorific value calculated from det. values/or
 According to prEN14961-1:2008.5 ANNEX B table B.3

Analysis result applies only to the sample examined. Copying the document partly is not allowed

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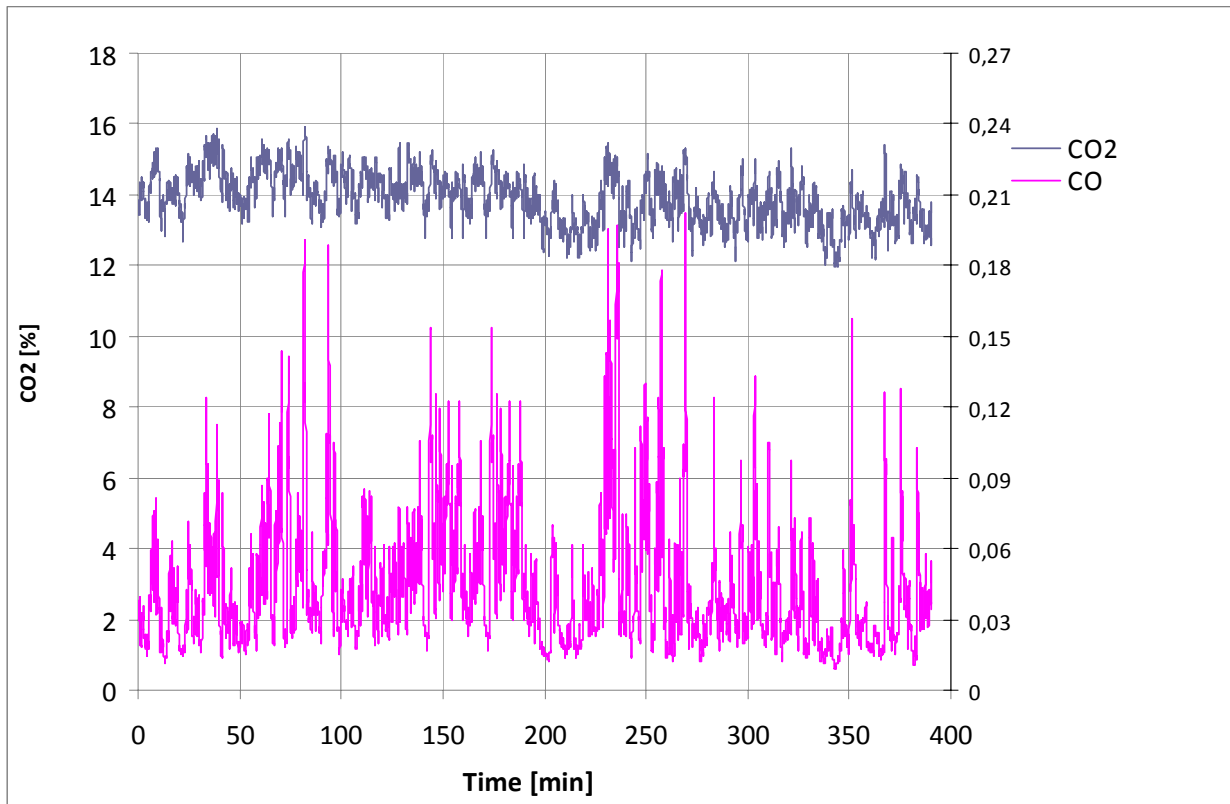
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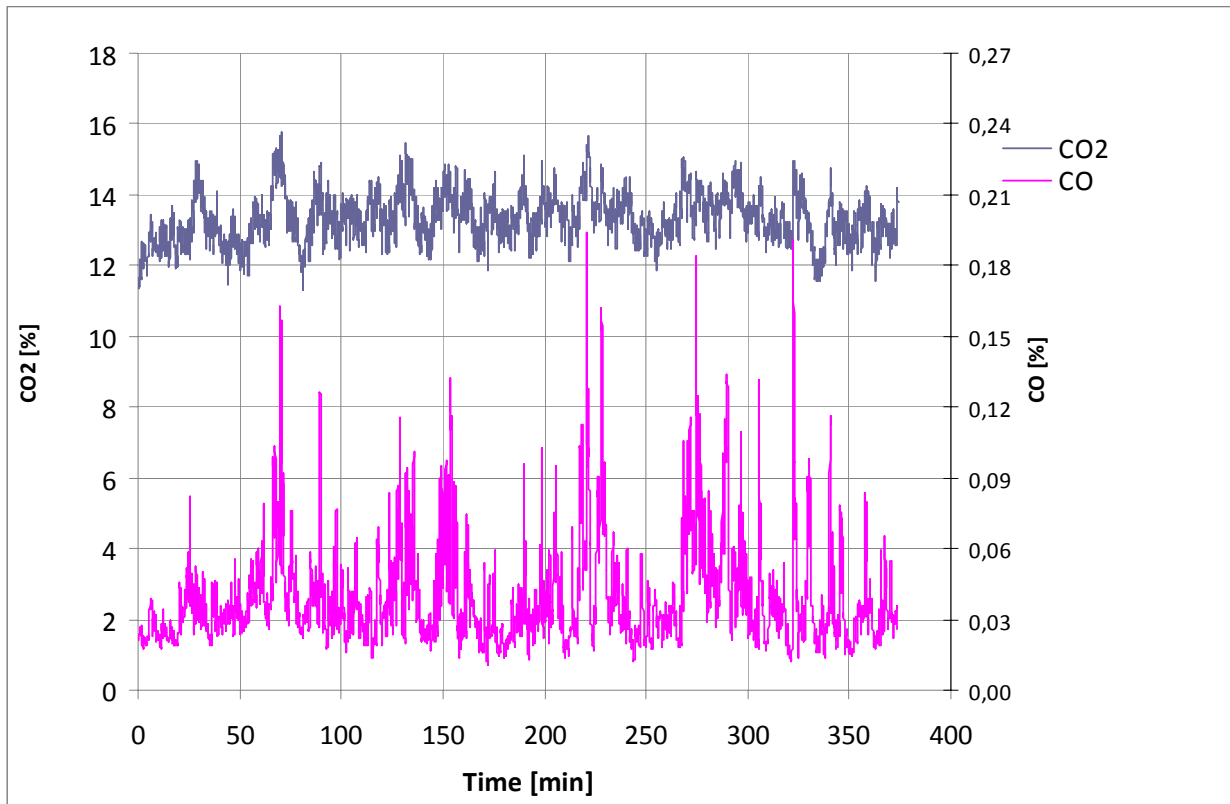
APPENDICE 2

CO₂ and CO concentrations versus test time

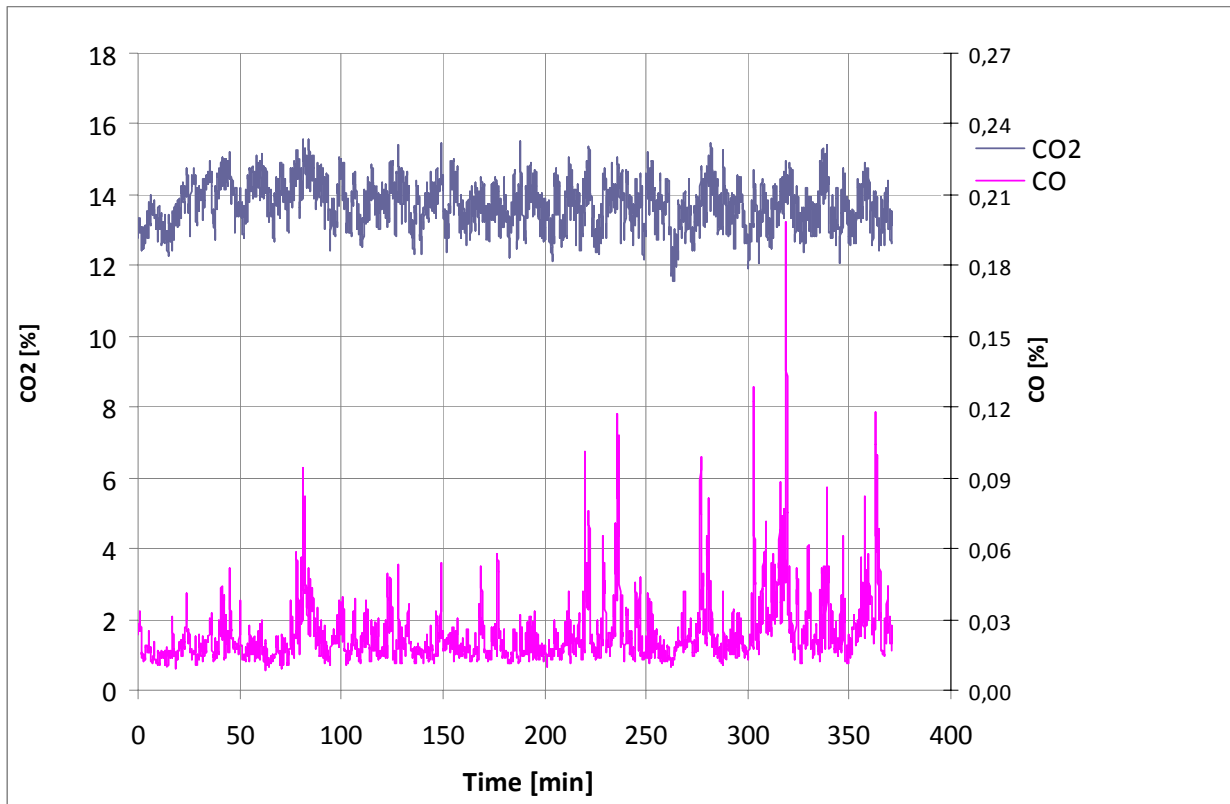
Test 1_1: Pellet I_201208_001



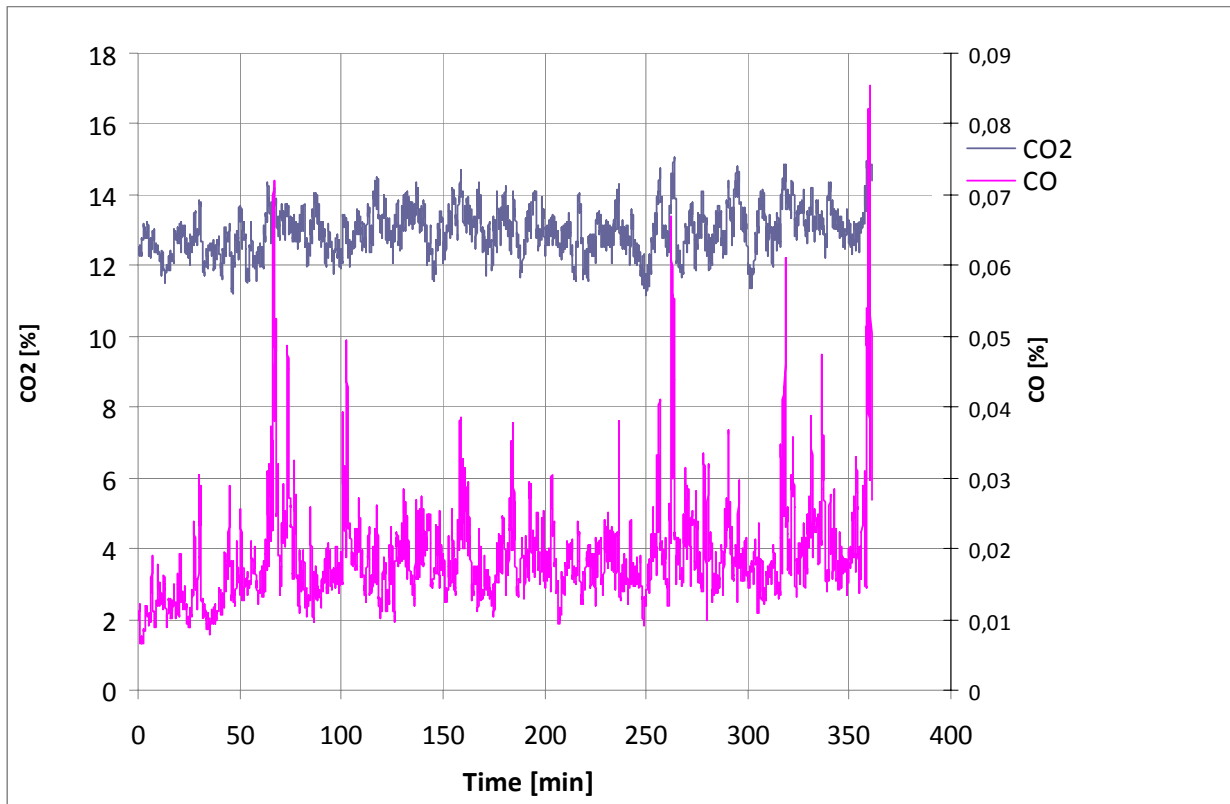
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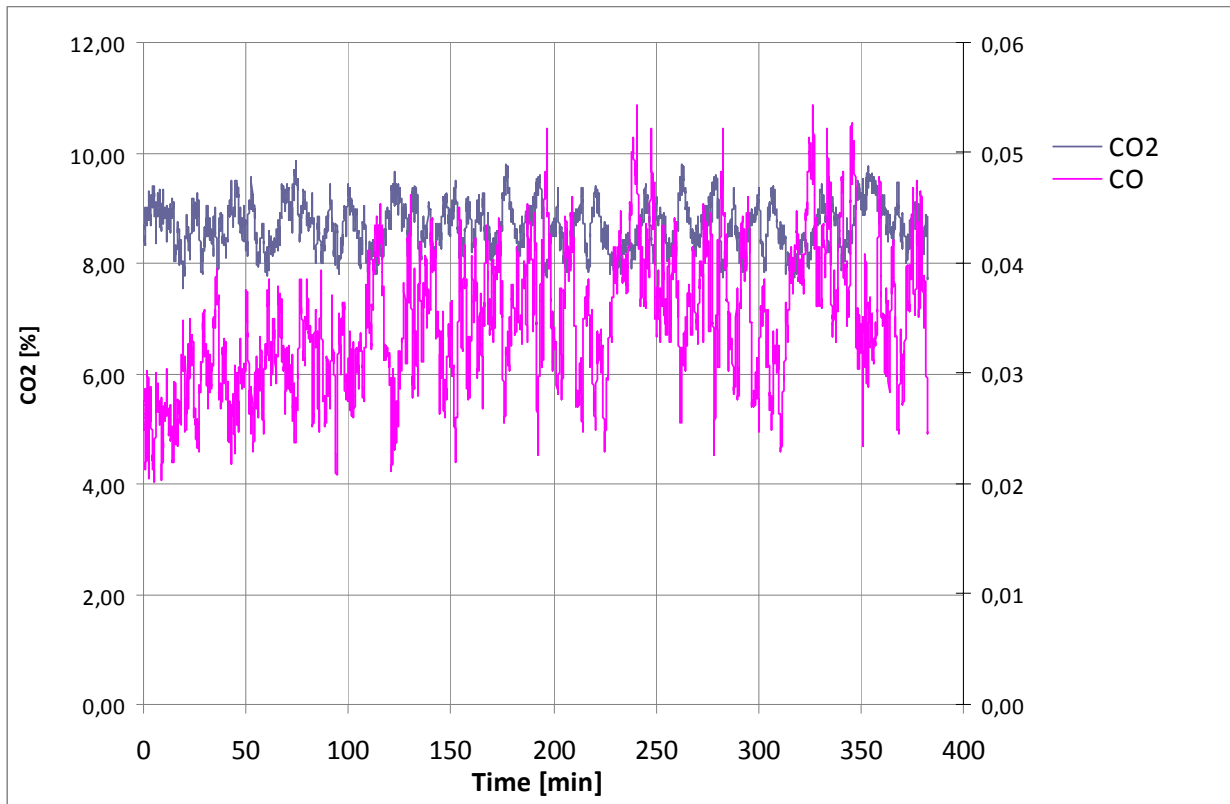
Test 2_1: Pellet F_281208_002



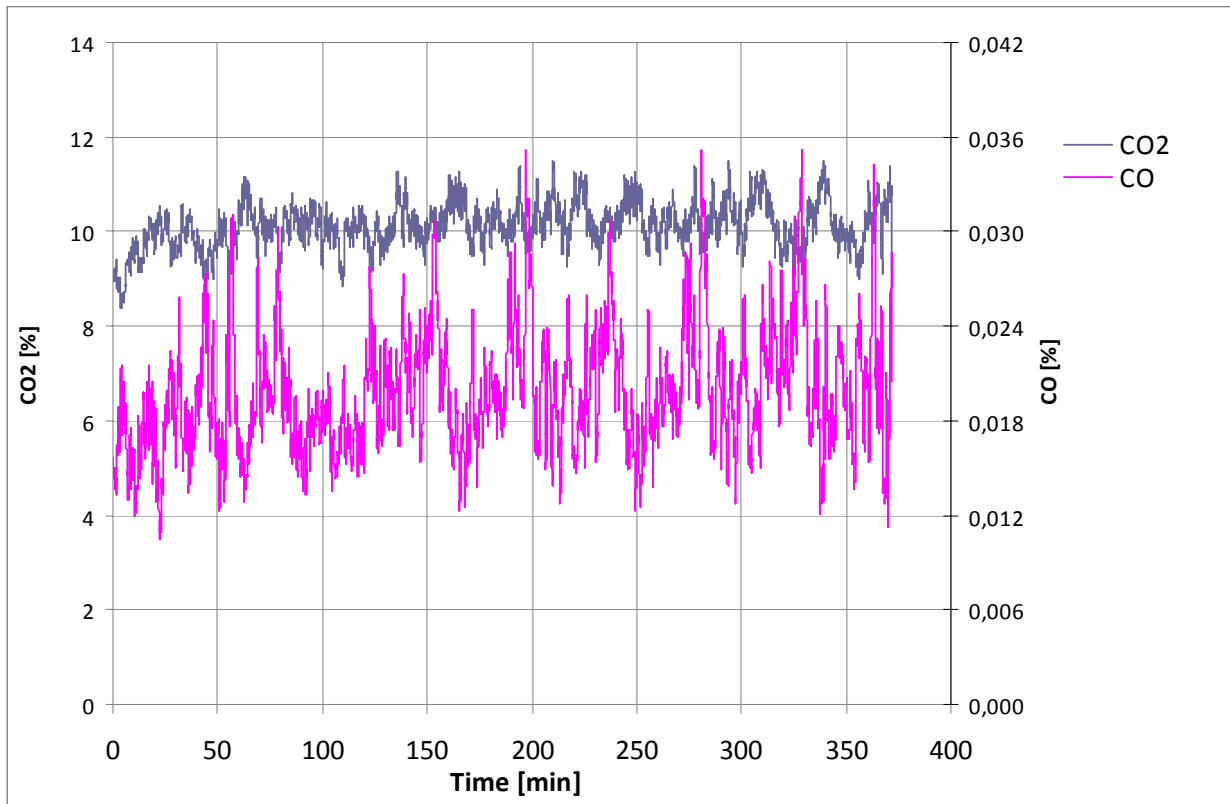
Test 2_2: Pellet F_281208_002



Test 3_1: Pellet V_030109_003



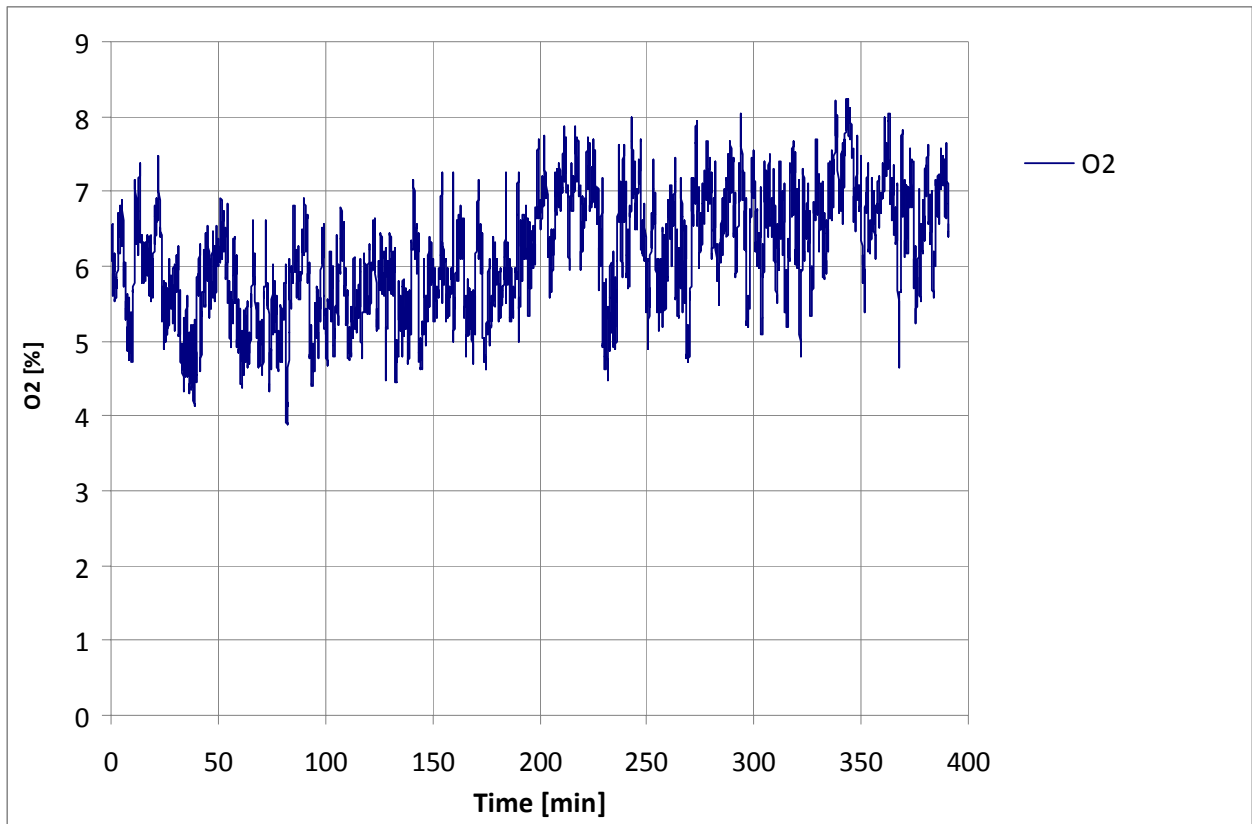
Test 3_2: Pellet V_030109_003



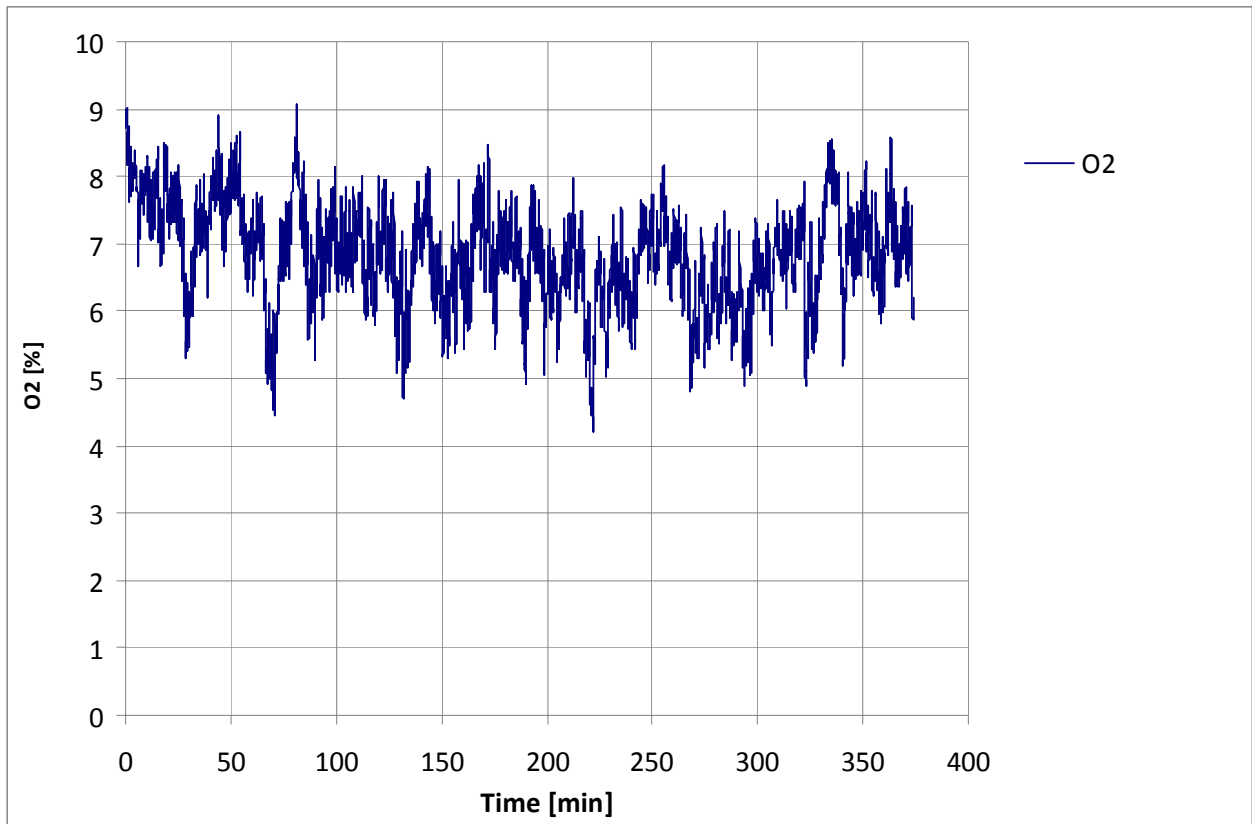
APPENDICE 3

O₂ concentrations versus test time

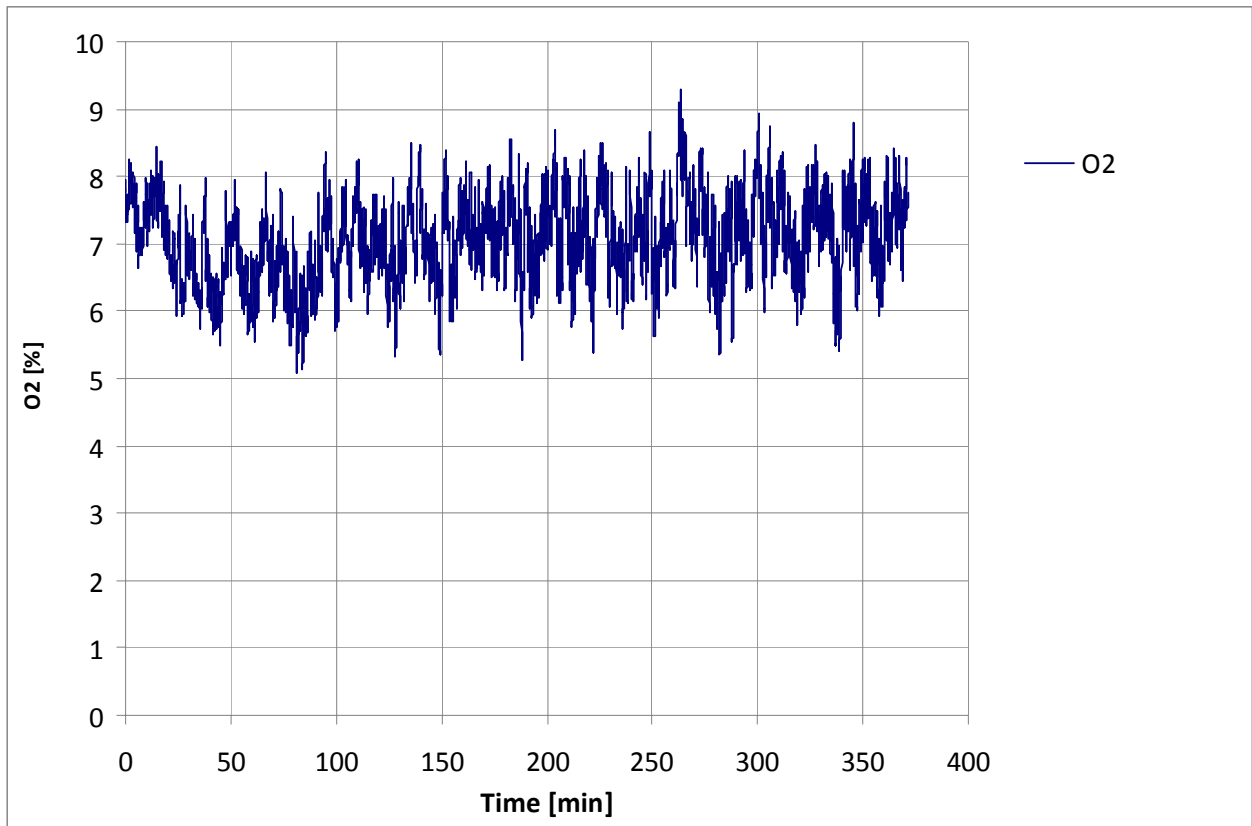
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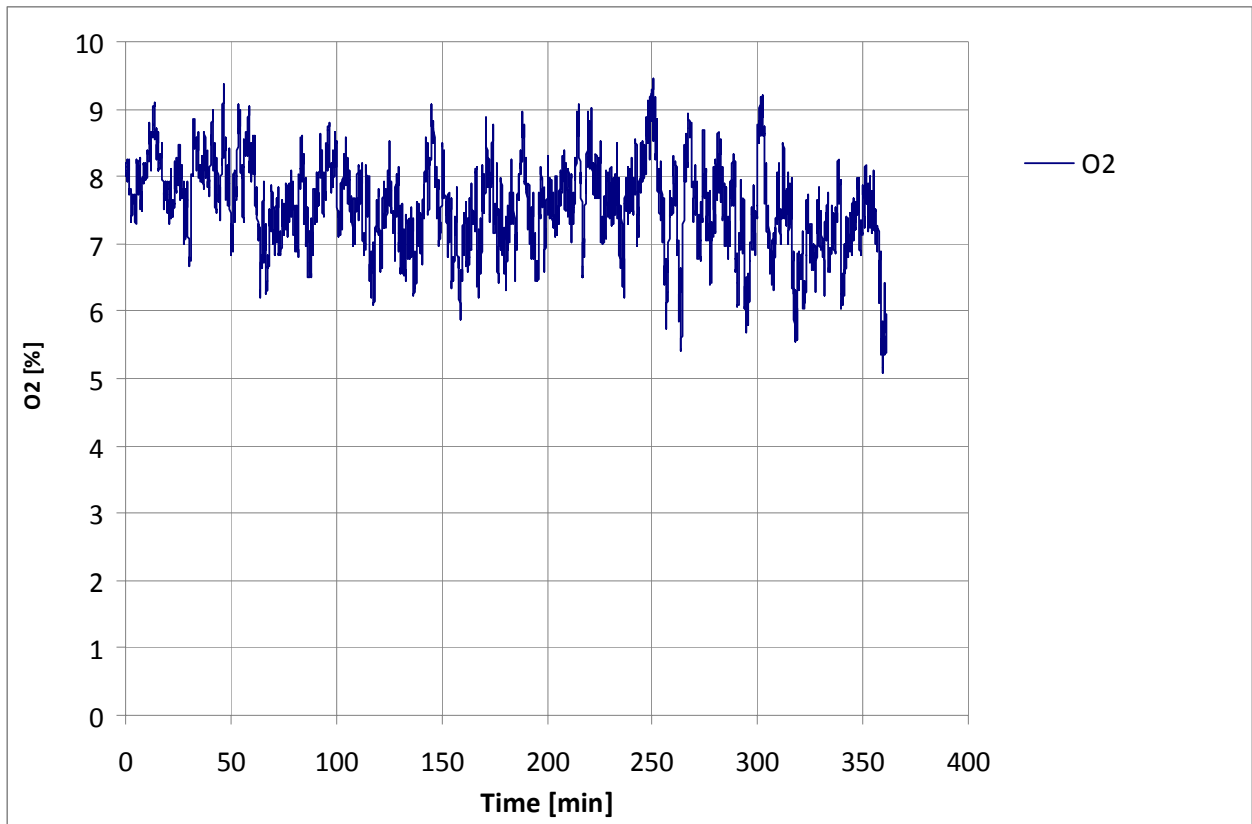
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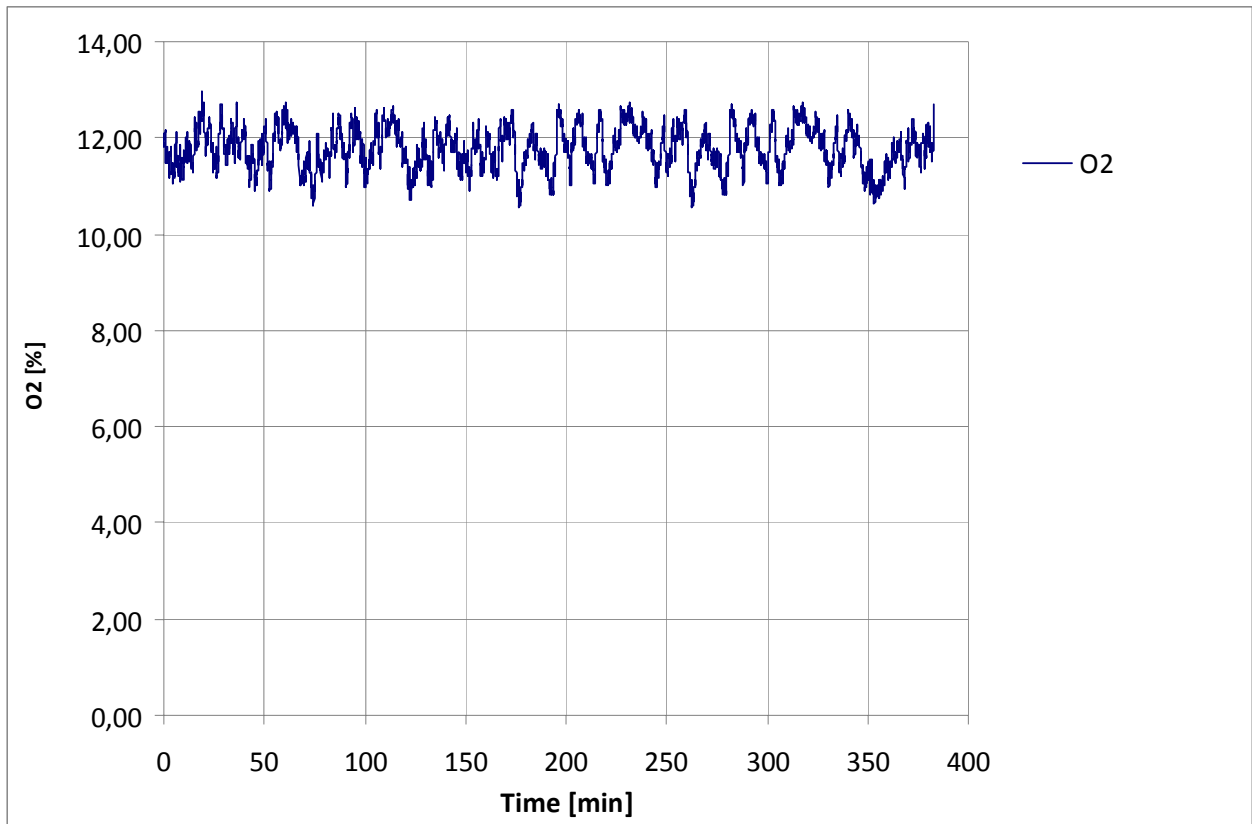
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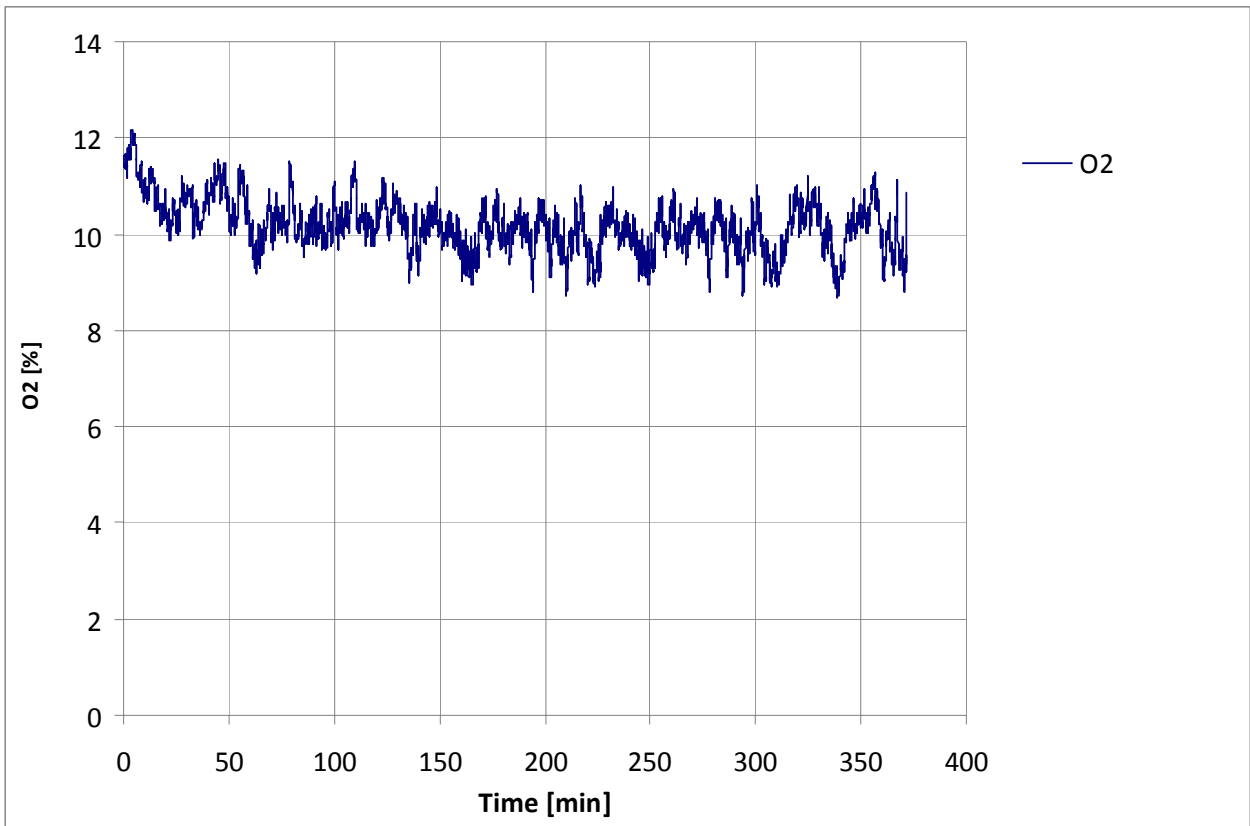
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Test 3_1: Pellet V_030109_003



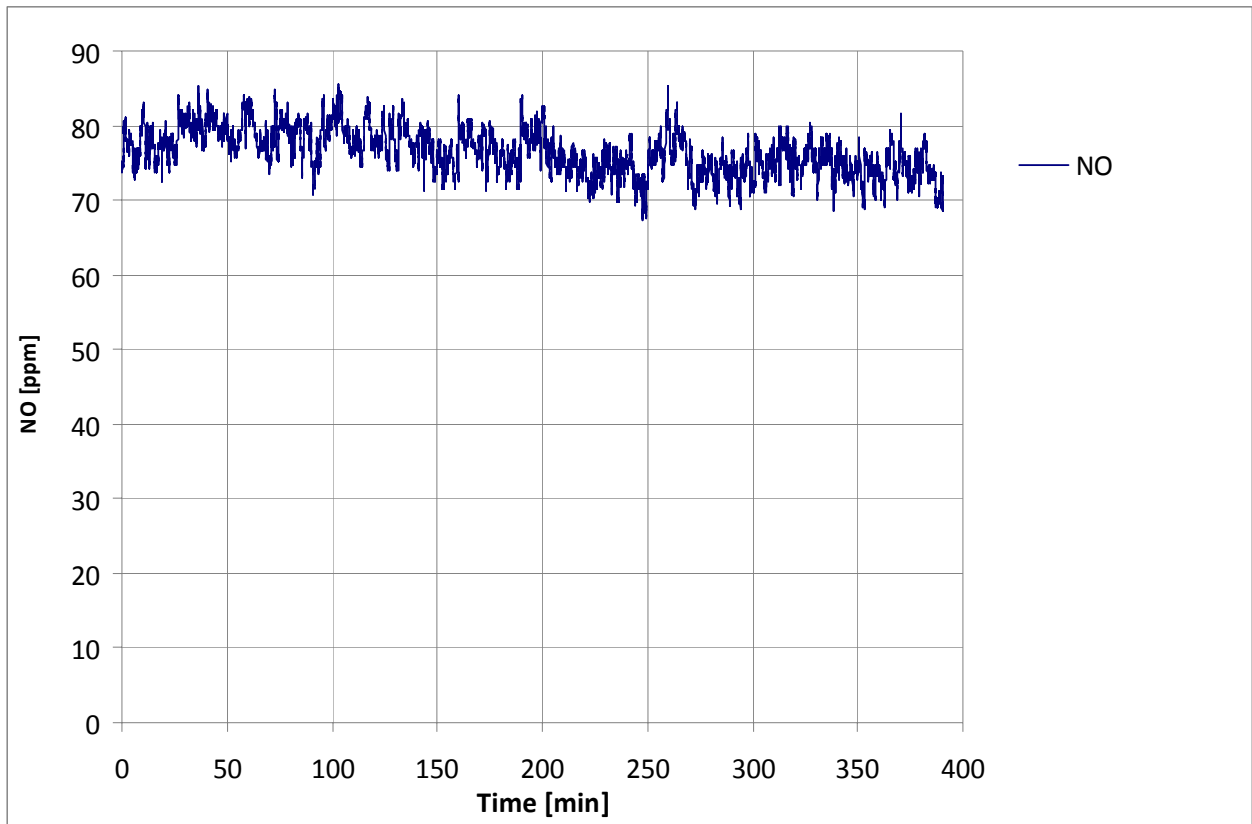
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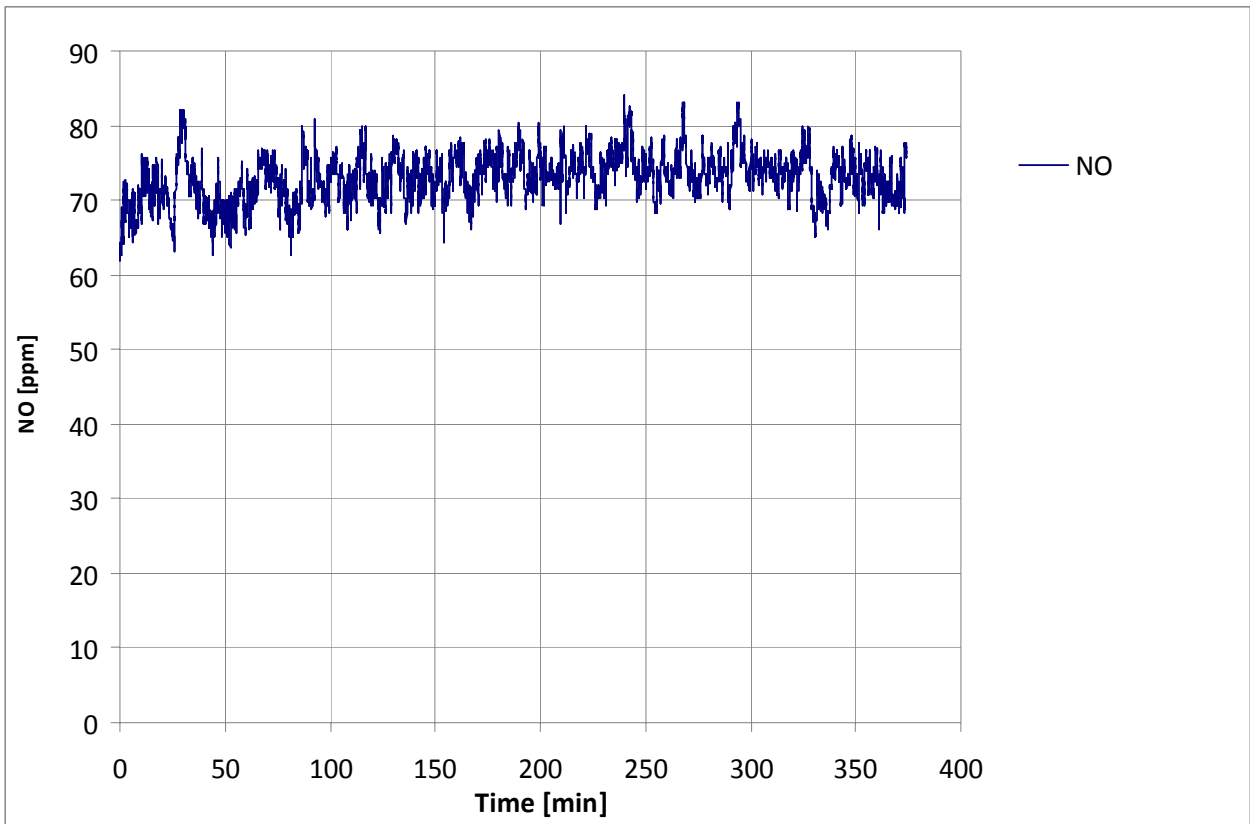
APPENDICE 4

NO concentrations versus test time

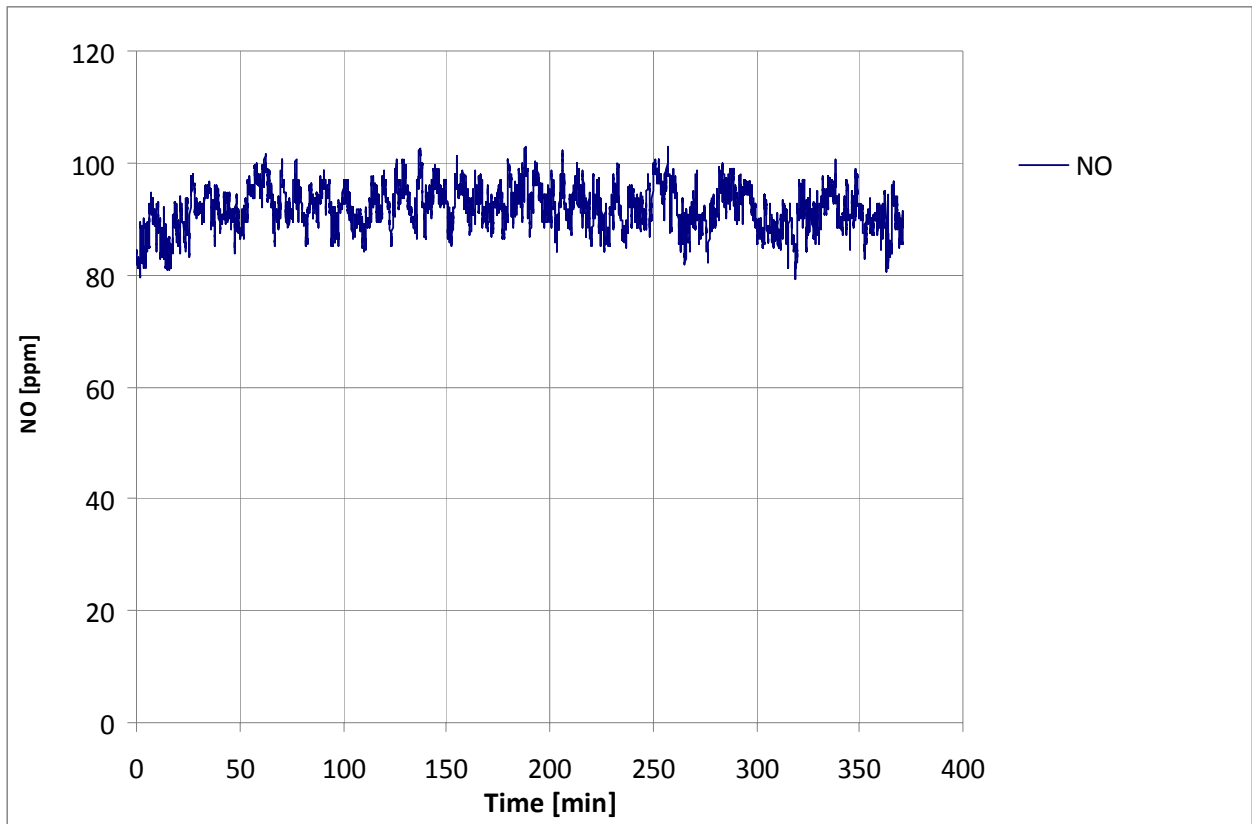
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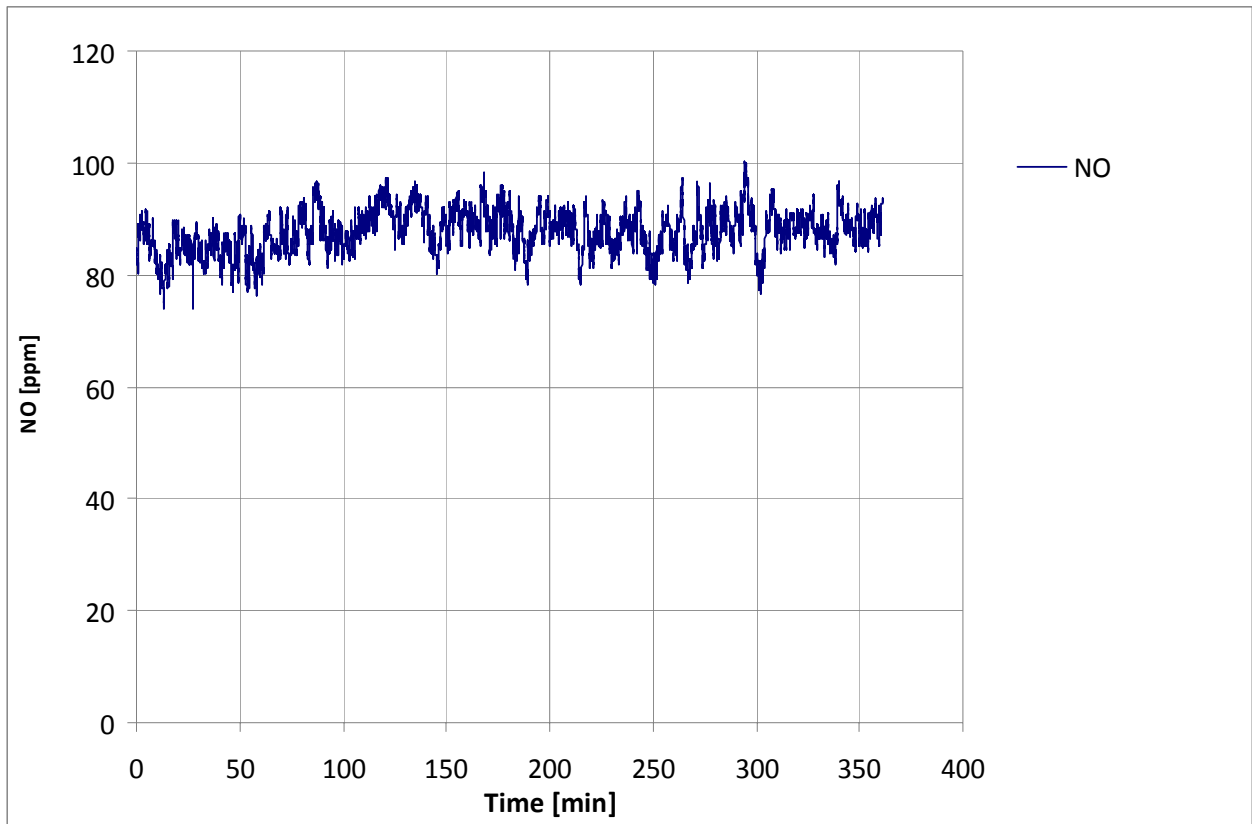
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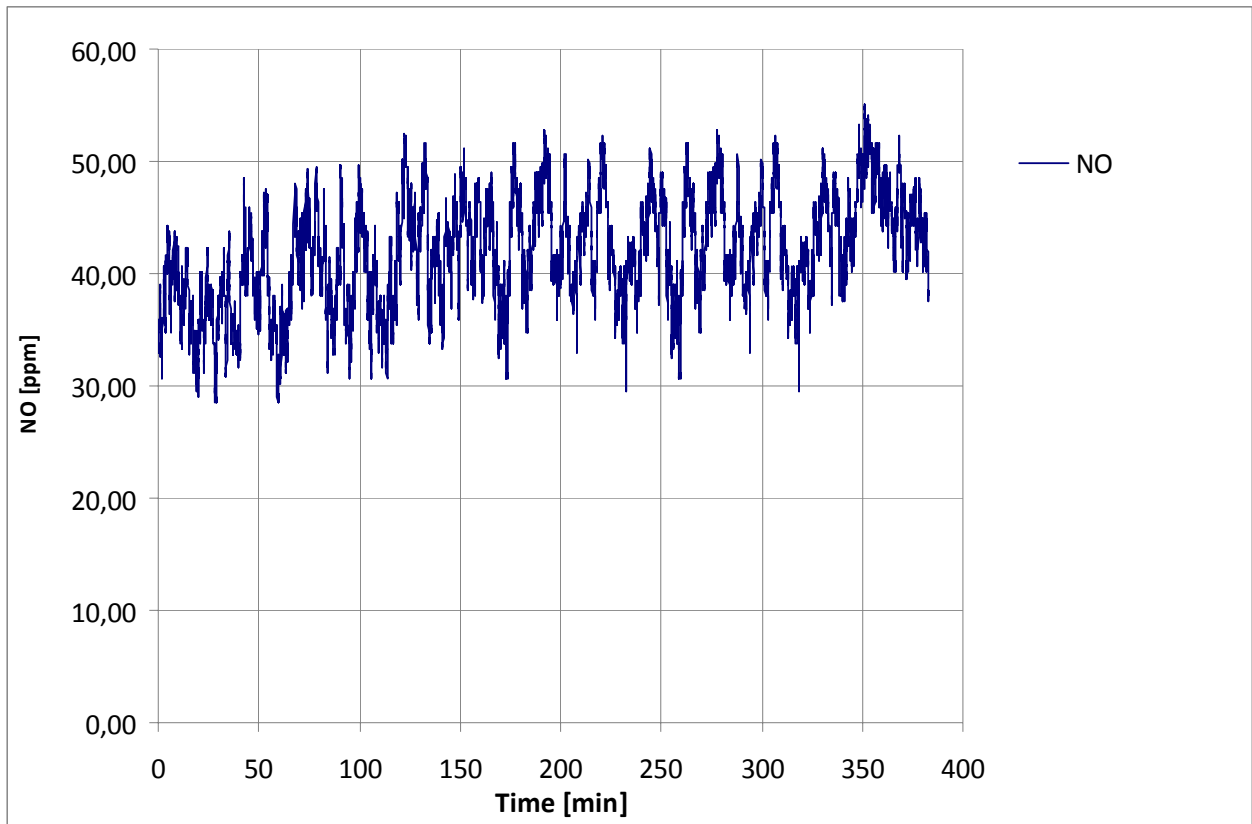
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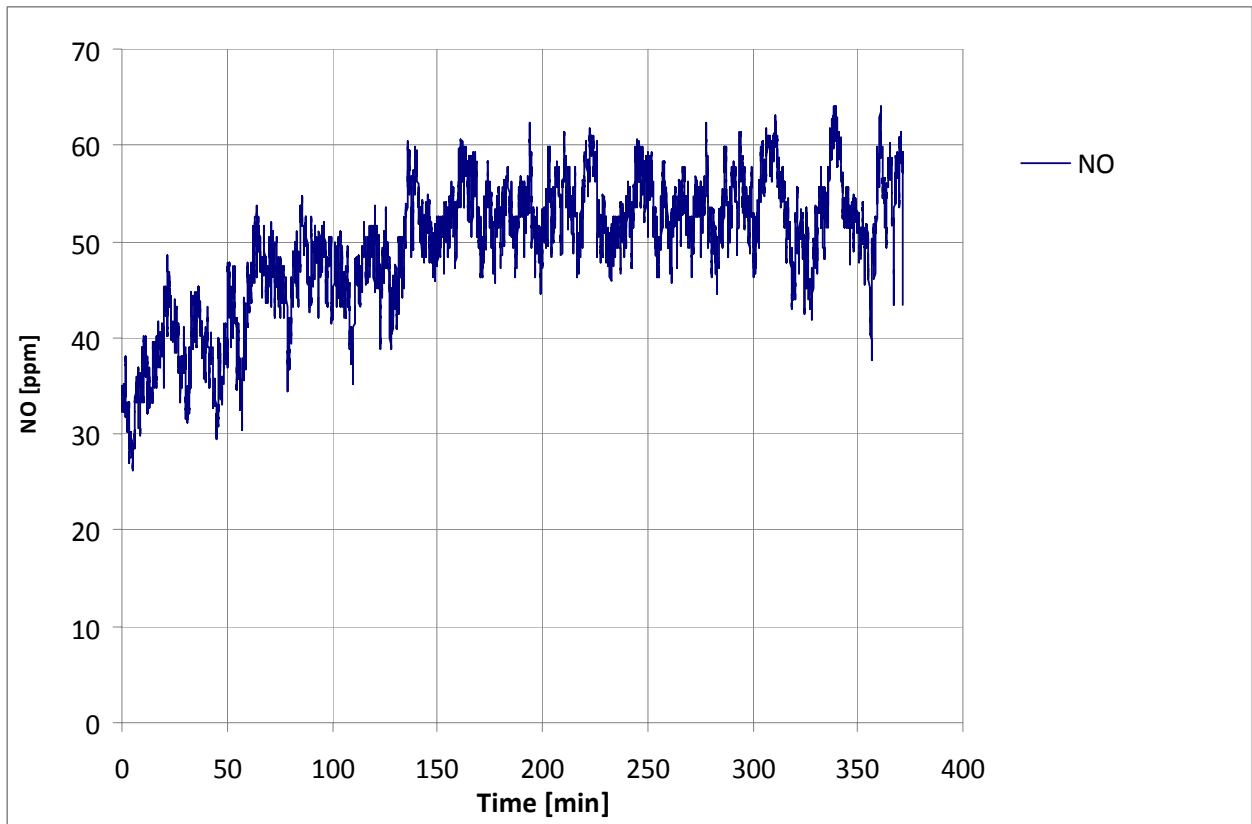
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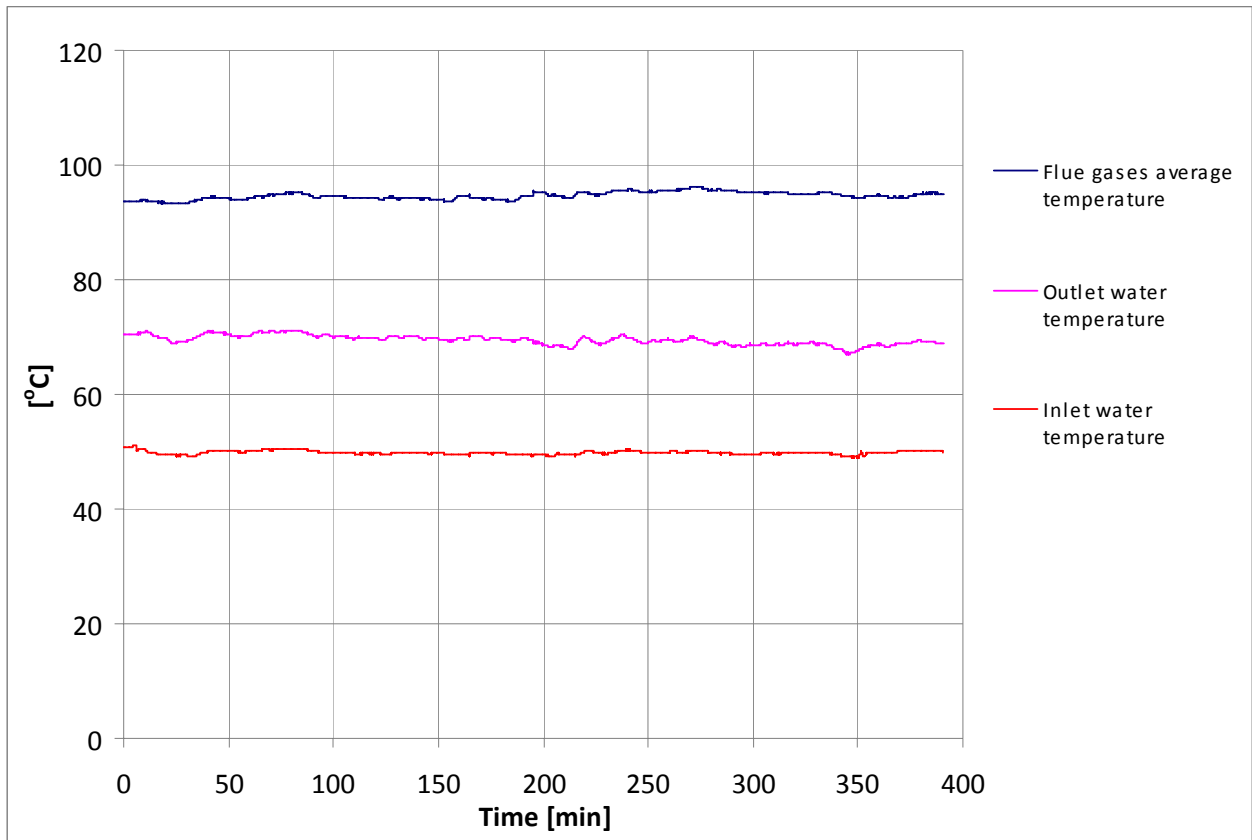
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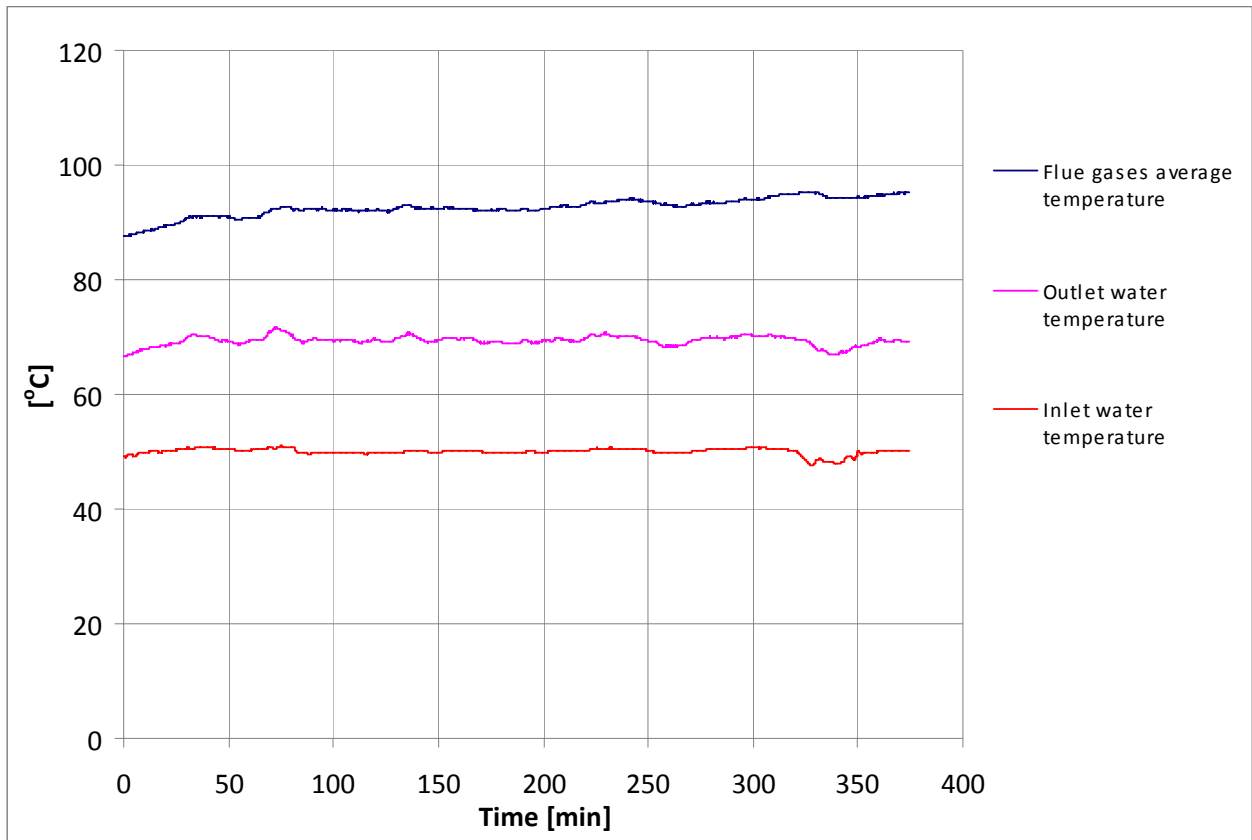
APPENDICE 5

Temperature of flue gases, inlet boiler water, outlet boiler water versus test time

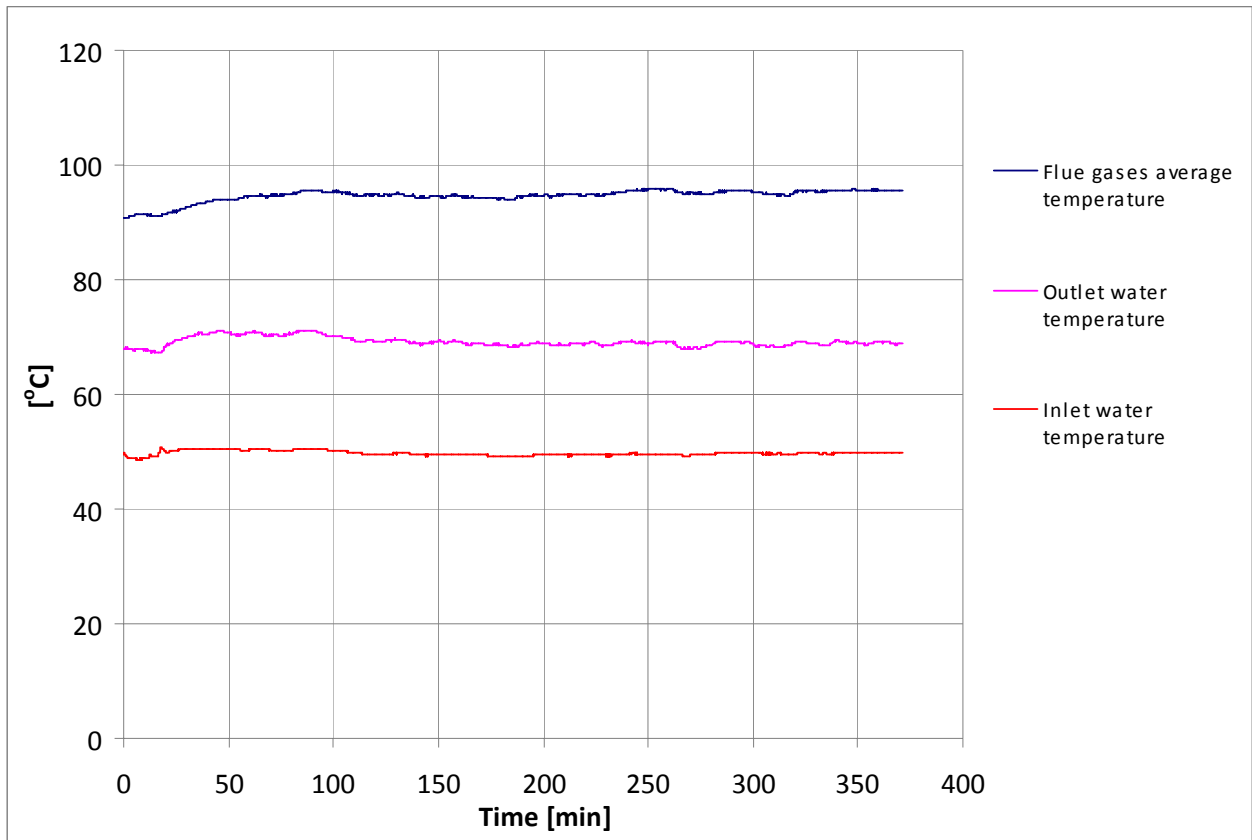
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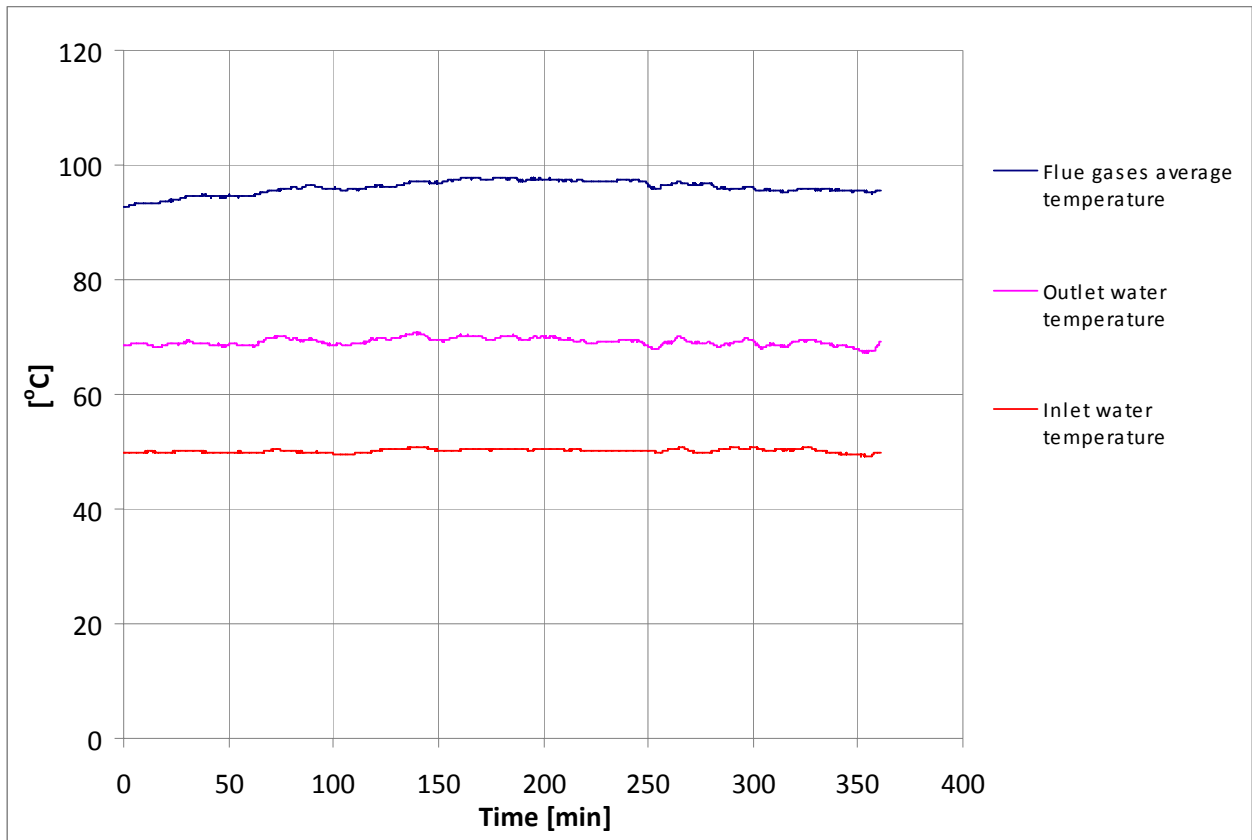
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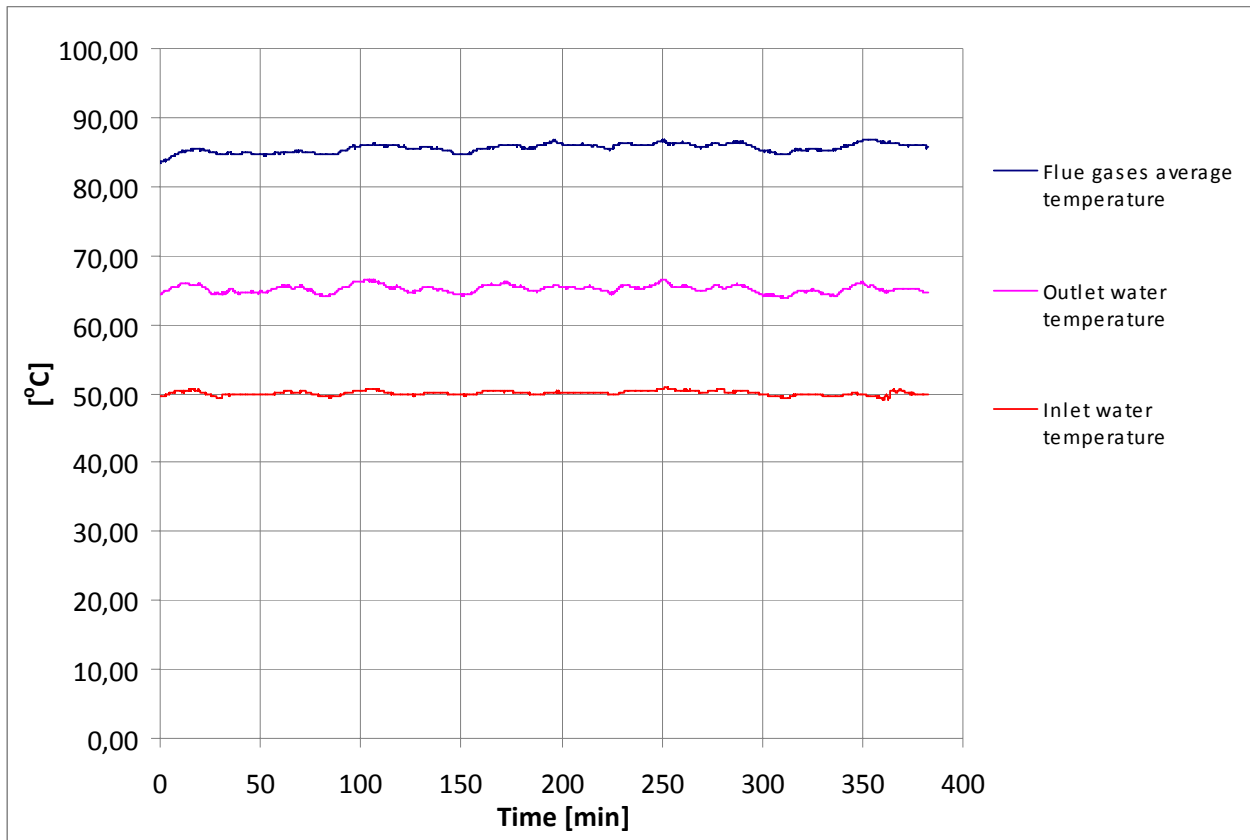
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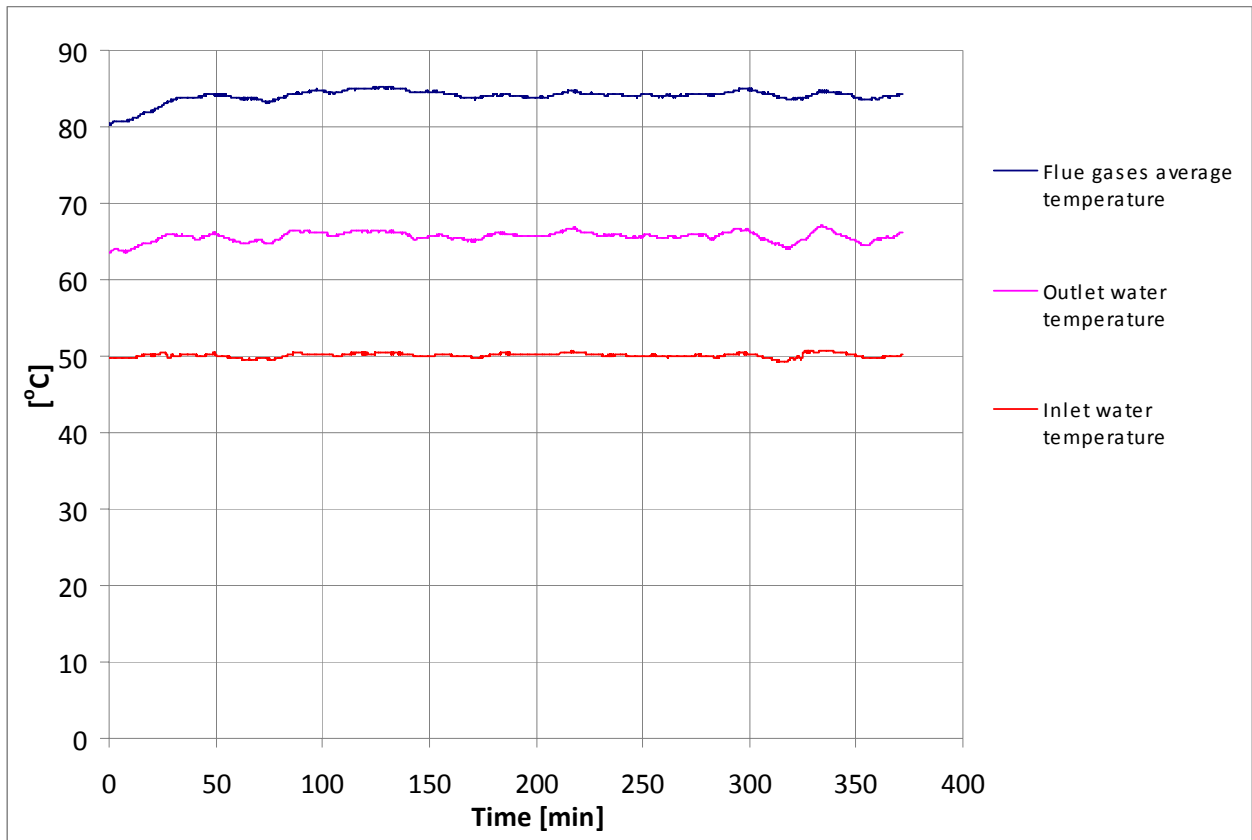
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Test 3_1: Pellet V_030109_003

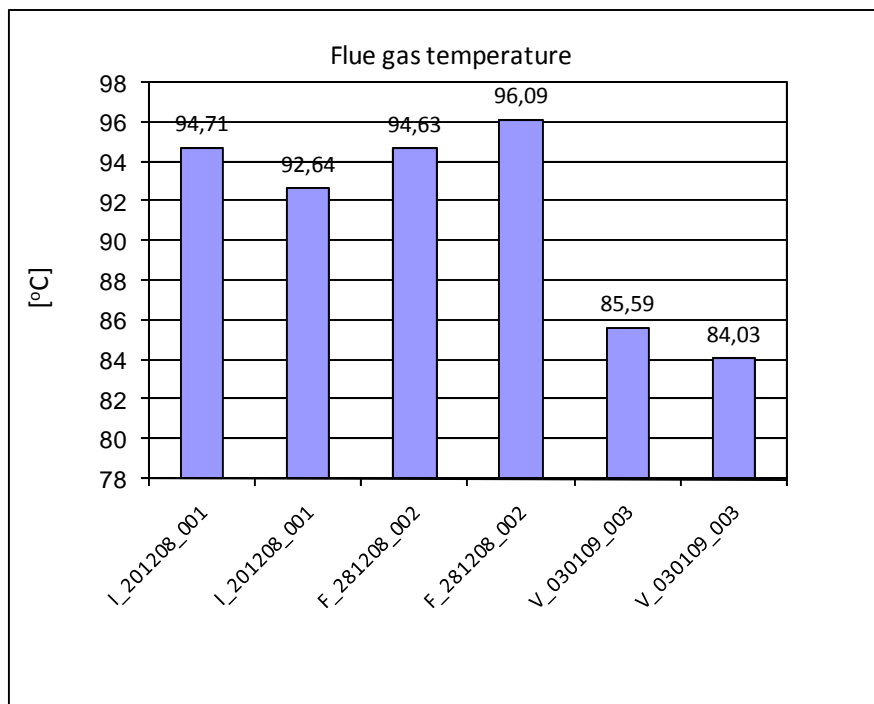
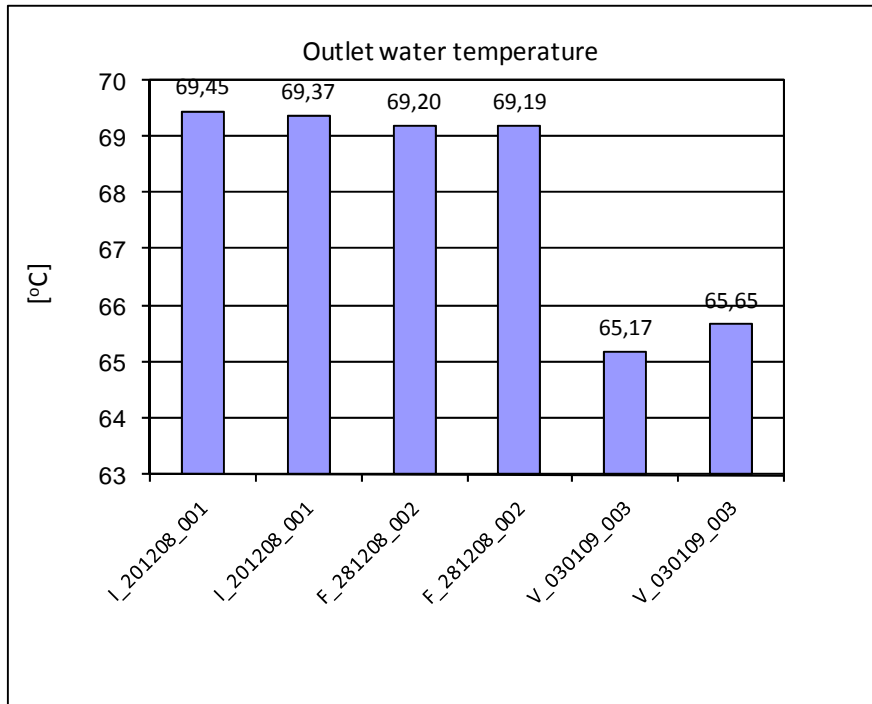


Test 3_2: Pellet V_030109_003



APPENDICE 6

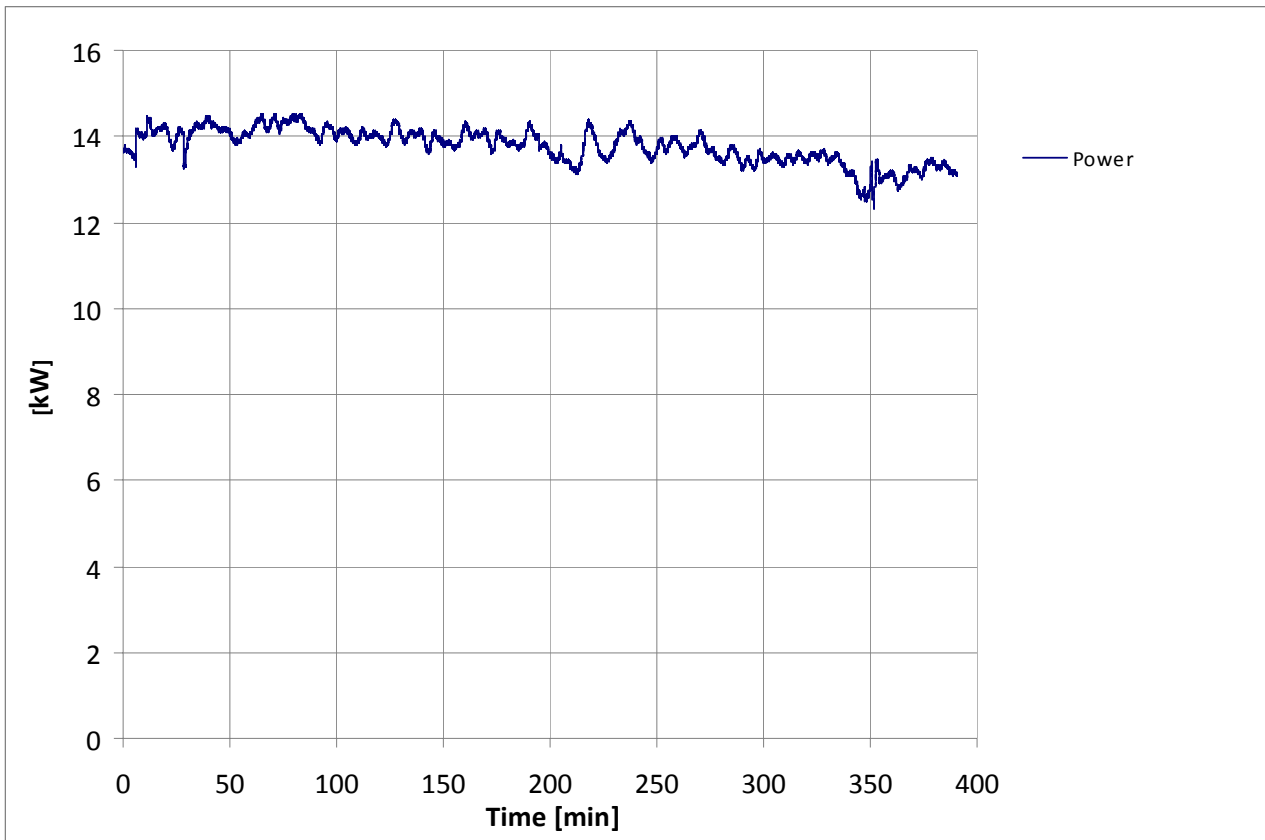
Test comparisons



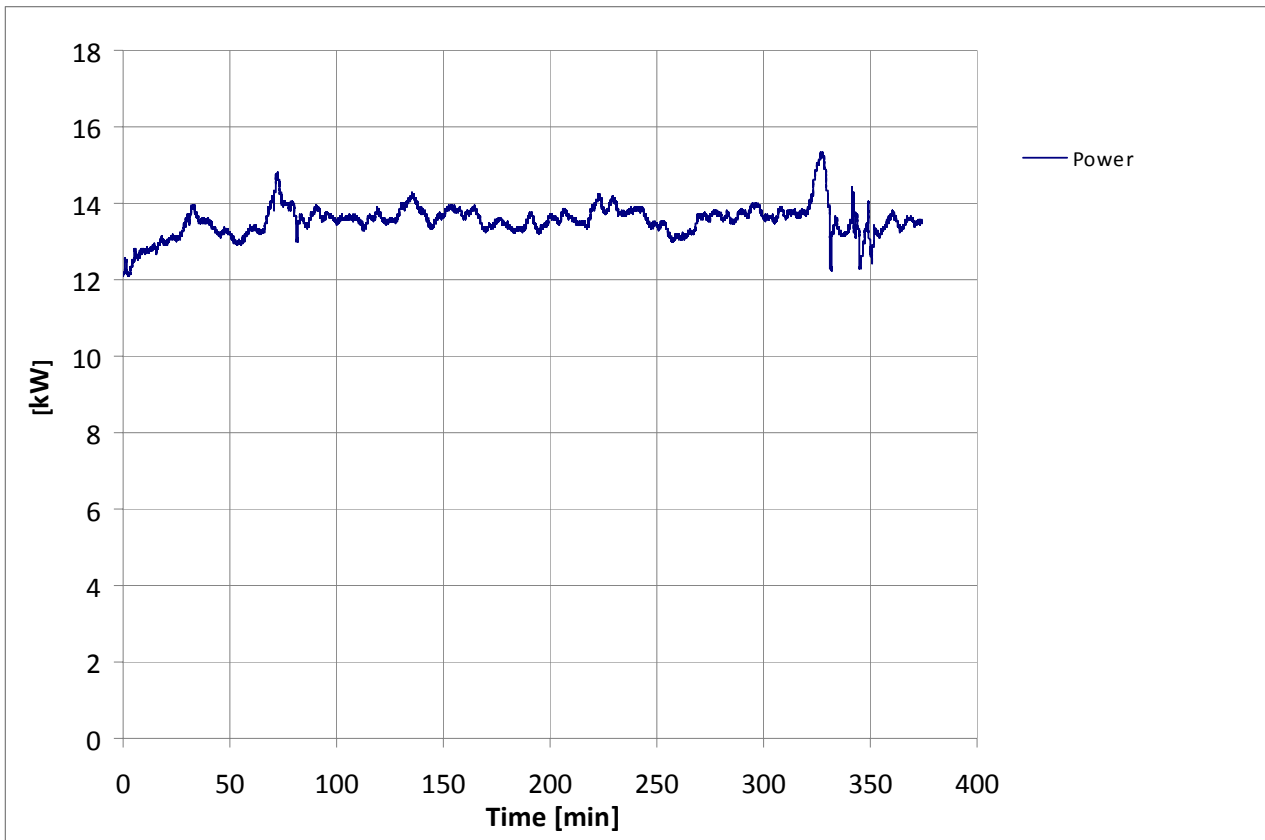
APPENDICE 7

Heating power

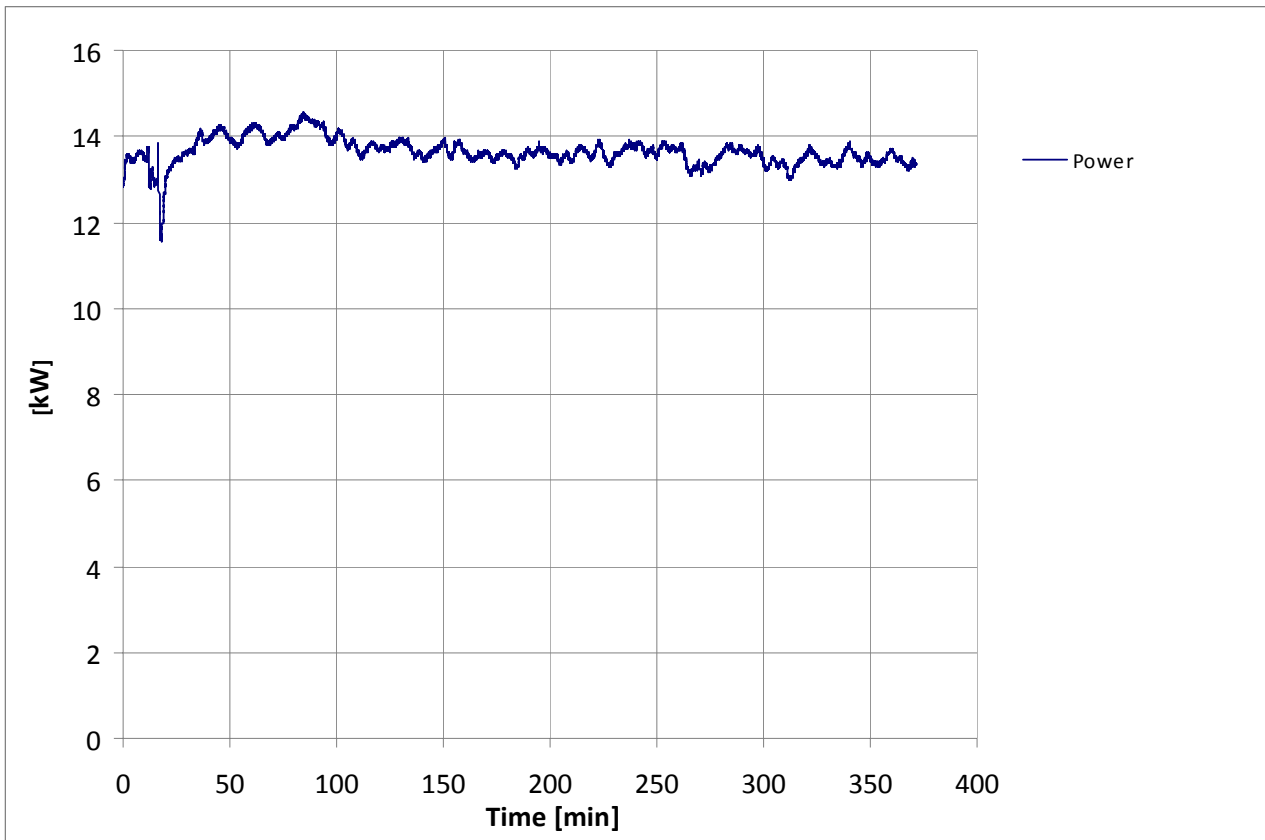
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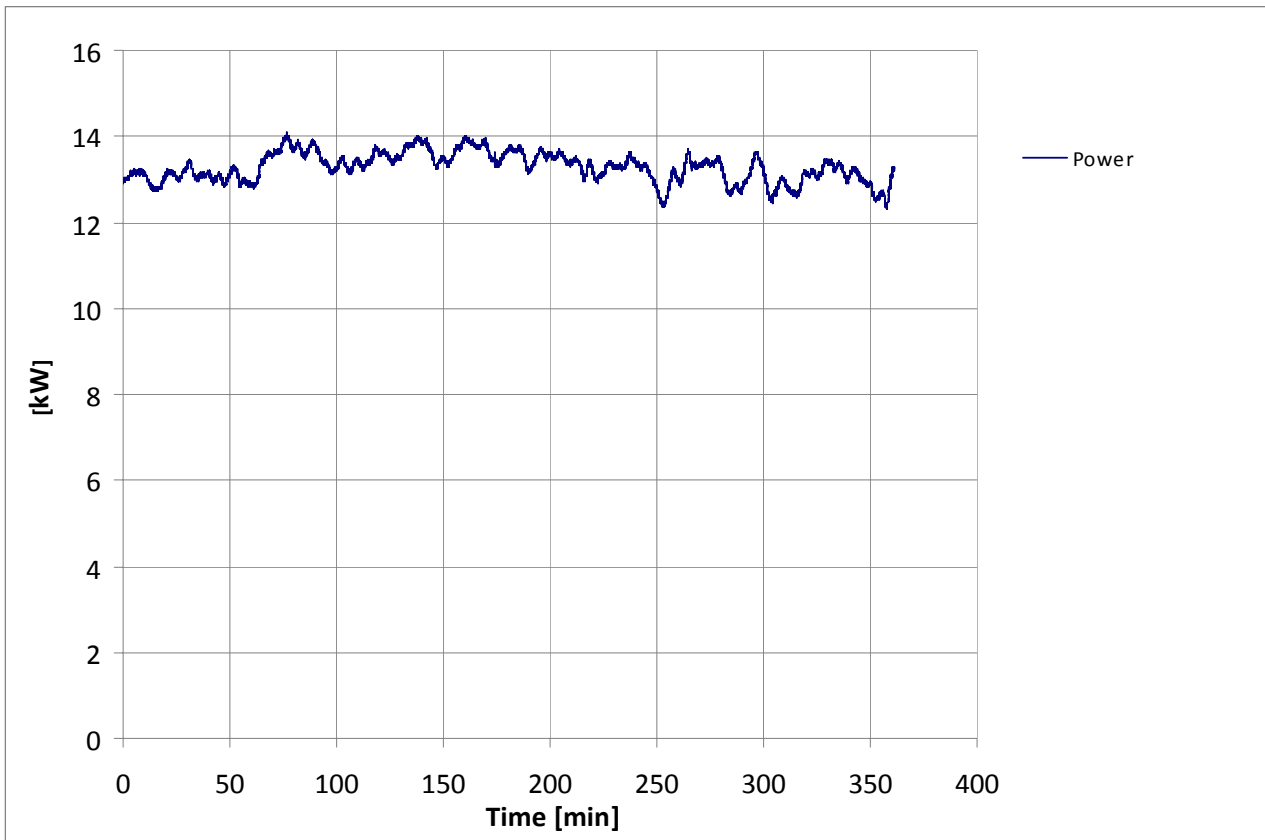
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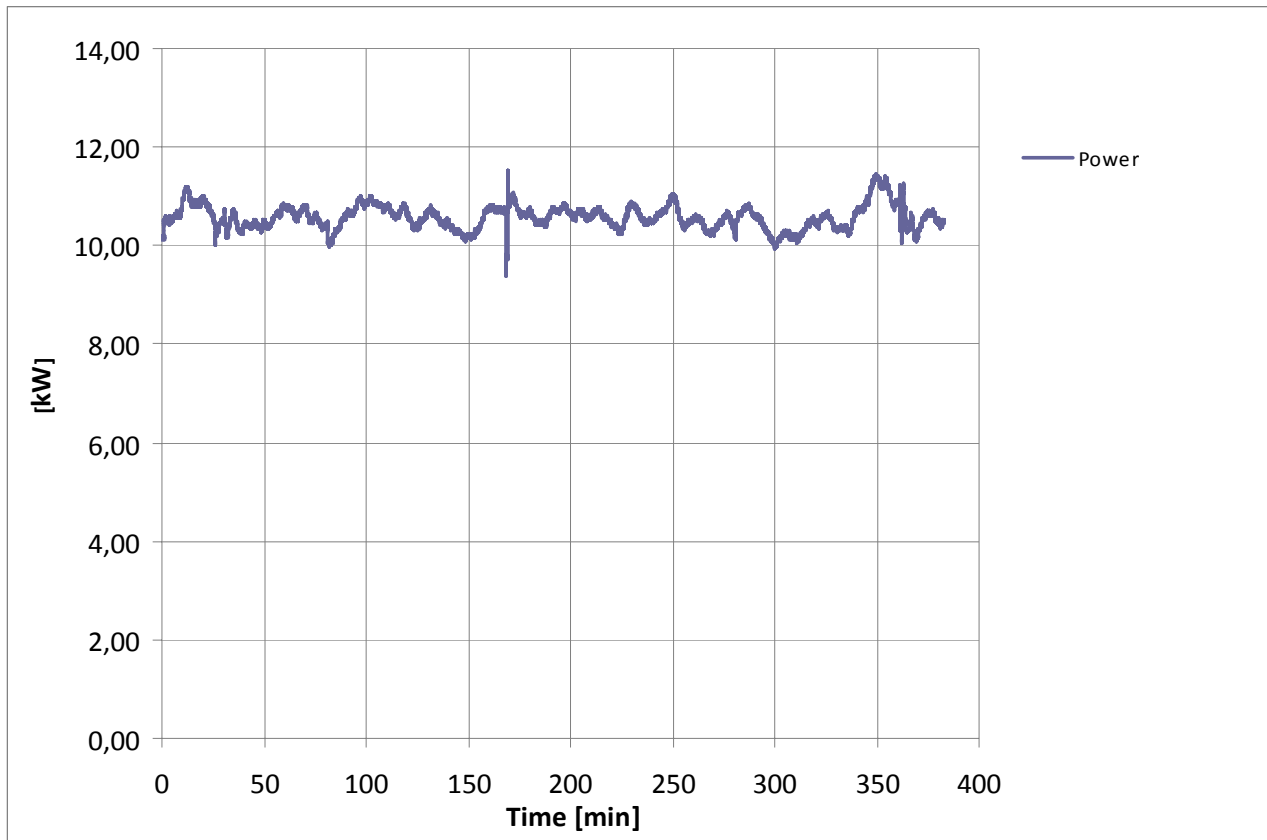
Test 2_1: Pellet F_281208_002



Test 2_2: Pellet F_281208_002



Test 3_1: Pellet V_030109_003



Test 3_2: Pellet V_030109_003

