



Faculty of Engineering

Development and Evaluation of a Horizontal Air-Staged Biomass-to-Heat Energy Converter

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Development and Evaluation of a Horizontal Air-Staged Biomass-to-Heat Energy Converter

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ABSTRACT

Biomass fuel in Malaysia contributes 16% of the energy consumption, of which 51% is from palm oil biomass waste and 27% from wood waste. The drying industry in Malaysia can utilize these biomass wastes as fuel instead of fossil fuel, which emits higher air pollutants. In the biomass combustion field, there is little or no research on the effects of the air velocity ratio on a horizontal combustor's temperature profile, flue gas composition and combustion efficiency; therefore, the investigation presented in this thesis is aimed at improving the understanding of the biomass combustion in this area. In this research project, an experimental study of an air-staged horizontal combustor with quantities of oil palm kernel shell (OPKS) and wood chips was conducted and carried out in two phases: Phase I – Development (Design and Fabrication) of Biomass-to-Heat (B2H) Converter and Phase II – Emission Evaluation of B2H Converter. A quantification of the thermal properties and moisture contents of the selected biomass was carried out, in addition to emission evaluation of the B2H converter. The influence of the air velocity ratio (AVR) on the temperature profile, flue gas composition and combustion efficiency from OPKS and wood chips was determined, using a Testo 350XL flue gas analyser. It was observed that by increasing the AVR, the mean temperature of the pyrolysis chamber would be increased; however, it would result in a decrease in the mean temperature in the exhaust. With respect to air emissions, CO, H₂, NO_x and SO₂ levels were inversely proportional to increase in the AVR and the combustion efficiency of the B2H converter was also inversely proportional to increase in AVR. The experimental results confirmed that the horizontal air-staged B2H converter allows cleaner and more efficient combustion with OPKS and wood chips as feedstock. Moreover, a biomass combustion model that can be validated with the experimental data generated in this work can be developed.

ABSTRAK

Bahan api biomas di Malaysia boleh menyumbang 16% dalam penggunaan tenaga, dimana 51% daripada sisa kelapa sawit and 27% daripada cip kayu. Industri pengeringan di Malaysia boleh menggunakan sisa biomas ini sebagai bahan api berbanding dengan bahan api fosil yang mengeluarkan bahan pencemar udara yang tinggi. Di dalam disiplin pembakaran biomas, terdapat sedikit atau tiada penyelidikan dalam kesan nisbah campuran angin terhadap profil suhu, komposisi serombong gas dan kecekapan pembakaran dalam pembakar yang mendatar. Kajian dalam tesis ini bertujuan untuk meningkatkan pemahaman dalam bidang pembakaran biomas. Dalam projek penyelidikan ini, kulit minyak sawit (OPKS) dan cip kayu telah dipakai terhadap pengajian pembakar yang mendatar serta udara dipentaskan. Projek penyelidikan ini telah dijalankan dalam dua fasa: 1) Fasa I – Pembangunan (Merekabentuk dan Fabrikasi) penukar biomass-kepada-haba (B2H), 2) Fasa II – Penilaian prestasi terhadap penukar biomass-kepada-haba. Selain daripada penilaian prestasi terhadap penukar biomass-kepada-haba, sifat-sifat terma dan kandungan lembapan daripada bahan kajian seperti kulit minyak sawit (OPKS) dan cip kayu juga dikuantifikasikan. Pengaruh oleh nisbah campuran angin (AVR) terhadap profil suhu, komposisi serombong gas dan kecekapan pembakaran daripada OPKS dan cip kayu telah dikaji dengan Testo 350XL. Diperhatikan bahawa dengan meningkatkan AVR akan meningkatkan purata suhu ruang pirolisis, tetapi menurunkan purata suhu ekzos. Bagi komposisi gas, kepekatan CO, H₂, NO_x and SO₂ adalah pertukaran songsang dengan peningkatan oleh AVR tetapi meningkatkan kepekatan oksigen pada ekzos B2H. Kecekapan pembakaran oleh penukar B2H adalah pertukaran songsang dengan peningkatan AVR. Kajian eksperimen ini membuktikan bahawa penukar B2H memberikan pembakaran yang cepat dan bersih dengan OPKS and cip kayu. Selain itu, model pembakaran biomas dapat diperolehi melalui pengesahan keputusan eksperimen.

RESEARCH PUBLICATIONS

During the tenure of PhD research and study, the following papers were produced, which were related to the broad research area – in Journals (5 papers), Conference Proceedings (4 papers) and Poster (3 posters).

Journal Publications:

1. Chong, K.H., Law, P.L., Rigit, A.R.H., Baini, R., Saleh, S.F. (2014). Performance evaluation of a horizontal air staged inclined biomass-to-heat energy converter for drying purpose in the production of paper egg trays. *International Journal of Renewable Energy Research*, 4(1), 159-167.
2. Chong, K.H., Law, P.L., Rigit, A.R.H. & Baini, R., Saleh, S.F., Awangku Yussuf, A. A. R. (2014). Operational parameters assessment of a biomass-to-fuel gas converter. *UNIMAS e-Journal of Civil Engineering*, 5(1), 1-6.
3. Chong, K.H., Law, P.L., Rigit, A.R.H. & Baini, R., Saleh, S.F. (2014). Sago bark as renewable energy. *UNIMAS e-Journal of Civil Engineering*, 5(2), 29-34.
4. Chong, K.H., Law, P.L., Rigit, A.R.H. & Baini, R. (2014). A newly horizontal air-staged biomass-to-heat energy combustion chamber: Part I. Development. *Asia Pacific Society for solar and hybrid technologies' world hybrid energy journal*. (accepted for publication)
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Conference Publications:

1. Chong, K.H., Law, P.L., Rigit, A.R.H. & Baini, R. (2013) Experimental study of the effect of air flow rate on combustible gases from a newly design biomass combustor. In: *Faculty of Engineering Postgraduate Colloquium, 17 April 2013*. Kota Samarahan: UNIMAS.

2. Chong, K.H., Law, P.L., Rigit, A.R.H. & Bains, R. (2013) A horizontal air-staged biomass-to-heat combustion chamber: Development and performance. In: Encon 2013 6th Engineering conference, "Energy and Environmentat" 2nd – 4th July 2013. Kuching: UNIMAS, ISBN 978-981-07-6059-5.
3. Chong, K.H., Law, P.L., Rigit, A.R.H. & Bains, R. (2013) A newly horizontal air-staged biomass-to-heat combustion chamber: Part I. Development. In: World Hybrid Technologies and Energy conference, 30th September – 1st October 2013. Kota Samarahan: UNIMAS.
4. Chong, K.H., Law, P.L., Rigit, A.R.H. & Bains, R., Saleh, S.F. (2014) Thermal analysis of Malaysia biomass waste. In: Postgraduate Colloquium, 23rd April 2014. Curtin University, Sarawak.

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3. Chong, K.H., Law, P.L., Rigit, A.R.H. & Bains, R. (2010) Determination of Malaysia Locally Biomass Moisture Content and its Respective Heating Values. Poster exhibition, International Conference on Food Research, 22nd – 24th November 2010. Kuala Lumpur: UPM.

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LIST OF NOTATIONS AND ABBREVIATIONS

Notation

AT	-	Mean surrounding temperature, °C
D	-	Diameter, m
FT	-	Mean exhaust temperature, °C
GCV	-	Gross calorific value, J/kg
J	-	Joule, W.s
K	-	Thermal conductivity of refractory, W/(m.K)
H	-	Height, m
M	-	Mass substance, g/mol
M	-	Molar mass, g/mol
M _{ar}	-	The moisture content in the sample as received, kg
m ₁	-	The mass in g of the empty drying container, kg
m ₂	-	The mass in g of the drying container and sample before drying, kg
m ₃	-	The mass in g of the drying container and sample after drying, kg
m ₄	-	The mass in g of the moisture associated with the packing, kg
N	-	Number of moles, moles
PT	-	Mean pyrolysis chamber temperature, °C
T _a	-	Ambient temperature, °C
T _o	-	Operating temperature, °C
T _s	-	Surface temperature, °C
$\bar{t}_{app}$	-	Apparent residence time, s
V	-	Velocity, m/s
V'_o	-	Inlet volumetric flow rate, m ³

$V_{chamber}$	-	Nominal volume, m ³
V_r	-	Reactor volume, m ³

Abbreviations

AFRL	-	After Filtered Residual Liquid
AVR	-	Air velocity ratio
APEC	-	Asia-Pacific Economic Cooperation
Avg	-	Mean
B	-	Blower
B2E	-	Biomass-to-Energy
B2F	-	Biomass-to-Fuel gas
B2H	-	Biomass-to-heat energy
Ca	-	Calcium
CH ₄	-	Methane
CHP	-	Combined heat and power
CO	-	Carbon monoxide
CO ₂	-	Carbon dioxide
CPO	-	Crude palm oil
Cu	-	Copper
DAF	-	Dissolved air flotation
DTG	-	Derivative thermogravimetric
Fe	-	Iron
EFB	-	Empty fruit bunch
FFB	-	Fresh fruit bunch

FOB	-	Free on Board
GC-MS	-	Gas chromatography-mass spectrometry
GHG	-	Greenhouse gas
IGCC	-	Integrated gasification combined cycle
K	-	Potassium
Ktoe	-	Kilo tonnes of oil equivalent
H ₂	-	Hydrogen
H ₂ SO ₄	-	Sulfuric acid
HCN	-	Hydrogen cyanide
H ₂ O	-	Water vapour
HNCO	-	Isocyanic acid
MIDA	-	Malaysian Industrial Development Authority
Mg	-	Magnesium
Mo	-	Molybdenum
MOA	-	Memorandum of agreement
Mn	-	Manganese
Mtoe	-	Million tonnes of oil equivalent
MW _e	-	Megawatt, electric
MW _{th}	-	Megawatt, thermal
N	-	Nitrogen
Na	-	Sodium
Nm ³	-	Normal cubic meter
NO	-	Nitrogen monoxide
NO _x	-	Nitrogen oxides

O ₂	-	Oxygen
OPKS	-	Oil palm kernel shell
ORC	-	Organic Rankine cycles
P	-	Phosphorus
PAH	-	Polycyclic aromatic hydrocarbon
ppmv	-	parts per million by volume
q_A	-	Calculated flue gas loss
R&D	-	Research and development
Si	-	Silicon
SO ₂	-	Sulphur dioxide
SO ₃	-	Sulfur trioxide
TGA	-	Thermogravimetric analysis
USD	-	United states dollar
VOC	-	Volatile organic compounds
Vol%	-	Volume percentage
W	-	Watt
% wt..	-	Weight wet base percentage
X _{destroyed}	-	Exergy destroyed
Zn	-	Zinc

Greek Letters

η	-	Combustion efficiency
σ	-	Standard deviation
ε	-	Emissivity

Chapter 1 INTRODUCTION

1.1 Research Background

1.1.1 Potential Renewable Energy from Oil Palm and Wood Waste in Malaysia

In the past 40 years or so, Malaysia's palm oil industry has grown tremendously, and crude palm oil production has increased from 2.84 million tonnes per year in 1980 to 24.97 million tonnes per year in 2011 (MPOB, 2014). In 2013, Malaysia was the world's second largest palm oil exporter, and accounted for around 29% globally (**Figure 1.1**) (Potts et al., 2014). In 1920, Malaysia had only 400 hectares of oil palm plantation, which increased to 0.6 million hectares in 1975 and to 5.0 million hectares in 2011 (**Figure 1.2**).

In 2011, there were 426 palm oil mills in Malaysia processing approximately 99.85 million tons of fresh fruit bunch (FFB) per year (MPOB, 2014). In 2010, palm oil waste achieved 21.27 Mtoe for empty fruit bunch (EFB), 10.80 Mtoe for mesocarp fibre, 4.98 Mtoe for oil palm kernel shell and 49.85 Mtoe for palm oil mill effluent (Ng, Lam, Ng, Kamal, & Lim, 2012). According to Yusoff (2006), the current most exploited co-products are the fibres and shells, which are used as boiler fuels to produce steam and electricity for palm oil and kernel production. Only rarely has EFB been considered as fuel, this being due to its high moisture content (65%) (Nash, 2000).

Wood waste is found mostly in the logging industries, and in 2013 an area of 46,994 hectares of forest were harvested (NRE, 2013). The total production of selected timber products amounts to

7,135,382 m³ (NRE, 2013). According to the Malaysia Timber Council, Malaysia generated a Free on Board (FOB) value of more than RM 202 million from January to February 2009 through logging activities. In addition to profits, these industries generate a huge amount of wood waste that, potentially, can give rise to environmentally sensitive disposal issues, particularly in sawmills. In 2005, the Ministry of Plantation Industries and Commodities (KPPK) was tasked to develop 375,000 hectares of forest plantation at an annual planting rate of 25,000 hectares per year for the next 15 years. Once successfully implemented, every 25,000 hectares of land planted would produce approximately 5 million cubic metres of timber (MTCC, 2013). Therefore, this programme should increase annually the quantity of wood residue that can be used for bio-energy. According to Shafie, Mahlia, Masjuki, & Ahmad-Yazid (2012), Malaysia has only five mills that use wood waste as fuel and produce between 900 kW and 10 MW of energy.

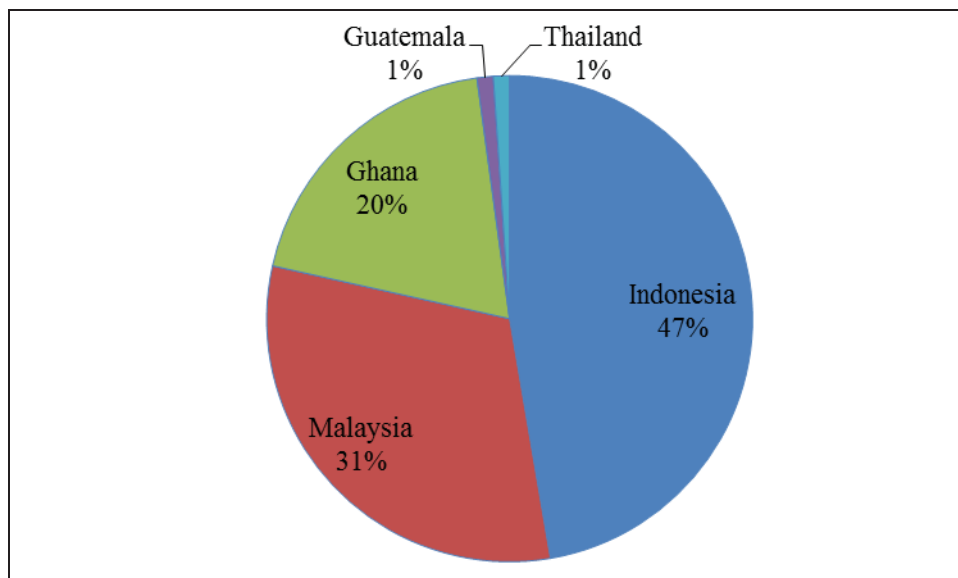


Figure 1.1: Top five palm oil exporters (96% of global)
(adapted from Potts et al., 2014)

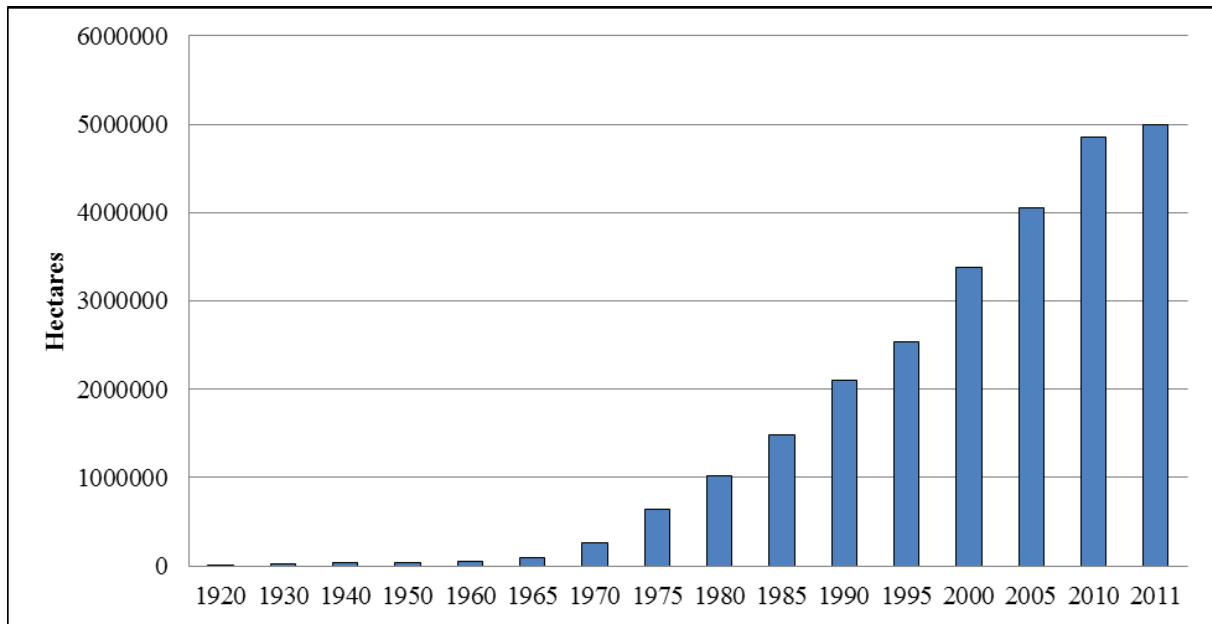


Figure 1.2: Oil palm planted area in Malaysia: 1920 - 2011 (million hectares)
(adapted from MPOB, 2014)

1.1.2 Biomass Energy through Combustion

Biomass energy can be categorized as a source of renewable energy that can contribute to long-term energy supply, reduce global emissions to the atmosphere, meet specific energy service needs, and create employment opportunities and welfare for the local communities. It is estimated that biomass contributes around 10% of the global annual primary energy consumption (Tiina, Kai, Satu, Kati, & Eija, 2013). According to Parikka (2004), an estimated 25% of the usage was in industrialised countries, and the other 75% in developing countries. The total worldwide sustainable biomass energy potential is about 100 EJ/year, which is around 30% of the total global energy consumption. An estimated 40 EJ/year of available biomass was used for energy; nearly 60% of this biomass was used in Asia only because of their fertile land for agriculture (Parikka, 2004). It was found that biomass is used most cost-effectively for heat production for low carbon taxes (below 50–100 USD/ton of carbon dioxide) (Grahn, Azar, Lindgren, Berndes, & Gielen, 2007).

Biomass combustion technologies were widely used for transportation and on farm systems during World War I and World War II. By 1945, it was estimated that there were around 9,000,000 vehicles worldwide running on biomass combustible (fuel) gas produced by the biomass combustion process. Such vehicles included trucks, buses, agricultural and industrial machines. After World War II, this technology fell out of favour due to the availability of cheaper fossil fuels (Srivastava, 2013). Due to the scarcity of fossil fuels, various types of biomass combustor are available commercially, such as updraft, downdraft, cross-draft, fluidized bed design features and others (Nessbaumer, 2003). The specific design of a biomass combustor can be affected by the properties of the specific biomass feedstock, such as energy contents, moisture contents, ash contents, chemical composition, size distribution, bulk density, charring properties, and volatile matters (Salam & Kumar, 2010). Generally, biomass combustors have three main applications: 1) heat production; 2) power generation; 3) fuel production (SINTEF, 2012). In 2009, only the Nibong Tebal Paper Mill Sdn. Bhd. utilized a biomass combustor as co-generation for production (Suruhanjaya Tenaga, 2009).

1.1.3 Background of Biomass-to-Fuel Gas Converter and Biomass-to-Energy Converter

Recently, a biomass-to-fuel gas (B2F) converter (**Figure 1.3**) was developed by Prima Natural Resources and Manufacturing Sdn. Bhd. (located at 12th Mile, Oya Road, Sibul, Sarawak) and it is patented in more than 120 countries (PCT/SG2004/000158). A *MEMORANDUM OF AGREEMENT (MOA)* was made on the 8th May 2006 between *PRIMA NATURAL RESOURCES AND MANUFACTURING SDN. BHD.* and *UNIVERSITI MALAYSIA SARAWAK (UNIMAS)*, with special focus on research and development (R&D)

(quantification and optimization) and the commercialization of B2F technology (Chong, 2009).

During 2006–2009, the performance of the B2F converter was tested and assessed by UNIMAS researchers for drying and heating purposes in several applications, including the mushroom culture industry, egg tray manufacturing facilities, coconut milk production processes, and paper recycling facilities (Chong, 2009). In this system, feedstock such as wood chips is gasified in the B2F converter, and the fuel or combustible gas is produced by a high temperature air velocity to maximize the efficiency of the combustion process. The fuel gas is purified by a filtration process to become a low-to-medium heat value fuel suitable for heating and drying processes (Chong, 2009).

However, it was found that the B2F converter encountered some significant design and technical drawbacks. The MOA of 8th May 2006 entrusted UNIMAS to quantify and improve or optimize the performance of the existing B2F combustion technology. Some of the major problems of the B2F converter identified by UNIMAS researchers during operation are outlined in the following.

- a. Feedstock input by batch resulted in non-continuous operation;
- b. Inconsistent production of combustible gas;
- c. Significant emissions or leakages of unburnt (raw) combustible fuel gas;
- d. As high as 1.5% tar and 13% of after filtered residual liquid or AFRL (by weight of total biomass feedstock) were produced as by-products; and
- e. Uncontrollable system overheating and tremendous heat wastage.

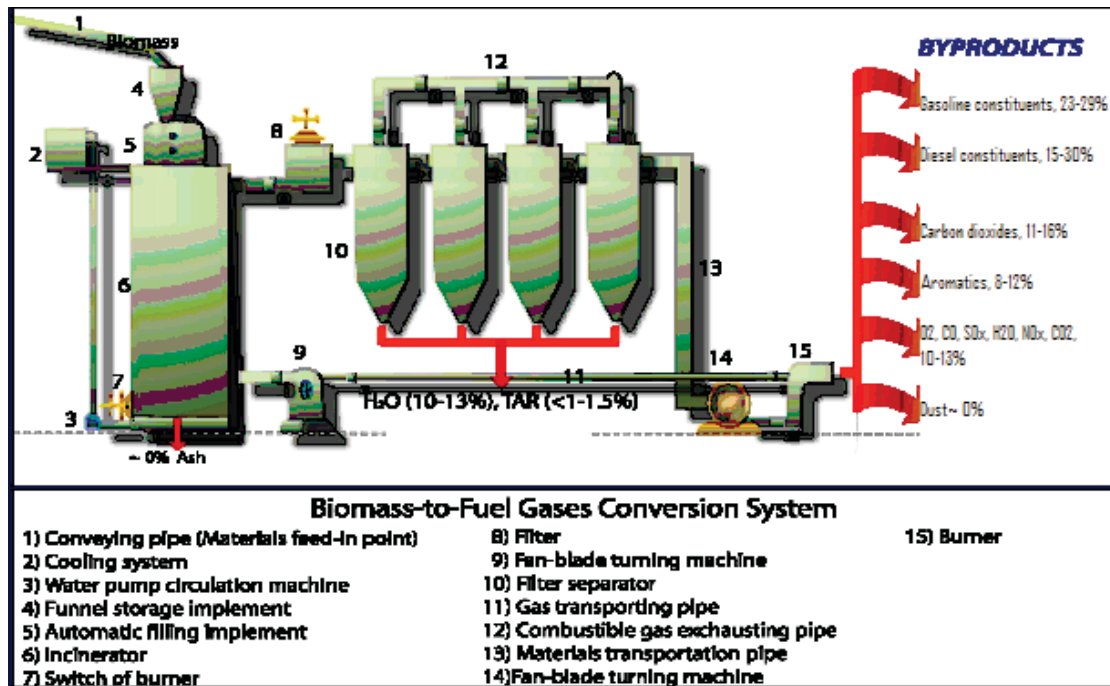


Figure 1.3: Simplified schematic diagram of B2F conversion system

UNIMAS researchers rectified the operational problems encountered by the B2F converter, which led to the creation of a completely revolutionized system: biomass-to-energy or B2E (Figures 1.4 to 1.13). The evaluation of the B2E converter that was applied to dry recycled paper egg tray production at a facility located at 14th Mile Off Kuching-Serian Highway was carried out for a period of 12 months. The following are some of principal studies conducted on the B2E converter (Chong, 2009).

- i. Evaluation of the performance of the B2E converter with a special focus on overall efficiency and exhaust gas temperature distribution in the combustible fuel gas-to-heat energy conversion chamber;
- ii. Assessment of the incremental levels of CO, combustible gases and total suspended particulate matters during operation within a radius of 20 m; and

iii. Evaluation of the performance of the B2E converter with emphasis on the following:

- a) Exergy destroyed, $X_{\text{destroyed}}$.
- b) Overall efficiency of B2E converter.
- c) Second Law Efficiency of B2E converter.
- d) Air flow rate.
- e) Effects of air supply on temperature distribution in the combustible fuel gas-to-heat energy conversion chamber.

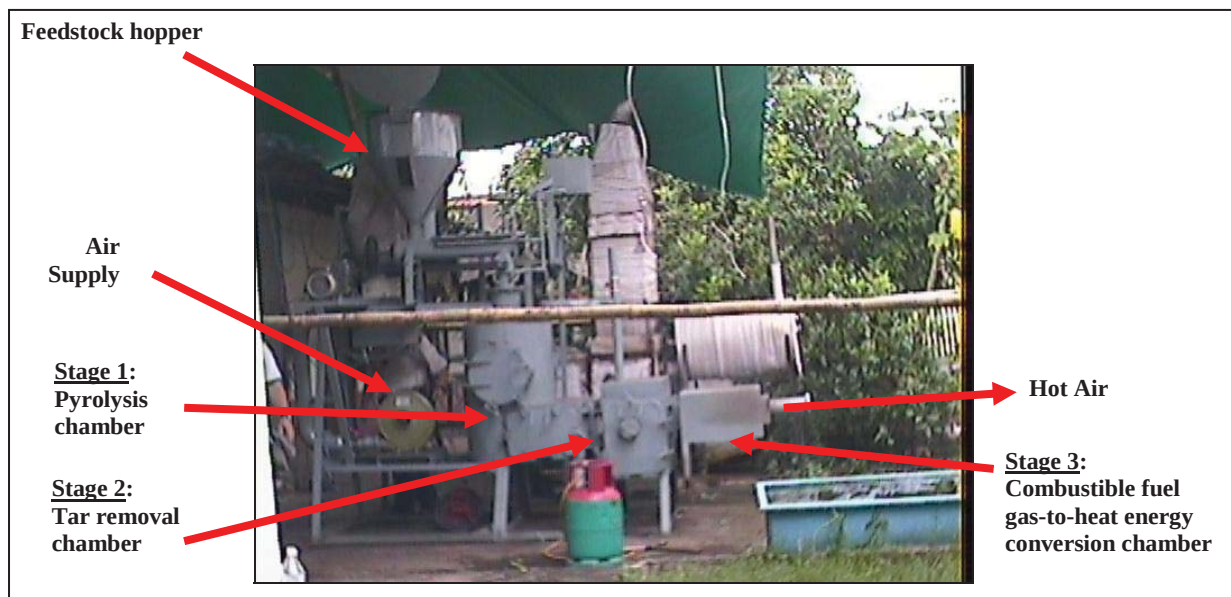


Figure 1.4: A view of B2E converter



Figure 1.5: A view of B2E converter (Onsite)

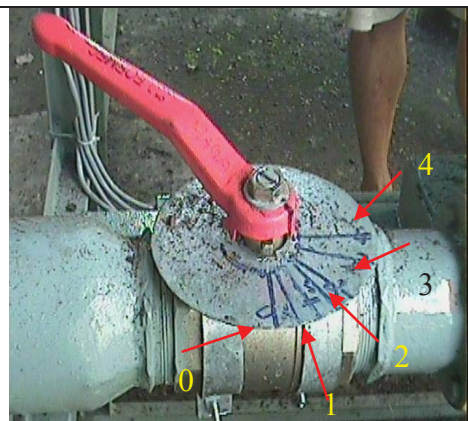


Figure 1.6: Air supply adjustments



Figure 1.7: A view of B2E pyrolysis chamber



Figure 1.8: B2E exhaust gas exit point



Figure 1.9: Feedstock input



Figure 1.10: Temperature indicators



Figure 1.11: Locations of thermocouples 1 & 2

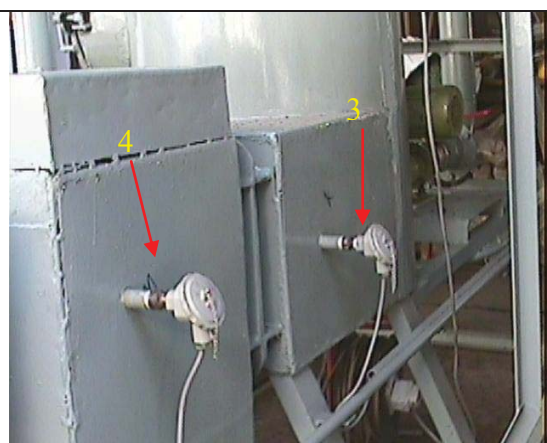


Figure 1.12: Locations of thermocouples 3 & 4



Figure 1.13: Initial ignition of feedstock in pyrolysis chamber

1.1.4 Material and Technical Weaknesses of B2E Converter

During the 3-month experimental trial, the B2E converter encountered five major problems:

- 1) The non-heat-resistant (ordinary mild steel) lining inside the combustion and tar removal chamber failed (**Figure 1.14**);
- 2) The non-heat-resistant concrete filler (ordinary Portland Cement) between the inner and outer linings disintegrated – turned into powder form;
- 3) The heat zones of the combustion and tar removal chambers broke open/through (**Figure 1.15**);
- 4) Slag formed at the bottom gasifier (pyrolysis chamber) and was difficult to remove – attributed to technical or design shortcomings (**Figure 1.16**); and
- 5) Difficulty in maintaining a consistent or continuous input of feedstock.



Figure 1.14: Main body of B2E converter broke open/through after 3 months into operation



Figure 1.15: Slag formed in pyrolysis chamber

1.1.5 Difference Between Previous Work and Current Work

Table 1.1 summarizes the difference between the previous works (B2F and B2E) and the current work (B2H). As a result of the problems such as pollutant emission, and material and technical weaknesses encountered in the previous works (B2F and B2E), the B2H converter was proposed to overcome these weaknesses.

To date, treatment technologies for drying in the paper egg tray and pulp and paper industries in terms of cost-effectiveness, local availability and serviceability of materials and equipment that require low technical skills for operation, and maintenance are not available (UNEP, 1996). A highly efficient and cost-effective biomass-to-heat energy (B2H) converter is deemed an appropriate solution for drying in the paper egg tray, pulp and paper industries, especially in developing countries.

Table 1.1: Summary of the difference between previous works and current work

	Parameter	B2F	B2E	B2H
1	Overall design	Updraft	Downdraft	Downdraft
2	Condensation filter	Yes	No	No
3	Feedstock input	Batch	Continues	Batch
4	Principle study	Emission evaluation	Section 1.1.3 (pages 7)	Development and emission evaluation
5	Parameter measured	CO, hydrogen sulphide (H ₂ S), after filter residue liquid, total suspended particulate	CO, H ₂ S, total suspended particulate	CO, NO, NO ₂ , NO _x , SO ₂ , H ₂ , O ₂ , combustion efficiency
6	Problem encountered	Section 1.1.3 (pages 5)	Section 1.1.4 (page 10)	

1.2 Problem Statement of Research

Biomass fuels in Malaysia contribute around 16% of the total energy consumption, out of which 51% is from palm oil biomass waste and 27% from wood waste (Kamaruzzan & Baharuddin, 2000). The trend of biomass as fuel is increasing in Malaysia, as the government is actively promoting the success of this change, as indicated in the 5th Fuel Diversification Policy (Jamaludin, 2009), Clean Development Mechanism (Oh, Pang, & Chua, 2010), and in the Small Renewable Energy Power program and Renewable Energy Power Purchase Agreement (Mekhilef, Saidur, Safari, & Mustaffa, 2011).

Stationary industries (heavy industrial sources such as food processing plant, pulp and paper industry and power plant) contribute around 20 to 25% of air pollution in Malaysia (Afroz, 2003). Malaysia's pulp and paper industries depend mainly on natural gas, fuel oil, and coal as their principal fossil fuel (Fadhlillah, 2006). As of 2009, the Nibong Tebal Paper Mill Sdn.

Bhd. has been the only one among Malaysia's pulp and paper industries to utilize wood dust as co-generation, with a capacity of 0.8 MW (SuruhanjayaTenega, 2009). Generally, fossil fuel has a higher calorific value than biomass but it emits more air pollutants. Biomass gaseous pollutants such as CO, NO_x, and SO₂ can have an adverse impact upon human health (Demirbas, 2005; EPA, 2008). In 2010, an estimated 51,880 Malaysians contracted acute respiratory infections that can be attributed to air pollution (HIMS, 2010).

Table 1.1 summarizes the differences between previous works (B2F and B2E) and the current work (B2H). One of the major differences between the previous works and the current work is their overall design. The overall design for the B2H converter is downdraft, thus the produced gases flow from top to bottom. This should yield lesser pollutant gases as the generated gases are forced to go through the hotter temperature zone at the bottom of the B2H converter. Generally, the B2H converter has larger dimensions in the pyrolysis chamber and tar removal chamber compared to the B2E converter. The larger dimensions are proposed to increase the time of reaction for complete biomass combustion.

In the biomass combustion field, many researches have been conducted on the influence of the biomass physical properties, the influence of air, and the impact of physical design in the vertical combustor; however, there is little or no research on the effects of the air velocity ratio on the horizontal combustor's temperature profile, flue gas composition and combustion efficiency.

To get a better understanding of the biomass combustion in this area, an experimental study of an air-staged horizontal combustor with quantities of oil palm kernel shell (OPKS) and wood chips was deemed appropriate.

1.3 Objectives of This Research

The research is intended to improve the understanding of the effects of the air velocity ratio on the horizontal combustor's (B2H) flue gas composition (CO , NO_x and SO_2), temperature profile and combustion efficiency. The objectives of the present research work are as follows:

- I. To develop a B2H converter for emission evaluation;
- II. To fabricate a B2H converter for emission evaluation; and
- III. To perform emission evaluation on the B2H converter.

The above objectives were realized in the following steps:

Phase I – Development (Design and Fabrication) of B2H Converter

- To use highly heat-resistant mild steel – 6mm in thickness (in consideration of its specific heat resistance properties and construction cost optimization) as the inner lining;
- To use highly heat-resistant refractory concrete (as the B2E converter broke open, which might be due to the use of normal concrete) as filler between the inner and outer linings;
- To minimize the heat waste by surrounding the pyrolysis chamber of the B2H converter with copper coil;

- To build a semi-circular door measuring approximately 400 mm × 300 mm (minimum allowance for rake or broom) located at the bottom of the pyrolysis chamber for regular removal of ash;
- To increase the gaseous reaction time by enlarging the outer diameter of the pyrolysis chamber from 584.2 mm (B2E) to 675.0 mm (B2H) (in consideration of available rolling technology onsite and refractory thickness);
- To increase the gasification time by extending the length of the tar removal chamber from 584.2 mm (B2E) to 1100.0 mm (B2H) (in consideration of economic material);
- To build an inclined (about 6° from horizontal, in consideration of 11 mm narrow outlet) tar removal chamber; and
- To fabricate a B2H converter with B2E and B2F as key references with respect to design and operational parameters.

Phase II – Emission Evaluation of B2H Converter

- To determine the thermal properties of the selected biomass with a Shimadzu DTG-60H thermal analyser;
- To determine the moisture content of the selected biomass with a Binder drying oven with natural convection; and
- To study the influence of the air velocity ratio on the B2H converter temperature profile, flue gas composition (CO, NO_x and SO₂) and combustion efficiency from OPKS and wood chips with a Testo 350XL flue gas analyser.

1.4 Thesis Outline

This research focuses on the development and evaluation of emissions for a B2H converter used for drying purposes, for example, in the production of paper egg trays. The presentation of the thesis is described in the following paragraphs. **Chapter 1** provides the research background and problem statements, together with the potential renewable energy from biomass in Malaysia and the research objectives. In **Chapter 2**, the role of biomass combustion in the pulp and paper industry in Malaysia is reviewed, together with its limitations. This is followed by a study on the state-of-the-art of biomass combustion technology, its sources and characteristics of pollution, and previous researches on biomass combustion. **Chapter 3** describes the research methodology used in this project. In **Chapter 4 and Chapter 5**, the results and discussion of the observed experimental data are presented, respectively. Finally, the conclusions drawn from the current work, contributions, limitations and recommendations for future research are summarized in **Chapter 6**.

Chapter 2 LITERATURE REVIEW

2.1 Introduction

This chapter gives an overview of the potential of renewable energy in Malaysia, especially in the pulp and paper industries; in addition, the limitations of drying technology in the pulp and paper industries in Malaysia are examined. The state-of-the-art of biomass combustion technology is reviewed to highlight its merits and hurdles for practical implementation. An overview of the basic principle of biomass combustion and pollution from the combustion of solid fuels is considered. In the last part, previous researches on biomass combustion are reviewed to identify the sources and factors affecting the gaseous emissions and combustion efficiency. In addition, this chapter will identify the gaps in the biomass combustion literature in relation to physical design and air staging.

2.2 Energy Demand and Supply in Malaysia

Energy plays an important role in our daily life, especially in the forms of electrical energy, fuel energy and chemical energy. In Malaysia, biomass energy has been showing an increasing trend, compared to other types of energy such as wind, fossil and hydraulic energy (Tildy, 2011). The total current energy demand in Malaysia in 2013 was approximately 33.9 Mtoe; towards the year 2020, the energy demand is expected to grow at 5.4% per annum and to reach 83.5 Mtoe. This growth in consumption is driven mainly by industrialization, especially in the manufacturing and transportation sectors (Ahmad, Kadir, & Shafie, 2011). As a developing country, Malaysia is expected to have a faster growth rate. In parallel with

this, more alternative energy sources are needed to fulfil the energy demand. Although Malaysia has the 3rd largest oil reserves in the Asia Pacific Region, with about 4 trillion ft² of oil reserves in 2006, it has realized already that it cannot be totally dependent on it. Based on the 2005 production levels, it was estimated that the oil reserves will last for another 15 years, while gas reserves are estimated to last for just another 29 years (APEC, 2006, 2009).

The final commercial energy demand in 2008 was approximately 44,901 Ktoe with the highest share in the industrial sector of 42.6%, followed by 36.5% from the transport sector, 13.8% from the residential and commercial sectors, and 6.4% and 0.6% from the non-energy sector and agricultural sector, respectively (**Figure 2.1**) (PTM, 2010).

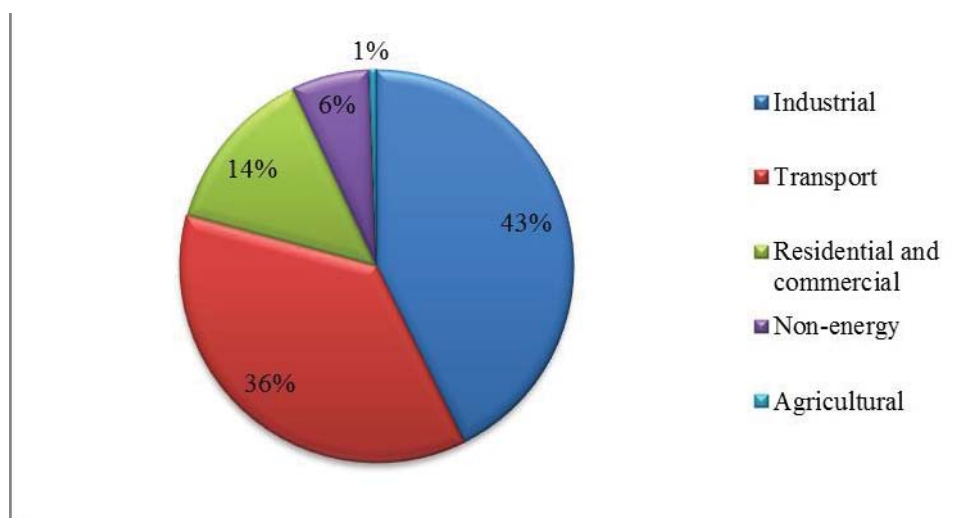


Figure 2.1: Commercial energy demands in Malaysia
(adapted from PTM, 2010)

Energy efficiency is considered to be a key element in sustainable development, especially in reducing the rate of energy resource depletion and mitigating greenhouse gas (GHG) emissions. It is a central greenhouse abatement option at low specific costs (IEA, 2008), in addition to the improvement of companies' competitiveness. The four-fuel diversification

policy in Malaysia that focuses on oil, gas, coal and hydro was extended to include renewable energy as the fifth fuel, particularly biomass, biogas, municipal waste, solar and mini-hydro (EPU, 2010). Under the Tenth Malaysia Plan, several new initiatives anchored upon the Renewable Energy Policy and Action Plan were undertaken to achieve a renewable energy target of 985 MW by 2015, contributing 5.5% to Malaysia's total electricity generation mix. For example, in 2010, a green technology soft loan scheme of RM1.5 billion was launched to provide soft loans to companies that supply and utilize green technology, in which the Malaysia government bears 2% of the total interest rate and a guarantee of 60% on the financing amount, and banking institutions back the remaining 40% (EPU, 2010). In 2009, the Malaysian Industrial Development Authority (MIDA) provided tax incentives and facilities for renewable energy development (Lim, 2009).

Although the Malaysian government has initiated numerous efforts in renewable energy, the response has not been very positive. For instance, under the Ninth Malaysia Plan with renewable energy projects, the targeted 350 MW in year 2010 was not achieved. At the end of 2009, of a total of 17 renewable energy projects approved with a total capacity of 116.4 MW, only 8 projects were commissioned, with a total capacity of 58.1 MW (Ali, 2011). In conclusion, renewable energy has a great growth potential in Malaysia.

2.3 Role of Biomass Combustion in Malaysia's Pulp and Paper Industries

According to Malaysia Pulp and Paper Manufacturing Association (MPPMA) (2003), as cited by CIFR (2006), there are 67 paper mills producing more than 50 tons per day (all kinds of

traditional, recycled, and special papers), of which 19 small paper manufacturing companies use wood fibre (**Figure 2.2**).

In 2000, Malaysia's annual pulp and paper import bill stood at RM2 billion; a total of 19 paper mills were in operation with 16 of these located in the northern states. The Minister of Primary Industries stated that Malaysia would be able to take advantage of the needs of the region, which is a net importer of pulp and paper with imports outstripping export by about 6 million tons annually. According to the MPPMA, Malaysia imported all types of paper and paperboard amounting to 762,359 metric tons worth RM1.75 billion in 1998 (CNNtext, 2000).

In 2011, there were 426 palm oil mills in Malaysia that produced an estimated 99.85 million tons of EFB per year (MPOB, 2012). Using the organosolv process, five tons of EFB can produce one ton of pulp (FRIM, 2002); therefore, assuming that 50% of the EFB was available for pulp production, Malaysia would have the potential to produce 9.99 million tons of pulp per year from EFB alone. Based on the 2013 pulp price of around USD806.62 per ton, the value of the pulp produced would be around USD8.0 billion (Mundi, 2013).



Figure 2.2: Locations of paper mills in Malaysia
(adapted from CIFR, 2006)

1. Cita Peuchoon Paper mill Sdn. Bhd.	8. United Paper Board Sdn. Bhd.	15. Johmewah Maju Sdn. Bhd.
2. Muda Paper Mills Sdn. Bhd. (Seberang Prai)	9. Pascorp Paper Industries Bhd.	16. Kimberly Clark Products (M) Sdn. Bhd.
3. Trio Paper Mills Sdn. Bhd.	10. Union Paper Industries Sdn. Bhd.	17. Hai Ming Paper Mills Sdn. Bhd.
4. Nibong Tebal Mills Sdn. Bhd.	11. Muda Paper Sdn. Bhd. (Kajang)	18. See Hua Paper Mill Sdn. Bhd.
5. Taiping Paper Mills Sdn. Bhd.	12. Genting Sanyen Industrial Paper Sdn. Bhd.	19. Sabah Forest Industries Sdn. Bhd.
6. Pembuatan Kertas (Perak) Sdn. Bhd.	13. Yeong Chaur Shing Industry Sdn. Bhd.	20. Malaysian Newsprint Industries Sdn. Bhd.
7. Theen Seng Paper Manufacturing Sdn. Bhd.	14. Le Kok Paper Sdn. Bhd.	

The managing director of 1Green Enviro, Datuk Raymond Chan, stated that the global paper and paperboard market in 2010 was estimated to be worth RM996.8 billion; and by 2015, it is

expected to expand to 21.8% or RM1,214 billion. Moreover, the price of paper, paper products and pulp has been showing an upward trend since 2009 (Borneo Post, 2012).

2.5 Overview of Paper Egg Trays Production

Wastepaper, newspaper and cardboard are regarded as the raw materials used for the production of the paper egg trays (McKinney, 1995). The process for the production of recycled paper egg trays is illustrated in **Figure 2.3**.

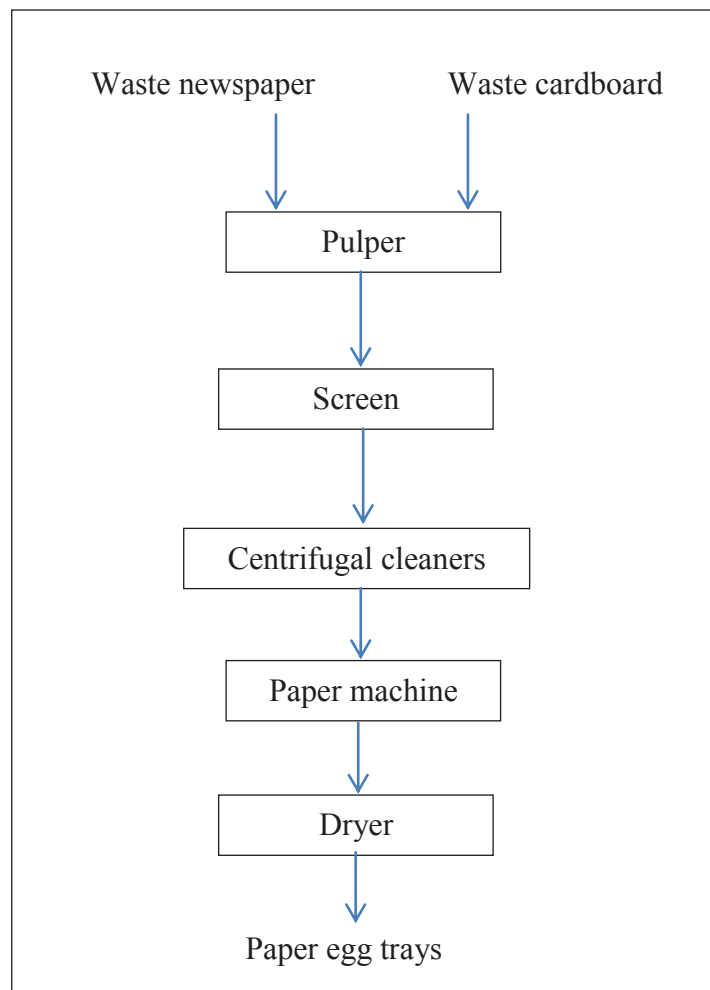


Figure 2.3: Process flow chart of the production of recycled paper egg trays (adapted from Zabaniotou & Kassidi, 2003)

Pulp Formation into the Final Product

The two main methods of pulping are mechanical and chemical processing. Pulping methods differ from each other in energy and wood use. Chemical pulping uses twice as much wood

per tonne when compared to mechanical pulping. Modern chemical pulp mills are self-sufficient in energy consumption, as half of the wood is dissolved and used as fuel in the chemical recovery phase. Mechanical pulping uses wood very efficiently but it consumes much more electricity (Szabó, Soria, Forsström, Keränen, & Hytönen, 2009).

Screening and Cleaning

The objective of both screening and cleaning is the removal of non-fibrous contaminants with minimal losses of useful fibre. The pulp is forced through a screen with holes of various shapes and sizes to remove small contaminants such as bits of plastic and globs of glue (All-recycling-facts, 2013). Before screening, the slurry enters the first part of the paper machine, (the wet end), where the fibres are filled and the paper web is formed. It is estimated that about 16–25% of solid content is present at this stage. At the dry end, the paper web enters the pressing section, at which stage the solid content is between 50 and 55% (Fleiter, Fehrenbach, Worrell, & Eichhammer, 2012).

Drying

The removal of humidity takes place in the conveyor room. Steam-heated can dryers are the most common drying method in the paper machine; they can heat up to temperatures of above 90°C and they are used in long sequences of more than 40 cans. The heat produced by these cans dries the paper easily, to less than 6% moisture content (Technology, 2012). According to Green and Perry (2008), the energy consumption per unit of product in the paper industry with integrated plant is about 18.8 GJ/Mg.

Water clarification

Process water needs to be clarified as it contains different dissolved chemicals and suspended solids. The water clarification is implemented through a dissolved air flotation process (DAF). For a typical pulp and paper factory, the processes of the paper machine involved are evaporating and cauterizing, cooking/washing, bleaching, and refining. The steam and electric power consumed for each of these processes are summarized in **Table 2.1**.

Table 2.1: Steam and electric power consumption for typical pulp and paper process

Energy consumed	Unit	Pulp and paper processes					
		Evaporating and cauterizing	Cooking/washing	Bleaching	Refining	Paper machine	Others
Steam (heat)	t/paper	1.5	1	0.4	N.A	3	0.3
Electric power	kWh/paper tonne	140	N.A	150	240	600	220

(adapted from Fadhlillah, 2006)

* N.A. means Not available

In 1990, a mean of 15–20 GJ of electricity was required to manufacture a ton of paper in a modern integrated mill, of which about 40% was required in the chipping and pulping operations, 25% in drying and finishing, 15% in bleaching, washing and refining and the remaining 20% was used in chemical recovery (UNEP, 2000).

2.6 Limitations of Drying Technology in Pulp and Paper Industry in Malaysia

Malaysia's pulp and paper industry is facing many challenges, both domestically and internationally (FRIM, 2002). To enhance its competitiveness, the industry must make continuous efforts to increase its production output and to improve its product quality. The

important issues in drying are energy efficiency, emissions, heat integration and dryer performance (Fagernäs, Mckeough, & Impola, 2005). Traditionally, pulp and paper production from wood discharges a considerable volume of effluents (50 to 200 m³ per tonne of pulp), gaseous and solid wastes into the environment (Leuenberger, Giger, Coney, Graydon, & Molnar-Kubica, 1985). The PTM's 2004 study (cited in UNDP, 2006) showed that the pulp and paper industries in Malaysia consumed 5,080,208 GJ of energy per year, with a carbon dioxide (CO₂) emission reduction potential of 194,403 tons per year, which is the second highest among the food, wood, ceramic, cement, glass, rubber, iron and steel industries. Malaysia's pulp and paper industry depends heavily on natural gas, fuel oil and coal as the principal fossil fuels (Fadhlillah, 2006). In 2009, among all the pulp and paper industries in Malaysia, only the Nibong Tebal Paper Mill Sdn. Bhd. utilized wood dust as co-generation, with a capacity of 0.8 MW (Energy Commission, 2009). **Figure 2.4** shows that, from 2000 to 2010, the demand for crude oil and petroleum in Malaysia has increased steadily.

Air emissions from the pulp and paper industries originate mainly from the incineration of fuels. Transport vehicles, power stations, and recovery boilers for chemical pulping emit sulphur and nitrogen oxides that acidify the atmosphere and in turn can contribute to regional environmental impacts (UNEP, 1999). **Table 2.2** shows the air emissions from European pulp and paper mills.

Table 2.2: Air emissions from European pulp and paper mills (kg/t pulp)

Source	Sulphur dioxide (SO ₂)	Nitrogen oxides (NO _x)	Particulates	Reference
Mechanical and high yield pulp mills	0.05-9.6	0.01-7.5	0.03-1.7	(UNEP, 2000)
Sulphite mills	3-8	2-4	-	(UNEP, 2000)
Kraft pulp mill	1.2-4.0	1.5-5.0	0.02-12	(UNEP, 2000)

(adapted from UNEP, 1999)

Andersson et al. (2006) conducted an experiment on three different technologies for pulp mill integrated biofuel drying (steam drying, flue gas drying and vacuum drying) and they concluded that the most attractive integrated drying technology option was the flue gas dryer, which uses flue gas from the black liquor boiler. The flue gas flow rate from the pulp mill recovery boiler was 115 kg per second (dry gas basis) at 160°C and 12% water content. An economic evaluation by Andersson et al. (2006) showed that a steam dryer is energy-efficient; however, the loss in electricity production leads to a high cost of drying heat and the reduction of CO₂ emissions is small, considering that the electricity loss has to be compensated. Fagernäs et al. (2010) suggested that, as a general rule, a low exhaust temperature (<100°C) should be maintained whenever possible, as it will carry out the drying of wood fuels to about 10% moisture content (Fagernäs, McKeough, & Impola, 2007).

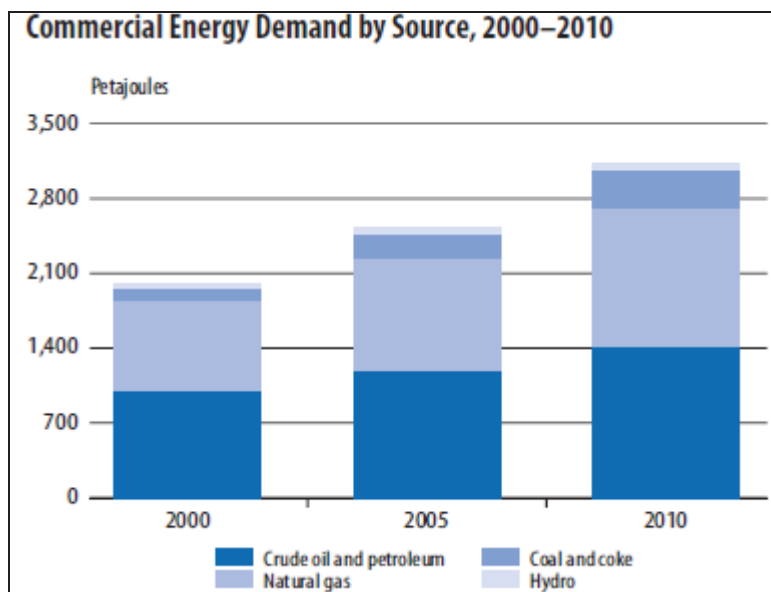


Figure 2.4: Malaysia commercial energy demand by source, 2000 – 2010 (adapted from EPU, 2006)

2.7 State-of-the-Art of Biomass Combustion Technology

Biomass combustion means burning organic materials; it is the main technology route for bioenergy, and is responsible for more than 90% of the global contribution to bioenergy (Loo & Koopejan, 2008). It is used mainly for heat production in small and medium scale units such as wood stoves, log wood boilers, pallet burners, automatic woodchip furnaces, and straw-fired furnaces.

District heating systems usually range in size from 0.5 MW_{th} to 5 MW_{th} with some applications up to 50 MW_{th}. Combined heat and power production (CHP) with biomass is applied to steam cycles (Rankine cycle) with steam turbines and engines, and organic Rankine cycles (ORC) with typical power outputs between 0.5 MW_e and 10 MW_e. Stirling engines (10 kW_e to 100 kW_e) and closed gas turbines are in development or demonstration mode (Nussbaumer, 2003). In principle, biomass combustion technology can be distinguished into three categories (**Figure 2.5**):

- (i) Fixed bed combustion (grate furnace or underfeed stoker);
- (ii) Fluidized bed combustion (stationary/bubbling or circulating); and
- (iii) Pulverized fuel (entrained flow/dust) combustion.

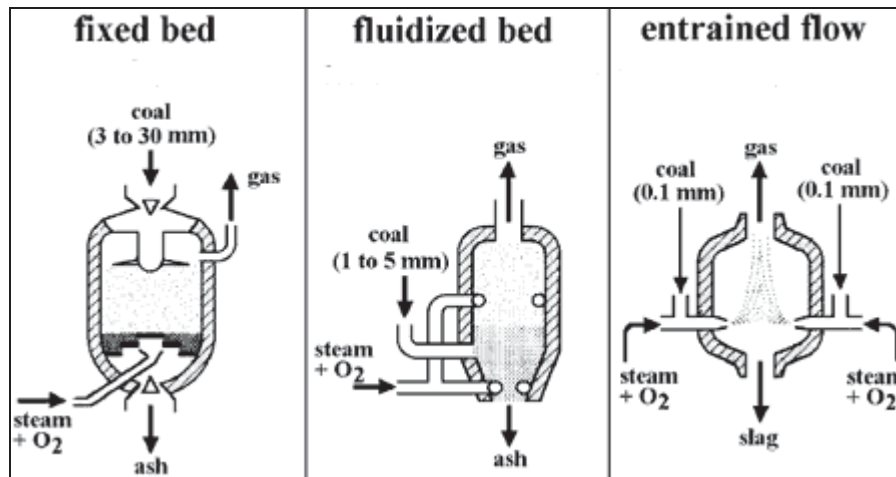


Figure 2.5: Furnace types: fixed bed, fluidized bed, and entrained flow reactor (adapted from Sugiyono, 2007)

2.7.1 Fixed Bed Combustion

In fixed bed combustion systems (grate furnace and underfeed stoker), primary air passes through a fixed bed where drying, gasification, and charcoal combustion occur. The combustible gases produced are burned after secondary air addition has taken place (usually in a combustion zone separated from the fuel bed) (EU, 2005).

a) Grate Furnace

A grate furnace is suitable for biomass fuels with high moisture content with varying particle sizes and high ash content (**Figure 2.6**). Mixtures of wood fuels can be used; however, current technology does not allow mixtures of wood fuels and straw, cereals, and grass, due to their different combustion behaviour, low moisture content, and low ash melting point. Moreover, a homogeneous distribution of the fuel and the bed of embers over the whole grate surface has to be guaranteed to assure an equal primary air supply over the various grate areas; if not, slagging, ash amounts and excess oxygen may increase. To achieve these aims, technology needs to include continuously moving grates, a height control system of the bed of

embers (e.g. by infrared beams) and a frequency height controls primary air fans for the various grate sections.

Another important aspect of the grate furnace is that a staged combustion should be obtained by separating the primary and the secondary combustion chambers to avoid back-mixing of the secondary air and to separate the gasification and oxidation zones. The geometry of the secondary combustion chamber and the secondary air injection has to guarantee a mixture of flue gas and air that is as complete as possible. The better the mixing, the lower the excess of oxygen that is necessary for complete combustion, and the higher the efficiency (Loo & Koopejan, 2003).

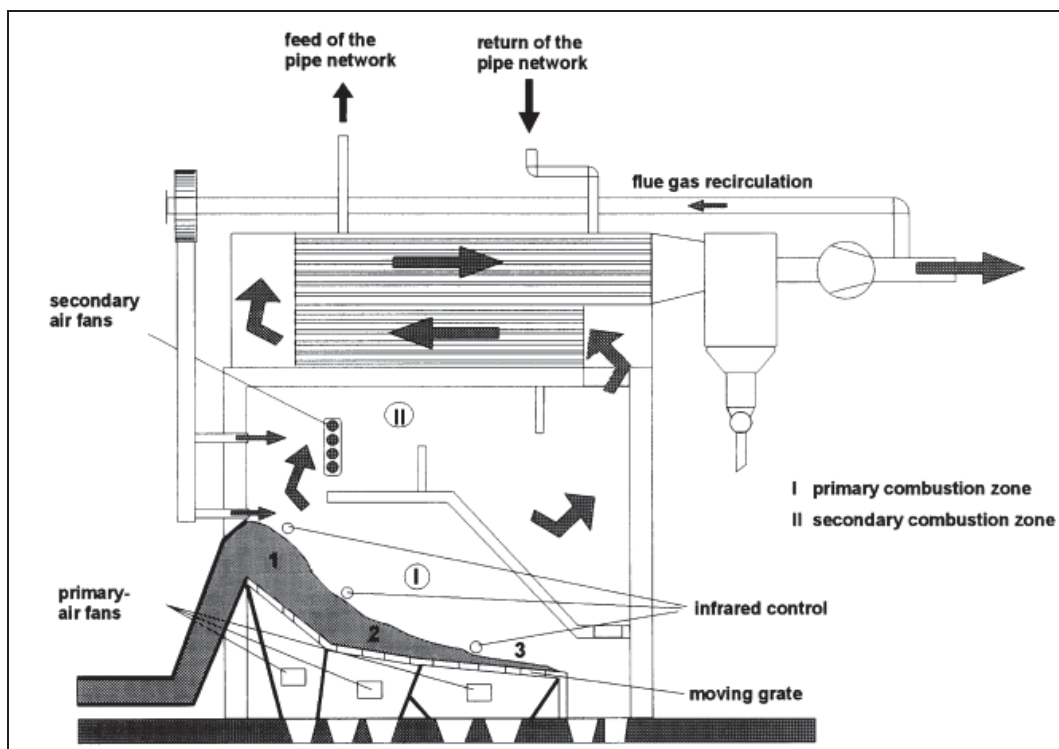


Figure 2.6: Modern grate furnace with infrared control system and section separation primary air control; 1: Drying zone; 2: Gasification zone; 3: Charcoal combustion zone (adapted from Obernberger, 1998)

b) Underfeed Stoker

An underfeed stoker is a less expensive and operationally safe technology for small- and medium-scale systems up to a nominal boiler capacity of 6 MW_{th} (Loo & Koopejan, 2003). The fuel is fed into the combustion chamber by screw conveyors from below and is transported upwards to an inner or an outer grate. Outer grates are more common because they allow a more flexible operation and an automatic ash removal system can be attained more easily. Primary air is supplied through the grate and secondary air usually at the entrance to the secondary combustion chamber (Figure 2.7).

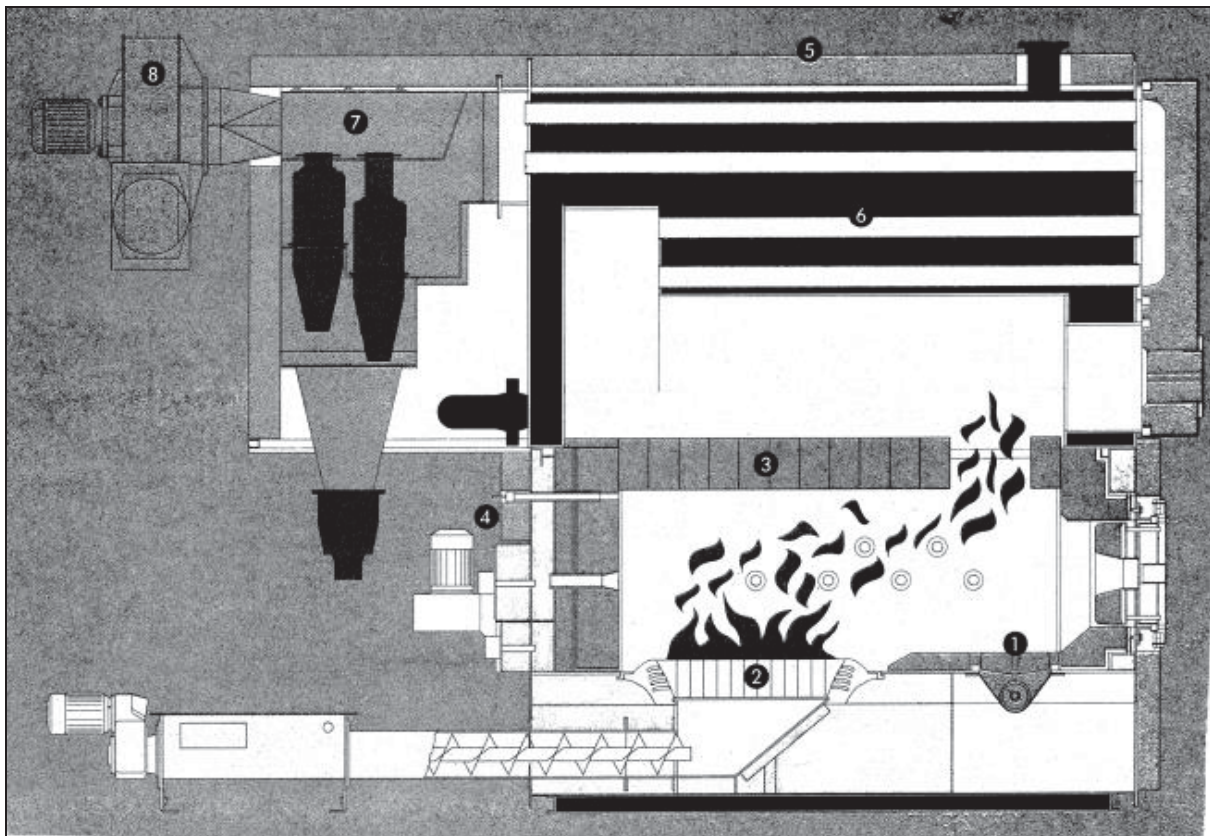


Figure 2.7: Underfeed stoker for wood chips and sawdust; 1: Ash hopper; 2: Grate; 3: Refractory and radiation wall; 4: Air fans; 5: Insulation; 6: Fire tube boiler; 7: Multi-cyclone; 8: Flue gas fan
(adapted from Obernberger, 1998)

2.7.2 Fluidized Bed Combustion

A fluidized bed (bubbling fluidized and circulating fluidized) consists of a cylindrical vessel with a perforated bottom plate filled with a suspension bed of hot, inert, and granular materials. The common bed materials are silica, sand, and dolomite. Primary combustion air enters the furnace from below through the air distribution plate and fluidizes the bed so that it becomes a seething mass of particles and bubbles. The combustion temperature has to be kept low (800– 900°C) to prevent ash sintering in the bed (EU, 2005).

As a result of the attained good mixing, fluidized bed combustion plants can deal flexibly with various fuel mixtures, but they are limited when it comes to particle sizes and impurities contained in the fuel (EU, 2005); therefore, appropriate fuel pre-treatment (particle size reduction, separation of metals) is necessary. The low excess air quantities can increase combustion efficiency and reduce the flue gas volume flow. It is interesting especially for large-scale applications (boiler capacity $>30 \text{ MW}_{\text{th}}$). Investment and operating costs are very high for small plants compared with fixed bed systems. The disadvantage of this technology is that high dust loads entrained with the flue gas make efficient dust precipitators and boiler cleaning systems necessary; in addition, bed material is lost with the ash, making it necessary to add new material to the plant periodically.

a) Bubbling Fluidized Bed (BFB) combustion

For bubbling fluidized bed combustion (**Figure 2.8**), particle size $<80\text{mm}$ is recommended; for plants with a boiler capacity of $>20 \text{ MW}_{\text{th}}$, BFB combustors have significant potential, and the fluidization velocity of the air varies between 2.0 and 2.5 m/s. The secondary air is introduced through several inlets in the form of horizontally arranged nozzles at the beginning

of the upper part of the furnace to ensure a staged air supply to reduce NO_x emissions. The advantage of BFB is its flexibility concerning the particle size and moisture content of the biomass fuels. It is possible to use mixtures of different biomass fuels. One disadvantage is the difficulty at partial load operation, which can be resolved by splitting or staging the bed.

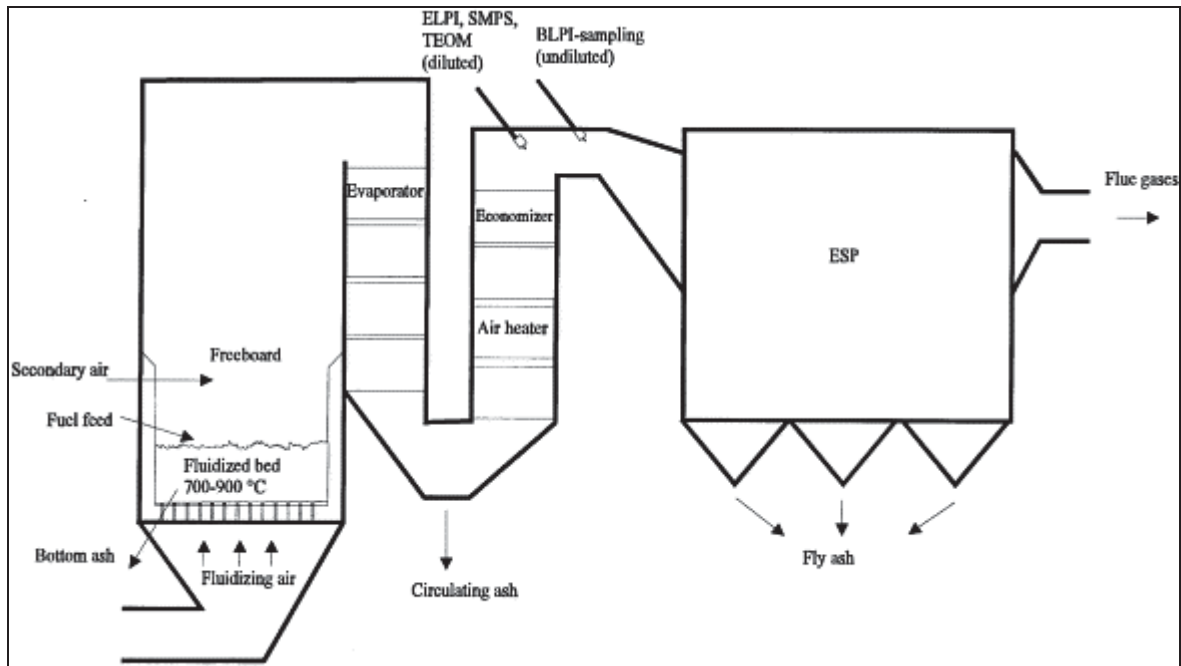


Figure 2.8: Schematic layout of BFB combustion
(adapted from Latva-Somppi et al., 1998)

b) Circulating Fluidized Bed (CFB) Combustion

By increasing the fluidizing velocity to 5–10 m/s and using smaller sand particles (0.2–0.4 mm in diameter), circulating fluidized bed combustion is achieved (**Figure 2.9**). The sand particles are carried with the flue gas, separated in a hot cyclone or U-beam separator and fed back into the combustion chamber. The higher bed temperature in the CFB combustor leads to a better heat transfer and a very homogeneous temperature distribution in the bed. This is

advantageous for stable combustion conditions, the control of air staging and the placement of heating surfaces right at the upper part of the furnace.

The disadvantages are the larger size and therefore the higher price; the even greater dust load in the flue gas leaving the sand particle separator than in BFB systems; the higher loss of bed material in the ash, and the small fuel particle size (0.1–40 mm in diameter) that is required. These systems are of interest for plants of more than 30 MW_{th} (Loo & Koopejan, 2003).

A horizontal circulating fluidized bed was developed by Hadavand, Jalali and Famouri (2008). The horizontal circulating fluidized bed is composed of a primary combustion chamber, secondary combustion chamber, burnout chamber, cyclone, loop seal, and heat recovery area (**Figure 2.10**). The primary combustion chamber is a riser similar to the vertical circulating fluidized bed, and the secondary combustion chamber is a downward passage that is a natural extension of the primary riser, which can reduce the overall height of the boiler. The field test showed that horizontal circulating fluidized bed combustion technology is promising and competitive due to its lower pollution and higher thermal efficiency than a grating furnace of the same or similar capacity (Hadavand, Jalali and Famouri, 2008).

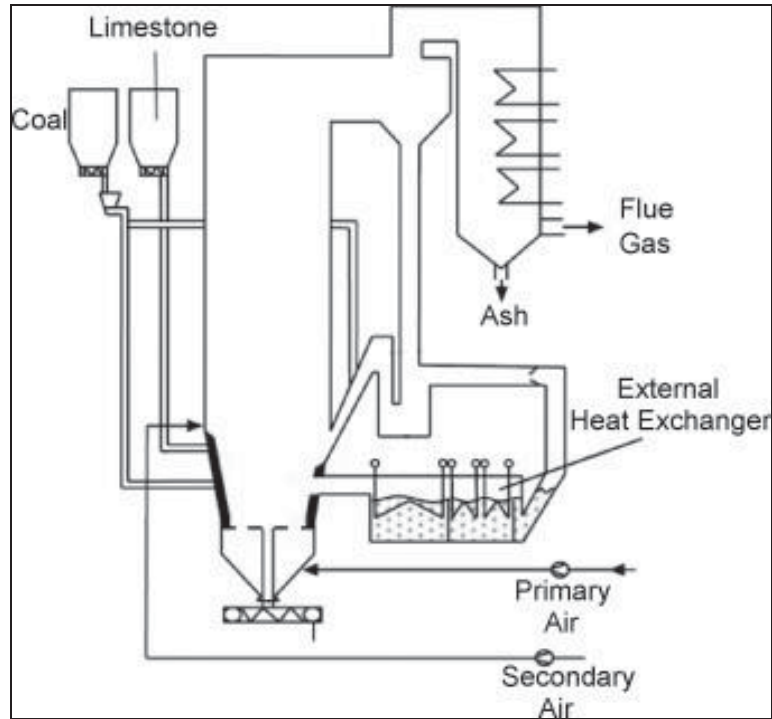


Figure 2.9: Schematic diagram of a circulating fluidized bed combustion system (adapted from Hadavand, Jalali, & Famouri, 2008)

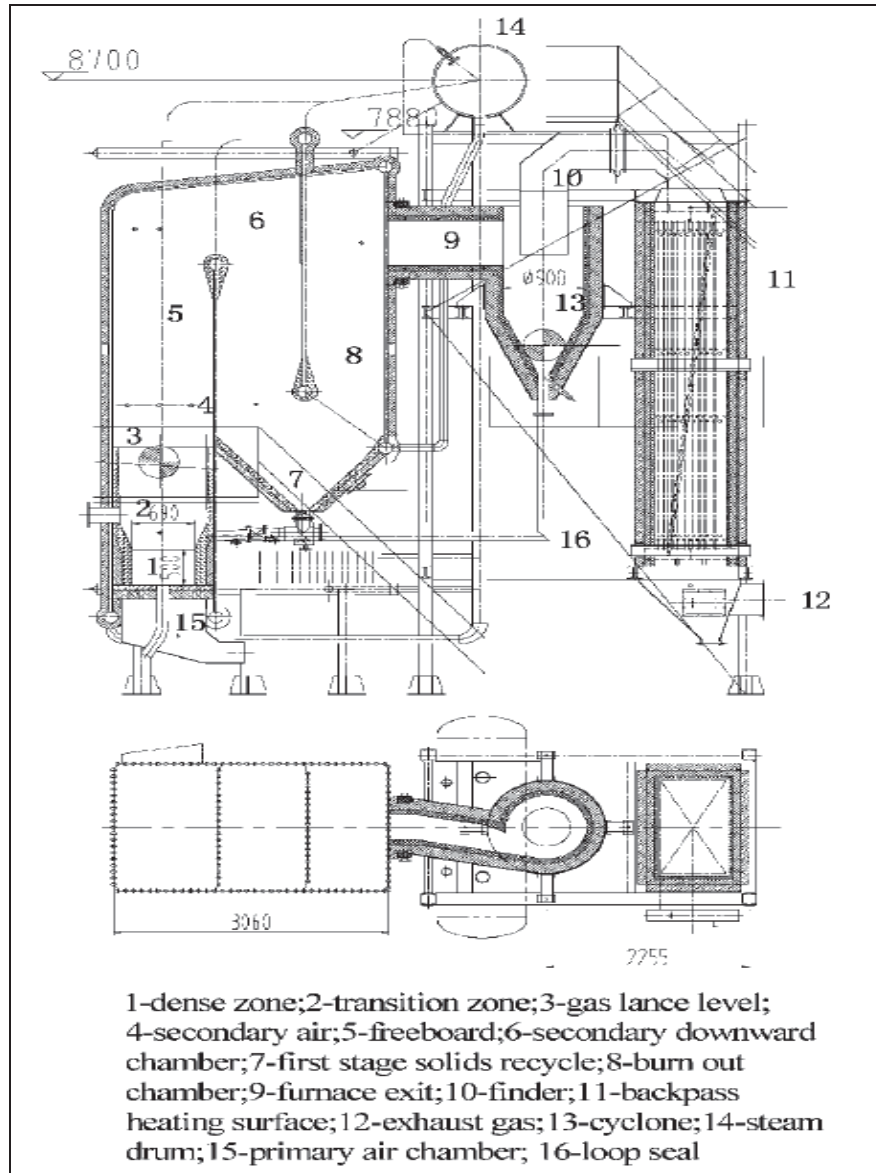


Figure 2.10: Horizontal circulating fluidized bed configuration
(adapted from (Q. H. Li, Zhang, & Meng, 2010))

2.7.3 Pulverized Fuel / Entrained Flow Combustion

Pulverised fuel combustion is suitable for fuels available as small particles (average <2 mm) like sawdust and fine shavings. A mixture of fuel and primary combustion air is injected pneumatically into the combustion chamber (**Figure 2.11**). Combustion occurs whilst the fuel is in suspension and gas burnout is achieved after secondary air addition. A maximum

particle size (10–20 mm) has to be maintained and fuel moisture content should not exceed 20% wt.

Usually, the fuel and air velocity is injected tangentially into the cylindrical furnace muffle to establish a rotational flow; fuel gasification and charcoal combustion occur at the same time because of the small particle size; therefore, quick load changes and an efficient load control can be achieved. A disadvantage is that the insulation bricks wear out quickly due to the thermal stress and erosion (EU, 2005).

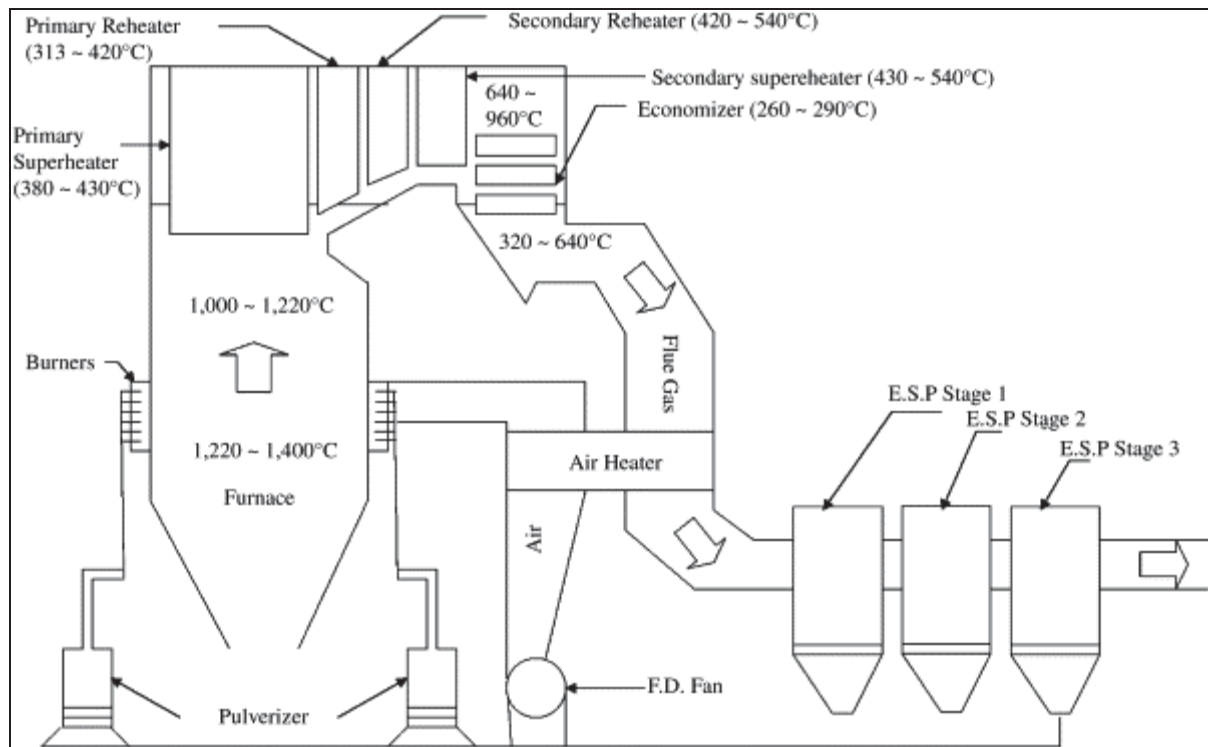


Figure 2.11: Schematic diagram of the pulverized coal power plant (adapted from Ahn & Lee, 2006)

Table 2.3 shows the most frequently used furnace types for biomass combustion. The systems can be distinguished by the flow conditions in the furnace, describing fixed bed combustion, fluidized bed combustion, and entrained flow or dust combustion (**Figure 2.5**).

Table 2.4 gives an overview of the advantages and disadvantages of different types of biomass combustion technology. Moreover, Van Swaaij, van der Ham, & Kronberg (2002) gave an extensive detailed description of the classification and properties of the gas–solid reactors.

Table 2.3: Types of biomass furnaces with typical application and fuels

Application	Type	Typical size range	Fuels	Ash	Water content
Manual	Wood stoves	2kW – 10 kW	Dry wood logs	<2%	5%-20%
	Log wood boilers	50 kW	Log wood, sticky wood residues	<2%	5%-30%
Pallet	Pallet stoves and boilers	2kW-25kW	Wood pallets	<2%	8%-10%
Automatic	Understoker furnaces	20kW-2.5MW	Woodchips, wood residues	<2%	5%-50%
	Moving grate furnaces	150kW-15MW	All wood fuels and most biomass	<50%	5%-60%
	Pre-oven with grate	20kW-1.5MW	Dry wood (residues)	<5%	5%-35%
	Understoker with rotating grate	2MW-5MW	Woodchips, high water content	<50%	40%-65%
	Cigar burner	3MW-5MW	Straw bales	<5%	20%
	Whole bale furnaces	3MW-5MW	Whole bales	<5%	20%
	Straw furnaces	100kW-5MW	Straw bales with bale cutter	<5%	20%
	Stationary fluidized bed	5MW-15MW	Various biomass, d<10mm	<50%	5%-60%
	Circulating fluidized bed	15MW-100MW	Various biomass, d<10mm	<50%	5%-60%
	Dust combustor, entrained flow	5MW-10MW	Various biomass, d<5mm	<5%	<20%
Co-firing ^a	Stationary fluidized bed	Total 50MW-150MW	Various biomass, d<10mm	<50%	5%-60%
	Circulating fluidized bed	Total 100-300MW	Various biomass, d<10mm	<50%	5%-60%
	Cigar burner	Straw 5MW-20MW	Straw bales	<5%	20%
	Dust combustor in coal boilers	Total 100MW-1GW	Various biomass, d<2-5mm	<5%	<20%

^a Biomass covers typically less than 10% of the total fuel input
(adapted from Nussbaumer, 2003)

Table 2.4: Advantages and disadvantages of different biomass combustion technologies

Biomass combustion technology	Advantages	Disadvantages	Reference
Fixed bed			
Underfeed stoker	• Low investment cost for plant <6 MW_{th}; • Simple and good load control due to continuous fuel feeding; and • Low emissions at partial load operation due to good fuel dosing.	• Suitable only for biofuels with low ash content and high ash melting point (wood fuels); and • Low flexibility in regard to particle size.	Loo & Koopejan, 2003
Grate furnace	• Low investment costs for plants <20 MW_{th}; • Low operating cost; • Low dust load in the flue gas; and • Less sensitive to slagging than fluidized bed furnaces.	• No mixing of wood fuels and herbaceous fuel possible; • Efficient NO_x reduction requires special technologies; • High excess oxygen (5-8% Vol) decreases efficiency; • Combustion conditions not as homogeneous as in fluidized bed furnaces; and • Low emission level at partial load operation is difficult to achieve.	Loo & Koopejan, 2003
Fluidized bed combustion			
BFB furnace	• No moving parts in the hot combustion chamber; • NO_x reduction by air staging works well; • High flexibility concerning moisture content and kind of biomass fuels used; and • Low excess oxygen (3-4 Vol%) raises efficiency and decreases flue gas flow.	• High investment costs, interesting only for plants > 20 MW_{th}; • High operating costs; • Low flexibility with regard to particle size (<80 mm); • High dust load in the flue gas; • Operation at partial load requires special technology; • Medium sensitivity concerning ash slagging; • Loss of bed material with the ash; and • Medium erosion of heat exchanger tubes in the fluidized bed.	EU, 2005
CFB furnaces	• No moving parts in the hot combustion chamber; • NO_x reduction by air staging works well; • High flexibility concerning moisture content and kind of biomass fuels used;	• High investment cost, interesting only for plants >30MW_{th}; • High operating costs; • Low flexibility with regard to particle size (<40mm); • High dust load in the flue gas; • Partial load operation	EU, 2005

	• Homogeneous combustion conditions in the furnace if several fuel injectors are used; • High specific heat transfer capacity due to high turbulence; • Use of additives easy; • Very low excess oxygen (1-2% Vol) raises efficiency and decreases flow gas flow.	requires a second bed; • Loss of bed material with the ash; • High sensitivity concerning ash slagging; and • Medium erosion of heat exchanger tubes in the furnace.	
Pulverized fuel combustion			
Pulverized fuel combustion	• Low excess oxygen (4-6% Vol) increase efficiency; • High NO_x reduction by efficient air staging and mixing possible if cyclone or vortex burner are used; and • Very good load control and fast alternation of load possible.	• Particle size of biofuel is limited (<10-20 mm); • High wear out of the insulation brickwork if cyclone or vortex burners are used; and • An extra start-up burner is necessary.	Loo & Koopejan, 2003

2.8 Basic Principles of Biomass Combustion

The process of biomass combustion involves a number of physical/chemical aspects of some complexity; the nature of the combustion process depends on both the fuel properties and combustion application, and the combustion process can be divided into several general processes: drying, pyrolysis, gasification, and combustion. The overall combustion process can be either a batch combustion process or a continuous combustion process: batch combustion is used in some small-scale combustion units, whereas medium- to large-scale combustion units are always continuous combustion applications (Loo & Koopejan, 2008).

2.8.1 Drying, Pyrolysis, Gasification, and Combustion

Drying: Moisture evaporates at low temperature (<100°C). As vaporization uses energy released from the combustion process, it lowers the temperature in the combustion chamber,

which slows down the combustion process; consequently, moisture content is a very important fuel variable (Loo & Koopejan, 2008).

Pyrolysis: Pyrolysis can be defined as thermal degradation (devolatilization) in the absence of an externally supplied oxidizing agent. Typically, the temperature at which pyrolysis starts is about 160–250°C for biomass fuel (Di Blasi, 2008; Moghtaderi, Meesri, & Wall, 2004; Saddawi, Jones, Williams, & Wójtowicz, 2009). The pyrolysis products are mainly tar and carbonaceous charcoal, and low molecular weight gases; in addition, carbon monoxide (CO) and CO₂ can be formed in considerable quantities, especially from oxygen-rich fuels such as biomass. The pyrolysis products can be used in a variety of ways: the char can be upgraded to activated carbon, for use in the metallurgical industry, and as domestic cooking fuel. Pyrolysis gas can be used for heat production or power generation or synthesized to produce methanol or ammonia. The tarry liquid, pyrolysis oil or bio-oil, can be upgraded to high-grade hydrocarbon liquid fuel for combustion engines, or used directly for electricity production or heating purposes (Loo & Koopejan, 2008).

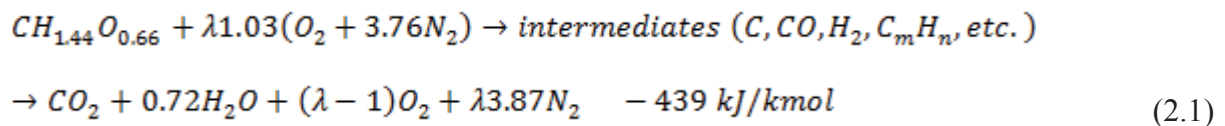
Gasification: Gasification can be defined as thermal degradation (devolatilization) in the presence of an externally supplied oxidizing agent. Usually, pyrolysis is optimized with respect to a maximum char or tar yield; however, gasification is optimized with respect to a maximum gas yield. The majority of the gases are released from the biomass at the temperature range of 201–279°C with the smoke (Greenwood, 2013) and they contain mainly CO, CO₂, water vapour (H₂O), hydrogen (H₂), methane (CH₄) and other hydrocarbons. Gasification can be carried out with air, oxygen, steam or CO₂ as oxidizing agents. Air gasification produces a low calorific value gas (gross calorific value - GCV) of 4–7 MJ/Nm³ (dry), while oxygen gasification produces a medium GCV of 10–18 MJ/Nm³ (dry). Through

synthesis, the fuel gas can be upgraded to methanol, burned externally in a boiler to produce hot water or steam, in a gas turbine for electricity production or in internal combustion engines such as diesel and spark ignition engines. Before the fuel gas can be used in gas turbines or internal combustion engines, the contaminants (tar, char particles, ash, and alkali compounds) have to be removed. The hot gas from the gas turbine can be used to raise steam to be utilized in a steam turbine (integrated gasification combined cycle – IGCC) (Loo & Koopejan, 2008).

Combustion: Combustion can be defined as a complete oxidation of the fuel. The hot gases from the combustion may be used for a direct heating process in small combustion units, for water heating in small central heating boilers, and for water heating in boilers for electricity generation in large units. Drying and pyrolysis/gasification will always be the first step in a solid fuel combustion process.

2.9 Conventional Biomass Combustion Pollutant Emissions

Conventional biomass combustion produces pollutants such as CO, NO, NO₂, NO_x and SO₂ (Dao, 2012; Lin et al., 2013; Williams, Jones, Ma, & Pourkashanian, 2012). Pollutant formation processes are strongly dependent on the fuel properties and combustion application. A typical biomass combustion reaction can be expressed by **Equation (2.1)** if the fuel constituents (N, K, Cl, etc.) are neglected:



where $\text{CH}_{1.44}\text{O}_{0.66}$ represents the average composition of typical biomass used for combustion. The following subsections describe the fundamentals of the chemical reaction mechanism of these pollutants.

2.9.1 CO Formation Mechanism in Biomass Combustion

Carbon monoxide is a colourless flammable gas, and it is highly toxic, which can lead to asphyxiation. In biomass combustion, CO formation is one of the principal intermediate gaseous species. Improper fuel–air mixing may cause the failure to oxidize the CO to CO_2 . The CO emission is governed by formation and destruction reactions which are illustrated in **Equations 2.2–2.4** (Annamalai & Puri, 2007):



or



where CO oxidized by hydroxyl (OH) in the reaction becomes CO_2



CO is formed if the oxygen, temperature and residence time are insufficient for the combustion reaction (Charles, 2004).

2.9.2 NO_x Formation Mechanism in Biomass Combustion

There are seven oxides of nitrogen that are generated by the chemical bonding of nitrogen and oxygen; namely, nitric oxide (NO), nitrogen dioxide (NO_2), nitrogen trioxide (NO_3), nitrous oxide (N_2O), dinitrogen trioxide (N_2O_3), dinitrogen tetroxide (N_2O_4) and dinitrogen pentoxide (N_2O_5). NO and NO_2 are the most important of these because they are emitted in large

quantities (Yaverbaum, 1979). NO and NO₂ are always grouped as NO_x due to their large emission quantities (Seinfeld & Pandis, 1997).

The three generally accepted mechanisms for NO_x production are: thermal NO_x, prompt NO_x and fuel NO_x. Hill and Douglas Smoot (2000) have modelled the detailed chemistry of the formation and destruction of NO_x in combustion systems, including formation mechanisms.

(a) Thermal NO_x

Thermal NO_x is formed by the high temperature reaction (hence the name thermal NO_x) of nitrogen and oxygen which, at above around 1100°C, is generally the predominant mechanism in combustion processes. The principal reaction governing the formation of NO from atmospheric nitrogen is given by the extended Zeldovich mechanism (Lavoie, Heywood, & Keck, 1970) and is represented by the following reactions (**Equations 2.5–2.7**):



Warnatz et al. found in an experiment that the NO formation rate shows a strong correlation with temperature and oxygen concentrations (**Equation 2.8**) (Warnatz, Maas, & Dibble, 2000):

$$d[\text{NO}]/dt = 2k[\text{O}][\text{N}_2] \quad (2.8)$$

where

[NO] = concentration of NO

[O] = concentration of O

k = forward constant rate

Thus, NO formation can be minimized by decreasing $[N_2]$, $[O]$ or k (by decreasing the temperature).

(b) Prompt NO_x

Prompt NO_x is formed by a relatively fast reaction that is confined to the region near the flame zone. Prompt NO_x can exceed thermal NO_x, especially for fuel-rich conditions (Sarangi, 2012). It is formed by a reaction sequence that is initiated by the rapid reaction of hydrocarbon radicals with molecular nitrogen, leading to the formation of hydrocyanic acid (HCN), which subsequently reacts to form NO (**Equations 2.9–2.14**) (Glassman, 1996).



The activation energy of the reaction in **Equation (2.9)** is only about 75 kJ.mol⁻¹, compared to 318 kJ.mol⁻¹ for the formation of thermal NO_x; therefore, prompt NO_x is produced at relatively low temperatures (about 1000 K) (Warnatz et al., 2000).

(c) Fuel NO_x

Fuel NO_x is formed by the direct oxidation of organonitrogen compounds contained in the fuel. The fuel NO_x formation mechanism from coal has been studied in detail by Pohl and Sarofim (1977). Its overall reaction is shown in **Equation (2.15)** (Charles, 2004):



Besides being selective on fuel type, Charles (2004) indicated that excess oxygen is the key to minimize fuel NO_x emissions.

2.9.3 SO₂ Formation Mechanism in Biomass Combustion

Dullien (1989) categorized SO₂ as the most important gaseous pollutant because of its damaging impact on humans, animals, vegetation, buildings and the environment; SO₂ tends to be produced at higher temperatures. As most combustion processes are at high temperature, SO₂ is the more predominant form of SO_x emitted from systems containing sulphur. In a high temperature combustion process, the sulphur is oxidized by oxygen from the combustion air to form SO_x. The first oxidation step (Charles, 2004) is as follows:



This step takes place inside the high temperature combustor. The second oxidation step is:



This step in **Equation (2.17)** can occur in the combustion system or in the atmosphere after leaving the combustor, if the conditions are right. At ambient temperatures, equilibrium strongly favours SO₃ rather than SO₂ formation. The latter dominates at temperatures below about 371°C. The problem starts when SO₃ reacts with H₂O (e.g. rain) to form sulphuric acid:



Sulphuric acid is known to cause damage to life and corrosion on buildings. The two general methods to minimize the SO₂ are: (1) removing the sulphur from the incoming fuel; (2) removing the SO₂ from the exhaust stream using a variety of dry and wet scrubbing techniques (Turns, 1996).

2.10 Conventional methods used to determine the biomass combustion pollutant

Various methods have been used to determine the pollutants from the combustion of solid fuels. Several researchers (Aghamohammadi, Nik Sulaiman, & Aroua, 2011; Cao, Casenas, & Pan, 2006; Salleh, Yunus, Atan, Radiah, & Biak, 2012) have used differential thermal analysis (DTA) and measurements of thermogravimetry analysis (TGA) to determine the thermal property of solid fuels. Moreover, British Standard EN 14774-2:2009 (British Standard, 2009) provides a procedure for the determination of moisture content in solid biofuels. British Standard EN 14181:2004 (British Standard, 2004) provides quality assurance of automated measuring systems for stationary source emissions.

2.11 Operation and Design Variables Affecting Biomass Combustion Emission and its Efficiency

The efficiency of the biomass combustion process is affected mainly by the physical and chemical properties of the biomass, the influence of the air inlet and the physical design of the combustor. This section reviews a selection of the most prevalent operation and design variables that affect the combustion emission and combustion efficiency of biomass.

i) Biomass Physical and Chemical Properties

a) Biomass Particle Size

According to Pérez, Melgar, and Benjumea (2012), an increase in biomass particle size decreases the effective surface available for reaction, which will inhibit the transport of mass and heat to the thermochemical process, leading to lower biomass consumption rates, equivalence fuel/air ratios and maximum process temperature (**Figure 2.12**). A study by Li,

Xu, Hui, and Wei (2009) shows that the influence of pulverized coal's fineness on NO_x emission is negligible if the mean particle size is < 2 mm. This shows that the surface reaction in biomass combustion decreases with the biomass particle size.

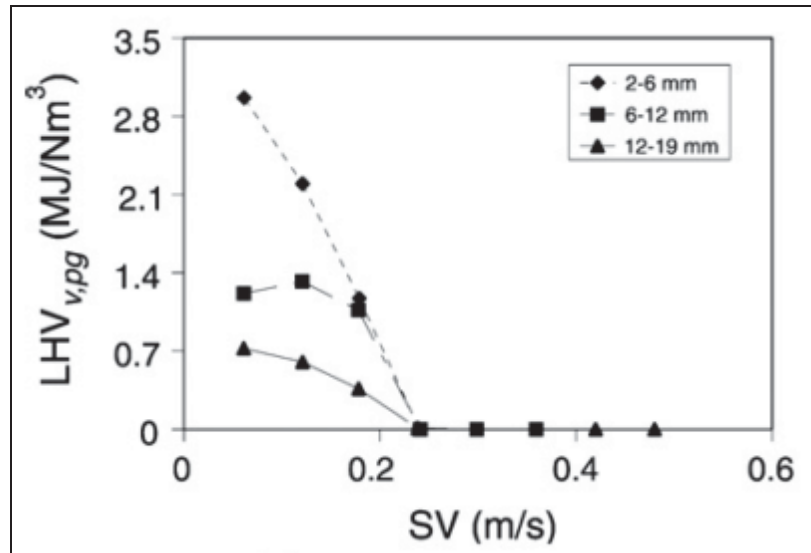


Figure 2.12: Effects of air superficial velocity (SV), particular diameter towards producer gas lower heating value (LHV)
(adapted from: Pérez *et al.* 2012, p.495)

b) Moisture Content

Various studies show that the higher the moisture content, the higher the energy consumption for water evaporation; consequently, the lower will be the net calorific value (Heschel, Rweyemamu, Scheibner, & Meyer, 1999; Mediavilla, Fernández, & Esteban, 2009). This was confirmed also by Pérez *et al.* (2012), whose study shows that the producer gas heating value from a studied biomass reactor decreases with increasing moisture content. According to Helin (2005), natural wood has a moisture content of about 50% wt.; thus, preheating the fuel before operation is recommended.

c) Effect of Cellulose and Lignin Content of Biomass

Generally, cellulose and lignin are recognized as the main components in the biomass (**Figure 2.13**) (Hajaligol, Waymack, & Kellogg, 2001). Gani and Naruse (2007) employed TGA to study the effect of cellulose and lignin content on pyrolysis and combustion characteristics for several types of biomass. They found that, with biomass with higher cellulose content, the pyrolysis rate becomes faster, and biomass with higher lignin content has a slower pyrolysis rate. Hence, the cellulosic content in the biomass may enhance the ignition characteristics, as cellulose compounds have the structure of branching chains of polysaccharides and of aromatic compounds, which are easily volatilized (Gani & Naruse, 2007).

Jones et al. (2004) suggested that, in the absence of catalytic species, higher lignin biomass might have a higher soot formation tendency because of its propensity to produce phenolic tars, which can participate in the soot formation mechanism; therefore, it can be inferred that the combustion characteristics of the actual biomass depend on its cellulose and lignin content. Based on the theoretical and experimental studies on the biomass combustion process in fixed beds, Yang et al. (2005) found that, once the bed was ignited, the flame front travelled downward at a speed depending on the fuel type (different proportions of cellulose and lignin) and operating parameters until it arrived at the bed bottom. It can be concluded that the cellulose and lignin content of biomass affect the combustion process.

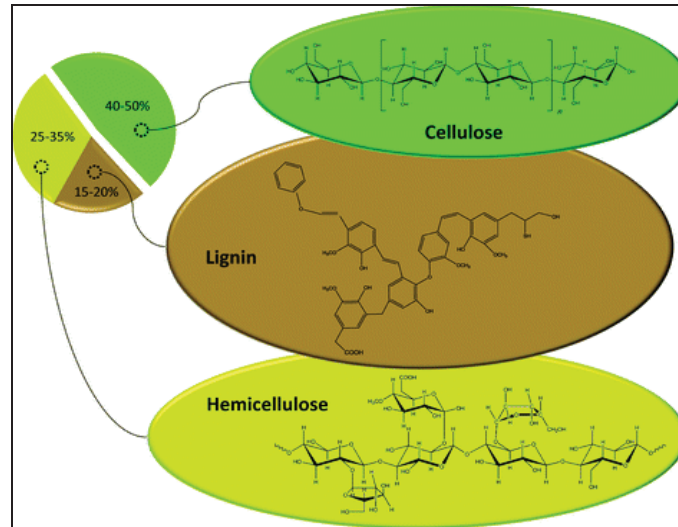


Figure 2.13: Wood compositions
(adapted from Alonso, Bond, and Dumesic, 2010)

d) Inorganic Constituents

Sami, Annamalai, and Wooldridge (2001) found that the inorganic constituents in the fuel are the main contributors to slagging and fouling, which is in agreement with Jenkins, Baxter, Jr, and Miles (1998). The major elements, including alkali metals (K, Na), alkaline earth metals (Ca, Mg), silicon, chlorine and sulphur, are involved in reactions leading to slagging and fouling (Pronobis, 2005). According to Munir, Nimmo, and Gibbs (2011), biomass has a lower ash content than coal. At the same time, biomass ash materials are rich in alkali and alkaline earth metals (Munir, Nimo, & Gibbs, 2010) and these are effectively fluxed for alumina-silicates and lower the ash fusion temperature, resulting in an increase in the propensity to slagging and fouling (Loo & Koopejan, 2008).

ii) Influence of Air on Combustion

a) Air Staging and its Location

The mixing of combustion air with fuel in two stages by creating a fuel-rich zone and fuel-lean zone delay (**Figure 2.14**) is an effective means of controlling nitrogen monoxide (NO)

and CO in coal-fired boilers (Hesselmann, 1997; Shaiful & Nazri, 2007). The general principle of air staging is to create a distinct fuel-rich (oxygen deficient) zone and a subsequent fuel-lean zone inside the reactor. The primary zone stoichiometric ratio (actual air/stoichiometric air) is kept less than 1. A portion of the secondary air is injected later in the reactor to create a fuel-lean zone to complete the combustion (the stoichiometric ratio in the secondary zone is more than 1).

A study by Li et al. (2008) as cited by Munir et al. (2011) shows that the combustion in the fuel-rich (oxygen-deficient) sub-stoichiometric primary region reduces the formation of thermal NO_x and fuel NO_x. Moreover, they found that increase in the primary zone length of a vertical combustor (**Figure 2.15**) has a positive effect on the NO reduction and a negative effect on carbon burnout, and this is due to the fact that an increase in the primary zone length increases the residence time in the oxygen-deficient fuel-rich primary zone. This is in agreement with the findings of Ribeirete and Costa (2009). Li et al.'s (2008) study shows that decreasing the stoichiometric ratio can lead to an increase of reducing species formed in the primary combustion zone, which is conducive to NO_x destruction. However, at the same time, when the stoichiometric ratio is too low, the pulverized coal combustion remains incomplete in the primary zone and large amounts of unburnt char enter the burnout zone, which may affect the combustion efficiency. Thus, there is a trade-off between NO reduction and carbon burnout when selecting an optimum air nozzle and stoichiometric ratio in the primary chamber.

Furthermore, their study (Munir et al., 2011) shows that the location of the air inlet can affect the geometry (diameter and length) of the primary zone chamber and NO reduction

efficiency. Varol and Atimtay (2007) found that an increase in the secondary air flow rate can result in a decrease in exhaust temperature; therefore, air staging is an important aspect that influences the air emission.

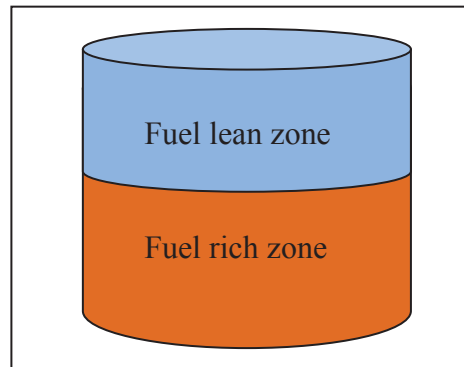


Figure 2.14: Fuel rich and fuel lean zones

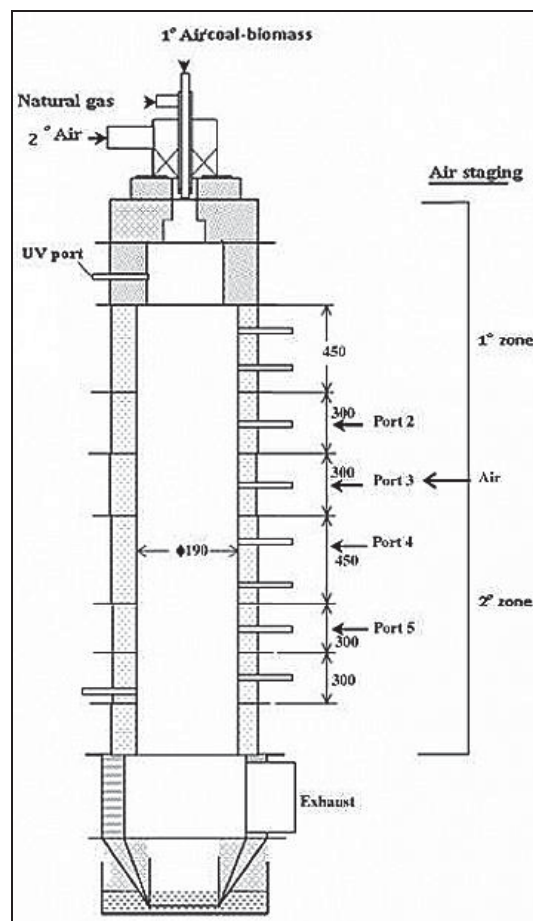


Figure 2.15: Vertical combustor
(adapted from Munir et al., 2011)

b) Excess Air Ratio

Generally, an increase in the excess air ratio increases the bed combustion temperature (Surjosatyo & Ani, 1998). Yang, Sharifi, and Swithenbank (2004) found that volatile release and burning intensify with an increase of the air flow rate until a critical point is reached where a further increase in the primary air results in a slowing down of the combustion process. The study by Habib, Elshafei, and Dajani (2008) shows that, as the air flow rate increases above the theoretical value, the boiler input energy per kg of flue gas reduces; thus, the exhaust gas temperature decreases, which might be because the excess air ratio gives higher air velocity than is needed for complete combustion and that reduces the time of reaction in the combustion. Nevertheless, Verma, Bram, Gauthier, and De Ruyck (2011) show that insufficient air coupled with high moisture contents of biomass can lead to poor combustion conditions and consequently more CO emissions.

c) Oxygen-Enriched Combustion

Luo, Xiao, Hu, Liu, and Guan (2009) conducted an experimental study on the oxygen-enriched combustion of biomass micro fuel (powdery biomass fuel with particles size of less than 250 μm). Their results show that, with the increasing oxygen concentration, the volatile releasing temperature, ignition temperature and burnout temperature decrease. The oxygen-enriched atmosphere reduces the burning time and improves the combustion activity of the biomass micro fuel because, by enriching the combustion air with additional oxygen, the amount of inert nitrogen contained in the flue gas is lowered, thereby reducing the amount of heat loss through the furnace exhaust and obtaining higher efficiency (Hu, Naito, Kobayashi, & Hasatani, 2000). However, the improvement is weakened when the oxygen concentration is above 40%.

Nimmo, Daood, and Gibbs (2010) studied the effect of oxygen (O_2) enrichment on NO_x formation in biomass co-fired pulverised coal combustion; their experiments were performed using a Russian coal and Pakistani cotton stalk as biomass fuels co-fired at a fraction of 15%th; the down-fired pulverized coal combustor was operated at 20 kW_{th} under air-staged conditions for NO_x control, and both the secondary and over-fire flows were enriched by up to 79% (100% O_2) for a range of splits giving a 35% overall O_2 concentration for full enrichment. They concluded that, to maintain NO_x emissions levels within acceptable ranges during enrichment of burner combustion air, it may be necessary to modify the flame dynamics by altering the mixing rates through the adjustment of swirl intensity. This may be associated with the flame being more attached to the burner at lower velocities.

iii) Physical Design

a) Geometrical and Heat Recovery Design

To achieve a good combustion with low CO content in the flue gas, the combustion temperature must be sufficiently high, the amount of O_2 must be sufficient, and mixed thoroughly with oxygen and combustion gases by air turbulence. The combustion chamber must have enough volume to ensure an adequate residence time of the combustion gases at high temperature before the flue gases are sent out. The retention time depends on the turbulence of the combustion chamber. The higher the turbulence, the shorter will be the residence time. Rotating and increasing the turbulence in the combustion air will improve the combustion; therefore, most air nozzles are equipped with a swirl at a distance of about one nozzle diameter from the outflow (Kristensen & Kristensen, 2004).

A study in a small-scale batch-fired straw boiler by Kristensen (2004) found that the high CO emission observed was caused mainly by a low combustion temperature due to the lack of insulation at the top of the combustion chamber. Moreover, it was observed that high values of CO emission occurred in the start-up period and at the end of the combustion period, when the temperature in the combustion chamber was at its lowest. The study reported that the efficiency of batch-fired straw boilers increased because of improved combustion conditions in the combustion chamber and improved heat recovery in the fire tubes. For the boiler with the highest efficiency, the flue gas temperature at the boiler outlet was below 175°C, whilst other tested boilers showed the mean flue gas temperature of 230°C (Kristensen & Kristensen, 2004).

At high temperatures in the combustion chamber, the ashes will often melt into a porous lump; however, this will not normally be a problem if the ashes are removed by means of a shovel mounted on a tractor front loader. In practice, for most batch-fired boilers, the ashes are removed 1 to 2 times a month (Kristensen & Kristensen, 2004). Sarasuk and Sajjakulnukit (2011) designed a lab scale two-stage rice husk gasifier. Their studies gave some insightful ideas to consider when designing a rice husk gasifier, which can facilitate varying parameters such as equivalence ratio, superficial velocity, and temperature.

Messerer, Schmatloch, Poschl, and Niessner (2007) applied a stainless steel miniature pipe (1.6mm) bundle heat exchanger for heat recovery from combustion exhaust for a small wood-fired appliance. Their results indicated that, for all operating conditions, the heat exchanger recovered between 75% and 90% of the exhaust heat. A wall-cooled reactor is common in combustion (Kirillov et al., 2001, cited by van Swaaij et al., 2002). Abid, Ali, and Alzubaidi

(2011) researched the heat transfer in a gas–solid fluidized bed with various heater inclinations; their results showed that the angle of inclination of the heat surface in a fluidized bed influenced the acquired heat transfer coefficient.

Researches on the geometry of combustor and recovery design were conducted in vertical combustors; however, there is little or no research on the effects of the air velocity ratio on a horizontal combustor's temperature profile, flue gas composition and combustion efficiency.

b) Feed Rate

From the study by Vamvuka et al. (2011), it was shown that when the feed rate was lowered, there was a significant drop in the combustion temperature of orange tree prunings, leading to an increase in CO emissions and a decrease in SO₂ and NO_x emissions. The effect of the lower feed rate led to a decrease in the combustion efficiency of the fuels because of heat losses due to CO emissions, and unburnt carbon in the cyclone or in the bed being higher.

c) Method of Ignition for Biomass

According to the study by Bhattacharya, Albina and Khaing (2002), the emission of CO and NO_x was significantly less in the case of top ignition than with bottom ignition. In addition, top ignition appeared to burn the wood fuel with much less smoke compared to burning with bottom ignition, particularly during start-up. For example, in the Indian “Harsha” stove, the CO emission factors for top ignition and bottom ignition were 41.7 g/kg and 52.4 g/kg respectively; whilst the NO_x emission factors for top ignition and bottom ignition were 0.099 g/kg, and 0.182 g/kg respectively. This serves as guidance to reduce the CO emission in the combustion of solid fuel.

d) Co-combustion

The study by Munir et al. (2011) found that an increase in the biomass blending ratio had a positive effect on NO reduction, which could be linked to an increase in the volatility of the fuel by the addition of biomass. Tillman (2000) reported that an increase in volatility (volatile matter over fixed carbon) of fuel had a positive effect on NO_x reduction until the volatility reached unity. However, an increase in volatility beyond 1 had no positive effect on the NO_x reduction during co-firing (Tillman, 2000).

e) Temperature

Fouling and corrosion in biomass-fired boilers are complicated and the theories behind these phenomena are still under development. It is widely agreed that the temperature and the amount of alkali metals in the flue are the most important factors. Higher temperatures increase the amount of contaminants in the melt and vapour phase, leading to the development of a sticky tube surface and sticky ash particles (Sandberg, Karlsson, & Fdhila, 2011). A study by Skrifvars (2008), cited in Sandberg, Karlsson and Fdhila (2011), showed that the corrosion increased significantly when the metal temperature exceeded 450–500°C. In biomass, alkali metals are associated primarily with organic compounds or present as simple salts, which means that alkali metals are released easily to the gas phase during combustion.

According to Nielsen's study (2000), cited in Sandberg, Karlsson and Fdhila (2011), the behaviour of alkali metals during biomass combustion is influenced by chlorine (Cl) and sulphur (S). If the sulphur content is high in biomass, sulphur is likely to react with alkali metals such as potassium to form sulphates, releasing chlorine in the process. Chlorine may react to form hydrochloric acid (HCl), but it may also form zinc chloride in the presence of

zinc (Sandberg, Karlsson, & Fdhila, 2011). According to Sandberg's research (2006) in particle deposits on super-heater tubes in a CFB biomass boiler, once ash particles are stuck on a tube, a sintering process occurs between the particles, making the deposit denser. Therefore, study of the biomass organic compound is needed to minimize the corrosion in the combustor. Additionally, Wiinikka, Gebart, Boman, Boström and Öhman (2007) confirmed that the combustion temperature and fuel ash composition are of major importance to the formation of high-temperature aerosols in the fixed bed combustion of woody biomass pellets. Consequently, a balance is needed in the biomass combustion temperature to avoid sticky ash particles and incomplete combustion.

2.11 Summary of Literature Review

Table 2.5 gives the overview studies of operation and design variables affecting the efficiency of the combustion process. A thorough literature review of more than 129 papers and articles was conducted to review the development and evaluation of emissions for biomass combustion in Malaysia's context.

Table 2.5: Summary of literature on operation and design variable combustion process efficiency

Research Areas	Major Findings	References
Biomass Physical and Chemical Properties		
Biomass particle size: Increase	• Lower process temperature • Decrease surface reaction	Li et al., (2009); Pérez et al. (2012)
Moisture content: Higher	• Lower calorific value	Helin (2005); Heschel et al. (1999); Mediavilla et al. (2009); Pérez et al. (2012)
Effect of cellulose and lignin content of biomass	• Higher cellulose content leads to faster pyrolysis rate, while higher lignin content leads to lower pyrolysis rate. • Higher lignin content leads to higher soot formation.	Gani & Naruse, (2007); Gani & Naruse (2007); Hajaligol et al. (2001); Jones et al. (2004); Y. Yang et al. (2005)

Inorganic constituents	Main contributor to slagging and fouling	Jenkins et al. (1998); Loo & Koopejan, (2008); Munir et al. (2011, 2010); Pronobis (2005); Sami et al. (2001)
Influence of Air		
Air staging and its location	Nitrogen monoxide (NO) and CO control	Hesselmann (1997); Li et al. (2008); Munir et al. (2011); Ribeirete & Costa (2009); Shaiful & Nazri (2007); Varol & Atimtay (2007)
Excess air ratio: Increase	Increase combustor temperature and reduce combustor temperature if exceed theoretical air fuel ratio	Habib et al. (2008); Surjosatyo & Ani (1998); Verma et al. (2011); Y. B. Yang et al. (2004)
Oxygen-enriched combustion: Increase	Decrease volatile releasing temperature, ignition temperature and burnout temperature	Hu et al. (2000); Luo et al. (2009); Nimmo et al. (2010)
Physical Design		
Geometrical and heat recovery design	Critical parameter: - Residence time - Temperature - Turbulence	Abid et al. (2011); Kristensen & Kristensen (2004); Messerer et al. (2007); Sarasuk & Sajjakulnukit (2011); van Swaaij et al. (2002)
Feed rate: Lower	- Increase in CO emissions - Decrease in SO₂ and NO_x emissions - Decrease the combustion efficiency	Vamvuka et al. (2011)
Method of ignition for biomass	Top ignition emits lesser CO, NO_x emission and smoke compare to bottom ignition	Bhattacharya et al. (2002)
Co-combustion	Reduce NO emission	Munir et al. (2011); Tillman (2000)
Temperature: Higher	Lead to the development of sticky tube surface and sticky ash particles	Sandberg et al. (2011); Sandberg (2006); Wiinikka et al. (2007)

From the literature review, it is clear that Malaysia's pulp and paper industries have yet to tap into the wealth of OPKS and wood chips as fuels for drying purposes. There are three categories of biomass combustion technology that have been reviewed. Many researches were conducted on vertical combustors, rather than horizontal combustors. Past studies have revealed that, generally, the biomass combustion emission and efficiency are governed by three main components; that is, temperature, time and turbulence. These three parameters are affected directly by oxidation input. Various explanations are provided in the literature to justify the observed trends of emissions and performance in vertical biomass combustion;

however, there is little or no research on the effects of the air velocity ratio on the horizontal combustor's temperature profile, flue gas composition and combustion efficiency. To have a better understanding of the biomass combustion in this area, a quantitative study of an air-staged horizontal combustor with oil palm kernel shell and wood chip is deemed appropriate.

Chapter 3 RESEARCH METHODOLOGY

3.1 Introduction

This chapter has two parts, namely Phase I – Development of B2H converter, and Phase II – Evaluation of B2H converter. The first part consists of the design and fabrication of the B2H converter, while the second part emphasizes the evaluation of the B2H converter and includes the sample preparation for OPKS and wood chips, as well as the instrumentation for data collection.

3.2 Development (Design and Fabrication) of B2H Converter

This section describes the development of the B2H converter, which consists of design and fabrication in **Phase I**. The design criteria of the B2H include design specifications, development concept, development specifications, design of individual components and fabrication of the B2H converter (**Figure 3.1**). The concluding remarks of this section are given in **section 3.8**.

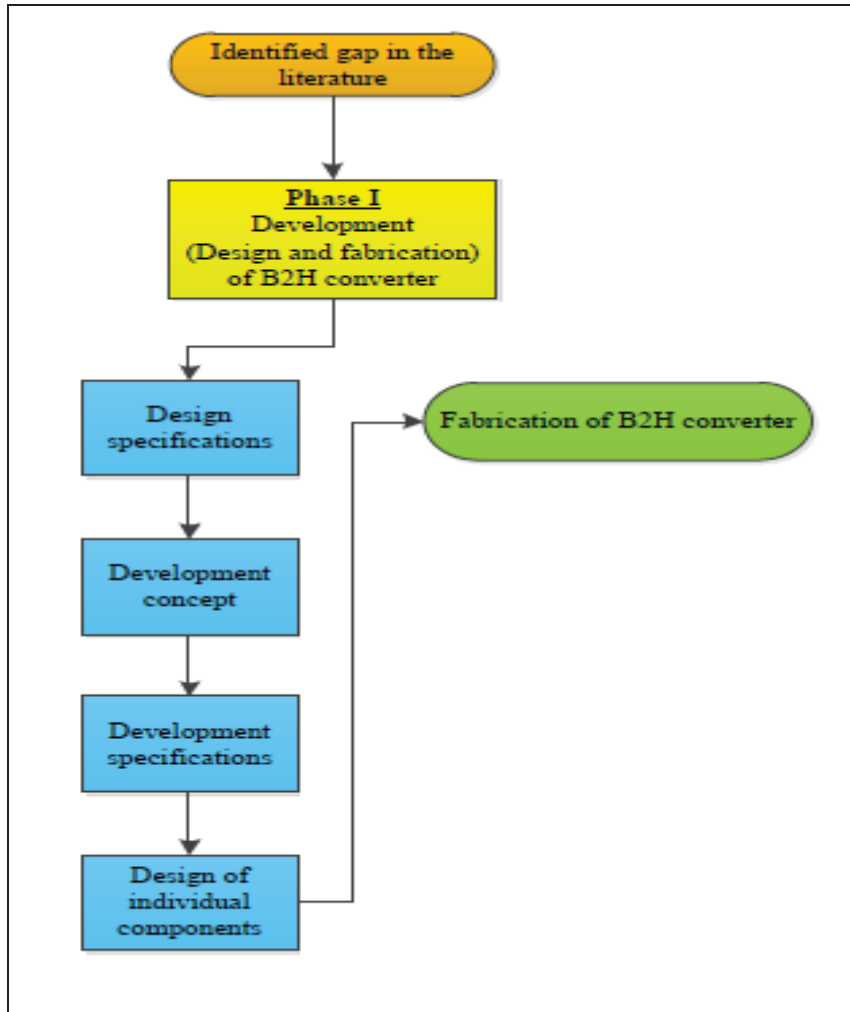


Figure 3.1: Flow chart for development of B2H converter

3.3 Design Specifications

The B2H converter is designed as a horizontal layout comprising three chambers: 1) pyrolysis chamber, 2) tar converter chamber, and 3) combustible fuel gas-to-heat energy conversion chamber. The overall dimensions of the B2H are 1.5 m × 2.1 m × 1.0 m. The pyrolysis chamber consists of a cylindrical structure 1.5 m in height and 0.775 m in diameter (considering the available rolling technology onsite and refractory thickness) and it has a thick layer of refractory and an anchor with a length of 100 mm. The enlarged B2H diameter of the pyrolysis chamber and increased length of the tar removal chamber increase the surface area

and thus enhance the rate of heat transfer through conduction, convection and radiation mechanisms. The B2H converter contains a moveable lid at the hopper section. The B2H converter is designed to produce (a) no after-filter residual liquid, and (b) no formation of slag inside the pyrolysis chamber during operation (**Figure 3.2**).

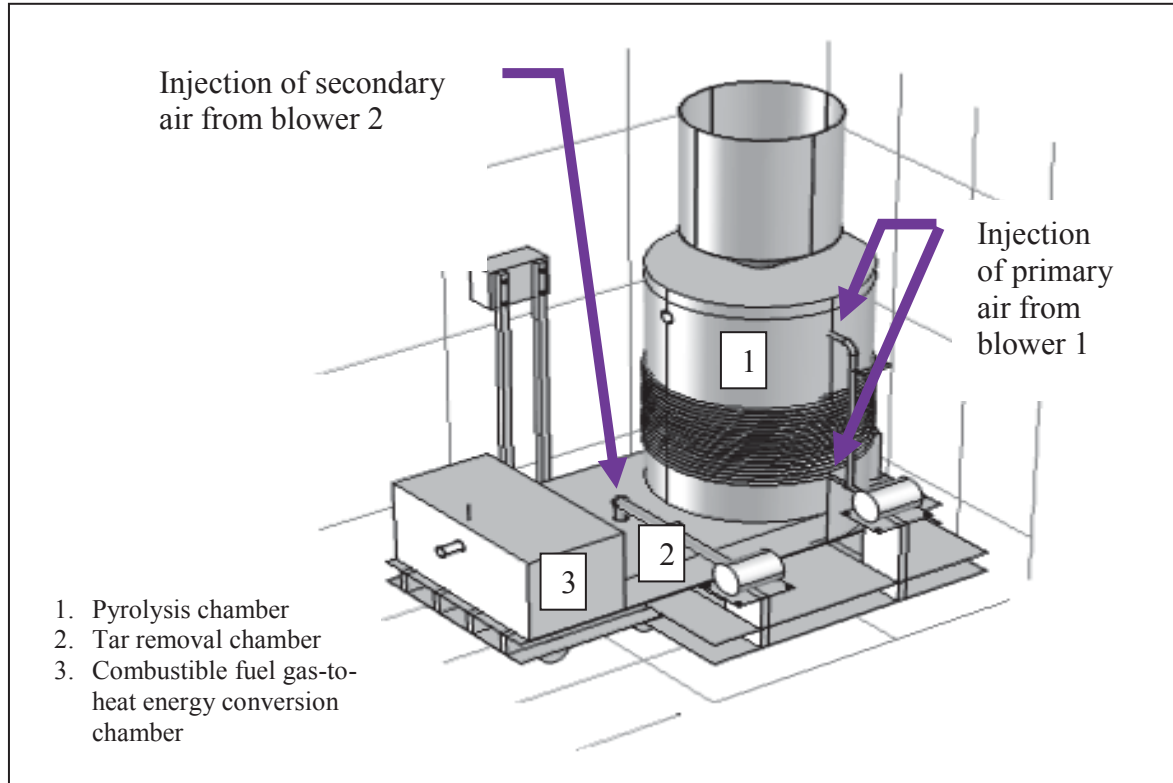


Figure 3.2: Design of B2H converter

3.3.1 Evaluation of Apparent Residence Time

The apparent residence time, as shown in **Equation (3.1)**, is defined as the ratio of the reactor volume to the inlet volumetric flow rate (Walas, 1990); it is a representation of how long it takes for the concentration of biomass to change significantly in the solid state; and it is typically used for the size rating of reactors for comparison (Brown, 2011). The total volume of the B2H converter (excluding the refractory) is 2.9 m^3 . The chosen inlet volumetric flow rate is $0.044 \text{ m}^3/\text{s}$ from Group A in Experiment (i). This inlet volumetric flow rate is chosen

in the apparent residence time calculation because it is the minimum excess air in this experimental research (**Table O 10**).

$$\bar{t}_{app} = \frac{V_r}{V'_o} = \frac{2.9m^3}{0.044m^3/s} = 65.91 s \quad (3.1)$$

where

$\bar{t}_{app}$ = apparent residence time, (s)

V_r = reactor volume, (m³)

V'_o = inlet volumetric flow rate (m³/s)

m = metre

s = second

3.3.2 Dimensions of B2H Converter

The diameter of the pyrolysis chamber can be calculated by **Equation (3.2)** from Green and Perry (2008). A cylindrical chamber with diameter D and height H equal to D has a nominal volume of:

$$V_{chamber} = \frac{\pi}{4} D^2 \times \left(H + \frac{\sqrt{3}}{2} D \right) = 1.47 D^3 \quad (3.2)$$

where

D = diameter

H = height

$V_{chamber}$ = nominal volume

Flow rate of drying gas: 0.0315 kg/s (from a blower with middle capacity between

VB-800G and VB-2200G)

Outlet gas density: 1.4 kg/m³ (at 316°C and 1.4 bar – a general operation temperature)

Apparent residence time: 65.91 seconds

$$V_{chamber} = \left(0.0315 \frac{kg}{s} \div 1.4 \frac{kg}{m^3} \right) 65.91 s = 1.48 m^3$$

$$D = \sqrt[3]{\frac{1.48 m^3}{1.47}} = 1.00 m$$

3.4 Development Concept

Generally, the main process of biomass combustion follows the sequence of preheating and drying, devolatilization/pyrolysis, gasification, char combustion, gas-phase oxidation (Loo & Koopejan, 2008). With an inclined horizontal biomass combustor, the biomass combustion reaction may experience a longer reaction time, leading to thorough combustion. The injection of primary air into the fuel chamber and consecutive secondary air injection into the combustion chamber enable good mixing of the combustible gases formed by the devolatilization and gasification in the fuel bed.

3.5 Development Specifications

The primary objective of Phase I is to design a B2H converter with the following specifications:

- High heat resistant concrete as filler between inner and outer linings, which can sustain temperature up to 1400°C (The B2E converter might break open due to use of normal concrete). According to Chong's previous experiment (2009), the maximum temperature inside the B2E pyrolysis chamber was around 900°C;
- Copper coil surrounded the pyrolysis chamber of B2H converter to minimize the heat waste;

- A semi-circular door 400mm by 300mm (minimum allowance for rake or broom) built at bottom of pyrolysis chamber for regular removal of slag;
- Outer diameter of pyrolysis chamber: 675.0 mm (in consideration of available rolling technology onsite and refractory thickness);
- Length of tar removal chamber: 1100.0 mm (in consideration of construction cost optimization); and
- An inclined tar removal chamber for tar removal enhancement (about 6° from horizontal in consideration of 11mm narrow outlet at tar removal chamber) (**Figures 3.5 and 3.6**).

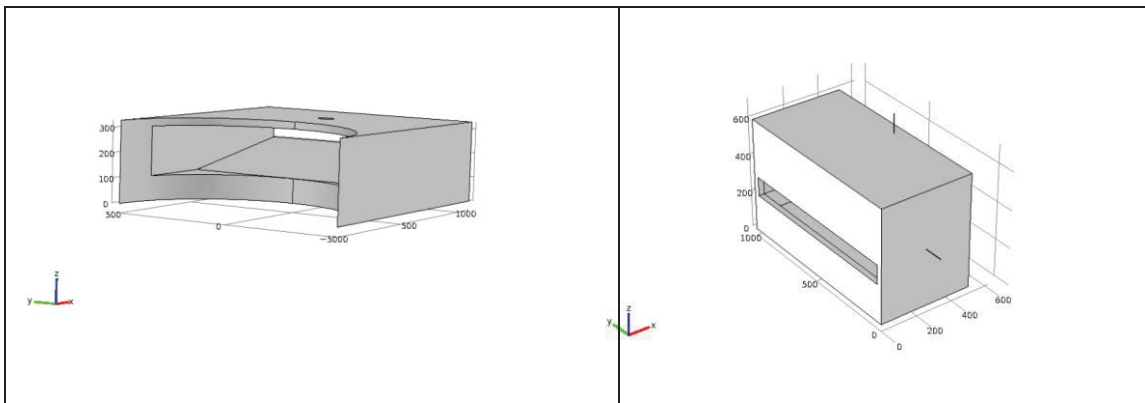


Figure 3.3: Inclined tar removal chamber (6° from horizontal layout)

Figure 3.4: 11mm narrow outlet at tar removal

3.6 Design of Individual Components

3.6.1 External Lining – Mild Steel Sheet

Mild steel is used as the external lining of the B2H converter because of its specific heat resistance properties. The purpose of the external lining is to provide a frame for lining of the refractory in the B2H converter. A 6 mm thickness mild steel sheet has been used in order to optimise the construction cost; a 12.5 mm ceramic fire blanket (model: DIMAL 1260) is

placed between the refractory and external lining to allow for thermal expansion. The specifications of this ceramic fire blanket are given in **Appendix A**. The total volume of the B2H converter (excluding the refractory) is 2.9 m³.

3.6.2 DIVAL 140 Refractory and Its Thickness

Refractory is used as filler between the inner and outer linings because of the following characteristics: the ability to withstand high temperatures of up to 1400°C, the ability to withstand sudden changes of temperature, and the low coefficient of thermal expansion of 8.8 dL/L.K.10⁶ (Racher, Road, & McConnell, 2014). Based on the previous experiment, the highest temperature that the B2E converter can sustain is about 900°C (the B2E converter broke open during the 3-month experimental trial). Therefore, a DIVAL 140 refractory that can sustain elevated temperatures is used. The application temperature for DIVAL 140 refractory is 1400°C. Technical data for DIVAL 140 refractory are presented in **Appendix B**. According to Bases (2002), the calculated refractory thickness on the 3E PLUS insulation thickness computer program, as shown in **Equation 3.3**, was 40 mm (NAIMA, 2005). A thickness of 100 mm with a safety factor of 2.5 is chosen for safety considerations (Eclipse, 2012). Detailed calculation of this refractory thickness can be found in **Appendix C1 – C3**.

Refractory thickness:

$$\text{Refractory thickness} = \left[\frac{T_o - T_s}{(1 + 0.225 \times V)(T_s - T_a) + (0.1714 \times \varepsilon) \times \left[\left(\frac{T_s + 460}{100} \right)^4 - \left(\frac{T_a + 460}{100} \right)^4 \right]} \right] \times K \quad (3.3)$$

where

T_o = operating temperature, °C

T_s = surface temperature, °C

V = velocity, m/s

T_a = ambient temperature, °C

ϵ = emissivity

K = thermal conductivity of refractory, W/(m.K)

The refractory in the pyrolysis chamber is compacted with a concrete vibrator to prevent void formation (**Figure 3.5**). The refractory combustor must allow for thermal expansion to permit the furnace shell, burner block and surrounding refractory to move as one unit in the event of unequal expansion of the refractory wall and furnace shell. The tar removal chamber is filled with a DIVAL 140 refractory 100 mm bottom, 30 mm top, and 30 mm side (wall). After casting, the refractory is allowed to cure for a minimum of 24 hours prior to initial operation. The surface is kept from drying out by continuous watering and covering with wetted cloth.



Figure 3.5: Refractory is compact with concrete vibrator to avoid void form

3.6.3 Anchor of Refractory – “V” Type

A “V” type mild steel anchor is chosen for the anchor, as it serves to secure the refractory when it experiences expansion during elevated temperatures (**Figure 3.6**). The length of wire

anchors allows the tips of the anchor to be positioned within a minimum of one inch (25.4 mm) behind the hot surface. Generally, the length of wire anchors measures approximately 0.75 of the lining thickness. The securing of the welded anchor is checked using the strike of a hammer. Anchors are welded in a square pattern to strengthen the gripping effect. The tine of each anchor is rotated 90° from its neighbouring anchors, as shown in **Figure 3.7**. A refractory thickness of about 101.6 mm and anchor length of 76.2 mm are recommended; a centre-to-centre anchor spacing of 304.8 mm is used (CANDEC, 2003).



Figure 3.6: “V” Type Anchor

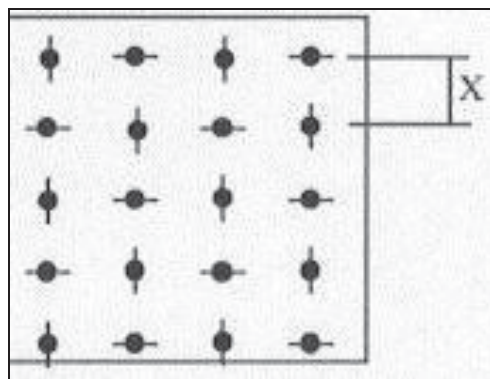


Figure 3.7: Square Pattern of Anchors
(adapted from CANDEC, 2003)

3.6.4 Ductwork

The duct is made of mild steel for economic reasons, as compared to more expensive stainless steel. The duct outer diameters for Blower-1 and Blower-2 are 1.5 inches and 3 inches, respectively and according to the recommendations of Eclipse (1986). The duct is divided into two sections, the pyrolysis chamber and tar removal chamber. Ball valves are connected to each duct channel to regulate and obtain the desired air flow. The detailed layout of the duct is shown in **Figure 3.8**.

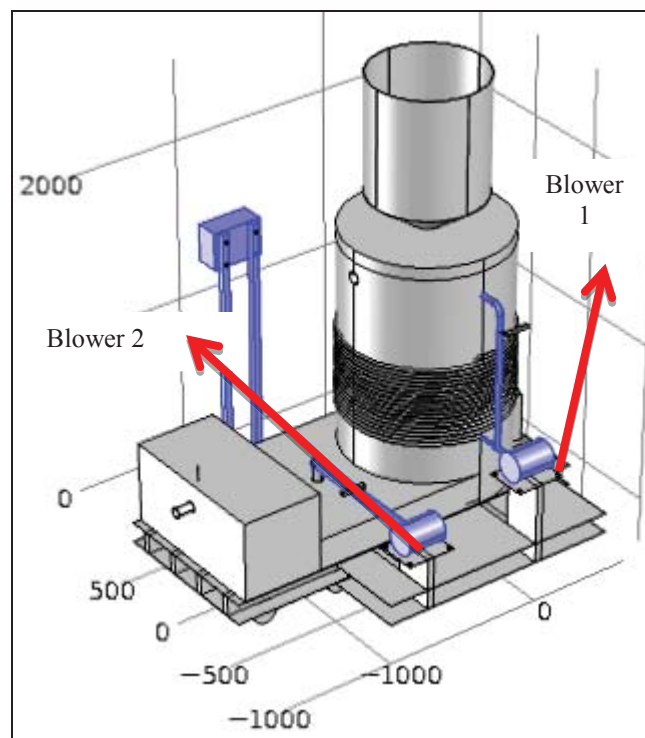


Figure 3.8: Ductwork of B2H converter

3.6.5 HAILEA VB-800G and VB-2200G Impeller Blower Pump

HAILEA VB-800G and VB-2200G impeller blower pumps are used to introduce air as an oxidant for the primary and secondary air inlets (**Figures 3.11–3.12**); they are capable of delivering 1000 litre/min and 2100 litre/min at 2900 rotations/min and 2840 rotations/min,

respectively. **Table 3.1** shows the specifications of the HAILEA VB-800G and VB-2200G impeller blower pumps (**Appendix D**).

Table 3.1: Specifications of HAILEA Blowers

Model	Voltage	Frequency	Rotations / min	Litre/min	Mpa	Weight	Size
VB-800G	110/220V	50/60Hz	2900	1000	0.015	15.4 kg	295x295x305mm
VB-2200G	380V	50Hz	2840	2100	0.022	22.5 kg	330x315x450mm



Figure 3.9: HAILEA VB-800G



Figure 3.10: HAILEA VB-2200G

3.6.6 Type K (Chromel – Alumel) Thermocouple

A type-K thermocouple, as shown in **Figure 40**, is fixed on the inside of the pyrolysis chamber (distances for the head of the thermocouple and the inner wall are around 40 mm) (**Figure 41**) to (a) monitor the temperatures of the pyrolysis chamber during combustion, and (b) obtain the horizontal combustor temperature profiles. It is important to measure the temperature profile within the combustor because, if there are hot spots in the combustor, the B2H converter may be subjected to thermal stress or other types of damage (Mattingly, Heiser, & Pratt, 2003). The measurements of temperature profiles can be used to obtain

quantitative kinetic and thermodynamic information (Boddington, Laye, Pude, & Tipping, 1982).

The type-K thermocouple is a temperature sensor that consists of two dissimilar materials in thermal contact: chromel as the positive leg and nickel-5% aluminium and silicon as the negative leg (Pyromation, 2012). When these two junctions are kept at different temperatures, a small electric current is induced; a voltage drop occurs due to the flow of current – a drop that depends on the temperature difference between the two junctions. Then, the measurement of the voltage drop can be correlated with this temperature difference. The type-K thermocouple in this experiment can operate in continuous temperatures as high as 1,204°C and its accuracy is $\pm 0.75^{\circ}\text{C}$ (PMC, 2012). The product details are included in **Appendix E**. However, the performance of the type-K thermocouple degrades rapidly at temperatures exceeding 1,050°C; thermal instability occurs after 100 to 1,000 hours' exposure (James, William, & Kenneth, 1993).

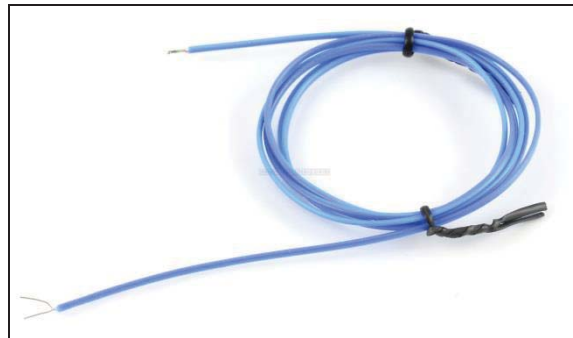


Figure 3.11: Type K (Chromel-Alumel) Thermocouple
(adapted from RobotItaly, 2012)

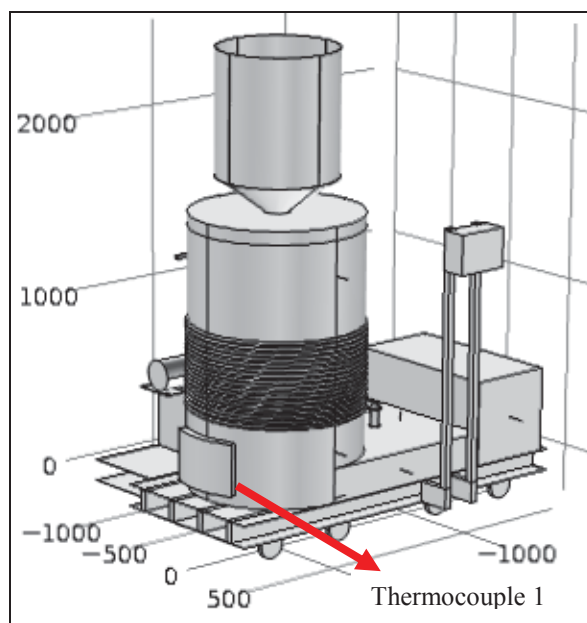


Figure 3.12: Positions and location of thermocouple at B2H converter

3.7 Fabrication of B2H Converter

Fabrication of the B2H converter focuses on its construction and installation. It is worth noting that the technical and operational strengths and shortcomings of B2E and B2F have been considered with respect to the design and operational elements of the B2H converter. The pyrolysis chamber is fabricated by Kiong Shen Machinery Sdn. Bhd. (Kuching) because of the availability of the rolling machine. The tar removal chamber and combustible fuel gas-to-heat energy conversion chamber are fabricated at UNIMAS's Chemical Engineering general workshop.

3.7.1 Three Dimensional Drawings of B2H Converter

Appendix F provides the geometrical and dimensional details of the B2H converter, including the pyrolysis chamber, the tar removal chamber and the combustible fuel gas-to-heat-energy conversion chamber.

3.7.2 Fabrication Process of B2H Converter

Table 3.2 shows the B2H converter fabrication process and priority. The sequence of fabrication for the B2H converter is purchase material, B2H-based, anchor of refractory, B2H converter structure, refractory lining, connection of piping and hopper, installation of thermocouple and its display board.

Table 3.2: B2H converter fabrication process

Priority	Task
1.	Purchase material
2.	B2H based
3.	Anchor of refractory
4.	B2H converter structure (lining)
5.	Refractory lining
6.	Connection of piping and hopper
7.	Installation of thermocouple and its display board

3.8 Concluding Remarks

In this first part, a B2H converter was developed. The B2H converter was designed according to such criteria as design specifications, development concept, development specifications and design of individual components. With this geometrical and dimensional design, the B2H converter is produced and then fabricated. The diameter of the pyrolysis chamber is 1,000 mm. Considering the unavailability of technology onsite and the 200 mm refractory thickness, the inner diameter was adjusted to 575 mm and the height to 1600 mm. The actual inner dimensions (width, length and height) of the rectangular tar converter chamber are 724.1 mm, 1100 mm and 184.6 mm, respectively; those of the combustible fuel gas-to-heat energy conversion chamber are 775 mm, 500 mm and 500 mm, respectively.

3.9 Evaluation Procedure of B2H Converter

This section describes the components of the experimental set-up for the research on the effect of the air velocity ratio on a horizontal combustor's temperature profile, flue gas composition (CO , NO_x and SO_2) and combustion efficiency. To fill in the gap identified in the literature, the development (design and fabrication) of a horizontal B2H converter must take place (**Phase I**). The experimental set-up enables **Phase II**, which emphasizes the evaluation of the B2H converter and includes the sample preparation for OPKS and wood chips, and the instrumentation for data collection (**Figure 3.13**). **Figure 3.14** illustrates the layout of the experimental site for the B2H converter at UNIMAS's Chemical Engineering heat transfer laboratory. All the laboratory windows and doors were opened and a fire extinguisher was in place during the experiment to ensure a safe environment.

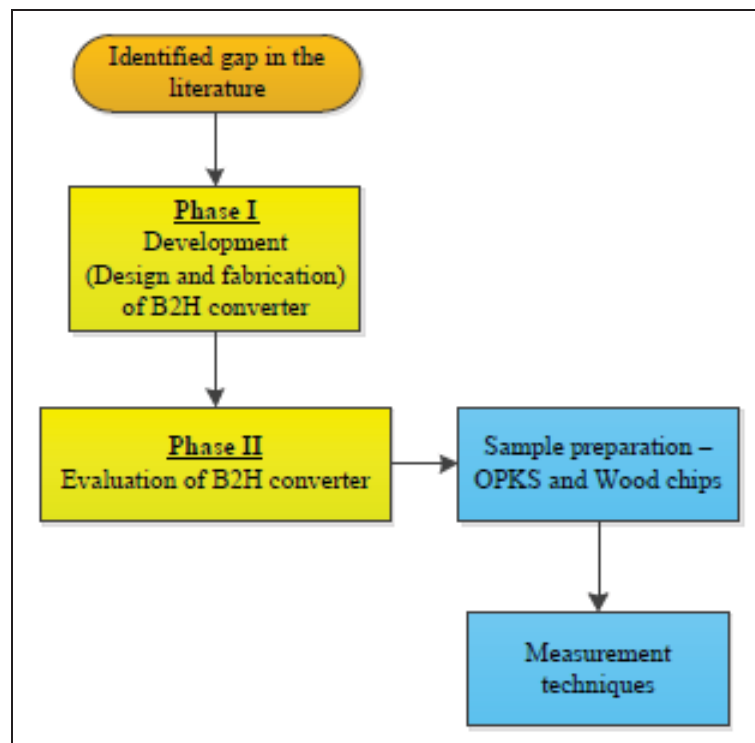


Figure 3.13: Flow chart of research methodology

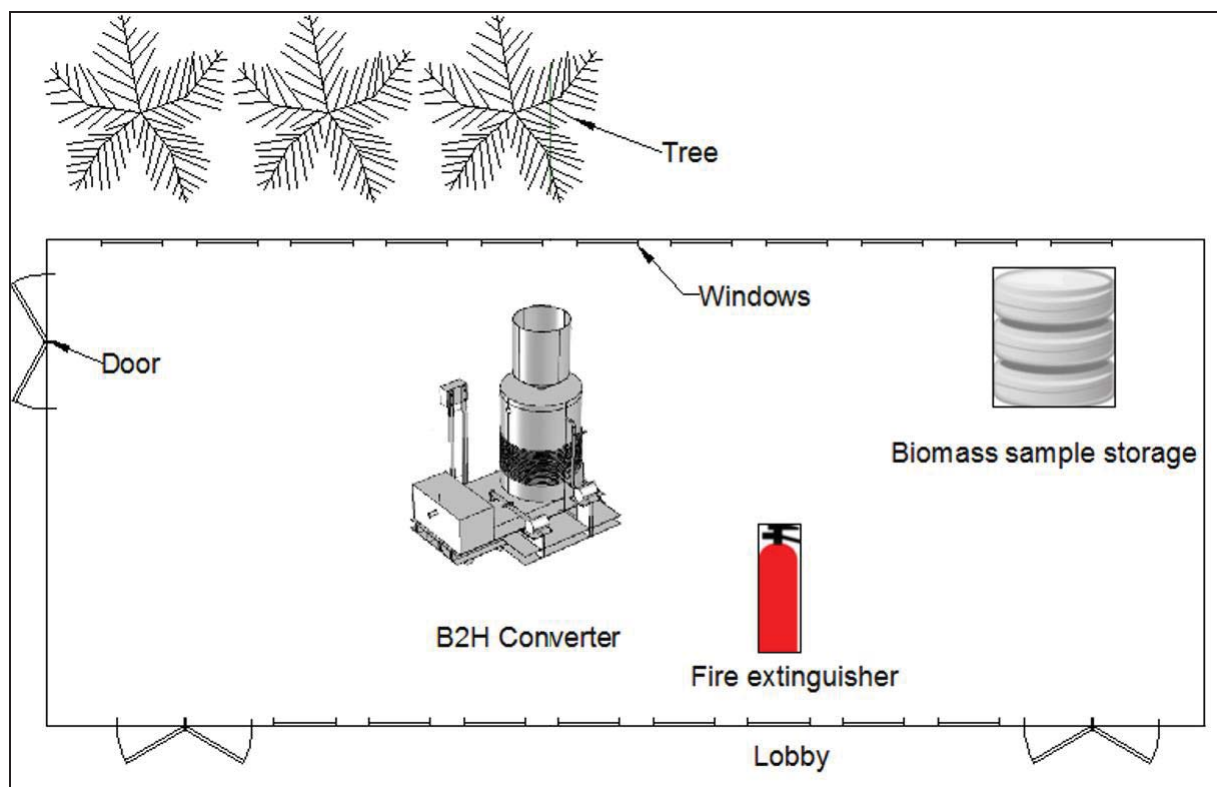


Figure 3.14: Layout of the evaluation of B2H converter

3.10 Sample Preparation – OPKS and Wood Chips

An estimated 200 kg of fresh OPKS was collected from Bau Palm Oil Mill Sdn. Bhd.; for representative samplings, the samples were collected and mixed from five different spots of the heap storage, as shown in **Figure 3.15**. The mean size of the OPKS measured 10.4 mm (width) by 4.8 mm (thick) by 12.8 mm (length). The moisture content of the OPKS, as determined by previous researchers, such as Zafar (2013) and Dagwa, Builders, and Achebo (2012), is within the range of 11–13% wt. The wood chips were collected from a furniture factory at Kota Samarahan; the sample was mixed, divided and covered to avoid adulteration; the weight of the specimen sample was measured and it was dried under the hot sun for about seven days (**Figure 3.16**). Seven days was chosen as coconut kernel typically only takes five days to reach 8% of moisture content (Frank, John, & Albert, 2007).

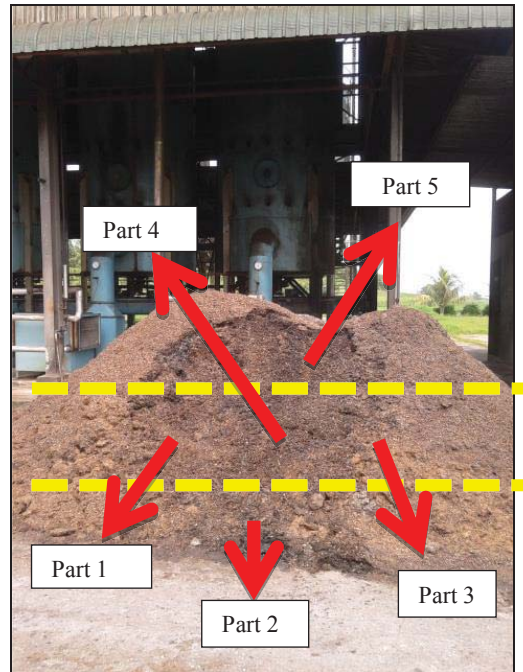


Figure 3.15: Mixing of sample in different parts (OPKS)



Figure 3.16: Drying OPKS under hot sun

3.11 Measurement Techniques with Instrumentation

Four instruments are used in this experimental research. Firstly, the Shimadzu DTG-60H thermal analyser is used to evaluate the sample's thermal characteristics by measuring its weight – temperature histories; secondly, a Binder drying oven is used to determine the

sample moisture content by measuring its weight loss; thirdly, a Dwyer VT120 integral vane thermo-anemometer is used to determine the air flow rate by measuring the superficial air velocity from the blowers; and lastly, a Testo 350 XL flue gas analyser is used to determine the flue gas composition (CO, NO, NO₂, NO_x, SO₂, H₂ and O₂), combustion efficiency, exhaust temperature and surrounding temperature at the exhaust of the B2H converter at various air velocity ratios (AVR). A brief description of the instrumentation used in this work is given in sections 3.11.1 to 3.11.4.

3.11.1 Shimadzu DTG-60H Thermal Analyser

The Shimadzu DTG-60H thermal analyser (**Figure 3.17**) provides thermogravimetry analysis (TGA) on a single sample (**Appendix G**). It gives the thermal properties of the sample including the transition temperature, melting point, and reaction temperature, regardless of thermal change or change in weight. The information on the chemical changes can be due to adsorption and decomposition or physical changes such as fusion.

The thermal analysis of the sample was conducted at UNIMAS's Chemical Engineering analytical laboratory. The operating procedure of the Shimadzu DTG-60H thermal analyser was according to its manual (Shimadzu, 2006). First, two clean sample pans were prepared. A reference substance with twice the weight of the sample was put in one pan (α -alumina powder). The pan containing the reference material was put on the left stage of the detector plate; the other pan containing the 20 mg sample was put on the right stage. The thermogravimetry signal (weight value) was delayed until it was stabilized. Atmosphere gas was supplied (the purge gas flow rate is set to 60 ml/min). The temperature range was set at between 20°C and 900°C. The rate of temperature was set at 10°C/min as this would increase

the resolution of the result (Salin & Seferis, 1993). Finally, data acquisition, analysis and reporting were carried out through the TA60WS device within the system. This procedure was repeated three times for the selected biomass samples.



Figure 3.17: Shimadzu DTG-60H thermal analyser

3.11.2 Binder Drying Oven

The moisture content of the sample was determined at UNIMAS's Chemical Engineering analytical laboratory according to the British Standard EN 1477-2:2009 (British Standard Institute, 2009) with a Binder drying oven using natural convection (**Figure 3.18**). The size of the investigated sample was ground to (1.0 ± 0.1) mm, and the weight at all times was around 200 g.

A brief description of the operating procedure of the Binder drying oven is given here: First, an empty clean drying container was weighed (**Figure 3.19**) to the nearest 0.1 g and the sample investigated was transferred to the drying container. Then, the drying container with the sample was weighed to the nearest 0.1 g, and dried in the Binder drying oven with

convection controlled at $(100 \pm 0.5)^\circ\text{C}$ (**Figure 3.18**) and weighed again after drying. Finally, the drying container with the sample was heated until constancy in mass was achieved. Constancy in mass is defined as a change not exceeding 0.2% of the total loss in mass during a further period of heating at $(100 \pm 0.5)^\circ\text{C}$ over a period of 60 min.

The moisture content, M_{ar} , of the investigated sample (as received), expressed as % of total mass, is calculated using **Equation 3.4**. The result is reported on a wet basis.

$$M_{ar} = \frac{(m_2 - m_3) + m_4}{(m_2 - m_1) + m_4} \times 100 \quad (3.4)$$

where

M_{ar} = the moisture content in the sample as received

m_1 = the mass in g of the empty drying container

m_2 = the mass in g of the drying container and sample before drying

m_3 = the mass in g of the drying container and sample after drying

m_4 = the mass in g of the moisture associated with the packing

The results are calculated to two decimal places and rounded to the nearest 0.1% for reporting. This procedure is repeated five times from the collected bulk sample.



Figure 3.18: Binder drying oven with natural convection



Figure 3.19: Analytical balance

3.11.3 Dwyer VT120 Integral Vane Thermo-Anemometer

The mean superficial air velocity of the HAILEA VB-800G and VB-2200G impeller blower pumps for Levels 0, 1, 2 and 3 were determined using a Dwyer VT120 integral vane thermo-anemometer at UNIMAS's Chemical Engineering heat transfer laboratory (**Figure 3.20**). The Dwyer VT120 integral vane thermo-anemometer can perform the minimum, maximum and mean readings of the measured superficial velocity. First, the air supply adjustment was regulated to Level 1, and the air's superficial exit velocity was detected at the B2H exhaust. The air or exit velocities for Levels 2 and 3 were measured using the same procedure. Specific operations of the Dwyer VT120 integral vane thermo anemometer are included in **Appendix H**.



Figure 3.20: Dwyer VT120 integral vane thermo anemometer

3.11.4 Testo 350XL Flue Gas Analyser

The flue gas composition (CO , NO , NO_2 , NO_x , SO_2 , H_2 and O_2), the combustion efficiency, the exhaust temperature and surrounding temperature were measured at the exhaust of the B2H converter with the Testo 350XL flue gas analyser, as shown in **Figures 3.21–22**. The Testo 350XL flue gas analyser was equipped with measurement modules for measuring oxygen, O_2 (0–25%) in the flue gas after combustion has occurred; for carbon monoxide, CO (0–10,000 parts per million by volume-ppmv), a dangerous by-product produced by incomplete combustion; for nitric oxide, NO (0–3,000 ppmv), a by-product of combustion, also called mononitrogen monoxide or nitrogen monoxide and for nitrogen dioxide, NO_2 (0–500 ppmv). All the measured values were referenced to 7% vol. O_2 . The measurement accuracies were as follows: $\pm 0.5\%$ for the temperature; $\pm 0.2\%$ vol. for O_2 ; $\pm 5\%$ for CO ; ± 5 ppmv for NO_2 ; ± 5 ppmv for NO ; ± 5 ppm for SO_2 (**Appendix I**). The flue gas concentration was measured by an NDIR (non-dispersive infrared) detector. In this method, the sample gases were pumped into the analyser box through which infrared light passed and,

specifically, the wavelength of the infrared light was selected depending on which of the gas components was to be detected. The components of the flue gas absorbed infra-red light, thereby reducing the light intensity, which was then compared against a reference infrared light source. The resulting difference was expressed as concentration of the specific gas component (Horiba, 2001). The Testo 350XL flue gas analyser has a Peltier gas preparation with a peristaltic hose pump for the controlled removal of condensate as well as a fresh air valve for long-term measurement over several hours.

The emission analyser was calibrated regularly before conducting the experiments (**Appendix J**). The operating procedure of the Testo 350XL flue gas analyser was according to Testo (Testo, 2012) and the BS EN 14181:2004 (British Standard Institute, 2004). Firstly, a gas sampling probe was located at the middle of the exhaust through the extended pipe for correct measurement as suggested by Testo (2012) (**Figure 3.23**). Measurement was taken during the operating condition; the data was logged in the control unit. The mean value was based on the data logged every second for a 2-minute interval. An estimated 3.0 kg of the selected biomass was allocated inside the pyrolysis chamber; around three litres of methanol were poured and mixed evenly with the selected biomass. Then, ignition of the biomass combustion was started from the surface of the biomass as this would reduce the emission of CO and NO_x (Bhattacharya et al., 2002). The principles of the calculation of the above parameters are included in **Appendix K** (Testo, 2012).

3.11.4.1 Measurement of Combustion Efficiency

The combustion efficiency in this study is determined directly by the Testo 350XL flue gas analyser. This measured combustion efficiency is a calculation of the maximum heat

available in the combustion process minus the exhaust losses. It should be noted that this is a modified equation that considers combustion efficiency and stack losses: it is a part thermal, part combustion efficiency calculation and it is applied in most of the current manufactured analysers (Bergmann, 2005). The assumption in this formula is that either all latent heat energy has been extracted from the flue gases after they have reached the dew point or none of the latent heat energy has been extracted; therefore, this combustion efficiency will be a function of the actual dry flue gas, and not of the thermal efficiency of a condensing appliance (Testo 2005, p. 9–10). Moreover, it is an indication of the total amount of heat available from the fuel minus the losses from the exit gases from the B2H exhaust, as proposed by the manufacturer (**Equation 3.5**) (Testo, 2004). **Equation (3.6)** is also known as the Siegert formula. Stack loss is a measure of the heat carried away by dry flue gases and the moisture loss, and the combustion efficiency does not include the unburned carbon and incomplete combustion.

$$\eta = 100 - qA \quad (3.5)$$

$$qA = f \times \frac{FT - AT}{CO_2} \quad (3.6)$$

where

η	= combustion efficiency
qA	= calculated flue gas loss
f	= fuel specific factor
FT	= flue gas temperature
AT	= ambient air temperature
CO_2	= maximum carbon dioxide from the fuel

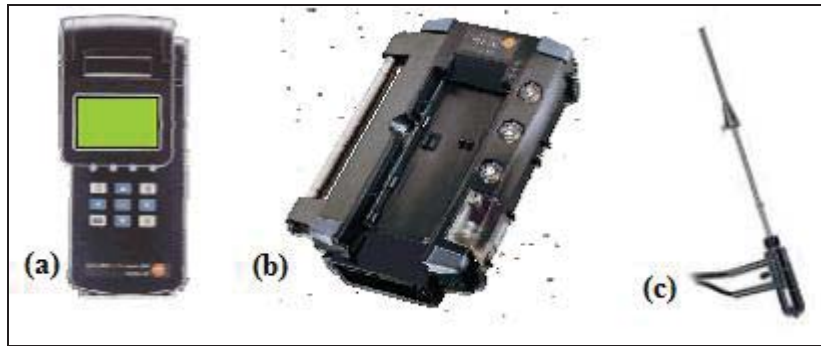


Figure 3.21: Components of Testo 350XL flue gas analyser (a) Control Unit; (b) Analyser Box; (c) Gas Sampling Probe (adopted from Testo, 2012)



Figure 3.22: Gas sampling probe located in the middle of B2H exhaust

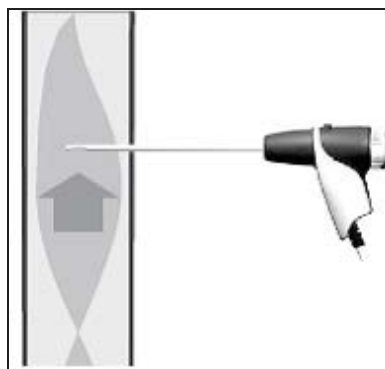


Figure 3.23: The correct measurement method (adapted from Testo, 2012)

3.11.4.2 Flue Gas Experimental Procedures

Flue gas experiments were conducted at UNIMAS's Chemical Engineering heat transfer laboratory, as illustrated in the schematic of the flue gas experiment (**Figure 3.24**). Three groups of flue gas experiment trials were carried out in this study. Air velocities of 9.65 m/s and 5.79 m/s from blower VB-2200G were selected as these are the maximum and minimum air velocity according to the experiment. Air velocities of 4.00 m/s and 3.83 m/s from blower VB-800G were selected as these are the maximum and minimum air velocity according to the experiment (**Appendix N**).

A) **Group A:** To study the influence of the air velocity ratio (AVR) on OPKS with AVR = 9.65 m/s : 0.00 m/s, 9.65 m/s : 3.83 m/s and 9.65 m/s : 4.00 m/s.

In Group A, a *non-ideal* air staging method is applied to examine the effect of the air velocity ratio on the horizontal combustor's temperature profile, flue gas composition and combustion efficiency. This was achieved through the creation of a fuel-lean zone (with a stoichiometric ratio more than 1) in the pyrolysis chamber, then a fuel-rich zone (stoichiometric ratio less than 1) in the tar removal chamber. The Group A (*non-ideal* air staging method) set-up allows a clear comparison with Group B (*ideal* air staging method).

B) **Group B:** To study the influence of the air velocity ratio on OPKS with AVR = 4.00 m/s : 0.00 m/s, 4.00 m/s : 5.79 m/s and 4.00 m/s : 9.65 m/s.

In Group B, an *ideal* air staging method is applied to examine the effect of the air velocity ratio on the horizontal combustor's temperature profile, flue gas composition and combustion efficiency. This was achieved through the creation of a fuel-rich zone (stoichiometric ratio

less than 1) in the pyrolysis chamber, then a fuel-lean zone (stoichiometric ratio more than 1) in the tar removal chamber. Section 2.11, (ii), (a) includes the detail of the air staging method.

C) **Group C:** To compare the results of OPKS and wood chips with AVR = 3.83 m/s : 9.65 m/s.

In Group C, an *ideal* air staging method (with the optimum AVR obtained through Groups A and B) is applied to examine the effect of the air velocity ratio on the horizontal combustor's temperature profile, flue gas composition and combustion efficiency with OPKS and wood chips. This was achieved through the creation of a fuel-rich zone (stoichiometric ratio less than 1) in the pyrolysis chamber, then a fuel-lean zone (stoichiometric ratio more than 1) in the tar removal chamber. This allows a clear comparison of the result for the selected biomass.

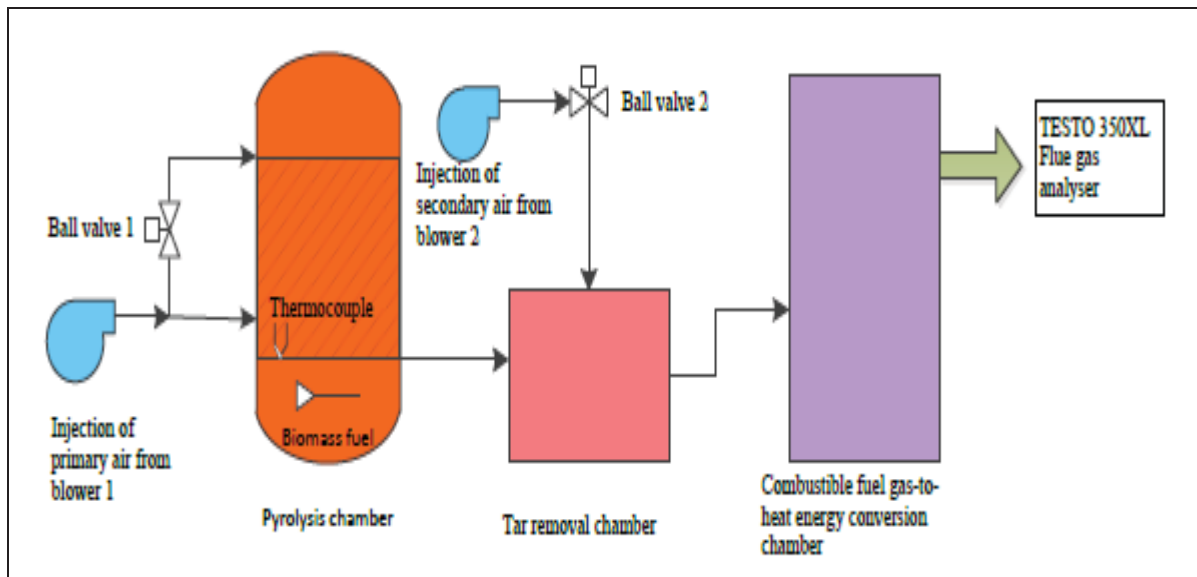


Figure 3.24: Schematic of flue gas experiment

Experimental procedures and setups of the three categories are as follows:

- A) Group A: To study the influence of the air velocity ratio on OPKS with AVR = 9.65 m/s : 0.00 m/s, 9.65 m/s : 3.83 m/s and 9.65 m/s : 4.00 m/s.**

Experimental Set (i):

A total of three tests were carried out: To study the optimum air velocity ratio at the pyrolysis chamber of 9.65 m/s and tar removal chamber of 0.00 m/s with about 3.0 kg of OPKS and about 3.0 litres of methanol, as shown in **Table 3.3**.

Experimental Set (ii):

A total of three tests were carried out: To study the optimum air velocity ratio at the pyrolysis chamber of 9.65 m/s and tar removal chamber of 3.83 m/s with about 3.0 kg of OPKS and about 3.0 litres of methanol, as shown in **Table 3.4**.

Experimental Set (iii):

A total of three tests were carried out: To study the optimum air velocity ratio at the pyrolysis chamber of 9.65 m/s and tar removal chamber of 4.00 m/s with about 3.0 kg of OPKS and about 3.0 litres of methanol, as shown in **Table 3.5**.

- B) Group B: To study the influence of the air velocity ratio on OPKS with AVR = 4.00 m/s : 0.00 m/s, 4.00 m/s : 5.79 m/s and 4.00 m/s : 9.65 m/s.**

Experimental Set (iv):

A total of three tests were carried out: To study the optimum air velocity ratio at the pyrolysis chamber of 4.00 m/s and tar removal chamber of 0.00 m/s with about 3.0 kg of OPKS and about 3.0 litres of methanol, as shown in **Table 3.6**.

Experimental Set (v):

A total of three tests were carried out: To study the optimum air velocity ratio at the pyrolysis chamber of 4.00 m/s and tar removal chamber of 5.79 m/s with about 3.0 kg of OPKS and about 3.0 litres of methanol, as shown in **Table 3.7**.

Experimental Set (vi):

A total of three tests were carried out: To study the optimum air velocity ratio at the pyrolysis chamber of 4.00 m/s and tar removal chamber of 9.65 m/s with about 3.0 kg of OPKS and about 3.0 litres of methanol, as shown in **Table 3.8**.

C) Group C: To compare the results of OPKS and wood chips with AVR = 3.83 m/s : 9.65 m/s.

Experimental Set (vii):

A total of three tests were carried out: To study the results at the pyrolysis chamber of 3.83 m/s and tar removal chamber of 9.65 m/s with about 3.0 kg of OPKS and about 3.0 litres of methanol, as shown in **Table 3.9**.

Experimental Set (viii):

A total of three tests were carried out: To study the results at the pyrolysis chamber of 3.83 m/s and tar removal chamber of 9.65 m/s with about 3.0 kg of wood chips and about 3.0 litres of methanol, as shown in **Table 3.10**.

Table 3.3: AVR for Experiment Set (i)

Air velocity		Flue gas composition							PT, °C	FT, °C	AT, °C	Operating period, min
B1, m/s	B2, m/s	CO, ppmv	NO, ppmv	NO ₂ , ppmv	NO _x , ppmv	SO ₂ , ppmv	H ₂ , ppmv	O ₂ , %				
9.65	0.00	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	20 – 110
9.65	0.00	Test 2	Test 2	Test 2	Test 2	Test 2	Test 2	Test 2	Test 2	Test 2	Test 2	20 – 110
9.65	0.00	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3	20 – 110

B – Blower

PT – Mean pyrolysis chamber temperature

FT – Mean exhaust temperature

AT – Mean surrounding temperature

Table 3.4: AVR for Experiment Set (ii)

Air velocity		Flue gas composition							PT, °C	FT, °C	AT, °C	Operating period, min
B1, m/s	B2, m/s	CO, ppmv	NO, ppmv	NO ₂ , ppmv	NO _x , ppmv	SO ₂ , ppmv	H ₂ , ppmv	O ₂ , %				
9.65	3.83	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	20 – 110
9.65	3.83	Test 2	Test 2	Test 2	Test 2	Test 2	Test 2	Test 2	Test 2	Test 2	Test 2	20 – 110
9.65	3.83	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3	20 – 110

B – Blower

PT – Mean pyrolysis chamber temperature

FT – Mean exhaust temperature

AT – Mean surrounding temperature

Table 3.5: AVR for Experiment Set (iii)

Air velocity		Flue gas composition							PT, °C	FT, °C	AT, °C	Operating period, min
B1, m/s	B2, m/s	CO, ppmv	NO, ppmv	NO ₂ , ppmv	NO _x , ppmv	SO ₂ , ppmv	H ₂ , ppmv	O ₂ , %				
9.65	4.00	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	20 – 110
9.65	4.00	Test 2	Test 2	Test 2	Test 2	Test 2	Test 2	Test 2	Test 2	Test 2	Test 2	20 – 110
9.65	4.00	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3	20 – 110

B – Blower

PT – Mean pyrolysis chamber temperature

FT – Mean exhaust temperature

AT – Mean surrounding temperature

Table 3.6: AVR for Experiment Set (iv)

Air velocity		Flue gas composition							PT, °C	FT, °C	AT, °C	Operating period, min
B1, m/s	B2, m/s	CO, ppmv	NO, ppmv	NO ₂ , ppmv	NO _x , ppmv	SO ₂ , ppmv	H ₂ , ppmv	O ₂ , %				
4.00	0.00	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	20 – 110
4.00	0.00	Test 2	Test 2	Test 2	Test 2	Test 2	Test 2	Test 2	Test 2	Test 2	Test 2	20 – 110
4.00	0.00	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3	20 – 110

B – Blower

PT – Mean pyrolysis chamber temperature

FT – Mean exhaust temperature

AT – Mean surrounding temperature

Table 3.7: AVR for Experiment Set (v)

Air velocity		Flue gas composition							PT, °C	FT, °C	AT, °C	Operating period, min
B1, m/s	B2, m/s	CO, ppmv	NO, ppmv	NO ₂ , ppmv	NO _x , ppmv	SO ₂ , ppmv	H ₂ , ppmv	O ₂ , %				
4.00	5.79	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	20 – 110
4.00	5.79	Test 2	Test 2	Test 2	Test 2	Test 2	Test 2	Test 2	Test 2	Test 2	Test 2	20 – 110
4.00	5.79	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3	20 – 110

B – Blower

PT – Mean pyrolysis chamber temperature

FT – Mean exhaust temperature

AT – Mean surrounding temperature

Table 3.8: AVR for Experiment Set (vi)

Air velocity		Flue gas composition							PT, °C	FT, °C	AT, °C	Operating period, min
B1, m/s	B2, m/s	CO, ppmv	NO, ppmv	NO ₂ , ppmv	NO _x , ppmv	SO ₂ , ppmv	H ₂ , ppmv	O ₂ , %				
4.00	9.65	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	20 – 110
4.00	9.65	Test 2	Test 2	Test 2	Test 2	Test 2	Test 2	Test 2	Test 2	Test 2	Test 2	20 – 110
4.00	9.65	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3	20 – 110

B – Blower

PT – Mean pyrolysis chamber temperature

FT – Mean exhaust temperature

AT – Mean surrounding temperature

Table 3.9: AVR for Experiment Set (vii)

Air velocity		Flue gas composition							PT, °C	FT, °C	AT, °C	Operating period, min
B1, m/s	B2, m/s	CO, ppmv	NO, ppmv	NO ₂ , ppmv	NO _x , ppmv	SO ₂ , ppmv	H ₂ , ppmv	O ₂ , %				
3.83	9.65	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	20 – 110
3.83	9.65	Test 2	Test 2	Test 2	Test 2	Test 2	Test 2	Test 2	Test 2	Test 2	Test 2	20 – 110
3.83	9.65	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3	20 – 110

B – Blower

PT – Mean pyrolysis chamber temperature

FT – Mean exhaust temperature

AT – Mean surrounding temperature

Table 3.10: AVR for Experiment Set (viii)

Air velocity		Flue gas composition							PT, °C	FT, °C	AT, °C	Operating period, min
B1, m/s	B2, m/s	CO, ppmv	NO, ppmv	NO ₂ , ppmv	NO _x , ppmv	SO ₂ , ppmv	H ₂ , ppmv	O ₂ , %				
3.83	9.65	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	Test 1	20 – 110
3.83	9.65	Test 2	Test 2	Test 2	Test 2	Test 2	Test 2	Test 2	Test 2	Test 2	Test 2	20 – 110
3.83	9.65	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3	Test 3	20 – 110

B – Blower

PT – Mean pyrolysis chamber temperature

FT – Mean exhaust temperature

AT – Mean surrounding temperature

Chapter 4 RESULTS

4.1 Introduction

This chapter reports on the **Phase I** results for the development (design and fabrication) of a B2H converter with a horizontal air-staged design for drying purposes; and on **Phase II**, which includes the thermal properties and moisture content of selected biomass samples, the blower air flow rate of different experiments, and the effects of the air velocity ratio on the horizontal combustor's (B2H) flue gas composition, temperature profile and combustion efficiency. In addition, the statistical analysis for Experiment (vii) with the lowest CO emissions is discussed here.

4.2 Specification of Developed B2H Converter

A B2H converter was developed according to the specific objective in **Section 1.4**. The key features of the B2H converter were as follows: 6 mm mild steel used as the inner lining; highly heat-resistant concrete (up to 1400°C) as filler between the inner and outer linings; the pyrolysis chamber of the B2H converter surrounded with copper coil; a semi-circular door of 400 mm × 300 mm at the bottom of the combustion chamber for removal of slag; diameter of combustion chamber of 675 mm; length of tar removal chamber of 1,100 mm; an inclined tar removal chamber (about 6° from the horizontal) for enhanced tar removal (**Figure L 77**).

The B2H converter was fabricated according to this design and the diameter of the pyrolysis chamber was 1,000 mm. Taking into consideration the 200 mm refractory thickness, the inner diameter would be 575 mm and the height 1,600 mm; however, the actual inner dimensions

(width, length and height) of the rectangular tar converter chamber were 724.1 mm, 1100 mm and 184.6 mm, respectively and the dimensions (width, length and height) of the combustible fuel gas-to-heat energy conversion chamber were 775 mm, 500 mm and 500 mm, respectively. Detailed B2H converter fabrication photos are attached in **Appendix L**.500mm, respectively. Detailed B2H converter fabrication photos are attached in **Appendix L**.

4.3 Experimental Results

4.3.1 Thermal Property of Selected Biomass Samples

Experimental trials to determine the thermal properties of the selected biomass samples were conducted with alumina as the cell, an air flow rate of 60 ml/min, sample weight of 20 mg, and temperature rate of 10°C/min. The thermogravimetric analysis (TGA) results for the OPKS and wood chips samples were generated by TA60WS software and are shown in **Figures 4.1–4.4**, and **4.5–4.8**, respectively.

A) TGA Analysis Results of the Investigated OPKS

Table 4.1 and **Figures 4.1–4.4** illustrate the thermal analysis outcome of the investigated OPKS. It was observed that all three samples of OPKS had undergone four stages of transition, which correlated well with the theory of biomass combustion for drying, pyrolysis, gasification and combustion of Loo and Koopejan (2008).

The drying process of the selected OPKS Samples 1, 2, and 3 occurred mainly within the temperature ranges of 28–190°C, 28–190°C and 28–170°C, respectively (**Table 4.1**) and the mean drying temperature of the selected OPKS was between 28°C and 183.33°C. The observed pyrolysis temperatures of OPKS Samples 1, 2 and 3 occurred mainly within the

ranges of 190–305°C, 190–295°C and 170–300°C, respectively and the mean pyrolysis temperatures of OPKS samples ranged from 183.33°C to 300°C. The gasification process of the OPKS Samples 1, 2 and 3 occurred mainly within the temperature ranges of 305–380°C, 295–370.00°C and 300–370°C, respectively and the mean gasification temperature of the OPKS samples was approximately 300–373.33°C. The observed combustion temperatures of the OPKS Samples 1, 2 and 3 occurred mainly within the ranges of 380–900°C, 370–900°C and 370–900°C, respectively and the mean combustion temperature of the OPKS samples was between 373.33°C and 900°C.

The weight loss percentages of the OPKS samples are shown in **Table 4.2**. The weight loss percentages of OPKS Sample 1 for the drying, pyrolysis, gasification and combustion processes were 15.590%, 20.060%, 22.885%, and 23.740%, respectively and the total weight loss percentage of OPKS Sample 1 was approximately 82.275%. The weight loss percentages of OPKS Sample 2 for the drying, pyrolysis, gasification and combustion processes were 14.955%, 17.835%, 24.755%, and 23.790%, respectively and the total weight loss percentage of OPKS Sample 2 was about 81.35%. The weight loss percentages of OPKS Sample 3 for the drying, pyrolysis, gasification and combustion processes were 13.262%, 19.200%, 23.614%, 17.429%, respectively and the total weight loss percentage of OPKS Sample 3 was about 73.505%. The total mean weight loss of OPKS Samples 1, 2 and 3 was estimated to be 79.037%; the gasification process recorded the highest weight loss (23.751%), followed by the combustion process (21.653%), pyrolysis process (19.032%) and drying process (14.601%) (**Figure 4.1** and **Table 4.2**).

Table 4.1: Thermal analysis results of OPKS

Sample	Drying temperature (°C)	Pyrolysis temperature (°C)	Gasification temperature (°C)	Combustion temperature (°C)
OPKS 1	28.00 – 190.00	190.00 – 305.00	305.00 – 380.00	380.00 – 900.00
OPKS 2	28.00 – 190.00	190.00 – 295.00	295.00 – 370.00	370.00 – 900.00
OPKS 3	28.00 – 170.00	170.00 – 300.00	300.00 – 370.00	370.00 – 900.00
Mean	28.00 – 183.33	183.33 – 300.00	300.00 – 373.33	373.33 – 900.00

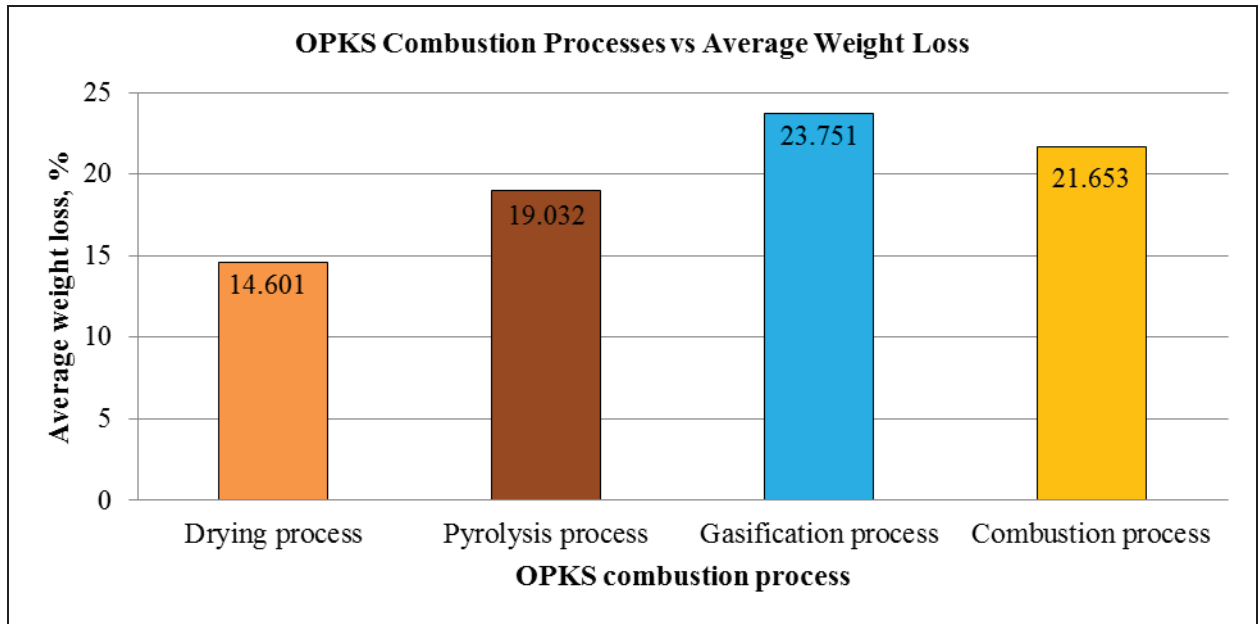


Figure 4.1: OPKS combustion process vs mean weight losses

Table 4.2: Weight loss (%) of OPKS vs process

Sample	Drying process (%)	Pyrolysis process (%)	Gasification process (%)	Combustion process (%)	Total weight loss (%)
OPKS 1	15.590	20.060	22.885	23.740	82.275
OPKS 2	14.955	17.835	24.755	23.790	81.335
OPKS 3	13.262	19.200	23.614	17.429	73.505
Mean	14.601	19.032	23.751	21.653	79.037

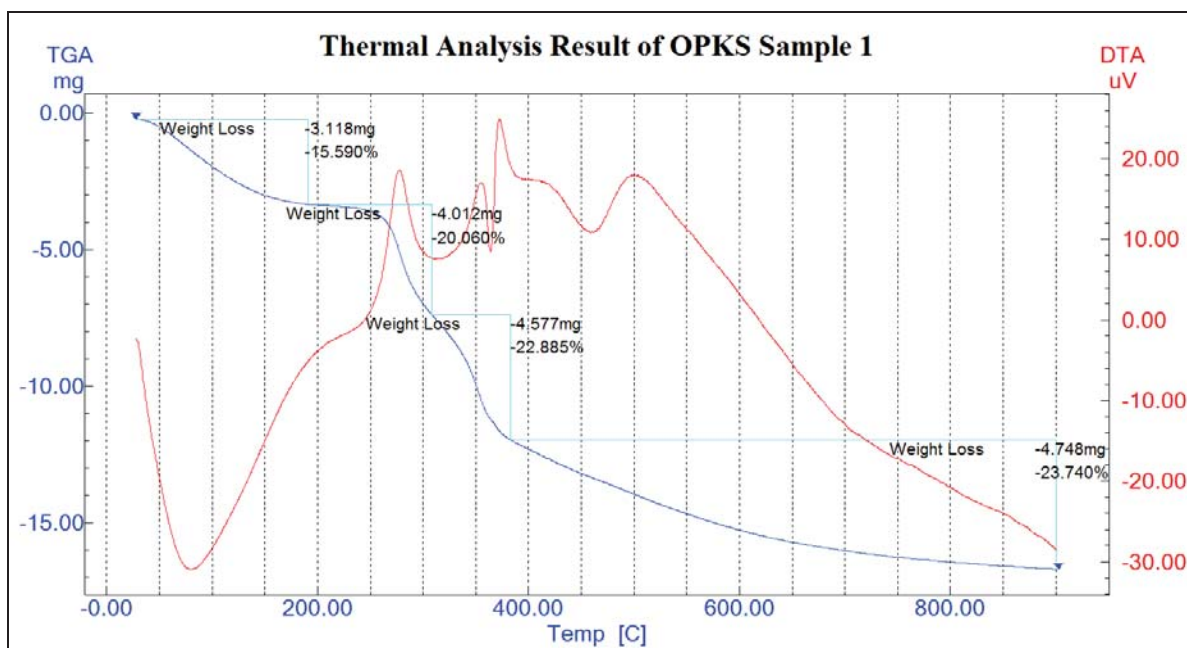


Figure 4.2: Thermal analysis result of OPKS Sample 1
(Sample: 20mg OPKS; Hold temperature: 900°C; Heating rate: 10°C/min;
Flowrate: 60 ml/min; Gas: Nitrogen)

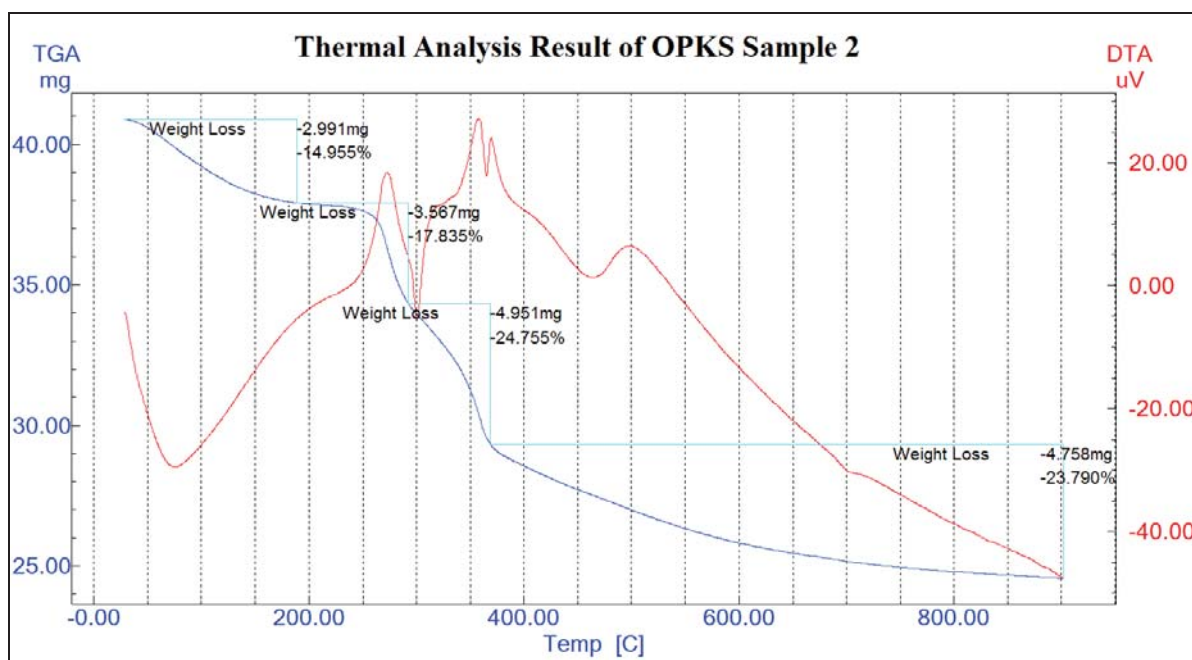


Figure 4.3: Thermal analysis result of OPKS Sample 2
(Sample: 20mg OPKS; Hold temperature: 900°C; Heating rate: 10°C/min;
Flowrate: 60 ml/min; Gas: Nitrogen)

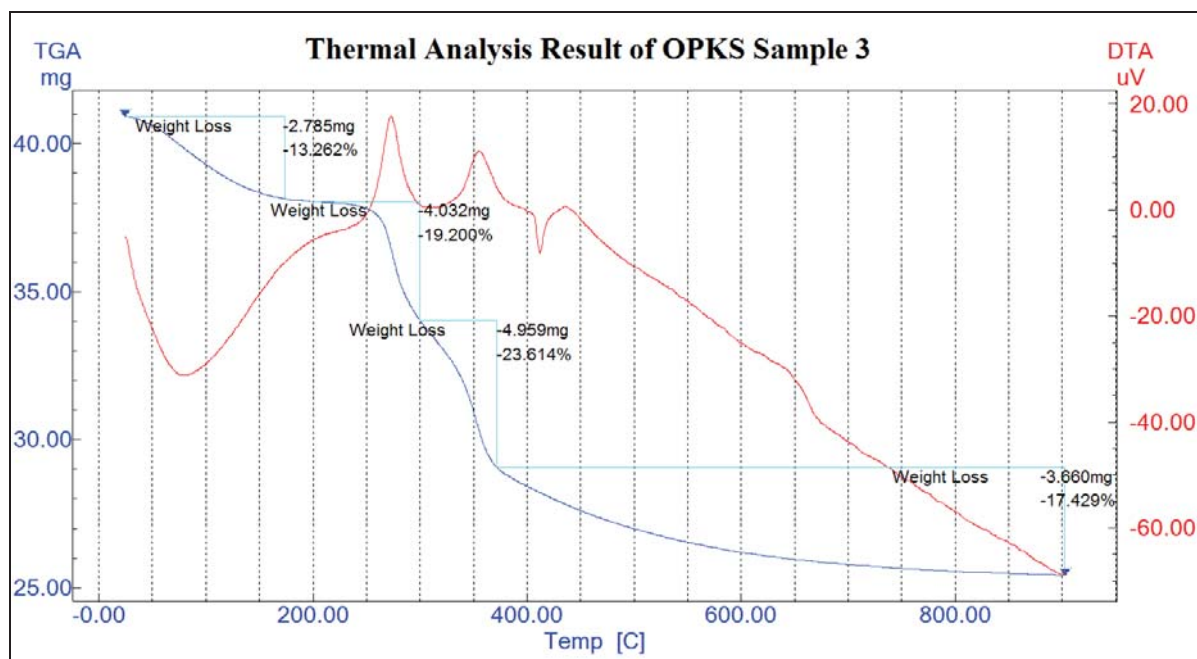


Figure 4.4: Thermal analysis result of OPKS sample 3
(Sample: 21mg OPKS; Hold temperature: 900°C; Heating rate: 10°C/min;
Flowrate: 60 ml/min; Gas: Nitrogen)

B) TGA Analysis Results of the Investigated Wood Chips

Table 4.3 and **Figures 4.5–4.8** illustrate the results of thermal analysis of the investigated wood chips. It was observed that all three samples of wood chips showed four stages of transition according to the biomass combustion theory put forward by Loo and Koopejan (2008) with respect to drying, pyrolysis, gasification and combustion.

The drying process of the selected wood chips Samples 1, 2 and 3 occurred mainly within the temperature ranges of 28–120°C, 28–120°C and 28–110.00°C, respectively and the mean drying temperature of the selected wood chips was 28–116.67°C. The observed pyrolysis temperatures of wood chips Samples 1, 2 and 3 occurred mainly within the temperature ranges of 120–260°C, 120–255°C and 110–265°C, respectively and the mean pyrolysis temperature of wood chips samples ranged from 116.67°C to 260°C. The gasification process

of wood chips Samples 1, 2 and 3 occurred mainly within the temperature ranges of 260–370°C, 255–360°C and 265–365°C, respectively and the mean gasification temperature of the wood chips sample was 260–365°C. The observed combustion temperature of the wood chips Samples 1, 2 and 3 occurred mainly within the ranges of 370–900°C, 360–900°C and 365–900°C, respectively and the mean combustion temperature of the wood chips sample was observed to fall between 365°C and 900°C. **Table 4.3** shows the comparison of thermal analysis results of the OPKS and wood chips samples.

The weight loss percentages for the individual wood chips samples are shown in **Table 4.4**. The weight loss percentages of wood chips Sample 1 for the drying, pyrolysis, gasification and combustion processes were approximately 11.957%, 2.924%, 48.700% and 14.290%, respectively and the total mean weight loss of wood chips Sample 1 was 77.871%. The weight loss percentages of wood chips Sample 2 for the drying, pyrolysis, gasification and combustion processes were 13.070%, 2.805%, 44.530% and 30.220 %, respectively and the total mean weight loss of wood chips Sample 2 was observed to be approximately 90.625%. The weight loss percentages of wood chips Sample 3 for drying, pyrolysis, gasification and combustion processes were 12.029%, 4.643%, 48.405% and 33.290%, respectively and the total mean weight loss of wood chips Sample 3 was 98.367%. The gasification process showed the highest weight loss of about 47.212%, followed by the combustion process (25.933%), drying process (12.352%) and pyrolysis process (3.457%) (**Table 4.4** and **Figure 4.5**).

Table 4.5 shows the comparison of the thermal analysis for OPKS and wood chips samples. The mean drying temperature ranges of OPKS and wood chips were 28–183.33°C and 28–116.67°C, respectively and the mean pyrolysis temperature ranges of OPKS and wood chips

were 183.33–300°C and 116.67–260°C, respectively. The mean gasification temperature ranges of OPKS and wood chips were 300–373.33°C and 260–365°C, respectively and the mean combustion temperature ranges of OPKS and wood chips were 373.33–900°C and 365–900°C, respectively. Generally, it can be concluded that the temperature ranges of OPKS are always higher than those of wood chips.

Table 4.6 and **Figure 4.9** illustrate the comparison of the mean weight loss in percentage of OPKS and wood chips samples. OPKS showed a higher weight loss than wood chips in the process of drying and pyrolysis, with 15.403% and 81.836% in difference, respectively. The weight loss in wood chips was higher than OPKS during the processes of gasification and combustion: 49.693% and 16.504% in difference, respectively.

Table 4.3: Thermal analysis of wood chips

Sample	Drying temperature (°C)	Pyrolysis temperature (°C)	Gasification temperature (°C)	Combustion temperature (°C)
Wood chips-1	28.00 – 120.00	120.00 – 260.00	260.00 – 370.00	370.00 – 900.00
Wood chips-2	28.00 – 120.00	120.00 – 255.00	255.00 – 360.00	360.00 – 900.00
Wood chips-3	28.00 – 110.00	110.00 – 265.00	265.00 – 365.00	365.00 – 900.00
Mean	28.00 – 116.67	116.67 – 260.00	260.00 – 365.00	365.00 – 900.00

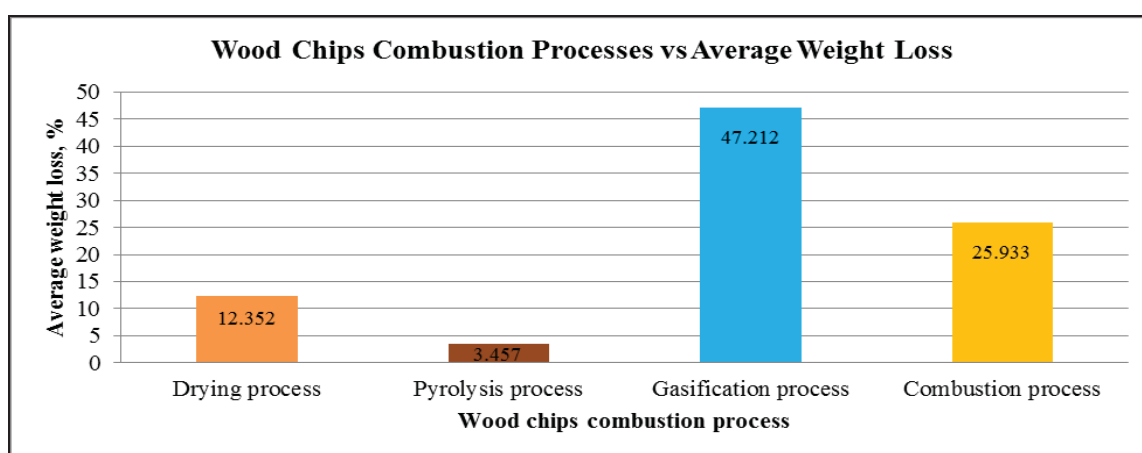


Figure 4.5: OPKS combustion process vs mean weight loss

Table 4.4: Weight loss (%) of wood chips vs respective processes

Sample	Drying process (%)	Pyrolysis process (%)	Gasification process (%)	Combustion process (%)	Total weight loss (%)
Wood chips-1	11.957	2.924	48.700	14.290	77.871
Wood chips-2	13.070	2.805	44.530	30.220	90.625
Wood chips-3	12.029	4.643	48.405	33.290	98.367
Mean	12.352	3.457	47.212	25.933	88.954

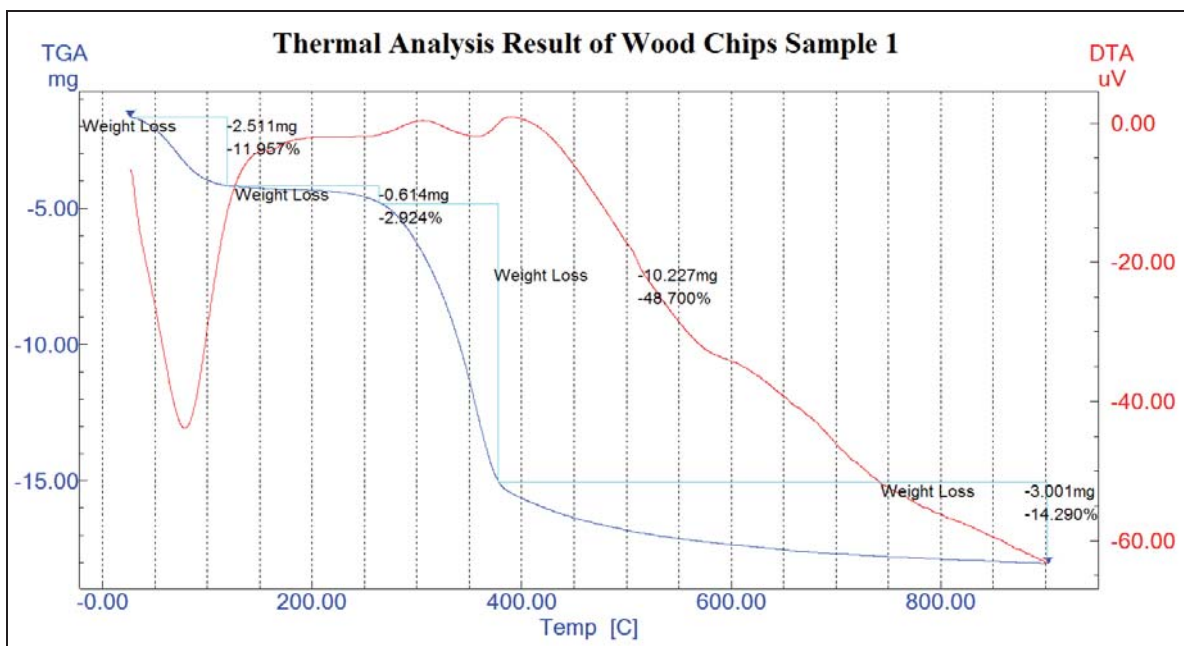


Figure 4.6: Thermal analysis result of wood chip Sample 1
(Sample: 21mg wood chips; Hold temperature: 900°C; Heating rate: 10°C/min;
Flowrate: 60 ml/min; Gas: Nitrogen)

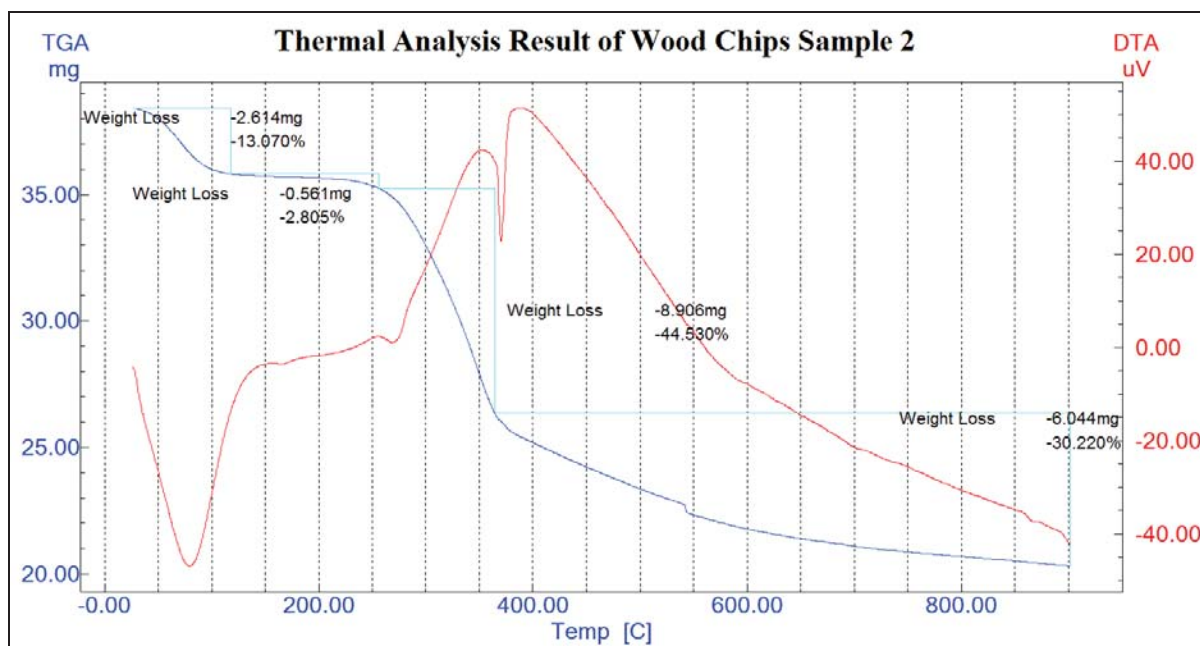


Figure 4.7: Thermal analysis result of wood chip Sample 2
 (Sample: 20mg wood chips; Hold temperature: 900°C; Heating rate: 10°C/min;
 Flowrate: 60 ml/min; Gas: Nitrogen)

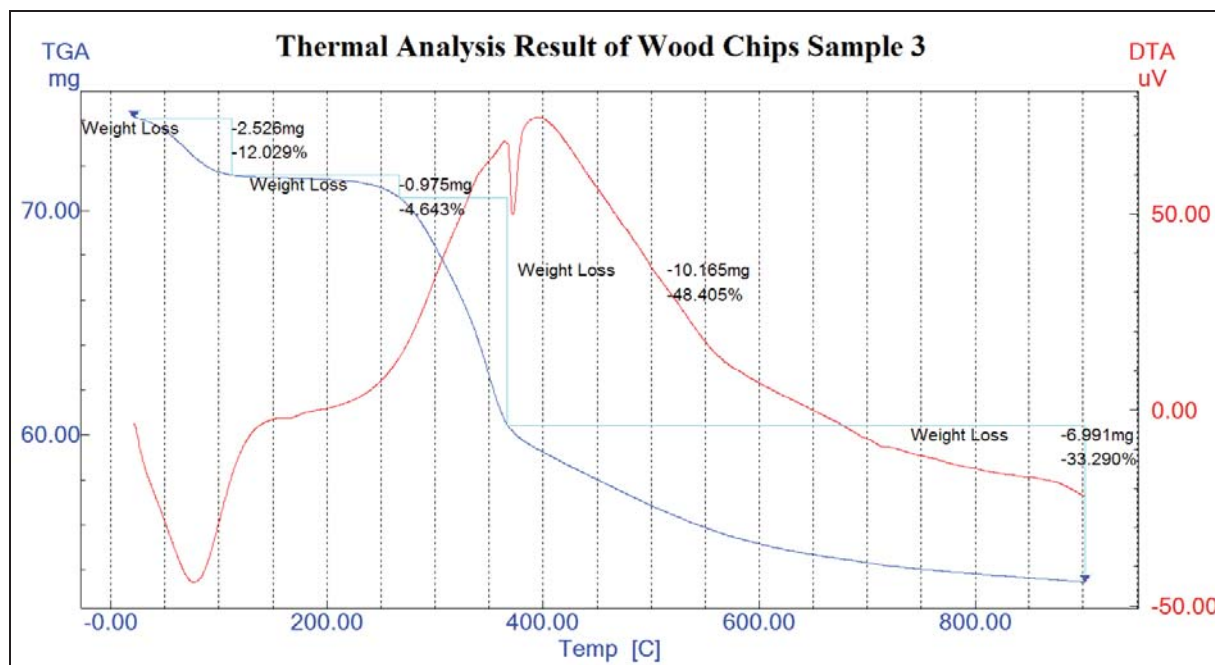


Figure 4.8: Thermal analysis result of wood chip Sample 3
 (Sample: 20mg wood chips; Hold temperature: 900°C; Heating rate: 10°C/min;
 Flowrate: 60 ml/min; Gas: Nitrogen)

Table 4.5: Thermal analysis of OPKS and wood chips

Sample	Mean drying temperature (°C)	Mean pyrolysis temperature (°C)	Mean gasification temperature (°C)	Mean combustion temperature (°C)
OPKS	28.00 – 183.33	183.33 – 300.00	300.00 – 373.33	373.33 – 900.00
Wood chips	28.00 – 116.67	116.67 – 260.00	260.00 – 365.00	365.00 – 900.00

Table 4.6: Mean weight loss of OPKS and wood chips

Sample	Drying process (%)	Pyrolysis process (%)	Gasification process (%)	Combustion process (%)	Total weight loss (%)
OPKS	14.601	19.032	23.751	21.653	79.037
Wood chips	12.352	3.457	47.212	25.933	88.954

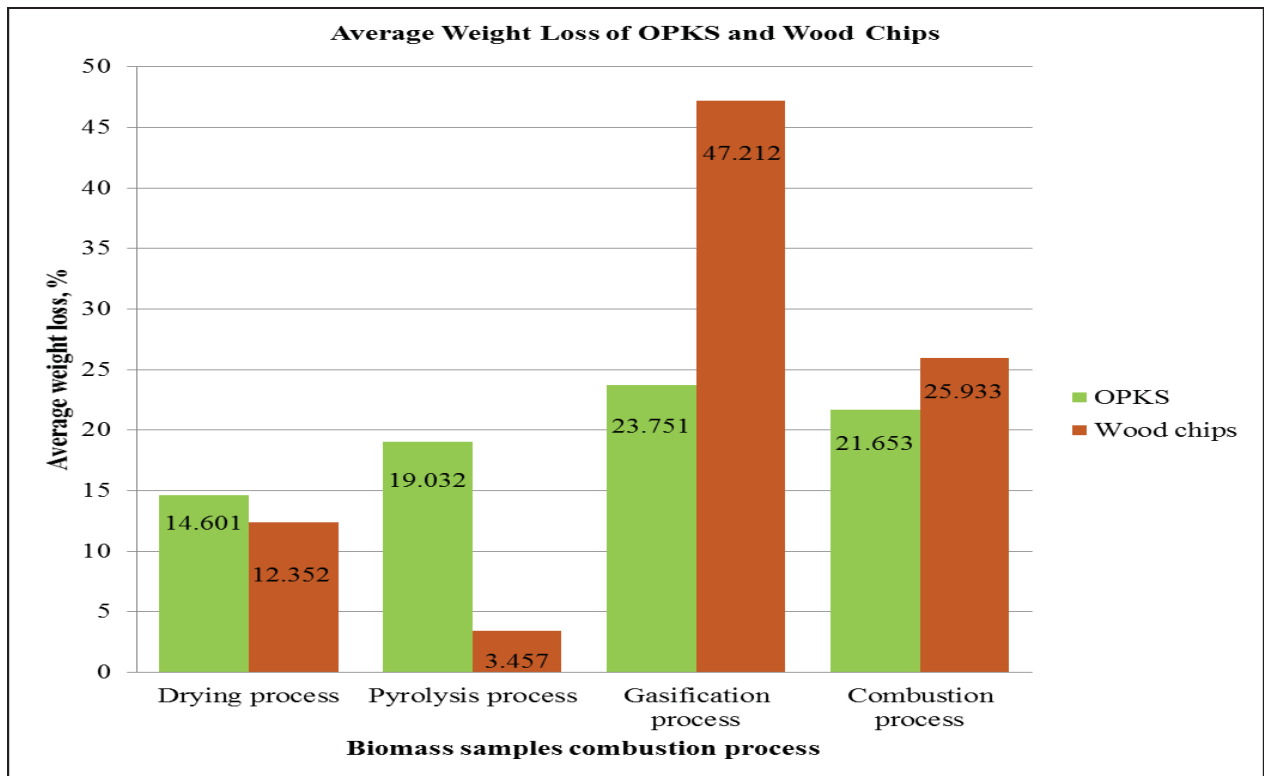


Figure 4.9: Mean weight loss of OPKS and wood chips

4.3.2 Moisture Content of Selected Biomass Samples

The moisture contents of the selected biomass samples are determined according to the British Standard EN 1477-2:2009 (British Standard Institute, 2009) and shown in **Table 4.7** and **Figure 4.10**. Details of the determination of the moisture contents for the selected biomass samples are included in **Appendix M**. Oil palm kernel shells recorded a moisture content of $11.7 \pm 0.1\%$ wt. and wood chip recorded a moisture content of $16.2 \pm 1.1\%$ wt.

Table 4.7: Mean and standard deviation in moisture content of investigated biomass

Sample	Mean (% wt.)	Standard deviation
Oil palm kernel shell	11.7	0.1
Wood chip	16.2	1.1

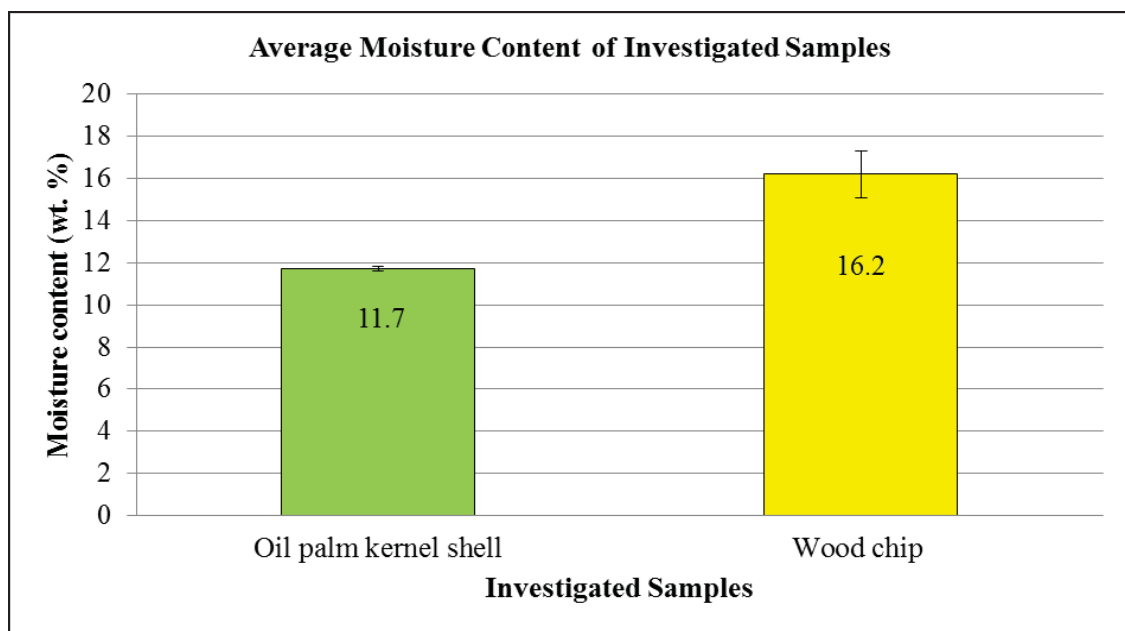


Figure 4.10: Mean moisture content of investigated biomass samples

4.3.3 Air Flow Rate Effect on Different Experiments

Table 4.8 and **Figure 4.11** illustrate the air flow rate versus experimental trials (**Appendix N**), according to the research methodology described in **Section 3.11.3**. Generally, the air flow rate increased from Experiment (i) to Experiment (iii), and from Experiment (iv) to Experiment (vi), as the velocity was increased.

In Group A (Experiments i, ii and iii), Experiment (i) recorded the lowest air flow rate with $0.04400 \text{ Nm}^3/\text{s}$ (2.84% excess air combustion); Experiment (iii) recorded the highest air flow rate with $0.07661 \text{ Nm}^3/\text{s}$ (106.13% excess air combustion), and it was the highest among all the experimental groups. The deviation between Experiment (ii) and Experiment (iii) was estimated to be about 1.79%.

In Group B (Experiments iv, v and vi), Experiment (iv) recorded the lowest air flow rate with $0.01824 \text{ Nm}^3/\text{s}$ (59.94% excess air combustion); Experiment (vi) recorded the highest air flow rate ($0.07296 \text{ Nm}^3/\text{s}$) with 114.34% excess air combustion. The deviation of the air flow rate between Experiment (v) and Experiment (vi) was 4.37%.

In Group C, the air flow rate for Experiment (vii) and Experiment (viii) was recorded as $0.05837 \text{ Nm}^3/\text{s}$ as intended by the experimental design. Among all the experimental trials, Experiment (iii) recorded the highest air flow rate ($0.7661 \text{ Nm}^3/\text{s}$) with 78.18% excess air combustion; Experiment (iv) recorded the lowest air flow rate ($0.01824 \text{ Nm}^3/\text{s}$) with 84.07% excess air combustion.

Table 4.8: Air Flow Rate and Excess or Deficient Air

Experiment ($V_{B1}:V_{B2}$) ^a	Air flow rate, $Q = AV$ (Nm^3/s)	Excess Air or Deficient Air
Group A		
Experiment Set i (9.65:0.00)	0.04400	2.84% excess air
Experiment Set ii (9.65:3.83)	0.07524	95.20% excess air combustion
Experiment Set iii (9.65:4.00)	0.07661	106.13% excess air combustion
Group B		
Experiment Set iv (4.00:0.00)	0.01824	53.94% deficient air combustion
Experiment Set v (4.00:5.79)	0.06977	94% excess air combustion
Experiment Set vi (4.00:9.65)	0.07296	114.34% excess air combustion
Group C		
Experiment Set vii (3.83:9.65)	0.05837	78.18% excess air combustion
Experiment Set viii (3.83:9.65)	0.05837	84.07% excess air combustion

*For Dwyer VT120 Integral Vane Thermo-Anemometer, the accuracy of the measured velocity is $\pm 3\%$.

^a V_{B1} = Blower 1 velocity, m/s

^a V_{B2} = Blower 2 velocity, m/s

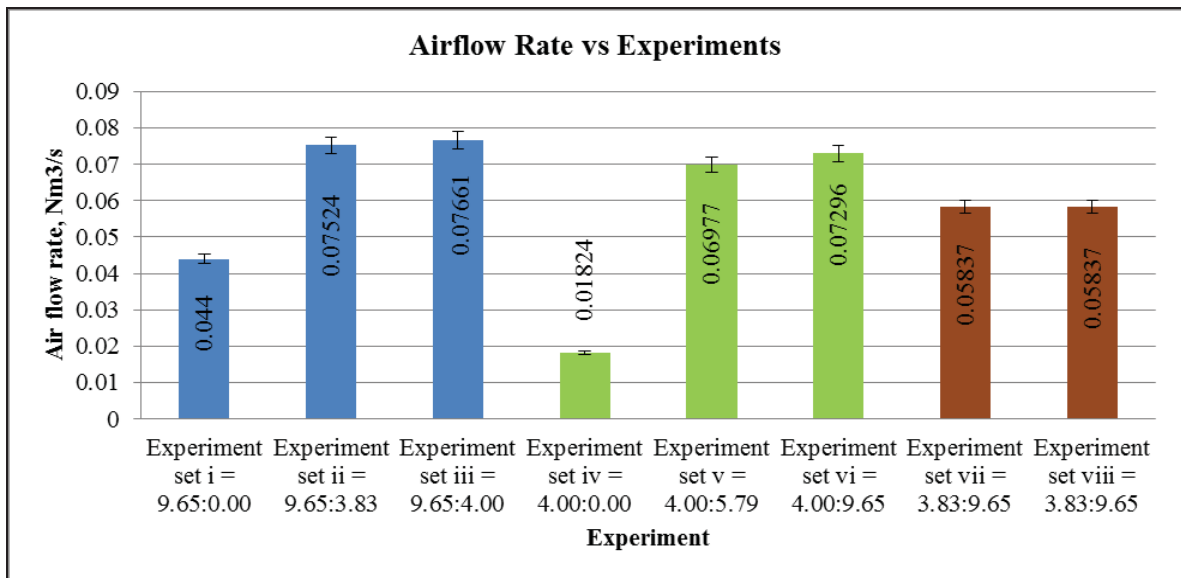


Figure 4.11: Air flow rate of the experiments
(Accuracy = $\pm 3\%$)

4.3.4 Effects of Air velocity Ratio on Temperature Profile, Flue Gas Composition and Combustion Efficiency

The experimental results of the effect of the air velocity ratio on the temperature profile, flue gas composition and combustion efficiency were calculated with a Statistical Product and Service Solutions (SPSS) version 19 statistical analysis tool. Moreover, the mean of each experimental trial, and the standard error of the mean (SEM) were included in the analysis. SEM is an indication of the reliability of the mean. The detailed statistical analysis results for these experimental trials are given in **Appendix O**.

(A) B2H Temperature Profile

The temperatures recorded in all the experiments were in the range between 94°C and 675°C (**Appendix O**). **Table 4.9** and **Figure 4.12** show the mean temperatures recorded during experimental trials at the pyrolysis chamber, exhaust and surroundings. Generally, the mean temperature of the pyrolysis chamber increased proportionally to the air velocity ratio. In Group A (Experiments i, ii and iii), the mean temperature of the pyrolysis chamber (PT) increased with the air velocity ratio. Experiment (iii) recorded the highest temperature ($227.76 \pm 5.40^\circ\text{C}$); Experiment (i) recorded the lowest temperature ($209.72 \pm 4.26^\circ\text{C}$). In Group B (Experiments iv, v and vi), the mean temperature of the pyrolysis chamber increased from Experiment (iv) ($218.26 \pm 4.81^\circ\text{C}$) to Experiment (v) ($301.52 \pm 8.14^\circ\text{C}$), then decreased to $199.86 \pm 3.68^\circ\text{C}$ in Experiment (vi), indicating the lowest temperature recorded in Group B, and among all the other experimental groups. In Group C (Experiments vii and viii), Experiment (viii) gave the highest mean temperature at the pyrolysis chamber ($330.52 \pm 5.31^\circ\text{C}$) compared to Experiment (vii) ($265.55 \pm 4.79^\circ\text{C}$).

It was observed that all the mean exhaust temperatures (FT) showed a decreasing trend with increasing AVR. In Group A (Experiments i, ii and iii), Experiment (i) recorded the highest mean exhaust temperature ($194.09 \pm 2.24^\circ\text{C}$), which was the highest among all the experimental groups; Experiment (iii) recorded the lowest mean exhaust temperature ($135.50 \pm 2.18^\circ\text{C}$). In Group B (Experiments iv, v and vi), Experiment (iv) recorded the highest mean exhaust temperature ($159.49 \pm 1.13^\circ\text{C}$); Experiment (vi) recorded the lowest mean exhaust temperature ($98.67 \pm 0.67^\circ\text{C}$). For Group C (Experiments vii and viii), Experiment (vii) had a marginally higher mean exhaust temperature than Experiment (viii); Experiment (vii) recorded $85.12 \pm 0.30^\circ\text{C}$; Experiment (viii) recorded $72.39 \pm 0.29^\circ\text{C}$, which was the lowest mean exhaust temperature recorded among all the experimental groups. There were insignificant differences in the B2H surrounding temperature (AT), as the lowest surrounding temperature recorded was $30.04 \pm 0.40^\circ\text{C}$ (Experiment viii). The highest surrounding temperature recorded was $31.69 \pm 0.04^\circ\text{C}$ (Experiment iv).

Table 4.9: Mean temperature of pyrolyzer, exhaust, and surrounding temperatures

Experiment	Pyrolyzer temperature ($^\circ\text{C}$)		Exhaust temperature ($^\circ\text{C}$)		Surrounding temperature ($^\circ\text{C}$)	
	Mean	SEM	Mean	SEM	Mean	SEM
Group A						
Experiment Set i	209.72	4.26	194.09	2.24	32.48	0.11
Experiment Set ii	219.55	4.97	148.21	1.76	32.16	0.05
Experiment Set iii	227.76	5.40	135.50	2.18	33.71	0.07
Group B						
Experiment Set iv	218.26	4.81	159.49	1.13	33.44	0.05
Experiment Set v	301.52	8.14	106.24	0.64	32.14	0.05
Experiment Set vi	199.86	3.68	98.67	0.67	32.75	0.05
Group C						
Experiment Set vii	265.55	4.79	85.12	0.30	31.69	0.04
Experiment Set viii	330.52	5.31	72.39	0.29	30.04	0.40

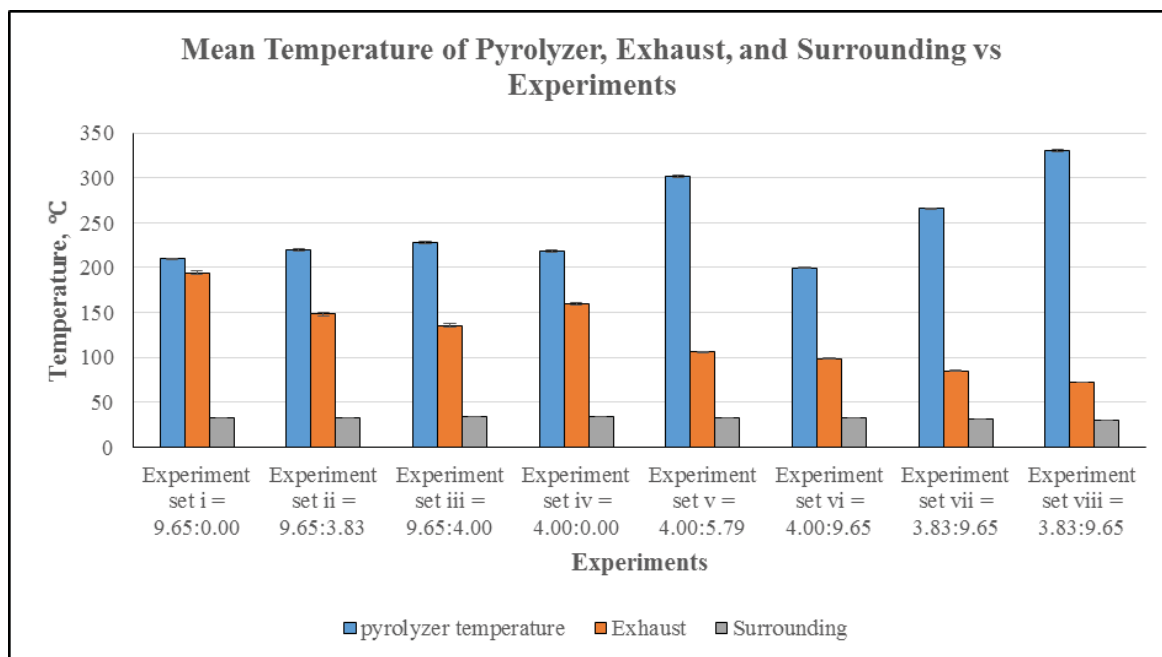


Figure 4.12: Mean temperature of pyrolyzer chamber, exhaust and surrounding areas

(B) Gas Compositions

Gas emissions from the B2H exhaust are based on 7% reference O₂ at standard conditions (1 atm, 20°C), according to the Testo 350XL flue gas analyser.

i) Combustible Gases (CO, H₂)

Table 4.10 and **Figure 4.13** illustrate the observed mean and standard error of the mean (SEM) of combustible gases (CO and H₂) at the B2H exhaust during the experimental trials. Generally, CO emissions are reduced significantly as the AVR is increased. In Group A (Experiments i, ii and iii), Experiment (i) recorded the highest CO concentration (751.61±15.35 ppmv) at 209.72±4.26°C; Experiment (ii) recorded the lowest CO concentration (394.12±8.57 ppmv) at 219.55±4.97°C. In Group B (Experiments iv, v and vi), Experiment (iv) recorded the highest CO concentration (1256.48±65.42 ppmv) at 218.26±4.81°C, which was the highest among all the experimental groups; Experiment (vi)

recorded the lowest CO concentration (243.48 ± 3.44 ppmv) at $199.86 \pm 3.68^\circ\text{C}$. In Group C (Experiments vii and viii), Experiment (viii) recorded the highest CO concentration (333.31 ± 6.80 ppmv) at $338.55 \pm 5.31^\circ\text{C}$; Experiment (vii) recorded the lowest CO concentration (195.03 ± 2.08 ppmv) at $265.55 \pm 4.79^\circ\text{C}$.

Moreover, measured H_2 concentrations at the B2H exhaust decrease with increase in the AVR. In Group A (Experiments i, ii and iii), Experiment (i) recorded the highest H_2 concentration (179.08 ± 6.09 ppmv) at $209.72 \pm 4.26^\circ\text{C}$; Experiment (ii) recorded the lowest H_2 concentration (87.57 ± 2.24 ppmv) at $219.55 \pm 4.97^\circ\text{C}$. In Group B (Experiments iv, v and vi), Experiment (iv) recorded the highest H_2 concentration (434.21 ± 24.13 ppmv) at $218.26 \pm 4.81^\circ\text{C}$, which was the highest among all the experimental groups; Experiment (vi) recorded the lowest H_2 concentration (68.62 ± 1.23 ppmv) at $199.86 \pm 3.68^\circ\text{C}$, which was the lowest among all the experimental groups. In Group C (Experiments vii and viii), Experiment (viii) recorded the highest H_2 concentration (79.89 ± 1.70 ppmv) at $338.55 \pm 5.31^\circ\text{C}$; Experiment (vii) recorded the lowest H_2 concentration (60.86 ± 0.98 ppmv) at $265.55 \pm 4.79^\circ\text{C}$.

Table 4.10: Experimental trials vs CO and H_2 Emissions

Experiment	CO (ppmv)		H_2 (ppmv)		Pyrolyzer temperature ($^\circ\text{C}$)	
	Mean	SEM	Mean	SEM	Mean	SEM
Group A						
Experiment Set i	751.61	15.35	179.08	6.09	209.72	4.26
Experiment Set ii	394.12	8.57	87.57	2.24	219.55	4.97
Experiment Set iii	499.72	16.58	116.56	4.56	227.76	5.40
Group B						
Experiment Set iv	1256.48	65.42	434.21	24.13	218.26	4.81
Experiment Set v	285.48	4.49	166.77	4.64	301.52	8.14
Experiment Set vi	243.48	3.44	68.62	1.23	199.86	3.68
Group C						
Experiment Set vii	195.03	2.08	60.86	0.98	265.55	4.79
Experiment Set viii	333.31	6.80	79.89	1.70	338.55	5.31

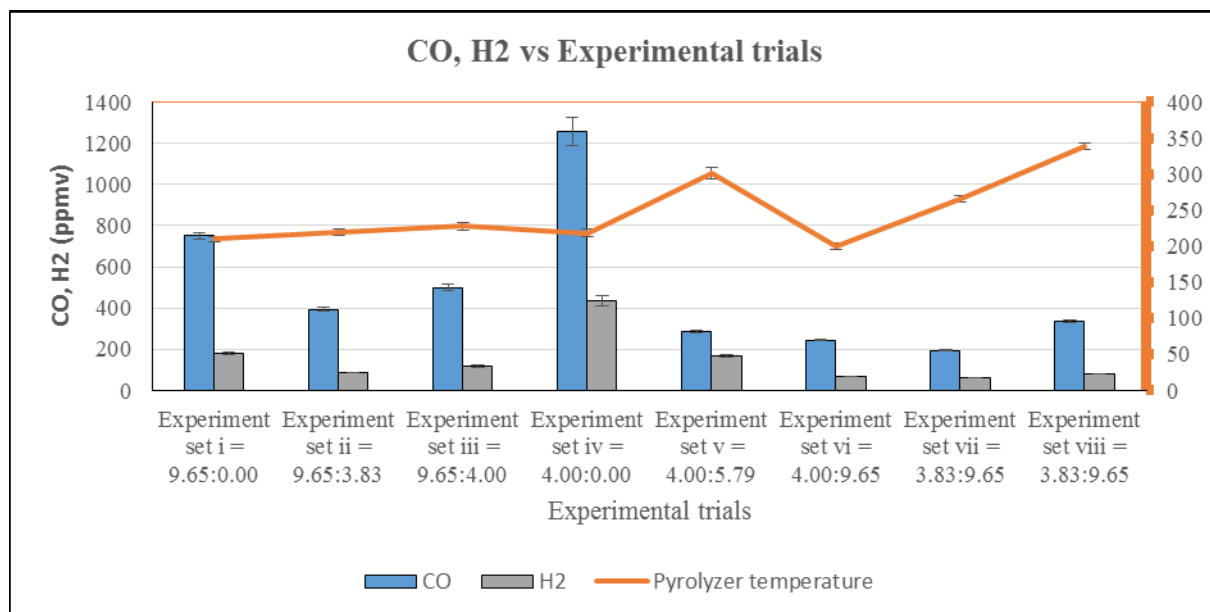


Figure 4.13: CO and H₂ vs experimental trials

ii) Nitrogen Oxides (NO, NO₂ & NO_x)

Table 4.11 and **Figure 4.14** illustrate the measured mean and SEM of nitrogen oxides (NO and NO₂) concentrations in the exhaust. It was noted that nitrogen monoxide (nitric oxide) decreases with increase of the AVR. In Group A (Experiments i, ii and iii), Experiment (i) recorded the highest NO concentration (18.30 ± 0.30 ppmv) at $209.72 \pm 4.26^\circ\text{C}$, which was the highest among the experimental groups; Experiment (iii) recorded the lowest NO concentration (10.31 ± 0.19 ppmv) at $227.76 \pm 5.40^\circ\text{C}$. For Group B (Experiments iv, v and vi), Experiment (iv) attained the highest NO concentration (8.55 ± 0.19 ppmv) at $218.26 \pm 4.81^\circ\text{C}$; Experiment (v) recorded the lowest NO concentration (3.73 ± 0.06 ppmv) at $301.52 \pm 8.14^\circ\text{C}$. In Group C (Experiments vii and viii), Experiment (vii) recorded the highest NO concentration (2.77 ± 0.04 ppmv) at $265.55 \pm 4.79^\circ\text{C}$; Experiment (viii) recorded the lowest NO concentration (2.29 ± 0.04 ppmv) at $338.55 \pm 5.31^\circ\text{C}$.

From the results, NO_2 generally decreases with an increase in AVR. In Group A (Experiments i, ii and iii), Experiment (i) recorded the highest NO_2 concentration (15.59 ± 0.30 ppmv) at $209.72 \pm 4.26^\circ\text{C}$; Experiment (iii) recorded the lowest NO_x concentration (8.24 ± 0.19 ppmv) at $227.76 \pm 5.40^\circ\text{C}$. For Group B (Experiments iv, v and vi), Experiment (iv) attained the highest NO_2 concentration (20.31 ± 0.24 ppmv) at $218.26 \pm 4.81^\circ\text{C}$, which was the highest among all the experimental groups; Experiment (vi) marked the lowest NO_2 concentration in Group B (6.65 ± 0.12 ppmv) at $199.86 \pm 3.68^\circ\text{C}$. In Group C (Experiments vii and viii), Experiment (vii) recorded the highest NO_2 concentration (6.42 ± 0.10 ppmv) at $265.55 \pm 4.79^\circ\text{C}$; Experiment (viii) recorded the lowest NO_2 concentration (0.98 ± 0.01 ppmv) at $338.55 \pm 5.31^\circ\text{C}$, which was the lowest among all the experimental groups.

The measured nitrogen oxide (NO_x) concentrations from the exhaust comprised NO and NO_2 . In Group A (Experiments i, ii and iii), Experiment (i) recorded the highest NO_x concentration (33.87 ± 0.54 ppmv) at $209.72 \pm 4.26^\circ\text{C}$, which was the highest among all the experimental groups; Experiment (iii) recorded the lowest NO_x in Group A. For Group B (Experiments iv, v and vi), Experiment (iv) attained the highest NO_x concentration (28.77 ± 0.57 ppmv) at $218.26 \pm 4.81^\circ\text{C}$; Experiment (vi) marked the lowest NO_x concentration. In Group C (Experiments vii and viii), Experiment (vii) recorded the highest NO_x concentration (9.17 ± 0.15 ppmv) at $265.55 \pm 4.79^\circ\text{C}$; Experiment (viii) recorded the lowest NO_x emission concentration (3.25 ± 0.05 ppmv) at $338.55 \pm 5.31^\circ\text{C}$, which was the lowest among all the experimental groups.

Table 4.11: Experimental trials vs NO, NO₂, and NO_x levels

Experiment	NO (ppmv)		NO ₂ (ppmv)		NO _x (ppmv)		Pyrolyzer temperature (°C)	
	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
Group A								
Experiment Set i	18.30	0.30	15.59	0.30	33.87	0.54	209.72	4.26
Experiment Set ii	10.88	0.27	9.41	0.19	20.31	0.41	219.55	4.97
Experiment Set iii	10.31	0.19	8.24	0.19	18.56	0.34	227.76	5.40
Group B								
Experiment Set iv	8.55	0.19	20.31	0.42	28.77	0.57	218.26	4.81
Experiment Set v	3.73	0.06	8.58	0.36	11.98	0.22	301.52	8.14
Experiment Set vi	3.86	0.08	6.65	0.12	10.55	0.18	199.86	3.68
Group C								
Experiment Set vii	2.77	0.04	6.40	0.10	9.17	0.15	265.55	4.79
Experiment Set viii	2.29	0.04	0.98	0.01	3.25	0.05	338.55	5.31

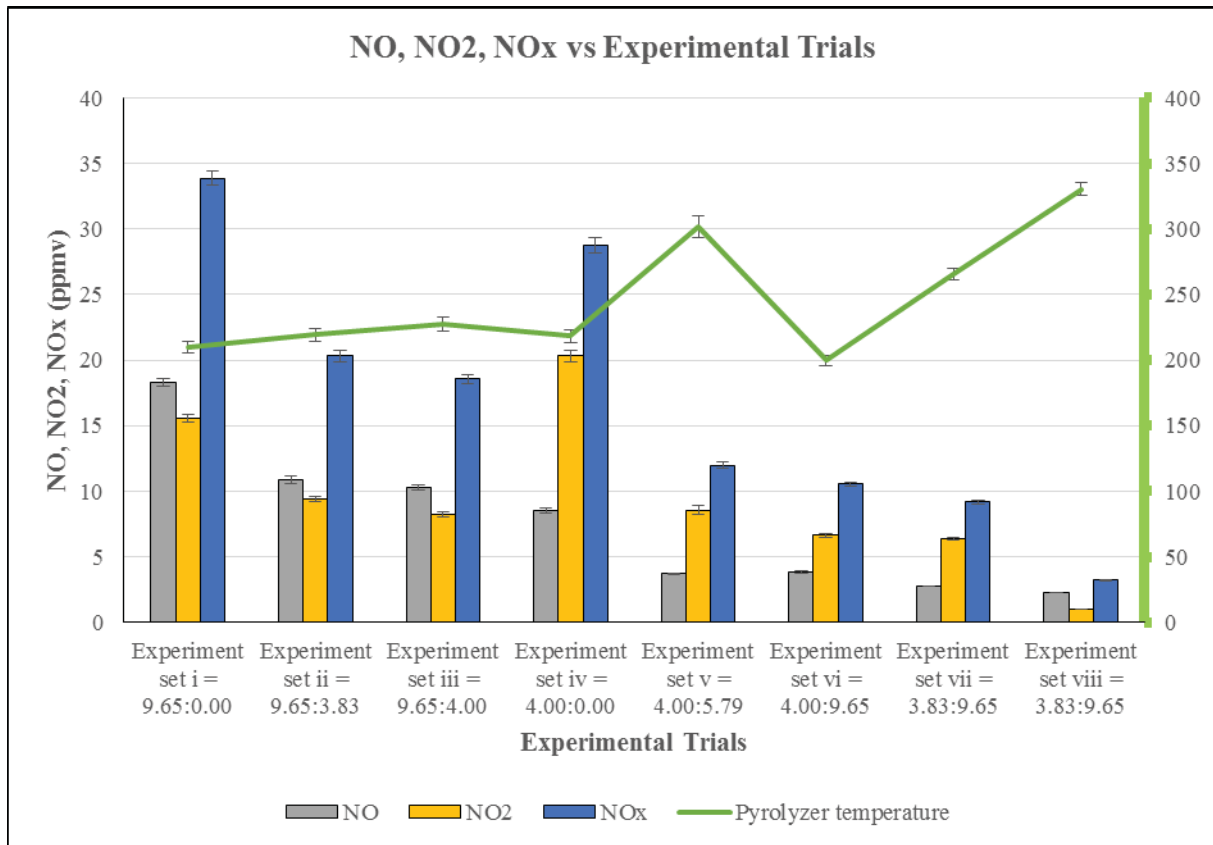


Figure 4.14: Nitrogen oxides vs experimental trials

iii) Sulphur Dioxide, SO₂

Table 4.12 and **Figure 4.15** illustrate the measured mean and SEM of sulphur dioxide (SO₂) concentrations in the exhaust. Based on the observed results, SO₂ decreases with increase in the AVR. In Group A (Experiments i, ii and iii), Experiment (i) recorded the highest SO₂ concentration (16.16±0.31 ppmv) at 209.72±4.26°C; Experiment (ii) recorded the lowest SO₂ concentration (9.54±0.27 ppmv) at 219.55±4.97°C. For Group B (Experiments iv, v and vi), Experiment (iv) showed the highest SO₂ concentration (17.24±0.66 ppmv) at 218.26±4.81°C, which was the highest among all the experimental groups; Experiment (vi) measured the lowest SO₂ concentration (4.61±0.10 ppmv) at 199.86±3.68°C, which was the lowest among all the experimental groups. In Group C (Experiments vii and viii), Experiment (viii) recorded the highest SO₂ concentration (9.08±0.19 ppmv) at 338.55±5.31°C, compared to Experiment (vii) (4.56±0.07 ppmv) which was at 265.55±4.79°C.

Table 4.12: Experimental trials vs SO₂ levels

Experiment	SO ₂ (ppmv)		Pyrolyzer mean temperature (°C)	
	Mean	SEM	Mean	SEM
Group A				
Experiment Set i	16.16	0.31	209.72	4.26
Experiment Set ii	9.54	0.27	219.55	4.97
Experiment Set iii	12.16	0.32	227.76	5.40
Group B				
Experiment Set iv	17.24	0.66	218.26	4.81
Experiment Set v	6.54	0.17	301.52	8.14
Experiment Set vi	4.61	0.10	199.86	3.68
Group C				
Experiment Set vii	4.56	0.07	265.55	4.79
Experiment Set viii	9.08	0.19	338.55	5.31

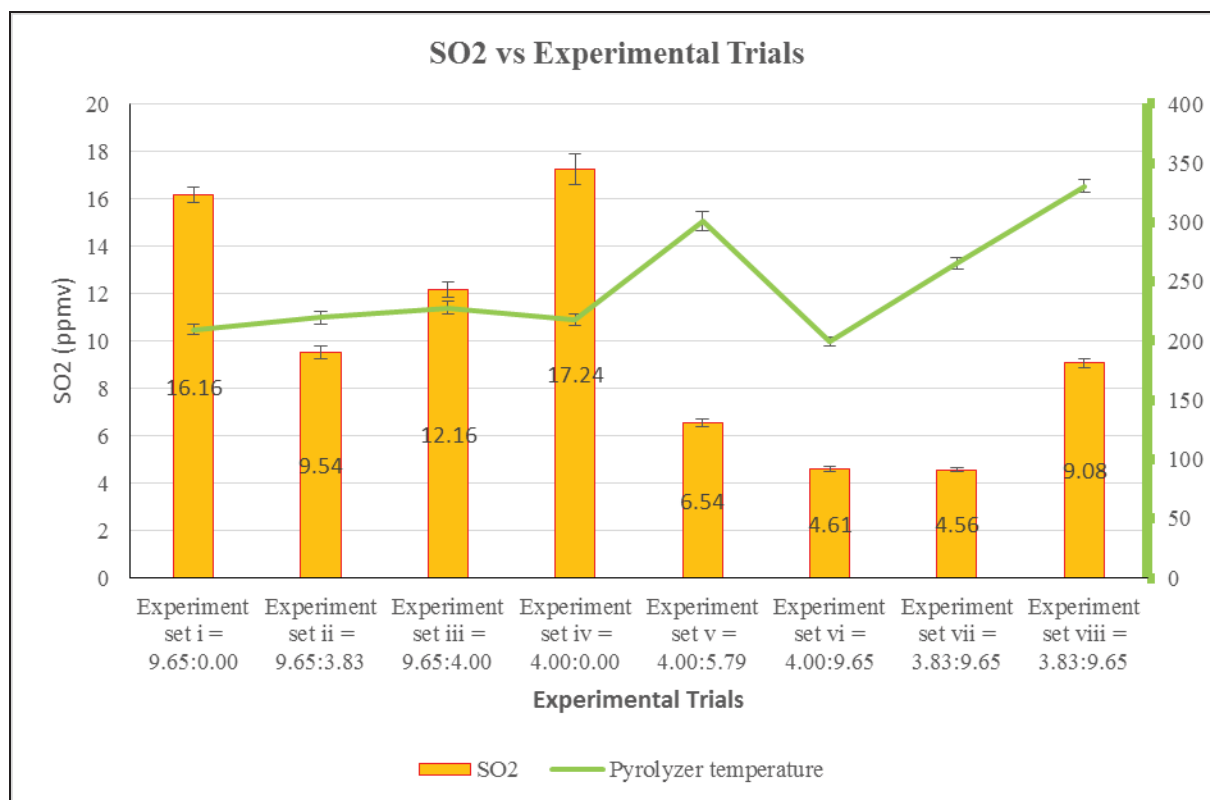


Figure 4.15: SO₂ vs experiments trials

iv) Oxygen Levels at B2H Exhaust

Table 4.13 and **Figure 4.16** illustrate the mean and SEM of oxygen levels in the exhaust. The oxygen levels in the exhaust increase as the AVR increases. In Group A (Experiments i, ii and iii), Experiment (iii) recorded the highest oxygen levels ($18.63 \pm 0.08\%$) at $227.76 \pm 5.40^\circ\text{C}$; Experiment (i) recorded the lowest oxygen levels ($16.49 \pm 0.21\%$) at $209.72 \pm 4.26^\circ\text{C}$. For Group B (Experiments iv, v and vi), Experiment (vi) measured the highest oxygen levels ($22.55 \pm 2.90\%$) at $199.86 \pm 3.68^\circ\text{C}$; Experiment (iv) attained the lowest oxygen levels ($16.25 \pm 0.11\%$) at $218.26 \pm 4.81^\circ\text{C}$, which was the lowest among all the experimental trials. In Group C (Experiments vii and viii), both Experiments recorded comparable oxygen levels; that is, $19.89 \pm 0.03\%$ at $265.55 \pm 4.79^\circ\text{C}$ and $20.08 \pm 0.01\%$ at $338.55 \pm 5.31^\circ\text{C}$. Finally, Experiment (viii) recorded the highest oxygen levels among all the experimental trials.

Table 4.13: Oxygen levels in B2H exhaust

Experiment	Oxygen level at B2H exhaust (%)		Pyrolyzer mean temperature ($^\circ\text{C}$)	
	Mean	SEM	Mean	SEM
Group A				
Experiment Set i	16.49	0.21	209.72	4.26
Experiment Set ii	18.05	0.07	219.55	4.97
Experiment Set iii	18.63	0.08	227.76	5.40
Group B				
Experiment Set iv	16.25	0.11	218.26	4.81
Experiment Set v	19.43	0.03	301.52	8.14
Experiment Set vi	22.55	2.90	199.86	3.68
Group C				
Experiment Set vii	19.89	0.03	265.55	4.79
Experiment Set viii	20.08	0.01	338.55	5.31

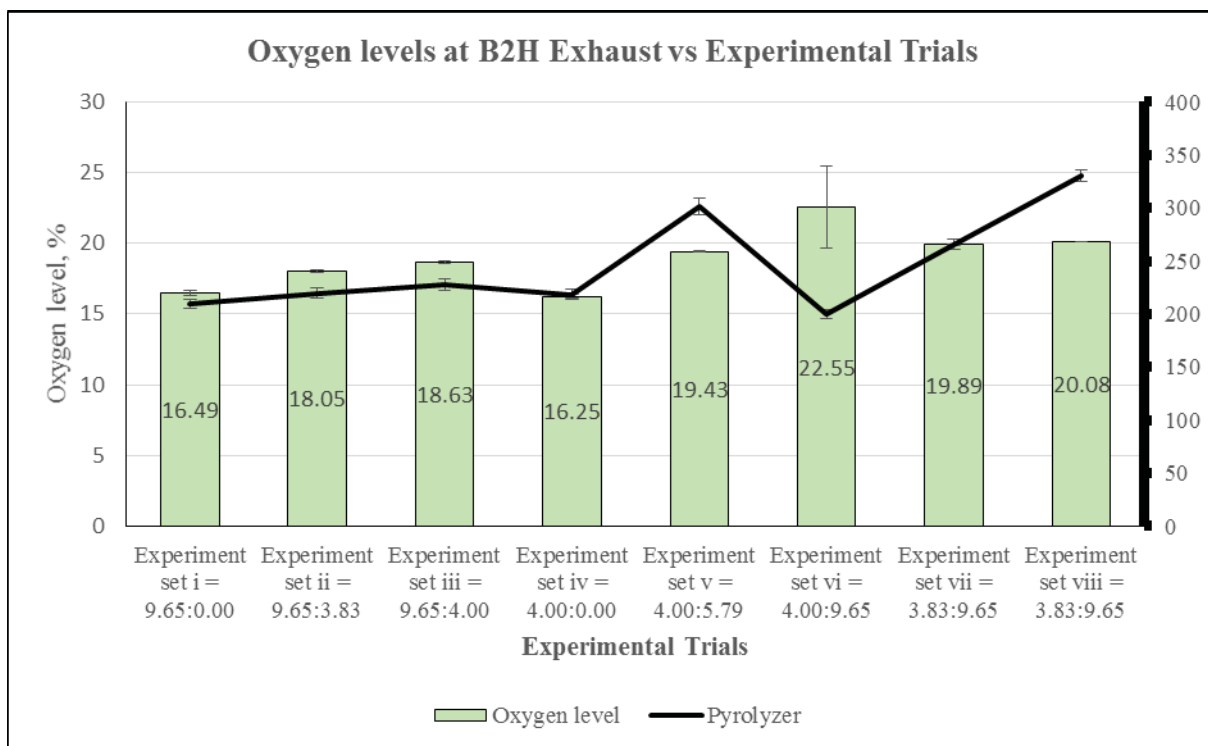


Figure 4.16: Oxygen levels at B2H exhaust vs experimental trials

v) Mean Gas Compositions Volumetric Percentage Measured at the Exhaust

Table 4.14 and **Figure 4.17** show the mean gas composition volumetric percentages in the B2H exhaust. In Group A (Experiments i, ii and iii), the volumetric percentages of the constituents (CO, NO, NO₂, NO_x, SO₂, and H₂) measured in Experiment (i) were 74.21%, 1.78%, 1.54%, 3.32%, 1.57% and 17.58%, respectively. The volumetric percentages of the constituents (CO, NO, NO₂, NO_x, SO₂, and H₂) recorded in Experiment (ii) were 74.26%, 2.03%, 1.75%, 3.79%, 1.78% and 16.39%, respectively. The volumetric percentages of the constituents (CO, NO, NO₂, NO_x, SO₂ and H₂) recorded in Experiment (iii) were 75.28%, 1.51%, 1.20%, 2.71%, 1.78% and 17.52%, respectively.

In Group B (Experiments iv, v and vi), the volumetric percentages of the constituents (CO, NO, NO₂, NO_x, SO₂, and H₂) recorded in Experiment (iv) were 71.15%, 0.47%, 1.11%, 1.56%, 0.92% and 24.79%, respectively. The volumetric percentages of the constituents (CO, NO, NO₂, NO_x, SO₂ and H₂) recorded in Experiment (v) were 69.31%, 0.95%, 2.15%, 3.02%, 1.58% and 22.99%, respectively. The volumetric percentages of the constituents (CO, NO, NO₂, NO_x, SO₂, and H₂) recorded in Experiment (vi) were 74.38%, 1.18%, 2.01%, 3.20%, 1.40% and 17.83%, respectively.

In Group C (Experiments vii and viii), the volumetric percentages of the constituents (CO, NO, NO₂, NO_x, SO₂, and H₂) recorded in Experiment (vii) were 69.82%, 1.01%, 2.32%, 3.32%, 1.64% and 21.88%, respectively. The volumetric percentages of the constituents (CO, NO, NO₂, NO_x, SO₂ and H₂) recorded in Experiment (viii) were 77.61%, 0.54%, 0.23%, 0.76%, 2.15% and 18.71%, respectively.

Table 4.14: Mean gas compositions volume measured in the exhaust

Experiment / Measured gas component	i (%)	ii (%)	iii (%)	iv (%)	v (%)	vi (%)	vii (%)	viii (%)
CO	74.21	74.26	75.28	71.15	69.31	74.38	69.82	77.61
NO	1.78	2.03	1.51	0.47	0.95	1.18	1.01	0.54
NO₂	1.54	1.75	1.20	1.11	2.15	2.01	2.32	0.23
NO_x	3.32	3.79	2.71	1.56	3.02	3.20	3.32	0.76
SO₂	1.57	1.78	1.78	0.92	1.58	1.40	1.65	2.15
H₂	17.58	16.39	17.52	24.79	22.99	17.83	21.88	18.71

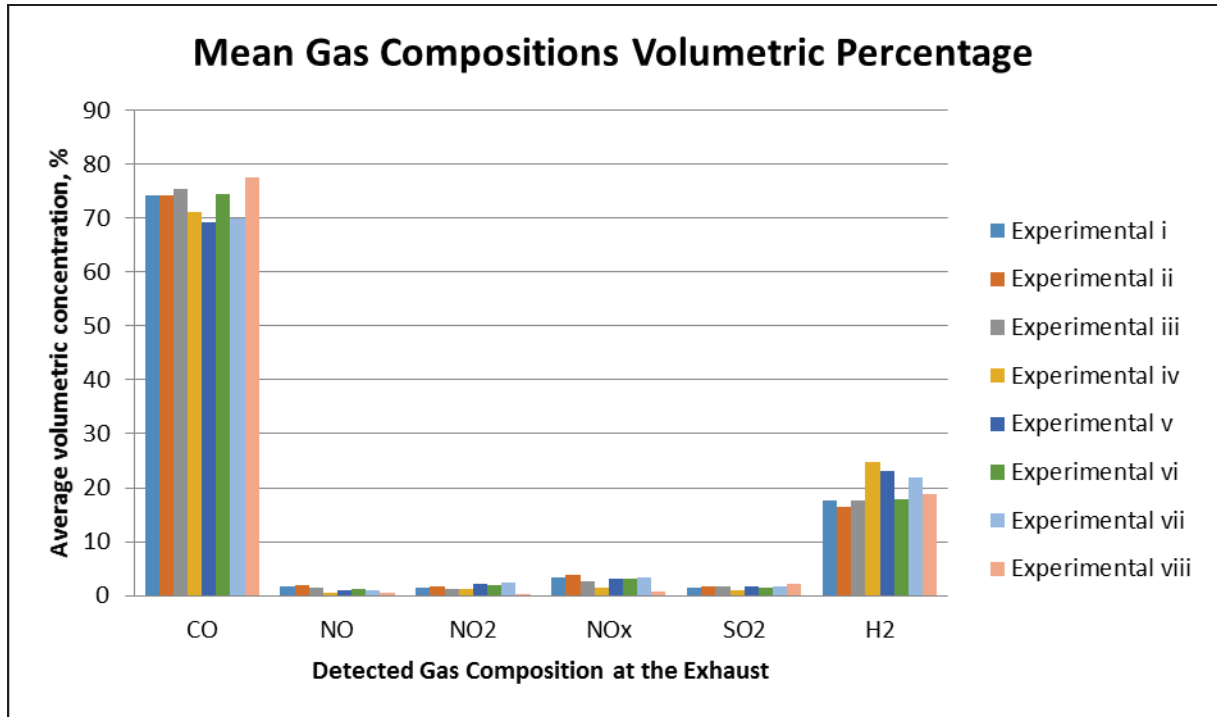


Figure 4.17: Mean gas compositions - volumetric percentage

(C) Combustion Efficiency

Table 4.15 and **Figure 4.18** illustrate the measured mean and SEM of B2H combustion efficiency from the experiments. In Group A (Experiments i, ii and iii), combustion efficiency decreased with increase in the AVR. Experiment (i) recorded the highest combustion efficiency ($66.60 \pm 0.43\%$) at $209.72 \pm 4.26^\circ\text{C}$; Experiment (iii) recorded the lowest combustion efficiency ($61.85 \pm 0.41\%$) at $227.76 \pm 5.40^\circ\text{C}$, which was the lowest among all the experimental groups.

In Group B (Experiments iv, v and vi), Experiment (iv) recorded the highest combustion efficiency ($73.89 \pm 1.59\%$) at $218.26 \pm 4.81^\circ\text{C}$, which was the highest among all the experimental groups. Experiment (v) recorded the lowest combustion efficiency ($62.33 \pm 0.41\%$) at $301.52 \pm 8.14^\circ\text{C}$. However, in Group C (Experiments vii and viii), both

experiments showed similar combustion efficiency; $66.97 \pm 0.47\%$ at $265.55 \pm 4.79^\circ\text{C}$ and $68.42 \pm 0.40\%$ at $338.55 \pm 5.31^\circ\text{C}$, respectively.

Table 4.15: Combustion efficiency of B2H

Experiment	Combustion efficiency (%)		Pyrolyzer mean temperature ($^\circ\text{C}$)	
	Mean	SEM	Mean	SEM
Group A				
Experiment Set i	66.60	0.43	209.72	4.26
Experiment Set ii	64.43	0.43	219.55	4.97
Experiment Set iii	61.85	0.41	227.76	5.40
Group B				
Experiment Set iv	73.89	1.59	218.26	4.81
Experiment Set v	62.33	0.41	301.52	8.14
Experiment Set vi	64.03	0.44	199.86	3.68
Group C				
Experiment Set vii	66.97	0.47	265.55	4.79
Experiment Set viii	68.42	0.40	338.55	5.31

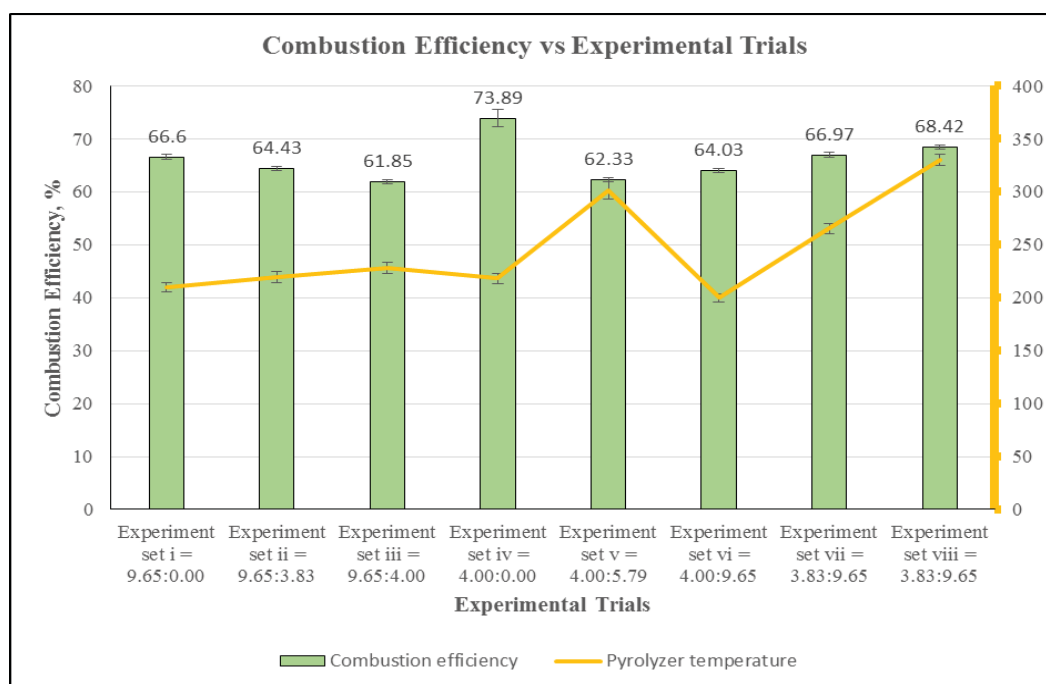


Figure 4.18: Combustion efficiency vs experimental trials

4.4 Statistical Analysis for Experiment (vii)

Statistical analysis (correlation and regression) was performed for Experiment (vii) as it emitted the lowest CO emissions of all the experiments. A correlation is a measure of the linear relationship between variables. In this analysis, a correlation was computed to investigate whether there was a statistically significant relationship between the pyrolyzer temperature (PT) and emissions (CO, H₂, NO_x, SO₂), exhaust temperature (FT) and combustion efficiency. The Pearson correlation statistic was used because it was a linear line from the SPSS computed result. Correlations can be a very useful research tool but tell us nothing about the predictive power of variables, so a simple linear regression analysis instead of a multiple linear regression analysis is used to predict the values of the independent variables (CO, H₂, NO_x, SO₂, FT and combustion efficiency) from the independent variable (PT). The only independent variable is the pyrolyzer temperature (PT). A summary of the results of the correlation and regression for Experiment (vii) are shown in **Tables 4.16–4.35**. Details of the statistical analysis can be found in **Appendix P**.

Table 4.16: Correlations between pyrolyzer temperature and emissions, combustion efficiency

		PT_vii	CO_vii	H2_vii	NOx_vii	SO2_vii	Eff_vii
PT_vii	Pearson Correlation	1	-0.146**	-0.269**	-0.337**	-0.217**	-0.205**
	Sig. (2-tailed)		0.004	0.000	0.000	0.000	0.000
	N	395	395	395	395	395	332
CO_vii	Pearson Correlation	-0.146**	1	0.603**	0.205**	0.178**	0.130*
	Sig. (2-tailed)	0.004		0.000	0.000	0.000	0.018
	N	395	600	600	600	600	332
H2_vii	Pearson Correlation	-0.269**	0.603**	1	0.254**	-0.085*	-0.019
	Sig. (2-tailed)	0.000	0.000		0.000	0.038	0.728
	N	395	600	600	600	600	332
NOx_vii	Pearson Correlation	-0.337**	0.205**	0.254**	1	-0.293**	-0.220**
	Sig. (2-tailed)	0.000	0.000	0.000		0.000	0.000
	N	395	600	600	718	718	332
SO2_vii	Pearson Correlation	-0.217**	0.178**	-0.085*	-0.293**	1	0.333**

	Sig. (2-tailed)	0.000	0.000	0.038	0.000		0.000
	N	395	600	600	718	718	332
Eff_vii	Pearson Correlation	-0.205**	0.130*	-0.019	-0.220**	0.333**	1
	Sig. (2-tailed)	0.000	0.018	0.728	0.000	0.000	
	N	332	332	332	332	332	332

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Table 4.17: Correlations between pyrolyzer temperature and exhaust temperature of Experimental (vii)

	PT_vii_Special _for_T	FT_vii_Special _for_T
PT_vii_Special_for_T	1	0.627**
Pearson Correlation		
Sig. (2-tailed)		0.000
N	120	120

** . Correlation is significant at the 0.01 level (2-tailed).

Table 4.18: Model summary for regression between pyrolyzer temperature and CO

R	R Square	Adjusted R Square	Std. Error of the Estimate
0.146 ^a	0.021	0.019	50.88235

a. Predictors: (Constant), PT_vii

Table 4.19: ANOVA^b for pyrolyzer temperature and CO

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	22057.214	1	22057.214	8.520	0.004 ^a
Residual	1017482.447	393	2589.014		
Total	1039539.661	394			

a. Predictors: (Constant), PT_vii

b. Dependent Variable: CO_vii

Table 4.20: Coefficients^a for pyrolyzer temperature and CO

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	211.123	7.593		27.805	0.000
PT_vii	-.079	0.027	-.146	-2.919	0.004

a. Dependent Variable: CO_vii

Table 4.21: Model summary for regression between pyrolyzer temperature and H₂

R	R Square	Adjusted R Square	Std. Error of the Estimate
.269 ^a	0.072	0.070	25.33706

a. Predictors: (Constant), PT_vii

Table 4.22: ANOVA^b for pyrolyzer temperature and H₂

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	19676.910	1	19676.910	30.651	0.000 ^a
Residual	252292.888	393	641.967		
Total	271969.797	394			

a. Predictors: (Constant), PT_vii

b. Dependent Variable: H₂_viiTable 4.23: Coefficients^a for pyrolyzer temperature and H₂

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	82.909	3.781		21.928	0.000
PT_vii	-0.074	0.013	-0.269	-5.536	0.000

a. Dependent Variable: H₂_viiTable 4.24: Model summary for regression between pyrolyzer temperature and NO_x

R	R Square	Adjusted R Square	Std. Error of the Estimate
0.337 ^a	0.114	0.112	3.49989

a. Predictors: (Constant), PT_vii

Table 4.25: ANOVA^b for pyrolyzer temperature and NO_x

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	618.414	1	618.414	50.486	0.000 ^a
Residual	4813.941	393	12.249		
Total	5432.354	394			

a. Predictors: (Constant), PT_vii

b. Dependent Variable: NO_{x_vii}Table 4.26: Coefficients^a for pyrolyzer temperature and NO_x

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	12.025	0.522		23.025	0.000
PT_vii	-0.013	0.002	-0.337	-7.105	0.000

a. Dependent Variable: NO_{x_vii}Table 4.27: Model summary for regression between pyrolyzer temperature and SO₂

R	R Square	Adjusted R Square	Std. Error of the Estimate
0.217 ^a	0.047	0.045	1.17339

a. Predictors: (Constant), PT_vii

Table 4.28: ANOVA^b for pyrolyzer temperature and SO₂

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	26.706	1	26.706	19.396	0.000 ^a
Residual	541.102	393	1.377		
Total	567.808	394			

a. Predictors: (Constant), PT_vii

b. Dependent Variable: SO_{2_vii}Table 4.29: Coefficients^a for pyrolyzer temperature and SO₂

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	4.407	0.175		25.169	0.000
PT_vii	-0.003	0.001	-0.217	-4.404	0.000

a. Dependent Variable: SO_{2_vii}

Table 4.30: Model Summary for regression between pyrolyzer temperature and exhaust temperature

R	R Square	Adjusted R Square	Std. Error of the Estimate
0.627 ^a	0.393	0.388	6.44931

a. Predictors: (Constant), PT_vii

Table 4.31: ANOVA^b for pyrolyzer temperature and exhaust temperature

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	3184.313	1	3184.313	76.558	0.000 ^a
Residual	4908.047	118	41.594		
Total	8092.360	119			

a. Predictors: (Constant), PT_vii_Special_for_T

b. Dependent Variable: FT_vii_Special_for_T

Table 4.32: Coefficients^a for pyrolyzer temperature and exhaust temperature

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	71.488	1.701		42.034	0.000
PT_vii_Special_for_T	0.053	0.006	0.627	8.750	0.000

a. Dependent Variable: FT_vii_Special_for_T

Table 4.33: Model Summary for regression between pyrolyzer temperature and combustion efficiency

R	R Square	Adjusted R Square	Std. Error of the Estimate
0.205 ^a	0.042	0.039	8.51382

a. Predictors: (Constant), PT_vii

Table 4.34: ANOVA^b for pyrolyzer temperature and combustion efficiency

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	1053.618	1	1053.618	14.536	0.000 ^a
Residual	23920.113	330	72.485		
Total	24973.731	331			

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	1053.618	1	1053.618	14.536	0.000 ^a
Residual	23920.113	330	72.485		
Total	24973.731	331			

a. Predictors: (Constant), PT_vii

b. Dependent Variable: η_{vii}

Table 4.35: Coefficients^a for pyrolyzer temperature and combustion efficiency

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	72.060	1.414		50.946	0.000
PT_vii	-0.018	0.005	-0.205	-3.813	0.000

a. Dependent Variable: η_{vii}

4.5 Summary of the Analytical Results

The analytical results can be summarized as follows. The p-values of the variables (pyrolyzer temperature, CO, H₂, NO_x, SO₂, exhaust temperature and combustion efficiency) are significant ($p < 0.01$). The correlations between pyrolyzer temperature and CO (-0.146), H₂ (-0.269), SO₂ (-0.217), combustion efficiency (-0.205) are in low to moderate relationship. The correlation between pyrolyzer temperature and NO_x (-0.337) is a moderate to substantial relationship. The correlation between pyrolyzer temperature and exhaust temperature (-0.627) is a substantial to very strong relationship. This clearly indicates that pollutants emission (CO, NO_x and SO₂) is less when the oil palm kernel shell and wood chips are burned in the developed B2H converter. This also indicates that the B2H converter's combustion efficiency is good. Thus, these findings satisfy the research question and objectives of this study.

Chapter 5 DISCUSSION

5.1 Thermal Property of Selected Biomass Samples

Generally, the OPKS and wood chips begin to decompose at about 28°C and will turn completely into ash at about 900°C. The selected biomass combustion undergoes four distinct stages, namely, drying, pyrolysis, gasification and combustion. An endothermic process is observed in the early stage, which represents the drying process (**Figures 4.2–4.4** and **Figures 4.6–4.8**). The mean drying temperatures of OPKS and wood chips are 28–183.33°C and 28–116.67°C, respectively (**Table 4.5**). In **Table 4.6** and **Figure 4.9**, the weight loss of OPKS in the drying process is a higher percentage (14.601%) than of wood chips (12.352%). Although the moisture content of the wood chips ($16.2 \pm 1.1\%$ wt.) is about 27.77% higher than the OPKS ($11.7 \pm 0.1\%$ wt.) (**Figure 4.10** and **Table 4.7**), the mean drying temperature of wood chips is lower than that of OPKS (**Table 4.5**). This might be because the permeability of OPKS is higher than wood chips, as pointed out by Simão, Egas, Carvalho, Baptista, and Castro (2008).

Drying occurs in two stages (**Figure 5.1**): the first stage is known as the constant drying rate, which is the evaporation of water on the biomass exterior, while the second stage is known as the falling drying rate and it is governed by the rate of diffusion within the biomass sample itself, as water travels along a moisture gradient from the centre towards its surface (Gigler, van Loon, Vissers, & Bot, 2000; Jirjis, 1995). Fyhr and Rasmuson (1997) found that the dimensions of the wood chips affected the drying time significantly. The total drying time

increased linearly with thickness as well as the square root of the length, as OPKS is at least 0.5 orders of magnitude larger than wood chips.

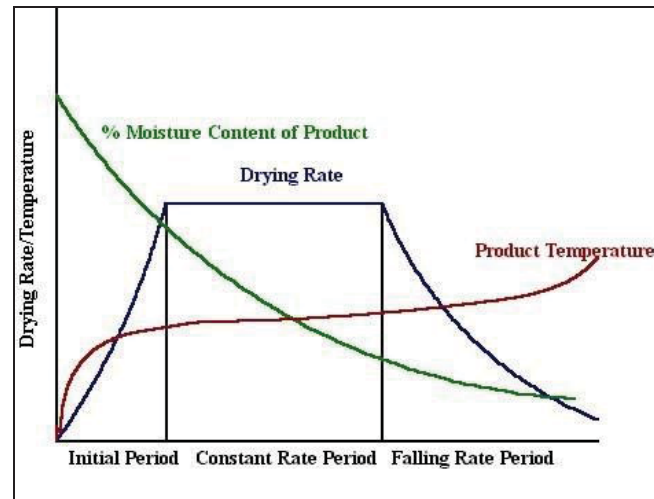


Figure 5.1: Typical drying curve of biomass (adapted from Bahavand, 2012)

After the drying process, the investigated biomass samples go through the pyrolysis, gasification and combustion processes, which contribute to the decomposition of cellulose, hemicellulose and lignin components in the biomass. Based on the literature review, the hemicelluloses start to degrade at 220°C; cellulose decomposes at temperatures >300°C; lignin degrades slowly in a wider temperature range (Pazó, Granada, Saavedra, Eguía, & Collazo, 2010). These findings were supported by Mahanim, Asma, and Rafidah (2011), who reported that hemicellulose starts to degrade at 250–320°C; cellulose pyrolysis occurs at 320–380°C; lignin decomposes slowly throughout the whole temperature range from room temperature up to 900°C. Thus, the decomposition of hemicellulose is responsible for the pyrolysis process. The decomposition of cellulose contributes to the gasification process, and the decomposition of lignin accomplishes the combustion process. The mean pyrolysis temperatures of the OPKS and wood chips samples are 183.33–300°C and 116.67–260°C,

respectively (**Table 4.5**). The mean gasification temperatures of the OPKS and wood chips samples are 300–373.33°C and 260–365°C, respectively. The mean combustion temperatures of the OPKS and wood chips samples are 373.33–900°C and 365–900°C, respectively (**Figure 5.2**).

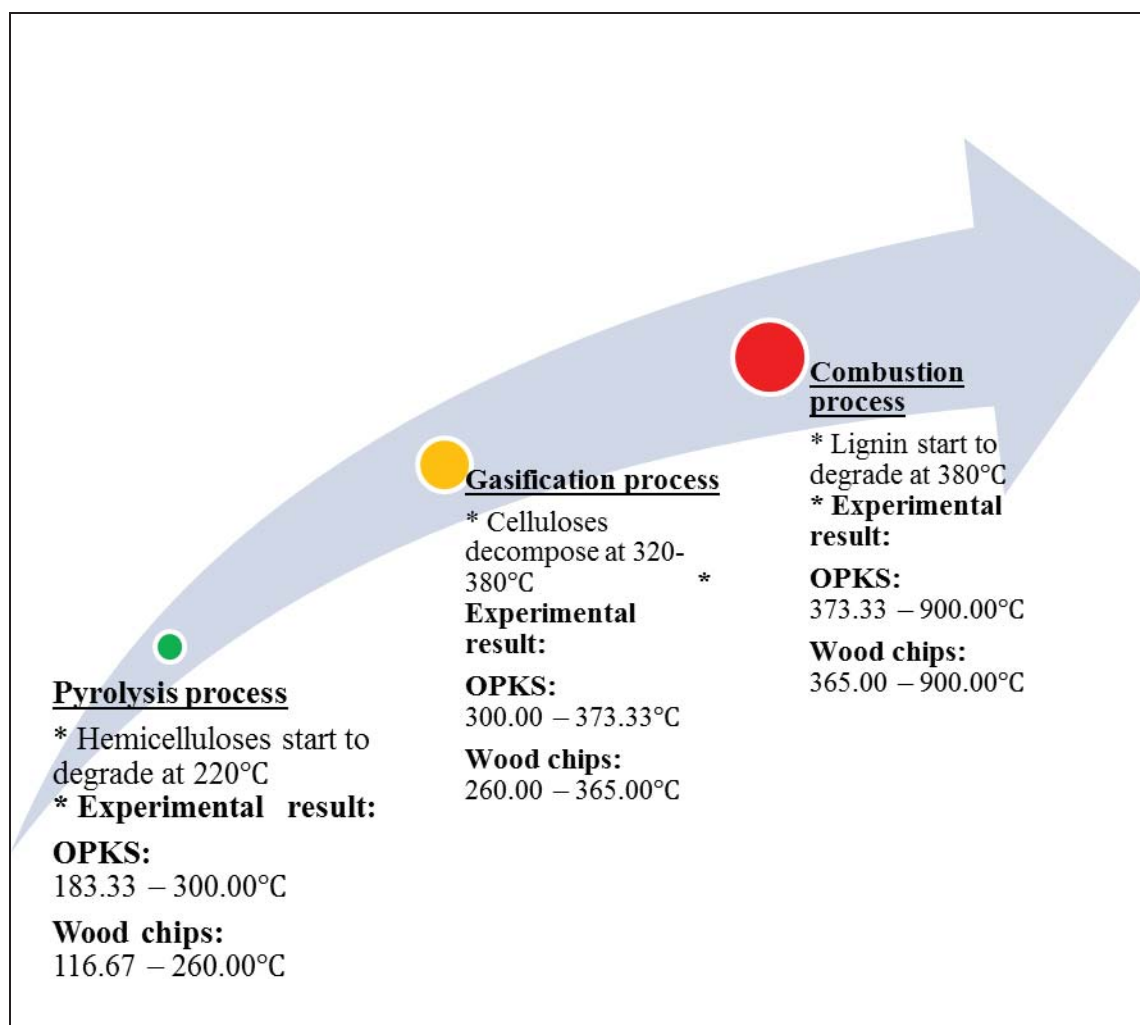


Figure 5.2: Thermal property of selected biomass sample

5.2 Moisture Content of Selected Biomass Samples

Figure 4.10 and **Table 4.7** illustrate that the moisture content of the selected wood chips ($16.2 \pm 1.1\%$ wt.) is higher than the selected oil palm kernel shell ($11.7 \pm 0.1\%$ wt.), which is a suitable moisture content ($<20\%$ wt.) for effective drying, as suggested by EU (2005). The

results for oil palm kernel shell correlate well with Zafar (2013) and Dagwa et al. (2012). The higher moisture content of the selected wood chips than the oil palm kernel shell might be attributed to their morphology that contains relatively more moisture (Helin, 2005) and/or being exposed to rain. Therefore, the producer gas temperature from oil palm kernel shell is expected to be higher than wood chips, as a result of the moisture content.

5.3 Air Flow Rate of B2H Blowers

The air flow rate (Nm^3/s) is directly proportional to the AVR. As the velocity of the blower is increased, the volume of the air supplied is increased (**Figure 4.11** and **Table 4.8**). Experimental Set (iv) gives the lowest air flow rate ($0.01824 \text{ Nm}^3/\text{s}$) of all the experimental trials and Experimental Set (iii) gives the highest air flow rate ($0.07661 \text{ Nm}^3/\text{s}$) of all the experimental trials. The air flow rate is one of the main determining factors with respect to performance evaluation of the B2H converter. According to Reed and Das (1988) and Yamazaki et al. (2005), it has an important effect on the gas production rate, gas energy content, fuel consumption rate, power output, char, tar production rates, and it is independent of the reactor dimensions.

5.4 Effect of Air velocity Ratio on the Temperature Profile, Flue Gas Composition and Combustion Efficiency

(A) B2H Temperatures

i) Temperature of Pyrolysis Chamber

Generally, the mean temperature of the pyrolysis chamber increased with increase of the AVR. This is in agreement with Yang et al. (2004) and Surjosatyo and Ani (1998), and could be because of the good mixing between fuel and air that promotes the heat and mass transfer in the biomass combustion (**Figure 4.12**). Group A (Experiments i, ii and iii) showed the lowest mean temperature ranges from $209.72 \pm 60.32^{\circ}\text{C}$ to $227.76 \pm 80.03^{\circ}\text{C}$. In Group B (Experiments iv, v and vi), the mean temperature ranges were from $199.86 \pm 72.12^{\circ}\text{C}$ to $301.52 \pm 150.52^{\circ}\text{C}$. However, Group C (Experiments vii and viii) contributed the highest mean temperature range overall; that is, $265.55 \pm 95.23^{\circ}\text{C}$ to $338.55 \pm 89.65^{\circ}\text{C}$, even though the AVR was lower than in Experiments (ii), (iii), (v), and (vi) (**Figure 4.12**). In Group C, Experiment (viii) recorded a higher mean temperature of pyrolysis due to the fact that wood chips possess a wider effective surface area for reaction than oil palm kernel shell (Pérez et al., 2012). The abnormally high mean temperature of the pyrolysis chamber in Experiment (v) could be because burning fuel spread over the measured thermocouple and was only removed after about 18 minutes (**Appendix O**).

ii) Temperature of Exhaust

It can be observed that the mean temperature of the exhaust decreased consistently with increase in the AVR and or excess air (**Figure 4.12**). This was attributed to the convective

cooling effect of the secondary air, which became higher than the energy released by the exothermic reaction and also higher than the radiative heat transfer from the solid phase (Tinaut, Melgar, Pérez, & Horrillo, 2008). As the air flow rate was increased above the theoretical value, the B2H input energy per kg of fuel gases was reduced and the exhaust gas temperature decreased. Previous studies by Habib et al. (2008) and Varol and Atimtay (2007) confirmed these factors. Therefore, it can be concluded that the AVR is an important factor to achieve the desired temperature. As shown in **Figure 4.12**, Group A recorded the highest mean exhaust temperatures generally, followed by Group B and Group C.

Fagnäs et al. (2010) suggested that an exhaust temperature of less than 100°C should be maintained when possible. It would then be possible to carry out drying of wood fuels to about 10% wt. moisture content without emitting a harmful amount of organic compounds (Fagnäs, Mckeough, & Impola, 2007). Prerequisites are that drying occurs in a bed; the inlet drying gas temperature is not higher than 180°C; the steam is not condensed. The mean exhaust temperatures of Experiments (vi), (vii) and (viii) fit these prerequisites (**Figure 4.12** and **Table 4.9**).

iii) Surrounding Temperature

Generally, a very small change in the temperature of the B2H's surroundings was observed (**Figure 4.12** and **Table 4.9**). In this experiment, the lowest surrounding temperature was 30.14±2.22°C, while the highest recorded was 33.32±1.44°C, which was due to the use of refractory possessing a high heat capacity and low thermal conductivity to absorb the radiated energy for energy-saving (UNEP, 2006).

(B) Gas Compositions

i) Combustible Gases (CO, H₂)

As shown in **Figure 4.13** and **Table 4.10**, CO and H₂ concentrations are inversely proportional to increase in the AVR and excess air, which is attributed to the air-staging method applied in this experiment, with a fuel-rich zone and fuel-lean zone at the pyrolysis and tar removal chambers. This finding is in agreement with the works of Atnaw, Sulaiman and Yusup (2011), Franco, Gulyurtlu, Vilela and Lopes (2008), Permatasari, Hui, Nazri and Ja (2013), Shaiful and Nazri (2007), Wan Ab Karim Ghani et al. (2009) and Yang et al. (2004).

There were CO emission reductions of 46.78% and 81.28% for Group A (Experiments i, ii and iii) and Group B (Experiments iv, v and vi), respectively. Experiment (iv) (non-air staging) in Group B recorded the highest CO emissions, which was attributed to the deficiency of air combustion of 53.94%. This is followed by Experiment (i) (non-air staging) in Group A, as it has only about 2.84% excess air combustion. In Group B, a CO emission reduction of more than 80% was achieved by using an air staging test (Experiment vi) as compared to a non-air staging test (Experiment iv). The CO emission from the combustion process was attributed to the lack of sufficient oxygen to complete the reactions from CO to CO₂. When the secondary air was added into the tar removal chamber to supply the oxygen to complete the combustion, the exhaust temperature dropped. In this particular experiment, the optimum condition of the air staging method in the B2H was about 78.18% excess air combustion with the lowest CO emission.

In Group A (Experiments i, ii and iii), the CO concentration in Experiment (iii) was higher than in Experiment (ii) because of the smoke measured at the B2H exhaust during the initial

combustion, which subsequently caused the Testo 350XL analyser to malfunction (Testo, 2012). This phenomenon happened mostly during the first 2 minutes (**Appendix O**: Experiments iii-1, iii-2 and iii-3), where the fuel was used as the “starter” for the combustion process with a limited oxygen supply and residence time (Calvo, Tarelho, Duarte, Evtyugina, & Alves, 2011; Soares Neto et al., 2011).

Generally, the phenomenon of high CO concentrations could be the result of a number of factors, such as the location of the air staging (Munir et al., 2011), insufficient air supplied (Verma et al., 2011), ignition from the bottom (Bhattacharya et al., 2002) or short residence time of the combustion gases in the combustion zone (Kristensen & Kristensen, 2004).

The CO emissions from biomass combustion are closely related to biomass content. As shown in **Figure 4.13**, the CO concentrations from OPKS are lower than from wood chips. The works of Wan Ab Karim Ghani and Alias (2013) showed that, with about 75% excess air combustion, the CO emissions from OPKS (collected from Perlis) recorded about 680 ppmv by using a Xentra 4904 B1 analyser, whilst in Experiment (vii), with 78.17% excess air (OPKS as fuel), the CO concentration was measured at around 195.03 ± 9.17 ppmv. Moreover, the study by Malat'ák and Passian (2011) showed that the CO emission from forest wood chips (spruce pellets) was about 822 ppmv under an excess air coefficient of about 210 excess air combustion, which is in agreement with the recorded results, showing that the CO emission from the wood chips is always higher than OPKS. The carbon content in OPKS (41.47–45.61%) (Luangkiattikhun, Tangsathitkulchai, & Tangsathitkulchai, 2008; May, Phaik, Ti, Eng, & Kit, 2013) was found to be always lower than the wood chips (51.8–54.9%) (Tillman, Rossi, & Kitto, 1981; Wilén, Moilanen, & Kurkela, 1996)). Thus, OPKS is more suitable for use as a biomass combustion fuel than wood chips because it generates lesser CO emissions.

Besides carbon content, volatile matters of biomass also contribute to CO emissions. Varol and Atimtay (2007) found that fuel containing a high level of volatile matters will lead to higher CO emissions, which agrees with literature review material showing that the volatile matters range of OPKS and wood chips is about 58–61.60% (Ojolo, Abolarin, & Adegbenro, 2012; Shamsuddin, 2010) and 78.54–85.00% (Helin, 2005; Zygarlicke & Folkedahl, 2003), respectively. If a higher amount of volatile matters cannot find enough oxygen to burn in the tar removal chamber, the biomass will leave the B2H exhaust in a partially oxidized state.

Moreover, Varol and Atimtay (2007) found that fuel with a lower dry density will release higher CO emissions, which might be due to weaker atomic bonding in such fuel that promotes disintegration more easily (Johansson, 2002; Nussbaumer, 2001). The literature search shows that the dry densities of OPKS and wood chips are in the range of 650–781 kg/m³ (Elham, 2001; Ndoke, 2006) and 240–523 kg/m³ (Forestpower, 2011; SCAN-CM, 1995), respectively.

The H₂ concentration was inversely proportional to AVR and excess air (**Figure 4.13** and **Table 4.10**). This was due to the dilution effect caused by the increase of nitrogen content (introduced along with air) – which explains the decrease of all the volumetric percentages (**Figure 4.17**). Additionally, the introduction of higher oxygen content will diminish the reduction conditions because the rate of oxidation reactions (exothermic burning) is opposite to the cracking and reforming reactions, so the H₂ content will decrease (Aznar, Caballero, Sancho, & Francés, 2006; Khor, Ryu, Yang, Sharifi, & Swithenbank, 2006).

ii) Nitrogen Oxides (NO, NO₂)

The measured nitrogen oxides (NO_x) are nitrogen monoxide (NO) and nitrogen dioxide (NO₂). **Figure 4.14** and **Table 4.11** show that an increase in AVR leads to a decrease in NO_x levels, which is in agreement with the findings of Baxter, Jenkins and Winter (1994), Habib et al. (2008), Qian, Chyang, Huang and Tso (2011) and Zainal, Rifau, Quadir and Seetharamu (2002). This trend might be due to the dilution of NO_x by an increase in excess combustion air.

Temperature and staged combustion play the most important roles in NO emissions. In **Figure 4.14**, it is observed that the NO concentration decreases with increase of the pyrolysis chamber temperature, which could be because the higher temperature favours both higher volatile-nitrogen release and oxidation of volatile-nitrogen species in the gas phase (Zhao, Grace, Lim, Brereton, & Legros, 1994). The higher temperature reduces carbon loading in the bed, and thereby lessens NO reduction by char (Harding, Smoot, & Hedman, 1982). Moreover, the amount of the volatile in the tar removal chamber increases with an increase in bed temperature. Secondary air introduced into the tar removal chamber will enhance mixing between the air and volatile, and hence NO can be reduced by the volatile (Winter, Wartha, & Hofbauer, 1999); subsequently, NO concentration in the B2H decreases as the bed temperature increases.

In **Figure 4.14**, the degree of reduction in NO_x at a greater secondary air ratio is clearly illustrated, and suggests that staged combustion is more effective in reducing NO_x emission at higher pyrolysis chamber temperatures, and even in a horizontal air-staged inclined B2H converter. In Group A (Experiments i, ii and iii), the NO_x concentrations could be reduced by about 39.37% (from Experiment i to Experiment ii) and 8.62% (from Experiment ii to Experiment iii) as the mean pyrolysis chamber temperatures increased by about 5.7% and

3.48%, respectively. For Group C (Experiments vii and viii), the NO_x emissions could be reduced by about 64.13% (from Experiment vii to Experiment viii) as the mean pyrolysis chamber temperatures increased by about 27.8%.

Figure 4.14 shows that the NO_x emission in Group A is higher than Group B, which is the result of the higher percentage of air (mostly composed of nitrogen) that is consumed for combustion. Comparatively, NO_x emissions from the wood chips are about 64.13% lower than OPKS. This is because the fuel nitrogen in OPKS is higher than the wood chips. Furthermore, other studies show that the bulk density and volatile matters of the fuels contribute to chemical reactions as well (FAO, 1985; Varol & Atimtay, 2007).

iii) Sulphur Dioxide (SO₂)

Figure 4.15 and **Table 4.12** show that SO₂ is inversely proportional to AVR. In Group B (Experiments iv, v and vi), SO₂ concentration is reduced significantly to approximately 73.26% with the air-staged combustion. A theoretical study by Gungor and Eskin (2008) on a circulating fluidized bed combustor confirmed this trend, and it was observed also in the study by Lyngfelt, Amand, & Leckner (1998). This might be due to the dilution caused by the increases of excess air (Gungor & Eskin, 2008; Stanger & Wall, 2011).

The SO₂ emissions from the investigated wood chip were higher than OPKS, possibly because of the fuel-bound sulphur, which can range from 0.01% to 2% in biomass fuel (Reed & Das, 1988, p.15). Werther, Saenger, Hartge, Ogada and Siagi (2000) confirmed that SO₂ emissions vary as a function of fuel-bound sulphur. Thus, SO₂ emissions are proportional to fuel-bound sulphur.

Moreover, SO₂ emissions can create environmental pollution, if not treated properly. During the flue gas cooling, a portion of SO₂ is converted to sulphur trioxide (SO₃), which may subsequently be converted into sulphuric acid (H₂SO₄), which can have significant corrosive characteristics if allowed to condense (Stanger & Wall, 2011). Technically, it is difficult and expensive to remove the fuel-bound sulphur before burning the fuel (Javed, Irfan, & Gibbs, 2007).

Furthermore, SO₂ is a major air pollutant contributing to acid rain and it has immediate impacts upon human health (Demirbas, 2005; EPA, 2008). Studies by Jiménez and Ballester (2005) showed that the concentrations of SO₂ in flue gas could drastically affect the chloride in the fine particles; practically, regulating SO₂ can help reduce the chlorine content of deposits and hence, corrosion-related operating problems. The environmental benefits of reducing SO₂ emissions make the B2H converter a favoured approach in drying applications.

iv) Oxygen Levels in B2H Exhaust

Figure 4.16 and **Table 4.13** show the trends of increase in the oxygen levels at the B2H exhaust, where the AVR is increased from Group A to Group B followed by Group C because an increase of the air volume from the blowers increases the oxygen levels (Al-Widyan, Tashtoush, & Hamasha, 2006). Generally, it can be seen that experiments with higher pyrolyzer temperatures have higher oxygen levels (**Figure 4.16**). Luo et al. (2009) showed that with an increase in oxygen concentration, the volatile release temperature, ignition temperature and burnout temperature will decrease, as shown in **Figure 4.16**.

v) Mean Gas Composition and Volumetric Percentage Concentration Measured at the Exhaust

Figure 4.17 and **Table 4.14** show that, among all the experiments, CO emissions account for the highest percentage measured at the B2H exhaust, followed by H₂, NO_x and SO₂. Generally, the experimental trials in Group A recorded higher CO emissions than Group B: Group B recorded higher H₂ emissions than Group A. From comparison of the investigated wood chips and OPKS in Group C, wood chips produced higher CO levels than OPKS and the latter produced higher H₂ than the wood chips. In view of this, the B2H converter can be modified to reap the combustible gases (CO and H₂) for pre-drying purposes.

vi) Combustion Efficiency

Figure 4.18 and **Table 4.15** show that the combustion efficiency will increase with an increase in AVR, but decrease with excess air (more than about 50% excess air). This is in agreement with Gungor and Eskin (2008), IEA (2013) and Srinath and Reddy (2011), who stated that high (more than about 50%) excess air can lead to a reduction of combustion efficiency. The reason for this might be the increase of the bed operating velocity that changes the hydrodynamic condition of the B2H chamber. An increase to an exceedingly high bed operating velocity would reduce the mean residence time of char particles in the chambers and thus reduce the combustion efficiency.

The combustion efficiency found in this experiment ranges from 61.85±0.41% to 73.89±1.59% (**Table 4.15**). Permatasari et al. (2013) found that the combustion efficiency of a fluidized bed with OPKS was 63% with a 40% excess air and 20% secondary air ratio. In a

modified fluidized combustor, a maximum of 99.2% combustion efficiency was achieved at 65% excess air combustion with sawdust (Reddy, 2008). Werther et al. (2000) stated that, normally, fluidized bed technology is reported to be the most efficient technology for converting agricultural waste into energy.

Marker (2004) indicated that reducing CO emissions does not significantly improve the combustion efficiency. According to Bhattacharya & Weizhang (1990), cited by Reddy (2008), the loss of unburned carbon in the form of CO is in the range of 3% to 10%. In conclusion, the combustion efficiency of the B2H converter is affected mainly by the air staging and incomplete combustion, but not by the CO emission. In this experimental operation condition, increasing the excess air leads to a decrease in combustion efficiency.

5.5 Summary of Mean B2H Combustion Operation

Table 5.1 summarizes the mean combustion operation data at the optimum condition (Experiment (vii) with OPKS as fuel (based on the lowest measured CO emissions). A combustion efficiency of $67.00 \pm 0.34\%$ was achieved with an AVR of 3.86:9.65; air flow rate of $0.05837 \text{ Nm}^3/\text{s}$; excess air combustion of 78.18%. The fluidized bed efficiency achieved by Permatasari et al. (2013) was 63% (with 60% excess air combustion), while 99.2% (with 65% excess air combustion) was achieved in a modified fluidized bed combustor by Reddy (2008). Under these conditions, the temperature of the pyrolysis chamber, B2H exhaust and B2H surroundings are $265.55 \pm 95.23^\circ\text{C}$, $85.71 \pm 4.64^\circ\text{C}$ and $31.67 \pm 1.26^\circ\text{C}$, respectively. Fagnäs et al.'s (2010) experiment showed that the optimum flue gas temperature for drying pulp was less than 100°C . Zaidi (2001) suggested that the paper sheet should be brought up to about 82°C . From comparison with the Environmental Quality Act (EQA), 1974 under the

Environmental Quality (Clean Air) Regulation 1978 (DOE, 2009), the CO and NO₂ and SO₂ emissions at the B2H exhaust (Experiment (vii)) met the EQA regulatory standard, with 195.03±9.17 ppmv (30.19 mg/m³), 9.20±0.87 ppmv (1.53 mg/m³) and 4.57±1.08 ppmv (2.49 mg/m³) respectively.

Table 5.1: Summary of mean combustion data with OPKS as fuel (lowest CO emissions)

Fuel	OPKS	Standard	Reference
Combustion efficiency, %	67.00 ± 0.34	63% (60% excess air combustion) 99.2% (65% excess air combustion)	Permatasari et al. (2013) Reddy (2008)
Air velocity ratio	3.83:9.65		
Air flow rate, Nm³/s	0.05837		
Excess air combustion, %	78.18		
B2H temperatures, °C			
Pyrolysis chamber	265.55 ± 95.23		
B2H exhaust	85.71 ± 4.64	100 °C	Andersson et al. (2006)
B2H surrounding	31.67 ± 1.26		
Flue gases composition			
CO, ppmv	195.03 ± 9.17		DOE (2009)
CO, mg/m ³	30.19 ± 9.17	50 mg/m ³	
H ₂ , ppmv	60.60 ± 5.20		
NO, ppmv	2.79 ± 0.25		
NO ₂ , ppmv	6.42 ± 0.68		DOE (2009)
NO ₂ , mg/m ³	1.53 ± 0.68	200 mg/m ³	
NO _x , ppmv	9.20 ± 0.87		
SO ₂ , ppmv	4.57 ± 1.08		DOE (2009)
SO ₂ , mg/m ³	2.49 ± 1.08	50 mg/m ³	
O ₂ (%)	19.87 ± 0.12		

5.6 Statistical Analysis for Experiment (vii)

A) Correlation

Statistical analysis (correlation and regression) was performed with SPSS version 19 for Experiment (vii), as it emitted the lowest CO emissions of all the experiments. The relationship between pyrolyzer temperature and emissions (CO, H₂, NO_x, SO₂), exhaust temperature (FT) and combustion efficiency was investigated using Pearson's correlation statistic (**Tables 4.16–4.17**).

The total number of tests for pyrolyzer temperature and CO emissions was 395 and the significance level (sig.) was 0.004; the calculated Pearson correlation statistic was $r(393) = -0.146$, $p = 0.004$. The direction of the correlation was negative (-0.146), a low to moderate relationship, which means that higher pyrolyzer temperature tends to lead to lower CO emissions and vice versa. The total number of tests for pyrolyzer temperature and H₂ emissions was 395 and the significance level (sig.) was 0.000. The Pearson correlation was written as $r(393) = -0.269$, $p = 0.000$. The direction of the correlation was negative (-0.269), a low to moderate relationship (Cohen, 1988), which means that a higher pyrolyzer temperature tends to lead to lower H₂ emissions and vice versa. Both of these statistical results (CO and H₂) confirmed the experimental results. There was a total of 395 tests for pyrolyzer temperature and NO_x emissions. The significance level (sig.) was 0.000. The Pearson correlation equation was $r(393) = -0.337$, $p = 0.000$. The direction of the correlation was also -0.337, a moderate to substantial relationship, which means that a higher pyrolyzer temperature tends to lead to lower NO_x emissions and vice versa. The total number of tests for pyrolyzer temperature and SO₂ emissions was 395 and the significance level (sig.) is 0.000. The Pearson correlation equation was $r(393) = -0.217$, $p = 0.000$. The direction of the

correlation was negative (-0.217), a low to moderate relationship, which means that a higher pyrolyzer temperature tends to lead to lower SO₂ emissions and vice versa. The total number of tests for pyrolyzer temperature and combustion efficiency was 332 and the significance level (sig.) was 0.000. The direction of the correlation was negative (-0.205), a low to moderate relationship, which means that the increase to an exceedingly high operating velocity changes the hydrodynamic condition of the B2H chamber, leading to a decrease of combustion efficiency (Srinath & Reddy, 2011). Lastly, the total number of tests for pyrolyzer temperature and exhaust temperature was 120 and the significance level was 0.000. The direction of the correlation was positive (0.627), a substantial to very strong relationship, which indicates that a higher pyrolyzer temperature tends to have a higher exhaust temperature and vice versa.

B) Regression Model Building

i) Regression line for CO:

Bivariate regression analysis was conducted to investigate how well the pyrolyzer temperature predicts emissions (CO, H₂, NO_x, SO₂), exhaust temperature (FT) and combustion efficiency. Bivariate regression was used as the variable results were distributed normally.

Statistically, the regression result for pyrolyzer temperature and CO emissions was significant $F(1, 393) = 8.520, p < 0.001$. The equation identified to understand this relationship was $\text{CO emissions} = 211.123 - 0.79 * (\text{pyrolyzer temperature})$ (**Figure 5.3**). The adjusted R squared value was 0.019, which indicates that 1.9% of the variance in CO emissions was explained by the pyrolyzer temperature (**Tables 4.18–4.20**).

$$Y_{(CO)} = a + bX_{(PT)} \quad (5.1)$$

where

$Y_{(CO)}$ = CO emissions

a = regression line/slop of the best-fit line

b = intercept point

$X_{(PT)}$ = pyrolyzer temperature

b = -0.79

a = 211.123

$$Y_{(CO)} = 211.123 - 0.79X_{(PT)} \quad (5.2)$$

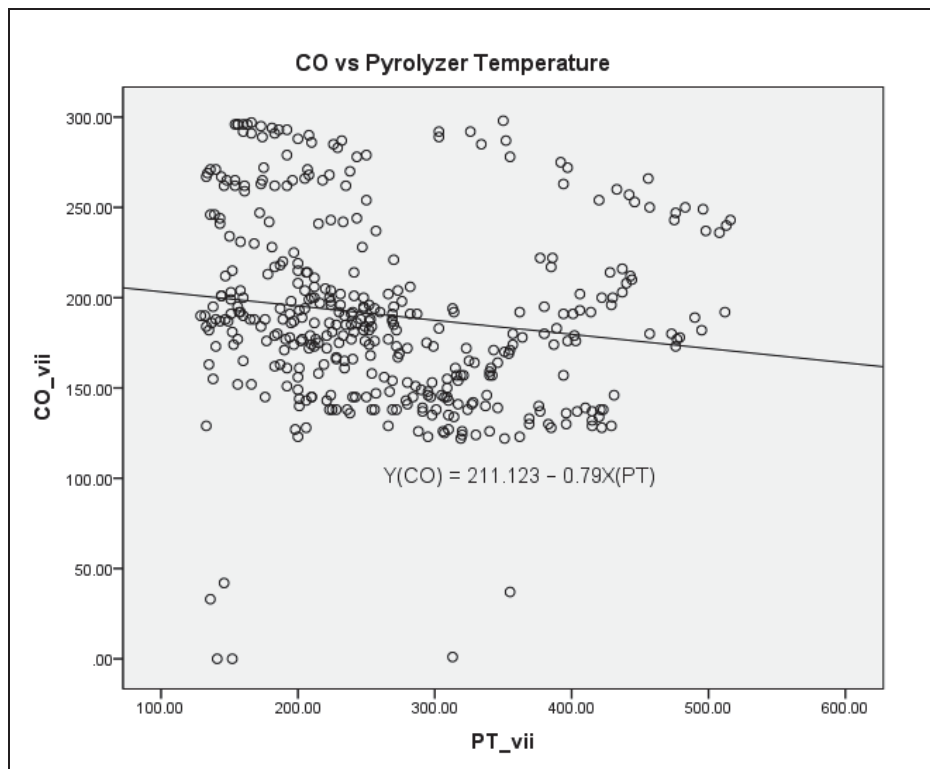


Figure 5.3: CO vs pyrolyzer temperature

ii) Regression line for H₂:

Statistically, the regression result for pyrolyzer temperature and H₂ emissions was significant $F(1, 393) = 30.651, p < 0.001$. The equation identified to understand this relationship was $H_2 \text{ emissions} = 82.909 - 0.74 * (\text{pyrolyzer temperature})$ (**Figure 5.4**). The adjusted R squared value was 0.070, which indicates that 7.0% of the variance in H₂ emissions was explained by the pyrolyzer temperature (**Tables 4.21–4.23**).

$$Y_{(H_2)} = a + bX_{(PT)} \quad (5.3)$$

where

$Y_{(H_2)}$ = H₂ emissions

a = regression line/slop of the best-fit line

b = intercept point

$X_{(PT)}$ = pyrolyzer temperature

b = -0.74

a = 82.909

$$Y_{(H_2)} = 82.909 - 0.74X_{(PT)} \quad (5.4)$$

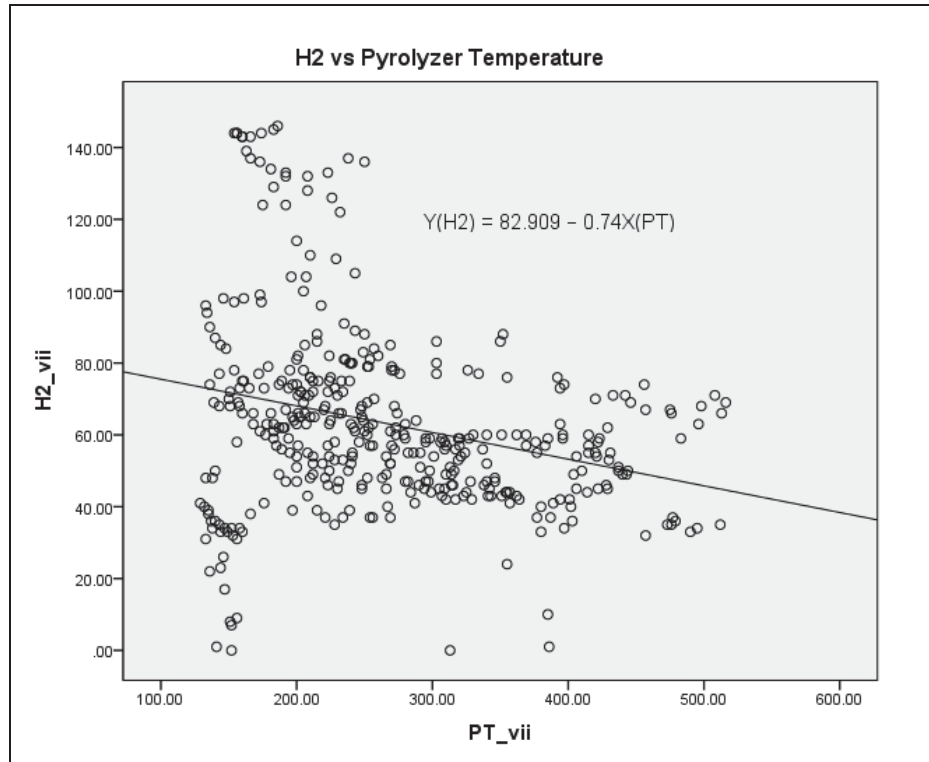


Figure 5.4: H₂ vs pyrolyzer temperature

iii) Regression line for NO_x:

Statistically, the regression result for pyrolyzer temperature and NO_x emissions was significant $F(1, 393) = 50.486$, $p < 0.001$. The equation identified to understand this relationship was NO_x emissions = $12.025 - 0.13 \times (\text{pyrolyzer temperature})$ (**Figure 5.5**). The adjusted R squared value was 0.112, which indicates that 11.2% of the variance in NO_x emissions was explained by the pyrolyzer temperature (**Tables 4.24–4.26**).

$$Y_{(\text{NO}_x)} = a + bX_{(\text{PT})} \quad (5.5)$$

where

$Y_{(\text{NO}_x)}$ = NO_x emissions

a = regression line/slop of the best-fit line

b = intercept point

$X_{(PT)}$ = pyrolyzer temperature

$b = -0.13$

$a = 12.025$

$$Y_{(NOx)} = 12.025 - 0.13X_{(PT)} \quad (5.6)$$

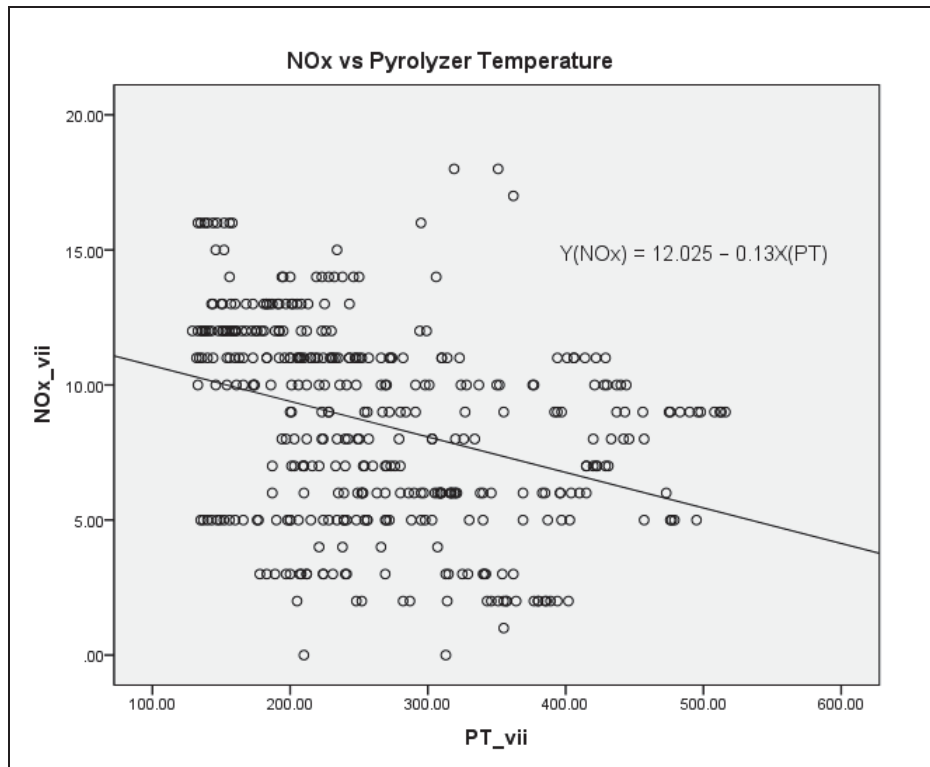


Figure 5.5: NOx vs pyrolyzer temperature

iv) Regression line for SO₂

Statistically, the regression result for pyrolyzer temperature and SO₂ emissions was significant $F(1, 393) = 19.396$, $p < 0.001$. The equation identified to understand this relationship was $SO_2 \text{ emissions} = 4.407 - 0.003 * (\text{pyrolyzer temperature})$ (**Figure 5.6**). The adjusted R squared value was 0.045, which indicates that 4.5% of the variance in SO₂ emissions was explained by the pyrolyzer temperature (**Tables 4.27–4.29**).

$$Y_{(SO_2)} = a + bX_{(PT)} \quad (5.7)$$

where

$Y_{(SO_2)}$ = SO_2 emissions

a = regression line/slop of the best-fit line

b = intercept point

$X_{(PT)}$ = pyrolyzer temperature

$b = -0.003$

$a = 4.407$

$$Y_{(SO_2)} = 4.407 - 0.003X_{(PT)} \quad (5.8)$$

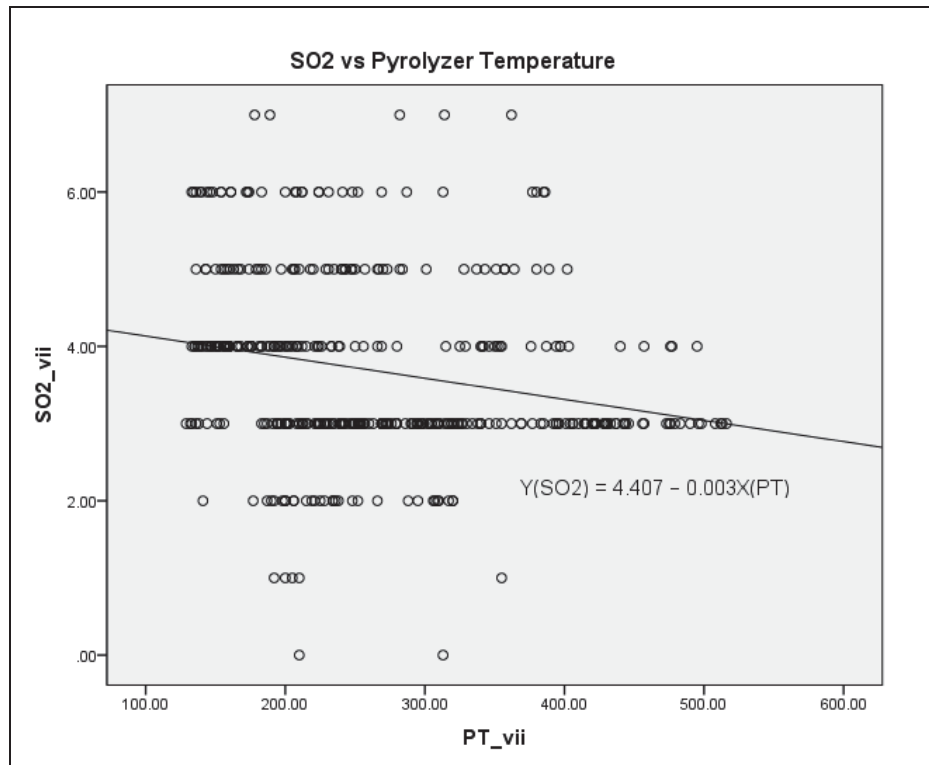


Figure 5.6: SO_2 vs pyrolyzer temperature

v) Regression line for Exhaust Temperature

Statistically, the regression result for pyrolyzer temperature and exhaust temperature was significant $F(1, 118) = 76.558$, $p < 0.001$. The equation identified to understand this

relationship was exhaust temperature = 71.488 + 0.053*(pyrolyzer temperature) (**Figure 5.7**). The adjusted R squared value was 0.388, which indicates that 38% of the variance in exhaust temperature was explained by the pyrolyzer temperature (**Tables 4.30–4.32**).

$$Y_{(FT)} = a + bX_{(PT)} \quad (5.9)$$

where

$Y_{(FT)}$ = exhaust temperature

a = regression line/slop of the best-fit line

b = intercept point

$X_{(PT)}$ = pyrolyzer temperature

b = +0.053

a = 71.488

$$Y_{(FT)} = 71.488 + 0.053X_{(PT)} \quad (5.10)$$

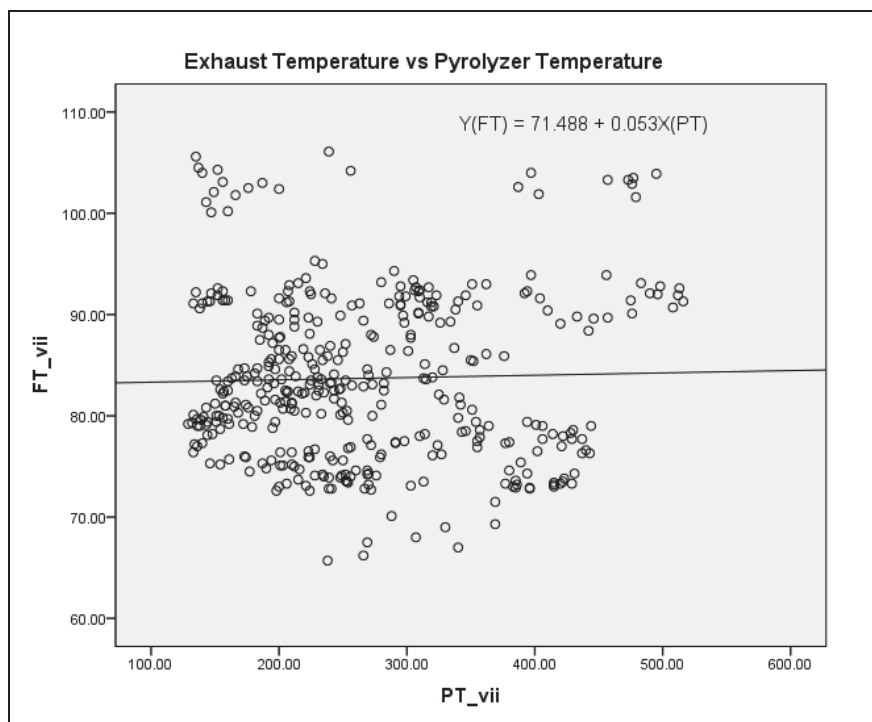


Figure 5.7: Exhaust temperature vs pyrolyzer temperature

vi) Regression line for Combustion Efficiency

Statistically, the regression result for pyrolyzer temperature and combustion efficiency was significant $F(1, 330) = 14.536$, $p < 0.001$. The equation identified to understand this relationship was combustion efficiency = $72.060 - 0.018 * (\text{pyrolyzer temperature})$ (**Figure 5.8**). The adjusted R squared value was 0.039, which indicates that 3.9% of the variance in combustion efficiency was explained by the pyrolyzer temperature (**Tables 4.33–4.35**).

$$Y(\eta_{\text{vii}}) = a + bX_{(\text{PT})} \quad (5.11)$$

where

$Y(\eta_{\text{vii}})$ = combustion efficiency at Experiment (vii)

a = regression line/slop of the best-fit line

b = intercept point

$X_{(\text{PT})}$ = pyrolyzer temperature

b = -0.018

a = 72.060

$$Y(\eta_{\text{vii}}) = 72.060 - 0.018X_{(\text{PT})} \quad (5.12)$$

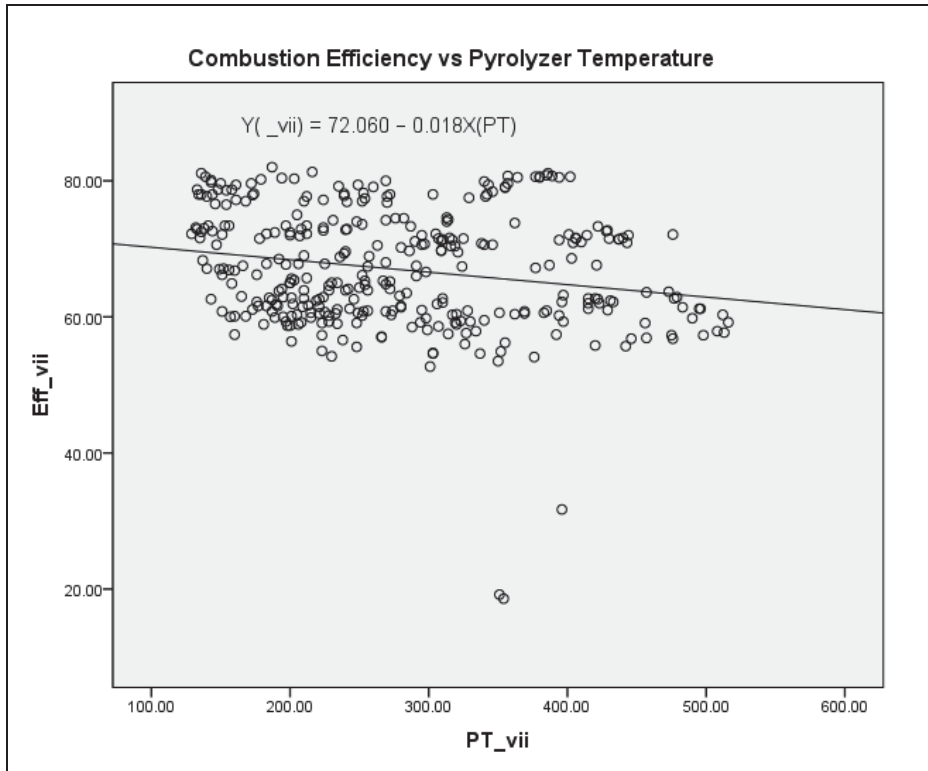


Figure 5.8: Combustion efficiency vs pyrolyzer temperature

5.7 Research Findings

The objectives of this research are to develop (design and fabricate) a biomass-to-heat energy (B2H) converter with a horizontal air-staged design for drying purposes; to evaluate the B2H's flue gas composition (CO , NO_x and SO_2), temperature profile and combustion efficiency. The research is intended to improve the understanding of the effects of the air velocity ratio on the horizontal combustor's (B2H) flue gas composition, temperature profile and combustion efficiency. Research findings from the results and discussion are summarized as follows.

The mean pyrolysis temperature ranges for the OPKS and wood chips samples are 183.33–300°C and 116.67–260°C, respectively. The mean gasification temperature ranges of the

OPKS and wood chips samples are 300–373.33°C and 260–365.00°C, respectively. The mean combustion temperature ranges of the OPKS and wood chips samples are 373.33–900°C and 365–900°C, respectively. The OPKS recorded a moisture content of $11.7 \pm 0.1\%$ wt., while wood chip recorded a moisture content of $16.2 \pm 1.1\%$ wt.

An increase in AVR leads to an increase in the mean temperature of the pyrolysis chamber, but it reduces the mean temperature in the exhaust, with insignificant change in the surrounding temperatures. The regression equation for the exhaust temperature in Experiment (vii) is $\text{exhaust temperature} = 71.488 + 0.053 * (\text{pyrolyzer temperature})$. The regression equation for CO emission in Experiment (vii) is $\text{CO emissions} = 211.123 - 0.79 * (\text{pyrolyzer temperature})$. The regression equation for H₂ emission in Experiment (vii) is $\text{H}_2 \text{ emissions} = 82.909 - 0.74 * (\text{pyrolyzer temperature})$. The regression equation for NO_x emission in Experiment (vii) is $\text{NO}_x \text{ emissions} = 12.025 - 0.13 * (\text{pyrolyzer temperature})$. The regression equation for SO₂ emission in Experiment (vii) is $\text{SO}_2 \text{ emissions} = 4.407 - 0.003 * (\text{pyrolyzer temperature})$.

The experimental results suggest that combustion efficiency will increase with increase in the AVR but decrease with (more than about 50%) excess air. The regression equation for combustion efficiency in Experiment (vii) is $\text{combustion efficiency} = 72.060 - 0.018 * (\text{pyrolyzer temperature})$.

The CO and NO_x emissions at the B2H exhaust in Experiment (vii) met the EPA regulatory standard, 195.03 ± 9.17 ppmv and 9.20 ± 0.87 ppmv, respectively, while the SO₂ emission detected at the B2H is lower than that of NIOSH (4.57 ± 1.08 ppmv).

This study showed that the horizontal air-staged biomass combustor with OPKS and wood chips as fuel reduces the emission of pollutants (CO, NO_x and SO₂) during combustion compared with a vertical biomass combustor. These studies are important in terms of research, as the results from this experiment design suggest that the B2H combustor is better than a vertical combustor. Thus, this can fit into the context of biomass combustion or carbon capture and storage systems, as it might enhance the knowledge needed to reduce pollutant emissions. Moreover, as a result of its insignificant pollutant emissions, it is likely that the B2H converter can be used in industrial drying applications, such as drying of paper egg trays and pulp and paper. Finally, the experimental results of this work can be used for validation through CFD to gain a better understanding of the transport phenomena in the horizontal air-stage biomass combustor.

5.8 Scenario Analysis of Research Findings

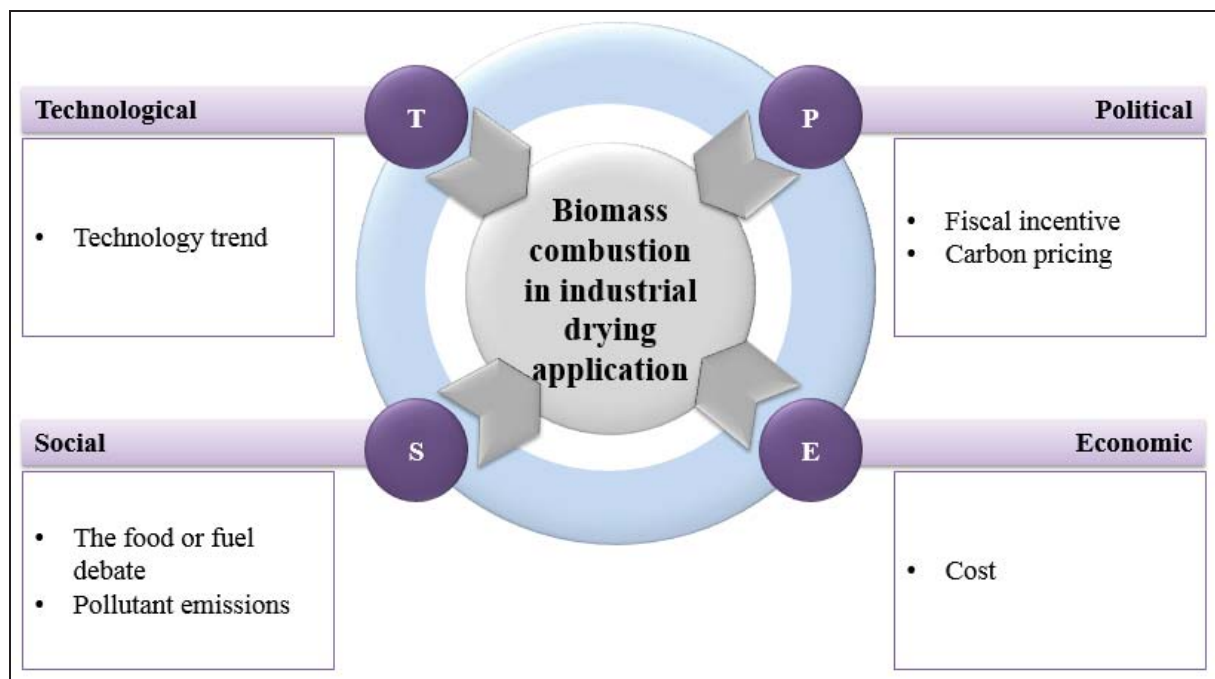


Figure 5.9: Scenario analysis chart

This section focuses on a brief scenario analysis of findings from this research (**Figure 6.1**). A review paper by Cochran, Mai and Bazilian (2014) on scenario analyses on a global level emphasizes a future (years range from 2005–2050) with a high penetration of renewable energy in industry. This review paper includes the qualitative and quantitative attributes. Qualitative attributes include the sensitivity analysis, policy and system operations. Quantitative attributes encompass projection demand, capital technology cost, discount rates, carbon prices, electricity prices, and electricity generation mix. The motivations for these scenario analyses are climate change mitigation (WWF, 2011), optimized resource use (Connolly, Lund, Mathiesen, & Leahy, 2011), and better understanding of the technical challenges of large-scale deployment of renewables (Hand et al., 2012).

The toughest challenges will be to promote social acceptance of new alternatives in infrastructure. Political intervention (e.g., fiscal incentives and carbon pricing) can play a major role in lowering costs and accelerating deployment (Cochran et al., 2014). Some studies recommend policies that target clean energy by reducing fossil fuel subsidies and implementing carbon prices and feed-in-tariffs (Greenpeace, 2012; IEA, 2011; Kemp & Wexler, 2010).

Many scenario analyses conclude that technology breakthroughs are unnecessary; nevertheless, significant operation and systems integration is required (ECF, 2010; Elliston, Diesendorf, & MacGill, 2012; Lund & Mathiesen, 2009).

An alternative to transmission from renewable energy might lead to higher costs (< \$0.005/kWh relative to scenarios with greater transmission expansion) and require

combinations of increased storage and reserve capacity (Hand et al., 2012). However, even with constrained transmission, flexibility, or resources, the system could still work, and do so with little increase in cost, because the renewable resource base is robust and diverse and can thus handle a wide range of conditions.

There is some debate regarding the risk of diverting farmland for renewable energy to the detriment of food supply, such as corn. However, this does not affect the B2H converter as it utilizes the abundance of OPKS and wood chips in Malaysia. With regard to pollutants emission, this research shows that a horizontal air-staged biomass combustor with OPKS and wood chips as fuel reduces the emission of pollutants (CO , NO_x and SO_2) during combustion compared with a vertical biomass combustor.

Chapter 6 CONCLUSIONS

6.1 Introduction

The palm oil and wood industries generate a huge amount of waste in Malaysia. Relying heavily on fossil fuel, the drying industry in Malaysia emits a high level of air pollutants. In the biomass combustion field, there has been little or no research on the effects of the air velocity ratio on the horizontal combustor's temperature profile, flue gas composition and combustion efficiency.

In this research project, the effects of the air velocity ratio on the horizontal combustor's (B2H) flue gas composition (CO , NO_x and SO_2), temperature profile and combustion efficiency were investigated to improve understanding of biomass combustion. Firstly, a horizontal B2H converter for drying purposes was developed (designed and fabricated) for this experimental trial (whereby the shortcomings of the design and operational parameters of B2E and B2F have been cross-referenced). Then, the thermal properties and moisture content of the selected biomass samples (OPKS and wood chips) were tested and determined with a Shimadzu DTG-60H thermal analyser and a Binder drying oven, respectively. The B2H converter's temperature profile, flue gas composition and combustion efficiency were studied, using the Testo 350XL Flue Gas Analyser in three experimental trial groups: Group A - Effects of the air velocity ratio on OPKS with AVR = 9.65:0.00, 9.65:3.83 and 9.65:4.00; Group B - Effects of the air velocity ratio on OPKS with AVR = 4.00:0.00, 4.00:5.79 and 4.00:9.65; Group C - Gas composition, temperature profile and combustion efficiency comparisons between OPKS and wood chips with AVR = 3.83:9.65. Finally, a statistical

analysis (correlation and regression) was performed for Experiment (vii) as it emitted the lowest CO emissions of all the experiments.

This present chapter lists the scenario analysis of the research findings, the major conclusions of this research, the implications of these findings for biomass combustion and recommendations for future work.

6.2 Conclusions

6.2.1 Development of B2H Converter

- i) A B2H converter was developed according to the specific objective in **Section 1.4**.
- ii) The diameter of the pyrolysis chamber is 1,000 mm. Taking into consideration the 200 mm refractory thickness, the inner diameter should be 575 mm with a height of 1,600 mm.
- iii) The actual inner dimensions (width, length and height) of the rectangular tar converter chamber are 724.1 mm, 1100 mm and 184.6 mm, respectively.
- iv) The dimensions (width, length and height) of the combustible fuel gas-to-heat energy conversion chamber are 775 mm, 500 mm and 500 mm, respectively.

6.2.2 Thermal Property of Selected Biomass Samples

- i) The OPKS and wood chips samples undergo four distinct stages: drying, pyrolysis, gasification and combustion.
- ii) The mean pyrolysis temperature ranges for the OPKS and wood chips samples are 183.33–300°C and 116.67–260°C, respectively – a result of decomposition of

hemicellulose. The mean gasification temperature ranges of the OPKS and wood chips samples are 300–373.33°C and 260–365.00°C, respectively – decomposition of cellulose. The mean combustion temperature ranges of OPKS and wood chips samples are 373.33–900°C and 365–900°C, respectively – attributed to the decomposition of lignin. It is possible that the drying temperatures were affected by the permeability and the dimensions of the biomass samples.

- iii) It was observed that wood chips release a higher level of volatile matters and gas emissions in the gasification and combustion processes, compared to OPKS.

6.2.3 Moisture Content of Selected Biomass Samples

- i) Because of its morphology in the biomass, OPKS recorded a moisture content of $11.7 \pm 0.1\%$ wt., while wood chips recorded a moisture content of $16.2 \pm 1.1\%$ wt. Both of the determined moisture contents correlate well with Dagwa et al. (2012) and Zafar (2013) (11–13 % wt.) and PSC (2012) (20–50 % wt.), respectively.

6.2.4 Effects of Air velocity Ratio on Temperature Profile, Flue Gas Composition and Combustion Efficiency

a) Effects of Air velocity Ratio on Temperature Profile

- i) It was observed that an increase in AVR leads to an increase in the mean temperature of the pyrolysis chamber, but decreases the mean temperature in the exhaust, with an insignificant change in surrounding temperatures.

- ii) The Pearson correlation for exhaust temperature was positive (0.627), indicating that a higher pyrolyzer temperature tends to have a higher exhaust temperature and vice versa.
- iii) The regression equation for exhaust temperature in Experiment (vii) is $\text{exhaust temperature} = 71.488 + 0.053 * (\text{pyrolyzer temperature})$. 38% of the variance in exhaust temperature was explained by the pyrolyzer temperature.

b) Effects of Air velocity Ratio on Flue Gas Composition

- i) The experimental results indicate that the gas composition, such as CO, H₂, NO_x and SO₂ concentrations, is inversely proportional to increase in AVR.
- ii) All the calculated Pearson correlations for CO, H₂, NO_x and SO₂ were negative (-0.146, -0.269, -0.337, -0.217), meaning that a higher pyrolyzer temperature tends to have lower CO, H₂, NO_x and SO₂ and vice versa.
- iii) The regression equation for CO emission in Experiment (vii) is $\text{CO emissions} = 211.123 - 0.79 * (\text{pyrolyzer temperature})$. 1.9% of the variance in CO emissions was explained by the pyrolyzer temperature.
- iv) The regression equation for H₂ emission in Experiment (vii) is $\text{H}_2 \text{ emissions} = 82.909 - 0.74 * (\text{pyrolyzer temperature})$. 7.0% of the variance in H₂ emissions was explained by the pyrolyzer temperature.
- v) The regression equation for NO_x emission in Experiment (vii) is $\text{NO}_x \text{ emissions} = 12.025 - 0.13 * (\text{pyrolyzer temperature})$. 11.2% of the variance in NO_x emissions was explained by the pyrolyzer temperature.

- vi) The regression equation for SO₂ emission in Experiment (vii) is $\text{SO}_2 \text{ emissions} = 4.407 - 0.003 * (\text{pyrolyzer temperature})$. 4.5% of the variance in SO₂ emissions was explained by the pyrolyzer temperature.

c) Effects of Air velocity Ratio on Combustion Efficiency

- i) The experimental results suggest that the combustion efficiency will increase with an increase in AVR but decrease with excess air (more than about 50% excess air).
- ii) The Pearson correlation for combustion efficiency was negative (-0.205), meaning that a higher temperature tends to result in lower combustion efficiency and vice versa.
- iii) The regression equation for combustion efficiency in Experiment (vii) is $\text{combustion efficiency} = 72.060 - 0.018 * (\text{pyrolyzer temperature})$. 3.9% of the variance in combustion efficiency was explained by the pyrolyzer temperature.

6.3 Contributions of this Work

The major contribution outlined in the previous section is the confirmation that the horizontal air-staged B2H converter allows cleaner and more efficient combustion with OPKS and wood chips as feedstock. From the results of this geometrical design and the experimental results, a biomass combustion model that can be validated with the experimental data generated in this work can be developed. The following are the main implications for the B2H converter in the biomass combustion field.

i) Drying application

As a result of its insignificant pollutant emissions, it is likely that the B2H converter can be used in industrial drying applications, such as drying of paper egg trays and pulp and paper. For quality control purposes, an automatic data monitoring system of temperature, pressure, gas emissions, fuel gauge and fuel loading should be implemented.

ii) Transport phenomena of horizontal air-staged biomass combustor

The experimental results of this work can be used for validation through computational fluid dynamics to gain a better understanding of the transport phenomena in the horizontal air-stage biomass combustor.

6.4 Scope and Limitations of the Experimental Research

The scope of current research is to develop (design and fabrication) a biomass-to-heat energy (B2H) converter with horizontal air-staged design for drying purposes (whereby the shortcomings of the design and operational parameters of B2E and B2F have been cross-referenced); to evaluate the B2H's flue gases compositions, temperature profile and combustion efficiencies.

The limitations/assumptions of current research are the following.

- i) The temperature at the pyrolysis chamber was collected manually as no automatic data acquisition unit was available.
- ii) Heat loss through the B2H converter door.
- iii) Testo 350XL flue gas analyser was unable to measure hydrocarbon gas.

- iv) The combustion efficiency did not consider the unburned carbon and incomplete combustion.

6.5 Recommendations for Future Work

From the present study, further development and research work would need to be carried out with special focus in the following areas.

- i. Study on the effect of AVR on the temperature profile, flue gas composition and combustion efficiency with other available biomass wastes, such as paddy straw and sago bark.
- ii. Understanding the composition and morphology of the ash produced would be useful for future after-treatment system development and optimization. This can be worked out with Atomic absorption spectrophotometers and scanning electron microscopy.
- iii. Comparison of fieldwork results (air velocity ratio, temperature, flue gas composition and combustion efficiency) with computer fluid dynamic simulated results.
- iv. Testing of the B2H converter's efficiency and effectiveness in industrial drying application, such as in the drying of paper egg trays.
- v. Study the effect of angle of inclination (inside the tar removal chamber) on biomass combustion efficiency and gaseous emissions.

6.6 Concluding Remarks of This Study

The research question of this study is whether a horizontal air-staged combustor burning oil palm kernel shell and wood chips is environmentally friendly, generates less pollutant emissions (CO, NO_x and SO₂) and is efficient. Thus, the objective of this study is to develop

a biomass-to-heat energy (B2H) converter with a horizontal air-staged design for drying purposes and to evaluate the B2H's flue gas composition (CO , NO_x and SO_2), temperature profile and combustion efficiency using a flue gas analyser and SPSS statistical analysis tool. The research findings showed that the p-values of the variables (pyrolyzer temperature, CO , H_2 , NO_x , SO_2 , exhaust temperature and combustion efficient) are significant (p-values < 0.01) and the correlations between them range from low to very strong relationships. This indicates that the pollutants emission (CO , NO_x and SO_2) is less when oil palm kernel shell and wood chips are burned in the developed B2H converter. This also indicates that the B2H converter combustion efficiency is good. Thus, these findings satisfy the research question and objectives of this study.

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APPENDIX A: 12.5-mm Ceramic Fire Blanket



DIMAL Asia Pacific Sdn. Bhd. (219956-D)

(Formerly Known As Didier Asia Sdn. Bhd.)

3221 & 3226 Batu 29, Jalan Ipoh, 44300 Batang Kali, Selangor, Malaysia.

Tel: +60(3) 6075 2011 Fax: +60(3)6075 2562

H/P: 012-718 2392 / 012-985 2011

E-mail: office@dimal.com.my website: www.dimal.com.my

1260 Blanket

		ASTM C201	Specification		Average	
Thermal conductivity Kcal/mh ² C (W/mK) 100ka/m ²		mean 400°C	≤	0.15 (0.12)	0.08 (0.09)	
		mean 600°C	≤	0.15 (0.17)	0.12 (0.14)	
		mean 800°C	≤	0.21 (0.24)	0.17 (0.20)	
128 kg/m ²		mean 400°C	≤	0.11 (0.13)	0.06 (0.07)	
		mean 600°C	≤	0.14 (0.19)	0.10 (0.12)	
		mean 800°C	≤	0.22 (0.25)	0.14 (0.16)	
96 kg/m ²		mean 400°C	≤	0.12 (0.14)	0.10 (0.12)	
		mean 600°C	≤	0.17 (0.20)	0.15 (0.17)	
		mean 800°C	≤	0.25 (0.29)	0.22 (0.25)	
64 kg/m ²		mean 400°C	≤	0.13 (0.15)	0.11 (0.13)	
		mean 600°C	≤	0.20 (0.23)	0.18 (0.21)	
		mean 800°C	≤	0.30 (0.34)	0.26 (0.30)	
Chemical composition %	Al ₂ O ₃		≥	45	47.1	
	Al ₂ O ₃ + SiO ₂		≥	98	99.4	
Available size	7200 x 600 mm	thickness	6 mm	12.5 mm	25 mm	
	3600 x 600 mm	thickness	30 mm			
	1200 x 600 mm	thickness	6 mm	12.5 mm	25 mm	30 mm
Dimensional	Tolerance					
Length	7200 mm	3600 mm	1200 mm	+ 4%	- 0%	
Width	600 mm			+ 3%	- 3%	
Thickness	6 mm			+ 3 mm	- 1 mm	
	12.5 mm			+ 4 mm	- 2 mm	
	25 mm			+ 6 mm	- 4 mm	
	30 mm			+ 8 mm	- 5 mm	



DIMAL Asia Pacific Sdn. Bhd. (219956-D)

(Formerly Known As Didier Asia Sdn. Bhd.)

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Tel: +60(3) 6075 2011 Fax: +60(3)6075 2562

H/P: 012-718 2392 / 012-985 2011

E-mail: office@dimal.com.my website: www.dimal.com.my

1260 Blanket

ISOWOOL Ceramic Fiber 1260 Blanket is made of high purity Alumino-Silicate fibrous wool.

Characteristics

- Non-felt blanket
- Non-combustible
- Can withstand temperature up to 2300° F
- Low density and low thermal conductivity
- Shorter heat up and cool down time
- Resilience and resistance to thermal shock
- Flexible and easy to cut or install
- Good acoustic properties
- Contains no organic binder
- Asbestos free

Application

- Refractory back-up installation
- Direct exposure to heat as furnace hot face lining
- Expansion joint seal
- Fire protection
- General high temperature insulation

Classification temperature

1260°C (2300° F)

Melting point

1700°C (3100° F)

Fiber diameter

2.5 micro meter

Fiber length

100 mm average, ~250 mm max.

Tensile strength

5 kg / 25 x 25 mm of 128 kg / m² 25 mm thickness

Bulk density	kg / m ³	Specification	
		150-195	Average
		115-150	160
		85-115	128
		58-85	96
			64
Liner shrinkage			
1100°C x 24 hrs		≤ 3.0	1.8
Silica content			
>212micro meter		≤ 25	18

APPENDIX B: DIVAL 140

	TECHNICAL DATA SHEET		Revision : 1/2010		
			Date of Issue : 21.07.2010		
			Page No. : 1 of 1		
Product	DIVAL 140	Product No.	9001		
Product Type	Conventional Castables	Main Component	Fireclay		
Type of Bonding	Hydraulic	Grain Size	0 - 6 mm		
Storage Limit (*)	12 months	Application Temperature	1400°C		
Amount of Material	1,900 kg/m ³ min	Water Addition (by weight)	14 - 18 %		
Installation	Vibrating				
Field of Application	General purpose 1400°C conventional castables				
Chemical Analysis	%	Al ₂ O ₃	SiO ₂	CaO	Fe ₂ O ₃
		30.0 min	60.0 max	6.0	3.0
Test Temperature	°C	110	1000	-	-
Cold Crushing Strength	M Pa	15 - 25	8 - 15	-	-
Cold Modulus of Rupture	M Pa	-	-	-	-
Permanent Linear Change	%	-	- 0.50 max	-	-
Precautions and Recommendations	Storage : Dry and cool area				
	Type of Mixer : High intensity mixer				
	Water : Drinking quality				
	Temperature : Temperature of the mixed material should be between 10°C and 25°C				
	Mixing Time : 3 - 6 minutes				
Remarks	(*) If stored in dry cool place				

APPENDIX C1: Refractory Thickness Calculation

Refractory thickness =

$$\left[\frac{(\text{operating temperature} - \text{surface temperature})}{(\text{convection} + \text{radiation})} \right] \cdot \text{Thermal conductivity of refractory}$$

(3.1)

thickness

$$= \left[\frac{(\text{operating deg F} - \text{surface deg F})}{(1 + 0.225 * \text{velocity}(fps)) * (\text{surface deg f} - \text{ambient deg F}) + (0.1714 * \text{emissivity}) * \left[\frac{(\text{surface deg F} + 460)^4}{100^4} - \frac{(\text{ambient deg F} + 460)^4}{100^4} \right]} \right] * K \text{ (value)}$$

The above calculation is performed by a 3E PLUS insulation thickness computer program (NAIMA, 2005). The calculated minimum thickness of the refractory is 40.0 mm (Appendix C2). A thickness of 100.00 is chosen (safety factor of 2.5) due to safety consideration (Appendix C3).

APPENDIX C2: Calculation of Refractory Thickness in Pyrolysis Chamber (Minimum Thickness)

NAIMA 3E Plus 4.0

Item Description = DIVAL 140

Calculation Type = Personnel Protection Report

Geometry Description = Steel Tank Shell - Vertical

System Units = ASTM C585

Bare Surface Emittance = 0.8

Nominal Pipe Size =

Process Temperature = 850.0 °C

Ave. Ambient Temperature = 25.0 °C

Ave. Wind Speed = 2.6 m/s

Relative Humidity = N/A

Dew Point = N/A

Personnel Protection Thickness = N/A

Outer Jacket Material = Galvanized steel, dipped or dull

Outer Surface Emittance = 0.28

Insulation Layer 1 = MF Insulating CEMENT, C195-07, 40.0 mm

Variable Insulation Thickness	Surface Temp (°C)	Heat Loss (W/m ²)	Efficiency (%)
Bare	834.5	74020.00	
Layer 1	271.2	2998.00	95.95

APPENDIX C3: Calculation of Refractory Thickness in Pyrolysis Chamber

NAIMA 3E Plus 4.0

Item Description = DIVAL 140

Calculation Type = Personnel Protection Report

Geometry Description = Steel Tank Shell - Vertical

System Units = ASTM C585

Bare Surface Emittance = 0.8

Nominal Pipe Size =

Process Temperature = 850.0 °C

Ave. Ambient Temperature = 25.0 °C

Ave. Wind Speed = 2.6 m/s

Relative Humidity = N/A

Dew Point = N/A

Personnel Protection Thickness = 115.0

Outer Jacket Material = Galvanized steel, dipped or dull

Outer Surface Emittance = 0.28

Insulation Layer 1 = MF Insulating CEMENT, C195-07, Varied

Variable Insulation Thickness	Surface Temp (°C)	Heat Loss (W/m ²)	Efficiency (%)
Bare	834.5	74020.00	
15.0	452.2	7424.00	89.97
25.0	339.3	4376.00	94.09
40.0	278.1	3125.00	95.78
50.0	238.6	2437.00	96.71
65.0	210.7	2000.00	97.30
80.0	189.8	1698.00	97.71
90.0	173.4	1475.00	98.01
100.0	160.3	1305.00	98.24
115.0	149.5	1170.00	98.42
125.0	140.4	1060.00	98.57
140.0	132.7	969.90	98.69
150.0	126.0	893.70	98.79
165.0	120.2	828.60	98.88
175.0	115.0	772.40	98.96
190.0	110.4	723.40	99.02
200.0	106.4	680.30	99.08
215.0	102.7	642.00	99.13
225.0	99.3	607.90	99.18
240.0	96.3	577.20	99.22
250.0	93.5	549.40	99.26

APPENDIX D: HAILEA Blower

Vortex


HAILEA 海利
 ISO9001:2000 国际质量体系认证

Blower

VB-G系列旋涡式喷气机是本公司自行设计研制开发的最新高品质、高技术产品。经中国专利局批准，荣获二项设计专利。专利号：ZL: 962110280 ZL: 963043269

本旋涡式喷气机结构严密，不同于一般形式的增氧机，它没有进出气阀结构，具有使用寿命长、故障率低、工作性能稳定等优点。而且采用优质专用电机，低功耗、高效率，可连续不停工作。由电机驱动设计独特的三维制式叶轮高速运转，空气从吸入口进入横截面积变化的环形通道，至出口口压缩喷出，气压强、排气量大，并且在进出气通道上设有消音及过滤装置，噪音低、压缩空气纯净。

本产品适用于水产养殖业，当压缩空气进入水中溶解后，能起到改善水质，从而加氧增氧的理想效果(每台机均在0.55公斤氧/千瓦以上，增氧率高，是普通增氧机的几倍)。也广泛应用于酒店、海鲜馆以及活鱼运输车等蓄养鲜活水产品，为鱼类提供良好的生长环境，保证鱼类安全生长。

本旋涡式喷气机，有不同的功率容量，还可作为印刷、纺织、化工等其他行业的气源配套设备。

Blower

 VB-125G
  VB-185G
  VB-290G
  VB-390G
  VB-600G
  VB-800G
  VB-1200G
  VB-2200G

型号 Model	电压 Voltage	频率 Frequency	转速 r/min	气量 L/min	压力 Mpa	重量 Weight	外形尺寸 Size
VB-125G	110/220V	50/60Hz	2900	250	0.006	5.2kg	236x179x186mm
VB-185G	110/220V	50/60Hz	2900	300	0.007	6.8kg	233x199x207mm
VB-290G	110/220V	50/60Hz	2900	350	0.009	7.4kg	230x199x215mm
VB-390G	110/220V	50/60Hz	2900	500	0.01	8.7kg	255x223x230mm
VB-600G	110/220V	50/60Hz	2900	640	0.012	9.8kg	256x245x250mm
VB-800G	110/220V	50/60Hz	2900	1000	0.015	15.4kg	295x295x305mm
VB-1200G	110/220V	50/60Hz	2900	1350	0.019	19.3kg	315x310x325mm
VB-2200G	380V	50Hz	2840	2100	0.022	22.5kg	330x315x450mm
VB-600A (传动式)			3400	640	0.011	6.9kg	210x275x160mm
VB-800A (传动式)			3200	1020	0.015	10.8kg	285x290x302mm

 VB-600A
(传动式)
  VB-800A
(传动式)



制造商: 广东海利集团有限公司

ISO9001:2000 国际质量体系认证 广东省高新技术企业

总机: 0768-8888888 销售热线: 0768-8888829 传真: 0768-8888813

www.hallea.com E-mail: jingd@pub.chaozhou.gd.cn

工厂: 广东省饶平县新力路新力工业园

FACTORY ADDRESS: 3961 INDUSTRIAL AREA, SHUI ROAD, RAOPIING COUNTY, GUANGDONG PROVINCE, 51700, CHINA

北京 BEIJING	电话 TEL: 010-63361213	传真 FAX: 010-63361213
上海 SHANGHAI	电话 TEL: 021-63581168	传真 FAX: 021-63581177
广州 GUANGZHOU	电话 TEL: 020-81931388	传真 FAX: 020-81952184
深圳 SHENZHEN	电话 TEL: 0755-25147889	传真 FAX: 0755-82270103
香港 HONGKONG	电话 TEL: 852-24935286	传真 FAX: 852-24902700
福建 FUJIAN	电话 TEL: 0595-25013336	传真 FAX: 0595-25023338
汕头 SHANTOU	电话 TEL: 0754-8970888	传真 FAX: 0754-8730888
潮州 CHAOZHOU	电话 TEL: 0768-2386299	传真 FAX: 0768-2386299

APPENDIX E: Type-K Thermocouple



PRODUCT CODE: CF/CF

Our customers have come to expect only the highest quality products from PMC.

This construction was developed to operate in extreme applications to withstand continuous temperatures as high as 2200°F (1204°C). Ceramaflex[®] is being used under conditions where beaded ceramic or sheathed thermocouples previously were necessary. Because the insulation retains its overall product integrity at these elevated temperatures, it increases serviceability while reducing replacement and maintenance cost.

Ceramaflex is cost effective over traditional thermocouples because long lengths of sheathed thermocouples create problems in handling as well as shipping, and beaded thermocouples are labor intensive.

Ceramaflex contains the single conductors insulated with an aluminaboric-silica fiber braid. The singles are laid parallel and jacketed with the same material. Ceramaflex is flexible, and offers good abrasion and chemical resistance.

The insulation contains no residual acids or chlorides to leach out and cause etching of the wires.

You will find our qualified sales and engineering staff eager to assist in selecting a design to meet the requirements of your specific application. Variations of this construction, including protective metal coverings for improved abrasion resistance, are available upon request.

® Registered Trademark of PMC Corporation

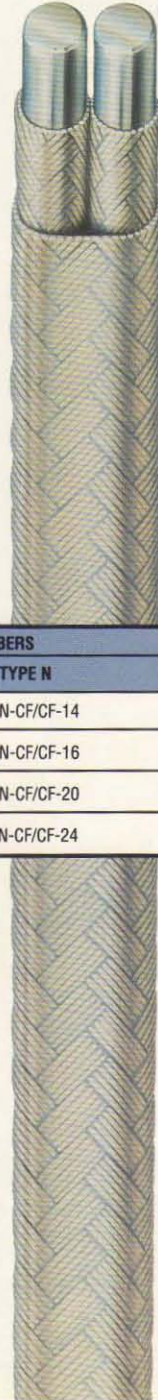
CERAMAFLEX[®] Insulated Thermocouple Wire

DATA SHEET 155

Calibrated conductors
for high system accuracy

2200°F (1204°C)
CERAMAFLEX insulation
for maximum flexibility at
ultra high temperature

2200°F (1204°C)
CERAMAFLEX jacket for
good chemical and
abrasion resistance



GRADE OF WIRE	GAUGE SIZE	WIRE TYPE	PART NUMBERS	
			TYPE K	TYPE N
THERMOCOUPLE	14	SOLID	K-CF/CF-14	N-CF/CF-14
THERMOCOUPLE	16	SOLID	K-CF/CF-16	N-CF/CF-16
THERMOCOUPLE	20	SOLID	K-CF/CF-20	N-CF/CF-20
THERMOCOUPLE	24	SOLID	K-CF/CF-24	N-CF/CF-24

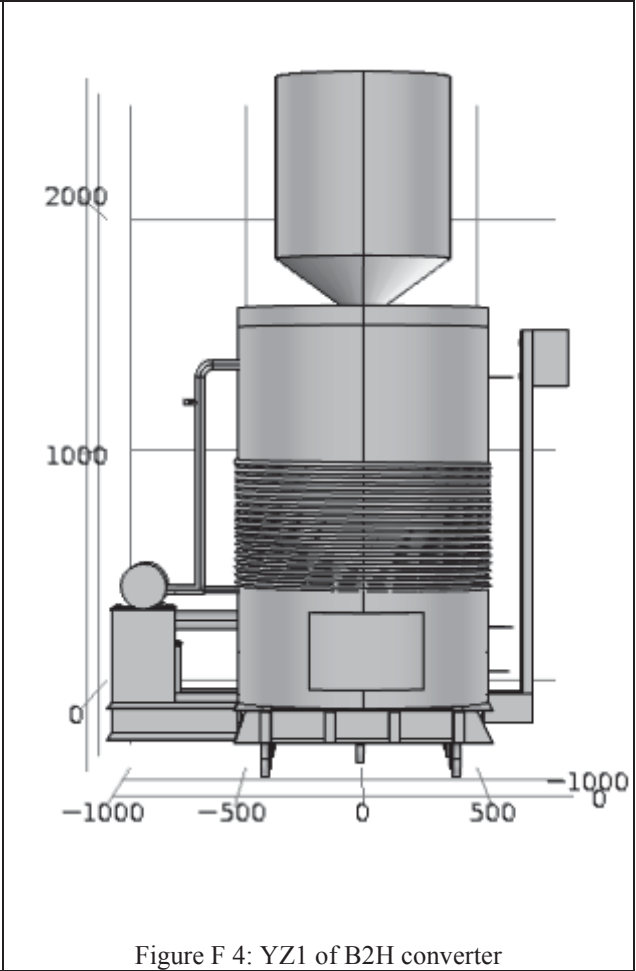
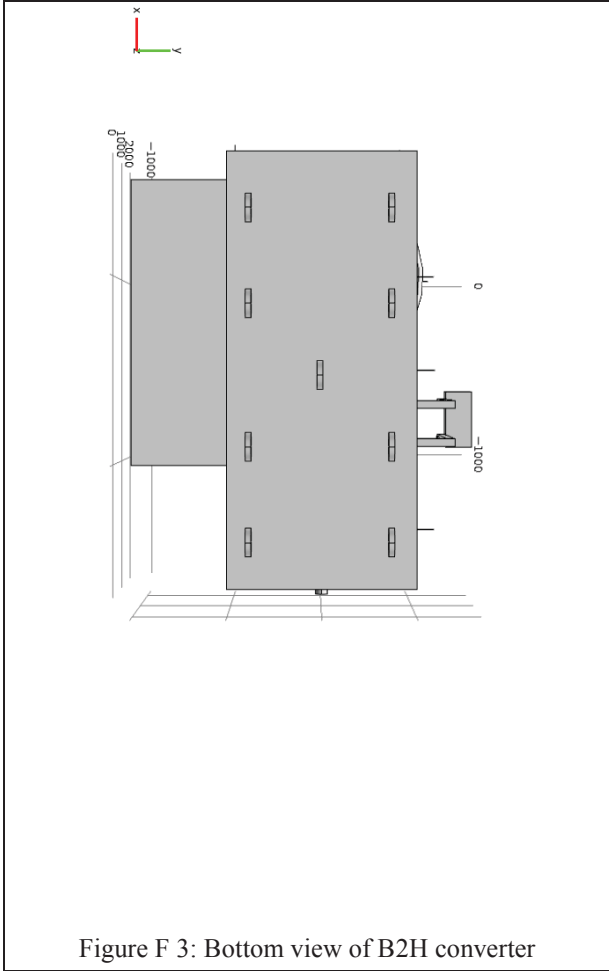
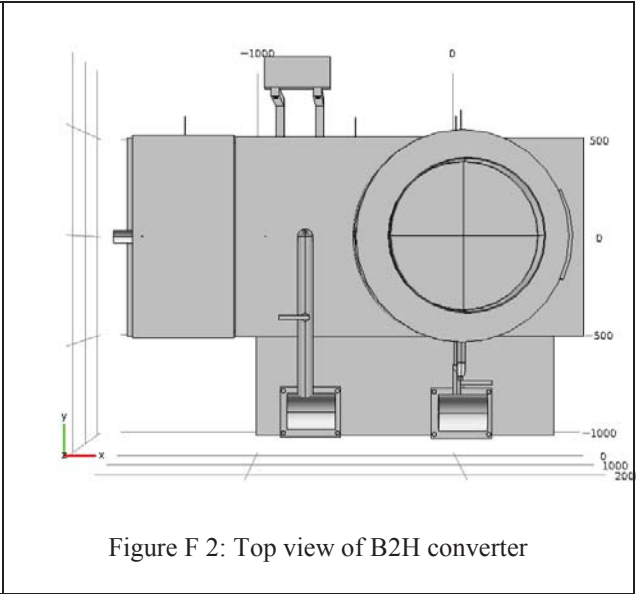
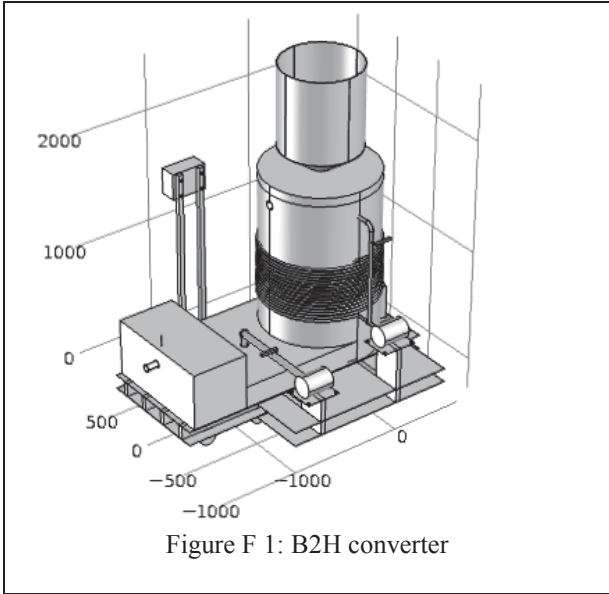
The above part numbers represent the more popular constructions. However, other designs are available upon request.

PMC CORPORATION

57 Harvey Road
Londonderry, NH
03053

Tel. (603) 432-9473
FAX (800) 639-5701

APPENDIX F: Three Dimensions Drawing of B2H Converter



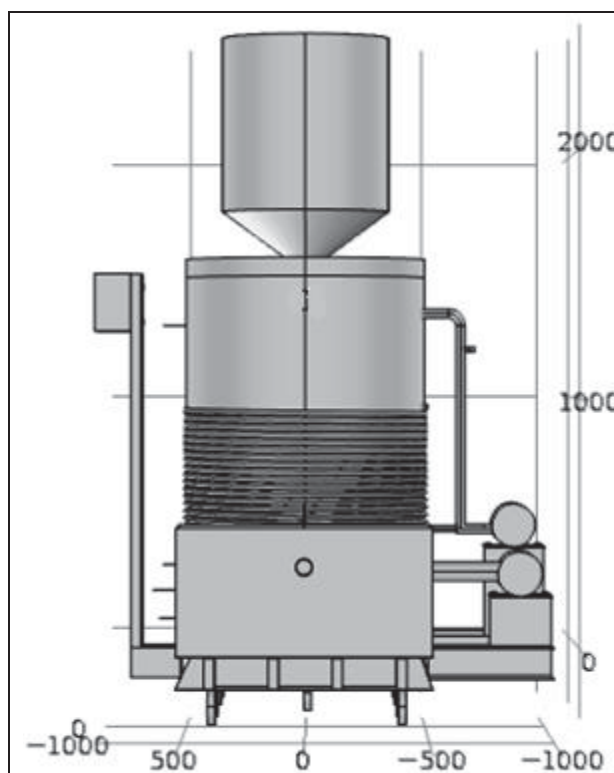


Figure F 5: YZ2 of B2H converter

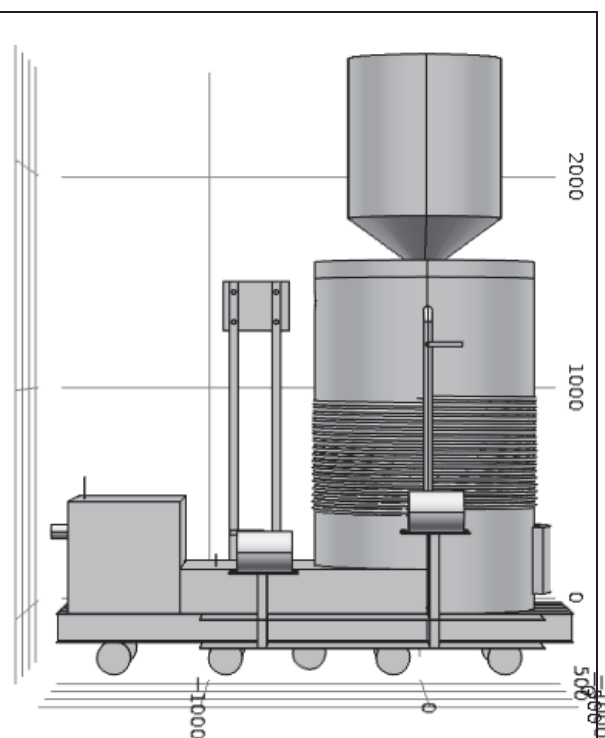


Figure F 6: XZ1 of B2H converter

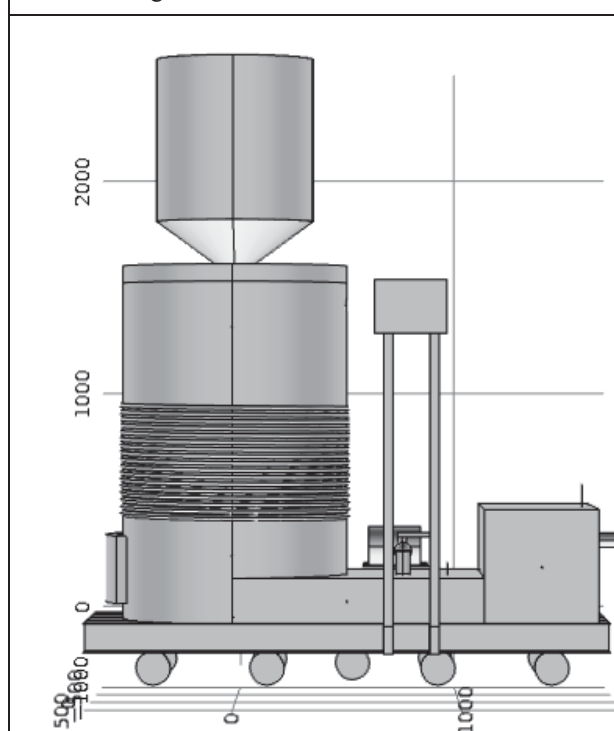


Figure F 7: XZ2 of B2H converter

(B) Procedure sheet for B2H based stand with rollerblade wheels

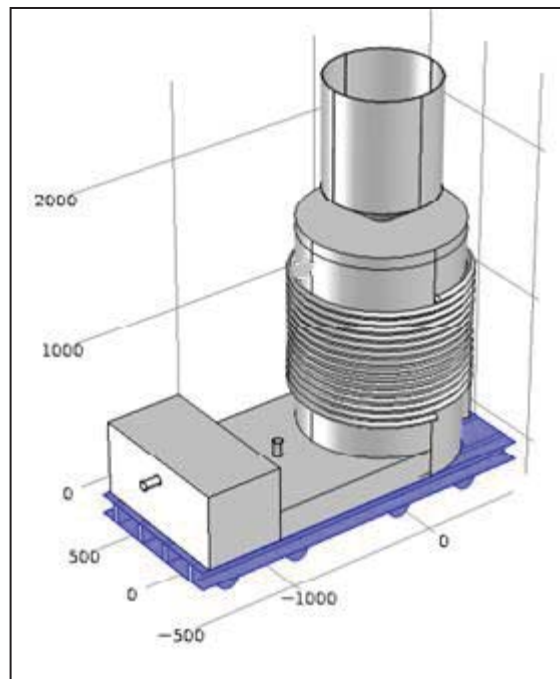


Figure F 8: B2H based stand with rollerblade wheels

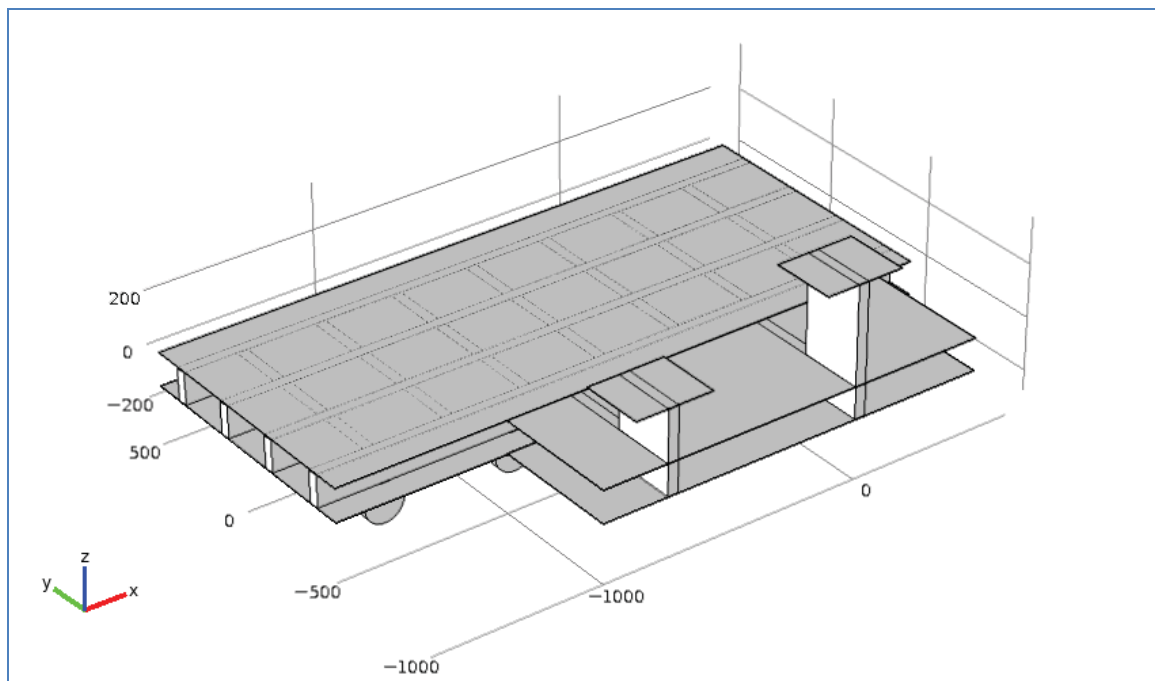


Figure F 9: Rollerblade wheels

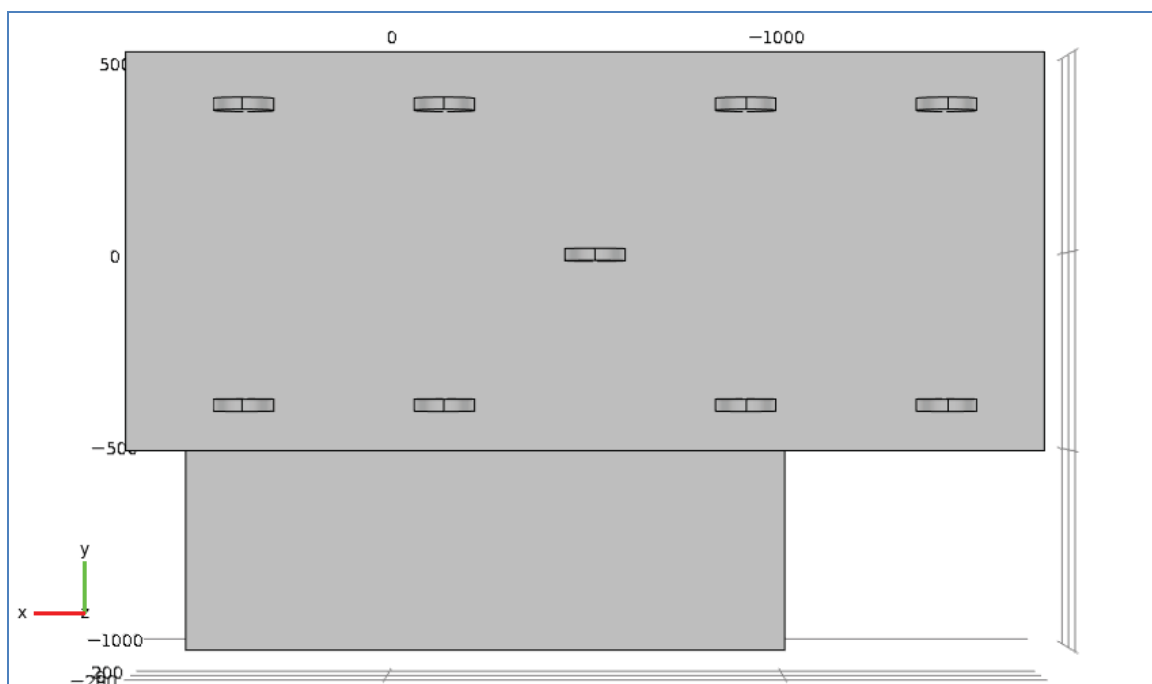


Figure F 10: B2H based stand with rollerblade wheels (bottom)

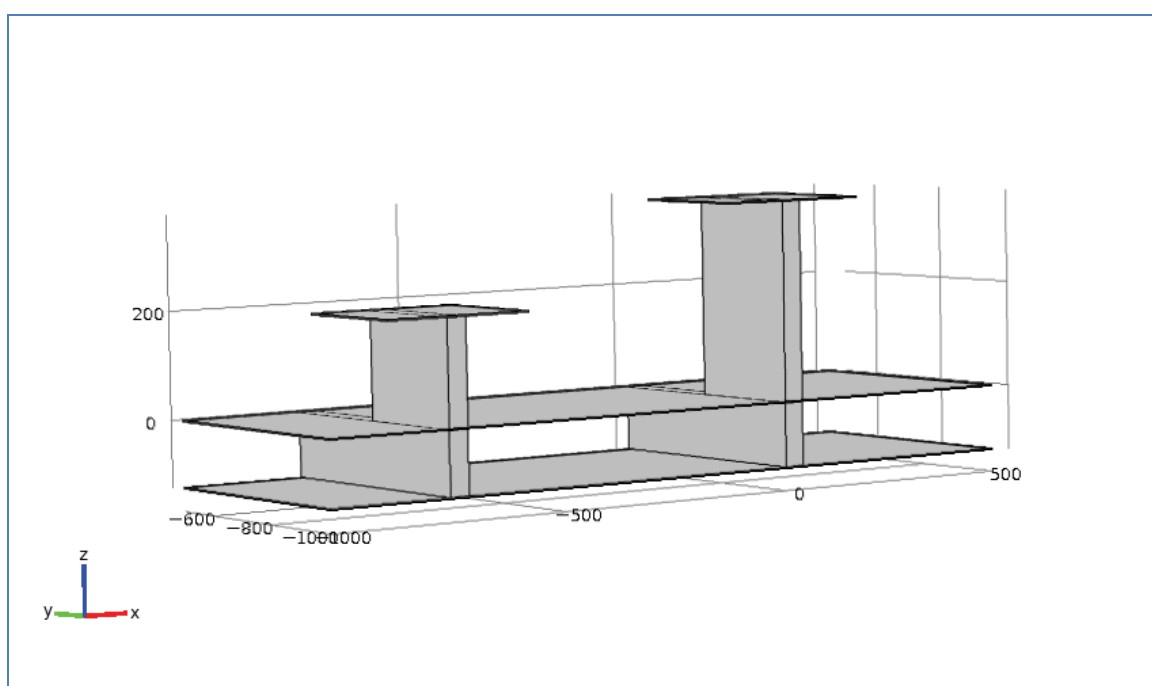
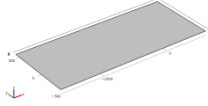
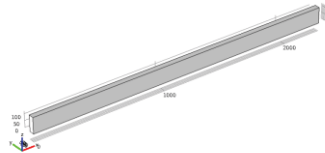
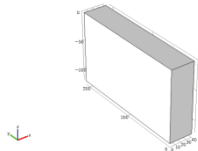
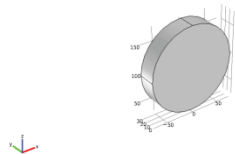
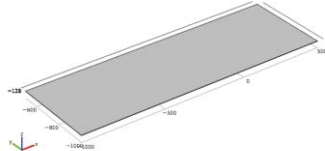
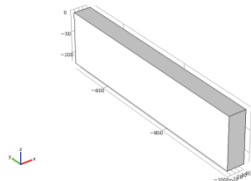
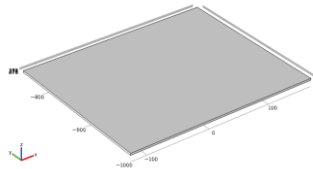
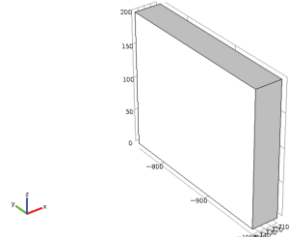
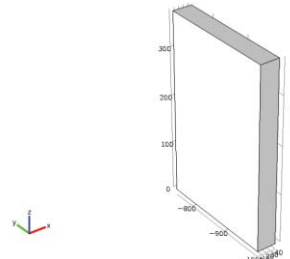


Figure F 11: Blower stand

Table F 1: B2H based stand with rollerblade wheels

No.	Operation name	Sketch of operation	Dimension (mm)	Quantity	Process involved
1	B2H based stand (Square plate)		2300(W) x 1000(D) x 3(H)	2	Cut the plate
2	B2H based stand (Square beam 1)		2300(W) x 40(D) x 120(H)	4	Cut the square beam
3	B2H based stand (Square beam 2)		120(W) x 210(D) x 40(H)	21	Cut the rectangle beam
4	Roller wheel		75(R) x 30(H)	9	Wield the roller wheel
5	Blower plate 1		1500(W) x 500(D) x 3(H)	2	Cut the plate
6	Blower plate 1 stand		40(W) x 500(D) x 120(H)	2	Cut the rectangle beam
7	Blower plate 2		300(W) x 250(D) x 3(H)	2	Cut the plate

8	Blower plate 2a stand		40(W) x 250(D) x 200(H)	1	Cut the rectangle beam
9	Blower plate 2b stand		40(W) x 250(D) x 375(H)	1	Cut the rectangle beam

(C) Procedure sheet for B2H chamber frame

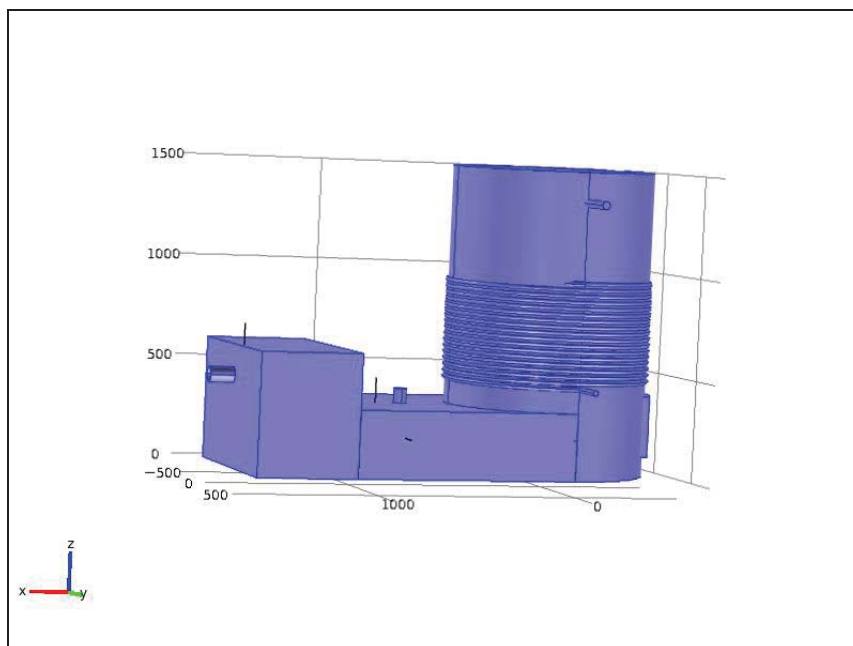


Figure F 12: B2H chamber frame

C1: Pyrolysis Chamber

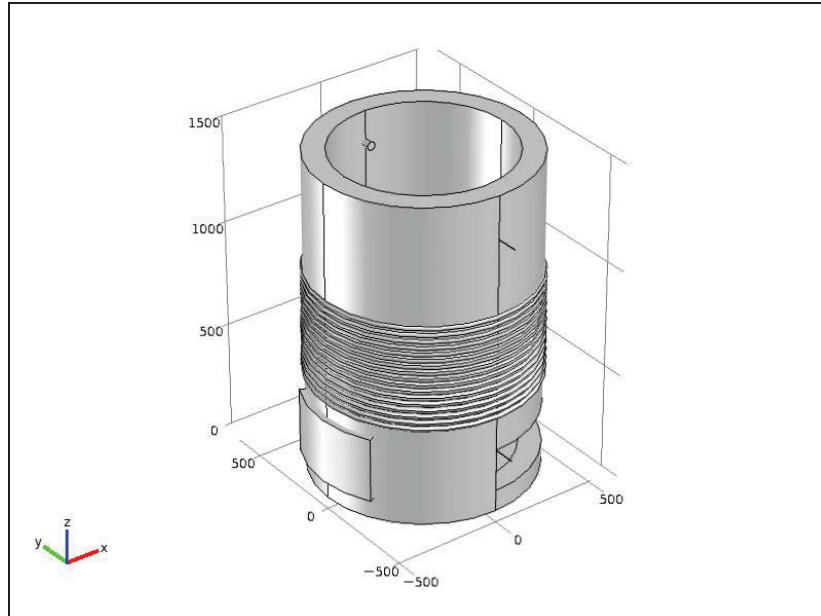


Figure F 13: Pyrolysis chamber

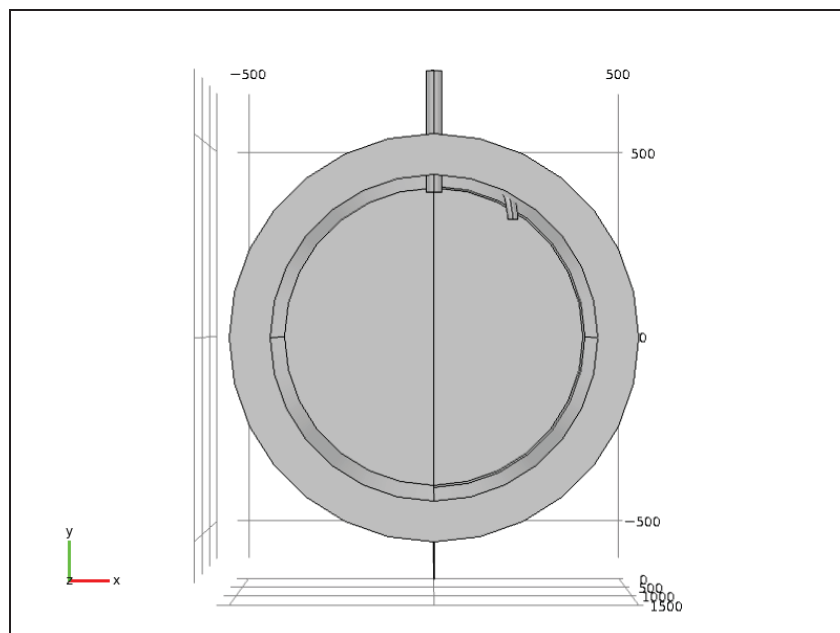


Figure F 14: Pyrolysis chamber (Top view)

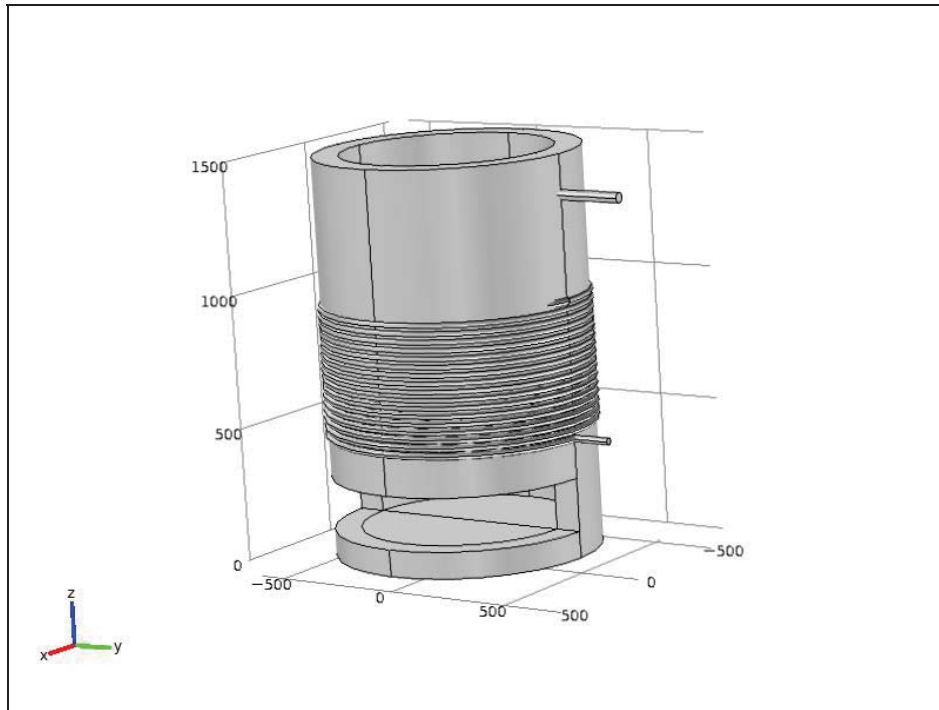
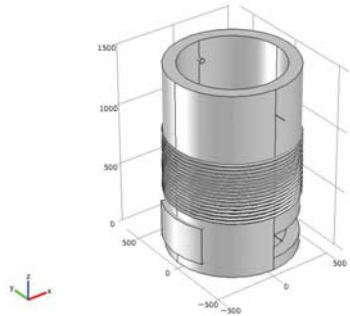
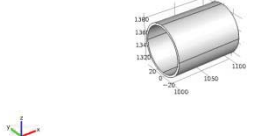
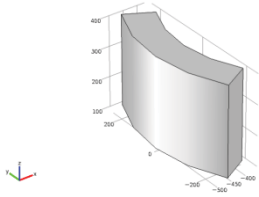
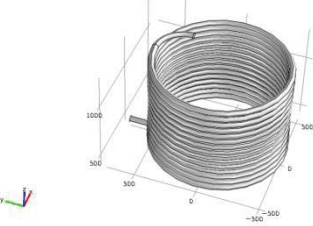
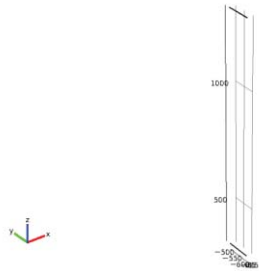


Figure F 15: Side view of pyrolysis chamber

Table F 2: Pyrolysis chamber frame

No.	Operation name	Sketch of operation	Dimension (mm)	Quantity	Process involved
1	Cylinder		W=3141 H=1600 500(R) x 50.8(T)	1	Form the structure by welding Wield the Y bar at the outer layer Install refractor-y
2	Main inlet pipe		(1.5"x100) Located at 1350mm from the chamber	1	Wield the main inlet pipe

3	Pyrolysis chamber door		400(C) x 300(H)	1	Construct the Pyrolysis chamber door is and install by welding and mechanically
4	Copper tube (Heat exchanger)		Number of turns=17 Length=50m Location start at 450 from bottom chamber	1	Install copper tube mechanically and welding
5	Thermocouple		Thermocouple = 300	1	Install thermocouples mechanically and drilling

C2: Tar Removal Chamber

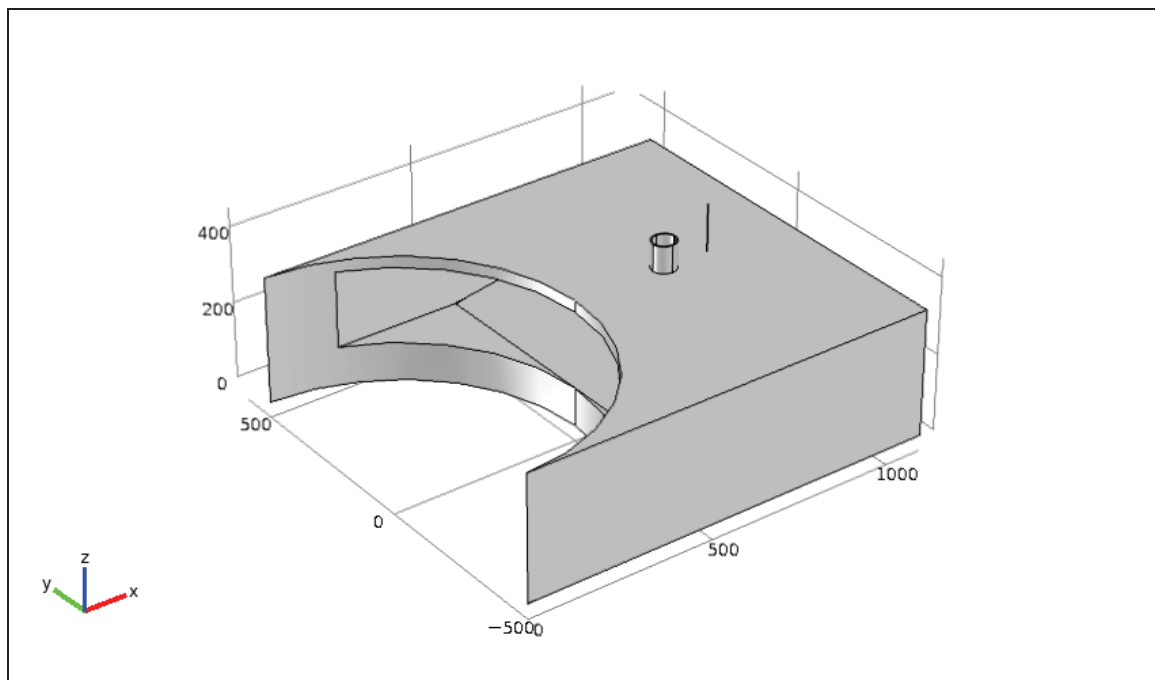
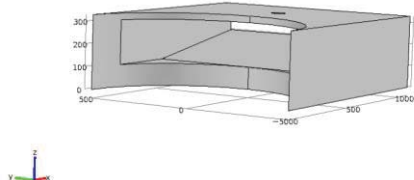
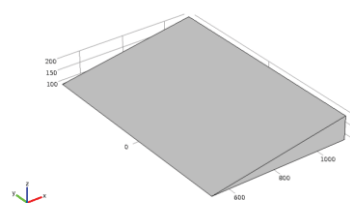
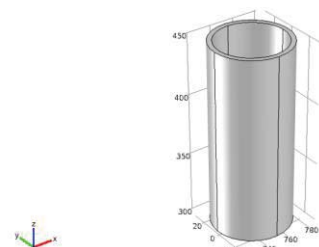
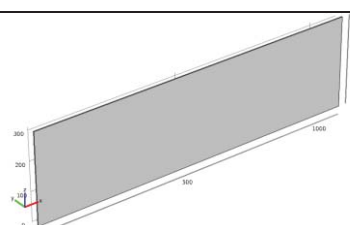
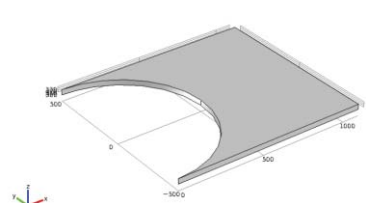


Figure F 16: Tar removal chamber

Table F 3: Tar removal chamber

No.	Operation name	Sketch of operation	Dimension (mm)	Quantity	Process involved
1	tar removal chamber with incline		1100(W) x 1000(D) x 330(H) Bottom thickness=100 Left, right thickness=30	1	Form the structure by welding Install refractory Form the incline by welding
2	Incline		780(W) x 1000(D) x 80(H)	1	Form the incline by welding Install refractory inside the incline and close it with welding
3	Secondary inlet pipe		(R=2.5"x100) Located at 1350mm from the chamber	1	Weld the secondary pipe
4	Side plate		1100(W) x 3(D) x 310(H)	2	Cut the side plate
5	Top/bottom plate		1100(W) x 1000(D) x 3(H) Semicircle radius=500	2	Cut the top and bottom plate by welding

C3: Combustible fuel gas-to-heat energy conversion chamber

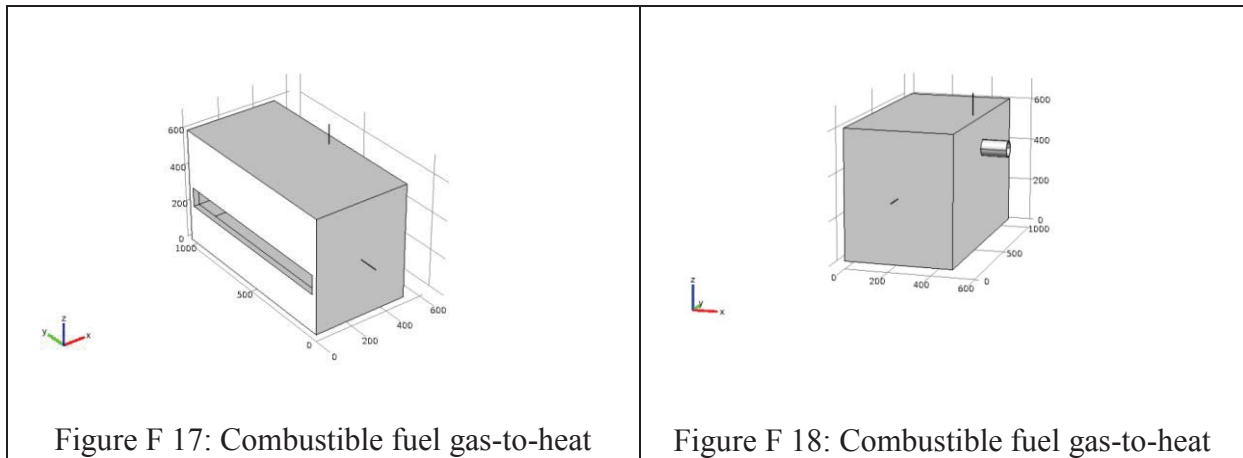
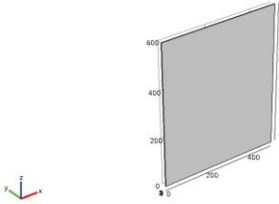
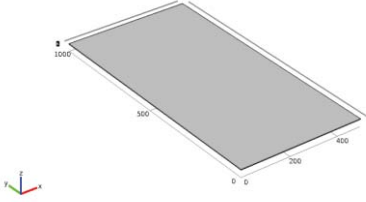
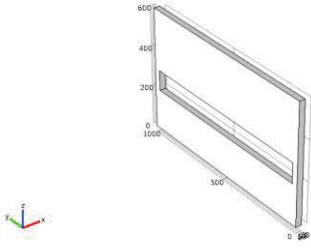
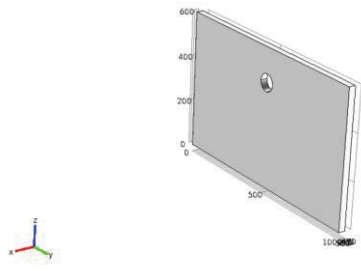
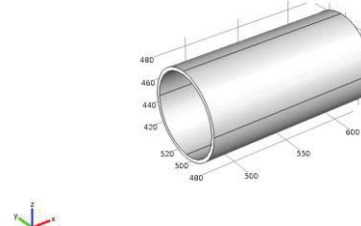


Table F 4: Combustible fuel gas-to-heat energy conversion chamber

No.	Operation name	Sketch of operation	Dimension (mm)	Quantity	Process involved
1	Side plate		500(W) x 3(D) x 600(H)	2	Cut the side plate
2	Top and bottom plate		500(W) x 1000(D) x 3(H)	2	Cut the side plate
3	Back plate		3(W) x 1000(D) x 600(H) Hole: 940(L) x 100(H) 200 from Z=0	1	Cut the back plate Cut the opening by welding

4	Front plate		3(W) x 1000(D) x 600(H) Hole: X=450 Y=500 Z=450	1	Cut the front plate
5	Exhaust		(R=3"x150) X=450 Y=500 Z=450	1	Wield the exhaust to front plate

C4: B2H Hopper

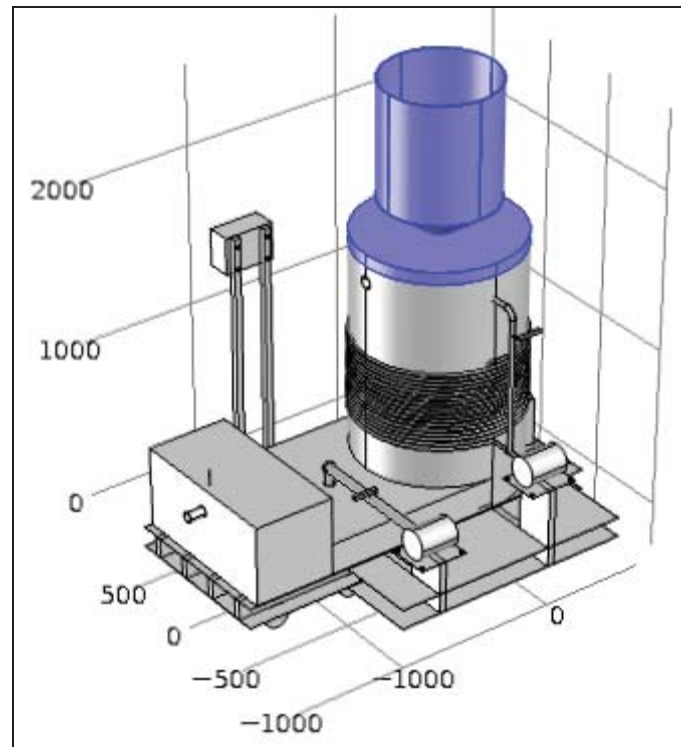
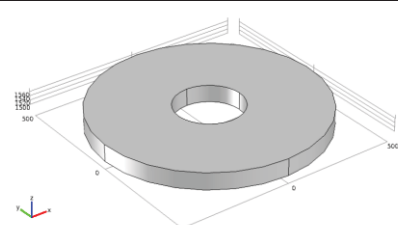
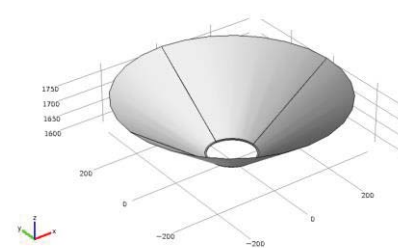
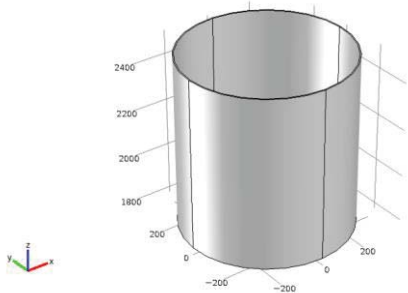


Figure F 19: B2H hopper

Table F 5: B2H hopper

No.	Operation name	Sketch of operation	Dimension (mm)	Quantity	Process involved
1	Hopper plate		R1=500 R2=75 Thickness=76.2	1	Form the structure by welding the plate
2	Cone		R1=75 R2=350 Slant height=403 Vertical height=200	1	Cut out the cone shape Weld the cone shape

3	Hopper cylinder		W=2199 H=725 R=350	1	Cut out the hopper cylinder and weld it together with the cone shape

(D) B2H Piping

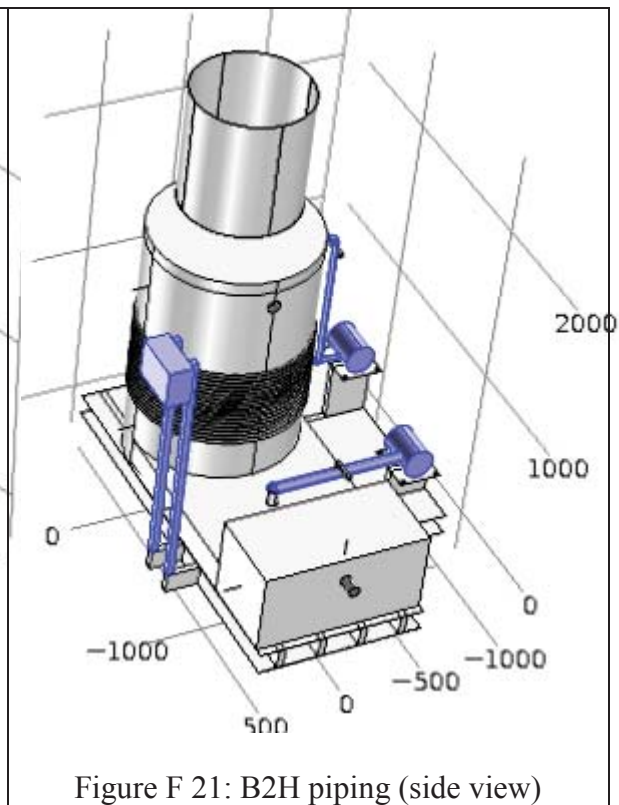
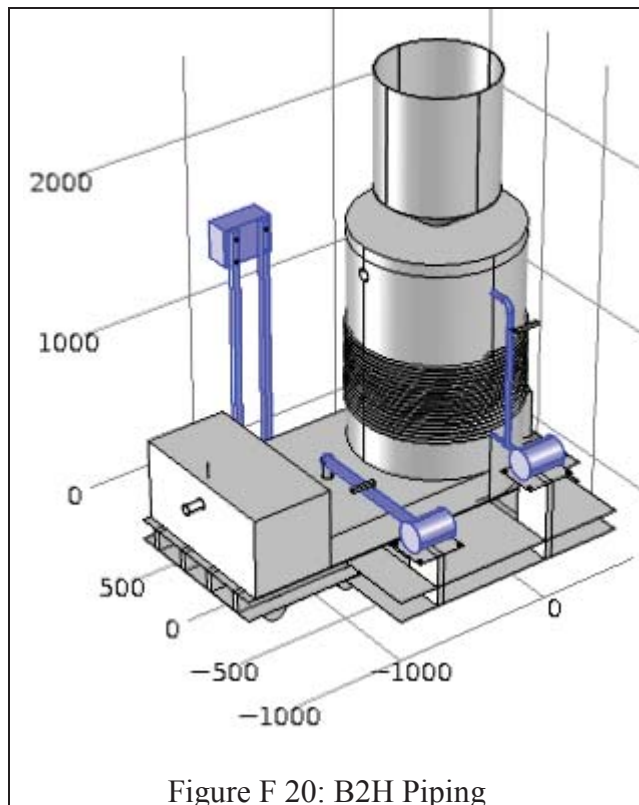
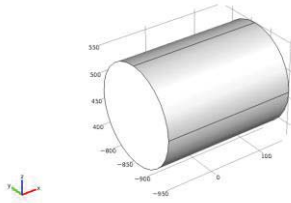
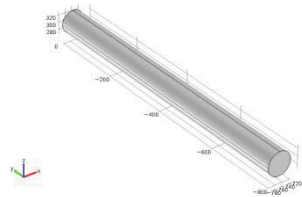
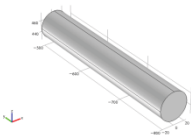
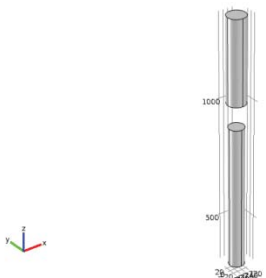
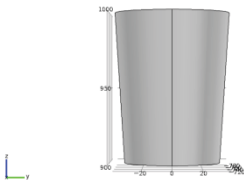
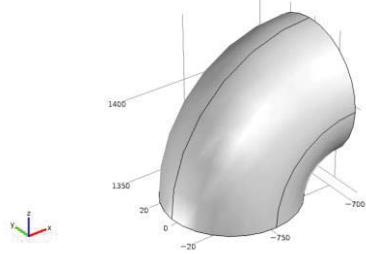
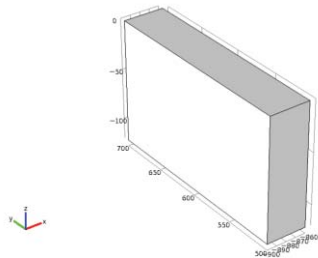
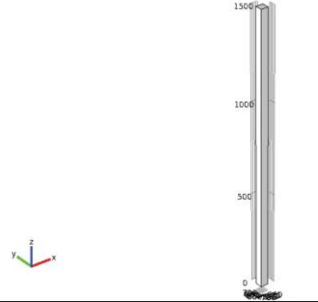
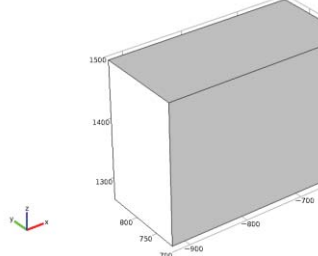


Table F 6: B2H Piping

Number	Operation name	Sketch of operation	Dimension (mm)	Quantity	Process involved
1	Blower			2	Install blower mechanically by fastening with screw and nut
2	Horizontal pipe for blower 1		3"x 800(L)	1	Cut the horizontal pipe for blower 1 and weld it to blower 1
3	Horizontal pipe for blower 2		48.8 x 300(L)	1	Cut the horizontal pipe for blower 1 and weld it to blower 2
4	Vertical pipe for blower 1		3" x 600 3" x 350	1 1	Cut the vertical pipe for blower 1 and weld it to horizontal pipe for blower 1
5	Reducer (3" to 2.5")		3" to 2.5"	1	Weld the reducer between 3" and 2.5" pipe
6	3" elbow		3"	1	Weld the 3" elbow to 3" pipe

7	Indicator block		40(W) x 200(D) x 120(H)	2	Cut the square block
8	Indicator stand		40(W) x 40(D) x 1500(H)	2	Cut the square beam
9	Temperature indicator box		310(W) x 230(D) x 145(H)	1	Install the temperature indicator box mechanically by screw and nut

(E) Y Anchor

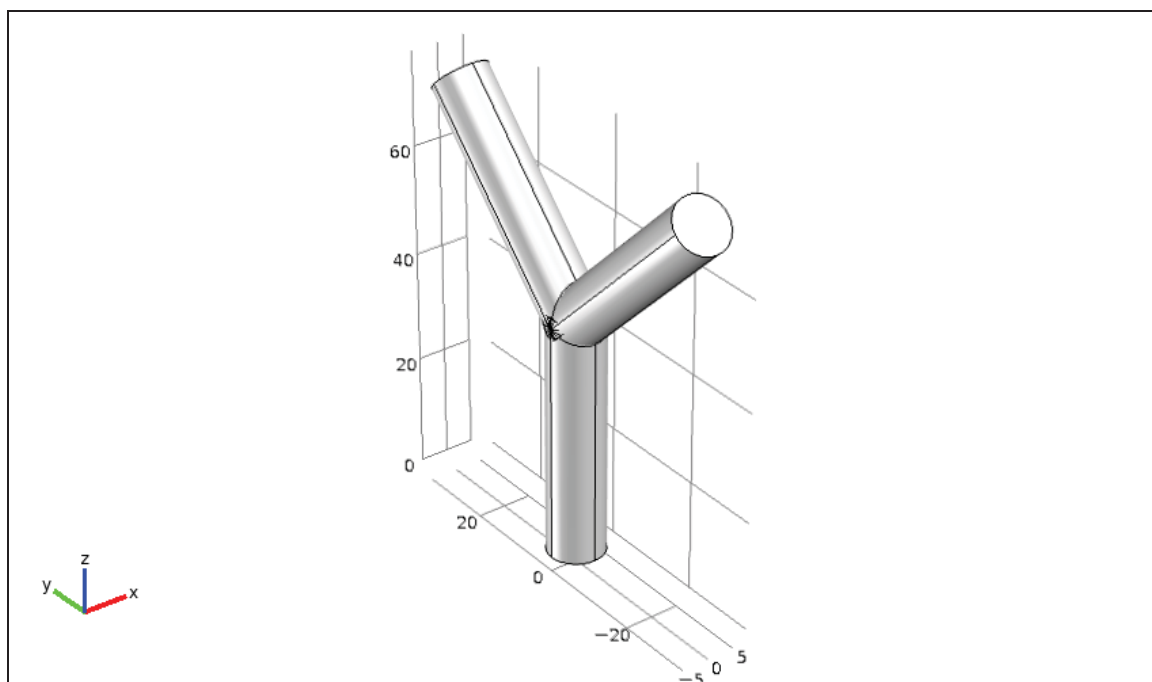


Figure F 22: Y anchor

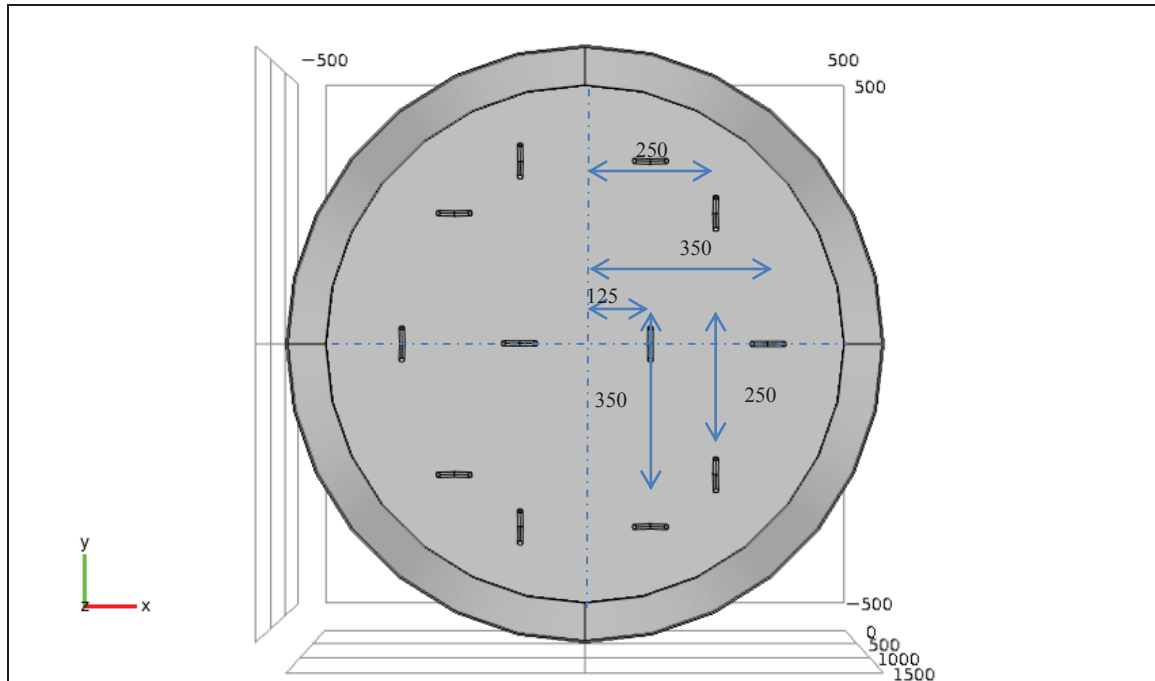


Figure F 23: Position of Y anchor at pyrolysis chamber based

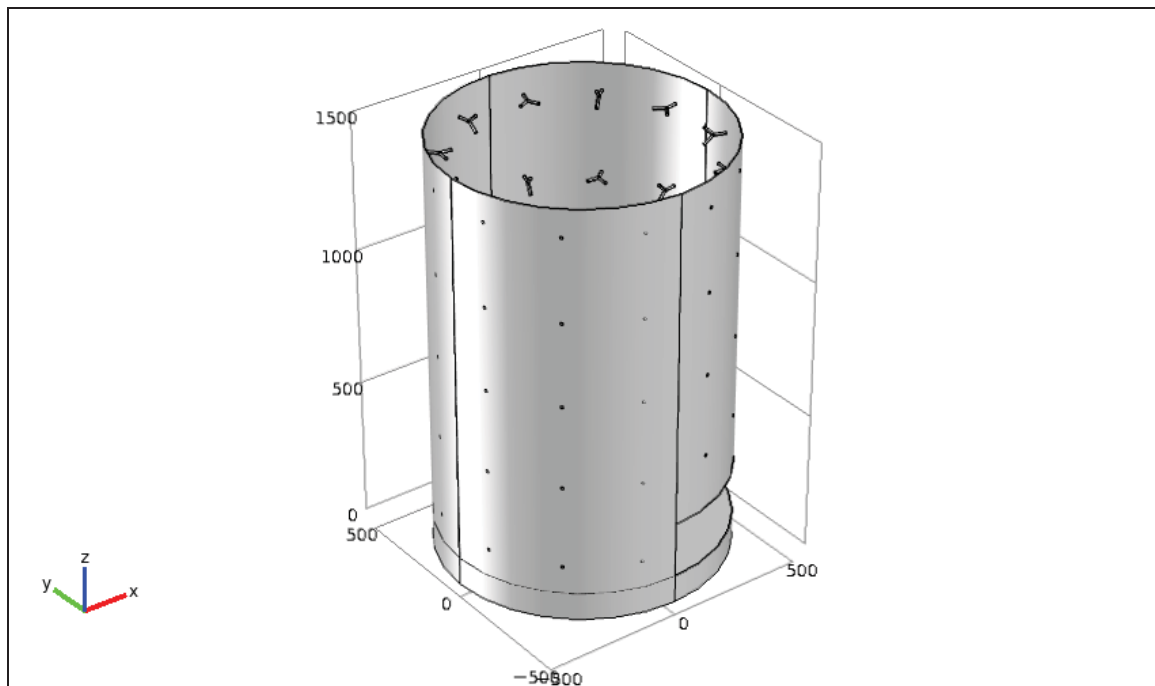


Figure F 24: Y anchor at pyrolysis chamber wall

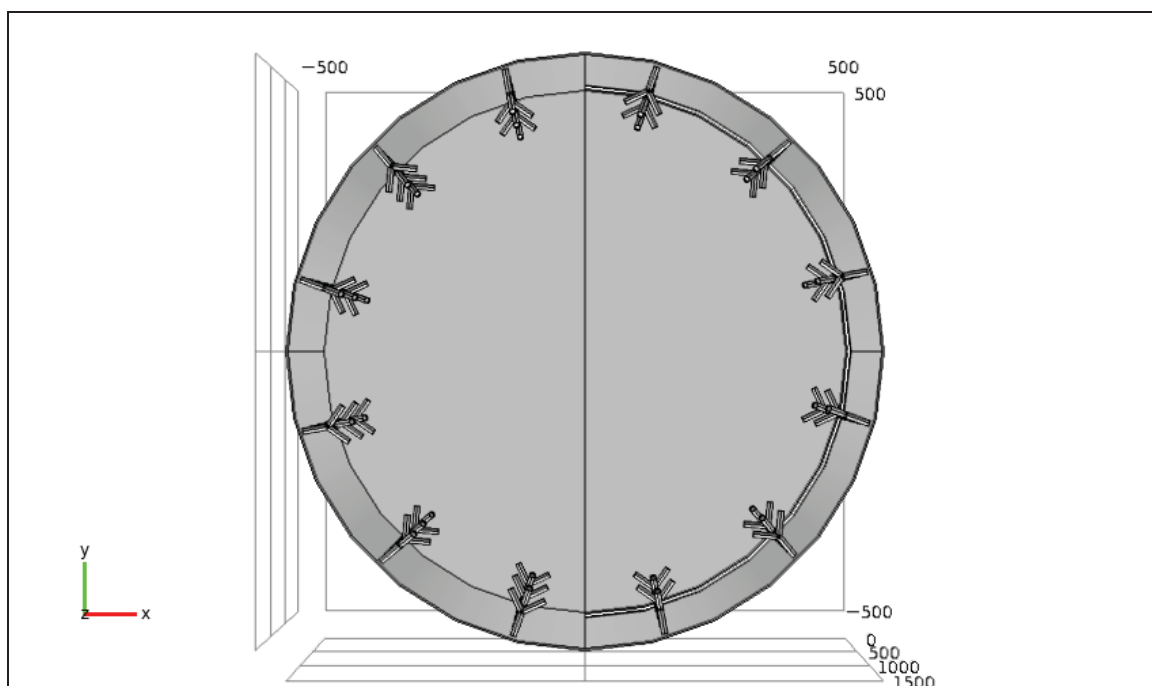


Figure F 25: Y anchor at pyrolysis chamber wall (top view)

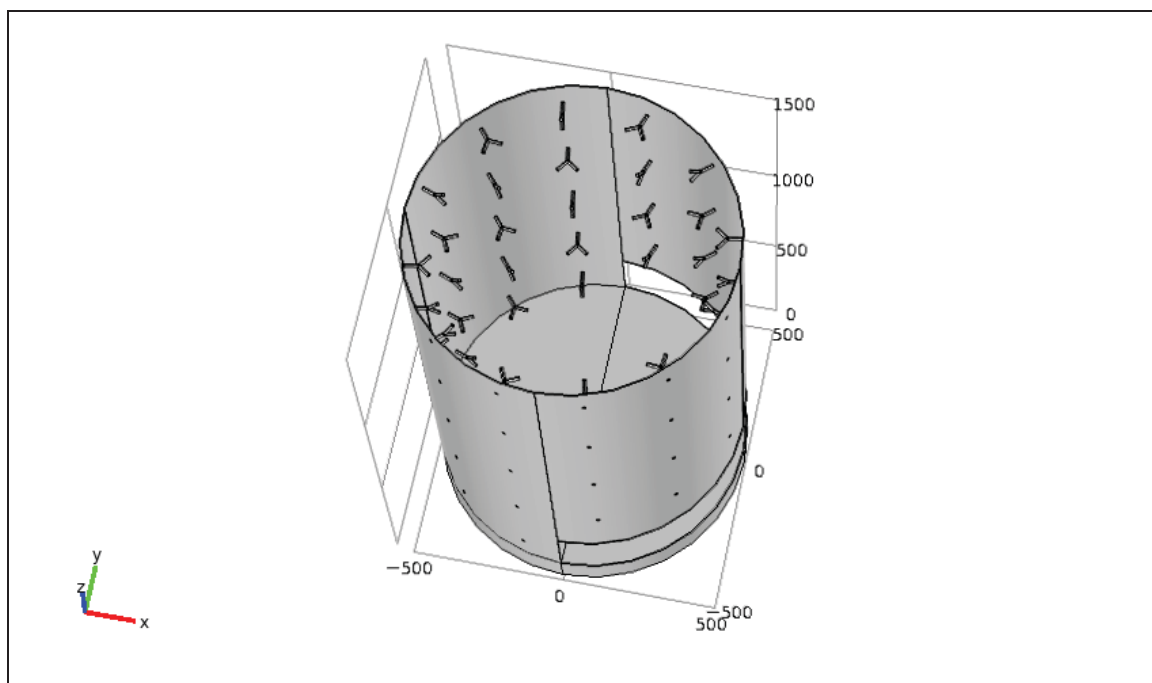
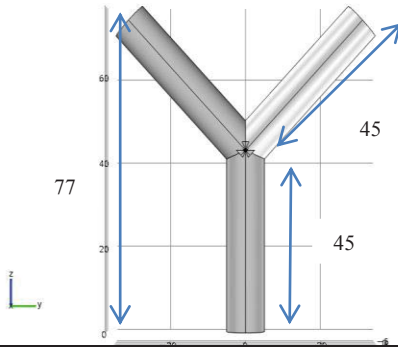
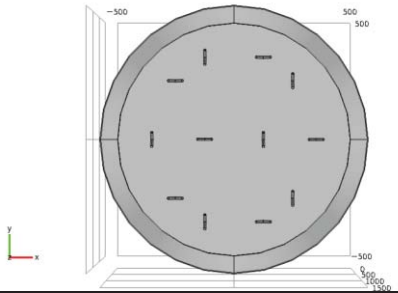
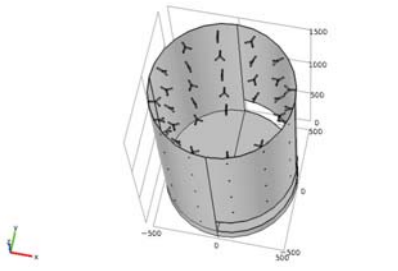


Figure F 26: Y anchor at pyrolysis chamber (side view)

Table F 7: Y anchor / wire mesh at B2H converter

No.	Operation name	Sketch of operation	Dimension (mm)	Quantity	Process involved
1	Y anchor*		45mm in each bar (S304), Thickness=10mm	Total=72	Cut the Y bar and weld it accordingly
2	Y anchor at pyrolysis chamber based		Refer to figure X	12	Wield the Y bar at pyrolysis chamber based accordingly
3	Y anchor at pyrolysis chamber wall		X distance = 30° Y distance = 300mm Bottom = 200	60	Wield the Y bar at pyrolysis chamber wall accordingly

*for safety factor purpose, the quantity of the anchors is more than the calculus formula

APPENDIX G: Shimadzu DTG-60H Thermal Analyser

TTPIS_ShimadzuDTG-60H_030310



Shimadzu Simultaneous TGA/DTA Analyzer DTG-60H

The Shimadzu DTG-60H thermal analyser provides simultaneous thermogravimetry/derivative thermogravimetry (TGA/DTG) and differential thermal analysis (DTA) on a single sample.

A high resolution top loading thermobalance provides TGA data along with two detectors for semi-quantitative DTA/DSC data. A motorized, self locating bifilar wound furnace is used.

Temperature Range is ambient to 1500°C

Included in the base instrument:

- two plug-in detectors and set of crucibles (aluminium, platinum)
- lighted LCD display for temperature and signal
- operation panel for direct access for emergency stop and service tasks
- remote system functions
- self-diagnostics by software
- three gas connectors
- operation manuals
- built in cooling fan allows controlled cyclic runs between 50 °C and 1500 °C
- auto-cleaning function



Specifications:

Temperature range:	RT to 1500°C	TG readability:	0.1 µg
Heating rate:	±0.01 to ±99.9°K/min at 0.1°K intervals	Dynamic range:	± 1000 µV
Temp reproducibility	0.1°K	DTA sensitivity:	0.1 µV
Temp accuracy:	0.1°K	Noise:	<0.2 µV
Time to cool:	<13 min to 100°C	Time constant:	<20 seconds.
Sample mass:	1000 mg	Crucible volume:	50-80 µl (typical)
TG mass range:	±500 mg	Atmosphere:	inert or reactive
TG noise:	<3 µg		
TG sensitivity:	1 µg		

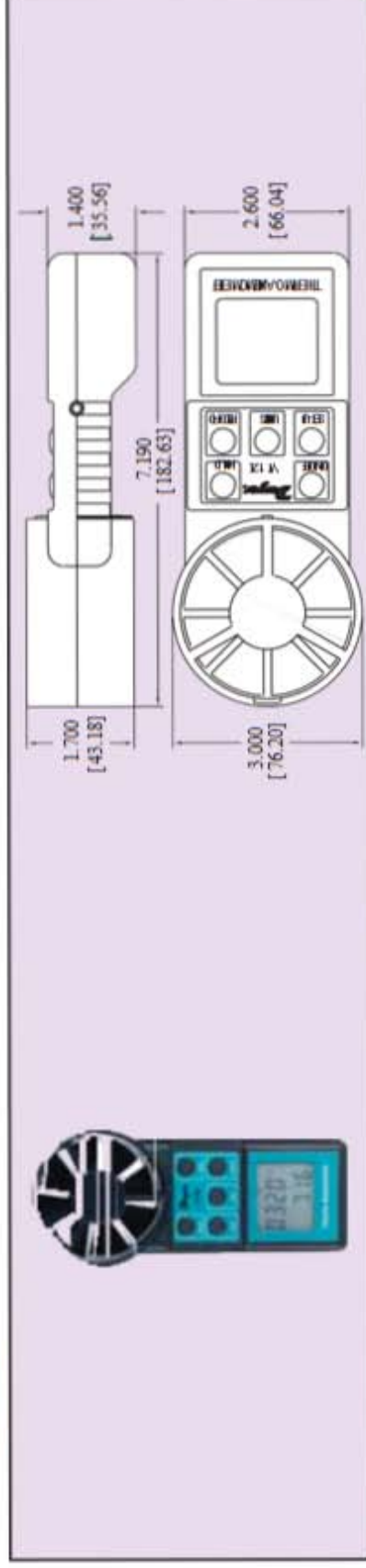
APPENDIX H: Dwyer VT120 Integral Vane Thermo-Anemometer



Model
VT120

Integral Vane Thermal-Anemometer

CE



Simultaneously measure air velocity and temperature with the Model VT120 Integral Vane Thermo-Anemometer. Easy view readings on the large 1.25" (31.75 mm) dual display. User-selectable air velocity ranges include fpm, m/sec, mph, knots, and km/hr. Built-in thermistor records ambient temperature in °F or °C. Model VT120 features module data hold and record/recall minimum, maximum and average readings. Also, units have the ability to record and average up to 2 hours of data while displaying the continuous running average. If desired, sleep mode automatically shuts down the meter after 20 minutes of non-use. Model VT120 includes hard copy case, one 9V battery, and instruction manual.

Model VT120, Integral Vane Thermo-Anemometer

APPLICATIONS

Air duct measurement and analysis, fume hood analysis, ionizer flow output monitoring, positive pressure reading in clean rooms, or ventilation system inspection.

SPECIFICATIONS

Air Velocity Ranges: 80 to 5900 fpm/min, 0.4 to 30 m/sec, 0.9 to 68 mph, 0.8 to 58 knots, 1.4 to 108 km/hr.

Temperature Range: 14 to 122°F (-10 to 50°C).

Accuracy:

Air velocity: ±3%;

Temperature: ±1°F (±0.6°C).

Resolution: 1 fpm, 0.01 m/sec, 0.1 mph, 0.1 knots, 0.1 km/hr, 0.1°F, 0.1°C.

Temperature Sensor: Thermistor.

Temperature Limits: 14 to 122°F (-10 to 50°C) max 80% RH.

Power Supply: One 9V battery.

Battery Life: 100 hours continuous (with 20 min sleep mode enabled).

Display: Large 1.25 x 1.62" (37 x 42 mm) LCD, 9999 count.

Housing: ABS plastic.

Sensor Diameter: 2.87" (70 mm).

Weight: 1.5 lb (680 g).

Agency Approvals: CE.

APPENDIX I: Testo 350XL Flue Gas Analyzer Measuring Ranges and Accuracies

Parameter	Measuring range	Accuracy
O ₂	0-25 vol. %	± 0.2 vol. %
CO	100-2000ppm	$\pm 5\%$ of reading
NO ₂	0-99ppm	± 5 ppm
SO ₂	0-99ppm	± 5 ppm
NO	0-99ppm	± 5 ppm
H ₂	40-300ppm	$\pm 5\%$ of reading

(adapted from: TESTO, 2008)

APPENDIX J: Calibration of Gas Sensors in Testo350XL

Procedure in operate the calibration of gas sensors in Testo 350XL (Figure 99):

1. The analyzer is ensured fully charged.
2. The ambient air is ensured free from background gas contaminants.
3. The analyzer is started and the pump is operated for 15 minutes to purge residual gases from sensors and to fully achieve operating stability.
4. The analyzer is zero by pressed the function key *Zero*.
5. *Menu* button is pressed.
6. *Sensors* is selected.
7. *Calibrate* is selected.
8. Sensor to be calibrated is selected.
9. Indicated value for calibrated is entered according to the manual.
10. The sample probe is connected to the calibration apparatus.
11. The needle valve to the calibration gas is closed.
12. *Start* function key is selected.
13. The needle valve is adjusted to start the flow of the calibration gas to the analyzer.
14. The flow is carefully adjusted to provide approximately 1 to 2 liters/minutes flow through the bypass vent.
15. The sensor reading indicates a change; the process is timed for 3 to 5 minutes.
16. The calibrated value is showed in the screen.
17. The analyzer is purged on fresh air for 5 minutes before the beginning the next gas.

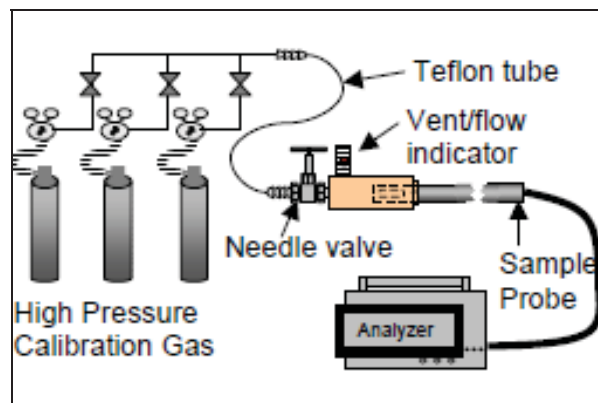


Figure 0.1: Schematic diagram for calibration of gas sensors in Testo 350XL
(adapted from: Testo 2012, p.36)

APPENDIX K: Principles of Calculation in Testo350XL

1) Gas measured (O₂ reference)

Unit	Description of formula
Ppmv	$x[ppmv] = x[ppmv] \cdot \frac{20.94 - O_{2ref}}{20.94 - O_2}$

Where

O_{2ref} = Oxygen reference at 7 % volume

APPENDIX L: Detail Fabrication of B2H Converter



Figure L 1: Welding the base of pyrolysis from outside



Figure L 2: Welding the base of pyrolysis from inside



Figure L 3: Cleaning the welded residue



Figure L 4: Welding "V" anchor bar inside the pyrolysis chamber



Figure L 5: Welded “V” anchor bar inside the pyrolysis chamber



Figure L 6: A 6mm mild steel is used as inner lining



Figure L 7: Galvanized pyrolysis chamber



Figure L 8: Galvanized tar removal chamber



Figure L 9: Drilling thermocouple hole in the pyrolysis chamber



Figure L 10: Drilling thermocouple hole in the tar removal chamber



Figure L 11: Retool the driller for drilling



Figure L 12: Lathed stainless steel for use as thermocouple well



Figure L 13: Plasma cutting 6-mm mild steel for fuel gas-to-heat energy conversion chamber



Figure L 14: Welding the fuel gas-to-heat energy conversion chamber



Figure L 15: Pyrolysis chamber door is cut



Figure L 16: "V" anchor bar is welded in pyrolysis chamber door



Figure L 17: Pyrolysis chamber door is welded



Figure L 18: 12.5-mm ceramic fire blanket is installed inside the pyrolysis chamber



Figure L 19: Side view of the pyrolysis that filled with 12.5-mm ceramic fire blanket



Figure L 20: Fitting the pyrolysis chamber framework into pyrolysis chamber before fill in refractory



Figure L 21: Filled in pyrolysis chamber (left)



Figure L 22: Filled in pyrolysis chamber (right)



Figure L 23: Wooden framework is formed at tar removal chamber before fill in refractory



Figure L 24: Refractory is mixing with water accordingly



Figure L 25: Customized tools to compact the refractory



Figure L 26: Refractory is filled in the tar removal chamber framework (left for 24 hours)



Figure L 27: Wet cloth is covered the surface area of refractory in tar removal chamber for 24 hours



Figure L 28: Void formed inside the tar removal chamber



Figure L 29: Refilled the refractory in the void found



Figure L 30: Inclined is built inside the tar removal chamber



Figure L 31: Refractory door at pyrolysis chamber is formed



Figure L 32: Pyrolysis chamber is transfer to civil lab by hydraulic lifter



Figure L 33: Concrete mixer machine is used for mixing refractory



Figure L 34: Top view on the working concrete mixer machine



Figure L 35: Mixed refractory produced by concrete machine



Figure L 36: Filling the mixed refractory into the pyrolysis chamber framework



Figure L 37: Refractory is compact with concrete vibrator to avoid void form



Figure L 38: Process of working with concrete vibrator



Figure L 39: Filled in refractory inside the pyrolysis chamber (left for 24 hours)



Figure L 40: Filled in refractory inside the pyrolysis chamber (side view)



Figure L 41: Refractory surface is wetted for curing process



Figure L 42: Refractory surface is covered with wetted cloth for 24 hours



Figure L 43: Chiseled the extra refractory by chisel machine



Figure L 44: Chiseled the extra refractory by hammer and chisel



Figure L 45: Chiseling and cutting work on pyrolysis chamber



Figure L 46: Welding "U" bars inside the pyrolysis chamber for lifting work



Figure L 47: Pyrolysis chamber is lifted up by overhead crane for transportation



Figure L 48: Pyrolysis chamber is transported back to workshop with a mechanical lifter



Figure L 49: Welding pyrolysis chamber and tar removal chamber (holding by overhead crane)



Figure L 50: Welded pyrolysis chamber with tar removal chamber



Figure L 51: Positioning the B2H by overhead crane for welding



Figure L 52: Welding the fuel gas-to-heat energy conversion chamber with the main body



Figure L 53: B2H body is welded



Figure L 54: Blower stand is fabricated



Figure L 55: Installing the blower 1 on the blower stand



Figure L 56: Blowers is installed on its stand



Figure L 57: Cutting process for pipe connection



Figure L 58: Installing thermocouple indicator box and its stand



Figure L 59: Installation of thermocouples



Figure L 60: Welding pipes by electrical discharge machining



Figure L 61: Hopper (cylinder)



Figure L 62: Spot welding hopper cone



Figure L 63: Completion of hopper and B2H cover



Figure L 64: Welding B2H cover and hopper in the main body



Figure L 65: Welded B2H cover and hopper in the main body



Figure L 66: Pipe and 1.5-inch ball valve at the blower 1 is welded



Figure L 67: Pipe and 1.5-inch ball valve at the blower 2 is welded



Figure L 68: A ball valve pipe is installed at the middle of the exhaust for flue gas measurement



Figure L 69: Door latch is installed at pyrolysis chamber



Figure L 70: Copper tubes is surrounded the pyrolysis chamber



Figure L 71: Copper tube is welded



Figure L 72: Copper is fastened



Figure L 73: Discover the difficulty in fit in the copper hole inlet



Figure L 74: Copper tube is fitted with a copper jointer



Figure L 75: Air flow rate level indicator at blower 1



Figure L 76: Air flow rate level indicator at blower 2



Figure L 77: Fabrication of B2H is completed

APPENDIX M: Moisture Content Determination

The moisture content, M_{ar} , of the investigated sample, as received expressed as a percentage by mass with the following Equation (3.2). The result is reported on a wet basis:

$$M_{ar} = \frac{(m_2 - m_3) + m_4}{(m_2 - m_1) + m_4} \times 100 \quad (3.4)$$

Where

- M_{ar} = the moisture content in the sample as received
- m_1 = the mass in g of the empty drying container
- m_2 = the mass in g of the drying container and sample before drying
- m_3 = the mass in g of the drying container and sample after drying
- m_4 = the mass in g of the moisture associated with the packing

There are five repetition of this procedure from the bulk sample collected.

Figure M 1: Cylindersweight for oil palm kernel

Cylinder for oil palm kernel	1	2	3	4	5
Weight, g	286.82	287.99	282.74	287.09	285.88

Figure M 2: Cylinders weight for wood chip

Cylinder for wood chip	1	2	3	4	5
Weight, g	258.95	284.96	286.15	283.81	287.28

Figure M 3: Drying hours of Batch 1 Sample

Dried hours	0	52.66	57.6	24	25.5	Moisture content (wet basis)
Oil palm kernel – 1	486.82	462.89	46274	463.06	462.71	12.0%
Wood chip – 1	458.95	426.44	426.39	426.79	426.37	16.3%

Figure M 4: Drying hours of Batch 2 Sample

Dried hours	0	16.75	24.75	23	24	Moisture content (wet basis)

Oil palm kernel – 2	487.99	464.95	464.51	464.58	464.59	11.7%
Wood chip – 2	484.96	455.69	454.79	454.79	454.79	15.1%

Figure M 5: Drying hours of Batch 3 Sample

Dried hours	0	16.75	24.75	23	24	Moisture content (wet basis)
Oil palm kernel – 3	482.74	459.68	459.25	459.25	459.33	11.7%
Wood chip – 3	486.15	452.06	451.28	451.20	451.20	17.4%

Figure M 6: Drying hours of Batch 4 Sample

Dried hours	0	16.75	24.75	23	24	Moisture content (wet basis)
Oil palm kernel – 4	487.09	464.30	463.79	463.78	463.80	11.6%
Wood chip – 4	483.81	454.44	453.55	453.58	453.56	15.1%

Figure M 7: Drying hours of Batch 5 Sample

Dried hours	0	16.75	24.75	23	24	Moisture content (wet basis)
Oil palm kernel – 5	485.88	462.80	462.22	462.22	462.25	11.8%
Wood chip – 5	487.28	453.23	452.34	452.36	452.34	17.4%

Figure M 8: Moisture content of oil palm kernel

Moisture content for oil palm kernel	1	2	3	4	5	Mean	Standard deviation
Moisture content (wet basis), %	12.0	11.7	11.7	11.6	11.8	11.7	0.1

Figure M 9: Moisture content of wood chips

\Moisture content for wood chip	1	2	3	4	5	Mean	Standard deviation
Moisture content (wet basis)	16.3	15.1	17.4	15.1	17.4	16.2	1.1

Figure M 10: Moisture content of investigated samples

Sample	Mean	Standard deviation
Oil palm kernel	11.7	0.1
Wood chip	16.2	1.1

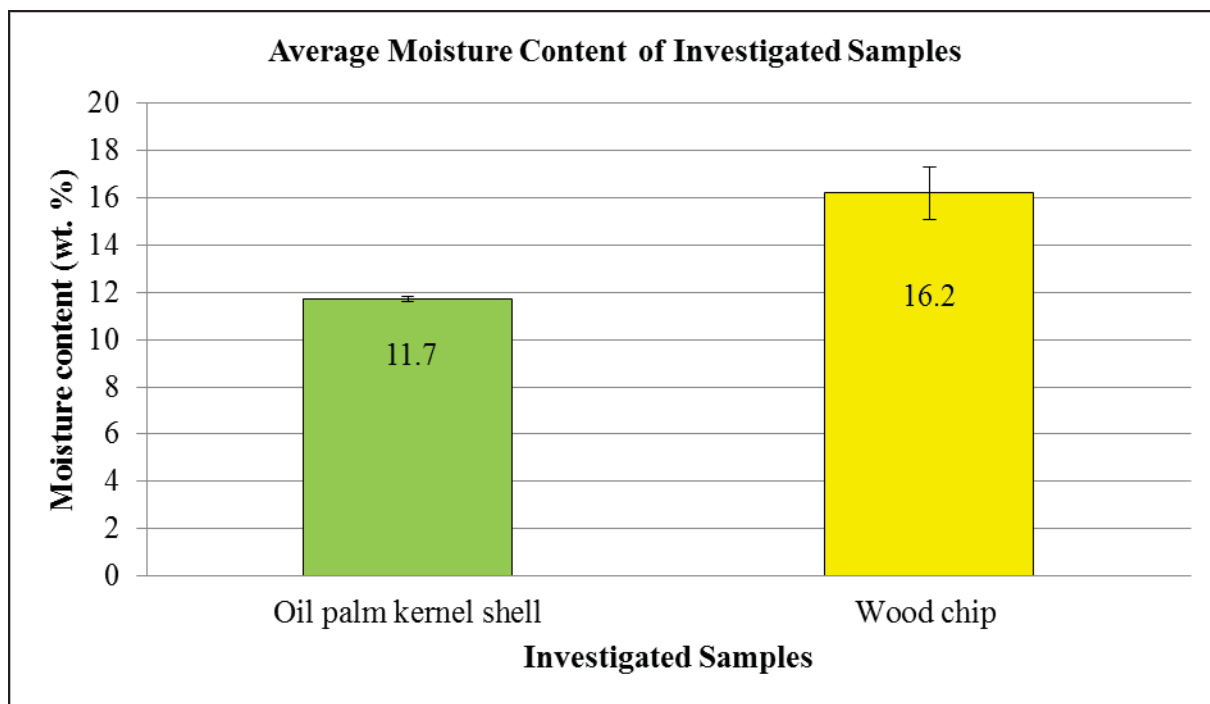


Figure M 11: Mean moisture content of investigated biomass samples

APPENDIX N: Air flow Rate and Excess/Deficient Air from Different Experiments

Level 0, 1, 2 and 3 were assigned according to 30° from the 90° ball valve handle.

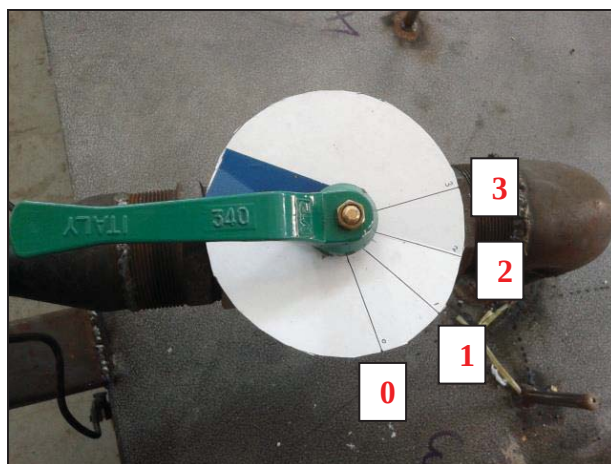


Figure N 1: Air flow rate level indicator

Figure N 1: Superficial air velocity of HAILEA VB-2200G

Level	Test 1, m/s	Test 2, m/s	Test 3, m/s	Test 4, m/s	Test 5, m/s	Average
0	0	0	0	0	0	0
1	5.84	5.75	5.84	5.74	5.76	5.79
2	8.96	8.97	8.83	8.85	8.89	8.90
3	9.75	9.69	9.67	9.61	9.55	9.65

Figure N 2: Superficial air velocity of HAILEA VB-800G

Level	Test 1, m/s	Test 2, m/s	Test 3, m/s	Test 4, m/s	Test 5, m/s	Average
0	0	0	0	0	0	0
1	3.82	3.84	3.82	3.82	3.83	3.83
2	3.99	3.98	3.97	3.96	3.96	3.97
3	4.01	3.98	3.98	4.01	4.00	4.00

Air flow rate, Q = Air flow rate at the B2H exhaust

Exit diameter, $D = 0.0762$ m (3.0-inch)

Area of the exit diameter, $A = \Pi \left(\frac{D^2}{4} \right)$

$$A = 0.00456 \text{ m}^2$$

(N1)

Air flow rate, $Q = AV$

Figure N 3: Air flow rate Experiment (i): (9.65:0.00)

Test number	Superficial velocity (Exit), m/s	Air flow rate, $Q = AV$ (Nm ³ /s)
1	9.75	
2	9.69	
3	9.67	
4	9.61	
5	9.55	
Mean	9.65	0.04400

Figure N 4: Air flow rate Experiment (ii) : (9.65:3.83)

Test number	Superficial velocity (Exit), m/s	Air flow rate, $Q = AV$ (Nm ³ /s)
1	16.5	
2	16.6	
3	16.2	
4	16.4	
5	17.0	
Mean	16.5	0.07524

Figure N 5: Air flow rate Experiment (iii): (9.65:4.00)

Test number	Superficial velocity (Exit), m/s	Air flow rate, $Q = AV$ (Nm ³ /s)
1	16.9	
2	16.8	
3	17.0	
4	16.7	
5	16.5	
Mean	16.8	0.07661

Figure N 6: Air flow rate Experiment (iv): (4.00:0.00)

Test number	Superficial velocity (Exit), m/s	Air flow rate, $Q = AV$ (Nm ³ /s)
1	4.01	
2	3.98	
3	3.98	
4	4.01	
5	4.00	
Mean	4.00	0.01824

Figure N 7: Air flow rate Experiment (v): (4.00:5.79)

Test number	Superficial velocity (Exit), m/s	Air flow rate, Q = AV (Nm ³ /s)
1	15.4	
2	15.6	
3	15.6	
4	15.3	
5	14.5	
Mean	15.3	0.06977

Figure N 8: Air flow rate Experiment (vi): (4.00:9.65)

Test number	Superficial velocity (Exit), m/s	Air flow rate, Q = AV (Nm ³ /s)
1	16.1	
2	16.2	
3	16.1	
4	15.9	
5	15.8	
Mean	16.0	0.07296

Figure N 9: Air flow rate Experiment (vii) and (viii): (3.83:9.65)

Test number	Superficial velocity (Exit), m/s	Air flow rate, Q = AV (Nm ³ /s)
1	13.1	
2	12.8	
3	12.8	
4	12.7	
5	12.8	
Mean	12.8	0.05837

Excess/Deficient Air from Different Experiments

Air mass flow rate in kg = (Mean Air flow rate) x (Air density at temperature y) x (Exhaust area) x (Require time for complete combustion of 1 kg-Fixed)

$$Mass_{air} = \left(\frac{m}{s}\right) \left(\frac{kg}{m^3}\right) (m^2)(s) \quad (N2)$$

$$AFR_{OPKS} = 4.225 \text{ kg} \quad (\text{Equation 3.4})$$

$$Theoretical \text{ air} = Mass_{air} / AFR_{OPKS} \quad (N3)$$

Figure N 10: Air flow rate and excess/deficient air from Experiment i to viii

Experiment	Air flow rate, $Q = AV$ (Nm ³ /s)	Theoretical air	Excess/Deficient air
Experiment set i	0.04400	102.84 %	2.84 % excess air
Experiment set ii	0.07524	195.20 %	95.20 % excess air combustion
Experiment set iii	0.07661	206.13 %	106.13 % excess air combustion
Experiment set iv	0.01824	46.06 %	53.94 % deficient air combustion
Experiment set v	0.06977	194.22 %	94 % excess air combustion
Experiment set vi	0.07296	214.34 %	114.34 % excess air combustion
Experiment set vii	0.05837	178.18 %	78.18 % excess air combustion
Experiment set viii	0.05837	184.07 %	84.07 % excess air combustion

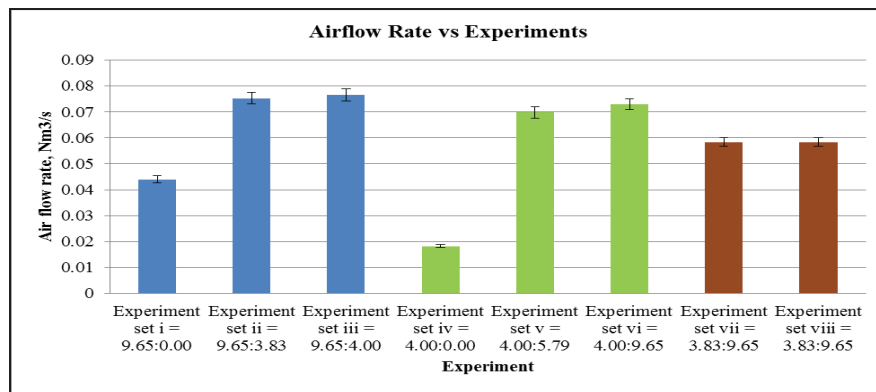


Figure O 1: Air flow rate of the experiments
(Accuracy = 3%)

APPENDIX O: TESTO 350XL Flue Gas Results

Experiment set (i-1)

Date = 2/1/2013; Sample = About 3 Kg of OPKS; Methanol = About 3 Liter; AVR = 9.65:0.00

Measurement rate = 5 seconds; Gas time = 2 minutes; Rinse time = 5 minutes; Mean = 1 second; To make the data meaningful, rinse time is neglected

Table O 1: Results of TESTO Experiment (i-1); AVR = 9.65:0.00 (OPKS)

Mean	200.91	30.16	720.44	187.61	15.47	15.45	30.91	13.66	15.84	67.90
Time	FT (°C)	AT (°C)	CO (ppmv)	H2 (ppmv)	NO (ppmv)	NO2 (ppmv)	NOx (ppmv)	SO2 (ppmv)	O2 (%)	η (%)
8:55:03	251.90	29.40	0.00	1.00	0.00	0.10	0.00	0.00	20.94	
8:55:08	324.90	29.60	90.00	58.00	1.00	2.40	4.00	2.00	17.23	24.60
8:55:13	303.70	29.60	501.00	210.00	4.00	4.90	9.00	12.00	11.80	73.60
8:55:18	274.20	29.60	871.00	184.00	5.00	5.20	11.00	23.00	10.80	77.90
8:55:23	258.10	29.60	1062.00	79.00	6.00	4.90	11.00	29.00	11.22	78.20
8:55:28	249.90	29.50	1139.00	52.00	6.00	5.10	11.00	30.00	11.31	78.60
8:55:33	254.90	29.50	1177.00	138.00	5.00	5.10	11.00	30.00	11.27	78.30
8:55:38	267.80	29.50	1182.00	209.00	6.00	5.40	11.00	30.00	10.98	77.80
8:55:43	265.70	29.60	1167.00	265.00	6.00	5.60	11.00	30.00	11.18	77.60
8:55:48	252.10	29.50	1118.00	307.00	7.00	5.90	13.00	28.00	11.83	77.40
8:55:53	258.50	29.60	1059.00	328.00	7.00	6.50	13.00	26.00	12.02	76.60
8:55:58	260.30	29.50	1081.00	304.00	7.00	7.20	15.00	26.00	11.53	77.40
8:56:03	247.40	29.50	1113.00	307.00	8.00	7.20	15.00	27.00	12.16	77.10
8:56:08	248.20	29.50	1081.00	339.00	8.00	7.70	16.00	26.00	12.43	76.50
8:56:13	253.00	29.50	1033.00	359.00	8.00	8.40	17.00	24.00	12.16	76.70
8:59:03	253.30	29.60	1011.00	356.00	8.00	8.80	17.00	23.00	12.15	76.80
8:56:23	248.90	29.50	1007.00	346.00	8.00	8.90	17.00	23.00	12.40	76.60
8:56:28	245.50	29.60	991.00	351.00	8.00	9.20	17.00	23.00	12.62	76.40
8:56:33	242.80	29.60	948.00	367.00	9.00	9.70	19.00	21.00	12.72	76.40

8:56:38	245.60	29.60	875.00	379.00	9.00	10.40	20.00	19.00	12.62	76.40
8:56:43	230.40	29.70	834.00	359.00	9.00	10.60	20.00	18.00	12.80	77.50
8:56:48	227.20	29.60	801.00	341.00	10.00	10.30	20.00	17.00	13.20	76.90
8:56:53	227.40	29.70	758.00	329.00	10.00	10.40	20.00	16.00	13.04	77.30
8:56:58	218.90	29.60	740.00	303.00	9.00	10.60	19.00	16.00	13.07	78.00
9:02:05	208.50	30.00	598.00	102.00	15.00	16.30	31.00	8.00	15.28	72.60
9:02:10	201.00	30.10	603.00	116.00	15.00	16.60	31.00	8.00	15.42	73.00
9:02:15	204.90	30.00	592.00	130.00	15.00	16.60	31.00	8.00	15.57	71.80
9:02:20	211.30	30.10	591.00	131.00	15.00	17.10	32.00	8.00	15.34	71.90
9:02:25	210.30	30.00	609.00	126.00	15.00	17.80	33.00	8.00	15.36	72.00
9:02:30	204.80	30.10	614.00	134.00	15.00	17.80	33.00	8.00	15.62	71.60
9:02:35	199.10	30.10	593.00	149.00	15.00	17.30	33.00	8.00	15.84	71.40
9:02:40	193.80	30.10	564.00	157.00	16.00	17.00	33.00	7.00	15.92	71.80
9:02:45	191.00	30.10	537.00	159.00	18.00	17.00	35.00	6.00	15.90	72.40
9:02:50	190.90	30.10	525.00	153.00	18.00	17.60	35.00	6.00	15.74	73.10
9:02:55	191.70	30.10	537.00	142.00	17.00	17.40	35.00	6.00	15.83	72.60
9:03:00	200.00	30.10	549.00	137.00	16.00	17.20	34.00	7.00	15.79	71.60
9:03:05	207.50	30.10	591.00	123.00	16.00	17.60	33.00	7.00	15.66	71.10
9:03:10	207.50	30.10	639.00	120.00	16.00	17.30	34.00	9.00	15.70	70.80
9:03:15	189.00	30.20	659.00	136.00	17.00	16.60	33.00	10.00	16.07	71.70
9:03:20	182.40	30.10	632.00	167.00	17.00	15.20	32.00	9.00	16.35	71.30
9:03:25	163.50	30.10	602.00	178.00	18.00	13.80	32.00	8.00	16.35	74.40
9:03:30	192.00	30.20	570.00	182.00	19.00	13.50	32.00	8.00	16.26	70.40
9:03:35	232.80	30.20	552.00	174.00	18.00	16.40	35.00	8.00	15.15	70.00
9:03:40	242.90	30.20	564.00	152.00	20.00	18.60	38.00	7.00	13.85	73.70
9:03:45	216.90	30.20	612.00	124.00	21.00	18.40	40.00	8.00	13.81	76.50
9:03:50	219.10	30.20	632.00	126.00	22.00	17.40	39.00	9.00	14.37	74.60
9:03:55	219.70	30.20	674.00	11.00	22.00	17.00	39.00	10.00	14.52	74.00
9:04:00	212.60	30.10	740.00	94.00	23.00	16.60	39.00	11.00	14.56	74.30

9:09:07	187.40	30.20	659.00	138.00	21.00	22.20	43.00	6.00	16.84	67.40
9:09:12	191.20	30.20	663.00	145.00	20.00	21.90	42.00	7.00	16.99	65.60
9:09:17	194.50	30.30	674.00	146.00	20.00	22.40	43.00	7.00	16.85	66.00
9:09:22	184.80	30.30	700.00	142.00	20.00	22.50	43.00	7.00	16.96	67.00
9:09:27	170.60	30.30	695.00	161.00	21.00	21.30	42.00	7.00	17.24	67.60
9:09:32	160.00	30.40	678.00	170.00	21.00	20.00	41.00	7.00	17.32	68.60
9:09:37	210.10	30.40	666.00	172.00	21.00	20.10	41.00	7.00	16.70	64.20
9:09:42	232.90	30.30	678.00	160.00	19.00	22.50	41.00	8.00	14.85	71.10
9:09:47	228.90	30.30	707.00	150.00	17.00	23.40	41.00	9.00	14.47	73.10
9:09:52	214.40	30.40	747.00	142.00	17.00	22.80	40.00	10.00	14.93	73.10
9:09:57	216.90	30.40	744.00	160.00	18.00	21.70	40.00	10.00	15.67	69.50
9:10:02	221.40	30.30	720.00	172.00	18.00	22.10	40.00	10.00	15.84	68.00
9:10:07	211.40	30.40	698.00	178.00	18.00	22.80	41.00	9.00	16.16	67.70
9:10:12	205.20	30.40	666.00	185.00	18.00	22.30	40.00	8.00	16.66	65.60
9:10:17	200.50	30.50	634.00	186.00	18.00	22.30	40.00	7.00	16.82	65.30
9:10:22	193.10	30.40	621.00	180.00	18.00	22.40	40.00	6.00	17.03	65.10
9:10:27	196.30	30.30	614.00	176.00	18.00	22.20	40.00	6.00	17.15	63.40
9:10:32	194.80	30.40	611.00	173.00	18.00	22.60	40.00	7.00	17.11	64.10
9:10:37	183.20	30.50	621.00	169.00	18.00	22.50	41.00	6.00	17.29	64.80
9:10:42	189.40	30.80	615.00	179.00	18.00	22.00	40.00	6.00	17.48	61.90
9:10:47	176.00	30.40	605.00	183.00	18.00	21.80	40.00	6.00	17.42	65.20
9:10:52	162.30	30.40	609.00	182.00	20.00	20.40	40.00	6.00	17.50	67.40
9:10:57	175.20	30.50	605.00	187.00	19.00	19.30	38.00	7.00	17.49	64.80
9:11:02	178.70	30.50	624.00	178.00	17.00	19.10	36.00	7.00	17.15	66.90
9:16:09	161.30	30.60			19.00	19.60	39.00	17.00	18.31	60.60
9:16:14	161.00	30.50			19.00	19.00	38.00	17.00	18.37	60.00
9:16:19	156.00	30.60			19.00	18.70	38.00	17.00	18.41	60.80
9:16:24	153.70	30.50			19.00	17.90	37.00	17.00	18.56	59.30
9:16:29	149.70	30.50			19.00	17.20	36.00	17.00	18.63	59.40

9:16:34	147.50	30.60				19.00	16.60	35.00	17.00	18.68	59.30
9:16:39	150.40	30.50				19.00	16.20	35.00	17.00	18.68	58.30
9:16:44	147.50	30.60				19.00	16.40	35.00	17.00	18.59	60.80
9:16:49	140.70	30.50				19.00	15.90	34.00	17.00	18.71	61.00
9:16:54	141.10	30.60				18.00	14.90	33.00	17.00	18.81	59.20
9:16:59	144.50	30.50				18.00	14.50	33.00	17.00	18.86	57.20
9:17:04	150.40	30.60				18.00	14.60	33.00	18.00	18.78	56.60
9:17:09	149.10	30.60				19.00	14.70	33.00	18.00	18.69	58.70
9:17:14	139.60	30.60				19.00	14.20	33.00	19.00	18.77	60.40
9:17:19	129.00	30.60				18.00	12.90	31.00	19.00	18.99	30.40
9:17:24	127.70	30.50				18.00	11.80	30.00	18.00	19.11	58.70
9:17:29	146.00	30.60				18.00	12.10	30.00	18.00	18.96	54.80
9:17:34	151.70	30.50				19.00	13.30	32.00	19.00	18.75	56.80
9:17:39	158.70	30.50				19.00	14.60	33.00	19.00	18.64	56.30
9:17:44	160.80	30.60				19.00	16.20	35.00	18.00	18.48	58.40
9:17:49	162.90	30.60				19.00	17.80	37.00	19.00	18.41	58.80
9:17:54	167.40	30.60				19.00	18.60	38.00	18.00	18.36	58.20
9:17:59	157.80	30.60				19.00	19.30	39.00	17.00	18.30	61.80
9:18:04	149.50	30.60				20.00	18.70	38.00	17.00	18.44	62.20

Table O 2: Temperature at pyrolysis chamber for Experiment (i-1); AVR = 9.65:0.00 (OPKS)

Mean		198.47	
Duration, minute	PT, (°C)	Duration, minute	PT, (°C)
0	0.00	14.5	244.00
0.5	216.00	15	213.00
1	228.00	15.5	194.00
1.5	236.00	16	200.00
2	247.00	16.5	179.00
2.5	238.00	17	204.00
3	236.00	17.5	185.00
3.5	235.00	18	172.00
4	240.00	18.5	198.00
4.5	236.00	19	183.00
5	236.00	19.5	169.00
5.5	228.00	20	199.00
6	229.00	20.5	175.00
6.5	225.00	21	167.00
7	225.00	21.5	163.00
7.5	218.00	22	154.00
8	211.00	22.5	154.00
8.5	240.00	23	162.00
9	235.00	23.5	151.00
9.5	231.00	24	142.00
10	218.00	24.5	144.00
10.5	261.00	25	147.00
11	226.00	25.5	148.00
11.5	216.00	26	143.00

12	210.00	26.5	140.00
12.5	201.00	27	134.00
13	275.00		
13.5	239.00		
14	216.00		

Experiment set (i-2)

Date = 3/1/2013; Sample = About 3 Kg of OPKS; Methanol = About 3 Liter; AVR = 9.65:0.00

Measurement rate = 5 seconds; Gas time = 2 minutes; Rinse time = 5 minutes; Mean = 1 second; To make the data meaningful, rinse time is neglected

Table O 3: Results of TESTO Experiment (i-2); AVR = 9.65:0.00 (OPKS)

Mean	189.22	31.17	766.78	180.51	18.72	14.25	32.96	15.84	16.48	66.09
Time	FT (°C)	AT (°C)	CO (ppmv)	H2 (ppmv)	NO (ppmv)	NO2 (ppmv)	NOx (ppmv)	SO2 (ppmv)	O2 (%)	η (%)
9:28:03	258.00	30.00	2.00	2.00	0.00	0.10	0.00	0.00	20.87	
9:28:08	295.40	30.00	77.00	47.00	1.00	2.70	3.00	2.00	17.58	
9:28:13	278.80	30.00	312.00	127.00	2.00	4.90	7.00	8.00	14.19	68.30
9:28:18	269.30	29.90	593.00	149.00	4.00	5.30	9.00	15.00	12.03	75.90
9:28:23	253.50	29.90	695.00	148.00	4.00	4.30	10.00	19.00	11.34	78.60
9:28:28	237.90	30.00	899.00	48.00	4.00	4.90	9.00	24.00	11.41	79.60
9:28:33	247.90	30.00	975.00	105.00	5.00	5.00	10.00	26.00	11.64	78.30
9:28:38	251.20	30.00	904.00	188.00	5.00	5.80	11.00	24.00	11.41	78.50
9:28:43	254.00	30.00	864.00	214.00	6.00	6.60	12.00	22.00	11.72	77.70
9:28:48	250.70	30.00	870.00	212.00	7.00	7.40	14.00	24.00	11.82	77.80
9:28:53	247.90	30.00	864.00	229.00	7.00	8.60	16.00	21.00	11.91	77.90
9:28:58	236.50	30.00	837.00	248.00	8.00	9.50	17.00	20.00	12.14	78.40
9:29:03	241.50	30.10	796.00	264.00	9.00	10.60	20.00	18.00	12.32	77.60
9:29:08	250.60	30.20	759.00	269.00	9.00	12.30	22.00	17.00	11.97	77.60
9:29:13	242.90	30.10	748.00	257.00	10.00	13.10	23.00	16.00	11.80	78.60
9:29:18	242.50	30.10	742.00	251.00	11.00	13.50	25.00	16.00	11.94	78.40
9:29:23	256.00	30.10	717.00	255.00	12.00	14.60	26.00	15.00	11.70	77.70
9:29:28	266.10	30.20	700.00	243.00	12.00	15.10	27.00	14.00	11.51	77.30

9:29:33	254.80	30.30	714.00	226.00	13.00	15.60	28.00	14.00	11.77	77.70
9:29:38	259.70	30.20	704.00	232.00	13.00	16.00	29.00	14.00	12.16	76.50
9:29:43	243.10	30.30	678.00	235.00	15.00	16.30	31.00	14.00	12.29	77.70
9:29:48	243.60	30.30	647.00	241.00	16.00	16.30	32.00	13.00	12.57	77.00
9:29:53	239.80	30.30	617.00	228.00	15.00	16.70	32.00	12.00	12.27	78.00
9:29:58	229.50	30.30	669.00	185.00	15.00	16.50	32.00	13.00	12.38	78.70
9:35:05	219.40	30.70	564.00	127.00	18.00	20.80	39.00	8.00	15.15	71.90
9:35:10	219.30	30.70	554.00	131.00	19.00	21.10	40.00	8.00	14.95	72.70
9:35:15	214.20	30.70	554.00	129.00	19.00	21.40	40.00	8.00	14.90	73.50
9:35:20	212.20	30.60	548.00	132.00	19.00	21.10	40.00	8.00	14.98	73.40
9:35:25	211.80	30.70	544.00	133.00	19.00	20.90	40.00	7.00	15.06	73.20
9:35:30	216.40	30.70	543.00	134.00	19.00	20.70	40.00	7.00	15.08	72.50
9:35:35	206.40	30.70	554.00	127.00	19.00	21.40	40.00	8.00	15.03	74.00
9:35:40	209.10	30.70	567.00	126.00	18.00	21.00	39.00	8.00	15.25	72.70
9:35:45	209.40	30.70	582.00	124.00	18.00	21.10	39.00	9.00	15.22	72.80
9:35:50	206.50	30.70	621.00	115.00	18.00	20.60	38.00	10.00	15.38	72.50
9:35:55	216.80	30.60	639.00	125.00	18.00	20.40	38.00	10.00	15.46	70.70
9:36:00	218.50	30.70	640.00	137.00	18.00	21.30	39.00	10.00	15.24	71.40
9:36:05	209.20	30.70	650.00	137.00	18.00	21.60	39.00	10.00	15.27	72.60
9:36:10	199.40	30.70	658.00	139.00	18.00	20.70	38.00	10.00	15.67	72.10
9:36:15	204.60	30.60	641.00	154.00	17.00	20.10	37.00	10.00	15.85	70.60
9:36:20	198.10	30.70	630.00	155.00	17.00	20.50	37.00	10.00	15.68	72.30
9:36:25	197.00	30.80	639.00	149.00	18.00	20.30	38.00	10.00	15.75	72.20
9:36:30	197.60	30.80	648.00	148.00	18.00	19.90	37.00	10.00	15.80	71.80
9:36:35	202.70	30.80	683.00	134.00	18.00	20.30	38.00	10.00	15.68	71.60
9:42:40	201.70	30.80	761.00	112.00	18.00	20.30	39.00	13.00	15.66	71.80
9:36:45	208.90	30.80	840.00	11.00	18.00	21.10	39.00	15.00	15.68	70.60
9:36:50	204.00	30.80	909.00	125.00	18.00	21.40	40.00	16.00	15.76	70.80
9:36:55	187.80	30.80	938.00	151.00	19.00	20.90	40.00	17.00	75.96	72.10

9:37:00	207.90	30.90	923.00	186.00	20.00	20.10	40.00	17.00	15.99	69.00
9:42:07	202.10	31.20	880.00	178.00	23.00	19.10	42.00	13.00	16.86	64.50
9:42:12	201.60	31.20	867.00	184.00	23.00	19.30	42.00	13.00	16.94	63.90
9:42:17	195.80	31.20	858.00	186.00	23.00	19.30	42.00	13.00	16.97	64.80
9:42:22	188.90	31.20	855.00	187.00	23.00	19.00	42.00	13.00	17.06	65.30
9:42:27	193.20	31.20	853.00	187.00	24.00	19.20	43.00	12.00	17.02	64.90
9:42:32	198.20	31.20	860.00	184.00	24.00	19.80	44.00	12.00	16.89	65.00
9:42:37	194.20	31.20	871.00	183.00	24.00	20.00	44.00	13.00	16.89	65.70
9:42:42	187.70	31.20	915.00	177.00	24.00	19.70	44.00	14.00	17.03	65.70
9:42:47	183.20	31.20	954.00	181.00	24.00	18.90	43.00	15.00	17.22	65.00
9:42:52	184.20	31.20	968.00	185.00	24.00	18.50	43.00	15.00	17.33	63.90
9:42:57	182.40	31.20	981.00	205.00	24.00	18.00	42.00	16.00	17.38	63.80
9:43:02	181.80	31.20	1008.00	207.00	24.00	17.80	42.00	16.00	17.44	63.30
9:43:07	185.00	31.20	1086.00	216.00	24.00	17.50	42.00	17.00	17.48	62.20
9:43:12	175.00	31.20	1048.00	232.00	24.00	17.40	42.00	17.00	17.52	63.90
9:43:17	158.20	31.20	1042.00	253.00	25.00	16.30	41.00	18.00	17.60	66.80
9:43:22	180.60	31.20	1017.00	275.00	25.00	15.90	41.00	17.00	17.45	63.40
9:43:27	222.20	31.30	964.00	296.00	25.00	17.40	42.00	16.00	16.03	66.20
9:43:32	215.50	31.30	937.00	287.00	24.00	19.40	44.00	15.00	15.08	72.20
9:43:37	207.10	31.30	943.00	264.00	25.00	19.10	44.00	15.00	15.27	72.50
9:43:42	218.50	31.30	962.00	244.00	25.00	19.40	44.00	15.00	15.26	69.70
9:43:47	211.10	31.30	1013.00	220.00	25.00	20.00	45.00	17.00	15.83	69.30
9:43:52	199.10	31.30	1047.00	225.00	25.00	19.70	45.00	17.00	16.29	68.50
9:43:57	199.10	31.30	1046.00	239.00	25.00	19.30	44.00	17.00	16.61	66.50
9:44:02	195.10	34.40	1020.00	258.00	24.00	19.10	43.00	17.00	16.82	65.80
9:49:09	153.30	31.70			23.00	13.20	36.00	19.00	18.52	60.30
9:49:14	155.00	31.70			23.00	13.10	36.00	20.00	18.56	59.20
9:49:19	160.10	31.70			23.00	13.30	36.00	20.00	18.57	57.60
9:49:24	158.50	31.70			23.00	14.00	37.00	20.00	18.44	60.00

9:49:29	158.80	31.70				24.00	14.30	38.00	19.00	18.47	59.60
9:49:34	157.70	31.70				23.00	14.60	38.00	20.00	18.47	59.70
9:49:39	157.70	31.70				23.00	14.60	38.00	19.00	18.48	59.60
9:49:44	155.30	31.70				23.00	14.50	37.00	19.00	18.50	60.00
9:49:49	156.60	31.70				22.00	14.50	37.00	19.00	18.52	59.40
9:49:54	163.00	31.70				23.00	15.00	38.00	19.00	18.40	59.30
9:49:59	158.50	31.80				23.00	15.50	39.00	19.00	18.32	61.60
9:50:04	154.40	31.70				23.00	15.00	38.00	20.00	18.45	61.00
9:50:09	153.30	31.80				23.00	14.40	37.00	20.00	18.55	59.90
9:50:14	153.20	31.80				22.00	14.00	36.00	20.00	18.63	58.70
9:50:19	151.50	31.80				22.00	13.80	35.00	20.00	18.63	59.30
9:50:24	149.00	31.80				21.00	13.40	35.00	20.00	18.70	59.00
9:50:29	151.50	31.90				22.00	13.00	35.00	20.00	18.75	57.30
9:50:34	148.80	31.80				22.00	13.10	35.00	20.00	18.68	59.30
9:50:39	148.20	31.80				21.00	12.80	34.00	20.00	18.79	57.70
9:50:44	144.30	31.80				21.00	12.20	33.00	20.00	18.85	57.90
9:50:49	145.40	31.80				21.00	11.80	32.00	20.00	18.89	56.90
9:50:54	139.90	31.80				20.00	11.40	32.00	21.00	18.92	58.10
9:50:59	141.50	31.70				20.00	10.80	31.00	21.00	19.00	56.00
9:51:04	139.30	31.80				20.00	10.60	30.00	20.00	19.02	56.60
9:56:11	137.80	32.00				20.00	8.40	29.00	18.00	19.02	57.20
9:56:16	134.10	31.90				20.00	8.40	29.00	19.00	19.02	58.50
9:56:21	135.90	32.00				20.00	8.00	28.00	19.00	19.08	56.50
9:56:26	128.40	31.90				20.00	7.60	28.00	19.00	19.17	57.70
9:56:31	126.50	31.90				19.00	7.20	26.00	19.00	19.34	54.50
9:56:36	132.50	31.90				18.00	6.80	25.00	18.00	19.35	51.60
9:56:41	132.10	32.00				18.00	6.80	25.00	18.00	19.24	54.70
9:56:46	130.60	32.00				19.00	6.80	25.00	18.00	19.22	55.70
9:56:51	127.30	31.90				18.00	6.80	25.00	19.00	19.29	55.50

9:56:56	125.00	31.90				18.00	6.40	25.00	18.00	19.35	54.90
9:57:01	124.50	31.90				18.00	6.10	24.00	18.00	19.41	53.80
9:57:06	124.80	32.00				17.00	5.90	23.00	18.00	19.41	53.40
9:57:11	121.70	31.90				17.00	5.60	23.00	18.00	19.45	53.80
9:57:16	115.20	31.90				17.00	5.20	22.00	18.00	19.46	56.70
9:57:21	113.90	31.90				17.00	4.80	22.00	18.00	19.43	58.00
9:57:26	147.90	31.90				18.00	5.50	23.00	18.00	19.22	48.30
9:57:31	164.40	31.90				19.00	7.40	27.00	18.00	18.61	55.30
9:57:36	167.90	31.90				22.00	9.50	32.00	18.00	18.27	59.70
9:57:41	168.80	31.90				24.00	11.00	35.00	18.00	18.13	61.30
9:57:46	166.40	31.80				26.00	12.10	38.00	18.00	18.10	62.30
9:57:51	162.90	31.90				27.00	12.40	39.00	18.00	18.17	62.40
9:57:56	161.00	31.90				27.00	12.70	40.00	17.00	18.23	62.10
9:58:01	157.80	31.90				27.00	12.80	40.00	17.00	18.26	62.60
9:58:06	154.30	31.80				27.00	12.60	40.00	16.00	18.35	62.40

Table O 4: Temperature at pyrolysis chamber for Experiment (i-2); AVR = 9.65:0.00 (OPKS)

Mean		200.64			
Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)
0	0.00	15	203.00	30	164.00
0.5	257.00	15.5	236.00	30.5	158.00
1	274.00	16	214.00	31	151.00
1.5	273.00	16.5	198.00	31.5	143.00
2	230.00	17	193.00	32	139.00
2.5	268.00	17.5	191.00	32.5	151.00
3	285.00	18	175.00	33	154.00
3.5	276.00	18.5	169.00		
4	279.00	19	180.00		
4.5	281.00	19.5	184.00		
5	263.00	20	181.00		
5.5	272.00	20.5	175.00		
6	250.00	21	171.00		
6.5	252.00	21.5	168.00		
7	252.00	22	169.00		
7.5	244.00	22.5	163.00		
8	238.00	23	161.00		
8.5	230.00	23.5	156.00		
9	243.00	24	183.00		
9.5	234.00	24.5	171.00		
10	224.00	25	163.00		
10.5	232.00	25.5	155.00		
11	227.00	26	164.00		
11.5	257.00	26.5	166.00		
12	236.00	27	165.00		

12.5	222.00	27.5	160.00
13	213.00	28	157.00
13.5	227.00	28.5	152.00
14	211.00	29	147.00
14.5	205.00	29.5	158.00

Experiment set (i-3)

Date = 3/1/2013; Sample = About 3 Kg of OPKS; Methanol = About 3 Liter; AVR = 9.65:0

Measurement rate = 5 seconds; Gas time = 2 minutes; Rinse time = 5 minutes; Mean = 1 second; To make the data meaningful, rinse time is neglected

Table O 5: Results of TESTO Experiment (i-3); AVR = 9.65:0.00 (OPKS)

Mean	193.62	35.13	759.96	164.17	19.84	16.82	36.63	18.10	16.52	66.16
Time	FT (°C)	AT (°C)	CO (ppmv)	H2 (ppmv)	NO (ppmv)	NO2 (ppmv)	NOx (ppmv)	SO2 (ppmv)	O2 (%)	η (%)
12:53:07	256.80	35.30	23.00	192.00	3.00	0.10	3.00	2.00	20.29	
12:53:12	323.90	35.70	244.00	315.00	4.00	3.10	7.00	7.00	16.22	37.50
12:53:17	312.80	35.70	323.00	490.00	7.00	5.90	13.00	26.00	11.38	73.90
12:53:22	285.00	35.70	1347.00	445.00	9.00	6.80	15.00	46.00	10.15	78.30
12:53:27	266.90	35.60	1425.00	128.00	9.00	7.20	16.00	49.00	10.66	78.70
12:53:32	260.40	35.60	1202.00	114.00	9.00	7.60	17.00	41.00	11.20	78.40
12:53:37	252.70	35.50	975.00	204.00	10.00	8.40	18.00	32.00	11.51	78.60
13:53:42	232.30	35.40	859.00	190.00	10.00	9.40	20.00	26.00	11.37	80.60
12:53:47	199.10	35.40	823.00	150.00	11.00	9.80	20.00	24.00	11.41	83.20
12:53:52	218.90	35.40	795.00	126.00	10.00	10.10	20.00	24.00	11.88	80.90
12:53:57	241.60	35.40	774.00	107.00	11.00	11.40	22.00	23.00	11.88	79.00
12:54:02	255.90	35.40	747.00	95.00	12.00	12.70	24.00	22.00	12.16	77.20
12:54:07	259.00	35.50	706.00	88.00	12.00	14.40	27.00	20.00	11.84	77.70
12:54:12	261.60	35.40	686.00	69.00	13.00	16.10	30.00	19.00	11.70	77.80
12:54:17	268.20	35.40	676.00	53.00	15.00	17.60	33.00	18.00	11.44	77.70
12:54:22	271.40	35.50	687.00	33.00	16.00	18.80	35.00	18.00	11.44	77.50
12:54:27	277.70	35.50	697.00	23.00	17.00	20.00	37.00	18.00	11.25	77.30

12:54:32	272.40	35.50	695.00	23.00	17.00	20.60	38.00	18.00	11.23	77.80
12:54:37	283.90	35.40	695.00	8.00	19.00	21.40	40.00	18.00	11.21	76.90
12:54:42	285.60	35.50	757.00	17.00	20.00	22.40	43.00	19.00	11.08	77.00
12:54:47	290.00	35.50	766.00	6.00	21.00	23.10	44.00	20.00	11.22	76.40
12:54:52	283.10	35.50	732.00	28.00	22.00	24.00	46.00	19.00	11.41	76.60
12:54:57	283.80	35.50	691.00	36.00	23.00	24.60	47.00	17.00	11.67	76.00
12:55:02	265.40	35.50	660.00	30.00	24.00	25.30	49.00	16.00	11.52	77.80
13:00:09	219.60	35.10	636.00	149.00	21.00	23.30	44.00	13.00	15.24	71.90
13:00:14	225.30	34.90	625.00	160.00	21.00	22.80	44.00	12.00	15.29	70.90
13:00:19	223.20	34.90	618.00	163.00	22.00	23.30	45.00	12.00	15.08	72.10
13:00:24	217.90	35.00	628.00	159.00	22.00	23.20	45.00	12.00	15.11	72.70
13:00:29	214.50	35.00	637.00	162.00	22.00	22.80	45.00	12.00	15.18	72.80
13:00:34	223.70	35.10	652.00	162.00	22.00	23.20	45.00	13.00	15.05	72.20
13:00:39	216.30	35.10	701.00	154.00	22.00	24.20	46.00	14.00	14.99	73.30
13:00:44	218.60	35.00	732.00	164.00	22.00	23.40	46.00	15.00	15.33	71.50
13:00:49	226.30	34.90	744.00	179.00	22.00	24.20	46.00	15.00	15.12	71.40
13:00:54	221.30	34.90	764.00	185.00	22.00	25.20	47.00	16.00	15.11	72.10
13:00:59	216.60	35.00	780.00	194.00	21.00	25.20	46.00	16.00	15.36	71.60
13:01:04	207.70	35.10	781.00	207.00	21.00	24.30	46.00	16.00	15.63	71.60
13:01:09	202.60	35.20	763.00	223.00	21.00	22.60	44.00	16.00	15.85	71.40
13:01:14	214.70	35.20	732.00	233.00	22.00	22.80	44.00	15.00	15.63	70.70
13:01:19	215.90	35.20	753.00	218.00	22.00	24.10	46.00	15.00	15.39	71.60
13:01:24	209.20	35.20	807.00	201.00	21.00	24.80	46.00	17.00	15.33	72.70
13:01:29	212.30	35.20	859.00	207.00	21.00	24.60	46.00	18.00	15.46	71.70
13:01:34	208.90	35.20	884.00	221.00	21.00	24.50	46.00	19.00	15.50	71.90
13:01:39	206.40	35.30	886.00	227.00	21.00	24.30	45.00	19.00	15.60	71.80
13:01:44	205.70	35.40	874.00	265.00	21.00	23.10	44.00	19.00	15.84	70.80
13:01:49	207.00	35.40	871.00	271.00	21.00	23.10	44.00	19.00	15.80	70.90
13:01:54	210.00	35.40	887.00	268.00	21.00	23.40	44.00	19.00	15.82	70.30

13:01:59	209.30	35.40	924.00	263.00	21.00	24.00	45.00	20.00	15.70	71.00
13:02:04	203.70	35.40	955.00	275.00	22.00	24.20	46.00	21.00	15.85	71.00
13:07:11	204.50	35.30			23.00	21.70	44.00	16.00	16.52	68.50
13:07:16	200.20	35.30			22.00	21.80	44.00	17.00	16.62	68.60
13:07:21	181.90	35.30			22.00	20.90	43.00	17.00	16.87	70.30
13:07:26	180.40	35.30			23.00	19.40	43.00	17.00	17.06	69.30
13:07:31	212.60	35.20			23.00	19.70	42.00	16.00	16.57	66.80
13:07:36	218.90	35.30			21.00	21.70	42.00	15.00	15.40	72.10
13:07:41	211.20	35.30			21.00	21.60	42.00	16.00	15.00	74.70
13:07:46	214.20	35.40			21.00	21.00	42.00	16.00	15.26	73.40
13:07:51	214.70	35.20			21.00	21.40	43.00	17.00	15.54	72.10
13:07:56	212.30	35.30			22.00	21.70	44.00	17.00	15.82	71.10
13:08:01	208.10	35.30			22.00	21.60	44.00	18.00	16.21	69.70
13:08:06	204.40	35.30			23.00	21.70	44.00	18.00	16.46	68.90
13:08:11	199.70	35.30			23.00	21.70	45.00	18.00	16.62	68.70
13:08:16	198.00	35.20			23.00	21.20	44.00	18.00	16.79	67.90
13:08:21	199.50	35.20			23.00	21.50	44.00	17.00	16.67	68.40
13:08:26	192.00	35.20			23.00	21.60	44.00	17.00	16.73	69.30
13:08:31	191.10	35.10			23.00	20.60	43.00	18.00	17.06	67.20
13:08:36	195.10	35.10			23.00	20.00	43.00	17.00	17.14	65.80
13:08:41	195.40	35.20			23.00	20.30	43.00	17.00	17.10	66.10
13:08:46	195.30	35.20			23.00	20.30	43.00	17.00	17.12	66.00
13:08:51	196.80	35.20			23.00	20.90	43.00	17.00	17.12	65.70
13:08:56	192.10	35.30			23.00	20.70	44.00	17.00	17.19	66.00
13:09:01	195.70	35.30			23.00	20.50	43.00	18.00	17.29	64.50
13:09:06	189.40	35.20			22.00	20.40	43.00	18.00	17.41	64.70
13:14:13	174.20	34.80			23.00	16.80	40.00	20.00	17.84	63.90
13:14:18	173.90	34.70			23.00	16.50	39.00	20.00	17.92	63.20
13:14:23	178.90	34.80			23.00	16.50	39.00	20.00	17.95	61.60

13:14:28	173.90	34.80				23.00	16.60	39.00	21.00	17.99	62.50
13:14:33	171.50	34.80				23.00	16.30	39.00	21.00	18.14	61.20
13:14:38	173.10	34.90				22.00	16.10	38.00	20.00	18.18	60.30
13:14:43	167.80	35.00				22.00	16.40	39.00	20.00	18.17	61.90
13:14:48	169.90	35.10				23.00	15.80	39.00	20.00	18.24	60.50
13:14:53	171.00	35.10				23.00	16.00	39.00	20.00	18.07	62.30
13:14:58	169.40	35.10				23.00	15.90	39.00	20.00	18.17	61.50
13:15:03	167.40	35.10				23.00	15.70	38.00	20.00	18.22	61.40
13:15:08	163.70	35.10				23.00	15.50	38.00	20.00	18.28	61.60
13:15:13	157.20	35.20				22.00	14.90	37.00	20.00	18.47	60.90
13:15:18	156.40	35.20				21.00	13.90	35.00	20.00	18.56	59.80
13:15:23	165.00	35.10				21.00	13.90	35.00	19.00	18.43	59.10
13:15:28	157.20	35.10				22.00	14.70	37.00	20.00	18.26	63.70
13:15:33	159.90	35.10				22.00	14.30	37.00	20.00	18.41	61.00
13:15:38	159.70	35.20				22.00	14.30	37.00	21.00	18.33	62.20
13:15:43	158.80	35.10				22.00	14.00	36.00	21.00	18.48	60.30
13:15:48	160.30	35.00				22.00	13.60	35.00	21.00	18.55	58.80
13:15:53	151.60	35.00				21.00	13.20	34.00	21.00	18.63	60.20
13:15:58	141.70	35.00				22.00	12.00	34.00	21.00	18.70	62.30
13:16:03	167.80	35.10				22.00	12.10	34.00	20.00	18.58	56.10
13:16:08	188.30	35.00				23.00	15.30	38.00	20.00	17.77	61.30
13:21:15	164.10	35.00				26.00	17.60	44.00	18.00	18.05	64.20
13:21:20	165.00	35.00				25.00	16.10	41.00	17.00	18.30	60.90
13:21:25	174.40	35.00				25.00	16.00	41.00	17.00	18.15	60.40
13:21:30	174.50	35.00				25.00	16.50	41.00	17.00	17.99	62.20
13:21:35	174.10	35.10				25.00	16.70	42.00	18.00	18.07	61.40
13:21:40	169.90	35.10				24.00	16.40	40.00	18.00	18.21	60.80
13:21:45	166.20	35.00				23.00	15.60	38.00	18.00	18.36	59.90
13:21:50	167.10	35.00				22.00	14.70	37.00	18.00	18.47	57.90

13:21:55	162.50	34.90				21.00	14.50	36.00	18.00	18.52	58.50
13:22:00	167.00	35.00				21.00	14.20	35.00	18.00	18.57	56.50
13:22:05	168.10	35.00				20.00	14.20	35.00	18.00	18.53	56.70
13:22:10	163.00	34.90				20.00	14.10	35.00	18.00	18.57	57.60
13:22:15	156.90	34.90				20.00	13.40	33.00	17.00	18.70	57.30
13:22:20	155.20	34.90				19.00	12.70	32.00	17.00	18.80	56.10
13:22:25	151.50	34.90				19.00	12.40	31.00	17.00	18.85	56.60
13:22:30	153.70	34.90				18.00	11.80	30.00	17.00	18.93	54.20
13:22:35	155.40	34.90				18.00	12.00	30.00	17.00	18.77	56.60
13:22:40	153.60	34.90				19.00	12.00	31.00	18.00	18.80	56.80
13:22:45	153.20	34.90				18.00	11.70	30.00	18.00	18.85	55.90
13:22:50	152.70	35.00				18.00	11.60	30.00	18.00	18.84	56.40
13:22:55	149.60	34.90				18.00	11.70	30.00	18.00	18.83	57.50
13:23:00	155.00	35.00				18.00	11.20	29.00	18.00	18.89	54.50
13:23:05	150.60	35.00				18.00	11.20	29.00	18.00	18.89	56.20
13:23:10	140.60	35.00				17.00	10.70	28.00	18.00	19.03	57.00
13:28:17	118.60	34.80				9.00	4.10	13.00	15.00	19.68	50.00
13:28:22	115.20	34.90				9.00	3.90	13.00	15.00	19.70	50.90
13:28:27	110.50	35.00				9.00	3.80	13.00	15.00	19.70	53.90
13:28:32	109.40	35.00				9.00	3.70	13.00	15.00	19.69	54.60
13:28:37	109.90	34.90				9.00	3.70	13.00	15.00	19.60	57.20
13:28:42	133.80	34.90				10.00	4.60	15.00	15.00	19.33	52.70
13:28:47	194.00	34.80				13.00	7.90	21.00	15.00	18.18	53.70
13:28:52	209.00	34.80				15.00	13.80	29.00	15.00	17.21	62.40
13:28:57	208.40	34.90				19.00	18.10	37.00	16.00	16.81	65.80
13:29:02	191.50	35.00				22.00	20.30	43.00	17.00	16.85	68.60
13:29:07	196.30	35.00				24.00	20.40	44.00	17.00	17.05	66.30
13:29:12	189.80	35.00				25.00	20.80	45.00	16.00	17.04	67.60
13:29:17	176.20	35.00				25.00	20.40	46.00	16.00	17.33	68.10

13:29:22	169.70	35.00				25.00	19.30	44.00	16.00	17.67	66.60
13:29:27	165.00	35.00				24.00	18.50	42.00	16.00	17.87	65.80
13:29:32	159.90	34.90				23.00	17.60	41.00	15.00	18.08	64.90
13:29:37	156.30	34.90				23.00	16.70	40.00	15.00	18.20	64.50
13:29:42	148.80	34.90				23.00	16.00	39.00	15.00	18.35	64.90
13:29:47	146.60	35.00				22.00	15.30	37.00	14.00	18.48	63.90
13:29:52	144.20	34.90				22.00	14.80	36.00	14.00	18.51	64.10
13:29:57	143.40	34.90				22.00	14.30	36.00	14.00	18.53	64.10
13:30:02	140.70	34.90				22.00	14.00	36.00	14.00	18.56	64.50
13:30:07	136.20	34.90				21.00	12.80	34.00	14.00	18.68	64.40
13:30:12	136.50	34.90				21.00	12.10	33.00	14.00	18.74	63.30

Table O 6: Temperature at pyrolysis chamber for Experiment (i-3); AVR = 9.65:0.00 (OPKS)

Mean		217.11			
Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)
0	0.00	15	223.00	30	157.00
0.5	289.00	15.5	213.00	30.5	153.00
1	250.00	16	208.00	31	150.00
1.5	263.00	16.5	209.00	31.5	149.00
2	282.00	17	201.00	32	146.00
2.5	277.00	17.5	195.00	32.5	139.00
3	294.00	18	200.00	33	140.00
3.5	300.00	18.5	201.00	33.5	137.00
4	278.00	19	195.00	34	134.00
4.5	302.00	19.5	193.00	34.5	133.00
5	286.00	20	192.00	35	133.00
5.5	440.00	20.5	194.00	35.5	159.00
6	425.00	21	187.00	36	176.00
6.5	413.00	21.5	180.00	36.5	170.00
7	426.00	22	174.00	37	163.00
7.5	406.00	22.5	170.00	37.5	154.00
8	402.00	23	186.00	38	147.00
8.5	381.00	23.5	185.00	38.5	143.00
9	354.00	24	183.00	39	140.00
9.5	319.00	24.5	182.00	39.5	134.00
10	317.00	25	168.00	40	132.00
10.5	290.00	25.5	162.00		
11	276.00	26	161.00		
11.5	244.00	26.5	158.00		

12	232.00	27	169.00
12.5	252.00	27.5	182.00
13	245.00	28	178.00
13.5	236.00	28.5	171.00
14	225.00	29	164.00
14.5	249.00	29.5	160.00

Experiment set (ii-1)

Date = 24/12/2012; Sample = About 3 Kg of OPKS; Methanol = About 3 Liter; AVR = 9.65:3.83

Measurement rate = 5 seconds; Gas time = 2 minutes; Rinse time = 5 minutes; Mean = 1 second; To make the data meaningful, rinse time is neglected

Table O 7: Results of TESTO Experiment (ii-1); AVR = 9.65:3.83 (OPKS)

Mean	145.37	31.39	415.24	88.38	11.24	8.71	19.97	8.63	18.02	66.19
Time	FT (°C)	AT (°C)	CO (ppmv)	H2 (ppmv)	NO (ppmv)	NO2 (ppmv)	NOx (ppmv)	SO2 (ppmv)	O2 (%)	η (%)
11:38:26	192.40	30.10	0.00	0.00	0.00	0.00	0.00	0.00	20.98	
11:38:31	225.00	30.60	39.00	26.00	0.00	1.20	1.00	0.00	18.89	
11:38:36	209.00	30.60	263.00	117.00	1.00	2.70	4.00	6.00	15.27	72.90
11:38:41	193.60	30.70	470.00	101.00	2.00	2.90	5.00	12.00	14.88	76.20
11:38:46	195.80	30.60	539.00	30.00	2.00	3.00	5.00	14.00	14.88	75.80
11:38:51	191.70	30.60	559.00	31.00	2.00	3.20	5.00	14.00	15.04	75.80
11:38:56	194.80	30.60	528.00	88.00	2.00	3.70	6.00	13.00	15.23	74.70
11:39:01	188.80	30.60	494.00	113.00	3.00	4.30	7.00	12.00	15.39	75.00
11:39:06	181.70	30.60	469.00	121.00	3.00	4.80	8.00	10.00	15.67	74.90
11:39:11	176.80	30.70	441.00	127.00	3.00	5.10	8.00	9.00	15.83	75.00
11:39:16	169.60	30.70	414.00	130.00	3.00	5.60	9.00	8.00	15.86	76.00
11:39:21	168.60	30.70	385.00	130.00	3.00	5.60	9.00	7.00	16.03	75.40
11:39:26	170.20	30.60	379.00	114.00	3.00	5.50	9.00	7.00	16.04	75.10
11:39:31	169.50	30.70	411.00	91.00	4.00	5.50	9.00	8.00	16.13	74.80
11:39:36	168.00	30.70	442.00	87.00	4.00	5.60	9.00	9.00	16.32	74.20
11:39:41	166.70	30.70	420.00	110.00	4.00	6.00	10.00	8.00	16.43	73.90
11:39:46	165.30	30.60	390.00	122.00	4.00	6.30	10.00	7.00	16.44	74.10
11:39:51	163.90	30.70	378.00	116.00	4.00	6.30	10.00	7.00	15.55	73.80

11:39:56	163.60	30.60	355.00	104.00	5.00	6.60	11.00	6.00	16.65	73.30
11:40:01	160.30	30.60	346.00	97.00	5.00	6.70	11.00	6.00	16.66	73.80
11:40:06	163.70	30.70	341.00	90.00	5.00	6.70	11.00	6.00	16.79	72.60
11:40:11	166.70	30.70	334.00	86.00	5.00	7.00	12.00	5.00	16.78	72.10
11:40:16	166.40	30.70	336.00	79.00	5.00	7.20	12.00	5.00	16.75	72.40
11:40:21	160.50	30.70	335.00	78.00	5.00	7.30	12.00	5.00	16.89	72.60
11:45:28	164.20	31.00	303.00	47.00	10.00	10.70	20.00	2.00	17.00	71.40
11:45:33	160.90	31.10	305.00	50.00	10.00	10.60	21.00	2.00	17.06	71.60
11:45:38	159.50	31.00	298.00	56.00	10.00	10.30	21.00	1.00	17.14	71.40
11:45:43	159.50	31.10	292.00	57.00	10.00	10.20	20.00	2.00	17.10	71.70
11:45:48	157.90	31.10	298.00	54.00	10.00	10.30	20.00	2.00	17.15	71.60
11:45:53	158.50	31.00	295.00	57.00	9.00	10.30	20.00	2.00	17.21	71.10
11:45:58	161.70	31.00	297.00	54.00	9.00	10.50	19.00	2.00	17.15	70.90
11:46:03	160.60	31.00	310.00	50.00	9.00	10.80	20.00	2.00	17.18	70.90
11:46:08	157.60	31.00	319.00	53.00	9.00	10.60	19.00	2.00	17.34	70.40
11:46:13	154.30	31.00	307.00	62.00	9.00	10.10	19.00	2.00	17.37	70.80
11:46:18	153.70	31.00	291.00	67.00	10.00	10.20	20.00	2.00	17.34	71.20
11:46:23	154.90	31.10	297.00	58.00	9.00	10.50	20.00	1.00	17.34	71.00
11:46:28	156.30	31.00	316.00	51.00	9.00	10.50	19.00	2.00	17.35	70.50
11:46:33	158.40	31.00	330.00	53.00	8.00	10.40	19.00	2.00	17.47	69.20
11:46:38	158.20	31.10	321.00	64.00	8.00	10.30	18.00	2.00	17.49	69.10
11:46:43	155.80	31.20	312.00	67.00	8.00	10.20	19.00	2.00	17.45	70.00
11:46:48	155.70	31.10	316.00	63.00	9.00	9.90	19.00	2.00	17.44	70.10
11:46:53	156.50	31.10	320.00	60.00	9.00	9.90	19.00	2.00	17.43	70.00
11:46:58	155.70	31.10	327.00	62.00	8.00	9.70	18.00	2.00	17.46	69.80
11:47:03	151.40	31.20	332.00	66.00	8.00	9.50	18.00	2.00	17.54	70.20
11:47:08	148.20	31.20	337.00	66.00	8.00	9.40	17.00	2.00	17.65	70.00
11:47:13	149.70	31.20	337.00	71.00	8.00	9.00	17.00	3.00	17.66	69.60
11:47:18	150.70	31.20	338.00	71.00	9.00	8.90	18.00	3.00	17.54	70.30

11:47:23	152.70	31.10	344.00	71.00	9.00	9.00	18.00	3.00	17.44	70.60
11:52:30	154.90	31.50	525.00	72.00	15.00	12.90	28.00	5.00	17.61	68.60
11:52:35	155.50	31.50	558.00	74.00	15.00	13.40	29.00	6.00	17.57	68.70
11:52:40	154.30	31.50	597.00	83.00	15.00	13.80	29.00	7.00	17.69	67.90
11:52:45	151.40	31.50	599.00	104.00	15.00	13.90	29.00	7.00	17.79	67.60
11:52:50	142.10	31.50	590.00	118.00	15.00	13.80	29.00	6.00	17.86	69.20
11:52:55	145.50	31.50	576.00	130.00	15.00	12.90	28.00	6.00	17.99	67.30
11:53:00	172.80	31.50	523.00	152.00	14.00	13.80	28.00	5.00	17.61	64.50
11:53:05	174.40	31.50	474.00	151.00	14.00	15.10	29.00	3.00	17.25	67.50
11:53:10	171.20	31.60	455.00	138.00	14.00	15.40	30.00	2.00	17.22	68.30
11:53:15	166.70	31.60	458.00	121.00	15.00	15.20	30.00	2.00	17.23	69.20
11:53:20	164.60	31.60	486.00	103.00	14.00	14.90	29.00	3.00	17.28	69.10
11:53:25	166.80	31.50	518.00	97.00	14.00	14.90	29.00	4.00	17.37	68.00
11:53:30	167.50	31.60	534.00	105.00	15.00	15.40	30.00	4.00	17.41	67.50
11:53:35	164.60	31.50	530.00	115.00	15.00	15.70	31.00	4.00	17.42	68.00
11:53:40	164.00	31.50	524.00	120.00	15.00	15.60	30.00	4.00	17.55	67.10
11:53:45	164.90	31.50	537.00	111.00	15.00	15.80	31.00	4.00	17.49	67.40
11:53:50	163.70	31.50	571.00	103.00	15.00	15.50	30.00	4.00	17.62	66.40
11:53:55	162.90	31.60	589.00	109.00	15.00	15.20	30.00	5.00	17.72	65.70
11:54:00	163.80	31.60	590.00	113.00	15.00	15.20	30.00	5.00	17.76	65.10
11:54:05	163.70	31.60	588.00	123.00	15.00	15.30	30.00	5.00	17.74	65.30
11:54:10	159.60	31.60	594.00	125.00	16.00	15.20	31.00	5.00	17.75	66.20
11:54:15	157.40	31.60	607.00	126.00	16.00	14.80	31.00	5.00	17.84	65.70
11:54:20	153.80	31.60	620.00	127.00	15.00	14.40	30.00	6.00	17.94	65.60
11:54:25	152.30	31.60	644.00	125.00	15.00	13.70	29.00	6.00	18.03	65.00
11:59:32	122.10	31.80			15.00	8.40	24.00	17.00	19.09	61.80
11:59:37	116.30	31.80			16.00	8.20	24.00	17.00	19.13	63.30
11:59:42	124.70	31.80			16.00	7.90	24.00	17.00	19.18	58.80
11:59:47	147.20	31.80			15.00	8.50	24.00	16.00	18.82	57.20

11:59:52	151.60	31.80				15.00	9.30	24.00	15.00	18.34	63.20
11:59:57	148.80	31.80				15.00	9.50	25.00	15.00	18.09	66.80
12:00:02	145.40	31.70				16.00	9.40	25.00	15.00	18.17	66.90
12:00:07	137.80	31.70				16.00	9.30	26.00	15.00	18.37	66.90
12:00:12	134.10	31.80				16.00	9.00	25.00	15.00	18.66	64.30
12:00:17	130.90	31.80				16.00	8.70	25.00	15.00	18.79	63.50
12:00:22	129.10	31.70				16.00	8.50	24.00	15.00	18.91	62.20
12:00:27	126.20	31.80				16.00	8.40	24.00	15.00	18.98	62.00
12:00:32	125.90	31.90				16.00	8.20	24.00	14.00	19.09	60.30
12:00:37	123.60	31.80				15.00	8.10	23.00	14.00	19.11	60.80
12:00:42	122.20	31.80				15.00	7.90	23.00	14.00	19.21	59.40
12:00:47	121.50	31.80				15.00	7.60	23.00	14.00	19.26	58.60
12:00:52	118.80	31.80				15.00	7.40	22.00	14.00	19.32	58.30
12:00:57	117.10	31.70				15.00	7.30	22.00	14.00	19.40	57.10
12:01:02	116.00	31.80				14.00	7.10	22.00	14.00	19.45	56.70
12:01:07	112.20	31.80				14.00	6.90	21.00	14.00	19.47	57.80
12:01:12	105.00	31.80				14.00	6.20	21.00	13.00	19.58	58.70
12:01:01	114.00	31.80				15.00	5.90	21.00	13.00	19.60	53.40
12:01:22	128.90	31.80				14.00	6.20	20.00	13.00	19.28	54.90
12:01:27	134.80	31.80				13.00	6.60	20.00	12.00	18.93	59.80
12:06:34	125.40	32.00				15.00	7.30	22.00	15.00	19.23	57.70
12:06:39	123.30	31.90				16.00	7.60	23.00	14.00	19.24	58.20
12:06:44	119.30	31.80				16.00	7.60	23.00	14.00	19.28	59.10
12:06:49	115.30	31.80				16.00	7.50	23.00	14.00	19.40	58.10
12:06:54	112.10	31.90				16.00	7.30	23.00	13.00	19.49	57.40
12:06:59	110.90	31.80				16.00	7.00	23.00	13.00	19.52	57.10
12:07:04	109.50	31.90				16.00	6.80	23.00	13.00	19.55	57.20
12:07:09	108.30	31.90				16.00	6.60	22.00	13.00	19.61	56.10
12:07:14	106.30	31.90				15.00	6.50	22.00	13.00	19.66	55.60

12:07:19	105.10	31.90				15.00	6.30	21.00	14.00	19.72	54.50
12:07:24	104.20	31.90				15.00	6.40	21.00	14.00	19.75	53.80
12:07:29	103.30	32.00				14.00	6.10	21.00	14.00	19.81	52.30
12:07:34	102.60	31.90				14.00	6.00	20.00	15.00	19.88	50.20
12:07:39	101.70	31.90				14.00	5.70	20.00	15.00	19.93	48.40
12:07:44	100.20	32.00				13.00	5.50	19.00	15.00	19.98	47.50
12:07:49	100.20	32.00				13.00	5.30	18.00	15.00	20.02	
12:07:54	99.30	32.00				13.00	5.30	18.00	15.00	20.05	
12:07:59	97.90	31.90				13.00	5.00	18.00	15.00	20.10	
12:08:04	96.50	32.00				12.00	4.80	17.00	15.00	20.14	
12:08:09	94.00	31.90				12.00	4.70	17.00	15.00	20.15	
12:08:14	90.00	31.90				12.00	4.60	17.00	15.00	20.16	
12:08:19	89.60	31.90				12.00	4.10	17.00	14.00	20.20	
12:08:24	92.40	31.90				12.00	4.00	16.00	14.00	20.29	
12:08:29	99.20	32.00				11.00	4.20	15.00	13.00	20.21	

Table O 8: Temperature at pyrolysis chamber for Experiment (ii-1); AVR = 9.65:3.83 (OPKS)

Mean		207.87			
Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)
0	0.00	14.5	246.00	29	171.00
0.5	276.00	15	246.00	29.5	159.00
1	248.00	15.5	230.00	30	153.00
1.5	231.00	16	225.00	30.5	163.00
2	219.00	16.5	245.00	31	158.00
2.5	220.00	17	225.00	31.5	148.00
3	213.00	17.5	222.00	32	138.00
3.5	219.00	18	215.00	32.5	132.00
4	215.00	18.5	207.00	33	129.00
4.5	214.00	19	205.00		
5	211.00	19.5	240.00		
5.5	241.00	20	219.00		
6	256.00	20.5	201.00		
6.5	247.00	21	190.00		
7	246.00	21.5	215.00		
7.5	242.00	22	195.00		
8	236.00	22.5	180.00		
8.5	231.00	23	193.00		
9	234.00	23.5	184.00		
9.5	262.00	24	176.00		
10	254.00	24.5	183.00		
10.5	240.00	25	191.00		
11	237.00	25.5	192.00		
11.5	249.00	26	184.00		
12	243.00	26.5	180.00		

12.5	242.00	27	174.00
13	229.00	27.5	164.00
13.5	274.00	28	180.00
14	257.00	28.5	183.00

Experiment set (ii-2)

Date = 24/12/2012; Sample = About 3 Kg of OPKS; Methanol = About 3 Liter; AVR = 9.65:3.83

Measurement rate = 5 seconds; Gas time = 2 minutes; Rinse time = 5 minutes; Mean = 1 second; To make the data meaningful, rinse time is neglected

Table O 9: Results of TESTO Experiment (ii-2); AVR = 9.65:3.83 (OPKS)

Mean	162.58	33.32	432.56	90.65	14.48	10.53	24.98	12.53	17.79	62.73
Time	FT (°C)	AT (°C)	CO (ppmv)	H2 (ppmv)	NO (ppmv)	NO2 (ppmv)	NOx (ppmv)	SO2 (ppmv)	O2 (%)	η (%)
12:57:09	130.70	32.90	2.00	24.00	1.00	0.00	1.00	0.00	20.89	
12:57:14	246.00	33.10	93.00	92.00	4.00	1.40	5.00	0.00	18.31	
12:57:19	230.10	33.20	409.00	197.00	5.00	2.80	7.00	12.00	14.94	71.80
12:57:24	221.00	33.10	616.00	132.00	5.00	3.40	9.00	18.00	14.76	73.40
12:57:29	209.00	33.00	632.00	27.00	5.00	3.80	9.00	18.00	14.91	74.30
12:57:34	203.10	32.90	581.00	56.00	5.00	4.20	10.00	16.00	15.01	74.70
12:57:39	201.80	32.90	519.00	95.00	5.00	4.60	10.00	14.00	15.22	74.20
12:57:44	200.50	32.80	477.00	105.00	6.00	5.10	11.00	12.00	15.24	74.30
12:57:49	191.20	32.90	440.00	106.00	6.00	5.50	11.00	10.00	15.36	75.10
12:57:54	191.60	32.90	428.00	108.00	6.00	5.70	12.00	10.00	15.42	74.90
12:57:59	200.70	32.90	384.00	97.00	6.00	6.00	12.00	9.00	15.40	73.80
12:58:04	196.30	32.90	367.00	79.00	6.00	6.50	13.00	7.00	15.55	73.80
12:58:09	198.20	32.90	342.00	82.00	6.00	7.00	13.00	7.00	15.67	73.10
12:58:14	203.00	32.90	313.00	76.00	7.00	7.50	15.00	6.00	15.55	73.00
12:58:19	204.70	33.00	329.00	53.00	7.00	8.10	15.00	6.00	15.47	73.00
12:58:24	210.70	32.80	345.00	46.00	8.00	8.50	16.00	6.00	15.43	72.40
15:58:29	214.40	32.80	350.00	47.00	8.00	8.80	17.00	6.00	15.39	72.00
12:58:34	209.40	32.80	357.00	46.00	9.00	9.20	18.00	6.00	15.32	73.00

12:58:39	211.80	32.70	352.00	53.00	9.00	9.80	19.00	6.00	15.32	72.70
12:58:44	215.20	32.70	338.00	56.00	10.00	10.30	20.00	5.00	15.28	72.40
12:58:49	219.20	32.80	341.00	47.00	11.00	10.80	21.00	5.00	15.16	72.40
12:58:54	221.80	32.90	362.00	37.00	11.00	11.40	22.00	5.00	15.17	72.00
12:58:59	216.20	33.00	378.00	38.00	11.00	11.60	23.00	6.00	15.24	72.40
12:59:04	221.60	32.90	376.00	47.00	12.00	11.60	23.00	6.00	15.35	71.20
13:04:11	197.10	33.20	535.00	87.00	16.00	14.60	30.00	8.00	16.59	68.20
13:04:16	190.00	33.20	548.00	96.00	16.00	14.80	31.00	8.00	16.65	68.90
13:04:21	191.20	33.10	546.00	109.00	16.00	14.30	30.00	8.00	16.88	67.20
13:04:26	185.50	33.00	544.00	111.00	15.00	14.50	30.00	8.00	16.79	68.80
13:04:31	168.50	33.10	538.00	118.00	16.00	13.90	30.00	8.00	16.90	71.20
13:04:36	208.90	33.00	509.00	131.00	17.00	13.80	31.00	7.00	16.80	64.60
13:04:41	227.00	33.10	438.00	151.00	17.00	16.10	33.00	5.00	15.70	68.60
13:04:46	215.80	33.10	404.00	137.00	18.00	16.50	34.00	4.00	15.15	72.80
13:04:51	198.00	33.10	424.00	107.00	18.00	15.70	34.00	4.00	15.28	74.60
13:04:56	193.90	33.20	438.00	99.00	19.00	14.90	34.00	5.00	15.59	73.90
13:05:01	191.00	33.10	441.00	98.00	19.00	14.70	34.00	5.00	15.69	73.90
13:05:06	185.50	33.20	456.00	97.00	21.00	13.70	36.00	6.00	16.27	71.90
13:05:11	179.70	33.20	472.00	90.00	20.00	12.80	33.00	6.00	16.61	71.10
13:05:16	176.10	33.20	488.00	91.00	19.00	12.30	31.00	7.00	16.82	70.40
13:05:21	175.60	33.20	481.00	99.00	19.00	12.10	31.00	7.00	16.95	69.70
13:05:26	172.30	33.10	485.00	99.00	20.00	11.90	32.00	7.00	17.07	69.40
13:05:31	168.30	33.20	472.00	109.00	21.00	11.60	32.00	7.00	17.16	69.00
13:05:36	168.30	33.10	454.00	112.00	21.00	11.20	32.00	7.00	17.22	69.20
13:05:41	169.20	33.10	479.00	95.00	20.00	10.90	31.00	7.00	17.27	68.60
13:05:46	168.70	33.10	506.00	92.00	20.00	10.60	31.00	9.00	17.31	68.40
13:05:51	165.90	33.20	521.00	100.00	20.00	10.30	31.00	9.00	17.40	68.30
13:05:56	153.40	33.20	510.00	116.00	20.00	9.80	30.00	9.00	17.51	70.10
13:06:01	165.60	33.10	487.00	127.00	20.00	9.40	30.00	8.00	17.64	66.40

13:06:06	186.90	33.20	456.00	134.00	19.00	10.50	29.00	7.00	17.32	64.70
13:11:13	169.00	33.40			19.00	16.20	35.00	17.00	17.92	64.00
13:11:18	170.00	33.40			19.00	16.20	35.00	17.00	17.94	63.60
13:11:23	165.40	33.40			19.00	16.10	35.00	18.00	18.03	63.70
13:11:28	165.40	33.40			19.00	16.00	35.00	18.00	18.12	62.70
13:11:33	160.70	33.40			19.00	16.00	35.00	18.00	18.09	64.20
13:11:38	149.00	33.40			19.00	15.10	34.00	18.00	18.24	65.70
13:11:43	163.40	33.50			19.00	14.00	33.00	17.00	18.35	60.40
13:11:48	189.70	33.40			17.00	15.60	33.00	17.00	17.78	60.50
13:11:53	183.00	33.40			17.00	16.80	34.00	17.00	17.40	65.70
13:11:58	172.90	33.50			17.00	16.40	34.00	17.00	17.58	66.40
13:12:03	171.60	33.40			18.00	15.70	33.00	17.00	17.68	65.80
13:12:08	174.20	33.40			18.00	15.70	33.00	17.00	17.69	65.10
13:12:13	173.80	33.40			18.00	15.90	34.00	17.00	17.80	64.10
13:12:18	171.80	33.40			18.00	15.90	34.00	18.00	17.94	63.10
13:12:23	163.40	33.40			18.00	15.50	33.00	18.00	18.08	63.70
13:12:28	167.30	33.40			18.00	15.20	33.00	17.00	18.08	62.60
13:12:33	165.80	33.50			18.00	15.40	33.00	17.00	17.97	64.30
13:12:38	161.00	33.40			18.00	15.20	33.00	17.00	18.10	64.10
13:12:43	162.60	33.40			18.00	14.70	33.00	16.00	18.19	62.60
13:12:48	161.00	33.50			18.00	14.70	33.00	16.00	18.16	63.40
13:12:53	158.50	33.50			18.00	14.60	33.00	16.00	18.23	63.20
13:12:58	159.50	33.50			18.00	14.20	32.00	16.00	18.28	62.30
13:13:03	160.30	33.50			18.00	14.40	32.00	17.00	18.24	62.70
13:13:08	163.70	33.60			17.00	14.60	32.00	17.00	18.30	60.90
13:18:15	135.50	33.60			16.00	9.10	25.00	16.00	19.18	55.20
13:18:20	134.60	33.60			16.00	9.20	26.00	16.00	19.12	57.00
13:18:28	126.00	33.50			17.00	9.10	26.00	16.00	19.19	58.90
13:18:30	124.00	33.60			16.00	8.50	24.00	16.00	19.28	57.90

13:18:35	152.40	33.60				17.00	8.70	25.00	16.00	19.16	48.90
13:18:40	155.20	33.60				17.00	10.20	27.00	16.00	18.64	58.40
13:18:45	154.60	33.60				17.00	10.60	28.00	16.00	18.49	60.90
13:18:50	151.50	33.60				18.00	11.00	29.00	16.00	18.41	62.90
13:18:55	149.50	33.60				18.00	10.80	29.00	16.00	18.50	62.30
13:19:00	141.20	33.60				18.00	10.70	29.00	17.00	18.63	63.00
13:19:05	141.40	33.60				18.00	10.30	28.00	16.00	18.86	59.50
13:19:10	142.00	33.60				17.00	10.20	27.00	16.00	18.87	59.00
13:19:15	137.40	33.60				17.00	10.10	27.00	16.00	18.93	59.60
13:19:20	135.80	33.70				17.00	9.70	26.00	16.00	19.07	57.60
13:19:25	134.80	33.60				16.00	9.30	25.00	16.00	19.08	57.70
13:19:30	134.10	33.60				16.00	9.10	25.00	15.00	19.15	57.30
13:19:35	131.80	33.70				15.00	8.80	24.00	15.00	19.21	56.20
13:19:40	129.10	33.60				15.00	8.50	24.00	15.00	19.24	56.60
13:19:45	128.90	33.60				15.00	8.10	24.00	15.00	19.33	54.40
13:19:50	131.30	33.60				15.00	8.10	23.00	15.00	19.31	53.90
13:19:55	129.30	33.70				15.00	8.10	23.00	15.00	19.32	54.50
13:20:00	129.80	33.60				14.00	7.70	22.00	15.00	19.40	52.30
13:20:05	128.70	33.60				14.00	7.60	22.00	15.00	19.38	53.20
13:20:10	125.70	33.50				14.00	7.40	21.00	14.00	19.48	52.00
13:25:17	129.80	33.50				12.00	7.40	19.00	15.00	19.63	44.50
13:25:22	135.80	33.50				12.00	9.00	21.00	15.00	19.30	51.90
13:25:27	133.80	33.50				13.00	9.70	22.00	14.00	19.15	56.60
13:25:32	132.00	33.40				13.00	10.20	24.00	14.00	19.10	58.40
13:25:37	131.40	33.50				14.00	10.40	24.00	14.00	19.08	59.10
13:25:42	128.80	33.50				14.00	10.30	24.00	14.00	19.11	59.50
13:25:47	128.50	33.50				15.00	10.10	25.00	14.00	19.14	59.00
13:25:52	126.50	33.50				14.00	10.00	24.00	14.00	19.22	58.10
13:25:57	122.70	33.50				14.00	9.60	23.00	14.00	19.35	56.80

13:26:02	119.80	33.40				14.00	9.20	23.00	15.00	19.50	54.00
13:26:07	119.30	33.40				14.00	8.90	22.00	15.00	19.55	53.00
13:26:12	118.60	33.50				13.00	8.60	22.00	15.00	19.58	52.30
13:26:17	117.90	33.50				13.00	8.50	22.00	15.00	19.59	52.30
13:26:22	116.30	33.40				13.00	8.30	21.00	15.00	19.67	50.60
13:26:27	112.80	33.40				12.00	7.90	20.00	15.00	19.78	48.60
13:26:32	111.60	33.50				11.00	7.30	19.00	14.00	19.85	46.60
13:26:37	111.70	33.50				11.00	7.20	18.00	15.00	19.84	47.10
13:26:42	110.40	33.50				11.00	7.10	18.00	15.00	19.86	47.10
13:26:47	108.40	33.70				11.00	7.00	18.00	15.00	19.89	46.90
13:26:52	107.70	33.60				11.00	6.60	17.00	15.00	19.92	46.20
13:26:57	107.20	33.60				11.00	6.40	17.00	16.00	19.93	45.80
13:27:02	107.00	33.60				11.00	6.10	17.00	16.00	19.95	45.30
13:27:07	107.40	33.60				11.00	6.10	17.00	16.00	19.97	43.90
13:27:12	105.70	33.50				10.00	5.90	16.00	16.00	19.98	44.30

Table O 10: Results of TESTO Experiment (ii-2); AVR = 9.65:3.83 (OPKS)

Mean		267.31			
Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)
0	0.00	14.5	270.00	29	194.00
0.5	291.00	15	260.00	29.5	182.00
1	431.00	15.5	260.00	30	170.00
1.5	525.00	16	246.00	30.5	163.00
2	588.00	16.5	238.00	31	155.00
2.5	516.00	17	234.00	31.5	149.00
3	510.00	17.5	233.00	32	145.00
3.5	363.00	18	227.00		
4	418.00	18.5	272.00		
4.5	349.00	19	260.00		
5	351.00	19.5	251.00		
5.5	350.00	20	246.00		
6	310.00	20.5	231.00		
6.5	294.00	21	227.00		
7	286.00	21.5	241.00		
7.5	323.00	22	226.00		
8	294.00	22.5	219.00		
8.5	278.00	23	206.00		
9	291.00	23.5	213.00		
9.5	288.00	24	227.00		
10	295.00	24.5	224.00		
10.5	275.00	25	209.00		
11	281.00	25.5	205.00		
11.5	274.00	26	228.00		
12	269.00	26.5	222.00		

12.5	268.00	27	210.00
13	271.00	27.5	201.00
13.5	266.00	28	202.00
14	261.00	28.5	213.00

Experiment set (ii-3)

Date = 28/12/2012; Sample = About 3 Kg of OPKS; Methanol = About 3 Liter; AVR = 9.65:3.83

Measurement rate = 5 seconds; Gas time = 2 minutes; Rinse time = 5 minutes; Mean = 1 second; To make the data meaningful, rinse time is neglected

Table O 11: Results of TESTO Experiment (ii-3); AVR = 9.65:3.83 (OPKS)

Mean	136.71	31.78	347.39	84.74	6.93	9.00	15.99	7.48	18.32	64.54
Time	FT (°C)	AT (°C)	CO (ppmv)	H2 (ppmv)	NO (ppmv)	NO2 (ppmv)	NOx (ppmv)	SO2 (ppmv)	O2 (%)	η (%)
10:50:54	221.70	30.00	0.00	1.00	0.00	0.20	0.00	0.00	20.90	
10:50:59	241.20	30.80	71.00	42.00	1.00	1.70	3.00	1.00	17.90	35.40
10:51:04	206.50	30.80	327.00	125.00	2.00	2.50	4.00	8.00	15.25	73.80
10:51:09	195.70	30.80	475.00	87.00	2.00	2.70	4.00	12.00	15.00	75.50
10:51:14	189.90	30.80	535.00	16.00	2.00	2.50	4.00	14.00	14.98	76.30
10:51:19	186.10	30.80	541.00	40.00	2.00	2.60	4.00	14.00	15.26	75.80
10:51:24	182.50	30.80	526.00	78.00	2.00	2.90	5.00	14.00	15.39	75.80
10:51:29	183.30	30.80	521.00	92.00	2.00	3.20	5.00	13.00	15.49	75.30
10:51:34	176.90	30.80	521.00	101.00	2.00	3.60	6.00	13.00	15.63	75.70
10:51:39	175.70	30.90	506.00	115.00	2.00	3.80	6.00	12.00	15.82	75.10
10:51:44	181.40	30.80	485.00	124.00	2.00	4.10	6.00	11.00	15.88	74.10
10:51:49	179.30	30.80	476.00	121.00	2.00	4.60	7.00	11.00	18.85	74.50
10:51:54	179.50	30.90	463.00	124.00	2.00	4.80	7.00	10.00	15.98	73.90
10:51:59	178.20	30.90	446.00	126.00	3.00	5.20	8.00	10.00	15.98	74.20
10:52:04	173.10	30.90	434.00	124.00	2.00	5.50	8.00	9.00	16.12	74.30
10:52:09	174.30	30.90	426.00	123.00	3.00	5.60	9.00	9.00	16.18	73.90
10:52:14	173.20	30.90	421.00	121.00	3.00	5.90	9.00	9.00	16.22	73.90
10:52:19	172.90	30.90	413.00	121.00	3.00	6.00	9.00	9.00	16.30	73.50

10:52:24	171.70	30.90	406.00	119.00	3.00	6.40	10.00	8.00	16.26	73.90
10:52:29	170.00	30.90	402.00	117.00	3.00	6.70	10.00	8.00	16.29	74.10
10:52:34	164.70	30.90	390.00	120.00	3.00	6.70	10.00	8.00	16.47	74.10
10:52:39	165.40	30.90	371.00	122.00	4.00	7.00	11.00	7.00	16.51	73.80
10:52:44	165.30	30.90	359.00	117.00	4.00	7.30	11.00	7.00	16.51	73.80
10:52:49	165.40	30.90	355.00	112.00	4.00	7.40	11.00	6.00	16.56	73.60
10:57:56	153.40	31.30	287.00	56.00	5.00	7.00	12.00	4.00	17.80	67.80
10:58:01	150.40	31.40	303.00	56.00	5.00	7.20	12.00	4.00	17.83	68.10
10:58:06	150.20	31.40	298.00	55.00	5.00	7.20	12.00	4.00	17.90	67.50
10:58:11	149.10	31.30	281.00	74.00	5.00	7.30	13.00	4.00	17.83	68.50
10:58:16	148.40	31.40	268.00	76.00	6.00	7.40	13.00	3.00	17.76	69.20
10:58:21	147.70	31.30	265.00	71.00	6.00	7.60	13.00	3.00	17.74	69.60
10:58:26	148.90	31.40	266.00	68.00	5.00	7.60	13.00	3.00	17.77	69.10
10:58:31	150.10	31.40	268.00	67.00	5.00	7.80	13.00	3.00	17.83	68.30
10:58:36	147.00	31.40	270.00	66.00	5.00	7.80	13.00	3.00	17.83	69.00
10:58:41	147.00	31.40	273.00	67.00	5.00	7.80	13.00	3.00	17.92	68.20
10:58:46	146.00	31.40	276.00	66.00	5.00	7.90	13.00	3.00	17.93	68.40
10:58:51	145.80	31.50	275.00	70.00	5.00	7.90	13.00	3.00	17.97	68.00
10:58:56	144.70	31.40	278.00	67.00	5.00	7.80	13.00	3.00	17.98	68.20
10:59:01	145.70	31.40	282.00	67.00	6.00	7.90	14.00	3.00	17.96	68.10
10:59:06	144.80	31.40	289.00	65.00	5.00	8.10	13.00	3.00	18.00	67.90
10:59:11	147.00	31.40	296.00	67.00	5.00	8.00	13.00	4.00	18.08	66.60
10:59:16	146.00	31.40	295.00	72.00	5.00	8.00	13.00	3.00	18.12	66.40
10:59:21	141.90	31.40	293.00	75.00	5.00	7.90	13.00	3.00	18.19	66.80
10:59:26	141.40	31.30	285.00	78.00	5.00	7.80	13.00	4.00	18.27	66.10
10:59:31	139.50	31.30	277.00	81.00	5.00	7.90	13.00	3.00	18.23	67.00
10:59:36	139.60	31.40	273.00	79.00	6.00	8.00	14.00	3.00	18.16	67.80
10:59:41	138.70	31.50	280.00	73.00	7.00	7.80	14.00	3.00	18.18	67.80
10:59:46	141.00	31.50	287.00	72.00	6.00	7.60	14.00	4.00	18.22	66.70

10:59:51	140.00	31.40	292.00	74.00	6.00	7.80	13.00	3.00	18.23	66.90
11:04:58	167.20	31.90	251.00	84.00	8.00	14.20	22.00	1.00	17.21	69.60
11:05:03	163.10	31.80	278.00	64.00	8.00	14.60	23.00	1.00	17.21	70.40
11:05:08	160.10	31.80	322.00	50.00	8.00	14.60	23.00	2.00	17.24	70.70
11:05:13	155.30	31.90	356.00	53.00	8.00	14.60	23.00	3.00	17.48	69.90
11:05:18	151.30	31.90	369.00	62.00	8.00	14.60	23.00	3.00	17.67	69.30
11:05:23	151.50	31.80	370.00	74.00	8.00	14.60	23.00	3.00	17.78	68.30
11:05:28	148.80	31.80	366.00	80.00	9.00	14.50	23.00	3.00	17.87	68.10
11:05:33	147.30	31.80	365.00	84.00	9.00	14.40	23.00	3.00	18.00	67.20
11:05:38	142.50	31.90	361.00	86.00	9.00	14.30	23.00	2.00	18.10	67.50
11:05:43	144.70	31.90	359.00	88.00	9.00	14.20	23.00	2.00	18.25	65.40
11:05:48	145.40	31.90	361.00	86.00	8.00	14.30	23.00	2.00	18.29	64.70
11:05:53	144.60	31.90	366.00	87.00	8.00	14.50	23.00	2.00	18.32	64.50
11:05:58	143.50	31.80	364.00	92.00	8.00	14.40	23.00	2.00	18.41	63.70
11:06:03	141.30	31.90	360.00	94.00	8.00	14.40	23.00	2.00	18.47	63.70
11:06:08	126.80	31.90	362.00	94.00	8.00	14.10	22.00	2.00	18.53	67.10
11:06:13	143.80	31.90	358.00	98.00	8.00	13.20	21.00	2.00	18.63	60.70
11:06:18	164.30	32.00	335.00	109.00	7.00	13.60	21.00	2.00	18.16	61.20
11:06:23	159.90	32.00	318.00	107.00	7.00	14.20	21.00	1.00	17.70	67.20
11:06:28	154.70	32.00	331.00	93.00	7.00	13.90	21.00	2.00	17.70	68.40
11:06:33	148.60	32.00	352.00	86.00	7.00	13.70	21.00	2.00	17.82	68.70
11:06:38	150.00	32.00	366.00	88.00	8.00	13.80	22.00	3.00	17.98	66.80
11:06:43	146.00	31.90	373.00	92.00	8.00	14.40	22.00	3.00	18.04	67.20
11:06:48	139.10	31.90	374.00	97.00	8.00	14.20	22.00	3.00	18.23	67.10
11:06:53	141.90	31.90	368.00	103.00	8.00	14.20	22.00	3.00	18.34	65.00
11:12:00	110.20	32.30			9.00	10.70	19.00	11.00	19.57	56.40
11:12:05	104.80	32.30			8.00	10.50	19.00	11.00	19.60	58.40
11:12:10	96.20	32.30			9.00	9.80	19.00	11.00	19.65	61.80
11:12:15	101.70	32.30			8.00	8.80	18.00	11.00	19.74	55.80

11:12:20	108.40	32.40				8.00	8.40	17.00	10.00	19.74	52.00
11:12:25	112.30	32.30				8.00	8.70	17.00	10.00	19.59	54.80
11:12:30	111.70	32.30				8.00	9.30	17.00	10.00	19.51	57.20
11:12:35	111.80	32.30				8.00	9.90	18.00	10.00	19.45	58.80
11:12:40	110.10	32.30				9.00	10.30	19.00	10.00	19.44	59.90
11:12:45	113.80	32.30				8.00	10.50	19.00	10.00	19.45	57.80
11:12:50	114.80	32.30				8.00	11.00	19.00	10.00	19.40	58.70
11:12:55	115.70	32.40				8.00	11.40	20.00	10.00	19.44	57.20
11:13:00	115.30	32.30				9.00	11.70	20.00	10.00	19.43	57.70
11:13:05	115.40	32.40				9.00	12.10	21.00	11.00	19.42	57.90
11:13:10	114.80	32.40				9.00	12.10	21.00	10.00	19.43	58.00
11:13:15	115.80	32.40				9.00	12.30	21.00	11.00	19.42	57.70
11:13:20	112.40	32.40				9.00	12.20	21.00	11.00	19.43	59.00
11:13:25	110.70	32.40				9.00	11.90	21.00	11.00	19.48	58.60
11:13:30	108.90	32.30				9.00	11.90	21.00	10.00	19.48	59.50
11:13:35	105.10	32.30				9.00	11.70	21.00	10.00	19.48	61.20
11:13:40	97.00	32.30				9.00	10.90	20.00	10.00	19.55	63.70
11:13:45	90.60	32.30				10.00	10.40	20.00	10.00	19.55	67.00
11:13:50	95.90	32.30				10.00	9.70	19.00	10.00	19.63	62.30
11:13:55	105.40	32.20				8.00	8.90	17.00	10.00	19.76	53.20
11:19:02	103.40	32.50				10.00	8.70	19.00	11.00	19.68	57.10
11:19:07	103.20	32.40				11.00	8.60	19.00	12.00	19.73	55.50
11:19:12	102.10	32.50				10.00	8.40	19.00	12.00	19.77	55.00
11:19:17	100.60	32.50				10.00	8.30	19.00	12.00	19.83	53.60
11:19:22	101.10	32.50				10.00	8.00	18.00	11.00	19.89	50.90
11:19:27	101.10	32.50				10.00	8.00	18.00	12.00	19.86	52.30
11:19:32	101.60	32.50				11.00	8.20	19.00	12.00	19.86	52.10
11:19:37	101.60	32.50				10.00	8.30	19.00	12.00	19.84	52.80
11:19:42	100.50	32.50				10.00	8.50	19.00	12.00	19.83	53.70

11:19:47	98.80	32.50				10.00	8.30	19.00	12.00	19.87	53.50
11:19:52	98.50	32.50				11.00	8.00	19.00	12.00	19.91	51.80
11:19:57	99.20	32.40				10.00	8.00	19.00	12.00	19.93	50.80
11:20:02	97.70	32.50				10.00	8.00	18.00	12.00	19.95	51.00
11:20:07	95.50	32.50				11.00	7.80	18.00	12.00	19.99	
11:20:12	95.20	32.50				10.00	7.40	17.00	12.00	20.03	
11:20:17	95.80	32.40				10.00	7.60	17.00	12.00	20.02	
11:20:22	96.30	32.40				10.00	7.70	18.00	13.00	19.99	50.10
11:20:27	97.10	32.50				10.00	7.80	18.00	13.00	19.97	50.30
11:20:32	96.00	32.40				10.00	7.70	18.00	13.00	20.00	
11:20:37	94.70	32.50				11.00	7.50	18.00	13.00	20.02	
11:20:42	94.40	32.50				10.00	7.30	18.00	13.00	20.07	
11:20:47	93.60	32.50				10.00	7.20	18.00	13.00	20.08	
11:20:52	93.70	32.50				10.00	7.00	18.00	13.00	20.09	
11:20:57	94.60	32.50				10.00	7.00	17.00	13.00	20.08	

Table O 12: Temperature at pyrolysis chamber for Experiment (ii-3); AVR = 9.65:3.83 (OPKS)

Mean		176.38			
Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)
0	0.00	14.5	221.00	29	139.00
0.5	216.00	15	204.00	29.5	135.00
1	217.00	15.5	225.00	30	130.00
1.5	218.00	16	206.00	30.5	125.00
2	217.00	16.5	193.00	31	129.00
2.5	221.00	17	212.00	31.5	131.00
3	220.00	17.5	185.00	32	121.00
3.5	215.00	18	175.00	32.5	112.00
4	222.00	18.5	185.00	33	120.00
4.5	213.00	19	175.00	33.5	127.00
5	214.00	19.5	180.00	34	120.00
5.5	220.00	20	176.00		
6	208.00	20.5	168.00		
6.5	210.00	21	160.00		
7	205.00	21.5	159.00		
7.5	209.00	22	162.00		
8	209.00	22.5	160.00		
8.5	201.00	23	156.00		
9	198.00	23.5	151.00		
9.5	194.00	24	148.00		
10	193.00	24.5	140.00		
10.5	187.00	25	144.00		
11	184.00	25.5	145.00		
11.5	179.00	26	140.00		

12	260.00	26.5	138.00
12.5	224.00	27	133.00
13	215.00	27.5	140.00
13.5	206.00	28	147.00
14	237.00	28.5	141.00

Experiment set (iii-1)

Date = 12/12/2012; Sample = About 3 Kg of OPKS; Methanol = About 3 Liter; AVR = 9.65:4.00

Measurement rate = 5 seconds; Gas time = 2 minutes; Rinse time = 5 minutes; Mean = 1 second; To make the data meaningful, rinse time is neglected

Table O 13: Results of TESTO Experiment (iii-1); AVR = 9.65:4.00 (OPKS)

Mean	131.68	34.55	480.51	107.35	11.76	9.06	20.84	11.34	18.88	59.53
Time	FT (°C)	AT (°C)	CO (ppmv)	H2 (ppmv)	NO (ppmv)	NO2 (ppmv)	NOx (ppmv)	SO2 (ppmv)	O2 (%)	η (%)
12:59:50	32.70	34.30	1.00	1.00	0.00	0.10	0.00	0.00	20.98	
12:59:55	32.10	34.30	1.00	1.00	0.00	0.10	0.00	0.00	21.17	
13:00:00	32.10	34.30	0.00	0.00	0.00	0.20	0.00	0.00	21.28	
13:00:05	32.40	34.30	0.00	1.00	0.00	0.40	0.00	0.00	21.20	
13:00:10	32.50	34.30	0.00	1.00	0.00	0.40	0.00	0.00	21.15	
13:00:15	32.50	34.40	0.00	1.00	0.00	0.40	0.00	0.00	21.13	
13:00:20	32.30	34.40	0.00	0.00	0.00	0.20	0.00	0.00	21.12	
13:00:25	32.30	34.40	0.00	0.00	0.00	0.20	0.00	0.00	21.12	
13:00:30	32.30	34.40	0.00	1.00	0.00	0.00	0.00	0.00	21.13	
13:00:35	32.10	34.40	1.00	0.00	0.00	0.30	0.00	0.00	21.12	
13:00:40	32.10	34.40	1.00	1.00	0.00	0.20	0.00	0.00	21.12	
13:00:45	32.00	34.40	1.00	0.00	0.00	0.20	0.00	0.00	21.13	
13:00:50	32.10	34.30	1.00	0.00	0.00	0.00	0.00	0.00	21.13	
13:00:55	78.10	34.30	1.00	1.00	0.00	0.10	0.00	0.00	21.11	
13:01:00	192.00	34.30	78.00	49.00	1.00	2.20	3.00	1.00	17.88	52.40
13:01:05	233.90	34.30	334.00	128.00	4.00	6.20	10.00	7.00	14.58	73.00
13:01:10	240.30	34.40	517.00	91.00	6.00	8.00	14.00	11.00	14.36	72.80
13:01:15	243.90	34.40	577.00	20.00	6.00	8.90	15.00	12.00	14.50	71.90
13:01:20	251.30	34.40	567.00	49.00	7.00	8.90	17.00	10.00	14.50	71.00
13:01:25	259.50	34.40	648.00	82.00	10.00	10.80	21.00	9.00	13.34	70.70
13:01:30	243.00	34.40	529.00	100.00	12.00	11.40	23.00	8.00	14.41	72.40

13:01:35	247.20	34.40	528.00	101.00	12.00	12.10	24.00	7.00	14.49	71.60
13:01:40	246.50	34.40	542.00	94.00	13.00	12.90	26.00	7.00	14.21	72.60
13:01:45	237.40	34.40	580.00	99.00	13.00	13.20	26.00	7.00	14.30	73.30
13:06:52	195.10	34.40	439.00	78.00	16.00	17.10	33.00	1.00	17.03	65.80
13:06:57	187.30	34.40	431.00	82.00	16.00	17.20	33.00	0.00	16.98	67.60
13:07:02	180.50	34.50	421.00	89.00	16.00	16.50	32.00	0.00	17.30	66.50
13:07:07	184.60	34.50	393.00	98.00	16.00	16.60	32.00	0.00	17.21	66.50
13:07:12	190.10	34.40	396.00	86.00	15.00	17.20	33.00	1.00	16.99	67.10
13:07:17	188.50	34.40	436.00	68.00	15.00	18.10	33.00	0.00	16.99	67.30
13:07:22	184.50	34.50	470.00	66.00	15.00	17.70	33.00	1.00	17.23	66.20
13:07:27	186.70	34.50	475.00	80.00	15.00	17.50	33.00	1.00	17.32	65.00
13:07:32	188.40	34.50	474.00	87.00	15.00	18.20	34.00	1.00	17.17	65.90
13:07:37	183.70	34.50	491.00	82.00	16.00	18.50	34.00	1.00	17.28	65.90
13:07:42	179.70	34.50	495.00	91.00	15.00	18.10	34.00	1.00	17.41	65.70
13:07:47	177.80	34.50	478.00	103.00	16.00	17.70	34.00	1.00	17.53	65.00
13:07:52	176.60	34.40	474.00	101.00	15.00	17.60	33.00	1.00	17.53	65.30
13:07:57	177.10	34.50	487.00	94.00	14.00	17.60	32.00	1.00	17.56	64.90
13:08:02	177.50	34.50	509.00	89.00	14.00	17.90	32.00	1.00	17.61	64.30
13:08:07	176.90	34.50	530.00	90.00	14.00	17.90	32.00	2.00	17.64	64.10
13:08:12	170.90	34.40	546.00	94.00	14.00	17.80	32.00	2.00	17.73	64.50
13:08:17	171.40	34.40	554.00	101.00	14.00	17.60	32.00	3.00	17.71	64.50
13:08:22	168.90	34.50	567.00	104.00	14.00	17.30	32.00	3.00	17.73	64.90
13:08:27	172.90	34.50	556.00	117.00	15.00	17.50	32.00	3.00	17.66	64.80
13:08:32	172.70	34.50	557.00	115.00	15.00	17.90	32.00	3.00	17.57	65.60
13:08:37	167.70	34.50	578.00	110.00	15.00	17.80	32.00	3.00	17.75	65.00
13:08:42	167.00	34.50	581.00	117.00	14.00	17.40	32.00	3.00	17.83	64.40
13:08:47	167.40	34.50	583.00	118.00	14.00	17.40	32.00	3.00	17.83	64.20
13:13:54	149.30	34.60	815.00	183.00	16.00	12.40	28.00	10.00	18.40	61.80
13:13:59	148.00	34.60	798.00	199.00	16.00	12.70	28.00	9.00	18.42	62.00
13:14:04	145.90	34.60	781.00	205.00	16.00	12.60	28.00	9.00	18.51	61.40
13:14:09	143.70	34.60	767.00	208.00	16.00	12.60	28.00	9.00	18.50	62.30
13:14:14	141.70	34.60	765.00	207.00	16.00	12.60	28.00	9.00	18.53	62.40
13:14:19	159.30	34.60	727.00	225.00	15.00	12.70	28.00	8.00	18.44	58.50
13:14:24	168.80	34.60	705.00	213.00	15.00	13.80	29.00	6.00	18.03	61.50

13:14:29	166.30	34.60	745.00	182.00	16.00	14.10	30.00	7.00	17.93	63.20
13:14:34	162.90	34.50	773.00	174.00	16.00	14.00	30.00	8.00	18.00	63.20
13:14:39	158.90	34.60	786.00	176.00	16.00	13.80	30.00	9.00	18.13	62.60
13:14:44	151.10	34.60	783.00	185.00	16.00	13.50	30.00	9.00	18.35	62.10
13:14:49	144.90	34.60	758.00	195.00	16.00	12.70	29.00	9.00	18.54	61.30
13:14:54	143.70	34.60	717.00	204.00	16.00	11.80	28.00	8.00	18.57	61.40
13:14:59	143.40	34.60	713.00	191.00	16.00	11.70	28.00	8.00	18.43	63.40
13:15:04	145.10	34.60	740.00	174.00	15.00	11.60	27.00	9.00	18.50	61.90
13:15:09	138.50	34.60	778.00	167.00	16.00	11.70	27.00	10.00	18.54	63.20
13:15:14	131.90	34.60	786.00	182.00	16.00	11.00	27.00	11.00	18.73	62.60
13:15:19	143.50	34.60	725.00	222.00	15.00	10.90	26.00	10.00	18.86	56.80
13:15:24	154.90	34.60	666.00	226.00	15.00	11.70	27.00	7.00	18.53	58.80
13:15:29	155.10	34.60	659.00	200.00	15.00	12.30	27.00	7.00	18.31	61.70
13:15:34	151.20	34.60	676.00	183.00	15.00	12.00	27.00	7.00	18.36	62.10
13:15:39	145.60	34.60	700.00	172.00	16.00	11.70	27.00	8.00	18.44	62.70
13:15:44	142.90	34.60	703.00	182.00	16.00	11.40	27.00	8.00	18.48	63.00
13:15:49	144.80	34.60	703.00	193.00	16.00	11.10	27.00	9.00	18.41	63.30
13:20:56	132.30	34.60			15.00	9.90	25.00	19.00	19.08	59.00
13:21:01	134.10	34.60			15.00	9.90	25.00	20.00	19.10	58.00
13:21:06	133.90	34.60			15.00	10.00	25.00	20.00	19.03	59.40
13:21:11	134.80	34.60			15.00	10.00	25.00	20.00	19.04	58.90
13:21:16	131.90	34.60			14.00	9.80	24.00	20.00	19.10	58.80
13:21:21	128.20	34.60			14.00	9.50	24.00	20.00	19.25	57.20
13:21:26	127.20	34.60			14.00	9.30	23.00	20.00	19.30	56.30
13:21:31	126.70	34.60			14.00	9.10	23.00	20.00	19.33	55.90
13:21:36	127.60	34.60			14.00	8.90	23.00	20.00	19.35	55.20
13:21:41	128.30	34.60			13.00	8.80	22.00	20.00	19.32	55.60
13:21:46	125.30	34.60			13.00	8.90	22.00	21.00	19.37	55.60
13:21:51	124.10	34.70			13.00	8.60	22.00	20.00	19.46	53.70
13:21:56	122.60	34.60			13.00	8.50	22.00	20.00	19.42	55.60
13:22:01	106.24	34.60			13.00	8.30	21.00	20.00	19.47	55.70
13:22:06	114.00	34.60			13.00	7.90	21.00	20.00	19.51	57.40
13:22:11	121.70	34.60			12.00	7.80	20.00	19.00	19.55	52.30
13:22:16	128.20	34.60			12.00	8.50	21.00	19.00	19.39	53.60

13:22:21	132.40	34.60				13.00	9.20	23.00	19.00	19.20	56.50
13:22:26	130.30	34.60				14.00	9.60	23.00	19.00	19.13	58.90
13:22:31	128.80	34.60				14.00	9.80	24.00	19.00	19.14	59.30
13:22:36	131.00	34.60				14.00	10.00	24.00	19.00	19.08	59.60
13:22:41	129.90	34.60				14.00	9.90	24.00	19.00	19.11	59.30
13:22:46	131.30	34.70				14.00	9.90	24.00	19.00	19.12	58.60
13:22:51	130.20	34.50				14.00	9.80	24.00	19.00	19.16	58.30
13:27:58	112.70	34.40				14.00	6.10	20.00	20.00	19.69	52.70
13:28:03	110.80	34.30				14.00	6.10	20.00	20.00	19.66	54.70
13:28:08	103.80	34.50				14.00	5.90	20.00	21.00	19.72	56.70
13:28:13	109.00	34.50				14.00	5.70	20.00	20.00	19.81	50.30
13:28:18	116.10	34.50				13.00	6.00	19.00	19.00	19.68	50.90
13:28:23	116.50	34.50				13.00	6.60	20.00	19.00	19.56	54.80
13:28:28	119.20	34.50				14.00	6.90	21.00	19.00	19.52	54.60
13:28:33	123.60	34.60				14.00	7.40	22.00	19.00	19.33	57.20
13:28:38	119.20	34.60				14.00	7.50	22.00	19.00	19.40	57.70
13:28:43	119.10	34.50				14.00	7.40	22.00	19.00	19.51	54.70
13:28:48	119.90	34.60				14.00	7.40	21.00	19.00	19.53	53.80
13:28:53	117.20	34.70				13.00	7.20	20.00	18.00	19.58	53.70
13:28:58	116.10	34.70				13.00	7.00	20.00	18.00	19.65	52.20
13:29:03	115.40	34.70				13.00	7.20	20.00	18.00	19.65	52.60
13:29:08	113.40	34.70				13.00	7.00	20.00	18.00	19.70	52.10
13:29:13	111.60	34.70				13.00	6.80	19.00	17.00	19.75	51.10
13:29:18	110.80	34.70				12.00	6.80	19.00	17.00	19.79	50.40
13:29:23	111.40	34.70				12.00	6.60	19.00	17.00	19.78	50.40
13:29:28	110.50	34.70				12.00	6.60	19.00	18.00	19.79	50.50
13:29:33	108.40	34.70				12.00	6.40	18.00	18.00	19.83	50.30
13:29:38	102.70	34.70				12.00	6.00	18.00	18.00	19.91	50.70
13:29:43	103.90	34.70				12.00	5.70	18.00	17.00	19.90	47.40
13:29:48	125.10	34.70				12.00	6.60	19.00	17.00	19.74	43.70
13:29:53	137.00	34.80				13.00	8.10	21.00	17.00	19.31	51.80
13:35:00	117.90	34.70				9.00	4.90	14.00	16.00	19.79	45.60
13:35:05	120.30	34.70				10.00	5.80	16.00	16.00	19.59	52.00
13:35:10	118.80	34.70				11.00	6.40	17.00	16.00	19.54	54.30

13:35:15	113.70	34.70				11.00	6.50	18.00	15.00	19.59	55.30
13:35:20	110.90	34.70				11.00	6.20	17.00	15.00	19.69	53.80
13:35:25	108.60	34.70				11.00	5.80	17.00	15.00	19.73	53.70
13:35:30	106.40	34.60				11.00	5.60	16.00	15.00	19.81	52.10
13:35:35	105.10	34.60				10.00	5.40	16.00	15.00	19.89	50.00
13:35:40	102.60	34.60				10.00	5.10	15.00	15.00	19.94	49.50
13:35:45	99.70	34.60				10.00	5.00	15.00	15.00	20.01	
13:35:50	98.90	34.70				10.00	4.70	14.00	15.00	20.05	
13:35:55	99.00	34.70				10.00	4.50	14.00	16.00	20.04	
13:36:00	96.40	34.70				10.00	4.40	14.00	16.00	20.07	
13:36:05	93.20	34.70				9.00	4.20	14.00	17.00	20.15	
13:36:10	90.80	34.70				9.00	3.90	13.00	17.00	20.24	
13:36:15	89.69	34.60				9.00	3.60	13.00	17.00	20.26	
13:36:20	90.00	34.60				9.00	3.60	13.00	18.00	20.29	
13:36:25	89.90	34.60				10.00	3.30	13.00	19.00	20.30	
13:36:30	88.80	34.50				9.00	3.10	12.00	19.00	20.33	
13:35:35	87.90	34.50				9.00	2.90	12.00	19.00	20.36	
13:36:40	89.00	34.60				8.00	2.80	11.00	19.00	20.36	
13:36:45	87.30	34.60				8.00	2.70	11.00	19.00	20.32	
13:36:50	82.70	34.60				9.00	2.50	11.00	19.00	20.34	
13:36:55	78.90	34.70				8.00	2.30	11.00	18.00	20.48	

Table O 14: Temperature at pyrolysis chamber for Experiment (iii-1); AVR = 9.65:4.00 (OPKS)

Mean		262.43					
Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)
0	0.00	15	248.00	30	188.00		
0.5	436.00	15.5	245.00	30.5	201.00		
1	443.00	16	244.00	31	188.00		
1.5	452.00	16.5	263.00	31.5	177.00		
2	447.00	17	258.00	32	168.00		
2.5	458.00	17.5	252.00	32.5	179.00		
3	482.00	18	240.00	33	179.00		
3.5	474.00	18.5	255.00	33.5	161.00		
4	480.00	19	240.00	34	158.00		
4.5	484.00	19.5	232.00	34.5	152.00		
5	463.00	20	231.00	35	149.00		
5.5	414.00	20.5	234.00	35.5	164.00		
6	430.00	21	223.00	36	154.00		
6.5	409.00	21.5	211.00	36.5	139.00		
7	382.00	22	202.00	37	139.00		
7.5	386.00	22.5	208.00				
8	357.00	23	201.00				
8.5	347.00	23.5	195.00				
9	334.00	24	190.00				
9.5	304.00	24.5	198.00				
10	287.00	25	202.00				
10.5	295.00	25.5	192.00				
11	306.00	26	191.00				
11.5	290.00	26.5	204.00				
12	277.00	27	206.00				
12.5	249.00	27.5	192.00				
13	246.00	28	181.00				
13.5	254.00	28.5	189.00				
14	247.00	29	184.00				

14.5	264.00	29.5	178.00

Experiment set (iii-2)

Date = 18/12/2012; Sample = About 3 Kg of OPKS; Methanol = About 3 Liter; AVR = 9.65:4.00

Measurement rate = 5 seconds; Gas time = 2 minutes; Rinse time = 5 minutes; Mean = 1 second; To make the data meaningful, rinse time is neglected

Table O 15: Results of TESTO Experiment (iii-2); AVR = 9.65:4.00 (OPKS)

Mean	129.51	31.51	426.06	105.65	7.40	7.00	14.40	9.68	18.67	64.00
Time	FT (°C)	AT (°C)	CO (ppmv)	H2 (ppmv)	NO (ppmv)	NO2 (ppmv)	NOx (ppmv)	SO2 (ppmv)	O2 (%)	η (%)
9:41:35	164.00	29.70	1.00	2.00	0.00	0.30	0.00	0.00	20.81	
9:41:40	245.90	30.40	88.00	48.00	0.00	1.70	2.00	2.00	17.27	47.70
9:41:45	223.20	30.30	346.00	125.00	1.00	2.40	4.00	8.00	14.71	73.30
9:41:50	206.80	30.30	523.00	99.00	2.00	2.50	4.00	14.00	14.71	75.10
9:41:55	206.90	30.40	641.00	38.00	2.00	2.30	4.00	17.00	14.69	75.00
9:42:00	197.70	30.40	683.00	31.00	2.00	2.50	5.00	18.00	14.88	75.40
9:42:05	188.00	30.40	656.00	100.00	2.00	2.70	5.00	16.00	15.29	75.20
9:42:10	191.90	30.40	619.00	133.00	2.00	3.00	5.00	15.00	15.26	73.70
9:42:15	199.50	30.40	605.00	140.00	2.00	3.40	6.00	14.00	15.50	72.90
9:42:20	200.20	30.40	618.00	135.00	2.00	3.60	6.00	14.00	15.50	72.80
9:42:25	200.80	30.40	653.00	131.00	3.00	3.90	6.00	14.00	15.61	72.20
9:42:30	204.20	30.40	661.00	149.00	3.00	4.00	7.00	15.00	15.68	71.40
9:42:35	205.80	30.40	659.00	163.00	3.00	4.30	7.00	14.00	15.66	71.30
9:42:40	208.00	30.40	657.00	168.00	3.00	4.40	8.00	14.00	15.63	71.10
9:42:45	206.00	30.40	653.00	177.00	3.00	5.10	8.00	13.00	15.68	71.10
9:42:50	203.70	30.40	662.00	180.00	4.00	5.40	9.00	14.00	15.76	71.10
9:42:55	198.40	30.40	674.00	185.00	4.00	5.70	9.00	14.00	15.85	71.40
9:43:00	207.50	30.40	688.00	193.00	4.00	6.10	10.00	14.00	15.76	70.50

9:43:05	210.70	30.40	680.00	209.00	4.00	6.50	11.00	14.00	15.62	70.70
9:43:10	213.10	30.40	651.00	226.00	4.00	6.90	11.00	13.00	15.59	70.60
9:43:15	205.40	30.40	609.00	232.00	5.00	6.90	12.00	12.00	15.69	71.20
9:43:20	195.80	30.50	582.00	226.00	5.00	7.10	12.00	11.00	16.01	71.10
9:43:25	189.50	30.50	577.00	211.00	5.00	7.20	12.00	10.00	16.18	71.20
9:43:30	193.50	30.50	594.00	201.00	4.00	7.20	12.00	11.00	16.18	70.60
9:48:37	142.30	30.50	321.00	65.00	6.00	7.80	13.00	3.00	17.86	69.70
9:48:42	139.30	31.00	335.00	63.00	5.00	7.70	13.00	3.00	17.96	69.50
9:48:47	138.60	31.00	331.00	71.00	5.00	7.60	13.00	3.00	17.99	69.40
9:48:52	139.50	31.00	324.00	74.00	5.00	7.80	13.00	3.00	18.01	69.10
9:48:57	139.50	31.00	318.00	76.00	5.00	7.60	13.00	3.00	18.00	69.10
9:49:02	141.60	31.00	314.00	75.00	5.00	7.80	13.00	2.00	17.98	68.80
9:49:07	141.90	31.00	315.00	73.00	5.00	7.90	13.00	2.00	17.92	69.30
9:49:12	140.40	31.00	320.00	72.00	5.00	7.80	13.00	3.00	17.99	69.00
9:49:17	141.40	31.00	320.00	73.00	5.00	7.90	13.00	2.00	18.01	68.60
9:49:22	142.20	31.00	319.00	74.00	5.00	7.80	13.00	2.00	18.02	68.20
9:49:27	141.30	31.00	314.00	76.00	5.00	7.90	13.00	2.00	18.02	68.50
9:49:32	139.40	31.00	305.00	79.00	5.00	7.80	13.00	2.00	18.07	68.50
9:49:37	136.30	31.00	300.00	78.00	5.00	7.90	13.00	2.00	18.10	69.00
9:49:42	135.40	31.10	300.00	76.00	5.00	7.80	13.00	1.00	18.16	68.70
9:49:47	134.90	31.00	303.00	73.00	5.00	7.90	13.00	2.00	18.12	69.20
9:49:52	134.20	31.10	318.00	66.00	5.00	8.00	13.00	2.00	18.09	69.70
9:49:57	135.10	31.00	326.00	67.00	6.00	8.10	14.00	3.00	18.09	69.40
9:50:02	133.10	31.10	332.00	69.00	6.00	7.80	14.00	3.00	18.15	69.30
9:50:07	133.20	31.10	332.00	74.00	7.00	7.10	14.00	3.00	18.24	68.40
9:50:12	133.40	31.10	328.00	77.00	9.00	6.80	15.00	3.00	18.20	68.80
9:50:17	133.00	31.20	335.00	74.00	8.00	6.50	14.00	3.00	18.24	68.50
9:50:22	134.90	31.20	338.00	75.00	7.00	6.90	14.00	4.00	18.24	68.00
9:50:27	135.60	31.20	342.00	76.00	6.00	7.30	14.00	3.00	28.26	67.50

9:50:32	135.40	31.20	350.00	74.00	6.00	7.50	14.00	3.00	18.32	66.90
9:55:39	151.90	31.10	404.00	85.00	9.00	11.70	20.00	2.00	18.30	62.60
9:55:44	151.80	31.40	396.00	91.00	9.00	11.70	20.00	2.00	18.38	61.60
9:55:49	151.20	31.40	393.00	91.00	9.00	11.80	21.00	1.00	18.37	61.90
9:55:54	149.20	31.30	400.00	87.00	9.00	12.00	21.00	1.00	18.39	62.10
9:55:59	144.80	31.40	399.00	92.00	8.00	11.90	20.00	1.00	18.57	60.90
9:56:04	142.70	31.30	389.00	97.00	8.00	11.80	20.00	2.00	18.63	60.70
9:56:09	141.80	31.20	391.00	94.00	8.00	11.90	19.00	2.00	18.64	60.80
9:56:14	141.50	31.20	399.00	92.00	8.00	12.30	20.00	1.00	18.58	61.80
9:56:19	138.60	31.40	410.00	92.00	8.00	12.20	20.00	2.00	18.64	61.80
9:56:24	138.60	31.50	411.00	98.00	8.00	11.90	20.00	2.00	18.70	61.00
9:56:29	128.60	31.50	409.00	104.00	8.00	11.40	19.00	2.00	18.82	62.40
9:56:34	134.80	31.60	394.00	112.00	8.00	10.50	18.00	2.00	18.92	58.70
9:56:39	156.20	31.50	372.00	116.00	7.00	10.80	17.00	2.00	18.45	59.10
9:56:44	154.40	31.40	371.00	107.00	7.00	11.00	18.00	1.00	18.06	64.80
9:56:49	149.80	31.40	374.00	103.00	7.00	10.60	18.00	2.00	18.02	66.30
9:56:54	143.00	31.40	387.00	97.00	7.00	10.30	17.00	2.00	18.06	67.60
9:56:59	140.90	31.40	393.00	95.00	6.00	10.10	16.00	3.00	18.19	66.80
9:57:04	138.90	31.50	385.00	97.00	6.00	10.30	17.00	2.00	18.25	66.80
9:57:09	134.90	31.50	385.00	97.00	6.00	10.30	16.00	2.00	18.49	65.10
9:57:14	135.90	31.50	365.00	105.00	6.00	10.30	16.00	1.00	18.62	63.10
9:57:19	134.60	31.50	347.00	106.00	6.00	10.50	17.00	1.00	18.67	62.90
9:57:24	132.70	31.50	332.00	104.00	6.00	10.40	17.00	1.00	18.78	61.90
9:57:29	132.80	31.60	325.00	99.00	6.00	10.60	17.00	0.00	18.82	61.20
9:57:34	129.10	31.50	325.00	94.00	6.00	10.40	17.00	1.00	18.92	60.90
10:02:41	125.50	31.60			11.00	10.40	21.00	13.00	19.08	60.60
10:02:46	123.50	31.60			10.00	10.60	21.00	13.00	19.08	61.20
10:02:51	121.90	31.60			11.00	10.60	21.00	13.00	19.13	61.00
10:02:56	120.60	31.60			11.00	10.50	21.00	13.00	19.20	60.00

10:03:01	118.70	31.60				10.00	10.40	21.00	13.00	19.23	60.20
10:03:06	120.10	31.60				10.00	10.30	21.00	13.00	19.25	59.40
10:03:11	118.00	31.60				10.00	10.60	21.00	14.00	19.25	60.20
10:03:16	115.50	31.50				10.00	10.20	21.00	14.00	19.31	60.00
10:03:21	114.00	31.60				10.00	9.70	20.00	14.00	19.40	58.70
10:03:26	112.40	31.70				10.00	9.50	20.00	14.00	19.37	60.20
10:03:31	110.30	31.80				10.00	9.30	20.00	14.00	19.46	58.90
10:03:36	111.30	31.80				10.00	8.90	19.00	14.00	19.49	57.80
10:03:41	113.20	31.70				10.00	8.90	19.00	14.00	19.45	57.80
10:03:46	113.50	31.80				10.00	8.90	19.00	15.00	19.43	58.20
10:03:51	111.10	31.70				10.00	8.60	19.00	15.00	19.50	57.60
10:03:56	111.40	31.70				10.00	8.50	18.00	15.00	19.52	56.80
10:04:01	112.60	31.70				10.00	8.20	18.00	14.00	19.52	56.50
10:04:06	111.40	31.70				10.00	8.10	18.00	15.00	19.51	57.10
10:04:11	109.00	31.80				10.00	7.90	18.00	15.00	19.59	56.30
10:04:16	112.50	31.80				10.00	7.80	18.00	15.00	19.58	54.60
10:04:21	111.70	31.70				10.00	7.70	18.00	15.00	19.54	56.10
10:04:26	105.20	31.70				10.00	7.40	18.00	15.00	19.60	58.00
10:04:31	102.00	31.70				10.00	7.10	17.00	15.00	19.67	57.50
10:04:36	117.60	31.70				10.00	7.60	18.00	14.00	19.59	51.50
10:09:43	104.00	31.60				11.00	7.60	18.00	14.00	19.69	56.10
10:09:48	104.90	31.60				11.00	7.40	18.00	14.00	19.70	55.10
10:09:53	103.00	31.80				11.00	7.30	18.00	15.00	19.75	54.60
10:09:59	102.60	31.70				10.00	7.20	18.00	15.00	19.83	52.20
10:10:03	102.50	31.80				11.00	7.10	18.00	15.00	19.82	52.70
10:10:08	99.00	31.80				11.00	6.90	18.00	15.00	19.94	50.20
10:10:13	96.80	31.90				10.00	6.60	17.00	14.00	19.99	
10:10:18	96.70	32.00				10.00	6.40	16.00	14.00	19.99	
10:10:23	95.50	32.00				10.00	6.30	16.00	15.00	19.99	

10:10:28	95.40	32.00				10.00	6.10	16.00	15.00	20.03	
10:10:33	96.40	32.00				10.00	5.90	16.00	15.00	20.04	
10:10:38	94.20	32.10				10.00	5.80	16.00	15.00	20.07	
10:10:43	93.60	32.10				10.00	5.70	15.00	15.00	20.09	
10:10:48	93.20	32.10				10.00	5.70	15.00	15.00	20.08	
10:10:53	90.40	32.00				10.00	5.30	15.00	15.00	20.11	
10:10:58	85.50	32.10				10.00	5.10	15.00	15.00	20.14	
10:11:03	89.50	32.10				10.00	5.10	15.00	15.00	20.14	
10:11:08	100.60	32.10				10.00	5.40	15.00	15.00	20.00	
10:11:13	104.50	32.10				10.00	6.10	16.00	15.00	19.80	52.10
10:11:18	108.90	32.20				11.00	7.00	18.00	15.00	19.62	55.60
10:11:23	110.50	32.20				11.00	7.50	19.00	16.00	19.50	58.10
10:11:28	108.20	32.10				12.00	7.80	19.00	16.00	19.50	59.20
10:11:33	105.00	32.20				12.00	7.80	20.00	15.00	19.59	58.40
10:11:38	104.60	32.20				12.00	7.80	20.00	15.00	19.64	57.40
10:11:45	85.20	32.20				8.00	4.00	12.00	12.00	20.26	
10:16:50	84.90	32.20				8.00	4.00	12.00	13.00	20.24	
10:16:55	84.60	32.50				8.00	4.00	12.00	12.00	20.26	
10:17:00	84.70	32.50				8.00	4.00	12.00	13.00	20.25	
10:17:05	83.40	32.50				8.00	3.90	12.00	13.00	20.26	
10:17:10	83.00	32.60				8.00	3.80	12.00	13.00	20.29	
10:17:15	83.30	32.50				8.00	3.60	11.00	12.00	20.29	
10:17:20	83.40	32.60				8.00	3.60	12.00	12.00	20.28	
10:17:25	83.10	32.60				8.00	3.60	12.00	13.00	20.30	
10:17:30	81.40	32.60				8.00	3.50	11.00	12.00	20.34	
10:17:35	81.70	32.60				8.00	3.40	11.00	12.00	20.38	
10:17:40	81.60	32.60				8.00	3.40	11.00	12.00	20.34	
10:17:45	80.50	32.60				8.00	3.20	11.00	12.00	20.36	
10:17:50	80.00	32.50				8.00	3.00	11.00	12.00	20.37	

10:17:55	79.70	32.60				7.00	3.10	10.00	12.00	20.38	
10:18:00	80.00	32.60				7.00	3.00	10.00	13.00	20.37	
10:18:05	79.40	32.60				8.00	2.80	10.00	12.00	20.36	
10:18:10	78.90	32.60				8.00	2.80	10.00	12.00	20.38	
10:18:15	79.80	32.60				8.00	2.80	11.00	12.00	20.38	
10:18:20	80.10	32.70				8.00	2.80	11.00	13.00	20.36	
10:18:25	79.00	32.70				8.00	2.80	10.00	13.00	20.39	
10:18:30	79.10	32.70				8.00	2.70	10.00	12.00	20.41	
10:18:35	79.00	32.70				8.00	2.70	10.00	12.00	20.41	
10:18:40	78.70	32.70				7.00	2.50	10.00	12.00	20.43	

Table O 16: Temperature at pyrolysis chamber for Experiment (iii-2); AVR = 9.65:4.00 (OPKS)

Mean		184.17			
Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)
0	0.00	14.5	196.00	29	144.00
0.5	151.00	15	215.00	29.5	155.00
1	193.00	15.5	204.00	30	163.00
1.5	229.00	16	194.00	30.5	155.00
2	243.00	16.5	191.00	31	146.00
2.5	246.00	17	191.00	31.5	142.00
3	249.00	17.5	191.00	32	151.00
3.5	238.00	18	180.00	32.5	148.00
4	252.00	18.5	197.00	33	143.00
4.5	240.00	19	194.00	33.5	140.00
5	247.00	19.5	183.00	34	143.00
5.5	238.00	20	179.00	34.5	128.00
6	237.00	20.5	188.00	35	134.00
6.5	236.00	21	191.00	35.5	131.00
7	238.00	21.5	186.00	36	127.00
7.5	230.00	22	181.00	36.5	126.00
8	236.00	22.5	173.00	37	120.00
8.5	227.00	23	172.00		
9	218.00	23.5	172.00		
9.5	212.00	24	162.00		
10	212.00	24.5	161.00		
10.5	212.00	25	166.00		
11	205.00	25.5	159.00		
11.5	202.00	26	157.00		

12	197.00	26.5	157.00
12.5	189.00	27	170.00
13	231.00	27.5	165.00
13.5	218.00	28	161.00
14	204.00	28.5	151.00

Experiment set (iii-3)

Date = 18/12/2012; Sample = About 3 Kg of OPKS; Methanol = About 3 Liter; AVR = 9.65:4.00

Measurement rate = 5 seconds; Gas time = 2 minutes; Rinse time = 5 minutes; Mean = 1 second; To make the data meaningful, rinse time is neglected

Table O 17: Results of TESTO Experiment (iii-3); AVR = 9.65:4.00 (OPKS)

Mean	145.31	35.08	639.04	146.75	11.79	8.66	20.45	15.47	18.28	62.15
Time	FT (°C)	AT (°C)	CO (ppmv)	H2 (ppmv)	NO (ppmv)	NO2 (ppmv)	NOx (ppmv)	SO2 (ppmv)	O2 (%)	η (%)
10:59:12	178.40	34.60	2.00	33.00	2.00	0.10	2.00	0.00	20.99	
10:59:17	273.00	34.60	218.00	171.00	4.00	2.40	7.00	4.00	16.93	42.10
10:59:22	250.50	34.60	864.00	330.00	6.00	4.20	10.00	24.00	13.07	75.10
10:59:27	235.20	34.60	1038.00	138.00	6.00	4.40	11.00	31.00	13.23	76.30
10:59:32	232.60	34.60	1022.00	28.00	6.00	4.20	11.00	31.00	86.88	76.10
10:59:37	231.30	34.50	981.00	124.00	6.00	4.40	11.00	28.00	13.62	75.70
10:59:42	234.10	34.70	923.00	181.00	6.00	4.80	11.00	26.00	13.77	75.00
10:59:47	238.60	34.60	871.00	203.00	7.00	5.30	12.00	23.00	13.75	74.70
10:59:52	240.50	34.50	853.00	207.00	7.00	5.90	13.00	22.00	13.84	74.20
10:59:57	235.30	34.60	811.00	221.00	8.00	6.40	14.00	21.00	14.08	74.00
11:00:02	234.40	34.40	780.00	219.00	9.00	6.90	16.00	19.00	14.16	73.90
11:00:07	234.30	34.60	764.00	213.00	9.00	7.60	17.00	19.00	14.09	74.20
11:00:12	232.30	34.50	763.00	202.00	10.00	8.10	18.00	18.00	14.05	74.50
11:00:17	228.90	34.70	764.00	199.00	10.00	8.20	18.00	18.00	14.20	74.40
11:00:22	227.40	34.60	745.00	206.00	10.00	8.80	19.00	18.00	14.29	74.30
11:00:27	223.60	34.60	748.00	192.00	10.00	9.30	20.00	17.00	14.25	74.90
11:00:32	223.90	34.70	793.00	172.00	11.00	9.70	21.00	19.00	14.29	74.70
11:00:37	225.30	34.50	835.00	178.00	11.00	10.00	21.00	20.00	14.34	74.30

11:00:42	225.20	34.70	804.00	213.00	11.00	10.20	21.00	19.00	14.40	74.20
11:00:47	228.30	34.60	756.00	225.00	11.00	10.50	21.00	18.00	14.48	73.60
11:00:52	228.90	34.60	738.00	213.00	11.00	11.10	22.00	17.00	14.43	73.70
11:00:57	227.50	34.70	735.00	208.00	11.00	11.20	23.00	17.00	14.47	73.70
11:01:02	232.00	34.60	702.00	209.00	12.00	11.80	24.00	16.00	14.62	72.70
11:01:07	230.30	34.70	679.00	203.00	13.00	12.70	26.00	15.00	14.41	73.70
11:06:14	175.60	34.90	440.00	89.00	13.00	14.30	27.00	5.00	17.22	68.20
11:06:19	174.70	35.00	428.00	98.00	13.00	14.30	27.00	5.00	17.25	68.20
11:06:24	173.40	34.90	415.00	102.00	13.00	14.40	27.00	4.00	17.26	68.40
11:06:29	174.60	34.90	415.00	96.00	12.00	14.50	27.00	4.00	17.25	68.20
11:06:34	176.90	34.90	435.00	86.00	12.00	14.70	27.00	5.00	17.21	68.00
11:06:39	176.00	34.90	459.00	81.00	12.00	15.10	27.00	5.00	17.21	68.10
11:06:44	171.70	35.00	482.00	83.00	13.00	15.20	28.00	6.00	17.36	67.90
11:06:49	170.10	34.90	482.00	95.00	12.00	15.00	27.00	6.00	17.49	67.10
11:06:54	170.30	35.10	474.00	103.00	12.00	15.10	27.00	5.00	17.48	67.20
11:06:59	171.10	35.00	476.00	101.00	12.00	15.20	28.00	5.00	17.49	66.90
11:07:04	168.10	35.00	490.00	97.00	12.00	15.00	27.00	6.00	17.56	66.90
11:07:09	168.70	35.00	518.00	90.00	13.00	14.80	28.00	6.00	17.62	66.20
11:07:14	171.00	34.90	551.00	89.00	13.00	15.30	28.00	8.00	17.55	66.20
11:07:19	172.10	35.10	570.00	97.00	13.00	15.50	28.00	8.00	17.56	66.00
11:07:24	166.90	34.90	573.00	111.00	13.00	15.10	28.00	8.00	17.66	66.10
11:07:29	169.10	35.10	557.00	126.00	13.00	14.60	27.00	8.00	17.77	64.70
11:07:34	170.60	35.00	552.00	123.00	13.00	14.70	27.00	7.00	17.67	65.30
11:07:39	167.40	35.00	571.00	116.00	13.00	14.60	27.00	8.00	17.78	64.90
11:07:44	164.60	35.10	588.00	116.00	12.00	14.20	26.00	8.00	17.91	64.30
11:07:49	162.50	35.00	602.00	119.00	12.00	14.00	26.00	9.00	17.99	63.90
11:07:54	159.30	35.20	602.00	130.00	11.00	13.80	25.00	9.00	18.05	64.10
11:07:59	158.80	35.10	597.00	136.00	12.00	13.60	25.00	9.00	18.07	64.00
11:08:04	159.10	35.00	597.00	137.00	12.00	13.60	25.00	8.00	18.04	64.10

11:08:09	163.40	35.10	611.00	135.00	12.00	13.50	25.00	9.00	17.97	63.90
11:13:16	164.10	35.30			11.00	10.70	22.00	18.00	18.85	62.60
11:13:21	134.00	35.40			12.00	10.60	22.00	18.00	18.87	62.40
11:13:26	135.40	35.30			12.00	10.70	22.00	18.00	18.83	62.60
11:13:31	135.20	35.30			12.00	10.70	23.00	18.00	18.88	61.80
11:13:36	136.70	35.20			12.00	10.60	22.00	18.00	18.89	61.10
11:13:41	136.20	35.30			11.00	10.60	22.00	18.00	18.91	61.00
11:13:46	134.50	35.30			11.00	10.60	22.00	18.00	18.94	61.10
11:13:51	134.00	35.30			12.00	10.50	22.00	18.00	18.98	60.50
11:13:56	135.50	35.40			12.00	10.70	23.00	18.00	18.94	60.70
11:14:04	134.30	35.40			12.00	10.80	22.00	18.00	18.89	62.00
11:14:06	132.50	35.30			11.00	10.50	22.00	18.00	18.96	61.40
11:14:11	131.70	35.30			11.00	10.20	21.00	18.00	19.01	60.80
11:14:16	130.60	35.20			11.00	10.10	21.00	18.00	19.01	61.30
11:14:21	130.70	35.20			11.00	10.00	21.00	17.00	18.99	61.60
11:14:26	130.30	35.10			11.00	10.00	21.00	17.00	19.01	61.40
11:14:31	129.40	35.30			11.00	10.00	21.00	17.00	19.02	61.50
11:14:36	130.20	35.30			11.00	9.90	21.00	17.00	19.03	61.10
11:14:41	128.60	35.30			11.00	10.00	21.00	17.00	19.04	61.50
11:14:46	128.40	35.30			11.00	9.80	21.00	17.00	19.10	60.40
11:14:51	128.90	35.30			11.00	10.20	21.00	17.00	19.04	61.30
11:14:56	126.90	35.30			11.00	10.10	21.00	17.00	19.01	62.60
11:15:01	129.00	35.30			11.00	10.00	21.00	17.00	19.00	62.10
11:15:06	129.50	35.30			11.00	10.00	21.00	17.00	18.95	62.60
11:15:11	127.90	35.30			11.00	10.20	21.00	17.00	18.98	62.80
11:20:18	124.00	35.20			12.00	8.60	20.00	15.00	19.21	60.00
11:20:23	121.90	35.30			11.00	8.20	20.00	15.00	19.32	58.60
11:20:28	122.20	35.20			11.00	8.00	19.00	15.00	19.38	57.10
11:20:33	122.20	35.20			11.00	7.80	19.00	15.00	19.38	5.90

11:20:38	120.00	35.10				11.00	7.70	19.00	15.00	19.41	57.30
11:20:43	118.90	35.00				11.00	7.60	19.00	15.00	19.43	57.30
11:20:48	118.80	35.10				11.00	7.60	19.00	15.00	19.33	59.60
11:20:53	118.10	35.10				11.00	7.60	19.00	15.00	19.33	60.10
11:20:58	116.80	35.20				11.00	7.30	18.00	15.00	19.38	59.50
11:21:03	111.60	35.20				11.00	7.00	18.00	15.00	19.48	59.50
11:21:08	114.40	35.20				11.00	6.80	18.00	15.00	19.56	56.10
11:21:03	133.30	35.10				11.00	7.30	18.00	14.00	19.26	55.00
11:21:18	180.03	35.20				11.00	8.50	20.00	14.00	18.79	61.80
11:21:23	138.60	35.20				12.00	9.20	21.00	14.00	18.64	64.20
11:21:28	137.10	35.20				12.00	9.70	21.00	15.00	18.62	65.10
11:21:33	133.20	35.20				12.00	9.80	22.00	15.00	18.68	65.40
11:21:38	130.80	35.20				13.00	9.70	22.00	15.00	18.80	64.60
11:21:43	131.90	35.30				13.00	9.70	23.00	15.00	18.80	64.10
11:21:48	131.30	35.30				13.00	9.70	23.00	15.00	18.90	62.90
11:21:53	131.30	35.20				13.00	9.70	23.00	15.00	18.96	61.80
11:21:58	130.40	35.20				13.00	9.70	23.00	15.00	18.98	61.90
11:22:03	127.40	35.10				13.00	9.40	23.00	16.00	19.11	60.70
11:22:08	126.50	35.10				13.00	9.30	22.00	16.00	19.15	60.20
11:22:13	125.40	35.10				13.00	9.30	22.00	16.00	19.16	60.40
11:27:20	122.40	35.30				13.00	9.40	23.00	17.00	19.26	59.80
11:27:25	118.50	35.20				14.00	9.60	22.00	17.00	19.35	59.50
11:27:30	116.80	35.20				14.00	8.10	22.00	17.00	19.41	58.80
11:27:35	114.60	35.20				14.00	7.80	22.00	18.00	19.48	58.00
11:27:40	112.50	35.20				14.00	7.50	22.00	18.00	19.59	56.10
11:27:45	115.30	35.30				14.00	7.40	21.00	19.00	19.58	55.00
11:27:50	116.30	35.20				14.00	7.40	21.00	19.00	19.54	55.60
11:27:55	113.50	35.10				14.00	7.30	21.00	19.00	19.63	54.60
11:28:00	110.50	35.20				13.00	6.90	20.00	19.00	19.74	52.60

11:28:05	110.10	35.20				13.00	6.80	20.00	19.00	19.77	51.90
11:28:10	109.50	35.20				13.00	6.60	19.00	19.00	19.76	52.50
11:28:15	110.50	35.10				13.00	6.60	19.00	19.00	19.75	52.10
11:28:20	112.00	35.20				13.00	6.50	19.00	19.00	19.71	52.70
11:28:25	111.80	35.30				12.00	6.30	19.00	19.00	19.74	51.80
11:28:30	110.10	35.30				12.00	6.20	18.00	19.00	19.81	50.30
11:28:35	108.50	35.30				12.00	6.00	18.00	20.00	19.89	48.20
11:28:40	107.90	35.20				12.00	5.70	17.00	19.00	19.91	47.70
11:28:45	107.20	35.30				12.00	5.70	17.00	19.00	19.89	49.00
11:28:50	106.60	35.20				12.00	5.80	17.00	19.00	19.88	49.40
11:28:55	108.20	35.30				11.00	5.70	17.00	19.00	19.84	50.30
11:29:00	104.90	35.20				12.00	5.70	17.00	19.00	19.79	54.10
11:29:05	101.00	35.20				12.00	5.80	18.00	19.00	19.83	55.10
11:29:10	118.50	35.30				12.00	5.80	18.00	18.00	19.79	45.80
11:29:15	128.70	35.20				12.00	6.70	19.00	17.00	19.40	53.40
11:34:22	109.40	35.20				11.00	4.20	15.00	15.00	20.03	
11:34:27	120.50	35.30				11.00	4.90	16.00	15.00	19.65	49.80
11:34:32	124.30	35.30				12.00	5.70	18.00	15.00	19.32	57.40
11:34:37	125.10	35.30				13.00	6.40	20.00	14.00	19.15	60.70
11:34:42	123.60	35.30				15.00	6.60	21.00	14.00	19.02	63.80
11:34:47	119.30	35.20				15.00	6.50	21.00	14.00	19.07	64.50
11:34:52	114.40	35.20				15.00	6.30	22.00	14.00	19.20	64.20
11:34:57	110.20	35.00				15.00	5.90	21.00	14.00	19.38	62.40
11:35:02	106.10	35.10				15.00	5.70	21.00	14.00	19.55	60.50
11:35:07	101.40	35.30				14.00	5.40	20.00	15.00	19.71	58.80
11:35:12	98.10	35.20				14.00	4.90	19.00	15.00	19.88	55.40
11:35:17	95.40	35.30				13.00	4.70	18.00	15.00	20.05	
11:35:22	92.50	35.20				12.00	4.20	17.00	16.00	20.18	
11:35:27	91.00	35.20				12.00	3.70	16.00	16.00	20.27	

11:35:32	90.60	35.20				12.00	3.30	15.00	16.00	20.30	
11:35:37	89.60	35.20				12.00	3.00	15.00	16.00	20.28	
11:35:42	88.60	35.20				12.00	2.90	15.00	16.00	20.26	
11:35:47	87.90	35.10				13.00	2.80	16.00	17.00	20.19	
11:35:52	87.40	35.20				14.00	2.70	17.00	17.00	20.11	
11:35:57	86.70	35.10				15.00	2.70	18.00	18.00	20.03	
11:36:02	86.10	35.20				16.00	2.70	19.00	18.00	20.02	
11:36:07	85.10	35.30				16.00	2.70	19.00	18.00	20.02	
11:36:12	84.10	35.30				17.00	2.60	19.00	19.00	20.03	
11:36:17	83.30	35.30				17.00	2.50	20.00	18.00	20.03	

Table O 18: Temperature at pyrolysis chamber for Experiment (iii-3); AVR = 9.65:4.00 (OPKS)

Mean		227.58					
Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)
0	0.00	14.5	218.00	29	167.00		
0.5	287.00	15	220.00	29.5	158.00		
1	373.00	15.5	216.00	30	182.00		
1.5	327.00	16	214.00	30.5	179.00		
2	399.00	16.5	212.00	31	177.00		
2.5	344.00	17	208.00	31.5	168.00		
3	341.00	17.5	207.00	32	161.00		
3.5	372.00	18	204.00	32.5	161.00		
4	346.00	18.5	202.00	33	187.00		
4.5	339.00	19	201.00	33.5	174.00		
5	380.00	19.5	201.00	34	160.00		
5.5	358.00	20	192.00	34.5	154.00		
6	333.00	20.5	200.00	35	175.00		
6.5	347.00	21	182.00	35.5	186.00		
7	333.00	21.5	182.00				
7.5	314.00	22	200.00				
8	280.00	22.5	194.00				
8.5	263.00	23	189.00				
9	254.00	23.5	186.00				
9.5	246.00	24	185.00				
10	245.00	24.5	189.00				
10.5	238.00	25	182.00				
11	236.00	25.5	184.00				
11.5	233.00	26	197.00				
12	230.00	26.5	187.00				

12.5	227.00	27	182.00
13	233.00	27.5	175.00
13.5	228.00	28	184.00
14	225.00	28.5	173.00

Experiment set (iv-1)

Date = 8/1/2013; Sample = About 3 Kg of OPKS; Methanol = About 3 Liter; AVR = 4.00:0.00

Measurement rate = 5 seconds; Gas time = 2 minutes; Rinse time = 5 minutes; Mean = 1 second; To make the data meaningful, rinse time is neglected

Table O 19: Results of TESTO Experiment (iv-1); AVR = 4.00:0.00 (OPKS)

Mean	160.19	31.68	1621.08	582.54	11.59	19.45	31.05	14.51	15.87	78.53
Time	FT (°C)	AT (°C)	CO (ppmv)	H2 (ppmv)	NO (ppmv)	NO2 (ppmv)	NOx (ppmv)	SO2 (ppmv)	O2 (%)	η (%)
8:42:39	106.00	29.90	1.00	0.00	1.00	0.10	1.00	0.00	20.80	
8:42:44	219.60	30.40	76.00	49.00	2.00	1.70	3.00	2.00	18.62	
8:42:49	228.50	30.40	504.00	235.00	2.00	5.70	8.00	13.00	14.23	72.90
8:42:54	223.40	30.40	1192.00	352.00	3.00	8.10	11.00	32.00	11.15	80.80
8:42:59	214.80	30.40	1990.00	395.00	3.00	8.50	11.00	54.00	9.21	83.60
8:43:04	210.20	30.40	2690.00	203.00	3.00	8.00	11.00	76.00	8.86	83.80
8:43:09	205.50	30.30	2867.00	295.00	3.00	7.30	10.00	81.00	9.52	83.30
8:43:14	206.40	30.30	2639.00	658.00	3.00	7.20	10.00	75.00	9.44	83.50
8:43:19	201.70	30.40	2528.00	793.00	3.00	7.40	11.00	71.00	9.56	83.80
8:43:24	202.30	30.40	2345.00	910.00	4.00	7.70	12.00	66.00	9.86	83.50
8:43:29	202.60	30.40	2083.00	968.00	4.00	8.20	13.00	57.00	9.94	83.50
8:43:34	199.10	30.30	1934.00	931.00	5.00	8.70	14.00	53.00	10.00	83.80
8:43:39	195.70	30.30	1813.00	899.00	5.00	9.10	14.00	49.00	10.29	83.80
8:43:44	197.90	30.30	1667.00	863.00	6.00	9.80	15.00	46.00	10.13	83.90
8:49:49	194.90	30.30	1626.00	787.00	6.00	10.20	16.00	44.00	10.15	84.10
8:43:54	190.50	30.40	1608.00	730.00	6.00	10.30	16.00	44.00	10.59	83.90
8:43:59	189.90	30.30	1545.00	713.00	6.00	10.90	17.00	43.00	10.83	83.70
8:44:04	190.80	30.30	1496.00	677.00	6.00	11.70	18.00	42.00	10.72	83.80

8:44:09	189.90	30.30	1486.00	630.00	7.00	12.50	19.00	41.00	10.72	83.90
8:44:14	187.60	30.20	1461.00	617.00	7.00	12.70	20.00	41.00	10.96	83.80
8:44:19	186.10	30.30	1397.00	607.00	7.00	12.50	20.00	39.00	11.07	83.80
8:44:24	187.00	30.30	1361.00	578.00	7.00	12.50	19.00	38.00	11.17	83.70
8:44:29	191.00	30.30	1320.00	556.00	7.00	12.20	19.00	37.00	11.37	83.10
8:44:34	192.20	30.30	1277.00	535.00	7.00	12.60	19.00	36.00	11.25	83.20
8:49:41	183.70	30.60			11.00	20.10	32.00	9.00	11.99	82.30
8:49:46	183.30	30.60			12.00	19.80	32.00	9.00	13.11	82.10
8:49:51	184.60	30.60			12.00	19.50	32.00	9.00	13.17	81.90
8:49:56	185.90	30.70			12.00	20.70	32.00	9.00	12.90	82.30
8:50:01	186.80	30.60			12.00	20.50	33.00	9.00	12.84	82.30
8:50:06	185.00	30.70			12.00	19.70	32.00	9.00	13.03	82.10
8:50:11	187.20	30.70			11.00	18.90	30.00	9.00	13.31	81.40
8:50:16	186.20	30.70			11.00	18.80	30.00	9.00	13.29	81.50
8:50:21	192.30	30.70			10.00	18.90	29.00	9.00	13.27	81.00
8:50:26	193.60	30.70			10.00	19.30	29.00	9.00	13.21	81.00
8:50:31	191.00	30.80			10.00	19.60	29.00	9.00	13.19	81.20
8:50:36	189.20	30.90			10.00	20.10	30.00	9.00	13.17	81.50
8:50:41	188.80	30.90			9.00	20.20	30.00	9.00	13.26	81.30
8:50:46	189.30	30.90			9.00	20.10	29.00	9.00	13.53	80.70
8:50:51	190.80	30.80			8.00	20.50	29.00	9.00	13.57	80.50
8:50:56	189.90	30.80			8.00	21.10	29.00	9.00	13.32	81.10
8:51:01	185.00	30.70			8.00	21.50	29.00	9.00	13.25	81.70
8:51:06	185.70	30.90			8.00	21.10	29.00	9.00	86.88	981.30
8:51:11	183.00	30.80			8.00	20.70	29.00	9.00	13.54	81.30
8:51:16	186.50	30.70			7.00	20.50	28.00	9.00	13.66	80.70
8:51:21	186.80	30.80			7.00	20.30	27.00	9.00	13.76	80.50
8:51:26	189.00	30.80			7.00	20.50	28.00	9.00	13.72	80.40
8:51:31	181.30	31.00			7.00	20.80	28.00	9.00	13.65	81.30

8:51:36	182.90	30.90				7.00	20.60	27.00	9.00	13.86	80.70
8:56:43	204.00	31.40				13.00	20.80	35.00	9.00	13.37	79.60
8:56:48	200.40	31.40				13.00	23.10	36.00	10.00	12.10	82.30
8:56:53	193.50	31.40				13.00	22.80	36.00	10.00	11.82	83.30
8:56:58	184.60	31.30				13.00	21.60	35.00	11.00	12.46	83.20
8:57:03	180.50	31.30				13.00	20.60	33.00	10.00	13.16	82.40
8:57:08	178.40	31.40				13.00	20.20	33.00	10.00	13.64	81.70
8:57:13	176.80	31.40				13.00	20.50	33.00	9.00	13.96	81.20
8:57:18	176.10	31.40				13.00	20.50	34.00	9.00	14.41	80.20
8:57:23	171.60	31.40				13.00	20.80	34.00	9.00	14.75	79.90
8:57:28	167.90	31.40				13.00	20.50	34.00	8.00	15.01	79.60
8:57:33	169.70	31.40				13.00	21.30	35.00	8.00	15.28	78.60
8:57:38	167.30	31.40				13.00	21.90	35.00	8.00	15.31	78.80
8:57:43	173.50	31.40				14.00	22.60	36.00	8.00	15.39	77.80
8:57:48	173.90	31.30				14.00	23.60	37.00	8.00	15.42	77.60
8:57:53	162.20	31.50				14.00	23.90	38.00	8.00	15.61	78.60
8:57:58	176.50	31.40				15.00	23.70	38.00	8.00	15.54	76.90
8:58:03	195.60	31.40				14.00	25.20	39.00	8.00	14.50	77.60
8:58:08	195.00	31.50				14.00	26.30	40.00	7.00	13.48	80.30
8:58:13	188.90	31.40				14.00	25.60	39.00	8.00	13.43	81.10
8:58:18	186.10	31.50				13.00	24.40	38.00	8.00	13.78	80.60
8:58:23	185.60	31.50				13.00	23.80	37.00	7.00	14.23	79.60
8:58:28	184.20	31.50				14.00	23.80	38.00	7.00	14.35	79.50
8:58:33	179.60	31.50				14.00	23.90	39.00	7.00	14.72	79.00
8:58:38	174.40	31.40				14.00	23.70	38.00	7.00	15.06	78.70
9:03:45	178.00	31.80				18.00	30.60	48.00	10.00	15.02	78.40
9:03:50	176.10	31.90				18.00	30.60	49.00	10.00	15.34	77.60
9:03:55	177.20	32.00				19.00	31.00	50.00	10.00	15.44	77.10
9:04:00	175.80	31.90				19.00	31.50	51.00	10.00	15.58	76.90

9:04:05	177.30	31.90				19.00	32.00	51.00	10.00	15.79	75.90
9:04:10	175.00	31.90				19.00	33.00	52.00	9.00	15.88	75.80
9:04:15	174.60	32.00				19.00	33.70	53.00	9.00	15.94	75.60
9:04:20	178.60	32.00				19.00	34.80	54.00	10.00	15.86	75.40
9:04:25	174.90	32.00				19.00	35.50	55.00	10.00	15.77	76.30
9:04:30	174.10	32.00				20.00	35.30	55.00	10.00	15.97	75.60
9:04:35	173.40	32.00				20.00	34.60	54.00	10.00	16.11	75.10
9:04:40	170.90	32.00				21.00	33.60	55.00	10.00	16.20	75.10
9:04:45	171.70	32.00				21.00	32.90	54.00	10.00	16.20	75.00
9:04:50	172.20	32.00				22.00	32.70	55.00	10.00	16.20	74.90
9:04:55	167.40	31.90				22.00	32.10	54.00	11.00	16.38	74.80
9:05:00	166.10	31.80				22.00	30.30	52.00	10.00	16.57	74.10
9:05:05	167.30	31.80				22.00	29.90	52.00	10.00	16.57	73.90
9:05:10	162.10	31.80				22.00	29.70	51.00	10.00	16.65	74.40
9:05:15	156.40	31.80				21.00	28.90	50.00	10.00	16.80	74.60
9:05:20	160.80	31.80				22.00	27.50	49.00	10.00	16.90	73.20
9:05:25	161.20	31.80				22.00	27.50	49.00	10.00	16.83	73.60
9:05:30	159.50	31.90				21.00	27.50	49.00	10.00	16.85	73.80
9:05:35	156.10	31.80				21.00	27.30	48.00	11.00	16.92	74.00
9:05:40	158.70	31.80				21.00	26.20	47.00	11.00	17.06	72.80
9:10:47	151.50	32.30				17.00	27.60	44.00	12.00	17.37	72.30
9:10:52	150.80	32.30				17.00	27.20	44.00	12.00	17.48	71.70
9:10:57	149.90	32.30				17.00	26.70	43.00	12.00	17.62	70.90
9:11:02	151.50	32.30				16.00	26.60	42.00	12.00	17.65	70.30
9:11:07	150.60	32.40				16.00	26.90	43.00	11.00	17.59	71.00
9:11:12	149.10	32.40				16.00	26.60	43.00	11.00	17.65	70.80
9:11:17	150.00	32.50				17.00	26.10	43.00	11.00	17.71	70.20
9:11:22	151.20	32.50				16.00	26.50	43.00	11.00	17.70	70.00
9:11:27	149.50	32.40				16.00	26.80	42.00	11.00	17.74	70.00

9:11:32	148.30	32.40				15.00	26.90	42.00	11.00	17.80	69.80
9:11:37	150.20	32.40				15.00	26.80	42.00	11.00	17.85	68.90
9:11:42	148.90	32.40				15.00	27.10	42.00	10.00	17.85	69.30
9:11:47	147.80	32.40				15.00	27.00	42.00	10.00	17.88	69.20
9:11:52	146.20	32.30				14.00	26.30	41.00	10.00	17.96	68.90
9:11:57	146.80	32.30				14.00	25.70	40.00	10.00	18.03	68.10
9:12:02	145.10	32.40				14.00	25.70	40.00	10.00	18.00	68.80
9:12:07	142.20	32.40				14.00	25.40	40.00	10.00	18.01	69.50
9:12:12	141.20	32.50				14.00	24.70	39.00	10.00	18.06	69.20
9:12:17	141.60	32.50				14.00	23.80	38.00	11.00	18.16	68.20
9:12:22	140.40	32.60				13.00	23.10	37.00	11.00	18.20	68.20
9:12:27	137.50	32.60				14.00	22.30	36.00	10.00	18.23	68.60
9:12:32	133.90	32.60				14.00	21.10	35.00	10.00	18.35	68.40
9:12:37	134.30	32.60				14.00	19.80	34.00	11.00	18.49	66.70
9:12:42	135.10	32.60				14.00	19.10	33.00	10.00	18.55	65.70
9:17:49	128.60	32.40				11.00	15.40	26.00	10.00	18.74	65.20
9:17:54	127.70	32.40				11.00	15.60	26.00	10.00	18.71	65.90
9:17:59	125.40	32.40				11.00	15.30	27.00	11.00	18.77	65.80
9:18:04	126.20	32.30				11.00	14.50	25.00	10.00	18.85	64.40
9:18:09	124.10	32.30				11.00	14.10	25.00	10.00	18.91	64.20
9:18:14	122.60	32.30				11.00	13.40	24.00	10.00	18.96	64.00
9:18:19	122.00	32.30				11.00	13.00	24.00	10.00	18.98	63.80
9:18:24	122.90	32.30				10.00	12.70	23.00	10.00	19.01	63.00
9:18:29	121.90	32.40				10.00	12.50	23.00	10.00	18.99	63.70
9:18:34	123.30	32.30				10.00	12.30	23.00	10.00	19.02	62.70
9:18:38	120.90	32.30				10.00	12.30	23.00	10.00	19.00	63.90
9:18:44	119.20	32.40				10.00	12.00	22.00	10.00	19.03	64.20
9:18:49	118.40	32.40				11.00	11.60	22.00	10.00	19.08	63.50
9:18:54	118.50	32.40				10.00	11.40	22.00	10.00	19.09	63.50

9:18:59	119.20	32.40				10.00	11.20	21.00	10.00	19.08	63.30
9:19:04	119.80	32.40				10.00	11.00	21.00	10.00	19.14	62.00
9:19:09	118.30	32.40				10.00	10.80	21.00	10.00	19.13	62.70
9:19:14	117.60	32.50				10.00	10.60	21.00	10.00	19.14	62.90
9:19:19	116.90	32.40				10.00	10.10	20.00	10.00	19.22	61.60
9:19:24	116.50	32.30				10.00	9.90	20.00	10.00	19.29	60.40
9:19:29	117.50	32.30				10.00	9.60	19.00	10.00	19.28	60.20
9:19:34	115.10	32.30				10.00	9.30	19.00	9.00	19.29	60.90
9:19:39	114.20	32.30				9.00	9.10	18.00	9.00	19.34	60.10
9:19:44	113.00	32.30				9.00	8.90	18.00	9.00	19.38	59.80
9:24:51	110.60	32.70				7.00	10.70	18.00	9.00	19.57	56.40
9:24:56	110.70	32.70				7.00	10.40	17.00	9.00	19.55	56.80
9:25:01	110.70	32.60				7.00	10.30	17.00	9.00	19.57	56.40
9:25:06	109.00	32.60				7.00	10.10	17.00	9.00	19.58	57.00
9:25:11	107.00	32.50				7.00	10.00	17.00	9.00	19.61	57.20
9:25:16	107.90	32.60				7.00	9.60	16.00	9.00	19.66	55.10
9:25:21	108.70	32.60				7.00	9.50	16.00	9.00	19.67	54.30
9:25:26	106.60	32.60				7.00	9.40	16.00	9.00	19.68	55.40
9:25:31	103.30	32.50				7.00	9.20	16.00	9.00	19.67	57.40
9:25:36	113.80	32.50				7.00	9.30	16.00	9.00	19.63	52.90
9:25:41	127.80	32.40				7.00	11.20	18.00	8.00	19.39	52.80
9:25:46	136.30	32.40				7.00	14.70	22.00	8.00	19.04	57.40
9:25:51	138.60	32.50				8.00	18.10	26.00	8.00	18.84	60.30
9:25:56	141.50	32.50				8.00	20.40	28.00	8.00	18.68	61.90
9:26:01	138.10	32.60				8.00	22.50	31.00	8.00	18.51	65.30
9:26:06	133.00	32.60				9.00	22.80	32.00	8.00	18.52	66.70
9:26:11	132.70	32.60				9.00	22.80	32.00	8.00	18.58	66.10
9:26:16	132.60	32.70				9.00	23.00	32.00	8.00	18.55	66.50
9:26:21	128.70	32.70				9.00	23.00	32.00	8.00	18.54	67.80

9:26:26	126.10	32.70				9.00	22.30	32.00	8.00	18.60	67.90
9:26:31	124.80	32.70				9.00	21.60	31.00	8.00	18.66	67.50
9:26:36	124.10	32.60				9.00	21.00	30.00	8.00	18.72	67.00
9:26:41	121.70	32.60				9.00	20.30	29.00	8.00	18.78	67.10
9:26:46	121.90	32.50				9.00	19.20	28.00	8.00	18.86	65.80

Table O 20: Temperature at pyrolysis chamber for Experiment (iv-1); AVR = 4.00:0.00 (OPKS)

Mean		199.64					
Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)
0	0.00	14.5	237.00	29	150.00	43.5	123.00
0.5	212.00	15	206.00	29.5	144.00	44	122.00
1	250.00	15.5	211.00	30	140.00	44.5	118.00
1.5	275.00	16	199.00	30.5	134.00	45	113.00
2	296.00	16.5	187.00	31	128.00	45.5	107.00
2.5	307.00	17	178.00	31.5	131.00		
3	316.00	17.5	267.00	32	141.00		
3.5	321.00	18	233.00	32.5	147.00		
4	329.00	18.5	202.00	33	147.00		
4.5	325.00	19	197.00	33.5	144.00		
5	329.00	19.5	191.00	34	140.00		
5.5	345.00	20	181.00	34.5	136.00		
6	334.00	20.5	210.00	35	134.00		
6.5	342.00	21	198.00	35.5	131.00		
7	330.00	21.5	187.00	36	127.00		
7.5	319.00	22	183.00	36.5	125.00		
8	329.00	22.5	179.00	37	123.00		
8.5	325.00	23	170.00	37.5	120.00		
9	317.00	23.5	168.00	38	117.00		
9.5	323.00	24	167.00	38.5	114.00		
10	318.00	24.5	166.00	39	134.00		
10.5	320.00	25	165.00	39.5	142.00		
11	302.00	25.5	160.00	40	139.00		
11.5	298.00	26	154.00	40.5	132.00		
12	298.00	26.5	151.00	41	126.00		

12.5	298.00	27	157.00	41.5	122.00
13	291.00	27.5	158.00	42	118.00
13.5	266.00	28	157.00	42.5	113.00
14	286.00	28.5	154.00	43	111.00

Experiment set (iv-2)

Date = 8/1/2013; Sample = About 3 Kg of OPKS; Methanol = About 3 Liter; AVR = 4.00:0.00

Measurement rate = 5 seconds; Gas time = 2 minutes; Rinse time = 5 minutes; Mean = 1 second; To make the data meaningful, rinse time is neglected

Table O 21: Results of TESTO Experiment (iv-2); AVR = 4.00:0.00 (OPKS)

Mean	167.56	33.89	1261.44	441.48	8.49	22.20	30.68	19.47	15.98	72.45
Time	FT (°C)	AT (°C)	CO (ppmv)	H2 (ppmv)	NO (ppmv)	NO2 (ppmv)	NOx (ppmv)	SO2 (ppmv)	O2 (%)	η (%)
11:07:52	166.10	33.00	3.00	29.00	1.00	0.20	1.00	0.00	20.78	
11:07:57	237.00	33.00	159.00	137.00	3.00	3.10	6.00	5.00	17.39	40.90
11:08:02	232.70	33.00	911.00	442.00	2.00	7.80	10.00	30.00	12.21	78.60
11:08:07	222.40	33.00	1962.00	557.00	3.00	9.10	12.00	66.00	9.72	82.70
11:08:12	210.20	33.10	2695.00	336.00	3.00	8.90	12.00	92.00	9.01	83.90
11:08:17	204.80	33.20	2934.00	168.00	3.00	8.10	11.00	102.00	9.30	83.80
11:08:22	199.60	33.30	2707.00	621.00	2.00	7.50	10.00	94.00	9.68	83.90
11:08:27	196.20	33.40	2379.00	869.00	2.00	7.40	9.00	80.00	10.00	83.90
11:08:32	195.60	33.40	2130.00	935.00	2.00	7.40	9.00	72.00	10.21	83.90
11:08:37	197.40	33.40	1991.00	923.00	2.00	8.00	10.00	67.00	10.27	83.80
11:08:42	198.50	33.20	1948.00	860.00	2.00	8.70	11.00	65.00	10.15	83.90
11:08:47	200.40	33.10	1957.00	827.00	2.00	9.60	12.00	65.00	10.02	83.90
11:08:52	199.90	33.00	1917.00	835.00	2.00	10.10	12.00	64.00	10.28	83.60
11:08:57	198.00	33.10	1819.00	845.00	2.00	10.80	13.00	61.00	10.54	83.50
11:09:02	201.60	33.10	1717.00	834.00	2.00	12.10	14.00	57.00	10.60	83.20
11:09:07	207.40	33.20	1659.00	781.00	2.00	13.40	16.00	55.00	10.43	83.10
11:09:12	213.30	33.20	1637.00	739.00	3.00	14.10	17.00	54.00	10.30	82.80
11:09:17	216.20	33.10	1601.00	716.00	3.00	14.90	18.00	52.00	10.27	82.70

11:09:22	213.30	33.00	1568.00	692.00	3.00	16.30	19.00	51.00	10.08	83.10
11:09:27	214.60	33.00	1596.00	646.00	3.00	17.80	21.00	52.00	9.80	83.40
11:09:32	208.90	33.30	1635.00	626.00	4.00	18.40	22.00	53.00	9.75	83.80
11:09:37	204.50	33.30	1624.00	636.00	4.00	18.40	23.00	52.00	10.23	83.60
11:09:42	208.10	33.20	1564.00	656.00	4.00	18.50	22.00	50.00	10.37	83.20
11:09:47	207.30	33.20	1498.00	648.00	4.00	18.20	23.00	48.00	10.40	83.20
11:14:54	195.70	34.30	844.00	222.00	8.00	21.70	29.00	23.00	12.59	81.50
11:14:59	195.50	34.10	857.00	224.00	7.00	21.50	29.00	24.00	12.57	81.60
11:15:04	192.40	34.00	863.00	232.00	8.00	21.30	29.00	24.00	12.64	81.70
11:15:09	190.80	34.10	847.00	245.00	8.00	21.60	29.00	24.00	12.87	81.40
11:15:14	187.20	33.90	823.00	253.00	7.00	22.30	29.00	23.00	13.12	81.30
11:15:19	185.70	33.70	790.00	262.00	6.00	22.20	28.00	22.00	13.13	81.10
11:15:24	185.50	33.60	759.00	261.00	6.00	22.20	28.00	21.00	13.07	81.60
11:15:29	183.40	33.60	759.00	245.00	6.00	22.00	28.00	20.00	13.04	81.90
11:15:34	187.00	33.80	766.00	240.00	6.00	21.50	27.00	21.00	13.09	81.40
11:15:39	190.50	33.70	765.00	239.00	6.00	21.60	28.00	21.00	12.90	81.40
11:15:44	187.00	33.90	767.00	240.00	7.00	20.50	27.00	20.00	12.95	81.70
11:15:49	181.50	33.80	753.00	248.00	7.00	19.10	26.00	20.00	13.21	81.80
11:15:54	181.70	33.80	743.00	247.00	7.00	18.00	25.00	20.00	86.88	81.30
11:15:59	185.50	33.80	741.00	243.00	6.00	17.90	24.00	20.00	13.45	80.90
11:16:04	186.30	34.00	746.00	237.00	6.00	18.00	24.00	20.00	86.88	80.90
11:16:09	192.70	33.90	763.00	231.00	5.00	18.20	24.00	20.00	13.44	80.20
11:16:14	188.60	34.20	786.00	226.00	5.00	18.50	24.00	21.00	86.88	80.70
11:16:19	188.10	34.30	804.00	229.00	5.00	18.60	24.00	22.00	13.36	80.80
11:16:24	188.90	34.30	903.00	241.00	5.00	19.20	24.00	22.00	13.29	80.90
11:16:29	186.80	34.40	787.00	254.00	5.00	20.00	25.00	21.00	13.25	81.20
11:16:34	190.00	34.20	768.00	259.00	5.00	20.40	25.00	20.00	13.39	80.60
11:16:39	187.90	34.30	761.00	257.00	4.00	20.50	24.00	20.00	13.43	80.70
11:16:44	187.10	34.40	769.00	250.00	4.00	20.70	25.00	20.00	13.44	80.80

11:16:49	191.50	34.50	774.00	248.00	4.00	20.90	25.00	20.00	13.49	80.20
11:21:56	176.00	33.90			13.00	20.50	43.00	11.00	15.10	78.70
11:22:01	178.60	33.90			13.00	29.00	43.00	11.00	15.20	78.00
11:22:06	176.90	34.10			13.00	29.00	42.00	11.00	15.27	78.10
11:22:11	175.20	34.40			13.00	29.00	42.00	11.00	15.39	77.90
11:22:16	175.00	34.50			13.00	29.20	42.00	11.00	15.40	77.90
11:22:21	180.30	34.50			13.00	29.70	42.00	11.00	15.35	77.40
11:22:26	181.40	34.50			13.00	30.50	43.00	11.00	15.24	77.60
11:22:31	177.30	34.30			13.00	30.60	43.00	11.00	15.21	78.20
11:22:36	180.20	34.10			13.00	30.30	43.00	11.00	15.23	77.80
11:22:41	177.20	34.30			13.00	29.70	43.00	11.00	15.44	77.50
11:22:46	174.80	34.40			13.00	28.40	41.00	11.00	15.69	77.00
11:22:51	177.70	34.50			13.00	28.30	41.00	11.00	15.69	76.60
11:22:56	175.70	34.60			13.00	28.60	41.00	11.00	15.70	76.80
11:23:01	174.50	34.70			12.00	28.20	41.00	11.00	15.84	76.50
11:23:06	171.80	34.40			12.00	27.60	40.00	11.00	15.91	76.50
11:23:11	170.60	34.30			12.00	27.20	39.00	11.00	16.01	76.30
11:23:16	166.60	34.40			12.00	27.20	39.00	11.00	16.10	76.60
11:23:21	169.20	34.30			12.00	26.00	38.00	11.00	16.29	75.40
11:26:46	172.30	34.30			12.00	26.10	38.00	10.00	16.21	75.20
11:23:31	171.30	34.50			12.00	26.70	38.00	11.00	16.11	75.80
11:23:36	167.90	34.50			12.00	26.60	38.00	11.00	16.12	76.30
11:23:41	168.00	34.40			12.00	25.90	38.00	11.00	16.27	75.60
11:23:46	169.40	34.40			12.00	26.00	38.00	11.00	16.28	75.40
11:23:51	166.80	34.60			11.00	26.10	37.00	11.00	16.32	75.60
11:28:58	196.50	34.60			16.00	50.00	66.00	29.00	13.86	79.70
11:29:03	203.20	34.50			17.00	47.00	64.00	27.00	13.99	78.60
11:29:08	205.70	34.30			18.00	46.60	65.00	26.00	13.89	78.60
11:29:13	198.10	34.10			18.00	45.70	64.00	26.00	13.94	79.20

11:29:18	194.50	33.90				19.00	43.50	62.00	25.00	14.30	78.70
11:29:23	191.40	33.90				19.00	41.30	60.00	24.00	14.62	78.20
11:29:28	191.30	34.00				18.00	39.80	58.00	23.00	14.81	77.70
11:29:33	189.30	33.90				18.00	38.30	56.00	23.00	14.97	77.40
11:29:38	192.50	34.10				18.00	38.50	56.00	22.00	14.90	77.20
11:29:43	195.00	34.30				17.00	39.60	57.00	22.00	14.73	77.50
11:29:48	192.20	34.50				17.00	40.10	57.00	21.00	14.73	77.90
11:29:53	187.90	34.60				17.00	40.00	57.00	21.00	14.89	77.90
11:29:58	189.40	34.40				17.00	40.20	57.00	21.00	15.06	77.20
11:30:03	194.50	34.50				16.00	41.50	58.00	20.00	15.11	76.40
11:30:08	194.10	34.60				16.00	43.60	59.00	20.00	15.09	76.50
11:30:13	194.80	34.60				16.00	45.10	61.00	19.00	15.01	76.70
11:30:18	191.80	34.60				16.00	46.10	62.00	19.00	14.95	77.20
11:30:23	193.00	34.70				16.00	45.30	61.00	19.00	15.10	76.60
11:30:28	193.90	34.80				16.00	45.20	61.00	19.00	15.05	76.70
11:30:33	187.40	34.80				16.00	44.80	61.00	19.00	15.11	77.30
11:30:38	188.40	34.80				16.00	43.80	60.00	19.00	15.33	76.40
11:30:43	186.00	34.80				15.00	43.40	59.00	18.00	15.45	76.30
11:37:28	189.20	34.80				15.00	43.50	58.00	18.00	15.48	75.80
11:30:53	192.00	34.80				15.00	44.20	59.00	18.00	15.40	75.70
11:36:00	150.90	33.90				9.00	17.40	26.00	16.00	17.78	69.80
11:36:05	152.00	34.00				9.00	17.00	26.00	16.00	17.81	69.20
11:36:10	152.70	33.90				9.00	16.90	26.00	16.00	17.80	69.10
11:36:15	149.70	34.00				9.00	16.50	26.00	16.00	17.84	69.60
11:36:20	147.10	33.90				9.00	16.00	25.00	16.00	17.92	69.40
11:36:25	146.60	33.60				9.00	15.50	25.00	16.00	17.98	68.90
11:36:30	147.10	33.50				9.00	15.50	25.00	16.00	17.96	68.90
11:36:35	148.20	33.60				9.00	15.30	24.00	15.00	17.97	68.60
11:36:40	148.50	33.60				9.00	15.30	24.00	15.00	17.99	68.40

11:36:45	146.90	33.70				9.00	15.10	24.00	16.00	18.02	68.50
11:36:50	147.80	33.80				9.00	14.70	24.00	15.00	18.08	67.70
11:36:55	145.90	33.90				9.00	14.70	24.00	16.00	18.04	68.60
11:37:00	144.50	33.90				9.00	14.50	24.00	15.00	18.05	68.90
11:37:05	143.30	33.90				9.00	14.10	23.00	15.00	18.12	68.50
11:37:10	145.40	33.80				9.00	13.90	22.00	15.00	18.18	67.40
11:37:15	144.20	33.80				8.00	14.00	22.00	15.00	18.11	68.40
11:37:20	143.40	34.00				9.00	13.60	22.00	15.00	18.15	68.20
11:37:25	144.60	34.10				9.00	13.20	22.00	15.00	18.21	67.40
11:37:30	141.80	34.20				9.00	12.90	21.00	15.00	18.19	68.30
11:37:35	141.20	34.00				9.00	12.60	21.00	15.00	18.20	68.30
11:37:40	141.50	33.80				8.00	12.50	21.00	15.00	18.24	67.80
11:37:45	139.70	33.80				8.00	12.20	20.00	15.00	18.29	67.80
11:37:50	142.40	34.00				8.00	11.90	20.00	15.00	18.33	66.60
11:37:55	142.20	34.10				8.00	11.90	20.00	15.00	18.29	67.10
11:43:02	191.70	33.30				14.00	47.00	61.00	22.00	15.32	75.80
11:43:07	188.10	33.40				13.00	47.30	61.00	23.00	15.30	76.40
11:43:12	186.00	33.50				13.00	47.00	60.00	22.00	15.40	76.30
11:43:17	183.90	33.70				13.00	45.60	59.00	22.00	15.76	75.30
11:43:22	178.10	33.70				13.00	43.50	57.00	21.00	15.98	75.20
11:43:27	178.90	33.50				14.00	41.20	55.00	19.00	16.16	74.30
11:43:32	180.70	33.60				14.00	40.70	55.00	19.00	16.20	73.80
11:43:37	177.70	33.60				14.00	40.50	54.00	18.00	16.26	74.00
11:43:42	172.10	33.60				13.00	39.60	53.00	18.00	16.34	74.50
11:43:47	172.30	33.70				13.00	38.30	51.00	18.00	16.54	73.60
11:43:52	167.50	33.80				12.00	37.00	49.00	17.00	16.71	73.50
11:43:57	166.30	33.70				12.00	35.70	48.00	17.00	16.74	73.50
11:44:02	167.70	33.70				12.00	34.80	46.00	17.00	16.80	72.90
11:44:07	165.20	33.70				12.00	34.30	46.00	17.00	16.86	73.00

11:11:12	168.90	33.90				11.00	34.20	45.00	16.00	16.90	72.10
11:44:17	169.30	33.90				11.00	34.40	45.00	16.00	16.85	72.40
11:44:22	168.10	33.80				11.00	34.20	45.00	16.00	16.88	72.40
11:44:27	167.40	33.90				11.00	33.90	45.00	16.00	16.93	72.30
11:44:32	166.00	33.90				11.00	33.10	44.00	16.00	17.04	71.90
11:44:37	165.30	33.90				11.00	32.50	43.00	16.00	17.13	71.50
11:44:42	165.00	33.90				11.00	32.50	43.00	16.00	17.09	71.80
11:44:47	166.00	34.00				11.00	32.00	43.00	15.00	17.10	71.50
11:44:52	164.60	34.20				11.00	31.10	42.00	15.00	17.19	71.20
11:44:57	164.40	34.20				11.00	30.50	41.00	15.00	17.27	70.80
11:50:04	142.00	33.70				7.00	13.30	20.00	11.00	18.54	64.00
11:50:09	141.00	33.50				7.00	13.20	20.00	11.00	18.54	64.30
11:50:14	140.20	33.60				7.00	13.00	20.00	11.00	18.58	64.00
11:50:19	142.50	33.60				7.00	12.90	20.00	11.00	18.57	63.50
11:50:24	140.30	33.70				7.00	13.10	20.00	11.00	18.51	64.90
11:50:29	139.70	33.70				7.00	13.90	20.00	11.00	18.56	64.50
11:50:34	139.80	33.70				7.00	12.70	19.00	11.00	18.60	63.90
11:50:39	141.50	33.60				7.00	12.50	19.00	11.00	18.61	63.20
11:50:44	140.80	33.80				7.00	12.60	19.00	11.00	18.61	63.60
11:50:49	137.00	33.80				6.00	12.20	18.00	11.00	18.68	63.80
11:50:54	136.60	33.60				6.00	11.80	18.00	10.00	18.74	63.00
11:50:59	137.60	33.50				6.00	11.50	18.00	10.00	18.70	63.20
11:51:04	117.50	33.50				6.00	10.90	17.00	10.00	18.92	66.70
11:51:09	93.30	33.50				5.00	7.20	12.00	9.00	20.14	
11:51:14	100.50	33.40				4.00	4.70	8.00	7.00	20.52	
11:51:19	144.10	33.60				5.00	7.30	12.00	6.00	19.26	48.30
11:51:24	174.90	33.30				6.00	15.50	22.00	6.00	17.90	62.70
11:51:29	191.90	33.20				7.00	26.20	33.00	6.00	16.82	68.40
11:51:34	198.60	33.10				8.00	35.90	44.00	7.00	15.91	72.40

11:51:39	201.10	33.10				9.00	42.50	51.00	8.00	15.34	74.50
11:51:44	204.00	33.10				10.00	46.00	56.00	10.00	15.08	75.10
11:51:49	196.30	33.20				11.00	48.40	59.00	11.00	14.95	76.50
11:51:54	186.00	33.20				11.00	48.10	59.00	12.00	15.14	77.20
11:51:59	188.30	33.10				12.00	46.60	58.00	13.00	14.41	75.90
11:57:06	137.80	33.80				5.00	12.40	18.00	9.00	18.76	62.30
11:57:11	133.80	33.80				5.00	11.70	17.00	8.00	18.89	61.60
11:57:16	135.60	33.90				5.00	11.20	16.00	8.00	18.92	60.50
11:57:21	135.10	34.10				5.00	11.20	16.00	8.00	18.87	61.70
11:57:26	134.50	34.30				5.00	11.40	16.00	8.00	18.83	62.40
11:57:31	136.30	34.20				5.00	11.40	16.00	8.00	18.81	62.20
11:57:36	133.70	34.20				5.00	11.40	17.00	8.00	18.78	63.50
11:57:41	133.00	34.20				5.00	11.40	16.00	9.00	18.82	63.10
11:57:46	134.10	34.10				5.00	11.20	16.00	8.00	18.87	61.90
11:57:51	133.80	34.30				5.00	11.00	16.00	8.00	18.90	61.60
11:57:56	134.10	34.20				4.00	11.00	15.00	8.00	18.88	61.80
11:58:01	132.60	33.90				4.00	10.90	15.00	8.00	18.90	61.90
11:58:06	133.20	34.00				4.00	10.80	15.00	8.00	18.96	60.80
11:58:11	133.80	34.10				4.00	10.80	15.00	8.00	18.95	60.80
11:58:16	133.90	34.20				4.00	10.60	15.00	8.00	18.95	60.70
11:58:21	131.80	34.20				4.00	10.50	14.00	7.00	18.95	61.50
11:58:26	128.50	34.10				4.00	10.30	14.00	8.00	19.00	61.80
11:58:31	131.20	39.90				3.00	10.00	14.00	7.00	19.02	60.20
11:58:36	132.00	34.00				3.00	10.00	14.00	7.00	18.99	60.60
11:58:41	131.60	34.00				4.00	9.90	13.00	7.00	19.01	60.40
11:58:46	129.70	33.90				4.00	9.70	13.00	7.00	19.07	59.90
11:58:51	129.30	34.00				3.00	9.30	12.00	7.00	19.14	58.70
11:58:56	128.00	33.90				3.00	9.30	13.00	7.00	19.11	59.80
11:59:01	127.00	33.80				3.00	9.40	12.00	7.00	19.10	60.40

12:04:08	129.90	33.80				5.00	9.00	14.00	9.00	18.99	61.40
12:04:13	129.00	33.70				5.00	8.90	14.00	9.00	19.05	60.60
12:04:18	127.80	33.40				5.00	8.70	14.00	9.00	19.09	60.10
12:04:23	127.30	33.30				5.00	8.50	13.00	8.00	19.12	59.60
12:04:28	129.10	33.50				5.00	8.50	13.00	9.00	19.12	59.00
12:04:33	127.50	33.60				5.00	8.40	13.00	9.00	19.10	60.30
12:04:38	126.10	33.50				4.00	8.20	13.00	8.00	19.14	59.80
12:04:43	126.00	33.60				4.00	8.10	13.00	8.00	19.15	59.80
12:04:48	122.60	33.50				4.00	8.20	13.00	8.00	19.16	60.90
12:04:53	122.50	33.40				4.00	7.70	12.00	8.00	19.26	58.70
12:04:58	125.40	33.30				4.00	7.60	12.00	8.00	19.26	57.60
12:05:03	126.20	33.30				4.00	7.90	12.00	8.00	19.19	58.80
12:05:08	121.70	33.40				4.00	8.00	12.00	8.00	19.17	61.10
12:05:15	99.20	33.30				4.00	7.20	11.00	8.00	19.60	

Table O 22: Temperature at pyrolysis chamber for Experiment (iv-2); AVR = 4.00:0.00 (OPKS)

Mean		221.05					
Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)
0	0.00	14.5	256.00	29	195.00	43.5	150.00
0.5	274.00	15	262.00	29.5	192.00	44	173.00
1	301.00	15.5	268.00	30	188.00	44.5	174.00
1.5	350.00	16	283.00	30.5	220.00	45	167.00
2	373.00	16.5	262.00	31	236.00	45.5	162.00
2.5	362.00	17	246.00	31.5	224.00	46	157.00
3	362.00	17.5	309.00	32	208.00	46.5	153.00
3.5	368.00	18	282.00	32.5	196.00	47	149.00
4	379.00	18.5	253.00	33	186.00	47.5	147.00
4.5	374.00	19	240.00	33.5	174.00	48	144.00
5	372.00	19.5	225.00	34	181.00	48.5	140.00
5.5	380.00	20	222.00	34.5	188.00	49	138.00
6	396.00	20.5	240.00	35	191.00	49.5	137.00
6.5	364.00	21	305.00	35.5	183.00	50	135.00
7	362.00	21.5	294.00	36	177.00	50.5	133.00
7.5	340.00	22	262.00	36.5	171.00	51	131.00
8	352.00	22.5	246.00	37	167.00	51.5	137.00
8.5	322.00	23	244.00	37.5	162.00	52	159.00
9	316.00	23.5	238.00	38	160.00	52.5	157.00
9.5	313.00	24	243.00	38.5	155.00	53	151.00
10	301.00	24.5	255.00	39	152.00	53.5	145.00
10.5	301.00	25	254.00	39.5	149.00	54	141.00
11	286.00	25.5	231.00	40	147.00	54.5	136.00
11.5	312.00	26	230.00	40.5	145.00	55	133.00

12	284.00	26.5	222.00	41	142.00	55.5	131.00
12.5	275.00	27	222.00	41.5	140.00	56	130.00
13	268.00	27.5	214.00	42	139.00	56.5	127.00
13.5	259.00	28	202.00	42.5	137.00	57	125.00
14	164.00	28.5	199.00	43	135.00		

Experiment set (iv-3)

Date = 8/1/2013; Sample = About 3 Kg of OPKS; Methanol = About 3 Liter; AVR = 4.00:0.00.

Measurement rate = 5 seconds; Gas time = 2 minutes; Rinse time = 5 minutes; Mean = 1 second; To make the data meaningful, rinse time is neglected

Table O 23: Results of TESTO Experiment (iv-3); AVR = 4.00:0.00 (OPKS)

Mean	151.25	34.38	1069.23	352.79	6.25	19.19	25.19	17.25	16.81	72.35
Time	FT (°C)	AT (°C)	CO (ppmv)	H2 (ppmv)	NO (ppmv)	NO2 (ppmv)	NOx (ppmv)	SO2 (ppmv)	O2 (%)	η (%)
14:43:06	132.10	34.90	34.00	211.00	4.00	0.20	4.00	2.00	20.54	
14:43:11	209.20	35.20	223.00	329.00	4.00	2.70	7.00	7.00	18.09	39.80
14:43:16	218.00	35.20	1159.00	706.00	5.00	6.60	11.00	39.00	12.70	78.70
14:43:21	200.00	35.20	2454.00	736.00	5.00	7.60	12.00	88.00	10.54	83.10
14:43:26	186.50	35.10	2953.00	259.00	5.00	7.10	12.00	109.00	9.90	84.50
14:43:31	184.90	34.80	2893.00	273.00	5.00	6.30	11.00	106.00	9.79	84.70
14:43:36	191.10	34.40	2676.00	620.00	4.00	5.70	10.00	97.00	9.87	84.30
14:43:41	191.10	34.40	2502.00	778.00	4.00	5.40	10.00	97.00	10.09	84.20
14:43:46	189.30	34.40	2225.00	892.00	4.00	5.60	10.00	81.00	10.48	84.10
14:43:51	185.10	34.50	1937.00	922.00	4.00	5.90	10.00	71.00	10.81	84.20
14:43:56	185.00	34.60	1686.00	880.00	4.00	6.40	10.00	60.00	11.03	84.10
14:44:01	184.60	34.50	1495.00	778.00	4.00	6.80	11.00	54.00	11.13	84.10
14:44:06	182.80	34.50	1389.00	677.00	4.00	7.20	11.00	50.00	11.25	84.20
14:44:11	179.10	34.40	1311.00	579.00	4.00	7.60	11.00	47.00	11.57	84.10
14:44:16	176.50	34.40	1234.00	517.00	4.00	8.20	12.00	45.00	11.88	84.00
14:44:21	179.50	34.50	1170.00	446.00	4.00	8.70	13.00	43.00	11.96	83.70
14:44:26	184.30	34.40	1149.00	381.00	4.00	9.30	13.00	41.00	11.92	83.30

14:44:31	182.30	34.40	1146.00	330.00	4.00	10.00	13.00	42.00	12.00	83.40
14:44:36	181.80	34.30	1129.00	301.00	4.00	10.60	14.00	41.00	12.05	83.40
14:44:41	180.90	34.30	1097.00	279.00	4.00	11.10	15.00	40.00	12.02	83.50
14:44:46	180.40	34.30	1075.00	256.00	4.00	11.40	16.00	39.00	12.03	83.60
14:44:51	174.70	34.20	1065.00	228.00	4.00	12.30	17.00	38.00	12.13	83.90
14:44:56	175.30	34.20	1051.00	210.00	4.00	12.80	17.00	38.00	12.44	83.40
14:45:01	174.70	34.40	1020.00	202.00	4.00	13.50	17.00	37.00	12.65	83.20
14:50:08	173.70	34.80	642.00	192.00	2.00	18.30	20.00	18.00	14.26	80.60
14:50:13	175.80	34.80	669.00	185.00	2.00	18.00	20.00	19.00	14.41	80.00
14:50:18	174.60	34.80	681.00	192.00	2.00	17.70	19.00	20.00	14.57	79.70
14:50:23	172.50	34.80	673.00	204.00	2.00	17.10	19.00	19.00	14.73	79.50
14:50:28	169.40	34.90	657.00	213.00	1.00	17.20	19.00	19.00	14.65	80.10
14:50:33	168.80	34.90	644.00	217.00	1.00	17.20	18.00	19.00	14.80	79.80
14:50:38	169.20	34.90	633.00	216.00	1.00	17.40	18.00	18.00	14.74	79.90
14:50:43	169.50	35.00	635.00	210.00	1.00	17.40	18.00	18.00	14.60	80.30
14:50:48	171.10	35.00	645.00	207.00	1.00	17.50	18.00	19.00	14.57	80.10
14:50:53	172.60	35.00	652.00	209.00	1.00	17.60	18.00	19.00	14.65	79.80
14:50:58	170.50	34.80	656.00	212.00	0.00	17.30	17.00	19.00	14.72	79.80
14:51:03	169.80	34.40	646.00	219.00	1.00	17.20	17.00	18.00	14.81	79.60
14:51:08	169.60	34.40	636.00	221.00	1.00	17.20	16.00	18.00	14.85	79.50
14:51:13	164.90	34.40	629.00	222.00	1.00	16.70	15.00	18.00	15.04	79.60
14:51:18	163.20	34.50	618.00	225.00	1.00	16.50	15.00	18.00	14.99	79.90
14:51:23	163.40	34.60	610.00	226.00	1.00	16.60	15.00	18.00	14.85	80.30
14:51:28	164.90	34.50	609.00	223.00	1.00	16.80	16.00	18.00	14.80	80.30
14:51:33	166.20	34.40	610.00	221.00	2.00	16.80	15.00	18.00	14.79	80.10
14:51:38	170.90	34.30	609.00	221.00	2.00	16.70	14.00	17.00	14.81	79.50
14:51:43	171.60	34.40	610.00	221.00	3.00	16.80	14.00	17.00	14.79	79.50
14:51:48	174.50	34.30	610.00	223.00	3.00	16.80	14.00	18.00	14.76	79.20
14:51:53	172.00	34.30	617.00	219.00	2.00	17.10	15.00	18.00	14.65	79.80

14:51:58	166.70	34.30	630.00	219.00	3.00	17.30	14.00	18.00	14.70	80.20
14:52:03	160.50	34.40	629.00	227.00	4.00	16.90	13.00	18.00	14.98	80.30
14:57:10	145.20	34.40			11.00	17.80	29.00	8.00	16.78	77.20
14:57:15	148.00	34.40			11.00	18.20	30.00	8.00	16.80	76.60
14:57:20	148.70	34.50			12.00	18.40	30.00	8.00	16.73	76.80
14:57:25	148.20	34.60			12.00	18.20	30.00	8.00	16.78	76.70
14:57:30	149.30	34.50			12.00	18.30	30.00	8.00	16.82	76.30
14:57:35	147.60	34.50			12.00	18.20	30.00	9.00	16.91	76.10
14:57:40	147.40	34.50			12.00	18.10	30.00	8.00	16.98	76.10
14:57:45	148.00	34.30			12.00	18.40	31.00	9.00	16.88	76.20
14:57:50	149.90	34.00			13.00	19.10	32.00	8.00	16.79	76.20
14:57:55	146.50	34.20			13.00	19.50	32.00	9.00	16.74	77.10
14:58:00	145.90	34.40			13.00	19.30	32.00	9.00	16.84	76.70
14:58:05	147.70	34.00			13.00	19.10	32.00	9.00	16.91	76.00
14:58:10	143.50	34.20			13.00	18.90	32.00	9.00	16.92	76.80
14:58:15	144.40	34.40			13.00	18.50	31.00	9.00	17.03	76.10
14:58:20	144.50	34.50			13.00	18.30	31.00	8.00	17.16	75.40
14:58:25	144.90	34.40			13.00	18.50	31.00	8.00	17.08	75.70
14:58:30	146.50	34.40			13.00	19.00	32.00	8.00	16.96	76.10
14:58:35	147.00	34.30			13.00	19.40	33.00	9.00	16.93	76.10
14:58:40	146.20	34.20			13.00	19.40	32.00	9.00	16.95	76.10
14:58:45	147.40	34.00			13.00	19.30	32.00	9.00	16.96	75.80
14:58:50	137.20	34.10			13.00	19.00	32.00	9.00	17.11	77.00
14:58:55	117.50	34.30			12.00	14.50	27.00	9.00	18.64	68.10
14:59:00	136.60	34.40			12.00	13.20	25.00	8.00	18.34	66.90
14:59:05	172.50	34.40			13.00	17.00	30.00	7.00	16.75	72.40
15:04:12	168.80	34.30			10.00	30.30	40.00	13.00	16.33	75.20
15:04:17	167.70	34.50			10.00	30.10	40.00	13.00	16.39	75.10
15:04:22	165.60	34.50			10.00	29.60	39.00	13.00	16.47	75.10

15:04:27	165.90	34.50				10.00	29.60	39.00	13.00	16.42	75.30
15:04:32	168.10	34.50				10.00	29.90	40.00	13.00	16.37	75.20
15:04:37	168.20	34.50				10.00	30.10	40.00	13.00	16.36	75.20
15:04:42	167.00	34.50				10.00	30.00	40.00	13.00	16.38	75.30
15:04:47	164.00	34.60				10.00	29.50	40.00	13.00	16.49	75.30
15:04:52	163.80	34.40				10.00	28.40	39.00	13.00	16.61	74.80
14:04:57	161.90	34.10				10.00	27.50	38.00	14.00	16.70	74.60
15:05:02	158.90	33.90				10.00	26.50	37.00	14.00	16.75	74.80
15:05:07	156.50	34.00				10.00	25.60	36.00	14.00	16.83	74.80
15:05:12	154.10	34.00				10.00	24.40	35.00	14.00	16.93	74.70
15:05:17	154.20	34.00				10.00	23.90	34.00	13.00	16.93	74.70
15:05:22	155.00	34.10				10.00	23.50	34.00	14.00	16.95	74.50
15:05:27	157.60	34.20				10.00	22.90	33.00	14.00	17.00	73.70
15:05:32	157.30	34.30				10.00	22.50	32.00	14.00	17.01	73.80
15:05:37	153.90	34.20				10.00	22.00	32.00	14.00	17.07	74.00
15:05:42	153.10	34.20				9.00	21.20	31.00	14.00	17.20	73.40
15:05:47	152.70	34.10				9.00	20.60	30.00	14.00	17.24	73.30
15:05:52	153.70	34.10				9.00	20.20	30.00	14.00	17.25	73.00
15:05:57	156.10	34.20				9.00	20.00	29.00	14.00	17.28	72.30
15:06:02	155.40	34.20				9.00	19.90	29.00	13.00	17.28	72.50
15:06:07	155.50	34.10				9.00	19.70	29.00	14.00	17.31	72.30
15:11:14	175.00	35.00				9.00	42.00	51.00	22.00	16.22	74.90
15:11:19	170.80	34.90				9.00	40.70	50.00	21.00	16.47	74.30
15:11:24	170.20	35.00				9.00	39.60	48.00	19.00	16.57	74.00
15:11:29	173.10	35.10				9.00	39.50	48.00	18.00	16.52	73.70
15:11:34	168.30	35.10				9.00	40.40	50.00	16.00	16.43	75.00
15:11:39	161.60	35.10				10.00	39.40	49.00	16.00	16.61	75.20
15:11:44	161.80	35.20				9.00	37.20	46.00	16.00	16.87	73.90
15:11:49	165.20	35.10				9.00	36.60	46.00	15.00	16.92	73.00

15:11:54	162.30	35.20				9.00	36.10	45.00	14.00	16.97	73.20
15:11:59	157.90	35.20				9.00	34.80	44.00	14.00	17.20	72.70
15:12:04	157.90	35.20				9.00	33.60	43.00	14.00	17.27	72.20
15:12:09	160.20	35.20				9.00	34.10	43.00	14.00	17.21	72.20
15:12:14	159.70	35.20				9.00	34.20	43.00	14.00	17.17	72.50
15:12:19	160.40	35.30				9.00	33.70	43.00	14.00	17.26	71.90
15:12:24	157.40	35.30				9.00	33.50	42.00	14.00	17.32	72.10
15:12:29	156.30	35.00				9.00	32.60	41.00	14.00	17.42	71.50
15:12:34	155.00	34.70				9.00	32.00	41.00	14.00	17.46	71.40
15:12:39	157.90	34.60				8.00	31.80	40.00	13.00	17.44	70.90
15:12:44	155.10	34.80				8.00	31.80	40.00	13.00	17.42	71.70
15:12:49	154.10	34.70				8.00	31.30	40.00	13.00	17.49	71.50
15:12:54	152.90	34.70				8.00	30.90	39.00	13.00	17.50	71.60
15:12:59	149.60	34.80				8.00	30.40	39.00	13.00	17.57	71.80
15:13:04	152.10	34.90				8.00	29.50	38.00	13.00	17.68	70.50
15:13:09	151.10	34.80				8.00	28.90	37.00	13.00	17.73	70.30
15:18:16	157.90	33.80				7.00	31.70	39.00	13.00	17.50	70.40
15:18:21	156.70	34.00				7.00	31.50	39.00	13.00	17.52	70.50
15:18:26	155.10	34.00				7.00	30.70	38.00	13.00	17.62	70.10
15:18:31	149.70	33.90				8.00	29.70	37.00	13.00	17.70	70.70
15:18:36	144.00	33.80				7.00	28.00	35.00	14.00	17.86	70.60
15:18:41	144.30	33.70				7.00	26.70	34.00	14.00	17.97	69.70
15:18:46	145.90	33.80				7.00	26.00	33.00	14.00	17.95	69.40
15:18:51	143.80	33.70				7.00	25.40	32.00	14.00	18.00	69.50
15:18:56	145.10	33.80				7.00	24.70	31.00	14.00	18.09	68.40
15:19:01	144.70	34.00				7.00	24.60	31.00	14.00	18.04	69.00
15:19:06	144.40	34.10				7.00	24.30	31.00	14.00	18.08	68.70
15:19:11	145.70	34.20				7.00	23.70	30.00	14.00	18.10	68.20
15:19:16	143.70	34.30				6.00	23.20	30.00	14.00	18.17	68.00

15:19:21	140.60	34.50				6.00	22.50	29.00	14.00	18.19	68.70
15:19:26	138.60	34.40				6.00	21.90	28.00	14.00	18.21	69.00
15:19:31	138.10	35.40				6.00	21.40	28.00	15.00	18.26	68.70
15:19:36	139.00	34.30				6.00	20.90	27.00	15.00	18.31	67.90
15:19:41	140.00	34.30				6.00	20.10	26.00	15.00	18.36	67.00
15:19:46	140.70	34.40				6.00	19.80	26.00	14.00	18.35	67.00
15:19:51	138.30	34.50				6.00	19.30	25.00	15.00	18.38	67.30
15:19:56	138.70	34.50				6.00	18.80	25.00	14.00	18.43	66.70
15:20:01	138.10	34.50				6.00	18.50	24.00	15.00	18.47	66.40
15:20:06	135.90	34.30				6.00	17.90	24.00	15.00	18.53	66.20
18:50:11	133.60	33.90				5.00	16.90	22.00	15.00	18.60	65.90
15:25:18	141.10	34.10				7.00	22.70	30.00	14.00	17.98	70.40
15:25:23	138.70	34.00				8.00	21.80	29.00	14.00	18.07	70.20
15:25:28	138.00	33.90				7.00	21.10	28.00	14.00	18.14	69.70
15:25:33	139.10	33.50				7.00	20.30	28.00	14.00	18.14	69.30
15:25:38	140.80	33.50				7.00	20.10	27.00	13.00	18.18	68.50
15:25:43	180.03	33.60				7.00	19.80	27.00	14.00	18.18	68.90
15:25:48	137.50	33.60				7.00	19.50	26.00	14.00	18.21	69.10
15:25:53	136.40	33.50				7.00	19.10	26.00	14.00	18.27	68.80
15:25:58	135.30	33.50				7.00	18.50	25.00	14.00	18.30	68.80
15:26:03	137.20	33.50				7.00	18.10	25.00	14.00	18.30	68.20
15:26:08	136.50	33.50				7.00	17.90	25.00	14.00	18.32	68.20
15:26:13	135.90	33.40				7.00	17.50	24.00	14.00	18.37	67.80
15:26:18	138.20	33.40				6.00	17.30	23.00	14.00	18.38	67.10
15:26:23	137.60	33.50				6.00	17.40	24.00	14.00	18.34	67.70
15:26:28	135.20	33.50				6.00	17.30	23.00	14.00	18.36	68.10
15:26:33	134.80	33.70				6.00	16.80	23.00	14.00	18.43	67.50
15:26:38	133.80	33.80				6.00	16.40	22.00	14.00	18.50	67.00
15:26:43	133.10	33.80				5.00	16.10	21.00	14.00	18.53	67.00

15:26:48	134.50	33.60				5.00	15.90	21.00	13.00	18.47	67.20
15:26:53	134.90	33.70				5.00	16.00	22.00	14.00	18.43	67.50
15:26:58	133.60	33.80				5.00	15.90	21.00	13.00	18.48	67.30
15:27:03	134.50	33.80				5.00	15.80	21.00	13.00	18.53	66.60
15:27:08	135.60	33.50				5.00	15.70	21.00	13.00	18.52	66.20
15:27:13	133.50	33.40				5.00	15.40	21.00	13.00	18.53	66.70
15:32:20	124.30	33.70				4.00	9.90	14.00	10.00	19.01	63.00
15:32:25	122.90	33.70				4.00	10.20	14.00	10.00	18.97	64.20
15:32:30	122.30	33.90				4.00	10.20	15.00	10.00	18.99	64.10
15:32:35	123.70	34.00				4.00	10.30	14.00	10.00	19.00	63.50
15:32:40	120.00	34.00				4.00	10.30	15.00	10.00	19.03	64.40
15:32:45	122.10	34.10				4.00	9.90	14.00	9.00	19.10	62.50
15:32:50	120.00	34.20				4.00	9.80	14.00	10.00	19.08	63.60
15:32:55	118.80	34.20				4.00	9.70	13.00	9.00	19.10	63.70
15:33:00	120.40	34.20				4.00	9.60	13.00	10.00	19.10	63.20
15:33:05	120.90	34.20				4.00	9.30	13.00	9.00	19.09	63.10
15:33:10	119.20	34.20				4.00	9.20	13.00	10.00	19.10	63.60
15:33:15	119.30	34.20				3.00	9.10	12.00	10.00	19.15	62.80
15:33:20	115.10	34.30				3.00	9.00	12.00	10.00	19.14	67.70
15:33:25	109.20	34.40				3.00	8.70	12.00	9.00	19.12	67.30
15:33:30	99.10	34.40				3.00	7.90	11.00	9.00	19.41	66.10
15:33:35	116.60	34.40				3.00	7.10	10.00	8.00	19.55	54.40
15:33:40	152.40	34.20				4.00	11.70	15.00	8.00	18.46	61.70
15:33:45	175.60	34.20				3.00	21.20	25.00	6.00	17.45	66.90
15:33:50	179.00	34.30				3.00	28.70	32.00	6.00	16.71	71.50
15:33:55	176.40	34.20				4.00	34.30	38.00	7.00	16.12	74.90
15:34:00	178.80	34.30				4.00	37.30	42.00	8.00	15.82	75.80
15:34:05	175.40	34.30				5.00	39.70	44.00	9.00	15.50	77.50
15:34:10	174.30	34.40				5.00	40.30	45.00	10.00	15.59	77.40

15:34:15	172.30	34.40				5.00	40.30	45.00	10.00	15.74	77.10
15:39:22	125.80	34.90				4.00	11.40	15.00	9.00	18.92	64.40
15:39:27	128.80	34.90				4.00	11.40	15.00	9.00	18.88	64.00
15:39:32	128.60	34.70				4.00	11.50	15.00	8.00	18.81	65.00
15:39:17	126.20	34.80				4.00	11.70	16.00	9.00	18.77	66.40
15:39:42	124.50	34.80				4.00	11.40	15.00	9.00	18.84	66.00
15:39:47	126.50	34.80				4.00	11.20	15.00	9.00	18.88	64.60
15:39:52	129.10	34.80				4.00	11.20	15.00	9.00	18.84	64.40
15:39:57	130.40	35.00				4.00	11.30	15.00	8.00	18.81	64.50
15:40:02	129.60	34.80				3.00	11.30	14.00	9.00	18.84	64.20
15:40:07	129.90	34.70				3.00	11.10	14.00	9.00	18.90	63.10
15:40:12	129.40	34.60				3.00	11.20	14.00	8.00	18.84	64.20
15:40:17	126.20	34.70				3.00	11.20	14.00	9.00	18.84	65.30
15:40:22	124.10	34.90				3.00	11.00	14.00	9.00	18.90	65.20
15:40:27	123.20	34.90				3.00	10.70	13.00	8.00	18.98	64.30
15:40:32	123.60	34.90				3.00	10.40	13.00	8.00	18.99	64.10
15:40:37	121.80	34.80				3.00	10.00	13.00	8.00	19.02	64.20
15:40:42	122.30	34.30				2.00	10.00	12.00	8.00	19.07	62.90
15:40:47	121.50	34.20				2.00	9.90	12.00	8.00	19.05	63.50
15:40:52	122.10	34.20				2.00	10.00	12.00	8.00	19.02	63.90
15:40:57	124.40	34.10				2.00	10.10	12.00	8.00	19.00	63.90
15:41:02	126.20	34.20				2.00	10.40	12.00	8.00	18.94	63.70
15:41:07	124.60	34.40				2.00	10.40	12.00	8.00	18.93	64.40
15:41:12	124.80	34.60				1.00	10.40	12.00	8.00	18.94	64.30
15:41:17	123.90	34.70				1.00	10.30	12.00	8.00	18.95	64.50

Table O 24: Temperature at pyrolysis chamber for Experiment (iv-3); AVR = 4.00:0.00 (OPKS)

Mean		224.36											
Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)
0	0.00	14.5	307.00	29	176.00	43.5	151.00	58	137.00				
0.5	298.00	15	290.00	29.5	173.00	44	150.00	58.5	135.00				
1	387.00	15.5	268.00	30	169.00	44.5	147.00	59	134.00				
1.5	415.00	16	318.00	30.5	164.00	45	144.00	59.5	133.00				
2	436.00	16.5	248.00	31	156.00	45.5	145.00	60	131.00				
2.5	442.00	17	218.00	31.5	151.00	46	142.00						
3	428.00	17.5	267.00	32	178.00	46.5	140.00						
3.5	457.00	18	245.00	32.5	185.00	47	138.00						
4	442.00	18.5	235.00	33	182.00	47.5	138.00						
4.5	448.00	19	231.00	33.5	180.00	48	138.00						
5	454.00	19.5	224.00	34	176.00	48.5	136.00						
5.5	431.00	20	219.00	34.5	171.00	49	135.00						
6	429.00	20.5	217.00	35	166.00	49.5	135.00						
6.5	434.00	21	210.00	35.5	163.00	50	133.00						
7	401.00	21.5	227.00	36	157.00	50.5	139.00						
7.5	409.00	22	242.00	36.5	151.00	51	182.00						
8	412.00	22.5	217.00	37	148.00	51.5	182.00						
8.5	407.00	23	207.00	37.5	145.00	52	173.00						
9	392.00	23.5	248.00	38	144.00	52.5	167.00						
9.5	373.00	24	225.00	38.5	142.00	53	162.00						
10	347.00	24.5	208.00	39	139.00	53.5	158.00						
10.5	350.00	25	197.00	39.5	161.00	54	154.00						
11	347.00	25.5	189.00	40	192.00	54.5	150.00						
11.5	347.00	26	181.00	40.5	188.00	55	146.00						

12	333.00	26.5	174.00	41	178.00	55.5	144.00
12.5	326.00	27	160.00	41.5	170.00	56	144.00
13	324.00	27.5	180.00	42	165.00	56.5	143.00
13.5	313.00	28	184.00	42.5	158.00	57	139.00
14	304.00	28.5	179.00	43	154.00	57.5	139.00

Experiment set (v-1)

Date = 4/1/2013; Sample = About 3 Kg of OPKS; Methanol = About 3 Liter; AVR = 4.00:5.79

Measurement rate = 5 seconds; Gas time = 2 minutes; Rinse time = 5 minutes; Mean = 1 second; To make the data meaningful, rinse time is neglected

Table O 25: Results of TESTO Experiment (v-1); AVR = 4.00:5.79 (OPKS)

Mean	109.43	31.13	329.26	126.46	2.98	9.17	12.13	8.50	19.46	60.46
Time	FT (°C)	AT (°C)	CO (ppmv)	H2 (ppmv)	NO (ppmv)	NO2 (ppmv)	NOx (ppmv)	SO2 (ppmv)	O2 (%)	η (%)
15:17:34	134.60	32.10	10.00	109.00	4.00	0.10	3.00	0.00	20.82	
15:17:39	122.10	31.00	81.00	217.00	4.00	1.10	6.00	2.00	19.60	
15:17:44	121.30	31.00	244.00	267.00	4.00	2.70	7.00	9.00	17.99	73.80
15:17:49	127.50	31.20	336.00	241.00	5.00	3.00	8.00	12.00	17.70	73.60
15:17:54	117.40	31.20	337.00	180.00	5.00	3.00	8.00	12.00	17.57	77.40
15:17:59	122.40	31.20	305.00	141.00	4.00	3.10	7.00	11.00	17.54	76.50
15:18:04	122.70	31.30	272.00	122.00	4.00	3.40	8.00	9.00	17.44	77.10
15:18:09	119.80	31.30	253.00	116.00	4.00	3.70	8.00	9.00	17.45	77.70
15:18:14	121.60	31.20	234.00	114.00	4.00	4.00	8.00	8.00	17.50	77.10
15:18:19	124.10	31.10	214.00	112.00	4.00	4.40	8.00	7.00	17.49	76.60
18:18:24	122.80	31.20	209.00	117.00	5.00	4.70	9.00	6.00	17.45	77.10
15:18:29	123.90	31.20	209.00	119.00	4.00	4.90	9.00	6.00	17.46	76.90
15:18:34	122.00	31.20	207.00	125.00	4.00	5.60	10.00	6.00	17.48	71.10
15:18:39	123.10	31.20	200.00	122.00	4.00	5.90	10.00	6.00	17.54	76.60
15:18:44	122.30	31.10	194.00	124.00	4.00	6.40	10.00	6.00	17.52	76.80
15:18:49	128.50	31.10	195.00	127.00	4.00	6.60	11.00	6.00	17.55	75.30
15:18:54	128.80	31.20	199.00	129.00	4.00	6.80	11.00	6.00	17.51	75.50
15:18:59	129.50	31.20	196.00	128.00	5.00	7.20	12.00	6.00	17.53	75.30

15:19:04	128.10	31.20	188.00	126.00	4.00	7.50	12.00	5.00	17.55	75.50
15:19:09	127.50	31.20	182.00	126.00	4.00	7.80	12.00	5.00	17.58	75.50
15:19:14	127.60	31.10	181.00	129.00	5.00	8.10	13.00	5.00	17.58	75.40
15:19:19	130.20	31.00	183.00	133.00	5.00	8.30	13.00	5.00	17.56	74.90
15:19:24	129.70	31.00	185.00	133.00	4.00	8.60	13.00	5.00	17.57	74.90
15:19:29	131.90	31.00	184.00	131.00	4.00	8.70	13.00	5.00	17.60	74.30
15:24:36	131.30	31.90	156.00	54.00	1.00	10.00	11.00	3.00	18.35	68.50
15:24:41	132.30	32.00	154.00	56.00	1.00	10.10	11.00	3.00	18.33	68.50
15:24:46	132.00	31.80	155.00	56.00	1.00	10.40	12.00	3.00	18.30	68.80
15:24:51	131.40	31.60	156.00	57.00	1.00	10.40	12.00	3.00	18.35	68.40
15:24:56	130.60	31.70	158.00	56.00	1.00	10.30	11.00	3.00	18.36	68.50
15:25:01	132.90	31.60	159.00	58.00	1.00	10.40	11.00	2.00	18.35	67.90
15:25:06	131.90	31.30	161.00	57.00	0.00	10.50	11.00	2.00	18.36	68.00
15:25:11	131.60	31.40	162.00	58.00	1.00	10.20	11.00	3.00	18.41	67.60
15:25:16	131.10	31.40	167.00	57.00	1.00	10.20	11.00	3.00	18.45	67.30
15:25:21	128.20	31.50	173.00	57.00	1.00	10.10	11.00	3.00	18.52	67.30
15:25:26	127.40	31.70	174.00	60.00	1.00	10.00	11.00	3.00	18.56	67.10
15:25:31	125.70	31.70	174.00	60.00	0.00	10.00	11.00	3.00	18.56	67.70
15:25:36	128.30	31.50	175.00	62.00	0.00	10.10	11.00	3.00	18.56	66.90
15:25:41	126.00	31.30	174.00	65.00	0.00	10.60	11.00	3.00	18.55	67.60
15:25:46	124.50	31.30	172.00	67.00	0.00	10.50	11.00	3.00	18.60	67.40
15:25:51	124.40	31.40	171.00	68.00	1.00	10.40	11.00	3.00	18.64	67.00
15:25:56	125.90	31.40	175.00	67.00	1.00	10.30	11.00	3.00	18.67	66.20
15:26:01	125.50	31.60	181.00	66.00	0.00	10.30	10.00	3.00	18.66	66.40
15:26:06	124.20	31.40	187.00	66.00	0.00	10.30	11.00	3.00	18.69	66.40
15:26:11	125.30	31.50	192.00	69.00	1.00	10.20	11.00	3.00	18.74	65.40
15:26:16	126.50	31.40	197.00	70.00	0.00	10.50	10.00	3.00	18.68	65.70
15:26:21	126.20	31.30	202.00	72.00	0.00	10.50	10.00	3.00	18.73	65.10
15:26:26	123.20	31.50	203.00	76.00	0.00	10.60	10.00	4.00	18.77	65.70

15:26:31	123.20	31.30	203.00	78.00	0.00	10.50	10.00	4.00	18.84	64.60
15:31:38	132.60	31.30	193.00	102.00	3.00	12.70	16.00	4.00	18.39	67.40
15:31:43	130.90	31.10	195.00	89.00	4.00	13.30	17.00	4.00	18.37	68.10
15:31:48	130.70	31.20	201.00	80.00	4.00	13.40	17.00	4.00	18.40	67.70
15:31:53	127.90	31.00	210.00	73.00	4.00	13.50	17.00	4.00	18.48	67.60
15:31:58	125.90	31.20	220.00	70.00	4.00	13.40	17.00	4.00	18.59	67.00
15:32:03	126.00	31.30	227.00	71.00	4.00	13.40	17.00	4.00	18.67	65.90
15:32:08	126.00	31.30	231.00	72.00	4.00	13.50	17.00	4.00	18.72	65.30
15:32:13	123.40	31.40	237.00	71.00	4.00	13.40	17.00	4.00	18.79	35.10
15:32:18	122.50	31.50	241.00	71.00	4.00	13.30	17.00	5.00	18.88	64.10
15:32:23	120.70	31.60	247.00	73.00	4.00	13.20	17.00	5.00	18.93	64.10
15:32:28	117.40	31.50	253.00	74.00	4.00	13.10	17.00	5.00	19.00	64.00
15:32:33	117.80	31.70	254.00	78.00	4.00	12.90	17.00	5.00	19.06	63.00
15:32:38	116.40	31.80	254.00	78.00	4.00	12.90	17.00	5.00	19.07	63.40
15:32:43	114.00	31.90	255.00	80.00	4.00	12.30	16.00	5.00	19.15	62.90
15:32:48	114.10	31.00	254.00	83.00	4.00	11.90	16.00	5.00	19.22	61.60
15:32:53	113.50	32.10	258.00	79.00	4.00	11.90	16.00	5.00	19.15	61.20
15:32:58	111.70	32.00	264.00	79.00	4.00	11.70	16.00	5.00	19.30	61.00
15:33:03	112.20	32.10	266.00	83.00	4.00	11.40	16.00	5.00	19.36	59.50
15:33:08	112.00	32.10	269.00	83.00	4.00	11.30	16.00	5.00	19.36	59.60
15:33:13	106.40	32.20	276.00	82.00	4.00	11.00	15.00	6.00	19.41	61.00
18:33:18	107.00	32.00	280.00	86.00	4.00	10.30	14.00	6.00	19.50	58.20
15:33:23	123.60	31.90	268.00	96.00	4.00	10.10	14.00	6.00	19.44	51.90
15:33:28	130.50	31.90	245.00	105.00	4.00	11.10	15.00	6.00	19.03	58.80
15:33:33	127.90	32.10	220.00	108.00	4.00	12.20	16.00	4.00	19.80	63.80
15:38:40	116.30	31.50	261.00	61.00	4.00	15.50	20.00	4.00	19.26	59.50
15:38:45	114.20	31.50	268.00	61.00	4.00	15.40	19.00	5.00	19.31	59.40
15:38:50	113.00	31.50	271.00	62.00	4.00	15.20	20.00	4.00	19.34	59.30
15:38:55	114.10	31.50	273.00	64.00	5.00	15.10	20.00	5.00	19.39	57.70

15:39:00	113.80	31.70	272.00	66.00	5.00	15.40	20.00	5.00	19.37	58.30
15:39:05	111.40	31.70	274.00	66.00	5.00	15.10	20.00	5.00	19.45	57.40
15:39:10	111.80	31.90	273.00	68.00	5.00	14.60	19.00	4.00	19.51	55.70
15:39:15	111.80	31.90	275.00	69.00	5.00	14.60	19.00	4.00	19.51	55.70
15:39:20	113.30	31.80	281.00	67.00	4.00	14.70	19.00	5.00	19.50	55.20
15:39:25	110.20	31.70	286.00	68.00	4.00	14.80	19.00	5.00	19.51	56.30
15:39:30	109.50	31.70	284.00	73.00	5.00	14.10	19.00	5.00	19.59	54.50
15:39:35	109.40	31.80	280.00	76.00	5.00	13.80	18.00	5.00	19.62	53.80
15:39:40	111.20	31.90	280.00	76.00	5.00	13.80	18.00	5.00	19.61	53.00
15:39:45	110.40	31.90	281.00	76.00	5.00	13.80	18.00	5.00	19.61	53.50
15:39:50	108.80	31.80	285.00	77.00	4.00	13.80	18.00	5.00	19.64	53.40
15:39:55	108.40	31.60	284.00	79.00	4.00	13.80	18.00	5.00	19.64	53.50
15:40:00	106.40	31.80	282.00	79.00	4.00	13.40	18.00	5.00	19.67	53.70
15:40:05	105.70	32.00	281.00	79.00	4.00	13.20	17.00	5.00	19.70	53.30
15:40:10	106.50	32.20	280.00	79.00	4.00	12.90	17.00	5.00	19.73	52.00
15:40:15	107.00	32.20	285.00	77.00	5.00	13.10	18.00	5.00	19.68	53.20
15:40:20	106.10	32.20	290.00	79.00	4.00	13.00	17.00	5.00	19.69	53.40
15:40:25	107.30	32.20	289.00	82.00	4.00	12.70	17.00	5.00	19.72	51.90
15:40:30	105.70	32.10	293.00	81.00	4.00	12.70	17.00	6.00	19.72	52.50
15:40:35	105.00	31.90	296.00	82.00	4.00	12.40	16.00	6.00	19.76	51.60
15:45:42	93.70	31.10	409.00	136.00	3.00	5.30	8.00	11.00	20.18	
15:45:47	90.50	31.00	401.00	142.00	3.00	5.00	8.00	11.00	20.26	
15:45:52	102.58	31.10	381.00	146.00	3.00	4.70	8.00	10.00	20.22	
15:45:57	114.30	31.20	340.00	156.00	3.00	5.90	9.00	9.00	19.94	
15:46:02	121.40	31.10	296.00	159.00	3.00	8.40	12.00	8.00	19.51	50.20
15:46:07	125.60	30.80	265.00	146.00	3.00	10.80	14.00	6.00	19.14	57.80
15:46:12	125.50	30.90	253.00	124.00	4.00	12.80	16.00	6.00	18.91	62.30
15:46:17	123.30	31.00	255.00	106.00	4.00	14.20	18.00	5.00	18.88	63.70
15:46:22	120.60	31.00	257.00	93.00	4.00	14.50	19.00	5.00	18.90	64.20

15:46:27	117.10	31.10	255.00	85.00	4.00	14.50	19.00	5.00	18.99	64.10
15:46:32	119.00	31.00	249.00	80.00	5.00	14.50	19.00	4.00	19.05	62.40
15:46:37	116.70	30.70	250.00	71.00	5.00	15.00	20.00	4.00	19.04	63.40
15:46:42	114.20	30.80	258.00	63.00	5.00	14.80	19.00	4.00	19.13	62.70
15:46:47	115.20	30.80	259.00	62.00	4.00	14.40	18.00	4.00	19.20	60.90
15:46:52	116.80	30.80	261.00	61.00	4.00	14.50	19.00	4.00	19.21	60.20
15:46:57	118.40	31.00	270.00	57.00	4.00	14.80	18.00	5.00	19.21	59.50
15:47:02	117.90	31.10	275.00	56.00	4.00	15.00	19.00	5.00	19.21	59.70
15:47:07	114.70	31.10	280.00	55.00	4.00	14.70	19.00	5.00	19.26	60.70
15:47:12	114.40	31.10	280.00	57.00	4.00	14.20	18.00	5.00	19.34	58.40
15:47:17	114.70	31.20	275.00	60.00	4.00	14.00	18.00	5.00	19.36	57.90
15:47:22	112.60	31.30	268.00	62.00	4.00	13.90	18.00	5.00	19.40	58.10
15:47:27	111.80	31.10	267.00	59.00	4.00	13.60	18.00	5.00	19.44	57.40
15:47:32	110.60	31.20	266.00	58.00	4.00	13.30	17.00	5.00	19.46	57.30
15:47:37	110.00	31.20	266.00	58.00	4.00	12.90	17.00	5.00	19.51	56.50
15:52:44	107.90	30.40	308.00	65.00	4.00	11.50	15.00	6.00	19.70	50.90
15:52:49	109.50	30.50	317.00	64.00	4.00	11.20	15.00	7.00	19.72	49.50
15:52:54	108.90	30.60	329.00	63.00	4.00	11.10	15.00	7.00	19.72	49.70
15:52:59	107.80	30.50	336.00	68.00	4.00	10.90	15.00	7.00	19.75	49.30
15:53:04	108.20	30.40	337.00	72.00	4.00	10.80	14.00	7.00	19.77	48.20
15:53:09	109.10	30.40	336.00	77.00	4.00	10.90	15.00	7.00	19.75	48.30
15:53:14	107.60	30.30	343.00	76.00	4.00	10.80	15.00	7.00	19.75	49.20
15:53:19	105.50	30.40	349.00	79.00	4.00	10.50	14.00	8.00	19.80	48.60
15:53:24	106.60	30.30	346.00	85.00	4.00	9.80	13.00	8.00	19.85	45.70
15:53:29	105.50	30.30	341.00	88.00	3.00	10.00	13.00	8.00	19.84	46.70
15:53:24	103.10	30.20	341.00	87.00	3.00	9.70	13.00	8.00	19.87	47.00
15:53:39	104.30	30.10	341.00	88.00	4.00	9.40	13.00	8.00	19.89	45.10
15:53:44	105.10	30.20	348.00	85.00	4.00	9.30	13.00	8.00	19.89	44.50
15:53:49	104.20	30.30	354.00	86.00	3.00	9.30	12.00	9.00	19.88	45.70

15:53:54	103.80	30.40	355.00	87.00	3.00	9.30	12.00	9.00	19.88	45.90
15:53:59	97.00	30.50	352.00	92.00	3.00	9.00	12.00	8.00	19.95	
15:54:04	100.20	30.50	329.00	104.00	3.00	7.90	11.00	8.00	20.11	
15:54:09	118.60	30.30	296.00	111.00	4.00	9.20	13.00	7.00	19.96	
15:54:14	125.60	30.30	275.00	106.00	4.00	12.70	17.00	6.00	19.55	46.60
15:54:19	126.70	30.30	258.00	100.00	4.00	15.80	20.00	5.00	19.25	54.90
15:54:24	130.50	30.40	246.00	93.00	5.00	18.00	23.00	4.00	18.99	59.00
15:54:29	129.00	30.40	249.00	78.00	5.00	19.30	24.00	4.00	18.83	62.20
15:54:34	124.50	30.50	266.00	64.00	5.00	19.40	24.00	4.00	18.84	63.70
15:54:39	121.20	30.70	279.00	61.00	5.00	18.70	24.00	4.00	18.92	63.50
15:59:46	113.40	31.20	309.00	64.00	4.00	13.50	18.00	7.00	19.55	53.20
15:59:51	112.10	31.20	316.00	66.00	4.00	12.80	16.00	7.00	19.64	51.00
15:59:56	110.50	31.30	317.00	71.00	4.00	12.40	16.00	7.00	19.68	50.70
16:00:01	109.00	31.10	317.00	74.00	4.00	11.90	16.00	7.00	19.73	49.60
16:00:06	111.70	30.80	320.00	74.00	4.00	11.70	15.00	7.00	19.73	48.00
16:00:11	113.00	30.70	329.00	74.00	4.00	12.10	16.00	7.00	19.67	49.20
16:00:16	111.50	30.50	342.00	74.00	4.00	12.30	16.00	8.00	19.66	50.40
16:00:21	111.80	30.60	349.00	78.00	4.00	12.00	16.00	8.00	19.67	49.70
16:00:26	110.50	30.50	353.00	81.00	4.00	11.90	16.00	8.00	19.69	49.90
16:00:31	109.30	30.50	358.00	84.00	4.00	11.40	15.00	8.00	19.73	49.00
16:00:36	109.20	30.50	362.00	87.00	4.00	11.20	15.00	8.00	19.76	47.90
16:00:41	108.10	30.70	366.00	89.00	4.00	11.10	15.00	8.00	19.76	48.40
16:00:46	97.20	30.80	372.00	90.00	4.00	10.50	14.00	9.00	19.84	52.40
16:00:51	89.50	30.80	328.00	119.00	3.00	7.70	11.00	8.00	20.40	
16:00:56	89.80	30.70	284.00	114.00	3.00	8.10	11.00	6.00	20.00	
16:01:01	100.00	30.70	289.00	106.00	3.00	8.30	12.00	7.00	19.95	46.00
16:01:16	127.90	30.70	282.00	105.00	4.00	10.60	15.00	7.00	19.69	39.60
16:01:11	136.80	30.70	247.00	107.00	5.00	15.20	20.00	5.00	19.24	50.80
16:01:16	133.90	30.60	225.00	99.00	6.00	17.70	23.00	4.00	18.95	58.60

16:01:21	130.20	30.40	219.00	85.00	5.00	18.80	24.00	3.00	18.82	62.20
16:01:26	129.30	30.60	223.00	69.00	6.00	19.30	25.00	2.00	18.79	62.90
16:01:31	126.60	30.70	229.00	61.00	5.00	19.40	24.00	3.00	18.84	63.10
16:01:36	123.40	30.50	236.00	55.00	5.00	18.90	24.00	3.00	18.94	62.50
16:01:41	121.70	30.40	241.00	54.00	5.00	18.30	23.00	3.00	19.06	61.00
16:06:48	102.80	30.30	459.00	124.00	3.00	8.30	11.00	13.00	20.02	
16:06:53	101.50	30.40	466.00	130.00	3.00	8.30	11.00	13.00	20.04	
16:06:58	100.40	30.50	469.00	135.00	3.00	7.80	11.00	14.00	20.06	
16:07:03	99.90	30.50	474.00	138.00	3.00	7.70	10.00	14.00	20.09	
16:07:08	102.10	30.40	478.00	142.00	3.00	7.40	10.00	14.00	20.09	
16:07:13	101.60	30.30	487.00	142.00	3.00	7.60	10.00	15.00	20.06	
16:07:18	99.90	30.30	497.00	146.00	2.00	7.40	10.00	15.00	20.10	
16:07:23	99.10	30.30	499.00	154.00	3.00	7.00	10.00	15.00	20.14	
16:07:28	99.80	30.40	500.00	158.00	3.00	7.00	10.00	15.00	20.13	
16:07:33	99.80	30.40	504.00	161.00	3.00	6.90	9.00	15.00	20.13	
16:07:38	99.39	30.30	509.00	164.00	3.00	6.90	10.00	15.00	20.13	
16:07:43	98.60	30.50	511.00	167.00	2.00	6.70	9.00	15.00	20.14	
16:07:48	99.80	30.40	509.00	172.00	2.00	6.60	9.00	15.00	20.16	
16:07:53	100.00	30.30	520.00	168.00	2.00	6.70	9.00	16.00	20.11	
16:07:58	98.00	30.40	536.00	167.00	2.00	6.70	9.00	16.00	20.14	
16:08:03	96.80	30.40	536.00	176.00	3.00	6.30	9.00	17.00	20.18	
16:08:08	96.50	30.40	535.00	178.00	3.00	6.20	9.00	16.00	20.19	
16:08:13	97.30	30.50	523.00	187.00	2.00	5.90	8.00	16.00	20.20	
16:08:18	96.50	30.60	524.00	186.00	2.00	6.00	8.00	16.00	20.19	
16:08:23	95.80	30.50	525.00	188.00	2.00	5.80	8.00	16.00	20.22	
16:08:28	97.70	30.30	524.00	189.00	2.00	5.70	8.00	16.00	20.22	
16:08:33	98.00	30.30	537.00	183.00	2.00	5.90	8.00	17.00	20.18	
16:08:38	98.70	30.50	554.00	182.00	2.00	5.90	8.00	17.00	20.17	
16:08:43	97.40	30.50	569.00	185.00	2.00	6.10	8.00	18.00	20.16	

16:13:50	91.60	30.60	547.00	237.00	1.00	4.40	6.00	17.00	20.35	
16:13:55	91.50	30.70	539.00	236.00	1.00	4.40	6.00	17.00	20.36	
16:14:00	91.80	30.70	537.00	233.00	1.00	4.40	6.00	17.00	20.35	
16:14:05	91.90	30.60	542.00	230.00	1.00	4.40	6.00	17.00	20.34	
16:14:10	91.40	30.60	542.00	231.00	1.00	4.40	6.00	17.00	20.36	
16:14:15	91.30	30.60	536.00	234.00	1.00	4.30	6.00	17.00	20.36	
16:14:20	91.20	30.70	530.00	234.00	1.00	4.20	5.00	17.00	20.38	
16:14:25	91.10	30.80	526.00	232.00	1.00	4.10	5.00	17.00	20.38	
16:14:30	91.50	30.80	529.00	226.00	1.00	4.20	6.00	17.00	20.38	
16:14:35	92.20	31.00	537.00	223.00	1.00	4.20	6.00	17.00	20.36	
16:14:40	91.00	31.00	548.00	222.00	1.00	4.30	6.00	17.00	20.35	
16:14:45	89.10	31.00	547.00	229.00	1.00	4.10	5.00	18.00	20.39	
16:14:50	90.40	31.00	534.00	236.00	1.00	4.00	5.00	17.00	20.40	
16:14:55	90.60	31.00	530.00	232.00	1.00	4.00	5.00	17.00	20.39	
16:15:00	90.20	31.10	532.00	231.00	1.00	3.80	5.00	17.00	20.40	
16:15:05	90.50	30.90	529.00	230.00	1.00	3.90	5.00	17.00	20.40	
16:15:10	90.50	30.80	532.00	229.00	1.00	4.00	5.00	17.00	20.39	
16:15:15	90.30	30.90	535.00	228.00	1.00	4.00	5.00	17.00	20.40	
16:15:20	90.50	30.80	543.00	229.00	1.00	4.00	5.00	18.00	20.41	
16:15:25	90.60	30.90	555.00	227.00	1.00	4.00	5.00	18.00	20.38	
16:15:30	89.40	30.90	562.00	232.00	1.00	3.80	4.00	18.00	20.41	
16:15:35	88.30	31.10	553.00	242.00	1.00	3.60	4.00	18.00	20.43	
16:15:40	88.40	31.10	542.00	246.00	1.00	3.50	4.00	18.00	20.46	
16:15:45	89.60	31.10	531.00	247.00	0.00	3.70	4.00	18.00	20.46	
16:20:52	82.20	31.60	471.00	267.00	1.00	1.70	3.00	15.00	20.66	
16:20:57	82.50	31.60	461.00	268.00	1.00	1.70	3.00	15.00	20.65	
16:21:02	82.70	31.70	462.00	263.00	1.00	1.50	2.00	15.00	20.65	
16:21:07	82.30	31.60	461.00	263.00	1.00	1.50	3.00	15.00	20.66	
16:21:12	82.10	31.70	456.00	263.00	2.00	1.70	3.00	14.00	20.67	

16:21:17	81.70	31.60	453.00	262.00	2.00	1.50	3.00	15.00	20.67	
16:21:22	81.90	31.70	450.00	262.00	1.00	1.50	3.00	15.00	20.68	
16:21:27	81.90	31.70	446.00	263.00	1.00	1.50	3.00	14.00	20.67	
16:21:32	82.30	31.60	446.00	260.00	1.00	1.70	3.00	14.00	20.67	
16:21:37	82.10	31.80	449.00	258.00	1.00	1.60	3.00	15.00	20.67	
16:21:42	81.40	31.60	449.00	259.00	1.00	1.70	3.00	15.00	20.67	
16:21:47	80.80	31.70	442.00	260.00	1.00	1.60	3.00	14.00	20.69	
16:21:52	81.40	31.70	430.00	263.00	1.00	1.50	3.00	14.00	20.69	
16:21:57	81.80	31.80	427.00	256.00	1.00	1.50	3.00	14.00	20.69	
16:22:02	81.40	31.80	428.00	252.00	1.00	1.40	3.00	14.00	20.69	
16:22:07	81.40	31.80	426.00	253.00	1.00	1.40	3.00	14.00	20.69	
16:22:12	81.40	31.90	427.00	249.00	1.00	1.50	2.00	14.00	20.69	
16:22:17	80.10	31.80	428.00	248.00	1.00	1.50	2.00	14.00	20.69	
16:22:22	80.20	31.70	423.00	251.00	1.00	1.50	3.00	14.00	20.70	
16:22:27	80.50	31.80	404.00	255.00	1.00	1.50	3.00	13.00	20.73	
16:22:32	81.00	31.70	393.00	250.00	1.00	1.50	2.00	13.00	20.73	
16:22:37	81.00	31.80	393.00	240.00	1.00	1.50	2.00	13.00	20.72	
16:22:42	80.70	31.80	401.00	233.00	1.00	1.50	2.00	13.00	20.72	
16:22:47	80.50	31.80	412.00	231.00	1.00	1.50	2.00	13.00	20.71	

Table O 26: Temperature at pyrolysis chamber for Experiment (v-1); AVR = 4.00:5.79 (OPKS)

Mean		247.86															
Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)
0	0.00	14.5	307.00	29	282.00	43.5	211.00	58	173.00								
0.5	233.00	15	283.00	29.5	270.00	44	235.00	58.5	171.00								
1	270.00	15.5	258.00	30	263.00	44.5	223.00	59	169.00								
1.5	285.00	16	325.00	30.5	250.00	45	211.00	59.5	168.00								
2	293.00	16.5	270.00	31	244.00	45.5	202.00	60	170.00								
2.5	316.00	17	251.00	31.5	238.00	46	193.00	60.5	177.00								
3	307.00	17.5	326.00	32	259.00	46.5	189.00	61	187.00								
3.5	304.00	18	301.00	32.5	277.00	47	187.00	61.5	207.00								
4	299.00	18.5	298.00	33	274.00	47.5	208.00	62	224.00								
4.5	301.00	19	282.00	33.5	258.00	48	203.00	62.5	231.00								
5	313.00	19.5	259.00	34	265.00	48.5	195.00	63	232.00								
5.5	303.00	20	242.00	34.5	257.00	49	187.00	63.5	232.00								
6	304.00	20.5	383.00	35	241.00	49.5	182.00	64	232.00								
6.5	298.00	21	385.00	35.5	231.00	50	177.00	64.5	235.00								
7	291.00	21.5	362.00	36	228.00	50.5	173.00	65	239.00								
7.5	189.00	22	333.00	36.5	220.00	51	170.00	65.5	240.00								
8	288.00	22.5	396.00	37	240.00	51.5	165.00	66	240.00								
8.5	304.00	23	439.00	37.5	231.00	52	178.00										
9	289.00	23.5	417.00	38	217.00	52.5	179.00										
9.5	280.00	24	378.00	38.5	207.00	53	176.00										
10	278.00	24.5	360.00	39	198.00	53.5	175.00										
10.5	277.00	25	362.00	39.5	190.00	54	173.00										
11	274.00	25.5	372.00	40	209.00	54.5	170.00										
11.5	275.00	26	337.00	40.5	239.00	55	169.00										

12	277.00	26.5	283.00	41	236.00	55.5	167.00
12.5	272.00	27	279.00	41.5	226.00	56	165.00
13	269.00	27.5	260.00	42	214.00	56.5	165.00
13.5	255.00	28	242.00	42.5	209.00	57	167.00
14	283.00	28.5	276.00	43	206.00	57.5	172.00

Experiment set (v-2)

Date = 7/1/2013; Sample = About 3 Kg of OPKS; Methanol = About 3 Liter; AVR = 4.00:5.79

Measurement rate = 5 seconds; Gas time = 2 minutes; Rinse time = 5 minutes; Mean = 1 second; To make the data meaningful, rinse time is neglected

Table O 27: Result of TESTO Experiment (v-2); AVR = 4.00:5.79 (OPKS)

Mean	102.34	31.59	223.66	59.44	3.98	7.94	11.89	3.78	19.34	64.75
Time	FT (°C)	AT (°C)	CO (ppmv)	H2 (ppmv)	NO (ppmv)	NO2 (ppmv)	NOx (ppmv)	SO2 (ppmv)	O2 (%)	η (%)
10:41:30	110.90	29.80	0.00	1.00	0.00	0.10	0.00	0.00	20.92	
10:41:35	134.80	30.60	29.00	17.00	0.00	1.10	2.00	1.00	19.62	
10:41:40	119.30	30.50	147.00	61.00	1.00	1.90	3.00	4.00	17.86	75.30
10:41:45	114.10	30.60	217.00	46.00	1.00	2.00	3.00	6.00	17.69	77.50
10:41:50	116.70	30.50	245.00	16.00	1.00	2.00	3.00	7.00	17.52	77.80
10:41:55	121.80	30.60	271.00	2.00	1.00	1.90	3.00	7.00	17.40	77.30
10:42:00	115.10	30.60	298.00	9.00	1.00	1.90	3.00	8.00	17.37	78.90
10:42:05	118.50	30.60	307.00	24.00	1.00	2.00	3.00	8.00	17.49	77.50
10:42:10	120.70	30.60	302.00	39.00	1.00	2.10	3.00	8.00	17.49	77.10
10:42:15	122.80	30.60	297.00	48.00	1.00	2.30	3.00	8.00	17.45	76.80
10:42:20	121.90	30.60	291.00	51.00	1.00	2.50	4.00	8.00	17.46	77.00
10:42:25	122.90	30.60	293.00	50.00	2.00	2.70	4.00	8.00	17.53	76.40
10:42:30	127.50	30.60	290.00	54.00	2.00	2.70	4.00	8.00	17.50	75.60
10:42:35	127.30	30.60	283.00	57.00	2.00	2.90	5.00	7.00	17.41	76.10
10:42:40	122.60	30.60	280.00	56.00	2.00	3.20	5.00	7.00	17.47	76.80
10:45:45	124.70	30.70	285.00	54.00	1.00	3.20	4.00	7.00	17.60	75.60
10:42:50	121.60	30.60	290.00	54.00	1.00	3.40	5.00	7.00	17.57	76.40
10:42:55	123.00	30.70	292.00	55.00	2.00	3.40	5.00	8.00	17.62	75.80

10:43:00	124.10	30.70	294.00	56.00	1.00	3.60	5.00	7.00	17.62	75.60
10:43:05	117.90	30.70	297.00	55.00	1.00	3.80	5.00	7.00	17.63	76.80
10:43:10	117.30	30.70	299.00	57.00	1.00	4.00	5.00	7.00	17.76	76.20
10:43:15	115.50	30.70	294.00	62.00	2.00	4.20	6.00	7.00	17.77	76.60
10:43:20	113.90	30.70	295.00	61.00	2.00	4.30	6.00	7.00	17.81	76.70
10:43:25	114.50	30.70	296.00	61.00	2.00	4.40	6.00	7.00	17.86	76.20
10:48:32	119.80	31.20	230.00	52.00	2.00	6.00	8.00	4.00	18.83	71.50
10:48:37	118.20	31.20	228.00	57.00	2.00	5.90	8.00	4.00	18.41	71.10
10:48:42	113.10	31.20	226.00	57.00	2.00	6.00	8.00	4.00	18.38	70.10
10:48:47	121.70	31.20	233.00	54.00	2.00	6.30	8.00	4.00	18.34	70.90
10:48:52	119.30	31.20	233.00	58.00	2.00	6.20	8.00	4.00	18.40	70.90
10:48:57	118.60	31.20	228.00	60.00	2.00	6.20	8.00	3.00	18.44	70.80
10:49:02	118.40	31.20	225.00	62.00	2.00	6.30	8.00	3.00	18.43	71.00
10:49:07	118.40	31.20	226.00	60.00	2.00	6.30	8.00	3.00	18.40	71.20
10:49:12	121.50	31.20	229.00	59.00	2.00	6.10	8.00	4.00	18.43	70.10
10:49:17	128.20	31.20	231.00	61.00	2.00	6.20	8.00	4.00	18.41	71.20
10:49:22	115.10	31.30	232.00	60.00	2.00	6.10	8.00	4.00	18.47	71.50
10:49:27	114.60	31.30	229.00	64.00	2.00	6.10	8.00	3.00	18.55	70.90
10:49:32	116.90	31.30	224.00	66.00	1.00	6.10	7.00	4.00	18.53	70.40
10:49:37	115.90	31.20	224.00	65.00	1.00	6.10	7.00	4.00	18.51	70.80
10:49:42	116.00	31.30	221.00	66.00	1.00	6.10	7.00	3.00	18.54	70.50
10:49:47	113.90	31.30	224.00	64.00	2.00	6.20	8.00	3.00	18.54	71.20
10:49:52	116.50	31.20	228.00	63.00	1.00	6.10	7.00	3.00	18.56	70.10
10:49:57	117.40	31.30	230.00	64.00	1.00	6.10	7.00	4.00	18.56	69.90
10:50:02	116.20	31.30	228.00	68.00	1.00	6.10	7.00	4.00	18.60	69.80
10:50:07	118.30	31.30	226.00	69.00	1.00	6.20	7.00	3.00	18.61	69.10
10:50:12	118.00	31.30	227.00	68.00	1.00	6.30	7.00	3.00	18.59	69.40
10:50:17	116.80	31.30	231.00	66.00	1.00	6.10	7.00	3.00	18.61	69.50
10:50:22	115.80	31.30	230.00	70.00	1.00	6.10	7.00	3.00	18.64	69.60

10:50:27	115.50	31.30	228.00	71.00	1.00	6.20	7.00	4.00	18.69	69.10
10:55:34	93.10	31.30	246.00	81.00	3.00	5.30	8.00	5.00	18.74	59.10
10:55:39	93.00	31.30	248.00	80.00	3.00	5.60	9.00	5.00	19.73	59.60
10:55:44	90.50	31.30	251.00	81.00	3.00	5.70	9.00	5.00	19.74	60.60
10:55:49	85.00	31.30	250.00	85.00	3.00	5.50	9.00	5.00	19.78	62.80
11:04:03	87.40	31.30	247.00	88.00	3.00	5.20	8.00	5.00	19.86	58.60
10:55:59	106.70	31.20	229.00	95.00	3.00	5.40	8.00	4.00	19.79	48.90
10:56:04	115.40	31.20	212.00	97.00	3.00	7.00	10.00	4.00	19.33	58.20
10:56:09	114.10	31.20	201.00	95.00	3.00	8.00	11.00	3.00	19.08	64.10
10:56:14	110.90	31.30	195.00	90.00	3.00	8.70	11.00	3.00	18.97	67.00
10:56:19	107.20	31.30	199.00	82.00	3.00	8.60	12.00	3.00	18.99	68.10
10:56:24	105.70	31.30	213.00	74.00	3.00	8.40	12.00	3.00	19.07	67.40
10:56:29	105.50	31.40	225.00	72.00	3.00	8.50	12.00	3.00	19.12	66.70
10:56:34	106.50	31.40	234.00	73.00	3.00	8.50	12.00	4.00	19.16	65.60
10:56:39	106.90	31.30	242.00	74.00	4.00	8.70	12.00	4.00	19.16	65.50
10:56:44	103.70	31.30	246.00	77.00	3.00	9.10	12.00	4.00	19.19	66.20
10:56:49	102.90	31.30	242.00	83.00	3.00	9.10	13.00	4.00	19.29	64.80
10:56:54	101.40	31.50	238.00	85.00	3.00	9.10	13.00	4.00	19.34	64.70
10:56:59	99.80	31.40	239.00	85.00	4.00	9.00	13.00	4.00	19.39	64.30
10:57:04	99.20	31.40	243.00	85.00	3.00	8.70	12.00	3.00	19.46	63.00
10:57:09	99.10	31.50	250.00	83.00	4.00	8.60	12.00	4.00	19.49	62.40
10:57:14	98.10	31.50	253.00	85.00	3.00	8.50	12.00	4.00	19.52	62.30
10:57:19	97.70	31.50	253.00	90.00	4.00	8.40	12.00	4.00	19.56	61.40
10:57:24	97.40	31.40	251.00	93.00	4.00	8.40	12.00	4.00	19.57	61.40
10:57:29	97.40	31.40	248.00	95.00	3.00	8.40	12.00	4.00	19.59	60.90
11:02:36	112.70	31.90	186.00	50.00	5.00	10.80	16.00	1.00	19.05	65.40
11:02:41	111.10	31.90	189.00	49.00	5.00	10.80	16.00	1.00	19.04	66.10
11:02:46	106.20	31.90	202.00	47.00	5.00	10.60	16.00	1.00	19.11	66.80
11:02:51	104.60	31.90	207.00	49.00	6.00	10.70	16.00	2.00	19.22	65.60

11:02:56	102.50	31.90	207.00	51.00	6.00	10.90	17.00	1.00	19.30	65.10
11:03:01	103.50	31.90	199.00	58.00	6.00	11.10	17.00	1.00	19.38	63.20
11:03:06	104.10	31.90	190.00	60.00	5.00	11.60	17.00	1.00	19.37	63.20
11:03:11	103.70	31.90	187.00	58.00	6.00	12.00	18.00	1.00	19.38	63.10
11:03:16	103.40	31.90	186.00	58.00	6.00	12.20	18.00	1.00	19.41	62.60
11:03:21	103.30	31.90	183.00	58.00	6.00	12.30	18.00	1.00	19.46	61.60
11:03:26	105.50	32.00	179.00	59.00	6.00	12.60	18.00	0.00	19.47	60.30
11:03:31	103.50	32.00	177.00	58.00	6.00	13.10	19.00	1.00	19.44	62.10
11:03:36	101.50	32.00	177.00	58.00	6.00	12.80	18.00	0.00	19.49	61.90
11:03:41	100.80	31.90	177.00	58.00	6.00	12.60	18.00	0.00	19.53	61.20
11:03:46	98.40	31.90	180.00	57.00	6.00	12.50	18.00	1.00	19.57	61.50
11:03:51	97.50	31.90	180.00	59.00	6.00	12.20	18.00	1.00	19.65	59.90
11:03:56	99.30	32.00	179.00	60.00	6.00	12.20	18.00	1.00	19.64	59.30
11:04:01	98.90	32.00	181.00	60.00	6.00	12.30	18.00	1.00	19.63	59.60
11:04:06	98.10	32.00	185.00	59.00	6.00	12.30	18.00	1.00	19.64	60.00
11:04:11	97.80	31.90	188.00	60.00	6.00	12.20	18.00	1.00	19.65	59.60
11:04:16	98.10	31.90	189.00	61.00	6.00	12.20	18.00	1.00	19.67	59.10
11:04:21	97.50	31.90	190.00	64.00	5.00	12.20	18.00	1.00	19.68	59.00
11:04:26	95.90	31.90	191.00	66.00	5.00	11.90	17.00	1.00	19.71	59.20
11:04:31	95.50	31.90	193.00	65.00	5.00	11.70	17.00	1.00	19.75	58.20
11:09:38	109.50	32.30	194.00	37.00	6.00	15.60	21.00	1.00	19.27	62.90
11:09:43	109.40	32.40	191.00	40.00	6.00	15.90	22.00	1.00	19.27	63.30
11:09:48	107.80	32.40	190.00	40.00	6.00	15.90	22.00	0.00	19.27	63.70
11:09:53	106.70	32.40	191.00	38.00	6.00	15.70	22.00	0.00	19.36	62.50
11:09:58	104.10	32.40	194.00	38.00	6.00	15.40	22.00	0.00	19.40	62.60
11:10:03	102.90	32.40	191.00	41.00	6.00	14.70	21.00	0.00	19.50	61.20
11:10:08	102.30	32.40	187.00	42.00	6.00	14.50	21.00	0.00	19.54	60.40
11:10:13	100.90	32.40	187.00	42.00	6.00	14.30	20.00	0.00	19.56	60.70
11:10:18	99.30	32.40	191.00	41.00	6.00	13.70	20.00	0.00	19.62	60.00

11:10:23	98.60	32.50	196.00	40.00	6.00	13.10	19.00	1.00	19.67	58.90
11:10:28	98.80	32.40	200.00	40.00	6.00	12.90	19.00	1.00	19.68	58.60
11:10:33	98.20	32.40	208.00	40.00	6.00	12.60	19.00	1.00	19.69	58.70
11:10:38	96.70	32.30	216.00	42.00	6.00	12.30	18.00	1.00	19.74	57.90
11:10:43	95.80	32.40	220.00	47.00	6.00	11.60	17.00	2.00	19.80	56.30
11:10:48	95.50	32.40	222.00	49.00	6.00	11.20	17.00	2.00	19.82	56.10
11:10:53	94.30	32.40	225.00	50.00	6.00	11.00	17.00	2.00	19.83	56.30
11:10:58	95.00	32.50	227.00	53.00	6.00	10.80	16.00	2.00	19.85	55.20
11:11:03	94.60	32.40	232.00	54.00	5.00	10.60	16.00	2.00	19.87	54.50
11:11:08	94.50	32.40	237.00	57.00	5.00	10.40	16.00	2.00	19.90	53.80
11:11:13	90.90	32.40	240.00	58.00	5.00	10.40	16.00	3.00	19.91	55.70
11:11:18	85.50	32.40	239.00	64.00	6.00	9.80	15.00	3.00	19.95	
11:11:23	93.70	32.40	228.00	72.00	5.00	8.80	14.00	3.00	20.06	
11:11:28	100.20	32.40	209.00	77.00	5.00	8.90	14.00	2.00	19.95	
11:11:33	105.20	32.50	204.00	71.00	5.00	9.80	15.00	2.00	19.79	51.00
11:16:40	85.60	31.70			5.00	7.10	13.00	6.00	20.33	
11:16:45	75.50	31.70			5.00	6.00	11.00	6.00	20.57	
11:16:50	73.10	31.80			3.00	4.40	8.00	5.00	20.90	
11:16:55	74.60	31.90			4.00	4.50	8.00	5.00	20.74	
11:17:00	84.90	32.00			5.00	5.00	10.00	5.00	20.54	
11:17:05	92.40	32.00			5.00	5.70	11.00	5.00	20.46	
11:17:10	96.40	31.90			5.00	7.20	12.00	5.00	20.29	
11:17:15	100.00	31.80			5.00	9.30	15.00	5.00	20.11	
11:17:20	100.70	31.80			6.00	10.80	16.00	5.00	19.98	
11:17:25	103.40	31.80			6.00	12.10	18.00	6.00	19.87	50.00
11:17:30	106.70	31.80			6.00	13.50	20.00	6.00	19.73	53.20
11:17:35	105.10	31.80			7.00	14.80	21.00	6.00	19.62	57.50
11:17:40	104.00	31.90			7.00	15.00	22.00	7.00	19.63	57.80
11:17:45	105.10	31.90			7.00	15.30	22.00	7.00	19.62	57.40

11:17:50	104.40	31.90				7.00	15.60	22.00	7.00	19.62	57.80
11:17:55	100.30	31.80				7.00	15.30	22.00	7.00	19.66	58.90
11:18:00	98.20	31.80				7.00	14.50	21.00	7.00	19.74	57.80
11:18:05	99.80	31.70				7.00	14.00	21.00	7.00	19.78	55.40
11:18:10	99.70	31.70				7.00	14.00	21.00	7.00	19.77	55.80
11:18:15	100.20	31.70				7.00	13.80	21.00	7.00	19.80	54.50
11:18:20	98.50	31.80				7.00	13.60	20.00	8.00	19.83	54.60
11:18:25	96.90	31.80				7.00	13.00	20.00	8.00	19.93	51.70
11:18:30	98.70	31.70				7.00	12.60	19.00	7.00	19.94	50.00
11:18:35	101.20	31.80				6.00	13.00	19.00	7.00	19.87	51.20
11:23:42	73.60	31.80				4.00	1.10	6.00	4.00	20.69	
11:23:47	71.30	31.80				4.00	1.10	6.00	4.00	20.66	
11:23:52	73.30	31.80				4.00	1.10	5.00	4.00	20.65	
11:23:57	75.90	31.70				4.00	1.10	5.00	4.00	20.66	
11:24:02	79.80	31.70				4.00	1.50	6.00	4.00	20.63	
11:24:07	82.00	31.70				4.00	2.00	6.00	4.00	20.58	
11:24:12	82.90	31.70				4.00	2.70	7.00	4.00	20.50	
11:24:17	83.70	31.70				4.00	3.30	7.00	4.00	20.45	
11:24:22	84.40	31.80				4.00	3.70	8.00	4.00	20.41	
11:24:27	84.90	31.80				5.00	4.30	9.00	4.00	20.34	
11:24:32	84.00	31.80				5.00	4.60	9.00	4.00	20.28	
11:24:37	83.40	31.80				5.00	4.70	9.00	4.00	20.29	
11:24:42	83.90	31.80				4.00	4.70	9.00	4.00	20.32	
11:24:47	82.90	31.80				5.00	4.60	9.00	4.00	20.35	
11:24:52	81.00	31.80				5.00	4.60	9.00	4.00	20.38	
11:24:57	81.40	31.80				5.00	4.40	9.00	4.00	20.38	
11:25:02	81.20	31.80				5.00	4.30	9.00	4.00	20.41	
11:25:07	79.80	31.80				5.00	4.10	9.00	4.00	20.47	
11:25:12	79.80	31.80				5.00	3.70	8.00	3.00	20.51	

11:25:17	80.40	31.90				4.00	3.60	8.00	3.00	20.53	
11:25:22	80.30	31.90				4.00	3.60	8.00	3.00	20.53	
11:25:27	79.00	31.80				4.00	3.50	8.00	4.00	20.53	
11:25:32	79.30	31.90				4.00	3.40	8.00	3.00	20.55	
11:25:37	77.90	31.90				4.00	3.40	7.00	4.00	20.53	

Table O 28: Temperature at pyrolysis chamber for Experiment (v-2); AVR = 4.00:5.79 (OPKS)

Mean		343.86					
Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)
0	0.00	14.5	502.00	29	189.00	43.5	147.00
0.5	382.00	15	408.00	29.5	175.00	44	138.00
1	513.00	15.5	468.00	30	237.00	44.5	127.00
1.5	543.00	16	422.00	30.5	235.00	45	119.00
2	538.00	16.5	438.00	31	208.00		
2.5	569.00	17	413.00	31.5	195.00		
3	577.00	17.5	467.00	32	182.00		
3.5	580.00	18	393.00	32.5	168.00		
4	566.00	18.5	389.00	33	181.00		
4.5	587.00	19	352.00	33.5	190.00		
5	593.00	19.5	413.00	34	174.00		
5.5	585.00	20	356.00	34.5	160.00		
6	598.00	20.5	279.00	35	150.00		
6.5	598.00	21	266.00	35.5	143.00		
7	616.00	21.5	221.00	36	166.00		
7.5	613.00	22	204.00	36.5	172.00		
8	608.00	22.5	242.00	37	170.00		
8.5	608.00	23	273.00	37.5	218.00		
9	618.00	23.5	238.00	38	249.00		
9.5	623.00	24	298.00	38.5	293.00		
10	616.00	24.5	295.00	39	293.00		
10.5	610.00	25	266.00	39.5	219.00		
11	621.00	25.5	233.00	40	201.00		
11.5	617.00	26	223.00	40.5	182.00		

12	585.00	26.5	201.00	41	167.00
12.5	549.00	27	195.00	41.5	154.00
13	572.00	27.5	218.00	42	142.00
13.5	531.00	28	212.00	42.5	145.00
14	546.00	28.5	200.00	43	155.00

Experiment set (v-3)

Date = 7/1/2013; Sample = About 3 Kg of OPKS; Methanol = About 3 Liter; AVR = 4.00:5.79

Measurement rate = 5 seconds; Gas time = 2 minutes; Rinse time = 5 minutes; Mean = 1 second; To make the data meaningful, rinse time is neglected

Table O 29: Results of TESTO Experiment (v-3); AVR = 4.00:5.79 (OPKS)

Mean	105.73	33.71	271.21	87.43	4.38	8.43	11.88	6.52	19.47	62.20
Time	FT (°C)	AT (°C)	CO (ppmv)	H2 (ppmv)	NO (ppmv)	NO2 (ppmv)	NOx (ppmv)	SO2 (ppmv)	O2 (%)	η (%)
13:10:33	68.50	34.70	9.00	103.00	1.00	0.00	1.00	0.00	20.84	
13:10:38	124.80	34.80	58.00	197.00	3.00	0.70	4.00	1.00	19.93	
13:10:43	132.70	34.70	222.00	258.00	3.00	1.30	4.00	8.00	17.87	72.60
13:10:48	132.50	34.70	365.00	246.00	3.00	1.50	4.00	13.00	17.26	76.60
13:10:53	144.00	34.60	385.00	189.00	3.00	1.60	4.00	15.00	17.04	75.40
13:10:58	142.90	34.70	366.00	143.00	3.00	1.90	5.00	13.00	16.87	76.60
13:11:03	137.30	34.80	343.00	121.00	3.00	2.10	5.00	12.00	16.87	77.70
13:11:08	132.40	34.80	322.00	109.00	3.00	2.30	5.00	11.00	16.99	78.10
13:11:13	130.60	34.80	300.00	100.00	3.00	2.60	6.00	10.00	17.07	78.00
13:11:18	129.30	34.70	279.00	96.00	3.00	2.70	6.00	9.00	17.18	77.80
13:11:23	134.10	34.70	271.00	99.00	3.00	2.90	6.00	9.00	17.22	76.60
13:11:28	134.30	34.70	262.00	100.00	3.00	3.30	6.00	8.00	17.21	76.70
13:11:33	141.90	34.60	252.00	101.00	3.00	3.50	7.00	8.00	17.17	75.40
13:11:38	142.90	34.60	250.00	105.00	4.00	4.10	8.00	7.00	17.05	75.90
13:11:43	138.40	34.60	250.00	109.00	4.00	4.20	8.00	8.00	17.11	76.40
13:11:48	135.30	34.70	248.00	109.00	4.00	4.40	8.00	8.00	17.22	76.50
13:11:53	131.70	34.70	239.00	108.00	4.00	4.70	8.00	7.00	17.31	76.70
13:11:58	129.30	34.70	226.00	104.00	4.00	4.90	9.00	7.00	17.37	76.90

13:12:03	136.80	34.70	213.00	106.00	4.00	5.10	9.00	6.00	17.41	75.20
13:12:08	180.03	34.70	211.00	113.00	4.00	5.30	9.00	6.00	17.29	75.40
13:12:13	137.00	34.70	212.00	117.00	4.00	5.30	9.00	6.00	17.38	75.30
13:12:18	136.80	34.50	211.00	120.00	4.00	5.40	9.00	6.00	17.47	74.70
13:12:23	137.40	34.40	209.00	120.00	5.00	5.80	10.00	6.00	17.47	74.60
13:12:28	138.10	34.30	206.00	120.00	4.00	5.90	10.00	6.00	17.49	74.30
13:17:35	128.70	34.00	158.00	44.00	4.00	7.20	11.00	3.00	18.33	70.00
13:17:40	131.70	33.90	158.00	45.00	4.00	7.30	11.00	3.00	18.37	68.70
13:17:45	132.80	33.70	159.00	45.00	4.00	7.50	11.00	3.00	18.32	68.80
13:17:50	128.90	33.70	160.00	45.00	4.00	7.50	11.00	3.00	18.33	69.90
13:17:55	127.20	33.70	157.00	48.00	4.00	7.40	11.00	3.00	18.39	69.70
13:18:00	130.20	33.80	152.00	50.00	3.00	7.40	11.00	2.00	18.39	68.90
13:18:05	128.40	33.90	150.00	49.00	3.00	7.60	11.00	2.00	18.36	69.80
13:18:10	132.40	33.90	153.00	47.00	3.00	7.40	11.00	3.00	18.40	68.20
13:18:15	132.60	34.00	158.00	47.00	3.00	7.50	11.00	3.00	18.37	68.50
13:18:20	127.40	34.10	163.00	46.00	3.00	7.50	11.00	3.00	18.41	69.60
13:18:25	128.30	34.00	167.00	48.00	3.00	7.30	10.00	3.00	18.50	68.40
13:18:30	128.80	34.10	165.00	53.00	3.00	7.50	11.00	3.00	18.47	68.40
13:18:35	129.10	34.10	161.00	55.00	3.00	7.60	11.00	3.00	18.47	68.40
13:18:40	129.40	34.20	160.00	55.00	3.00	7.70	10.00	2.00	18.45	68.60
13:18:45	131.00	34.30	159.00	55.00	3.00	7.80	11.00	3.00	18.42	68.50
13:18:50	133.50	34.20	158.00	55.00	3.00	7.90	11.00	3.00	18.39	68.10
13:18:55	129.90	34.20	160.00	54.00	3.00	8.00	11.00	3.00	18.42	68.70
13:19:00	129.10	34.20	163.00	53.00	3.00	7.80	11.00	3.00	18.49	68.20
13:19:05	130.20	34.20	166.00	54.00	3.00	7.80	10.00	3.00	18.53	67.40
13:19:10	127.30	34.20	168.00	55.00	3.00	7.80	10.00	3.00	18.54	68.20
13:19:15	126.00	34.20	167.00	58.00	2.00	7.80	10.00	3.00	18.58	68.10
13:19:20	124.40	34.20	164.00	60.00	3.00	7.70	10.00	3.00	18.62	68.20
13:19:25	125.60	34.20	159.00	62.00	3.00	7.60	11.00	3.00	18.66	67.30

13:19:30	127.90	34.30	158.00	61.00	3.00	7.80	11.00	3.00	18.60	67.40
13:24:37	112.30	33.90	227.00	65.00	4.00	6.90	11.00	5.00	19.43	58.90
13:24:42	111.40	33.80	229.00	66.00	4.00	7.00	11.00	5.00	19.42	59.40
13:24:47	109.60	33.80	230.00	68.00	4.00	7.20	11.00	5.00	19.43	60.10
13:24:52	110.40	33.90	229.00	71.00	4.00	7.00	11.00	5.00	19.44	59.40
13:24:57	109.40	34.00	228.00	72.00	4.00	7.10	11.00	5.00	19.41	60.50
13:25:02	106.80	34.10	227.00	73.00	4.00	7.00	11.00	5.00	19.47	60.60
13:25:07	106.00	34.20	225.00	75.00	4.00	6.80	11.00	5.00	19.51	60.10
13:25:12	108.20	34.10	222.00	75.00	4.00	6.80	11.00	5.00	19.51	58.90
13:25:17	109.40	34.20	223.00	73.00	4.00	7.00	11.00	5.00	19.47	59.40
13:25:22	106.90	34.20	228.00	71.00	4.00	7.00	11.00	5.00	19.46	60.70
13:25:27	106.50	34.20	228.00	74.00	4.00	6.90	11.00	5.00	19.50	60.00
13:25:32	108.30	34.20	228.00	74.00	5.00	6.90	11.00	5.00	19.50	59.30
13:25:37	109.00	34.20	229.00	73.00	5.00	7.10	12.00	5.00	19.47	59.60
13:25:42	106.20	34.20	232.00	74.00	4.00	7.20	11.00	5.00	19.47	61.00
13:25:47	99.50	34.20	234.00	76.00	4.00	6.90	11.00	5.00	19.50	63.60
13:25:52	100.00	34.10	233.00	77.00	4.00	6.50	11.00	5.00	19.60	60.70
13:25:57	117.00	34.20	221.00	84.00	4.00	6.60	11.00	5.00	19.62	51.10
13:26:02	121.10	34.20	203.00	88.00	4.00	7.60	12.00	4.00	19.34	56.90
13:26:07	120.80	34.00	192.00	85.00	5.00	8.70	14.00	4.00	19.15	61.20
13:26:12	119.20	33.80	183.00	81.00	5.00	9.50	14.00	3.00	19.02	64.20
13:26:17	118.50	33.70	179.00	76.00	5.00	9.90	15.00	3.00	19.98	65.00
13:26:22	116.70	33.80	182.00	70.00	5.00	10.00	15.00	3.00	19.00	65.40
13:26:27	116.30	33.80	189.00	65.00	5.00	10.00	15.00	3.00	19.03	65.10
13:26:32	114.50	34.00	194.00	63.00	6.00	10.00	16.00	3.00	19.05	65.50
13:31:39	112.20	33.80	209.00	47.00	6.00	211.00	17.00	3.00	19.38	60.00
13:31:44	111.40	33.80	210.00	48.00	6.00	11.00	17.00	3.00	19.40	60.00
13:31:49	111.90	33.90	211.00	48.00	6.00	11.10	17.00	3.00	19.42	53.90
13:31:54	113.10	33.90	212.00	48.00	6.00	11.20	17.00	3.00	19.42	58.80

13:31:59	112.50	33.90	212.00	49.00	6.00	11.40	17.00	3.00	19.42	59.00
13:32:04	111.30	33.90	213.00	50.00	6.00	11.30	17.00	3.00	19.43	59.30
13:32:09	111.10	33.90	215.00	50.00	6.00	11.20	17.00	3.00	19.48	58.30
13:32:14	110.20	33.90	216.00	50.00	6.00	11.10	17.00	3.00	19.50	58.20
13:32:19	111.60	33.90	219.00	51.00	6.00	11.30	17.00	3.00	19.50	57.40
13:32:24	108.10	34.00	220.00	52.00	6.00	11.20	17.00	3.00	19.52	58.60
13:32:29	108.80	34.10	219.00	54.00	5.00	10.90	16.00	3.00	19.56	57.20
13:32:34	107.70	34.10	220.00	53.00	6.00	10.80	16.00	3.00	19.56	57.80
13:32:39	106.70	34.00	225.00	52.00	6.00	10.60	16.00	3.00	19.59	57.50
13:32:44	107.20	34.00	233.00	52.00	5.00	10.60	16.00	3.00	19.61	56.50
18:32:49	107.10	34.00	238.00	53.00	5.00	10.40	16.00	4.00	19.63	56.10
13:32:54	106.20	34.10	239.00	56.00	5.00	10.30	16.00	4.00	19.64	56.40
13:32:59	105.60	34.00	238.00	61.00	5.00	10.10	15.00	4.00	19.65	56.30
13:33:04	106.40	33.90	238.00	62.00	5.00	10.00	15.00	4.00	19.67	55.30
13:33:09	105.80	33.80	239.00	62.00	5.00	10.00	15.00	4.00	19.67	55.40
13:33:14	104.20	33.70	237.00	64.00	5.00	10.00	15.00	3.00	19.71	55.20
13:33:19	104.70	33.50	236.00	64.00	5.00	9.80	15.00	4.00	19.71	54.60
13:33:24	105.30	33.40	241.00	61.00	5.00	9.80	15.00	4.00	19.70	54.50
13:33:29	104.90	33.30	246.00	61.00	5.00	9.80	15.00	4.00	19.70	54.60
13:33:34	104.10	33.50	250.00	63.00	5.00	9.80	15.00	4.00	19.72	54.60
13:38:41	91.60	33.70	362.00	103.00	4.00	4.90	9.00	10.00	20.14	
13:38:46	90.60	33.70	357.00	106.00	5.00	4.80	9.00	10.00	20.18	
13:38:51	91.60	33.60	354.00	107.00	4.00	4.80	9.00	9.00	20.18	
13:38:56	90.80	33.40	360.00	103.00	4.00	4.90	9.00	10.00	20.16	
13:39:01	90.80	33.40	365.00	102.00	4.00	4.90	9.00	10.00	20.16	
13:39:06	90.50	33.50	366.00	105.00	4.00	4.70	9.00	10.00	20.17	
13:39:11	91.50	33.40	366.00	106.00	4.00	4.70	9.00	10.00	20.17	
13:39:16	92.50	33.30	371.00	105.00	4.00	4.70	9.00	10.00	20.16	
13:39:21	91.80	33.30	378.00	104.00	4.00	4.80	9.00	10.00	20.15	

13:39:26	91.80	33.30	380.00	108.00	4.00	4.90	9.00	10.00	20.15	
13:39:31	91.10	33.30	380.00	110.00	4.00	4.80	9.00	11.00	20.15	
13:39:36	91.00	33.30	378.00	112.00	4.00	4.70	9.00	11.00	20.16	
13:39:41	89.60	33.30	380.00	112.00	4.00	4.70	9.00	11.00	20.17	
13:39:46	89.80	33.20	380.00	113.00	4.00	4.50	9.00	11.00	20.20	
13:39:51	89.70	33.20	376.00	115.00	4.00	4.50	9.00	11.00	20.21	
13:39:56	90.10	33.20	372.00	117.00	4.00	4.50	9.00	10.00	20.21	
13:40:01	90.50	33.20	369.00	116.00	4.00	4.50	9.00	10.00	20.19	
13:40:06	90.10	33.20	370.00	113.00	4.00	4.50	9.00	10.00	20.18	
13:40:11	90.10	33.20	371.00	114.00	4.00	4.50	9.00	11.00	20.19	
13:40:16	88.90	33.20	374.00	112.00	4.00	4.40	9.00	11.00	20.20	
13:40:21	88.10	33.20	375.00	113.00	4.00	4.40	8.00	10.00	20.23	
13:40:26	88.30	33.20	373.00	115.00	4.00	4.20	8.00	11.00	20.25	
13:40:31	88.10	33.20	369.00	118.00	4.00	4.10	8.00	11.00	20.27	
13:40:36	89.00	33.10	367.00	116.00	4.00	4.10	8.00	11.00	20.26	
13:45:43	109.90	33.60	200.00	32.00	7.00	15.20	22.00	1.00	19.40	60.50
13:45:48	109.60	33.70	205.00	34.00	7.00	15.00	22.00	2.00	19.42	60.30
13:45:53	108.40	33.70	212.00	34.00	7.00	14.70	22.00	2.00	19.45	60.20
13:45:58	107.70	33.70	216.00	36.00	7.00	14.40	21.00	2.00	19.51	58.90
13:46:03	107.90	33.60	220.00	38.00	7.00	14.20	21.00	2.00	19.53	58.30
13:46:08	108.40	33.70	224.00	41.00	6.00	14.00	20.00	2.00	19.57	57.00
13:46:13	108.90	33.70	227.00	42.00	6.00	13.90	20.00	3.00	19.58	56.50
13:46:18	106.10	33.70	231.00	43.00	6.00	13.90	20.00	3.00	19.59	57.60
13:46:23	104.70	33.80	233.00	45.00	6.00	13.30	20.00	3.00	19.65	56.80
13:46:28	104.80	33.80	235.00	45.00	6.00	12.90	19.00	3.00	19.69	55.30
13:46:33	104.70	33.80	242.00	46.00	6.00	12.70	19.00	3.00	19.71	54.80
13:46:38	102.30	33.90	251.00	46.00	6.00	12.40	18.00	3.00	19.75	55.00
13:46:43	102.90	33.90	259.00	47.00	6.00	11.80	18.00	4.00	19.79	53.20
13:46:48	97.90	33.70	267.00	49.00	6.00	11.70	17.00	4.00	19.79	55.90

13:46:53	88.20	33.60	257.00	63.00	6.00	9.90	15.00	4.00	20.11	
13:46:58	84.00	33.70	209.00	79.00	5.00	8.30	13.00	3.00	20.23	
13:47:03	77.70	33.70	193.00	72.00	5.00	7.60	12.00	3.00	20.28	
13:47:08	92.40	33.60	166.00	73.00	4.00	7.00	11.00	2.00	20.33	
13:47:13	105.30	33.70	158.00	63.00	4.00	8.30	13.00	2.00	20.08	
13:47:18	110.30	33.70	164.00	53.00	5.00	10.50	15.00	2.00	19.86	46.10
13:47:23	111.70	33.80	176.00	47.00	5.00	12.50	18.00	2.00	19.65	53.20
13:47:28	110.40	33.80	186.00	45.00	5.00	13.90	19.00	2.00	19.56	56.50
13:47:33	111.20	33.50	190.00	45.00	5.00	14.30	20.00	2.00	19.51	57.20
13:47:38	109.70	33.60	200.00	42.00	6.00	14.60	20.00	2.00	19.47	58.90
13:52:45	108.20	33.40	204.00	33.00	6.00	15.30	22.00	2.00	19.46	59.90
13:52:50	108.30	33.40	205.00	36.00	6.00	15.10	21.00	3.00	19.49	59.10
13:52:55	107.70	33.30	210.00	34.00	6.00	14.80	21.00	3.00	19.51	58.80
13:53:00	106.00	33.40	216.00	35.00	6.00	14.50	21.00	3.00	19.57	58.30
13:53:05	104.50	33.30	219.00	37.00	6.00	14.00	20.00	3.00	19.62	57.60
13:53:10	103.60	33.30	225.00	37.00	6.00	13.60	19.00	3.00	19.67	56.40
13:53:15	104.20	33.20	232.00	37.00	6.00	13.20	19.00	4.00	19.69	55.60
13:53:20	103.40	33.20	244.00	36.00	6.00	13.00	19.00	4.00	19.70	55.60
13:53:25	102.50	33.30	259.00	37.00	6.00	12.80	19.00	5.00	19.72	55.50
13:53:30	100.70	33.30	270.00	39.00	6.00	12.30	18.00	5.00	19.76	54.90
13:53:35	99.80	33.30	277.00	44.00	6.00	11.70	17.00	5.00	19.82	53.30
13:53:40	100.60	33.50	284.00	46.00	6.00	11.40	17.00	6.00	19.86	51.70
13:53:45	98.80	33.50	297.00	47.00	5.00	11.10	17.00	6.00	19.87	52.30
13:53:50	98.10	33.50	308.00	51.00	6.00	10.70	16.00	6.00	19.91	50.90
13:53:55	98.40	33.50	313.00	56.00	5.00	10.50	16.00	7.00	19.94	49.50
13:54:00	99.30	33.60	323.00	58.00	5.00	10.40	15.00	7.00	19.94	48.80
13:54:05	98.70	33.60	340.00	57.00	5.00	10.30	16.00	8.00	19.93	49.60
13:54:10	98.80	33.50	354.00	61.00	5.00	10.00	15.00	8.00	19.95	48.30
13:54:15	98.00	33.50	364.00	67.00	5.00	9.80	15.00	8.00	19.96	48.40

13:54:20	96.90	33.40	373.00	73.00	5.00	9.50	15.00	9.00	20.00	
13:54:25	97.20	33.40	377.00	79.00	5.00	9.20	15.00	9.00	20.02	
13:54:30	97.40	33.30	382.00	82.00	5.00	8.90	14.00	10.00	20.03	
13:54:35	95.70	33.40	391.00	83.00	5.00	8.80	14.00	10.00	20.04	
13:54:40	94.40	33.30	400.00	85.00	5.00	8.60	14.00	10.00	20.07	
13:59:47	90.60	33.10	448.00	134.00	5.00	5.90	11.00	13.00	20.27	
13:59:52	90.00	33.30	453.00	135.00	5.00	5.80	11.00	13.00	20.27	
13:59:57	89.40	33.20	459.00	137.00	5.00	5.70	11.00	13.00	20.28	
14:00:02	88.70	33.20	459.00	142.00	5.00	5.50	11.00	13.00	20.30	
14:00:07	88.90	33.20	455.00	146.00	5.00	5.30	10.00	13.00	20.32	
14:00:12	89.30	33.20	457.00	146.00	5.00	5.30	10.00	13.00	20.31	
14:00:17	88.30	33.30	462.00	146.00	5.00	5.20	10.00	13.00	20.33	
14:00:22	88.40	33.20	463.00	147.00	5.00	5.00	10.00	13.00	20.33	
14:00:27	88.10	33.10	470.00	146.00	5.00	4.90	10.00	14.00	20.33	
14:00:32	87.30	33.10	475.00	148.00	5.00	4.70	10.00	14.00	20.35	
14:00:37	87.90	33.10	475.00	153.00	5.00	4.70	9.00	14.00	20.36	
14:00:42	79.10	33.00	473.00	156.00	5.00	4.40	9.00	14.00	20.39	
14:00:47	58.50	33.00	414.00	190.00	4.00	3.30	7.00	12.00	20.71	
14:00:52	57.50	33.10	230.00	242.00	3.00	1.90	5.00	6.00	20.95	
14:00:57	82.20	33.10	136.00	203.00	3.00	2.00	5.00	3.00	20.77	
14:01:02	102.30	33.10	182.00	121.00	4.00	4.40	8.00	4.00	20.41	
14:01:07	110.30	33.10	219.00	94.00	5.00	7.90	13.00	6.00	20.04	
14:01:12	110.50	33.10	223.00	92.00	6.00	10.50	16.00	5.00	19.71	51.30
14:01:17	110.60	33.20	211.00	91.00	6.00	12.30	19.00	4.00	19.54	56.50
14:01:22	108.90	33.30	203.00	83.00	6.00	13.50	20.00	4.00	19.43	60.30
14:01:27	107.80	33.30	200.00	74.00	7.00	13.80	21.00	3.00	19.44	60.50
14:01:32	106.60	33.30	205.00	61.00	7.00	13.70	21.00	3.00	19.46	60.50
14:01:37	104.00	33.10	212.00	53.00	8.00	13.20	21.00	3.00	19.54	59.90
14:01:42	102.20	33.20	215.00	49.00	7.00	12.50	20.00	3.00	19.63	58.40

14:06:49	83.90	33.40	371.00	134.00	3.00	2.60	5.00	12.00	20.48	
14:06:54	84.50	33.40	366.00	136.00	3.00	2.60	5.00	12.00	20.49	
14:06:59	85.00	33.40	367.00	135.00	3.00	2.60	5.00	12.00	20.47	
14:07:04	83.80	33.30	373.00	132.00	3.00	2.60	5.00	12.00	20.47	
14:07:09	83.40	33.30	370.00	136.00	2.00	2.60	5.00	12.00	20.49	
14:07:14	84.50	33.30	367.00	136.00	2.00	2.60	5.00	12.00	20.49	
14:07:19	84.50	33.30	370.00	134.00	2.00	2.80	5.00	12.00	20.48	
14:07:24	84.90	33.30	376.00	132.00	3.00	2.80	5.00	12.00	20.47	
14:07:29	84.20	33.20	385.00	131.00	3.00	2.80	6.00	12.00	20.46	
14:07:34	84.00	33.20	391.00	135.00	3.00	2.70	5.00	13.00	20.47	
14:07:39	83.80	33.20	392.00	138.00	2.00	2.80	5.00	13.00	20.47	
14:07:44	83.30	33.20	385.00	144.00	2.00	2.60	5.00	13.00	20.49	
14:07:49	83.80	33.20	376.00	146.00	3.00	2.50	5.00	12.00	20.50	
14:07:54	82.50	33.10	376.00	143.00	3.00	2.60	5.00	12.00	20.51	
14:07:59	82.30	33.10	373.00	144.00	2.00	2.50	4.00	12.00	20.52	
14:08:04	82.10	33.10	368.00	145.00	2.00	2.30	5.00	12.00	20.54	
14:08:09	82.00	33.10	362.00	145.00	2.00	2.50	5.00	12.00	20.54	
14:08:14	82.30	33.10	360.00	143.00	2.00	2.30	4.00	12.00	20.53	
14:08:19	82.50	33.20	362.00	140.00	2.00	2.30	4.00	12.00	20.53	
14:08:24	81.70	33.20	366.00	138.00	2.00	2.40	5.00	12.00	20.52	
14:08:29	81.70	33.20	367.00	139.00	2.00	2.30	4.00	12.00	20.54	
14:08:34	81.60	33.40	364.00	140.00	2.00	2.30	4.00	12.00	20.54	
14:08:39	81.10	33.40	366.00	138.00	2.00	2.20	4.00	12.00	20.55	
14:08:44	81.20	33.30	365.00	139.00	2.00	2.10	4.00	12.00	20.56	

Table O 30: Temperature at pyrolysis chamber for Experiment (v-3); AVR = 4.00:5.79 (OPKS)

Mean		318.51									
Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)
0	0.00	14.5	398.00	29	275.00	43.5	170.00	58	140.00		
0.5	468.00	15	370.00	29.5	262.00	44	164.00	58.5	134.00		
1	562.00	15.5	388.00	30	252.00	44.5	159.00	59			
1.5	607.00	16	375.00	30.5	272.00	45	155.00	59.5			
2	641.00	16.5	348.00	31	258.00	45.5	151.00				
2.5	675.00	17	386.00	31.5	239.00	46	165.00				
3	637.00	17.5	387.00	32	220.00	46.5	171.00				
3.5	612.00	18	387.00	32.5	199.00	47	168.00				
4	625.00	18.5	360.00	33	212.00	47.5	164.00				
4.5	626.00	19	304.00	33.5	199.00	48	159.00				
5	635.00	19.5	296.00	34	188.00	48.5	154.00				
5.5	642.00	20	285.00	34.5	182.00	49	150.00				
6	638.00	20.5	319.00	35	184.00	49.5	147.00				
6.5	639.00	21	368.00	35.5	181.00	50	143.00				
7	640.00	21.5	400.00	36	175.00	50.5	144.00				
7.5	636.00	22	408.00	36.5	175.00	51	158.00				
8	650.00	22.5	410.00	37	182.00	51.5	160.00				
8.5	637.00	23	413.00	37.5	182.00	52	156.00				
9	646.00	23.5	412.00	38	181.00	52.5	151.00				
9.5	621.00	24	417.00	38.5	174.00	53	147.00				
10	623.00	24.5	426.00	39	169.00	53.5	144.00				
10.5	597.00	25	436.00	39.5	165.00	54	142.00				
11	574.00	25.5	437.00	40	161.00	54.5	141.00				

11.5	555.00	26	426.00	40.5	157.00	55	139.00
12	544.00	26.5	408.00	41	165.00	55.5	136.00
12.5	520.00	27	386.00	41.5	178.00	56	134.00
13	502.00	27.5	361.00	42	183.00	56.5	136.00
13.5	445.00	28	329.00	42.5	181.00	57	140.00
14	433.00	28.5	296.00	43	176.00	57.5	144.00

Experiment set (vi-1)

Date = 3/1/2013; Sample = About 3 Kg of OPKS; Methanol = About 3 Liter; AVR = 4.00:9.65

Measurement rate = 5 seconds; Gas time = 2 minutes; Rinse time = 5 minutes; Mean = 1 second; To make the data meaningful, rinse time is neglected

Table O 31: Results of TESTO Experiment (vi-1); AVR = 4.00:9.65 (OPKS)

Mean	109.14	33.65	252.73	71.46	5.38	7.34	12.72	5.37	19.34	62.65
Time	FT (°C)	AT (°C)	CO (ppmv)	H2 (ppmv)	NO (ppmv)	NO2 (ppmv)	NOx (ppmv)	SO2 (ppmv)	O2 (%)	η (%)
15:46:02	96.20	34.9	12	50	5	0.2	5	1	20.89	
15:46:07	144.90	34.6	91	110	7	0.6	8	4	19.15	41.7
15:46:12	151.70	34.7	369	200	8	1.7	9	13	16.9	74.7
15:46:17	144.80	34.6	551	170	8	1.9	9	20	16.08	79.2
15:46:22	139.60	34.5	600	74	8	1.9	10	22	16.03	80.1
15:46:27	139.80	34.5	573	2	7	1.9	9	21	16.15	79.7
15:46:32	150.80	34.5	519	54	7	2.1	10	18	16.21	77.8
15:46:37	153.60	34.5	479	71	8	2.6	10	17	16.12	77.8
15:46:42	148.30	34.5	460	72	8	2.9	11	16	16.08	78.8
15:46:47	145.70	34.5	443	73	8	3.1	11	15	16.22	78.7
15:46:52	143.30	34.4	430	71	8	3.3	12	14	16.35	78.6
15:46:57	148.00	34.5	420	68	8	3.6	12	14	16.37	77.8
15:47:02	152.10	34.5	404	68	9	3.8	12	14	16.32	77.4
15:47:07	154.40	34.6	395	63	9	4.2	13	13	16.16	77.7
15:47:12	157.30	34.6	397	55	9	4.6	13	13	16.18	77.2
15:47:17	159.80	34.6	404	50	9	5.1	15	13	16.17	76.8
15:47:22	158.30	34.6	409	50	10	5.6	15	13	16.17	77
15:47:27	160.20	34.5	408	52	10	5.9	16	13	16.21	76.5

15:47:32	160.50	34.5	398	58	10	6.7	17	13	16.16	76.7
15:47:37	156.70	34.4	394	55	10	7.3	17	12	16.16	77.3
15:47:42	146.80	34.3	391	53	10	7.5	18	12	16.32	78.2
15:47:47	151.80	34.3	380	55	10	7.7	18	11	16.39	77.1
15:47:52	152.70	34.4	371	53	10	8.2	18	11	16.4	77
15:47:57	150.70	34.3	366	49	11	8.5	19	11	16.4	77.3
15:53:04	119.90	33.6	146	49	4	6.1	10	3	18.66	68.9
15:53:09	118.60	33.6	142	51	4	6.1	10	3	18.67	69.3
15:53:14	116.50	33.7	140	51	4	6.1	10	2	18.69	69.7
15:53:19	120.70	33.7	140	51	4	6.1	10	2	18.73	67.9
15:53:24	122.00	33.7	144	49	4	6.4	11	2	18.64	68.5
15:53:29	121.00	33.6	145	51	4	6.4	11	3	18.63	68.9
15:53:34	122.00	33.6	146	52	4	6.5	11	2	18.62	68.7
15:53:39	121.30	33.5	150	52	4	6.7	11	2	18.62	68.9
15:53:44	122.70	33.7	151	53	4	6.7	11	3	18.65	68.2
15:53:49	124.20	33.7	148	55	5	6.4	11	2	18.63	68
15:53:54	124.60	33.8	145	57	5	6	11	2	18.59	68.3
15:53:59	121.60	33.8	145	57	5	5.8	11	2	18.64	68.7
15:54:04	120.80	33.7	146	58	5	5.7	10	2	18.72	68
15:54:09	120.90	33.7	146	58	4	6	10	2	18.73	67.8
15:54:14	120.50	33.6	146	59	4	6.1	10	2	18.74	67.8
15:54:19	116.60	33.6	146	60	5	6.1	11	2	18.76	68.8
15:54:24	116.60	33.7	146	60	4	6.2	11	3	18.8	68.4
15:54:29	116.30	33.6	148	60	4	6.2	10	2	18.79	68.6
15:54:34	115.50	33.6	151	61	4	6.4	11	2	18.79	68.8
15:54:39	116.80	33.5	150	63	4	6.4	11	2	18.83	67.8
15:54:44	118.60	33.6	151	63	4	6.6	11	2	18.8	67.6
15:54:49	119.20	33.6	157	62	4	6.7	11	2	18.79	67.6
15:54:54	118.80	33.6	160	65	3	6.8	10	2	18.78	67.8

15:54:59	117.70	33.8	161	66	4	6.6	10	2	18.82	67.6
16:00:06	101.80	33.6	261	83	4	5.7	10	6	19.62	59
16:00:11	100.80	33.5	261	85	4	5.5	9	6	19.66	58.3
16:00:16	101.90	33.5	258	87	4	5.4	9	6	19.68	57
16:00:21	102.20	33.4	259	88	4	5.4	9	6	19.66	57.5
16:00:26	100.00	33.3	262	87	4	5.4	10	6	19.68	58.1
16:00:31	100.90	33.3	262	90	4	5.4	10	6	19.71	56.6
16:00:36	99.90	33.2	261	91	4	5.5	9	6	19.7	57.4
16:00:41	99.10	33.2	259	93	4	5.5	9	6	19.73	57
16:00:46	100.70	33.4	261	92	4	5.3	9	6	19.74	55.9
16:00:51	100.30	33.4	268	90	4	5.3	9	6	19.71	56.9
16:00:56	99.60	33.6	272	92	3	5.3	9	6	19.73	57
16:01:01	99.20	33.5	274	95	4	5.3	9	7	19.75	56.3
16:01:06	98.60	33.4	271	98	4	5.2	9	6	19.78	55.6
16:01:11	98.60	33.4	266	100	4	5.3	9	6	19.78	55.8
16:01:16	99.30	33.4	263	100	4	5.4	9	6	19.75	56.2
16:01:21	98.90	33.5	265	99	3	5.5	9	6	19.73	57.1
16:01:26	97.60	33.5	273	97	3	5.5	8	6	19.74	57.7
16:01:31	97.00	33.5	276	98	3	5.4	9	7	19.77	57
16:01:36	97.00	33.5	275	102	3	5.1	9	6	19.83	55.1
16:01:41	97.80	33.6	269	106	3	5.3	9	6	19.81	55.2
16:01:46	96.70	33.6	271	103	4	5.3	9	6	19.8	56.3
16:01:51	96.30	33.7	272	104	3	5.3	9	6	19.82	55.9
16:01:56	96.20	33.6	273	105	4	5.2	9	6	19.84	55.3
16:02:01	96.70	33.5	274	105	4	5.1	9	7	19.84	54.8
16:07:08	87.00	33.2	325	128	3	3.6	7	8	20.24	
16:07:13	85.50	33.2	326	129	3	3.9	7	8	20.22	
16:07:18	84.40	33.2	323	129	3	3.7	7	8	20.25	
16:07:23	111.00	33.3	302	139	3	4.1	7	8	20.14	

16:07:28	124.30	33.2	269	144	4	6.1	10	7	19.56	47.9
16:07:33	121.90	33.4	239	138	5	8.3	13	5	19.07	61.7
16:07:38	116.60	33.3	222	126	5	9.8	15	4	18.94	66
16:07:43	114.10	33.2	214	109	6	10.6	17	3	18.9	67.4
16:07:48	112.20	33.2	217	94	6	11	17	3	18.93	67.7
16:07:53	111.50	33.2	230	81	7	11.4	18	3	18.96	67.6
16:07:58	113.40	33.2	246	72	7	11.7	19	4	19.03	65.8
16:08:03	112.80	33.2	253	71	7	12.2	19	4	19.05	65.5
16:08:08	112.10	33.2	253	72	7	12.3	20	4	19.13	64.6
16:08:13	112.10	33.3	255	69	7	12.4	20	3	19.15	64.3
16:08:18	109.90	33.3	260	67	7	12.5	19	4	19.19	64.4
16:08:23	109.20	33.2	260	67	7	12.2	19	4	19.27	63.3
16:08:28	107.90	33.2	257	68	7	12.1	19	3	19.3	63.1
16:08:33	107.00	33.1	250	70	7	11.9	19	3	19.34	62.7
16:08:38	107.10	33	244	69	7	11.9	19	3	19.37	62
16:08:43	106.30	33	240	68	7	11.7	19	3	19.4	61.8
16:08:48	105.30	33.1	238	66	7	11.6	19	3	19.44	61.3
16:08:53	105.10	33	239	65	7	11.5	18	3	19.47	60.9
16:08:58	105.80	33	243	63	7	11.4	18	3	19.47	60.5
16:09:03	104.80	33	246	62	7	11.4	18	3	19.48	60.8
16:14:10	110.10	33.5	221	56	7	10.1	17	3	19.36	61.2
16:14:15	109.20	33.4	218	57	6	10	16	3	19.4	60.8
16:14:20	111.20	33.5	218	55	7	10	17	3	19.39	60
16:14:25	111.60	33.6	222	54	7	10.3	17	3	19.37	60.4
16:14:30	110.80	33.5	225	53	7	10.4	17	3	19.39	60.1
16:14:35	110.50	33.4	224	56	7	10.2	17	3	19.44	59.2
16:14:40	100.60	33.4	220	57	7	10.3	17	3	19.45	59
16:14:45	109.40	33.4	218	56	7	10.2	17	3	19.46	59.1
16:14:50	108.50	33.5	219	54	6	10.1	16	3	19.5	58.8

16:14:55	108.40	33.5	221	54	7	9.9	17	3	19.53	58.1
16:15:00	108.60	33.5	221	55	7	9.8	17	3	19.54	57.6
16:15:05	107.80	33.5	223	55	7	9.7	16	3	19.57	57.3
16:15:10	108.90	33.5	223	57	6	9.7	16	3	19.59	56.1
16:15:15	108.50	33.6	227	55	7	9.7	16	3	19.57	56.7
16:15:20	108.00	33.6	231	56	6	9.7	16	3	19.58	56.7
16:15:25	107.00	33.6	235	55	6	9.7	16	3	19.6	56.8
16:15:30	105.80	33.5	239	58	6	9.7	16	3	19.63	56.5
16:15:35	102.60	33.4	238	62	7	9.3	16	3	19.7	56.1
16:15:40	102.00	33.4	232	66	7	8.9	16	3	19.76	54.7
16:15:45	102.40	33.5	228	67	6	8.7	15	4	19.78	53.7
16:15:50	102.30	33.5	227	67	6	8.4	15	4	19.78	53.6
16:15:55	102.00	33.4	228	65	6	8.3	14	4	19.79	53.5
16:16:00	102.60	33.4	231	65	6	8.2	14	4	19.8	53
16:16:05	102.70	33.4	235	64	6	8.2	14	4	19.78	53.4
16:21:12	109.10	33.5	242	43	8	13.1	21	2	19.51	58.1
16:21:17	100.60	33.5	242	44	8	12.7	21	2	19.58	60.7
16:21:22	106.60	33.5	226	53	8	11.3	19	2	19.76	51.7
16:21:27	118.90	33.5	200	59	8	11.3	19	1	19.64	48.8
16:21:32	121.70	33.5	192	51	7	12.7	20	1	19.32	57
16:21:37	121.50	33.5	197	42	8	13.5	21	1	19.2	59.9
16:21:42	121.30	33.5	203	37	8	13.9	22	0	19.13	61.1
16:21:47	121.70	33.5	215	31	8	14.2	22	0	19.11	61.5
16:21:52	120.40	33.6	230	28	8	14.5	23	1	19.09	62.3
16:21:57	119.60	33.6	239	29	8	14.3	23	1	19.16	61.3
16:22:02	118.30	33.6	246	30	9	14	23	2	19.2	61
16:22:07	114.90	33.6	253	31	9	13.6	23	2	19.27	61
16:22:12	115.80	33.6	252	36	9	13.4	22	1	19.32	59.4
16:22:17	114.70	33.6	246	39	8	13.6	22	2	19.32	60

16:22:22	114.50	33.7	246	39	8	13.4	22	1	19.37	59
16:22:27	113.30	33.6	252	36	8	13.3	21	2	19.4	58.8
16:22:32	111.60	33.6	254	39	8	13.1	21	2	19.47	58
16:22:37	111.80	33.6	250	43	8	12.9	20	2	19.5	57
16:22:42	110.40	33.7	245	46	7	12.8	20	2	19.51	57.4
16:22:47	110.00	33.7	244	45	8	12.6	20	2	19.54	56.9
16:22:52	109.50	33.7	244	45	7	12.5	20	2	19.58	56.2
16:22:57	110.80	33.6	245	44	7	12.5	20	2	19.58	55.4
16:23:02	111.10	33.7	248	44	7	12.7	20	2	19.57	55.6
16:23:07	110.40	33.6	255	43	7	12.6	20	2	19.57	55.8
16:28:14	101.60	33.7	383	95	6	6.8	13	9	20.03	
16:28:19	101.40	33.7	388	97	6	6.7	13	9	20.05	
16:28:14	100.10	33.8	387	102	6	6.5	12	10	20.07	
16:28:29	100.60	33.8	383	105	6	6.3	12	10	20.09	
16:28:34	101.00	33.8	379	107	6	6.2	12	10	20.09	
16:28:39	99.30	33.9	384	104	6	6.2	12	10	20.09	
16:28:44	93.10	33.9	391	104	6	6	12	10	20.12	
16:28:49	87.40	34	382	113	5	5.5	11	10	20.2	
16:28:54	90.70	33.9	349	128	5	5	10	9	20.36	
16:28:59	112.90	33.8	292	138	5	5.4	11	7	20.2	
16:29:04	125.60	33.7	259	127	7	8.9	15	6	19.66	43.7
16:29:09	123.60	33.6	244	110	8	11.6	19	4	19.29	56.7
16:29:14	123.70	33.6	238	91	8	12.6	21	3	19.18	59.2
16:29:19	121.90	33.7	242	76	9	13.5	22	3	19.05	62.3
16:29:24	117.80	33.7	260	58	9	13.8	22	3	19.05	63.8
16:29:29	115.50	33.7	277	50	9	13.3	22	3	19.16	62.8
16:29:34	113.80	33.8	286	49	9	12.4	21	4	19.26	61.6
16:29:39	112.70	33.7	289	51	9	11.9	21	4	19.31	60.9
16:29:44	110.50	33.6	290	50	9	11.4	20	4	19.41	59.7

16:29:49	110.30	33.6	289	52	9	11.1	20	5	19.49	57.9
16:29:54	108.40	33.6	292	48	8	10.7	19	5	19.55	57.2
16:29:59	107.30	33.7	296	51	8	10.3	18	5	19.62	55.8
16:30:04	105.80	33.7	294	53	8	9.9	18	5	19.68	54.9
16:30:09	105.30	33.6	291	55	8	9.5	17	5	19.74	53
16:35:16	87.10	33.5	328	99	3	4.3	7	9	20.42	
16:35:21	82.80	33.6	317	108	3	3.9	7	9	20.47	
16:35:26	85.40	33.6	294	119	3	3.5	6	8	20.57	
16:35:31	96.60	33.7	246	129	3	4.2	7	6	20.52	
16:35:36	104.20	33.7	217	119	3	6.2	9	5	20.29	
16:35:41	105.80	33.6	205	104	3	8	11	4	20.1	
16:35:46	104.00	33.5	199	91	3	9	12	4	20.04	
16:35:51	102.50	33.5	196	79	4	9.4	13	3	20.04	
16:35:56	101.60	33.5	192	71	4	9.4	13	3	20.05	
16:36:01	100.10	33.5	190	64	4	9.1	13	3	20.06	
16:36:06	98.30	33.5	190	59	4	8.7	13	3	20.11	
16:36:11	97.50	33.5	189	57	4	8.3	12	3	20.15	
16:36:16	97.10	33.6	194	50	4	7.9	12	3	20.18	
16:36:21	96.40	33.6	202	45	4	7.5	11	4	20.2	
16:36:26	95.50	33.7	212	44	4	7.1	11	4	20.23	
16:36:31	94.30	33.8	221	43	3	6.7	10	4	20.27	
16:36:36	93.80	33.8	225	48	3	6.4	10	5	20.3	
16:36:41	94.00	33.7	229	50	4	6.1	10	5	20.32	
16:36:46	93.30	33.6	236	49	3	5.9	9	5	20.33	
16:36:51	92.50	33.5	244	52	3	5.7	9	6	20.35	
16:36:56	91.70	33.6	248	56	3	5.5	9	6	20.38	
16:37:01	91.90	33.5	252	58	3	5.1	8	6	20.41	
16:37:06	91.90	33.5	259	60	3	4.9	8	6	20.41	
16:37:11	91.50	33.5	269	61	3	4.9	8	7	20.41	

16:42:18	83.90	33.6	20.3	74	1	2.1	3	6	20.66	
16:42:23	84.00	33.6	201	75	1	2	3	6	20.66	
16:42:28	83.80	33.6	199	76	1	1.9	3	6	20.67	
16:42:33	83.90	33.6	199	75	1	1.9	3	6	20.67	
16:42:38	84.20	33.6	201	75	1	1.9	3	6	20.67	
16:42:43	83.90	33.6	205	73	1	2	3	6	20.66	
16:42:48	83.50	33.5	206	75	1	1.9	3	6	20.66	
16:42:53	83.30	33.6	206	76	1	1.9	3	6	20.68	
16:42:58	83.30	33.7	203	78	1	1.9	3	6	20.69	
16:43:03	83.40	33.7	199	80	1	1.8	3	6	20.69	
16:43:08	82.70	33.8	200	77	1	1.7	3	6	20.68	
16:43:13	83.00	33.9	201	76	1	1.9	3	6	20.69	
16:43:18	82.40	33.8	199	77	1	1.9	3	6	20.7	
16:43:23	82.40	33.8	196	78	1	1.8	3	6	20.71	
16:43:28	82.50	33.6	198	77	1	1.7	3	6	20.7	
16:43:33	82.10	33.6	201	75	1	1.7	3	6	20.7	
16:43:38	82.50	33.6	199	78	1	1.7	3	6	20.71	
16:43:43	82.50	33.6	197	78	1	1.7	2	6	20.72	
16:43:18	82.20	33.7	196	77	0	1.7	2	6	20.71	
16:43:53	82.10	33.7	197	77	1	1.7	2	6	20.72	
16:43:58	82.20	33.8	195	78	1	1.5	2	6	20.71	
16:44:03	81.90	33.8	197	76	1	1.6	2	6	20.71	
16:44:08	81.80	33.7	199	76	0	1.7	2	6	20.723	
16:44:13	81.10	33.6	195	78	0	1.6	2	6	20.73	

Table O 32: Temperature at pyrolysis chamber for Experiment (vi-1); AVR = 4 00:9.65 (OPKS)

Mean		186.13							
Duration, minute	PT ₁ (°C)	Duration, minute	PT ₁ (°C)	Duration, minute	PT ₁ (°C)	Duration, minute	PT ₁ (°C)	Duration, minute	PT ₁ (°C)
0	0.00	14.5	223.00	29	190.00	43.5	170.00	58	106.00
0.5	176.00	15	218.00	29.5	186.00	44	162.00	58.5	105.00
1	217.00	15.5	214.00	30	184.00	44.5	155.00	59	104.00
1.5	244.00	16	211.00	30.5	175.00	45	166.00		
2	247.00	16.5	206.00	31	173.00	45.5	171.00		
2.5	249.00	17	206.00	31.5	186.00	46	160.00		
3	262.00	17.5	201.00	32	184.00	46.5	152.00		
3.5	259.00	18	199.00	32.5	182.00	47	155.00		
4	266.00	18.5	193.00	33	174.00	47.5	157.00		
4.5	265.00	19	191.00	33.5	185.00	48	148.00		
5	266.00	19.5	190.00	34	185.00	48.5	142.00		
5.5	276.00	20	187.00	34.5	180.00	49	136.00		
6	280.00	20.5	181.00	35	175.00	49.5	134.00		
6.5	287.00	21	179.00	35.5	193.00	50	137.00		
7	277.00	21.5	205.00	36	187.00	50.5	133.00		
7.5	274.00	22	202.00	36.5	188.00	51	127.00		
8	272.00	22.5	197.00	37	178.00	51.5	124.00		
8.5	270.00	23	197.00	37.5	172.00	52	120.00		
9	262.00	23.5	196.00	38	164.00	52.5	118.00		
9.5	268.00	24	185.00	38.5	170.00	53	117.00		
10	261.00	24.5	191.00	39	187.00	53.5	118.00		
10.5	258.00	25	184.00	39.5	179.00	54	116.00		
11	250.00	25.5	184.00	40	175.00	54.5	115.00		
11.5	246.00	26	178.00	40.5	174.00	55	113.00		

12	244.00	26.5	175.00	41	167.00	55.5	112.00
12.5	236.00	27	216.00	41.5	164.00	56	110.00
13	233.00	27.5	210.00	42	159.00	56.5	109.00
13.5	223.00	28	202.00	42.5	156.00	57	108.00
14	225.00	28.5	194.00	43	163.00	57.5	107.00

Experiment set (vi-2)

Date = 4/1/2013; Sample = About 3 Kg of OPKS; Methanol = About 3 Liter; AVR = 4.00:9.65

Measurement rate = 5 seconds; Gas time = 2 minutes; Rinse time = 5 minutes; Mean = 1 second; To make the data meaningful, rinse time is neglected

Table O 33: Result of TESTO Experiment (vi-2); AVR = 4.00:9.65 (OPKS)

Mean	92.08	30.89	233.89	69.36	3.27	6.06	9.42	4.16	19.76	66.46
Time	FT (°C)	AT (°C)	CO (ppmv)	H2 (ppmv)	NO (ppmv)	NO2 (ppmv)	NOx (ppmv)	SO2 (ppmv)	O2 (%)	η (%)
9:35:52	115.20	29.00	0.00	1.00	0.00	0.10	0.00	0.00	20.99	
9:35:57	129.50	29.30	31.00	19.00	0.00	0.80	1.00	1.00	19.79	
9:36:02	128.40	29.20	197.00	80.00	0.00	1.80	2.00	5.00	18.07	71.00
9:36:07	124.00	29.20	307.00	73.00	1.00	2.00	3.00	9.00	17.57	75.50
9:36:12	116.70	29.20	346.00	23.00	1.00	2.00	3.00	10.00	17.48	77.50
9:36:17	117.50	29.30	334.00	21.00	1.00	1.90	3.00	9.00	17.48	77.40
9:36:22	118.20	29.30	319.00	44.00	0.00	1.90	2.00	9.00	17.45	77.50
9:36:27	118.50	29.30	309.00	56.00	1.00	2.10	3.00	8.00	17.44	77.50
9:36:32	112.20	29.30	298.00	63.00	1.00	2.20	3.00	8.00	17.55	78.20
9:36:37	110.60	29.30	380.00	71.00	1.00	2.40	3.00	8.00	17.71	77.80
9:36:42	110.80	29.30	268.00	71.00	1.00	2.50	3.00	7.00	17.76	77.50
9:36:47	115.10	29.30	262.00	68.00	1.00	2.80	4.00	7.00	17.81	76.10
9:36:52	116.20	29.30	260.00	66.00	1.00	3.10	4.00	7.00	17.76	76.20
9:36:57	115.20	29.30	262.00	65.00	1.00	3.40	4.00	7.00	17.79	76.30
9:37:02	114.90	29.30	256.00	67.00	1.00	3.60	5.00	7.00	17.83	76.10
9:37:07	116.00	29.30	250.00	68.00	1.00	3.80	5.00	6.00	17.82	75.90
9:37:12	115.00	29.30	244.00	69.00	1.00	3.90	5.00	6.00	17.82	76.10
9:37:17	114.80	29.40	241.00	66.00	1.00	4.30	5.00	6.00	17.89	75.80

9:37:22	115.50	29.40	236.00	65.00	1.00	4.40	6.00	6.00	17.92	75.40
9:37:27	113.00	29.40	234.00	63.00	1.00	4.70	6.00	6.00	17.93	76.00
9:39:32	108.80	29.40	231.00	64.00	1.00	4.80	6.00	6.00	18.01	76.50
9:37:37	109.40	29.40	223.00	66.00	1.00	4.90	6.00	6.00	18.07	75.90
9:37:42	113.20	29.40	221.00	62.00	1.00	5.30	6.00	5.00	18.06	75.10
9:37:47	116.20	29.40	22.00	60.00	2.00	5.30	7.00	5.00	17.98	74.80
9:42:54	119.70	29.70	175.00	43.00	3.00	6.30	9.00	2.00	18.49	69.70
9:42:59	118.00	29.80	178.00	46.00	3.00	6.30	9.00	2.00	18.50	70.10
9:43:04	115.50	29.90	181.00	46.00	3.00	6.20	9.00	3.00	18.54	70.40
9:43:09	115.00	29.80	180.00	49.00	2.00	6.10	8.00	3.00	18.58	70.20
9:43:14	113.30	29.80	178.00	51.00	3.00	6.30	9.00	2.00	18.60	70.40
9:43:19	114.30	29.80	175.00	53.00	3.00	6.30	9.00	2.00	18.62	69.90
9:43:24	112.90	29.80	172.00	54.00	3.00	6.10	9.00	2.00	18.62	70.30
9:43:29	114.00	29.90	168.00	54.00	2.00	6.20	8.00	2.00	18.65	69.70
9:43:34	112.80	29.90	165.00	55.00	2.00	6.30	8.00	2.00	18.66	70.00
9:43:39	113.50	30.00	161.00	54.00	2.00	6.30	8.00	2.00	18.69	69.50
9:43:44	115.70	29.90	161.00	52.00	2.00	6.30	8.00	2.00	18.65	69.20
9:43:49	116.80	29.90	163.00	51.00	2.00	6.30	8.00	2.00	18.66	68.70
9:43:54	115.20	29.90	167.00	50.00	2.00	6.40	9.00	2.00	18.67	69.10
9:43:59	115.20	30.00	167.00	52.00	2.00	6.50	9.00	2.00	18.71	68.70
9:44:04	112.50	29.90	163.00	54.00	2.00	6.40	9.00	2.00	18.74	69.10
9:44:09	111.30	29.90	165.00	52.00	2.00	6.30	8.00	2.00	18.80	68.80
9:44:14	114.60	29.90	164.00	53.00	2.00	6.30	8.00	2.00	18.82	67.40
9:44:19	115.00	30.00	162.00	54.00	2.00	6.40	9.00	2.00	18.76	68.10
9:44:24	110.30	30.00	162.00	53.00	2.00	6.50	9.00	2.00	18.78	69.30
9:44:29	110.20	30.00	161.00	54.00	2.00	6.40	9.00	2.00	18.90	68.00
9:44:34	110.80	30.00	160.00	54.00	2.00	6.50	9.00	2.00	18.90	67.70
9:44:39	111.10	30.00	162.00	53.00	2.00	6.50	9.00	2.00	18.87	68.00
9:44:44	107.50	30.00	167.00	52.00	2.00	6.70	9.00	2.00	18.90	68.80

9:44:49	108.90	30.00	165.00	55.00	2.00	6.50	8.00	2.00	18.97	67.30
9:49:56	105.80	30.40	182.00	59.00	4.00	9.20	13.00	1.00	19.24	64.40
9:50:01	104.40	30.40	183.00	59.00	4.00	9.30	13.00	2.00	19.27	64.30
9:50:06	97.30	30.30	184.00	58.00	4.00	9.10	13.00	2.00	19.29	66.90
9:50:11	108.40	30.40	183.00	60.00	4.00	8.50	12.00	2.00	19.41	59.40
9:50:16	123.70	30.40	176.00	63.00	4.00	9.20	13.00	1.00	19.16	58.10
9:50:21	120.50	30.40	178.00	60.00	3.00	10.00	13.00	2.00	18.78	66.00
9:50:26	115.60	30.40	189.00	56.00	3.00	9.80	13.00	2.00	18.64	69.40
9:50:31	111.90	30.50	206.00	54.00	4.00	9.30	13.00	2.00	18.65	70.40
9:50:36	106.00	30.40	218.00	56.00	3.00	8.40	12.00	3.00	18.81	70.40
9:50:41	104.90	30.50	227.00	57.00	3.00	7.90	11.00	3.00	18.98	68.70
9:50:46	104.50	30.50	237.00	61.00	3.00	7.80	11.00	3.00	19.08	67.30
9:50:51	102.10	30.50	239.00	65.00	3.00	7.60	11.00	4.00	19.17	66.90
9:50:56	101.50	30.40	236.00	70.00	3.00	7.50	11.00	4.00	19.28	65.20
9:51:01	101.70	30.40	232.00	72.00	3.00	7.60	11.00	3.00	19.34	64.00
9:51:06	100.70	30.50	232.00	73.00	3.00	7.80	11.00	3.00	19.39	63.40
9:51:11	100.50	30.50	231.00	74.00	3.00	7.90	11.00	3.00	19.45	62.30
9:51:16	100.50	30.50	230.00	75.00	3.00	8.10	12.00	3.00	19.48	61.70
9:51:21	99.80	30.40	228.00	76.00	4.00	8.20	12.00	3.00	19.51	61.20
9:51:26	97.20	30.50	231.00	74.00	4.00	8.20	12.00	3.00	19.56	61.50
9:51:31	95.40	30.50	231.00	77.00	3.00	8.20	12.00	3.00	19.62	60.70
9:51:36	88.20	30.50	228.00	78.00	4.00	8.00	12.00	3.00	19.67	63.50
9:51:41	101.00	30.50	215.00	85.00	4.00	7.50	11.00	3.00	19.83	50.70
9:51:46	108.50	30.50	196.00	89.00	3.00	7.90	11.00	2.00	19.57	54.90
9:51:51	106.40	30.60	188.00	86.00	3.00	8.30	11.00	2.00	19.37	61.50
9:56:58	91.50	30.60	203.00	48.00	5.00	8.40	13.00	2.00	19.91	54.20
9:57:03	90.20	30.60	203.00	49.00	5.00	8.30	13.00	2.00	19.95	53.50
9:57:08	90.00	30.60	204.00	51.00	5.00	8.10	13.00	2.00	19.97	52.80
9:57:13	88.80	30.70	204.00	54.00	5.00	7.90	12.00	2.00	19.99	52.90

9:57:18	88.20	30.70	204.00	56.00	5.00	7.60	13.00	2.00	20.01	
9:57:23	88.70	30.70	207.00	57.00	5.00	7.60	12.00	2.00	20.04	
9:57:28	88.40	30.70	211.00	57.00	5.00	7.30	12.00	2.00	20.07	
9:57:33	88.00	30.70	218.00	55.00	5.00	7.20	12.00	2.00	20.06	
9:57:38	87.90	30.60	223.00	57.00	4.00	7.20	12.00	3.00	20.07	
9:57:43	86.60	30.70	223.00	61.00	4.00	7.10	12.00	3.00	20.09	
9:57:48	85.80	30.70	223.00	63.00	4.00	6.80	11.00	3.00	20.15	
9:57:53	85.40	30.80	223.00	65.00	4.00	6.70	11.00	3.00	20.15	
9:57:58	85.60	30.80	227.00	65.00	5.00	6.50	11.00	3.00	20.17	
9:58:03	84.60	30.70	236.00	62.00	4.00	6.20	11.00	3.00	20.16	
9:58:08	84.10	30.70	245.00	64.00	4.00	6.00	10.00	4.00	20.20	
9:58:13	83.50	30.70	246.00	70.00	4.00	5.90	10.00	4.00	20.22	
9:58:18	82.80	30.70	245.00	75.00	5.00	5.50	10.00	4.00	20.26	
9:58:23	83.70	30.70	242.00	76.00	4.00	5.50	10.00	4.00	20.27	
9:58:28	83.90	30.70	245.00	76.00	4.00	5.50	10.00	4.00	20.25	
9:58:33	83.00	30.70	251.00	75.00	5.00	5.30	10.00	4.00	20.27	
9:58:38	82.20	30.70	252.00	78.00	4.00	5.10	9.00	4.00	20.31	
9:58:43	82.40	30.60	249.00	81.00	4.00	4.90	9.00	4.00	20.32	
9:58:48	82.30	30.60	253.00	79.00	4.00	5.10	9.00	4.00	20.30	
9:58:53	83.10	30.60	263.00	78.00	4.00	4.90	9.00	5.00	20.29	
10:04:00	81.80	30.90	238.00	64.00	4.00	6.20	11.00	4.00	20.36	
10:04:05	81.20	30.80	247.00	63.00	4.00	6.30	10.00	4.00	20.34	
10:04:10	80.80	30.90	255.00	64.00	4.00	6.30	10.00	4.00	20.35	
10:04:15	80.60	30.90	263.00	67.00	4.00	6.30	10.00	4.00	20.34	
10:04:20	80.70	30.90	266.00	72.00	4.00	6.50	11.00	4.00	20.35	
10:04:25	81.00	31.00	268.00	74.00	4.00	6.30	11.00	4.00	20.35	
10:04:30	79.50	30.90	276.00	73.00	4.00	6.20	11.00	4.00	20.35	
10:04:35	79.40	30.90	280.00	77.00	5.00	6.00	11.00	4.00	20.37	
10:04:40	79.20	30.90	280.00	80.00	4.00	5.80	10.00	4.00	20.40	

10:04:45	80.20	30.90	277.00	83.00	4.00	5.70	10.00	4.00	20.40	
10:04:50	80.20	30.90	283.00	81.00	4.00	5.70	10.00	4.00	20.39	
10:04:55	79.90	31.00	292.00	80.00	4.00	5.70	10.00	5.00	20.39	
10:05:00	78.50	31.00	298.00	83.00	4.00	5.50	10.00	5.00	20.41	
10:05:05	74.60	31.00	295.00	89.00	4.00	5.10	9.00	5.00	20.44	
10:05:10	71.00	31.00	283.00	97.00	4.00	4.70	9.00	5.00	20.48	
10:05:15	68.00	31.10	270.00	98.00	4.00	4.20	8.00	5.00	20.53	
10:05:20	66.80	31.00	243.00	107.00	4.00	3.50	7.00	4.00	20.65	
10:05:25	73.30	31.00	197.00	116.00	3.00	3.20	7.00	3.00	20.71	
10:05:30	79.60	31.00	174.00	106.00	3.00	3.50	7.00	2.00	20.60	
10:05:35	81.30	31.10	185.00	84.00	3.00	4.20	8.00	3.00	20.48	
10:05:40	82.90	31.00	199.00	75.00	3.00	4.90	8.00	3.00	20.41	
10:05:45	85.70	31.00	203.00	76.00	3.00	5.70	9.00	3.00	20.34	
10:05:50	86.60	31.00	202.00	78.00	3.00	6.60	10.00	3.00	20.24	
10:05:55	87.30	30.90	199.00	78.00	4.00	7.30	11.00	3.00	20.17	
10:11:02	81.70	31.10	244.00	55.00	4.00	7.70	12.00	3.00	20.27	
10:11:07	81.40	31.10	247.00	56.00	5.00	7.40	12.00	4.00	20.29	
10:11:12	81.50	31.10	251.00	58.00	4.00	7.40	12.00	4.00	20.30	
10:11:17	82.00	31.30	260.00	58.00	5.00	7.20	12.00	4.00	20.30	
13:31:22	80.80	31.20	272.00	58.00	4.00	7.00	11.00	4.00	20.32	
10:11:27	80.80	31.20	280.00	62.00	4.00	6.90	11.00	5.00	20.31	
10:11:32	81.20	31.20	286.00	65.00	4.00	6.80	11.00	5.00	20.31	
10:11:37	81.70	31.30	289.00	69.00	4.00	6.60	11.00	5.00	20.33	
10:11:42	82.10	31.20	293.00	71.00	4.00	6.60	11.00	5.00	20.33	
10:11:47	82.10	31.20	299.00	72.00	4.00	6.70	11.00	5.00	20.33	
10:11:52	81.00	31.30	303.00	75.00	4.00	6.60	11.00	5.00	20.34	
10:11:57	81.00	31.30	300.00	80.00	4.00	6.50	11.00	5.00	20.37	
10:12:02	79.40	31.30	302.00	80.00	4.00	6.50	11.00	5.00	20.37	
12:12:07	75.50	31.30	304.00	81.00	4.00	6.00	10.00	5.00	20.40	

12:12:12	71.50	31.30	294.00	90.00	4.00	5.40	10.00	5.00	20.49	
10:12:17	69.40	31.30	272.00	97.00	4.00	4.90	9.00	9.00	20.55	
10:12:22	81.20	31.30	232.00	107.00	4.00	4.70	8.00	4.00	20.62	
10:12:27	93.80	31.40	193.00	109.00	4.00	6.60	10.00	3.00	20.32	
10:12:32	99.60	31.30	176.00	93.00	4.00	9.20	13.00	2.00	20.04	
10:12:37	101.80	31.40	170.00	82.00	5.00	11.40	16.00	1.00	19.83	51.20
10:12:42	99.90	31.40	165.00	74.00	5.00	12.60	18.00	1.00	19.36	57.10
10:12:47	99.90	31.40	160.00	67.00	6.00	13.10	19.00	0.00	19.66	58.20
10:12:52	100.30	31.40	161.00	59.00	6.00	13.50	20.00	0.00	19.57	60.30
10:12:57	98.60	31.40	168.00	52.00	6.00	13.80	20.00	0.00	19.53	62.10
10:18:04	77.80	31.50	344.00	86.00	4.00	4.90	9.00	8.00	20.44	
10:18:09	73.70	31.30	339.00	93.00	4.00	4.40	8.00	7.00	20.50	
10:18:14	70.50	31.40	322.00	103.00	3.00	3.90	7.00	7.00	20.56	
10:18:19	74.10	31.50	289.00	112.00	3.00	3.60	7.00	6.00	20.66	
10:18:24	87.30	31.50	240.00	122.00	3.00	4.00	7.00	5.00	20.60	
10:18:29	98.60	31.60	212.00	107.00	3.00	6.60	10.00	4.00	20.29	
10:18:34	101.00	31.60	205.00	93.00	4.00	9.50	14.00	4.00	20.00	
10:18:39	99.80	31.40	195.00	85.00	5.00	11.00	16.00	2.00	19.87	50.70
10:18:44	101.10	31.40	183.00	78.00	5.00	12.10	17.00	2.00	19.76	54.30
10:18:49	100.00	31.40	175.00	71.00	6.00	13.10	19.00	1.00	19.66	58.00
10:18:54	100.30	31.50	172.00	61.00	6.00	13.50	19.00	1.00	19.65	58.30
10:18:59	66.70	31.50	176.00	53.00	6.00	13.60	20.00	1.00	19.60	59.90
10:19:04	97.40	31.50	187.00	45.00	6.00	13.60	20.00	1.00	19.62	60.50
10:19:09	95.40	31.50	196.00	42.00	6.00	13.10	19.00	1.00	19.71	59.00
10:19:14	94.10	31.50	202.00	41.00	6.00	12.40	19.00	1.00	19.79	57.40
10:19:19	93.40	31.40	213.00	39.00	6.00	11.90	18.00	2.00	19.84	56.00
10:19:24	90.80	31.40	224.00	37.00	6.00	11.30	17.00	2.00	19.92	54.60
10:19:29	89.70	31.40	233.00	38.00	6.00	10.70	17.00	2.00	19.98	53.10
10:19:34	88.80	31.40	239.00	43.00	6.00	10.10	16.00	3.00	20.03	

10:19:39	88.60	31.50	245.00	44.00	6.00	9.60	15.00	3.00	20.07	
10:19:44	87.90	31.50	259.00	43.00	5.00	9.20	14.00	4.00	20.10	
10:19:49	86.80	31.50	269.00	46.00	5.00	8.70	14.00	4.00	20.14	
10:19:54	85.50	31.60	278.00	49.00	5.00	8.30	13.00	5.00	20.18	
10:19:59	86.70	31.50	290.00	51.00	5.00	8.00	13.00	5.00	20.19	
10:25:06	81.00	31.70	253.00	53.00	4.00	5.20	9.00	5.00	20.43	
10:25:11	79.80	31.70	253.00	58.00	4.00	4.80	8.00	5.00	20.46	
10:25:16	81.30	31.70	254.00	60.00	3.00	4.70	8.00	5.00	20.46	
10:25:21	81.20	31.80	262.00	60.00	3.00	4.60	8.00	5.00	20.46	
10:25:26	80.90	31.80	273.00	60.00	3.00	4.50	8.00	6.00	20.46	
10:25:31	81.10	31.80	281.00	63.00	3.00	4.40	8.00	6.00	20.46	
10:25:36	80.40	31.80	287.00	67.00	3.00	4.30	7.00	6.00	20.48	
10:25:41	79.70	31.90	288.00	74.00	3.00	4.20	8.00	6.00	20.51	
10:25:46	80.30	31.90	285.00	78.00	3.00	4.20	7.00	6.00	20.51	
10:25:51	79.70	31.80	290.00	79.00	3.00	4.00	7.00	6.00	20.50	
10:25:56	79.50	31.80	296.00	79.00	3.00	4.00	7.00	7.00	20.51	
10:26:01	77.80	31.80	300.00	81.00	3.00	3.90	7.00	7.00	20.51	
10:26:06	74.50	31.80	300.00	86.00	3.00	3.70	7.00	7.00	20.54	
10:26:11	70.90	31.80	291.00	93.00	3.00	3.30	6.00	7.00	20.57	
10:26:16	73.70	31.90	269.00	101.00	3.00	3.00	6.00	6.00	20.64	
10:26:21	82.90	31.90	227.00	113.00	3.00	3.70	6.00	5.00	20.63	
10:26:26	86.60	31.80	195.00	107.00	3.00	5.10	8.00	4.00	20.47	
10:26:31	87.50	31.80	176.00	94.00	3.00	6.30	9.00	3.00	20.35	
10:26:36	88.30	31.80	164.00	84.00	3.00	7.20	11.00	2.00	20.27	
10:26:41	88.70	31.90	156.00	73.00	3.00	7.90	11.00	2.00	20.21	
10:26:46	88.00	31.80	153.00	64.00	4.00	8.40	12.00	2.00	20.17	
10:26:51	87.00	31.90	152.00	57.00	4.00	8.60	12.00	2.00	20.16	
10:26:56	86.20	31.90	151.00	52.00	4.00	8.70	13.00	2.00	20.17	
10:27:01	84.70	31.90	152.00	48.00	4.00	8.60	13.00	2.00	20.20	

10:32:08	75.10	32.00	284.00	75.00	2.00	2.80	5.00	7.00	20.62	
10:32:13	74.70	32.10	286.00	77.00	2.00	2.70	5.00	7.00	20.62	
10:32:18	74.60	32.10	286.00	79.00	2.00	2.70	5.00	7.00	20.62	
10:32:23	75.00	31.90	286.00	81.00	2.00	2.50	5.00	7.00	20.63	
10:32:28	74.30	32.00	290.00	79.00	2.00	2.50	5.00	7.00	20.64	
10:32:33	73.80	32.10	292.00	82.00	2.00	2.50	5.00	8.00	20.64	
10:32:38	73.90	32.20	291.00	84.00	2.00	2.40	5.00	7.00	20.63	
10:32:43	73.70	32.20	291.00	85.00	2.00	2.20	4.00	7.00	20.65	
10:32:48	73.90	32.20	290.00	86.00	2.00	2.10	4.00	8.00	20.66	
10:32:53	73.70	32.10	289.00	87.00	2.00	2.00	4.00	7.00	20.66	
10:32:58	72.90	32.10	286.00	89.00	2.00	1.90	4.00	8.00	20.69	
10:33:03	73.90	32.10	284.00	88.00	2.00	1.80	4.00	7.00	20.69	
10:33:08	74.30	32.20	292.00	85.00	2.00	1.80	4.00	8.00	20.66	
10:33:13	73.70	32.20	301.00	84.00	2.00	1.70	4.00	8.00	20.67	
10:33:18	73.30	32.10	301.00	89.00	2.00	1.70	4.00	8.00	20.69	
10:33:23	73.40	32.00	295.00	93.00	2.00	1.70	4.00	8.00	20.69	
10:33:28	73.00	32.20	289.00	94.00	2.00	1.90	4.00	8.00	20.65	
10:33:33	73.30	32.10	285.00	94.00	2.00	1.70	4.00	8.00	20.65	
10:33:38	73.50	32.10	283.00	92.00	2.00	1.80	4.00	8.00	20.66	
10:33:43	73.20	32.10	283.00	92.00	2.00	1.60	4.00	8.00	20.69	
10:33:48	72.20	32.10	282.00	90.00	2.00	1.50	4.00	8.00	20.70	
10:33:53	72.30	32.10	279.00	90.00	2.00	1.50	4.00	8.00	20.68	
10:33:58	72.90	32.10	277.00	91.00	2.00	1.70	4.00	7.00	20.63	
10:34:03	72.70	32.00	277.00	91.00	2.00	1.80	3.00	7.00	20.62	

Table O 34: Temperature at pyrolysis chamber for Experiment (vi-2); AVR = 4.00:9.65 (OPKS)

Mean		171.41					
Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)
0	0.00	14.5	264.00	29	139.00	43.5	155.00
0.5	210.00	15	229.00	29.5	153.00	44	141.00
1	223.00	15.5	206.00	30	162.00	44.5	140.00
1.5	228.00	16	218.00	30.5	161.00	45	167.00
2	226.00	16.5	211.00	31	156.00	45.5	157.00
2.5	231.00	17	209.00	31.5	151.00	46	145.00
3	237.00	17.5	198.00	32	146.00	46.5	135.00
3.5	242.00	18	186.00	32.5	147.00	47	149.00
4	239.00	18.5	181.00	33	176.00	47.5	146.00
4.5	236.00	19	175.00	33.5	173.00	48	134.00
5	236.00	19.5	202.00	34	162.00	48.5	127.00
5.5	240.00	20	213.00	34.5	156.00	49	121.00
6	243.00	20.5	207.00	35	148.00	49.5	127.00
6.5	241.00	21	195.00	35.5	143.00	50	144.00
7	237.00	21.5	192.00	36	145.00	50.5	136.00
7.5	236.00	22	185.00	36.5	177.00	51	126.00
8	228.00	22.5	190.00	37	174.00	51.5	119.00
8.5	227.00	23	197.00	37.5	164.00	52	114.00
9	222.00	23.5	185.00	38	151.00	52.5	111.00
9.5	217.00	24	168.00	38.5	142.00	53	127.00
10	212.00	24.5	166.00	39	157.00	53.5	125.00
10.5	202.00	25	181.00	39.5	179.00	54	120.00
11	260.00	25.5	193.00	40	167.00	54.5	115.00
11.5	236.00	26	186.00	40.5	155.00	55	115.00

12	225.00	26.5	178.00	41	145.00	55.5	115.00
12.5	211.00	27	166.00	41.5	137.00	56	110.00
13	254.00	27.5	157.00	42	134.00	56.5	107.00
13.5	230.00	28	155.00	42.5	172.00	57	103.00
14	218.00	28.5	147.00	43	168.00	57.5	100.00

Experiment set (vi-3)

Date = 4/1/2013; Sample = About 3 Kg of OPKS; Methanol = About 3 Liter; AVR = 4.00:9.65

Measurement rate = 5 seconds; Gas time = 2 minutes; Rinse time = 5 minutes; Mean = 1 second; To make the data meaningful, rinse time is neglected

Table O 35: Results of TESTO Experiment (vi-3); AVR = 4.00:9.65 (OPKS)

Mean	95.50	33.56	253.17	36.54	3.11	6.57	9.70	4.36	19.82	63.96
Time	FT (°C)	AT (°C)	CO (ppmv)	H2 (ppmv)	NO (ppmv)	NO2 (ppmv)	NOx (ppmv)	SO2 (ppmv)	O2 (%)	η (%)
12:18:33	128.10	34.00	5.00	33.00	3.00	0.00	3.00	1.00	20.85	
12:18:38	127.80	34.50	72.00	121.00	3.00	0.80	4.00	3.00	19.32	
12:18:43	123.60	34.50	285.00	192.00	3.00	2.90	6.00	9.00	17.83	75.20
12:18:48	128.70	34.50	400.00	150.00	3.00	4.10	7.00	13.00	17.41	76.40
12:18:53	126.60	34.50	412.00	89.00	3.00	4.70	8.00	12.00	17.23	77.80
12:18:58	119.80	34.50	389.00	43.00	3.00	4.90	8.00	11.00	17.27	79.00
12:19:03	120.50	34.50	352.00	12.00	2.00	4.70	7.00	10.00	17.38	78.40
12:19:08	122.50	34.50	316.00	1.00	3.00	4.70	7.00	8.00	17.39	78.00
12:19:13	124.80	34.50	291.00	1.00	3.00	4.50	7.00	8.00	17.37	77.70
12:19:18	121.70	34.50	282.00	4.00	3.00	4.40	7.00	8.00	17.38	78.30
12:19:23	124.60	34.50	272.00	6.00	3.00	4.30	7.00	8.00	17.48	77.20
12:19:28	127.30	34.50	259.00	5.00	3.00	4.20	7.00	8.00	17.43	76.90
12:19:33	125.40	34.50	251.00	9.00	3.00	4.20	7.00	8.00	17.39	77.50
12:19:38	124.80	34.50	245.00	10.00	3.00	4.20	7.00	8.00	17.42	77.50
12:19:43	122.90	34.50	241.00	12.00	3.00	4.10	7.00	7.00	17.53	77.30
12:19:48	120.30	34.50	239.00	15.00	3.00	4.00	7.00	8.00	17.59	77.50
12:19:53	120.70	34.50	237.00	16.00	3.00	3.90	7.00	8.00	17.65	77.10
12:19:58	122.10	34.50	230.00	16.00	3.00	3.90	7.00	8.00	17.70	76.50

12:20:03	120.50	34.50	225.00	17.00	3.00	3.90	7.00	8.00	17.68	77.00
12:20:08	119.10	34.50	220.00	20.00	3.00	3.90	7.00	7.00	17.70	77.20
12:20:13	123.00	34.50	215.00	22.00	3.00	4.00	7.00	7.00	17.72	76.20
12:20:18	122.10	34.50	214.00	25.00	3.00	4.20	7.00	7.00	17.70	76.60
12:20:23	122.60	34.40	212.00	27.00	3.00	4.20	7.00	7.00	17.75	76.10
12:20:28	126.10	34.50	212.00	31.00	3.00	4.40	8.00	7.00	17.72	75.50
12:25:35	121.50	34.20			2.00	6.10	8.00	2.00	18.57	70.10
12:25:40	120.20	34.20			3.00	6.50	9.00	2.00	18.59	70.30
12:25:45	123.70	34.20			3.00	6.60	9.00	2.00	18.52	70.00
12:25:50	123.10	34.30			3.00	6.70	10.00	2.00	18.45	70.90
12:25:55	120.00	34.30			3.00	6.70	9.00	2.00	18.46	71.70
12:26:00	117.80	34.30			3.00	6.60	10.00	2.00	18.51	71.80
12:26:05	117.80	34.30			3.00	6.40	9.00	2.00	18.60	70.90
12:26:10	116.90	34.30			3.00	6.20	9.00	2.00	18.63	70.90
12:26:15	115.90	34.30			3.00	6.10	9.00	2.00	18.70	70.50
12:26:20	118.60	34.20			3.00	6.10	9.00	2.00	18.72	69.40
12:26:25	117.90	34.30			3.00	6.30	9.00	2.00	18.69	69.90
12:26:30	119.00	34.20			3.00	6.30	9.00	2.00	18.69	69.60
12:26:35	106.24	34.30			3.00	6.40	9.00	2.00	18.68	69.50
12:26:40	118.30	34.20			3.00	6.40	9.00	2.00	18.71	69.50
12:26:45	117.40	34.10			3.00	6.60	10.00	2.00	18.74	69.50
12:26:50	118.80	34.20			3.00	6.50	9.00	2.00	18.75	68.80
12:26:55	116.70	34.10			3.00	6.60	10.00	2.00	18.73	68.80
12:27:00	117.00	34.20			3.00	6.70	10.00	2.00	18.79	69.00
12:27:05	115.20	34.20			3.00	6.80	10.00	2.00	18.77	69.80
12:27:10	116.30	34.10			3.00	6.70	10.00	2.00	18.83	68.70
12:27:15	117.70	34.10			3.00	6.70	10.00	2.00	18.79	68.70
12:27:20	116.30	34.10			3.00	6.80	10.00	2.00	18.83	68.60
12:27:25	118.10	34.20			3.00	7.00	10.00	2.00	18.86	67.70

12:27:30	115.00	34.00					3.00	7.00	10.00	2.00	18.91	68.10
12:32:37	96.50	34.00					2.00	6.40	9.00	3.00	19.80	58.20
12:32:42	96.30	34.00					2.00	6.40	9.00	4.00	19.82	57.80
12:32:47	95.40	34.00					3.00	6.10	8.00	3.00	19.88	56.20
12:32:52	96.20	34.00					2.00	6.10	8.00	3.00	19.89	55.50
12:32:57	94.00	33.90					2.00	6.10	8.00	3.00	19.90	56.50
12:33:02	94.90	34.00					2.00	6.10	8.00	4.00	19.93	54.90
12:33:07	96.00	33.90					2.00	6.20	8.00	4.00	19.87	56.10
12:33:12	95.60	33.90					2.00	6.30	8.00	4.00	19.85	57.00
12:33:17	93.90	33.90					2.00	6.20	8.00	3.00	19.88	57.10
12:33:22	94.20	33.80					2.00	6.10	8.00	3.00	19.90	56.10
12:33:27	93.60	33.90					2.00	6.30	8.00	4.00	19.90	56.60
12:33:32	93.90	33.80					2.00	6.30	8.00	4.00	19.92	55.70
12:33:37	93.50	33.70					2.00	6.10	8.00	4.00	19.92	55.90
12:33:42	93.50	33.60					1.00	6.30	8.00	4.00	19.92	55.90
12:33:47	93.40	33.60					2.00	6.10	8.00	4.00	19.93	55.70
12:33:52	94.20	33.70					1.00	6.20	7.00	3.00	19.93	54.90
12:33:57	94.30	33.80					1.00	6.30	7.00	4.00	19.92	55.40
12:34:02	93.10	33.80					1.00	6.40	7.00	4.00	19.91	56.40
12:34:07	91.90	33.90					1.00	6.20	7.00	4.00	19.94	56.40
12:34:12	92.60	33.80					1.00	6.20	7.00	4.00	19.96	55.00
12:34:17	93.20	33.90					1.00	6.30	7.00	4.00	19.95	55.20
12:34:22	92.90	33.90					1.00	6.30	7.00	4.00	19.97	54.50
12:34:27	91.80	33.90					1.00	6.30	7.00	4.00	19.98	54.70
12:34:32	91.20	33.90					0.00	6.00	6.00	4.00	20.00	
12:39:39	85.30	34.00					4.00	4.30	8.00	4.00	20.28	
12:39:44	86.50	33.90					4.00	4.40	8.00	4.00	20.25	
12:39:49	85.90	34.00					4.00	4.50	9.00	4.00	20.24	
12:39:54	85.70	33.90					4.00	4.50	9.00	4.00	20.25	

12:39:59	85.30	33.90				4.00	4.40	9.00	4.00	20.27	
12:40:04	84.80	34.00				4.00	4.40	9.00	4.00	20.28	
12:40:09	84.80	33.90				5.00	4.20	9.00	3.00	20.31	
12:40:14	83.90	34.00				5.00	4.20	9.00	4.00	20.32	
12:40:19	83.60	34.00				5.00	4.20	9.00	4.00	20.34	
12:40:24	84.40	33.90				5.00	4.20	9.00	4.00	20.33	
12:40:29	83.70	33.90				5.00	4.20	9.00	3.00	20.31	
12:40:34	82.60	33.90				5.00	4.10	10.00	4.00	20.33	
12:40:39	83.40	34.00				6.00	4.00	10.00	3.00	20.33	
12:40:44	83.60	34.00				5.00	4.10	10.00	3.00	20.32	
12:40:49	83.40	33.90				6.00	4.10	10.00	4.00	20.33	
12:40:54	83.80	33.90				6.00	4.10	10.00	4.00	20.31	
12:40:59	83.80	34.00				6.00	4.20	10.00	4.00	20.31	
12:41:04	83.30	33.90				6.00	4.10	10.00	3.00	20.31	
12:41:09	83.90	33.90				6.00	4.00	10.00	3.00	20.32	
12:41:14	83.30	33.90				6.00	4.10	11.00	4.00	20.33	
12:41:19	83.60	33.90				7.00	4.10	11.00	3.00	20.35	
12:41:24	84.30	34.00				7.00	4.10	11.00	4.00	20.33	
12:41:29	83.70	34.00				7.00	4.10	11.00	4.00	20.32	
12:41:34	83.60	34.00				7.00	4.00	11.00	3.00	20.34	
12:46:41	107.90	33.90				5.00	12.10	17.00	5.00	19.36	63.30
12:46:46	106.10	33.90				6.00	12.00	18.00	6.00	19.43	62.80
12:46:51	104.10	33.90				5.00	11.90	17.00	5.00	19.50	62.30
12:46:56	103.00	33.90				5.00	11.90	17.00	6.00	19.54	61.80
12:47:01	102.10	33.90				6.00	11.60	17.00	5.00	19.59	61.00
12:47:06	101.00	33.90				6.00	11.40	17.00	5.00	19.65	60.20
12:47:11	101.00	33.90				5.00	11.20	17.00	5.00	19.68	59.20
12:47:16	98.00	33.80				6.00	11.10	17.00	6.00	19.71	60.00
12:47:21	91.70	33.70				6.00	10.70	17.00	6.00	19.78	61.60

12:47:26	103.70	33.80				6.00	9.70	16.00	6.00	19.88	50.70
12:47:31	117.70	33.80				5.00	10.20	16.00	5.00	19.56	52.90
12:47:36	116.20	33.60				6.00	11.20	17.00	5.00	19.16	63.50
12:47:41	112.30	33.40				6.00	11.50	17.00	5.00	19.01	67.40
12:47:46	107.70	33.40				6.00	11.50	18.00	5.00	19.01	69.10
12:47:51	106.30	33.50				6.00	10.90	17.00	5.00	19.09	68.50
12:47:56	107.30	33.50				6.00	10.90	17.00	5.00	19.15	67.30
12:48:01	107.70	33.60				6.00	11.10	17.00	6.00	19.18	66.60
12:48:06	108.30	33.60				6.00	11.20	17.00	6.00	19.23	65.40
12:48:11	108.40	33.70				6.00	11.50	18.00	6.00	19.27	64.80
12:48:16	106.60	33.60				7.00	11.80	18.00	6.00	19.33	64.40
12:48:21	105.80	33.50				7.00	11.70	18.00	6.00	19.40	63.30
12:48:26	103.60	33.50				6.00	11.80	18.00	6.00	19.45	63.40
12:48:31	100.50	33.40				7.00	11.40	18.00	6.00	19.53	62.90
12:48:36	100.70	33.40				7.00	11.10	18.00	6.00	19.60	61.40
12:53:43	97.10	33.40				4.00	10.60	15.00	5.00	19.90	54.20
12:53:48	96.40	33.40				4.00	10.40	15.00	5.00	19.91	53.90
12:53:53	96.30	33.40				5.00	10.40	15.00	5.00	19.92	53.70
12:53:58	96.20	33.30				5.00	10.30	15.00	5.00	19.95	52.70
12:54:03	95.10	33.40				5.00	10.10	15.00	5.00	19.98	52.10
12:54:08	95.20	33.30				4.00	9.80	14.00	5.00	20.03	
12:54:13	96.10	33.40				5.00	9.80	15.00	5.00	20.03	
12:54:18	95.40	33.30				4.00	9.80	14.00	5.00	20.01	
12:54:23	94.40	33.30				4.00	9.80	14.00	5.00	20.05	
12:54:28	95.30	33.30				4.00	9.90	14.00	5.00	20.04	
12:54:33	96.40	33.40				4.00	10.00	14.00	5.00	20.03	
12:54:38	96.60	33.40				5.00	10.30	15.00	5.00	20.01	
12:54:43	96.40	33.40				4.00	10.40	15.00	5.00	20.00	
12:54:48	97.40	33.40				4.00	10.60	15.00	5.00	20.00	50.90

12:54:53	96.50	33.40				5.00	10.60	15.00	5.00	19.98	
12:54:58	95.80	33.40				4.00	10.60	15.00	5.00	20.00	
12:55:03	95.00	33.30				4.00	10.20	15.00	5.00	20.20	
12:55:08	95.30	33.40				4.00	9.90	14.00	5.00	20.50	
12:55:13	95.20	33.30				4.00	9.90	14.00	5.00	20.30	
12:55:18	89.40	33.30				4.00	9.80	14.00	5.00	20.30	
12:55:23	83.10	33.40				4.00	9.20	13.00	5.00	20.11	
12:55:28	87.00	33.40				4.00	8.10	13.00	5.00	20.26	
12:55:33	100.20	33.40				5.00	8.00	12.00	4.00	20.21	
12:55:38	105.00	33.50				4.00	10.30	14.00	4.00	19.94	54.00
13:00:45	98.00	33.50				4.00	11.80	16.00	6.00	19.89	52.00
13:00:50	98.20	33.50				4.00	11.60	16.00	5.00	19.93	52.10
13:00:55	98.70	33.50				4.00	11.60	16.00	6.00	19.92	52.30
13:01:00	97.90	33.50				4.00	11.50	15.00	5.00	19.93	51.20
13:01:05	97.00	33.50				4.00	11.40	16.00	5.00	19.97	
13:01:10	96.50	33.40				4.00	11.20	15.00	6.00	20.01	
13:01:15	98.60	33.40				4.00	11.20	15.00	5.00	19.99	50.40
13:01:20	97.80	33.50				4.00	11.40	15.00	5.00	19.97	49.00
13:01:25	98.30	33.50				4.00	11.30	15.00	5.00	20.00	
13:01:30	97.10	33.40				4.00	11.10	15.00	5.00	20.00	
13:01:35	96.20	33.50				4.00	10.80	14.00	5.00	20.03	
13:01:40	94.70	33.50				4.00	10.60	15.00	5.00	20.60	
13:01:45	95.10	33.40				4.00	10.40	14.00	5.00	20.10	
13:01:50	95.60	33.50				4.00	10.30	14.00	5.00	20.10	
13:01:55	94.80	33.50				4.00	10.20	14.00	5.00	20.09	
13:02:00	93.70	33.50				4.00	10.20	14.00	5.00	20.12	
13:02:05	92.70	33.50				4.00	10.00	14.00	5.00	20.14	
13:02:10	93.50	33.40				3.00	9.80	13.00	5.00	20.15	
13:02:15	89.60	33.40				3.00	9.50	13.00	5.00	20.15	

13:02:20	84.30	33.30				3.00	9.00	12.00	5.00	20.21	
13:02:25	93.10	33.40				3.00	8.30	11.00	5.00	20.34	
13:02:30	104.00	33.40				3.00	9.60	13.00	4.00	20.16	
13:02:35	108.80	33.40				4.00	11.90	15.00	5.00	19.89	52.70
13:02:40	109.60	33.40				4.00	14.00	18.00	5.00	19.72	
13:07:47	88.00	33.40				2.00	6.70	9.00	5.00	20.38	
13:07:52	88.50	33.40				2.00	6.40	9.00	4.00	20.38	
13:07:57	88.70	33.40				2.00	6.30	9.00	5.00	20.37	
13:08:08	88.40	33.40				2.00	6.40	9.00	5.00	20.37	
13:08:07	88.10	33.40				2.00	6.40	9.00	5.00	20.37	
13:08:12	87.10	33.40				2.00	6.20	8.00	5.00	20.39	
13:08:17	86.30	33.40				2.00	5.90	8.00	5.00	20.42	
13:08:22	87.30	33.40				2.00	5.70	8.00	5.00	20.43	
13:08:27	88.00	33.40				2.00	5.90	8.00	5.00	20.38	
13:08:32	86.90	33.40				2.00	5.90	8.00	5.00	20.39	
13:08:37	86.20	33.40				2.00	5.60	8.00	5.00	20.41	
13:08:42	86.50	33.40				2.00	5.50	7.00	5.00	20.42	
13:08:47	83.70	33.40				2.00	5.50	8.00	5.00	20.43	
13:08:52	79.00	33.40				2.00	5.10	7.00	4.00	20.47	
13:08:57	77.80	33.40				2.00	4.50	7.00	4.00	20.56	
13:09:02	89.40	33.40				2.00	4.50	6.00	4.00	20.59	
13:09:07	98.40	33.40				3.00	6.20	9.00	4.00	20.35	
13:09:12	101.40	33.40				2.00	8.90	11.00	3.00	20.11	
13:09:17	101.40	33.40				3.00	10.90	13.00	4.00	19.33	53.80
13:09:22	101.50	33.40				3.00	12.00	15.00	4.00	19.83	56.60
13:09:27	101.30	33.50				3.00	12.80	16.00	4.00	19.75	57.90
13:09:32	99.40	33.40				3.00	13.00	16.00	5.00	19.74	56.70
13:09:37	98.70	33.40				3.00	12.60	16.00	5.00	19.80	56.20
13:09:42	97.50	32.90				3.00	12.20	15.00	5.00	19.83	54.00

13:14:49	92.40	33.00				3.00	10.20	13.00	4.00	19.97	
13:14:54	90.70	32.90				3.00	9.70	13.00	4.00	20.04	
13:14:59	90.60	32.90				3.00	9.20	12.00	4.00	20.09	
13:15:04	89.80	32.90				3.00	8.80	12.00	4.00	20.12	
13:15:09	89.10	33.00				3.00	8.40	12.00	4.00	20.17	
13:15:14	89.40	32.90				3.00	8.10	11.00	4.00	20.19	
13:15:19	87.40	32.90				3.00	7.80	10.00	4.00	20.21	
13:15:24	87.80	32.90				3.00	7.30	10.00	5.00	20.25	
13:15:29	88.30	32.80				3.00	7.20	10.00	4.00	20.26	
13:15:34	88.00	32.80				3.00	6.90	10.00	4.00	20.30	
13:15:39	87.30	32.90				3.00	6.80	10.00	4.00	20.30	
13:15:44	86.80	32.90				3.00	6.60	9.00	4.00	20.32	
13:15:49	86.60	32.80				3.00	6.30	9.00	4.00	20.35	
13:15:54	85.90	32.90				3.00	6.10	9.00	4.00	20.36	
13:15:59	85.90	32.90				3.00	5.80	9.00	4.00	2039.00	
13:16:04	86.40	32.80				2.00	5.70	8.00	4.00	20.38	
13:16:09	86.70	32.90				2.00	5.70	8.00	4.00	20.37	
13:16:14	86.30	32.80				2.00	5.70	8.00	4.00	20.37	
13:16:19	85.80	32.90				2.00	5.40	8.00	4.00	20.39	
13:16:24	85.10	33.00				2.00	5.20	7.00	4.00	20.43	
13:16:29	84.20	32.90				2.00	4.90	7.00	4.00	20.44	
13:16:34	84.60	32.90				2.00	4.90	7.00	4.00	20.43	
13:16:39	83.50	32.90				2.00	4.80	7.00	4.00	20.45	
13:16:44	84.30	32.70				2.00	4.70	7.00	4.00	20.46	
13:21:51	81.90	32.60				2.00	4.20	6.00	4.00	20.53	
13:21:56	81.90	32.80				1.00	4.20	6.00	4.00	20.53	
13:22:01	81.30	32.80				2.00	4.10	6.00	4.00	20.54	
13:22:06	81.40	32.80				2.00	4.00	6.00	4.00	20.54	
13:22:11	81.30	32.90				2.00	4.00	6.00	4.00	20.55	

13:22:16	81.60	32.70				2.00	4.00	6.00	4.00	20.55	
13:22:21	81.70	32.70				1.00	3.90	5.00	4.00	20.56	
13:22:26	81.10	32.70				2.00	3.80	6.00	4.00	20.55	
13:22:31	81.00	32.70				1.00	3.80	5.00	4.00	20.56	
13:22:36	80.50	32.80				2.00	3.60	5.00	4.00	20.56	
13:22:41	80.30	32.70				1.00	3.40	5.00	4.00	20.58	
13:22:46	80.10	32.80				1.00	3.40	5.00	4.00	20.58	
13:22:51	80.10	32.80				2.00	3.20	5.00	4.00	20.59	
13:22:56	79.90	32.80				2.00	3.20	5.00	4.00	20.60	
13:23:01	80.50	32.70				1.00	3.20	5.00	4.00	20.60	
13:23:06	79.70	32.70				1.00	3.20	5.00	4.00	20.61	
13:23:11	78.90	32.90				1.00	3.00	4.00	3.00	20.62	
13:23:16	79.50	32.90				1.00	3.00	4.00	3.00	20.63	
13:23:21	79.60	32.90				1.00	2.90	4.00	3.00	20.62	
13:23:26	79.10	32.90				1.00	2.80	4.00	3.00	20.63	
13:23:31	79.40	32.90				1.00	2.80	4.00	3.00	20.63	
13:23:36	79.70	32.90				1.00	2.80	4.00	3.00	20.64	
13:23:41	78.70	32.80				1.00	2.70	4.00	3.00	20.62	
13:23:46	75.90	33.10				1.00	2.80	4.00	4.00	20.64	
13:28:53	75.80	33.00				2.00	1.90	4.00	3.00	20.76	
13:28:58	75.80	33.10				1.00	1.90	3.00	3.00	20.77	
13:29:03	75.80	33.20				1.00	1.90	3.00	3.00	20.77	
13:29:08	75.10	33.20				1.00	1.70	3.00	3.00	20.78	
13:29:13	74.40	33.20				1.00	1.70	3.00	3.00	20.78	
13:29:18	74.50	33.10				1.00	1.70	3.00	3.00	20.79	
13:29:23	74.80	33.10				1.00	1.70	3.00	3.00	20.79	
13:29:28	75.20	33.10				1.00	1.70	3.00	3.00	20.78	
13:29:33	75.00	33.10				1.00	1.70	3.00	3.00	20.78	
13:29:38	75.40	33.10				1.00	1.70	3.00	3.00	20.79	

13:29:43	75.00	33.10				1.00	1.70	3.00	3.00	20.78	
13:29:48	75.20	33.10				1.00	1.50	3.00	3.00	20.78	
13:29:53	75.00	33.10				1.00	1.60	3.00	2.00	20.77	
13:29:58	75.20	33.20				1.00	1.70	3.00	3.00	20.77	
13:30:03	74.90	33.10				1.00	1.70	3.00	2.00	20.78	
13:30:08	74.10	33.10				1.00	1.70	3.00	3.00	20.79	
13:30:13	74.70	33.10				1.00	1.70	3.00	3.00	20.79	
13:30:18	74.40	33.10				1.00	1.70	3.00	3.00	20.80	
13:30:23	74.20	33.20				1.00	1.50	2.00	2.00	20.80	
13:30:28	74.20	33.20				1.00	1.60	2.00	3.00	20.81	
13:30:33	74.00	33.20				1.00	1.50	2.00	2.00	20.80	
13:30:38	74.70	33.20				1.00	1.50	2.00	2.00	20.79	
13:30:43	74.30	33.20				0.00	1.60	2.00	3.00	20.80	
13:30:48	74.20	33.20				1.00	1.60	2.00	3.00	20.81	

Table O 36: Temperature at pyrolysis chamber for Experiment (vi-3); AVR = 4.00:9.65 (OPKS)

Mean	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)
	0	0.00	14.5	333.00	29	349.00	43.5	176.00	58	147.00
	0.5	171.00	15	339.00	29.5	300.00	44	185.00	58.5	142.00
	1	211.00	15.5	315.00	30	262.00	44.5	199.00	59	139.00
	1.5	256.00	16	291.00	30.5	243.00	45	189.00	59.5	135.00
	2	270.00	16.5	289.00	31	228.00	45.5	178.00	60	133.00
	2.5	314.00	17	270.00	31.5	213.00	46	194.00	60.5	139.00
	3	318.00	17.5	261.00	32	203.00	46.5	218.00	61	164.00
	3.5	331.00	18	249.00	32.5	226.00	47	210.00	61.5	161.00
	4	359.00	18.5	255.00	33	215.00	47.5	198.00	62	153.00
	4.5	389.00	19	247.00	33.5	207.00	48	187.00	62.5	146.00
	5	390.00	19.5	268.00	34	336.00	48.5	179.00	63	140.00
	5.5	390.00	20	251.00	34.5	379.00	49	172.00	63.5	134.00
	6	395.00	20.5	246.00	35	324.00	49.5	167.00	64	130.00
	6.5	401.00	21	250.00	35.5	260.00	50	160.00	64.5	127.00
	7	432.00	21.5	237.00	36	232.00	50.5	164.00	65	123.00
	7.5	424.00	22	239.00	36.5	217.00	51	193.00	65.5	126.00
	8	438.00	22.5	237.00	37	242.00	51.5	182.00	66	140.00
	8.5	458.00	23	227.00	37.5	252.00	52	174.00	66.5	138.00
	9	439.00	23.5	216.00	38	228.00	52.5	165.00	67	133.00
	9.5	450.00	24	216.00	38.5	223.00	53	161.00	67.5	126.00
	10	426.00	24.5	217.00	39	209.00	53.5	155.00	68	123.00
	10.5	435.00	25	206.00	39.5	201.00	54	149.00	68.5	120.00
	11	416.00	25.5	270.00	40	189.00	54.5	146.00	69	118.00
	11.5	391.00	26	246.00	40.5	219.00	55	142.00	69.5	114.00

12	412.00	26.5	231.00	41	235.00	55.5	151.00	70	112.00
12.5	406.00	27	223.00	41.5	213.00	56	178.00	70.5	110.00
13	378.00	27.5	235.00	42	201.00	56.5	170.00	71	108.00
13.5	375.00	28	236.00	42.5	189.00	57	159.00	71.5	106.00
14	346.00	28.5	211.00	43	183.00	57.5	153.00	72	105.00
									103.00
									72.5
									103.00

Experiment set (vii-1)

Date = 9/1/2013; Sample = About 3 Kg of OPKS; Methanol = About 3 Liter; AVR = .83:9.65

Measurement rate = 5 seconds; Gas time = 2 minutes; Rinse time = 5 minutes; Mean = 1 second; To make the data meaningful, rinse time is neglected

Table O 37: Results of TESTO Experiment (vii-1); AVR = 3.83:9.65 (OPKS)

Mean	79.94	30.28	183.54	61.35	2.70	5.67	8.34	3.34	19.99	67.36
Time	FT (°C)	AT (°C)	CO (ppmv)	H2 (ppmv)	NO (ppmv)	NO2 (ppmv)	NOx (ppmv)	SO2 (ppmv)	O2 (%)	η (%)
8:36:17	73.50	29.40	1.00	0.00	0.00	0.00	0.00	0.00	21.02	
8:36:22	77.50	29.50	37.00	24.00	0.00	1.00	1.00	1.00	20.25	
8:36:27	74.30	29.50	157.00	63.00	1.00	1.90	2.00	4.00	19.47	74.00
8:36:32	73.30	29.50	222.00	37.00	0.00	1.90	2.00	6.00	19.07	79.10
8:36:37	73.20	29.50	222.00	1.00	0.00	1.70	2.00	6.00	18.91	80.50
8:36:42	73.60	29.50	217.00	10.00	0.00	1.70	2.00	6.00	18.88	80.60
8:36:47	74.60	29.60	195.00	33.00	0.00	1.50	2.00	6.00	18.78	81.10
8:36:52	75.40	29.70	183.00	41.00	0.00	1.30	2.00	5.00	18.79	80.80
8:36:57	76.50	29.60	179.00	40.00	0.00	1.40	2.00	5.00	18.78	80.60
8:37:02	77.40	29.70	180.00	40.00	1.00	1.50	2.00	5.00	18.72	80.70
8:37:07	78.60	29.70	180.00	41.00	1.00	1.50	2.00	5.00	18.68	80.60
8:37:12	79.00	29.70	178.00	42.00	0.00	1.60	2.00	5.00	18.68	80.50
8:37:17	77.90	29.70	174.00	44.00	1.00	1.60	2.00	5.00	18.70	80.70
8:37:22	76.90	29.70	171.00	44.00	1.00	1.70	2.00	4.00	18.77	80.50
8:37:27	78.40	29.60	171.00	43.00	1.00	1.50	2.00	5.00	18.82	79.60
8:37:32	80.60	29.70	170.00	43.00	1.00	1.70	2.00	5.00	18.81	79.00
8:37:37	79.40	29.60	169.00	44.00	1.00	1.90	3.00	4.00	18.80	79.40
8:37:42	78.50	29.70	164.00	47.00	0.00	1.90	2.00	4.00	18.87	19.20
8:37:47	79.80	29.70	159.00	47.00	1.00	2.10	3.00	4.00	18.90	18.60

8:37:52	81.10	29.80	157.00	45.00	1.00	2.20	3.00	4.00	18.87	78.40
8:37:57	81.80	29.70	161.00	43.00	1.00	2.10	3.00	4.00	18.89	79.90
8:38:02	81.60	29.70	164.00	42.00	1.00	2.30	3.00	4.00	18.88	78.00
8:38:07	82.10	29.80	165.00	44.00	1.00	2.30	3.00	4.00	18.91	77.70
8:38:12	83.60	29.80	161.00	46.00	1.00	2.50	3.00	4.00	18.87	77.50
8:43:19	92.70	29.80	141.00	42.00	1.00	4.80	6.00	2.00	19.11	71.50
8:43:24	92.40	29.80	143.00	42.00	1.00	4.60	6.00	3.00	19.12	71.60
8:43:29	92.70	29.60	145.00	43.00	1.00	4.60	6.00	3.00	19.13	71.30
8:43:34	93.40	29.60	146.00	45.00	1.00	4.70	6.00	3.00	19.10	71.40
8:43:39	92.80	29.70	146.00	47.00	1.00	4.60	5.00	3.00	19.11	71.50
8:43:44	90.50	29.80	146.00	46.00	1.00	4.60	6.00	3.00	19.13	72.20
8:43:49	89.90	29.80	145.00	47.00	1.00	4.60	6.00	3.00	19.16	72.00
8:43:54	90.40	29.80	139.00	50.00	1.00	4.80	6.00	3.00	19.24	70.80
8:43:59	91.60	29.70	137.00	49.00	1.00	4.60	6.00	3.00	19.21	70.70
8:44:04	91.90	29.70	139.00	48.00	1.00	4.80	6.00	3.00	19.17	71.00
8:44:09	92.30	29.70	145.00	45.00	1.00	4.90	6.00	2.00	19.16	70.90
8:44:14	94.30	29.70	149.00	46.00	1.00	4.90	6.00	3.00	19.13	70.60
8:44:19	93.20	29.70	153.00	47.00	1.00	4.90	6.00	3.00	19.12	71.20
8:44:24	91.10	29.70	156.00	48.00	1.00	4.90	6.00	3.00	19.19	71.10
8:44:29	91.20	29.70	157.00	50.00	1.00	4.90	6.00	3.00	19.24	70.20
8:44:34	91.30	29.70	157.00	52.00	1.00	4.80	6.00	3.00	19.22	70.50
8:44:39	91.20	29.80	157.00	53.00	1.00	4.90	6.00	3.00	19.23	70.40
8:44:44	90.80	29.80	157.00	54.00	1.00	5.10	6.00	3.00	19.23	70.60
8:44:49	90.20	29.70	155.00	56.00	1.00	5.10	6.00	3.00	19.26	70.40
8:44:54	90.10	29.70	150.00	58.00	1.00	4.90	6.00	3.00	19.32	69.50
8:44:59	90.90	29.70	148.00	58.00	1.00	5.00	6.00	3.00	19.29	69.70
8:45:04	91.10	29.70	151.00	55.00	1.00	5.10	6.00	3.00	19.27	69.80
8:45:09	89.80	29.80	154.00	56.00	1.00	5.20	6.00	3.00	19.26	70.60
8:45:14	89.20	29.80	153.00	59.00	1.00	4.70	5.00	3.00	19.33	69.70

8:50:21	80.00	29.90	167.00	62.00	2.00	4.90	7.00	3.00	19.95	60.30
8:50:26	80.50	29.80	168.00	62.00	2.00	5.00	7.00	3.00	19.96	59.80
8:50:31	81.10	29.80	172.00	63.00	2.00	4.90	7.00	4.00	19.93	60.30
8:50:36	81.30	29.80	176.00	64.00	3.00	5.10	8.00	3.00	19.91	60.80
8:50:41	80.20	29.80	179.00	66.00	2.00	5.10	7.00	4.00	19.91	61.40
8:50:46	80.30	29.80	179.00	68.00	2.00	5.10	7.00	4.00	19.93	60.60
8:50:51	80.70	29.80	179.00	71.00	2.00	5.10	7.00	4.00	19.93	60.50
8:50:56	80.70	29.80	177.00	72.00	2.00	5.10	7.00	4.00	19.93	60.50
8:51:01	79.40	29.70	174.00	74.00	3.00	5.10	8.00	3.00	19.92	61.50
8:51:06	76.40	29.80	174.00	76.00	2.00	5.00	7.00	3.00	19.98	
8:51:11	83.20	29.80	166.00	80.00	3.00	4.70	7.00	3.00	20.06	
5:51:16	90.90	29.90	147.00	84.00	2.00	5.90	8.00	3.00	19.82	
8:51:21	92.10	29.90	138.00	81.00	2.00	7.10	10.00	2.00	19.50	65.40
8:51:26	92.00	29.80	138.00	76.00	3.00	7.60	10.00	2.00	19.38	67.70
8:51:31	91.20	29.90	143.00	71.00	3.00	7.90	10.00	2.00	19.33	69.00
8:51:36	89.70	29.90	151.00	67.00	3.00	8.00	11.00	2.00	19.33	69.60
8:51:41	88.90	29.90	162.00	63.00	3.00	8.00	11.00	3.00	19.39	68.90
8:51:46	87.80	29.90	169.00	66.00	3.00	7.80	11.00	3.00	19.43	68.80
8:51:51	88.00	30.00	173.00	68.00	3.00	7.80	11.00	3.00	19.47	67.80
8:51:56	87.10	29.90	174.00	69.00	3.00	7.90	11.00	3.00	19.50	67.80
8:52:01	83.80	29.90	175.00	71.00	3.00	7.90	11.00	3.00	19.54	68.50
8:52:06	80.50	29.90	173.00	75.00	3.00	7.40	10.00	3.00	19.66	67.80
8:52:11	87.80	30.00	161.00	82.00	3.00	7.10	10.00	3.00	19.78	60.90
8:52:16	91.60	30.00	149.00	81.00	3.00	8.10	11.00	2.00	19.57	64.10
8:57:23	85.60	29.10	178.00	59.00	4.00	9.40	14.00	3.00	19.61	66.10
8:57:28	87.50	30.10	180.00	57.00	4.00	9.50	13.00	3.00	19.62	65.00
8:57:33	87.20	30.10	186.00	55.00	4.00	9.70	14.00	3.00	19.60	65.70
8:57:38	85.50	29.80	188.00	58.00	4.00	9.60	14.00	3.00	19.63	65.60
8:57:43	84.10	29.80	186.00	61.00	4.00	9.50	13.00	3.00	19.69	65.00

8:57:48	83.50	29.80	181.00	64.00	4.00	9.30	13.00	3.00	19.75	64.10
8:57:53	83.90	29.80	177.00	65.00	4.00	9.10	13.00	3.00	19.79	62.80
8:57:58	83.60	29.80	176.00	65.00	4.00	9.10	13.00	3.00	19.79	62.90
8:58:03	82.80	29.70	177.00	62.00	4.00	8.90	13.00	3.00	19.82	62.60
8:58:08	83.40	29.80	179.00	61.00	4.00	8.50	13.00	4.00	19.85	61.20
8:58:13	84.70	29.80	184.00	61.00	4.00	8.60	13.00	4.00	19.84	60.70
8:58:18	84.60	29.80	188.00	63.00	4.00	8.90	13.00	4.00	19.81	61.70
8:58:23	83.40	29.70	190.00	66.00	4.00	9.00	13.00	4.00	19.82	61.90
8:58:28	83.50	29.70	191.00	68.00	4.00	8.90	13.00	4.00	19.83	61.60
8:58:33	82.40	29.80	192.00	69.00	4.00	8.80	13.00	4.00	19.86	61.60
8:58:38	81.40	29.90	194.00	69.00	4.00	8.70	13.00	4.00	19.89	61.10
8:58:43	81.30	30.00	193.00	71.00	4.00	8.60	13.00	4.00	19.93	60.10
8:58:48	81.50	29.90	188.00	75.00	4.00	8.70	12.00	4.00	19.92	60.10
8:58:53	80.80	29.90	188.00	73.00	3.00	8.60	12.00	4.00	19.92	60.80
8:58:58	80.90	29.90	188.00	73.00	3.00	8.40	12.00	4.00	19.94	60.00
8:59:03	81.00	30.00	192.00	73.00	4.00	8.40	12.00	4.00	19.93	60.30
8:59:08	80.00	30.00	199.00	72.00	4.00	8.30	12.00	4.00	19.96	60.10
8:59:13	79.70	30.10	200.00	75.00	4.00	7.90	12.00	4.00	20.01	
8:59:18	78.80	30.10	198.00	78.00	4.00	7.80	12.00	4.00	20.01	
9:04:25	81.60	29.80	225.00	65.00	5.00	8.60	13.00	5.00	20.12	
9:04:30	80.00	29.80	228.00	66.00	5.00	8.50	13.00	5.00	20.15	
9:04:35	80.30	29.80	230.00	66.00	4.00	8.00	12.00	5.00	20.19	
9:04:40	81.00	29.80	231.00	68.00	4.00	8.00	12.00	5.00	20.18	
9:04:45	81.20	29.90	234.00	70.00	5.00	8.20	13.00	5.00	20.17	
9:04:50	80.80	30.10	241.00	68.00	4.00	8.20	13.00	5.00	20.16	
9:04:55	79.60	30.00	246.00	69.00	4.00	7.90	12.00	6.00	20.18	
9:05:00	79.00	29.90	246.00	74.00	4.00	7.80	12.00	5.00	20.23	
9:05:05	79.10	29.90	244.00	77.00	4.00	7.70	12.00	5.00	20.24	
9:05:10	78.90	29.90	242.00	79.00	4.00	7.50	12.00	5.00	20.26	

9:05:15	79.20	29.80	247.00	77.00	4.00	7.40	12.00	6.00	20.24	
9:05:20	79.20	29.80	259.00	75.00	4.00	7.40	12.00	6.00	20.23	
9:05:05	78.70	30.00	265.00	78.00	4.00	7.60	12.00	6.00	20.25	
9:05:30	78.20	30.00	265.00	84.00	4.00	7.30	12.00	6.00	20.26	
9:05:35	78.10	30.00	267.00	85.00	4.00	7.20	11.00	6.00	20.26	
9:05:40	77.30	30.10	271.00	87.00	4.00	7.10	11.00	6.00	20.29	
9:05:45	77.00	30.10	271.00	90.00	4.00	6.80	11.00	6.00	20.32	
9:05:50	77.20	30.10	269.00	94.00	4.00	6.60	11.00	6.00	20.34	
9:05:55	76.40	30.10	267.00	96.00	4.00	6.50	10.00	6.00	20.35	
9:06:00	75.90	30.00	265.00	97.00	4.00	6.50	10.00	6.00	20.37	
9:06:05	76.00	30.10	263.00	99.00	4.00	6.30	10.00	6.00	20.38	
9:06:10	75.70	30.20	262.00	98.00	3.00	6.30	10.00	6.00	20.38	
9:06:15	75.20	30.20	262.00	97.00	4.00	6.10	10.00	6.00	20.40	
9:06:20	75.30	30.20	262.00	98.00	4.00	5.80	10.00	6.00	20.41	
9:11:27	79.90	30.80			4.00	8.40	12.00	2.00	20.14	
9:11:32	79.70	30.80			4.00	8.60	12.00	3.00	20.12	
9:11:37	80.10	30.90			4.00	8.50	12.00	3.00	20.12	
9:11:42	80.00	30.80			4.00	8.50	12.00	3.00	20.12	
9:11:47	79.80	30.80			4.00	8.50	12.00	3.00	20.13	
9:11:52	79.40	30.90			4.00	8.40	12.00	3.00	20.16	
9:11:57	79.40	30.80			4.00	8.10	13.00	3.00	20.17	
9:12:02	79.00	30.80			4.00	8.00	12.00	3.00	20.19	
9:12:07	79.30	30.90			4.00	8.00	11.00	3.00	20.20	
9:12:12	79.20	30.90			4.00	8.00	12.00	3.00	20.20	
9:12:17	79.40	30.90			3.00	7.80	11.00	3.00	20.21	
9:12:22	79.10	30.90			4.00	7.70	11.00	3.00	20.22	
9:12:27	78.20	31.00			4.00	7.50	11.00	3.00	20.24	
9:12:32	77.70	30.90			3.00	7.20	11.00	3.00	20.27	
9:12:37	77.70	30.90			4.00	7.20	11.00	3.00	20.29	

9:12:42	78.00	31.00				3.00	7.00	11.00	3.00	20.29	
9:12:47	78.30	31.00				3.00	7.10	10.00	3.00	20.28	
9:12:52	79.00	31.00				3.00	7.10	10.00	3.00	20.27	
9:12:57	79.00	31.00				3.00	7.10	11.00	3.00	20.26	
9:13:02	78.60	30.70				3.00	7.10	10.00	3.00	20.26	
9:13:07	77.70	30.50				3.00	6.80	10.00	3.00	20.28	
9:13:12	76.60	30.40				3.00	6.50	10.00	4.00	20.33	
9:13:17	76.30	30.40				3.00	6.30	9.00	3.00	20.34	
9:13:22	76.30	30.60				3.00	6.10	9.00	3.00	20.36	
9:18:29	74.30	31.30				3.00	4.40	7.00	3.00	20.51	
9:18:34	73.80	31.30				3.00	4.20	7.00	3.00	20.51	
9:18:39	73.30	31.30				3.00	4.20	7.00	3.00	20.52	
9:18:44	73.50	31.20				3.00	4.00	7.00	3.00	20.52	
9:18:49	73.40	31.30				3.00	3.90	7.00	3.00	20.53	
9:18:54	73.30	31.30				3.00	3.70	7.00	3.00	20.54	
9:18:59	73.20	31.30				3.00	3.60	7.00	3.00	20.56	
9:19:04	72.90	31.30				3.00	3.50	6.00	3.00	20.56	
9:19:09	73.00	31.30				3.00	3.40	6.00	3.00	20.55	
9:19:14	72.80	31.30				3.00	3.40	6.00	3.00	20.55	
9:19:19	72.90	31.40				3.00	3.30	6.00	3.00	20.56	
9:19:24	73.00	31.30				3.00	3.20	6.00	3.00	20.56	
9:19:29	71.50	31.30				3.00	3.20	6.00	3.00	20.56	
9:19:34	69.30	31.30				3.00	2.80	5.00	3.00	20.60	
9:19:39	67.00	31.30				3.00	2.50	5.00	3.00	20.66	
9:19:44	69.00	31.30				3.00	2.30	5.00	3.00	20.74	
9:19:49	76.10	31.30				3.00	3.00	6.00	2.00	20.64	
9:19:54	83.80	31.40				3.00	5.10	8.00	2.00	20.39	
9:19:59	91.70	31.40				3.00	8.10	11.00	2.00	20.03	
9:20:04	92.40	31.40				3.00	10.90	14.00	2.00	19.78	59.90

9:20:09	91.00	31.30					4.00	11.90	16.00	2.00	19.72	62.20
9:20:14	93.00	31.40					4.00	12.60	17.00	3.00	19.65	63.00
9:20:19	93.00	31.40					4.00	13.40	18.00	3.00	19.57	64.90
9:20:24	90.80	31.30					4.00	13.80	18.00	3.00	19.56	66.20
9:25:31	78.20	31.10					4.00	7.40	11.00	3.00	20.29	
9:25:36	78.00	31.00					4.00	7.20	11.00	3.00	20.30	
9:25:41	77.50	30.80					4.00	6.90	10.00	3.00	20.32	
9:25:46	77.30	30.60					4.00	6.70	10.00	3.00	20.35	
9:25:51	77.70	30.60					4.00	6.60	10.00	3.00	20.36	
9:25:56	77.00	30.50					4.00	6.40	10.00	3.00	20.37	
9:26:01	77.30	30.50					4.00	6.30	10.00	3.00	20.37	
9:26:06	77.10	30.60					3.00	6.30	10.00	3.00	20.39	
9:26:11	77.40	30.60					3.00	6.10	9.00	3.00	20.38	
9:26:16	77.10	30.70					3.00	5.90	9.00	3.00	20.40	
9:26:21	76.90	30.70					3.00	5.90	9.00	3.00	20.40	
9:26:26	76.80	30.70					3.00	5.70	9.00	3.00	20.41	
9:26:31	76.70	30.80					4.00	5.70	9.00	3.00	20.42	
9:26:36	76.50	30.70					3.00	5.60	9.00	4.00	20.43	
9:26:41	76.40	30.70					3.00	5.50	9.00	3.00	20.44	
9:26:46	76.20	30.70					3.00	5.40	9.00	3.00	20.44	
9:26:51	76.20	30.80					3.00	5.30	9.00	3.00	20.44	
9:26:56	75.90	30.70					3.00	5.10	8.00	3.00	20.46	
9:27:01	75.60	30.60					3.00	4.90	8.00	3.00	20.47	
9:27:06	75.60	30.60					3.00	4.90	8.00	3.00	20.48	
9:27:11	76.00	30.60					3.00	4.70	8.00	3.00	20.48	
9:27:16	75.90	30.70					3.00	4.60	8.00	3.00	20.48	
9:27:21	75.20	30.60					3.00	4.50	7.00	3.00	20.50	
9:27:26	75.10	30.70					3.00	4.30	7.00	3.00	20.50	
9:32:33	74.80	30.40					2.00	3.00	5.00	2.00	20.52	

9:32:38	74.50	30.40					2.00	3.00	5.00	2.00	20.50	
9:32:43	74.20	30.30					3.00	3.00	6.00	2.00	20.52	
9:32:48	74.20	30.30					2.00	3.00	5.00	3.00	20.54	
9:32:53	74.00	30.30					2.00	3.00	5.00	3.00	20.54	
9:32:58	73.90	30.30					2.00	3.00	5.00	2.00	20.55	
9:33:03	74.20	30.30					2.00	2.80	5.00	2.00	20.54	
9:33:08	74.10	30.40					2.00	2.80	5.00	3.00	20.55	
9:33:13	73.70	30.50					2.00	2.70	5.00	2.00	20.56	
9:33:18	73.30	30.60					2.00	2.70	5.00	2.00	20.57	
9:33:23	73.00	30.70					3.00	2.50	5.00	2.00	20.58	
9:33:28	72.60	30.70					3.00	2.40	5.00	2.00	20.58	
9:33:33	70.10	30.60					2.00	2.30	5.00	2.00	20.61	
9:33:38	68.00	30.50					2.00	2.10	4.00	2.00	20.66	
9:33:43	66.20	30.40					3.00	1.90	4.00	2.00	20.71	
9:33:48	65.70	30.20					2.00	1.70	4.00	2.00	20.77	
9:33:53	73.10	30.10					2.00	2.00	4.00	2.00	20.78	
9:33:58	81.30	30.20					2.00	4.10	6.00	1.00	20.49	
9:34:04	85.60	30.20					3.00	8.70	9.00	1.00	20.24	
9:34:08	88.00	30.30					3.00	8.70	12.00	1.00	20.02	
9:34:13	88.70	30.30					3.00	10.40	13.00	2.00	19.90	57.40
9:34:18	86.60	30.30					3.00	11.00	14.00	2.00	19.87	60.00
9:34:23	85.50	30.20					4.00	11.00	15.00	2.00	19.91	59.30
9:34:28	84.60	30.50					4.00	10.80	14.00	2.00	19.94	58.90
9:39:35	75.90	30.50					3.00	5.50	8.00	3.00	20.45	
9:39:40	75.00	30.50					3.00	5.30	8.00	3.00	20.48	
9:39:45	75.10	30.40					3.00	5.00	8.00	3.00	20.50	
9:39:50	75.60	30.60					3.00	4.90	8.00	3.00	20.50	
9:39:55	75.30	30.60					3.00	4.90	7.00	3.00	20.49	
9:40:00	74.70	30.50					2.00	4.80	7.00	3.00	20.51	

9:40:05	74.10	30.60				2.00	4.40	7.00	3.00	20.54	
9:40:10	74.30	30.60				3.00	4.40	7.00	3.00	20.56	
9:40:15	74.60	30.40				2.00	4.20	7.00	3.00	20.56	
9:40:20	74.60	30.40				2.00	4.20	6.00	3.00	20.55	
9:40:25	74.10	30.50				2.00	4.10	6.00	3.00	20.54	
9:40:30	74.00	30.50				2.00	4.00	6.00	3.00	20.55	
9:40:35	73.90	30.50				2.00	3.90	6.00	3.00	20.56	
9:40:40	73.50	30.50				2.00	3.80	6.00	3.00	20.57	
9:40:45	73.60	30.50				2.00	3.70	6.00	3.00	20.58	
9:40:50	73.40	30.60				2.00	3.60	5.00	3.00	20.60	
9:40:55	72.80	30.60				2.00	3.40	5.00	3.00	20.61	
9:41:00	72.70	30.60				2.00	3.20	5.00	3.00	20.62	
9:41:05	73.10	30.70				2.00	3.20	5.00	3.00	20.63	
9:41:10	73.20	30.50				2.00	3.20	5.00	3.00	20.61	
9:41:15	72.80	30.60				2.00	3.20	5.00	3.00	20.61	
9:41:20	72.60	30.60				2.00	3.00	5.00	3.00	20.62	

Table O 38: Temperature at pyrolysis chamber for Experiment (vii-1); $AVR = 3.83$; 9.65 (OPKS)

Mean		238.87					
Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)
0	0.00	14.5	295.00	29	210.00	43.5	157.00
0.5	313.00	15	338.00	29.5	240.00	44	205.00
1	355.00	15.5	297.00	30	257.00	44.5	201.00
1.5	394.00	16	410.00	30.5	236.00	45	189.00
2	377.00	16.5	404.00	31	225.00	45.5	176.00
2.5	386.00	17	346.00	31.5	206.00	46	165.00
3	385.00	17.5	309.00	32	192.00	46.5	158.00
3.5	380.00	18	290.00	32.5	183.00	47	151.00
4	389.00	18.5	280.00	33	274.00	47.5	160.00
4.5	402.00	19	263.00	33.5	272.00	48	195.00
5	380.00	19.5	316.00	34	252.00	48.5	197.00
5.5	357.00	20	340.00	34.5	230.00	49	181.00
6	364.00	20.5	319.00	35	212.00	49.5	168.00
6.5	357.00	21	321.00	35.5	201.00	50	158.00
7	355.00	21.5	309.00	36	200.00	50.5	150.00
7.5	343.00	22	309.00	36.5	194.00	51	143.00
8	351.00	22.5	295.00	37	185.00	51.5	139.00
8.5	354.00	23	286.00	37.5	195.00	52	136.00
9	346.00	23.5	317.00	38	246.00	52.5	143.00
9.5	340.00	24	298.00	38.5	243.00	53	179.00
10	342.00	24.5	273.00	39	225.00	53.5	172.00
10.5	341.00	25	253.00	39.5	213.00	54	161.00
11	329.00	25.5	280.00	40	202.00	54.5	154.00
11.5	325.00	26	249.00	40.5	191.00	55	148.00

12	315.00	26.5	233.00	41	183.00	55.5	144.00
12.5	317.00	27	221.00	41.5	173.00	56	140.00
13	310.00	27.5	209.00	42	168.00	56.5	136.00
13.5	307.00	28	203.00	42.5	160.00	57	134.00
14	305.00	28.5	197.00	43	151.00	57.5	133.00

Experiment set (vii-2)

Date = 9/1/2013; Sample = About 3 Kg of OPKS; Methanol = About 3 Liter; AVR = 3.83:9.65

Measurement rate = 5 seconds; Gas time = 2 minutes; Rinse time = 5 minutes; Mean = 1 second; To make the data meaningful, rinse time is neglected

Table O 39: Results of TESTO Experiment (vii-2); AVR = 3.83:9.65 (OPKS)

Mean	86.82	32.72	194.80	65.38	2.59	6.58	9.19	5.04	19.85	66.68
Time	FT (°C)	AT (°C)	CO (ppmv)	H2 (ppmv)	NO (ppmv)	NO2 (ppmv)	NOx (ppmv)	SO2 (ppmv)	O2 (%)	η (%)
11:04:08	85.90	32.50	0.00	1.00	0.00	0.00	0.00	0.00	20.99	
11:43:13	86.50	32.50	33.00	22.00	1.00	0.90	2.00	1.00	19.98	
11:43:18	84.60	32.40	129.00	48.00	1.00	1.80	3.00	4.00	18.99	77.00
11:43:23	86.50	32.50	174.00	32.00	1.00	1.70	2.00	6.00	18.71	78.70
11:43:28	86.10	32.70	195.00	9.00	1.00	1.60	3.00	7.00	18.62	79.60
11:43:33	85.10	32.90	203.00	8.00	1.00	1.50	2.00	7.00	18.63	79.80
11:43:38	82.50	33.00	201.00	23.00	1.00	1.50	2.00	7.00	18.64	80.60
11:43:43	80.10	33.00	195.00	34.00	1.00	1.60	2.00	6.00	16.68	81.10
11:43:48	83.10	32.80	190.00	40.00	1.00	1.70	3.00	6.00	18.68	80.10
11:43:53	83.50	32.80	190.00	41.00	1.00	1.70	2.00	6.00	18.66	80.20
11:43:58	83.70	32.90	191.00	42.00	1.00	1.70	3.00	6.00	18.72	79.60
11:44:03	84.60	33.00	191.00	42.00	1.00	1.80	3.00	6.00	18.72	79.40
11:44:08	86.90	32.90	192.00	44.00	1.00	1.90	3.00	5.00	18.73	78.60
11:44:13	88.10	33.00	193.00	45.00	1.00	2.00	3.00	6.00	18.67	78.70
11:44:18	90.20	33.00	196.00	45.00	1.00	2.30	3.00	6.00	18.67	78.00
11:44:23	91.30	32.80	200.00	45.00	1.00	2.30	3.00	6.00	18.65	77.70
11:44:28	91.60	32.70	214.00	46.00	1.00	2.30	3.00	6.00	18.59	78.00
11:44:33	92.30	32.60	210.00	50.00	1.00	2.60	3.00	6.00	18.56	78.00

11:44:38	89.50	32.40	202.00	54.00	1.00	2.50	3.00	6.00	18.58	78.70
11:44:43	89.50	32.50	200.00	53.00	1.00	2.40	3.00	6.00	18.66	78.10
11:44:48	89.40	32.50	203.00	51.00	1.00	2.30	3.00	7.00	18.69	77.90
11:44:53	90.10	32.60	208.00	49.00	1.00	2.40	3.00	6.00	18.74	77.20
11:44:58	92.30	32.70	212.00	49.00	1.00	2.40	3.00	7.00	18.74	76.50
11:45:03	92.30	32.60	216.00	50.00	1.00	2.50	3.00	6.00	18.73	76.60
11:50:10	102.40	32.40	146.00	55.00	1.00	2.40	5.00	4.00	18.73	73.40
11:50:15	103.00	32.40	138.00	59.00	1.00	4.40	6.00	4.00	18.81	72.50
11:50:20	102.50	32.50	129.00	62.00	1.00	4.40	5.00	4.00	18.79	72.90
11:50:25	101.80	32.50	128.00	58.00	1.00	4.40	5.00	4.00	18.77	73.40
11:50:30	100.20	32.60	129.00	57.00	1.00	4.20	5.00	4.00	18.82	73.40
11:50:35	103.10	32.70	134.00	55.00	1.00	4.20	5.00	4.00	18.84	72.10
11:50:40	104.30	32.80	137.00	55.00	0.00	4.40	5.00	4.00	18.77	72.60
11:50:45	102.10	32.60	136.00	59.00	1.00	4.40	5.00	4.00	18.79	73.00
11:50:50	100.10	32.40	132.00	60.00	1.00	4.40	5.00	4.00	18.84	73.10
11:50:55	101.10	32.30	130.00	60.00	1.00	4.40	5.00	4.00	18.89	72.20
11:51:00	104.00	32.30	128.00	59.00	0.00	4.50	5.00	4.00	18.88	71.30
11:51:05	104.50	32.40	130.00	57.00	0.00	4.50	5.00	4.00	18.79	72.10
11:51:10	105.60	32.60	133.00	57.00	0.00	4.60	5.00	4.00	18.77	72.00
11:51:15	106.10	32.70	130.00	60.00	0.00	4.70	5.00	4.00	18.80	71.60
11:51:20	104.20	32.60	126.00	60.00	0.00	4.70	5.00	4.00	18.76	72.70
11:51:25	101.90	32.70	124.00	60.00	0.00	4.70	5.00	4.00	18.77	73.30
11:51:30	102.60	32.60	124.00	59.00	0.00	4.70	5.00	4.00	18.81	72.60
11:51:35	102.90	32.50	126.00	57.00	0.00	4.70	5.00	4.00	18.85	72.00
11:51:40	104.00	32.50	127.00	57.00	1.00	4.70	5.00	4.00	18.87	71.50
11:51:45	103.30	32.60	126.00	58.00	1.00	4.80	5.00	4.00	18.89	71.50
11:51:50	103.30	32.50	123.00	59.00	1.00	4.90	6.00	3.00	18.90	71.40
11:51:55	101.60	32.50	123.00	60.00	0.00	4.80	5.00	3.00	18.93	71.60
11:52:00	103.50	32.60	122.00	60.00	0.00	4.80	5.00	4.00	18.94	70.90

11:52:05	103.90	32.60	122.00	59.00	0.00	4.90	5.00	4.00	18.89	71.40
11:57:12	92.10	32.70	134.00	49.00	2.00	6.30	9.00	3.00	19.70	62.40
11:57:17	91.90	32.80	135.00	49.00	3.00	6.30	9.00	3.00	19.72	62.00
11:57:22	93.10	32.80	135.00	50.00	3.00	6.40	9.00	3.00	19.73	61.00
11:57:27	92.00	32.80	137.00	51.00	3.00	6.40	9.00	3.00	16.69	62.60
11:57:32	91.30	32.80	138.00	52.00	2.00	6.40	9.00	3.00	19.70	62.70
11:57:37	90.70	32.90	138.00	54.00	3.00	6.40	9.00	3.00	19.72	62.70
11:57:42	92.80	32.90	137.00	55.00	3.00	6.30	9.00	3.00	19.73	61.20
11:57:47	92.60	32.80	138.00	55.00	3.00	6.50	9.00	3.00	19.69	62.20
11:57:52	91.40	32.40	139.00	55.00	2.00	6.40	9.00	3.00	19.72	62.00
11:57:57	90.10	32.40	138.00	56.00	2.00	6.40	9.00	3.00	19.76	31.70
11:58:02	89.70	32.60	138.00	57.00	2.00	6.20	8.00	3.00	19.80	60.90
11:58:07	89.60	32.70	138.00	57.00	2.00	6.20	8.00	3.00	19.81	60.60
11:58:12	89.10	32.70	138.00	58.00	2.00	6.20	8.00	3.00	19.82	60.80
11:58:17	88.40	32.80	138.00	57.00	2.00	6.10	8.00	3.00	19.84	60.50
11:58:22	89.80	33.00	140.00	57.00	2.00	6.20	8.00	3.00	19.85	59.50
11:58:27	92.30	33.10	141.00	59.00	3.00	6.30	9.00	3.00	19.81	59.30
11:58:32	93.90	33.10	141.00	59.00	2.00	6.40	9.00	3.00	19.79	58.90
11:58:37	93.90	33.20	143.00	60.00	2.00	6.60	9.00	4.00	19.74	60.40
11:58:42	92.10	33.10	145.00	61.00	2.00	6.80	9.00	3.00	19.71	62.10
11:58:47	90.90	33.00	145.00	62.00	2.00	6.70	9.00	3.00	19.74	61.90
11:58:52	89.30	32.80	145.00	63.00	2.00	6.50	8.00	3.00	19.80	61.00
11:58:57	89.20	32.80	146.00	63.00	2.00	6.40	8.00	3.00	19.82	60.40
11:59:02	88.00	32.70	145.00	65.00	2.00	6.40	8.00	3.00	19.84	60.60
11:59:07	87.70	32.70	144.00	66.00	2.00	6.10	8.00	3.00	19.89	59.20
12:04:14	85.40	32.60	171.00	62.00	3.00	6.50	10.00	4.00	20.07	
12:04:19	85.50	32.60	176.00	60.00	3.00	6.60	10.00	4.00	20.06	
12:04:24	85.90	32.50	182.00	60.00	3.00	6.80	10.00	4.00	20.05	
12:04:29	86.70	32.60	188.00	61.00	3.00	6.80	10.00	5.00	20.03	

12:04:34	86.40	32.70	194.00	63.00	3.00	6.80	10.00	5.00	20.02	
12:04:39	84.50	32.70	195.00	68.00	3.00	6.70	10.00	5.00	20.05	
12:04:44	84.30	32.60	190.00	72.00	3.00	6.50	9.00	5.00	20.11	
12:04:49	72.80	32.60	185.00	73.00	3.00	6.10	9.00	5.00	20.17	
12:04:54	67.50	32.60	158.00	86.00	2.00	4.80	7.00	4.00	20.54	
12:04:59	79.60	32.60	128.00	85.00	2.00	4.40	7.00	3.00	20.45	
12:15:04	95.00	32.60	123.00	74.00	3.00	5.20	8.00	3.00	20.22	
12:05:09	95.30	32.70	127.00	64.00	3.00	7.00	9.00	3.00	19.80	57.50
12:05:14	93.60	32.80	126.00	64.00	3.00	7.50	10.00	3.00	19.65	62.70
12:05:19	93.10	32.80	125.00	59.00	3.00	8.00	11.00	3.00	19.49	66.60
12:05:24	92.90	32.90	129.00	54.00	3.00	8.10	11.00	3.00	19.45	67.50
12:05:29	91.90	32.90	136.00	50.00	3.00	8.10	11.00	3.00	19.45	68.00
12:05:34	91.80	32.80	143.00	48.00	3.00	8.20	12.00	3.00	39.47	67.60
12:05:39	91.80	32.80	145.00	48.00	4.00	8.10	12.00	3.00	19.49	67.20
12:05:44	89.40	32.90	156.00	47.00	3.00	8.10	11.00	4.00	19.54	67.40
12:05:49	89.90	32.80	161.00	47.00	3.00	8.30	11.00	3.00	19.59	66.00
12:05:54	89.30	32.90	163.00	49.00	3.00	8.30	12.00	3.00	19.64	65.20
12:05:59	89.70	33.00	163.00	52.00	3.00	8.30	12.00	3.00	19.69	63.90
12:06:04	88.80	33.10	165.00	53.00	3.00	8.40	12.00	4.00	19.68	64.70
12:06:09	87.70	33.10	167.00	53.00	3.00	8.30	11.00	3.00	19.74	63.90
12:11:16	83.30	32.10	186.00	72.00	3.00	7.00	10.00	5.00	20.00	
12:11:21	84.00	32.30	186.00	72.00	3.00	7.00	10.00	5.00	20.02	
12:11:26	82.90	32.40	189.00	72.00	3.00	7.20	10.00	5.00	20.01	
12:11:31	83.20	32.40	191.00	73.00	4.00	7.20	11.00	5.00	20.03	
12:11:36	83.10	32.30	194.00	74.00	4.00	7.20	11.00	5.00	20.03	
12:11:41	82.70	32.30	197.00	75.00	3.00	7.30	10.00	5.00	20.04	
12:11:46	82.50	32.50	198.00	77.00	3.00	7.40	11.00	5.00	20.06	
12:11:51	82.30	32.40	195.00	79.00	3.00	7.50	11.00	5.00	20.05	
12:11:56	82.30	32.40	192.00	82.00	4.00	7.50	11.00	5.00	20.07	

12:12:01	82.60	32.20	187.00	85.00	4.00	7.40	11.00	5.00	20.09	
12:12:06	83.00	32.30	184.00	83.00	3.00	7.70	11.00	5.00	20.07	
12:12:11	83.60	32.20	185.00	81.00	3.00	7.80	11.00	4.00	20.05	
12:12:16	83.10	32.10	185.00	80.00	3.00	8.00	11.00	4.00	20.04	
12:12:21	82.40	32.20	188.00	79.00	3.00	7.80	11.00	4.00	20.06	
12:12:26	81.70	32.10	187.00	79.00	3.00	7.70	11.00	5.00	20.10	
12:12:31	80.30	32.10	184.00	81.00	3.00	7.40	11.00	5.00	20.13	
12:12:36	82.30	32.20	181.00	80.00	3.00	7.30	11.00	5.00	20.15	
12:12:41	82.20	32.40	182.00	78.00	3.00	7.50	11.00	5.00	20.13	
12:12:46	82.50	32.30	183.00	77.00	3.00	7.60	11.00	5.00	20.13	
12:12:51	83.20	32.10	185.00	78.00	3.00	7.70	11.00	4.00	20.12	
12:12:56	82.40	32.30	191.00	75.00	4.00	7.80	11.00	5.00	20.11	
12:13:01	82.50	32.30	196.00	75.00	3.00	7.60	11.00	5.00	20.14	
12:13:06	82.00	32.20	200.00	76.00	3.00	7.60	11.00	5.00	20.14	
12:13:11	81.20	32.30	204.00	78.00	4.00	7.50	11.00	5.00	20.17	
12:18:18	86.50	33.00	187.00	39.00	4.00	9.60	14.00	3.00	19.96	57.30
12:18:23	86.50	32.90	191.00	41.00	4.00	9.40	14.00	3.00	19.98	56.40
12:18:28	86.30	32.90	192.00	43.00	4.00	9.20	14.00	4.00	20.01	
12:18:33	85.90	33.00	192.00	46.00	4.00	9.10	14.00	4.00	20.03	
12:18:38	85.80	32.90	191.00	47.00	4.00	9.10	14.00	3.00	20.04	
12:18:43	85.60	33.00	194.00	46.00	4.00	8.80	13.00	4.00	20.06	
12:18:48	85.30	33.10	196.00	47.00	4.00	8.60	13.00	4.00	20.08	
12:18:53	84.70	33.20	196.00	48.00	4.00	8.50	13.00	4.00	20.09	
12:18:58	83.90	33.20	194.00	51.00	4.00	8.40	12.00	4.00	20.11	
12:19:03	84.90	32.80	191.00	52.00	4.00	8.20	12.00	4.00	20.12	
12:19:08	85.10	32.80	192.00	52.00	4.00	8.30	12.00	4.00	20.09	
12:19:13	84.40	32.90	198.00	50.00	4.00	8.30	12.00	4.00	20.10	
12:19:18	83.60	32.90	200.00	52.00	4.00	8.00	12.00	4.00	20.14	
12:19:23	84.20	32.80	199.00	55.00	4.00	7.90	12.00	4.00	20.16	

12:19:28	83.50	32.80	201.00	54.00	4.00	7.90	11.00	4.00	20.16	
12:19:33	83.90	32.80	204.00	54.00	4.00	7.60	11.00	4.00	20.17	
12:19:38	83.70	32.80	211.00	54.00	4.00	7.70	11.00	5.00	20.16	
12:19:43	82.50	32.80	219.00	54.00	4.00	7.40	11.00	5.00	20.20	
12:19:48	82.20	32.70	220.00	56.00	4.00	7.20	11.00	5.00	20.22	
12:19:53	82.60	32.80	217.00	59.00	4.00	7.20	11.00	5.00	20.23	
12:19:58	82.20	32.60	213.00	63.00	3.00	7.00	10.00	5.00	20.24	
12:20:03	80.50	32.80	214.00	63.00	4.00	6.90	11.00	5.00	20.27	
12:20:08	81.10	32.90	215.00	63.00	4.00	6.60	10.00	5.00	20.29	
12:20:13	81.30	32.90	218.00	62.00	3.00	6.70	10.00	5.00	20.27	
12:25:20	91.40	32.40	145.00	41.00	3.00	9.00	12.00	4.00	19.86	57.60
12:25:25	92.30	32.40	152.00	38.00	4.00	10.20	14.00	4.00	19.71	61.60
12:25:30	92.60	32.40	165.00	33.00	4.00	10.80	15.00	4.00	19.64	63.10
12:25:35	91.30	32.50	177.00	31.00	4.00	11.10	15.00	4.00	19.62	64.30
12:25:40	91.40	32.40	181.00	34.00	4.00	11.20	16.00	4.00	19.62	64.10
12:25:45	91.40	32.50	187.00	33.00	4.00	11.30	16.00	4.00	19.64	63.90
12:25:50	91.90	32.50	188.00	34.00	4.00	11.20	16.00	4.00	19.67	62.90
12:25:55	92.10	32.40	187.00	35.00	4.00	11.40	16.00	4.00	19.66	62.70
12:26:00	91.30	32.40	188.00	36.00	5.00	11.40	16.00	4.00	19.68	62.80
12:26:05	91.10	32.50	186.00	36.00	5.00	11.20	16.00	4.00	19.72	61.80
12:26:10	90.60	32.50	182.00	39.00	5.00	11.30	16.00	4.00	19.74	61.60
12:26:15	92.20	32.50	177.00	39.00	5.00	11.20	16.00	4.00	19.76	60.20
12:26:20	91.10	32.50	176.00	37.00	4.00	11.40	16.00	4.00	19.76	60.80
12:26:25	88.80	32.50	176.00	36.00	4.00	11.20	15.00	3.00	19.81	60.90
12:26:30	89.30	32.50	174.00	37.00	4.00	10.90	15.00	3.00	19.85	59.10
12:26:35	90.60	32.40	173.00	35.00	4.00	10.90	15.00	3.00	19.83	59.00
12:26:40	90.90	32.50	176.00	34.00	4.00	11.30	15.00	3.00	19.79	60.20
12:26:45	90.50	32.40	180.00	32.00	4.00	11.40	16.00	4.00	19.80	59.90
12:26:50	90.30	32.40	180.00	35.00	4.00	11.20	16.00	4.00	19.84	58.90

12:26:55	90.00	32.40	178.00	36.00	4.00	11.20	16.00	3.00	19.85	58.70
12:27:00	91.50	32.40	177.00	37.00	4.00	11.00	15.00	3.00	19.85	58.70
12:27:05	91.50	32.40	182.00	34.00	4.00	11.00	15.00	4.00	19.88	58.50
12:27:10	90.30	32.50	189.00	33.00	4.00	10.90	15.00	4.00	19.85	58.60
12:27:15	90.00	32.50	192.00	35.00	4.00	10.50	15.00	4.00	19.90	57.00
12:32:22	87.50	32.50	250.00	59.00	4.00	8.60	12.00	6.00	20.08	
12:32:27	85.50	32.60	249.00	63.00	4.00	8.40	12.00	6.00	20.11	
12:32:32	85.50	32.50	243.00	69.00	4.00	8.10	12.00	6.00	20.15	
12:32:37	85.90	32.40	236.00	71.00	4.00	8.00	12.00	5.00	20.16	
12:32:42	85.70	32.40	237.00	68.00	4.00	7.80	11.00	6.00	20.16	
12:32:47	84.90	32.40	240.00	66.00	4.00	7.60	12.00	6.00	20.17	
12:32:52	84.60	32.40	243.00	67.00	4.00	7.40	11.00	6.00	20.19	
12:32:57	84.60	32.50	247.00	66.00	4.00	7.30	11.00	6.00	20.21	
12:33:02	85.10	32.60	250.00	67.00	4.00	7.20	11.00	6.00	20.21	
12:33:07	83.60	32.60	253.00	69.00	4.00	7.00	11.00	6.00	20.23	
12:33:12	83.70	32.50	254.00	70.00	4.00	6.80	10.00	7.00	20.25	
12:33:17	83.90	32.30	257.00	71.00	4.00	6.70	10.00	6.00	20.25	
12:33:22	83.40	32.40	260.00	71.00	3.00	6.70	10.00	7.00	20.25	
12:33:27	83.30	32.50	263.00	73.00	3.00	6.60	10.00	7.00	20.26	
12:33:32	83.80	32.50	266.00	74.00	4.00	6.60	10.00	7.00	20.26	
12:33:37	83.10	32.50	272.00	74.00	3.00	6.60	10.00	7.00	20.25	
12:33:42	83.00	32.50	275.00	76.00	3.00	6.40	10.00	7.00	20.26	
12:33:47	83.90	32.50	278.00	76.00	4.00	6.40	10.00	7.00	20.23	
12:33:52	84.10	32.70	285.00	77.00	4.00	6.40	10.00	8.00	20.23	
12:33:57	83.60	32.80	292.00	78.00	3.00	6.50	10.00	8.00	20.23	
12:34:02	83.10	32.80	292.00	80.00	3.00	6.40	10.00	8.00	20.24	
12:34:07	82.40	32.80	289.00	86.00	3.00	6.10	9.00	8.00	20.29	
12:34:12	82.50	32.90	287.00	88.00	3.00	6.10	9.00	7.00	20.29	
12:34:17	82.50	33.00	298.00	86.00	3.00	5.90	9.00	8.00	20.29	

12:39:24	94.60	33.10	140.00	58.00	3.00	10.30	13.00	4.00	19.84	56.60
12:39:29	94.00	33.20	140.00	56.00	4.00	12.00	16.00	4.00	19.70	61.50
12:39:34	92.30	33.30	138.00	54.00	4.00	12.50	17.00	3.00	19.64	63.90
12:39:39	90.10	33.30	142.00	47.00	4.00	12.50	17.00	3.00	19.65	65.00
12:39:44	88.50	33.10	145.00	44.00	4.00	12.10	16.00	3.00	19.73	63.80
12:39:49	88.70	32.80	148.00	40.00	4.00	11.70	16.00	3.00	19.76	62.50
12:39:54	88.00	32.60	154.00	37.00	4.00	11.50	16.00	2.00	19.78	62.40
12:39:59	87.80	32.80	158.00	37.00	4.00	11.10	15.00	3.00	19.83	61.10
12:40:04	88.30	32.80	161.00	37.00	4.00	10.80	15.00	3.00	19.87	59.30
12:40:09	88.90	32.70	166.00	35.00	4.00	10.80	15.00	3.00	19.87	59.10
12:40:14	87.10	32.80	172.00	37.00	4.00	10.70	15.00	4.00	19.90	
12:40:19	86.00	32.80	175.00	39.00	4.00	10.30	14.00	4.00	19.97	
12:40:24	85.50	32.90	172.00	43.00	4.00	9.70	13.00	4.00	20.02	
12:40:29	84.90	32.90	172.00	43.00	4.00	9.40	13.00	4.00	20.07	
12:40:34	84.90	33.00	173.00	44.00	4.00	9.00	13.00	4.00	20.10	
12:40:39	84.70	33.00	175.00	45.00	4.00	8.70	12.00	4.00	20.13	
12:40:44	84.60	33.00	177.00	45.00	3.00	8.50	12.00	4.00	20.15	
12:40:49	85.10	33.10	182.00	45.00	3.00	8.20	11.00	4.00	20.16	
12:40:54	84.70	33.10	192.00	45.00	3.00	8.10	12.00	5.00	20.16	
12:40:59	84.40	33.00	200.00	46.00	3.00	8.00	11.00	5.00	20.17	
12:41:04	83.70	32.80	206.00	49.00	3.00	7.80	11.00	5.00	20.19	
12:41:09	83.40	32.70	208.00	51.00	3.00	7.60	11.00	5.00	20.20	
12:41:14	84.10	32.80	214.00	55.00	3.00	7.40	11.00	6.00	20.24	
12:41:19	84.40	33.10	221.00	57.00	3.00	7.40	11.00	6.00	20.22	
12:46:26	85.70	33.40	202.00	49.00	3.00	9.50	12.00	5.00	20.09	
12:46:31	83.20	33.30	206.00	55.00	3.00	8.80	12.00	5.00	20.16	
12:46:36	83.40	32.90	204.00	60.00	3.00	8.10	11.00	5.00	20.24	
12:46:41	83.60	32.80	200.00	65.00	3.00	7.60	10.00	5.00	20.27	
12:46:46	83.70	32.90	202.00	66.00	3.00	7.40	10.00	5.00	20.27	

12:46:51	84.30	32.90	205.00	67.00	2.00	7.40	10.00	5.00	20.27	
12:46:56	83.70	32.80	214.00	66.00	3.00	7.40	10.00	5.00	20.25	
12:47:01	83.20	32.90	228.00	67.00	3.00	7.40	10.00	6.00	20.25	
12:47:06	83.00	32.90	237.00	70.00	2.00	7.10	9.00	6.00	20.27	
12:47:11	82.40	32.70	242.00	75.00	2.00	6.90	9.00	6.00	20.30	
12:47:16	81.40	32.70	243.00	82.00	2.00	6.50	9.00	7.00	20.34	
12:47:21	82.40	32.60	241.00	88.00	2.00	6.20	8.00	6.00	20.34	
12:47:26	83.20	32.70	244.00	89.00	2.00	6.30	8.00	7.00	20.33	
12:47:31	83.30	32.90	254.00	88.00	2.00	6.40	7.00	7.00	20.32	
12:47:36	82.30	32.70	262.00	91.00	2.00	6.20	8.00	7.00	20.34	
12:47:41	81.50	32.80	265.00	96.00	2.00	5.90	8.00	7.00	20.37	
12:47:46	81.30	32.70	266.00	100.00	2.00	5.80	8.00	7.00	20.39	
12:47:51	82.00	32.80	265.00	104.00	2.00	5.60	7.00	8.00	20.39	
12:47:56	81.80	32.80	271.00	104.00	2.00	5.50	7.00	8.00	20.38	
12:48:01	82.40	32.70	278.00	105.00	2.00	5.70	8.00	8.00	20.38	
12:48:06	82.00	32.80	283.00	109.00	2.00	5.60	7.00	8.00	20.38	
12:48:11	80.80	32.80	286.00	110.00	2.00	5.50	7.00	9.00	20.37	
12:48:16	80.00	32.80	288.00	114.00	2.00	5.50	7.00	9.00	20.40	
12:48:21	77.50	32.80	287.00	122.00	1.00	4.70	6.00	8.00	20.45	
12:53:28	75.10	33.40	279.00	136.00	1.00	2.80	4.00	9.00	20.63	
12:53:33	75.80	33.40	270.00	137.00	1.00	2.70	4.00	9.00	20.64	
12:53:38	75.20	33.30	268.00	133.00	1.00	2.80	4.00	8.00	20.63	
12:53:43	74.90	33.30	268.00	132.00	1.00	2.60	4.00	8.00	20.64	
12:53:48	75.10	33.50	262.00	133.00	1.00	2.50	4.00	8.00	20.66	
12:53:53	75.50	33.50	262.00	129.00	1.00	2.50	4.00	8.00	20.64	
12:53:58	75.30	33.20	272.00	124.00	1.00	2.50	4.00	9.00	20.63	
12:54:03	75.40	33.10	279.00	124.00	1.00	2.70	4.00	9.00	20.63	
12:54:08	75.60	33.20	285.00	126.00	1.00	2.50	4.00	9.00	20.62	
12:54:13	75.80	33.30	290.00	128.00	1.00	2.50	4.00	9.00	20.62	

12:54:18	75.90	33.10	293.00	132.00	1.00	2.50	4.00	9.00	20.62	
12:54:12	75.60	33.00	294.00	134.00	2.00	2.60	4.00	10.00	20.63	
12:54:28	75.40	33.00	295.00	136.00	1.00	2.50	4.00	10.00	20.63	
12:54:33	75.30	33.00	297.00	137.00	1.00	2.60	4.00	10.00	20.63	
21:54:38	74.90	33.10	296.00	139.00	1.00	2.50	4.00	10.00	20.64	
12:54:43	75.30	33.10	296.00	143.00	1.00	2.50	4.00	9.00	20.64	
12:54:48	75.10	33.10	296.00	144.00	1.00	2.50	3.00	9.00	20.64	
12:54:53	74.50	33.00	296.00	144.00	1.00	2.40	3.00	9.00	20.65	
12:54:58	75.00	32.90	293.00	146.00	1.00	2.30	3.00	10.00	20.66	
12:55:03	75.80	32.80	291.00	145.00	1.00	2.30	3.00	10.00	20.66	
12:55:08	74.90	32.80	289.00	144.00	1.00	2.20	3.00	9.00	20.66	
12:55:13	74.70	32.90	291.00	143.00	1.00	2.30	3.00	9.00	20.65	
12:55:18	74.60	33.00	292.00	143.00	1.00	2.30	3.00	9.00	20.65	
12:55:23	74.70	33.10	296.00	144.00	1.00	2.30	3.00	10.00	20.65	

Table O 40: Temperature at pyrolysis chamber for Experiment set (vii-2); AVR = 3.83:9.65 (OPKS)

Mean	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)
	0	0.00	14.5	340.00	29	242.00	43.5	223.00	58	248.00
	0.5	394.00	15	330.00	29.5	240.00	44	212.00	58.5	231.00
	1	401.00	15.5	320.00	30	224.00	44.5	203.00	59	252.00
	1.5	414.00	16	320.00	30.5	210.00	45	194.00	59.5	313.00
	2	406.00	16.5	310.00	31	201.00	45.5	187.00	60	269.00
	2.5	429.00	17	306.00	31.5	190.00	46	216.00	60.5	240.00
	3	422.00	17.5	295.00	32	177.00	46.5	276.00	61	224.00
	3.5	428.00	18	362.00	32.5	252.00	47	270.00	61.5	212.00
	4	444.00	18.5	351.00	33	269.00	47.5	260.00	62	208.00
	4.5	406.00	19	319.00	33.5	256.00	48	269.00	62.5	241.00
	5	430.00	19.5	314.00	34	248.00	48.5	249.00	63	224.00
	5.5	437.00	20	310.00	34.5	234.00	49	235.00	63.5	212.00
	6	440.00	20.5	298.00	35	228.00	49.5	239.00	64	200.00
	6.5	443.00	21	291.00	35.5	215.00	50	253.00	64.5	189.00
	7	437.00	21.5	269.00	36	206.00	50.5	252.00	65	183.00
	7.5	431.00	22	421.00	36.5	200.00	51	254.00	65.5	178.00
	8	423.00	22.5	377.00	37	198.00	51.5	241.00	66	207.00
	8.5	429.00	23	324.00	37.5	288.00	52	272.00	66.5	200.00
	9	422.00	23.5	291.00	38	307.00	52.5	303.00	67	187.00
	9.5	415.00	24	272.00	38.5	266.00	53	270.00	67.5	176.00
	10	420.00	24.5	256.00	39	238.00	53.5	239.00	68	166.00
	10.5	415.00	25	254.00	39.5	221.00	54	224.00	68.5	160.00
	11	396.00	25.5	228.00	40	210.00	54.5	210.00	69	156.00
	11.5	415.00	26	223.00	40.5	200.00	55	205.00	69.5	152.00

12	396.00	26.5	201.00	41	192.00	55.5	197.00	70	149.00
12.5	385.00	27	327.00	41.5	187.00	56	287.00	70.5	147.00
13	383.00	27.5	280.00	42	219.00	56.5	362.00	71	143.00
13.5	369.00	28	279.00	42.5	234.00	57	314.00	71.5	140.00
14	369.00	28.5	250.00	43	228.00	57.5	282.00	72	137.00
								72.5	135.00

Experiment set (vii-3)

Date = 9/1/2013; Sample = About 3 Kg of OPKS; Methanol = About 3 Liter; AVR = 3.83:9.65

Measurement rate = 5 seconds; Gas time = 2 minutes; Rinse time = 5 minutes; Mean = 1 second; To make the data meaningful, rinse time is neglected

Table O 41: Results of TESTO Experiment (vii-3); AVR = 3.83:9.65 (OPKS)

Mean	88.76	32.02	201.71	55.06	3.07	7.00	10.08	5.34	19.76	66.94
Time	FT (°C)	AT (°C)	CO (ppmv)	H2 (ppmv)	NO (ppmv)	NO2 (ppmv)	NOx (ppmv)	SO2 (ppmv)	O2 (%)	η (%)
15:26:09	110.50	33.70	0.00	0.00	2.00	0.00	2.00	0.00	20.88	
15:16:14	105.50	33.70	42.00	26.00	3.00	1.00	4.00	2.00	19.82	
15:26:19	93.20	33.50	152.00	58.00	2.00	2.20	4.00	6.00	18.62	77.70
15:26:24	87.70	33.40	204.00	34.00	2.00	2.30	4.00	7.00	18.47	80.30
15:26:29	87.20	33.50	215.00	7.00	2.00	2.00	4.00	8.00	18.47	80.40
15:26:34	80.60	33.40	212.00	17.00	2.00	1.80	4.00	8.00	18.53	82.00
15:26:39	78.30	33.30	201.00	33.00	2.00	1.60	3.00	7.00	18.75	81.30
15:26:44	97.90	33.40	173.00	50.00	2.00	2.00	4.00	6.00	18.80	74.50
15:26:49	102.00	33.50	155.00	48.00	1.00	2.50	4.00	5.00	18.39	76.80
15:26:54	98.80	33.60	163.00	38.00	2.00	2.70	5.00	6.00	18.19	79.10
15:26:59	95.70	33.70	184.00	31.00	2.00	2.60	4.00	6.00	18.17	80.00
15:27:04	97.10	33.80	215.00	26.00	2.00	2.50	4.00	7.00	18.21	79.40
15:27:09	96.30	33.80	247.00	29.00	2.00	2.40	4.00	8.00	18.26	79.20
15:27:14	99.60	33.80	260.00	40.00	2.00	2.30	4.00	9.00	18.28	78.10
15:27:19	99.30	33.70	265.00	50.00	2.00	2.30	4.00	9.00	18.27	78.20
15:27:14	103.20	33.70	270.00	55.00	2.00	2.40	4.00	10.00	18.29	77.00
15:27:29	103.30	33.70	283.00	56.00	2.00	2.60	4.00	10.00	18.22	77.40
15:27:34	105.50	33.70	279.00	65.00	2.00	3.00	5.00	10.00	18.21	76.90

15:27:39	102.90	33.90	259.00	77.00	2.00	3.10	5.00	9.00	18.17	78.00
15:27:44	101.30	34.00	243.00	78.00	2.00	3.20	5.00	8.00	18.25	78.00
15:27:49	100.30	34.10	241.00	72.00	2.00	3.20	5.00	8.00	18.33	77.70
15:27:54	98.60	34.10	240.00	70.00	2.00	3.20	5.00	8.00	18.38	77.80
15:27:59	99.70	33.80	240.00	66.00	2.00	3.20	5.00	8.00	18.41	77.20
15:28:04	101.30	33.60	242.00	63.00	2.00	3.40	5.00	8.00	18.37	77.00
15:33:11	97.00	34.00	190.00	49.00	1.00	5.90	7.00	5.00	18.79	75.00
15:33:16	100.40	33.90	202.00	47.00	1.00	5.90	7.00	5.00	18.83	73.40
15:33:21	102.50	34.00	212.00	46.00	1.00	6.10	7.00	6.00	18.77	73.30
15:33:26	102.30	34.00	219.00	50.00	1.00	6.10	7.00	6.00	18.73	73.80
15:33:31	100.60	34.10	216.00	57.00	2.00	6.10	8.00	6.00	18.73	74.30
15:33:36	99.00	34.20	210.00	60.00	2.00	5.90	8.00	6.00	18.78	74.50
15:33:41	99.30	34.40	205.00	62.00	2.00	5.90	7.00	5.00	18.83	74.00
15:33:46	98.80	34.40	202.00	61.00	1.00	5.90	7.00	5.00	18.82	74.20
15:33:51	100.10	34.40	203.00	59.00	1.00	6.10	7.00	5.00	18.83	73.60
15:33:56	97.50	34.50	205.00	60.00	1.00	6.10	7.00	5.00	18.83	74.60
15:34:01	95.80	34.50	207.00	60.00	1.00	6.10	7.00	5.00	18.92	74.20
15:34:06	96.90	34.40	208.00	61.00	1.00	5.90	7.00	5.00	19.01	72.80
15:34:11	96.80	34.10	203.00	64.00	1.00	5.90	7.00	5.00	18.98	73.10
15:34:16	96.00	33.80	202.00	63.00	1.00	5.90	7.00	5.00	18.96	73.40
15:34:21	95.60	33.70	205.00	60.00	1.00	5.90	7.00	5.00	19.02	72.90
15:34:26	94.50	33.60	204.00	63.00	1.00	5.90	7.00	5.00	19.05	72.90
15:34:31	93.50	33.40	200.00	64.00	1.00	5.90	7.00	5.00	19.10	72.70
15:34:36	93.50	33.40	194.00	66.00	1.00	5.80	7.00	5.00	19.13	72.20
15:34:41	93.60	33.30	190.00	65.00	1.00	5.90	7.00	5.00	19.15	72.00
15:34:46	94.10	33.50	190.00	63.00	1.00	5.90	7.00	5.00	19.10	72.40
15:34:51	95.30	33.70	190.00	63.00	1.00	5.90	7.00	5.00	19.09	72.20
13:34:56	97.20	33.60	188.00	65.00	1.00	6.10	7.00	5.00	19.08	71.50
15:35:01	96.90	33.50	191.00	64.00	1.00	6.20	7.00	5.00	19.06	71.90

15:35:06	95.50	33.60	193.00	63.00	1.00	6.20	8.00	5.00	19.06	72.40
15:40:13	87.50	33.00	129.00	57.00	2.00	5.10	7.00	3.00	20.08	
15:40:18	93.20	32.90	132.00	48.00	2.00	6.40	9.00	3.00	19.73	60.80
15:40:23	92.30	32.80	152.00	41.00	3.00	7.60	11.00	3.00	19.53	66.20
15:40:28	90.40	32.90	165.00	40.00	3.00	8.00	11.00	3.00	19.51	67.50
15:40:33	90.80	32.90	175.00	42.00	3.00	7.80	11.00	4.00	19.53	66.80
15:40:38	91.50	32.90	184.00	44.00	3.00	7.80	11.00	4.00	19.51	66.90
15:40:43	90.60	32.90	195.00	44.00	3.00	7.80	11.00	5.00	19.52	67.10
15:40:48	89.80	32.90	202.00	48.00	3.00	7.60	11.00	5.00	19.54	67.00
15:40:53	78.40	32.60	203.00	54.00	3.00	7.60	10.00	5.00	19.66	70.60
15:40:58	64.30	32.50	178.00	70.00	2.00	5.20	8.00	4.00	20.30	
15:41:03	76.90	32.60	116.00	85.00	2.00	4.10	6.00	2.00	20.45	
15:41:08	99.80	32.60	104.00	67.00	2.00	5.60	8.00	1.00	19.97	
15:41:13	102.80	32.50	122.00	48.00	3.00	8.00	11.00	2.00	19.45	62.60
15:41:18	102.10	32.40	145.00	40.00	3.00	9.20	12.00	3.00	19.23	67.10
15:41:23	103.20	32.50	162.00	40.00	3.00	10.00	13.00	3.00	19.12	68.30
15:41:28	96.40	32.70	170.00	46.00	3.00	10.30	13.00	4.00	19.08	71.60
15:41:33	94.20	32.80	167.00	53.00	3.00	9.20	12.00	3.00	19.30	69.30
15:41:38	96.50	32.80	165.00	55.00	3.00	8.90	12.00	3.00	19.35	67.40
15:41:43	95.60	32.80	172.00	52.00	3.00	9.10	12.00	4.00	19.31	68.60
15:41:48	96.50	32.70	179.00	53.00	3.00	9.10	12.00	4.00	19.34	67.60
15:41:53	85.10	32.40	178.00	57.00	3.00	9.00	12.00	4.00	19.38	72.10
15:41:58	60.40	32.40	154.00	73.00	2.00	6.10	8.00	3.00	20.28	
15:42:03	64.00	32.40	85.00	91.00	2.00	3.70	5.00	1.00	20.70	
15:42:08	81.20	32.40	67.00	73.00	2.00	4.80	7.00	0.00	20.25	
15:47:15	93.30	32.40	184.00	39.00	4.00	9.20	13.00	5.00	19.62	63.20
15:47:20	92.20	32.40	184.00	41.00	4.00	9.60	14.00	4.00	19.63	63.60
15:47:25	90.50	32.50	178.00	45.00	4.00	9.70	14.00	4.00	19.67	63.70
15:47:30	90.90	32.80	175.00	45.00	4.00	9.80	14.00	3.00	19.69	62.90

15:47:35	89.80	32.70	174.00	44.00	4.00	9.80	14.00	3.00	19.72	62.70
15:47:40	88.70	32.60	173.00	44.00	4.00	9.50	14.00	3.00	19.80	61.20
15:47:45	89.90	32.60	170.00	45.00	4.00	9.50	14.00	3.00	19.82	59.80
15:47:50	90.40	32.60	169.00	44.00	4.00	9.60	14.00	3.00	19.79	60.30
15:47:55	89.00	32.40	170.00	42.00	5.00	9.80	14.00	3.00	19.78	61.40
15:48:00	87.40	32.50	171.00	41.00	5.00	9.70	14.00	4.00	19.82	61.20
15:48:05	87.40	32.50	168.00	44.00	5.00	9.50	14.00	3.00	19.89	59.20
15:48:10	87.20	32.50	166.00	44.00	5.00	9.30	14.00	3.00	19.93	57.90
15:48:15	87.40	32.50	164.00	44.00	4.00	9.20	13.00	3.00	19.94	57.30
15:48:20	86.90	32.60	165.00	42.00	4.00	9.20	14.00	3.00	19.95	57.70
15:48:25	87.20	32.80	166.00	43.00	4.00	9.20	13.00	3.00	19.95	57.30
15:48:30	87.20	32.70	167.00	42.00	4.00	9.20	14.00	3.00	19.96	56.80
15:48:35	87.50	32.60	172.00	42.00	5.00	9.10	14.00	3.00	19.95	56.90
15:48:40	86.20	32.50	179.00	40.00	4.00	8.90	13.00	4.00	19.98	56.80
15:48:45	84.70	32.60	184.00	42.00	4.00	8.50	13.00	4.00	20.03	
15:48:50	84.30	32.70	185.00	45.00	4.00	8.20	13.00	4.00	20.06	
15:48:55	83.80	32.60	184.00	48.00	4.00	8.10	12.00	4.00	20.08	
15:49:00	83.40	32.40	187.00	47.00	4.00	7.70	12.00	5.00	20.10	
15:49:05	83.60	32.40	193.00	47.00	5.00	7.60	12.00	5.00	20.12	
15:49:10	84.40	32.50	198.00	49.00	5.00	7.60	12.00	5.00	20.11	
15:54:17	86.80	32.10	209.00	45.00	5.00	9.10	14.00	5.00	19.98	55.80
15:54:22	86.50	32.20	204.00	48.00	5.00	8.90	13.00	5.00	19.99	55.70
15:54:27	86.00	32.10	203.00	47.00	5.00	8.80	13.00	5.00	20.00	
15:54:32	85.50	32.20	203.00	47.00	5.00	8.60	14.00	5.00	20.03	
15:54:37	85.10	32.10	202.00	47.00	5.00	8.40	13.00	5.00	20.05	
15:54:42	85.70	32.00	203.00	47.00	5.00	8.40	13.00	4.00	20.06	
15:54:47	85.70	32.10	206.00	47.00	4.00	8.30	12.00	5.00	20.04	
15:54:52	84.10	32.10	206.00	48.00	5.00	8.10	13.00	5.00	20.08	
15:54:57	84.50	32.20	201.00	50.00	5.00	7.60	12.00	5.00	20.13	

15:55:02	85.60	32.20	198.00	50.00	4.00	7.70	12.00	5.00	20.10	
15:55:07	85.30	32.20	204.00	47.00	4.00	7.90	12.00	5.00	20.07	
15:55:12	85.40	32.10	212.00	46.00	4.00	7.80	12.00	5.00	20.08	
15:55:17	84.10	32.00	216.00	47.00	4.00	7.50	12.00	5.00	20.13	
15:55:22	83.80	32.10	216.00	50.00	4.00	7.30	11.00	5.00	20.15	
15:55:27	84.00	32.10	216.00	51.00	4.00	7.20	11.00	6.00	20.15	
15:55:32	84.40	31.90	222.00	51.00	4.00	7.20	11.00	6.00	20.14	
15:55:37	83.40	31.90	230.00	51.00	4.00	7.00	11.00	6.00	20.16	
15:55:42	82.90	32.00	234.00	53.00	4.00	6.80	11.00	6.00	20.17	
15:55:47	84.00	31.90	236.00	57.00	4.00	6.80	11.00	6.00	20.19	
15:55:52	81.10	31.90	236.00	60.00	4.00	6.80	11.00	6.00	20.20	
15:55:57	77.10	31.90	233.00	63.00	4.00	6.40	10.00	6.00	20.23	
15:56:02	76.10	32.00	223.00	67.00	4.00	5.80	9.00	6.00	20.32	
15:56:07	87.70	31.90	199.00	75.00	4.00	5.60	9.00	5.00	20.38	
15:56:12	95.50	31.90	177.00	74.00	4.00	7.60	11.00	5.00	20.11	
16:01:19	90.60	31.80	186.00	39.00	5.00	12.00	17.00	4.00	19.70	62.20
16:01:24	89.20	31.90	183.00	43.00	5.00	11.50	16.00	4.00	19.81	60.20
16:01:29	89.40	32.30	178.00	45.00	4.00	11.10	16.00	4.00	19.85	59.10
16:01:34	88.20	32.40	180.00	43.00	4.00	10.90	15.00	3.00	19.87	59.30
16:01:39	88.10	32.50	181.00	43.00	4.00	10.60	15.00	3.00	19.92	57.40
16:01:44	89.80	32.50	181.00	42.00	4.00	10.50	14.00	4.00	19.92	56.20
16:01:49	88.00	32.10	187.00	40.00	4.00	10.70	15.00	4.00	19.90	57.90
16:01:54	88.10	31.70	190.00	42.00	4.00	10.50	15.00	4.00	19.95	56.00
16:01:59	87.60	31.70	188.00	46.00	4.00	10.40	15.00	4.00	19.99	54.70
16:02:04	87.30	31.80	187.00	46.00	4.00	10.30	15.00	4.00	20.00	54.60
16:02:09	88.90	32.00	185.00	47.00	4.00	10.20	14.00	4.00	20.00	
16:02:14	88.70	31.80	189.00	45.00	4.00	10.40	14.00	4.00	19.97	54.90
16:02:19	89.20	31.70	196.00	43.00	4.00	10.30	15.00	5.00	19.99	53.50
16:02:24	88.60	31.70	202.00	43.00	4.00	10.30	14.00	5.00	19.98	54.10

16:02:29	88.00	31.80	209.00	44.00	4.00	10.40	14.00	5.00	19.98	54.60
16:02:34	87.20	31.90	212.00	46.00	4.00	10.20	14.00	5.00	20.01	
16:02:39	86.20	31.90	211.00	50.00	4.00	10.00	14.00	5.00	20.05	
16:02:44	87.20	31.80	208.00	52.00	4.00	9.70	14.00	5.00	20.08	
16:02:49	81.60	31.80	208.00	52.00	4.00	9.50	13.00	5.00	20.11	
16:02:54	74.80	31.90	191.00	62.00	3.00	7.50	10.00	4.00	20.46	
16:02:59	78.20	32.00	163.00	65.00	3.00	7.00	10.00	4.00	20.34	
16:03:04	86.30	32.00	161.00	58.00	3.00	7.10	10.00	4.00	20.37	
16:03:09	91.80	32.10	157.00	53.00	3.00	8.30	12.00	4.00	20.19	
16:03:14	95.10	32.20	157.00	50.00	4.00	10.20	14.00	4.00	19.95	
16:08:21	68.80	30.80	239.00	68.00	4.00	6.90	11.00	6.00	20.34	
16:08:26	52.60	30.80	174.00	98.00	2.00	4.10	6.00	3.00	20.91	
16:08:31	66.60	30.90	82.00	109.00	2.00	2.70	5.00	1.00	20.96	
16:08:36	91.10	30.70	77.00	70.00	3.00	4.10	7.00	1.00	20.55	
16:08:41	104.00	30.90	116.00	36.00	3.00	8.20	12.00	3.00	20.12	
16:08:46	106.20	31.00	137.00	30.00	4.00	12.00	16.00	4.00	19.70	52.70
16:08:51	102.30	30.80	141.00	33.00	5.00	14.70	20.00	3.00	19.49	60.90
16:08:56	100.00	30.70	144.00	32.00	6.00	15.30	21.00	2.00	19.43	63.50
16:09:01	97.80	30.60	156.00	27.00	6.00	15.20	21.00	2.00	19.39	65.30
16:09:06	99.20	30.70	174.00	22.00	6.00	15.30	21.00	2.00	19.38	64.80
16:09:11	98.00	30.70	190.00	19.00	6.00	15.40	21.00	3.00	19.37	65.30
16:09:16	95.90	30.60	195.00	24.00	6.00	15.00	21.00	3.00	19.43	65.00
16:09:21	93.10	30.60	195.00	28.00	5.00	14.30	20.00	3.00	19.52	64.60
16:09:26	92.10	30.70	193.00	31.00	5.00	13.40	19.00	3.00	19.63	62.60
16:09:31	92.40	30.70	188.00	33.00	5.00	13.00	18.00	3.00	19.70	60.60
16:09:36	94.10	30.50	184.00	33.00	5.00	12.90	18.00	3.00	19.71	59.20
16:09:41	93.70	30.40	186.00	32.00	5.00	12.80	18.00	3.00	19.71	59.40
16:09:46	93.80	30.60	188.00	33.00	5.00	12.50	18.00	4.00	19.76	58.10
16:09:51	91.50	30.60	187.00	35.00	5.00	12.60	18.00	3.00	19.77	59.20

16:09:56	91.20	30.60	184.00	39.00	5.00	12.00	17.00	3.00	19.84	57.10
16:10:01	90.20	30.60	181.00	41.00	5.00	11.60	16.00	3.00	19.90	55.60
16:10:06	91.00	30.50	180.00	40.00	5.00	11.20	16.00	3.00	19.92	54.20
16:10:11	88.90	30.30	185.00	37.00	5.00	11.00	16.00	4.00	19.93	55.00
16:10:16	87.80	30.30	188.00	40.00	5.00	10.60	15.00	4.00	20.00	
16:15:23	85.30	29.90	292.00	71.00	4.00	5.10	9.00	9.00	20.26	
16:15:28	86.20	29.90	298.00	71.00	4.00	5.10	9.00	9.00	20.24	
16:15:33	84.90	29.90	307.00	73.00	3.00	5.20	8.00	10.00	20.24	
16:15:38	84.50	30.00	310.00	78.00	3.00	5.00	8.00	9.00	20.27	
16:15:43	83.90	30.00	306.00	84.00	3.00	4.90	8.00	9.00	20.29	
16:15:48	84.10	29.90	303.00	87.00	3.00	4.70	8.00	10.00	20.30	
16:15:53	84.40	30.00	302.00	89.00	3.00	4.50	8.00	10.00	20.31	
16:15:58	84.70	30.00	303.00	90.00	3.00	4.50	7.00	9.00	20.31	
16:16:03	85.00	30.00	304.00	90.00	3.00	4.50	8.00	10.00	20.30	
16:16:08	84.40	30.00	306.00	91.00	3.00	4.50	8.00	10.00	20.31	
16:16:13	83.70	29.90	306.00	93.00	3.00	4.50	7.00	10.00	20.32	
16:16:18	83.50	29.90	304.00	95.00	3.00	4.40	7.00	10.00	20.34	
16:16:23	83.20	29.90	304.00	96.00	3.00	4.40	8.00	10.00	20.35	
16:16:28	83.90	29.90	305.00	96.00	3.00	4.40	7.00	10.00	20.34	
16:16:33	83.80	29.90	308.00	96.00	2.00	4.40	7.00	10.00	20.34	
16:16:38	83.00	30.10	310.00	97.00	3.00	4.30	7.00	10.00	20.34	
16:16:43	82.90	30.10	308.00	100.00	3.00	4.20	7.00	10.00	20.36	
16:16:48	83.70	30.00	305.00	101.00	2.00	4.10	6.00	10.00	20.36	
16:16:53	84.10	30.10	305.00	100.00	2.00	4.10	7.00	10.00	20.34	
16:16:58	83.20	30.20	308.00	99.00	2.00	4.20	7.00	10.00	20.35	
16:17:03	83.60	30.40	308.00	99.00	3.00	4.20	7.00	10.00	20.37	
16:17:08	84.10	30.50	309.00	101.00	2.00	4.20	7.00	10.00	20.36	
16:17:13	83.90	30.50	315.00	100.00	2.00	4.20	7.00	10.00	20.36	
16:17:18	83.40	30.50	319.00	101.00	2.00	4.20	7.00	11.00	20.37	

16:22:25	82.70	30.60	159.00	56.00	2.00	6.20	9.00	5.00	20.35	
16:22:30	82.40	30.50	160.00	52.00	2.00	6.00	8.00	5.00	20.36	
16:22:35	82.60	30.50	164.00	49.00	2.00	5.90	8.00	5.00	20.36	
16:22:40	81.60	30.50	169.00	46.00	2.00	5.70	8.00	5.00	20.37	
16:22:45	81.90	30.30	174.00	46.00	2.00	5.50	8.00	5.00	20.38	
16:22:50	81.70	30.10	178.00	46.00	2.00	5.20	7.00	6.00	20.40	
16:22:55	81.90	30.10	181.00	48.00	2.00	5.00	7.00	6.00	20.43	
16:23:00	81.90	30.30	184.00	49.00	2.00	5.00	7.00	6.00	20.43	
16:23:05	82.00	30.40	189.00	49.00	2.00	4.90	7.00	6.00	20.43	
16:23:10	81.00	30.50	196.00	49.00	2.00	4.80	7.00	7.00	20.43	
16:23:15	80.80	30.60	201.00	52.00	2.00	4.80	6.00	7.00	20.44	
16:23:20	80.50	30.50	205.00	55.00	2.00	4.50	7.00	7.00	20.46	
16:23:25	80.30	30.40	209.00	57.00	2.00	4.40	6.00	7.00	20.48	
16:23:30	80.40	30.50	214.00	58.00	2.00	4.30	6.00	7.00	20.49	
16:23:35	80.80	30.50	217.00	61.00	2.00	4.20	6.00	7.00	20.50	
16:23:40	80.40	30.60	220.00	62.00	2.00	4.20	6.00	7.00	20.50	
16:23:45	79.30	30.70	221.00	66.00	1.00	4.00	5.00	7.00	20.51	
16:23:50	79.30	30.70	222.00	67.00	2.00	3.90	6.00	7.00	20.53	
16:23:55	79.30	30.80	223.00	70.00	2.00	3.80	5.00	7.00	20.54	
16:24:00	79.10	30.80	225.00	72.00	1.00	3.70	5.00	7.00	20.55	
16:24:05	79.50	31.00	227.00	73.00	1.00	3.60	5.00	8.00	20.56	
16:24:10	79.90	30.90	230.00	73.00	1.00	3.60	5.00	8.00	20.55	
16:24:15	79.50	31.00	235.00	73.00	2.00	3.60	5.00	8.00	20.54	
16:24:20	78.90	30.90	238.00	75.00	1.00	3.60	5.00	8.00	20.55	

Table O 42: Temperature at pyrolysis chamber for Experiment (vii-3); AVR = 3.83:9.65 (OPKS)

Mean	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)
	0	0.00	14.5	397.00	29	212.00	43.5	238.00	58	144.00
	0.5	239.00	15	392.00	29.5	200.00	44	223.00	58.5	140.00
	1	256.00	15.5	355.00	30	241.00	44.5	208.00	59	138.00
	1.5	403.00	16	334.00	30.5	270.00	45	192.00	59.5	135.00
	2	387.00	16.5	326.00	31	266.00	45.5	183.00	60	133.00
	2.5	476.00	17	303.00	31.5	282.00	46	175.00		
	3	397.00	17.5	303.00	32	273.00	46.5	192.00		
	3.5	457.00	18	352.00	32.5	248.00	47	226.00		
	4	473.00	18.5	350.00	33	231.00	47.5	208.00		
	4.5	479.00	19	376.00	33.5	220.00	48	192.00		
	5	477.00	19.5	337.00	34	206.00	48.5	181.00		
	5.5	495.00	20	301.00	34.5	247.00	49	173.00		
	6	490.00	20.5	328.00	35	257.00	49.5	166.00		
	6.5	512.00	21	284.00	35.5	233.00	50	163.00		
	7	483.00	21.5	267.00	36	224.00	50.5	160.00		
	7.5	496.00	22	269.00	36.5	215.00	51	156.00		
	8	516.00	22.5	254.00	37	243.00	51.5	154.00		
	8.5	508.00	23	234.00	37.5	250.00	52	186.00		
	9	498.00	23.5	228.00	38	235.00	52.5	183.00		
	9.5	513.00	24	221.00	38.5	218.00	53	174.00		
	10	475.00	24.5	215.00	39	205.00	53.5	166.00		
	10.5	476.00	25	208.00	39.5	196.00	54	160.00		
	11	457.00	25.5	323.00	40	207.00	54.5	156.00		
	11.5	446.00	26	299.00	40.5	243.00	55	152.00		

12	420.00	26.5	294.00	41	229.00	55.5	146.00
12.5	442.00	27	266.00	41.5	210.00	56	156.00
13	433.00	27.5	248.00	42	200.00	56.5	158.00
13.5	394.00	28	230.00	42.5	232.00	57	152.00
14	456.00	28.5	223.00	43	250.00	57.5	147.00

Experiment set (viii-1)

Date = 10/1/2013; Sample = About 3 Kg of Wood chips; Methanol = About 3 Liter; AVR = 3.83:9.65

Measurement rate = 5 seconds; Gas time = 2 minutes; Rinse time = 5 minutes; Mean = 1 second; To make the data meaningful, rinse time is neglected

Table O 43: Results of TESTO Experiment (viii-1); AVR = 3.83:9.65 (Wood chips)

Mean	71.52	27.80	311.84	78.82	2.15	1.20	3.34	7.21	20.09	70.57
Time	FT (°C)	AT (°C)	CO (ppmv)	H2 (ppmv)	NO (ppmv)	NO2 (ppmv)	NOx (ppmv)	SO2 (ppmv)	O2 (%)	η (%)
8:38:11	53.80	27.90	0.00	1.00	0.00	0.00	0.00	0.00	21.02	
8:38:16	67.60	27.80	14.00	7.00	1.00	0.10	1.00	0.00	20.74	
8:38:21	65.30	27.70	58.00	22.00	0.00	0.20	1.00	2.00	20.01	
8:42:26	66.60	27.80	94.00	17.00	1.00	0.30	1.00	3.00	19.65	74.90
8:38:31	65.50	27.70	105.00	4.00	1.00	0.40	1.00	3.00	19.39	79.00
8:38:36	65.30	27.70	113.00	6.00	0.00	0.40	1.00	4.00	19.25	80.40
8:38:41	65.70	27.70	118.00	14.00	0.00	0.60	1.00	3.00	19.22	80.50
8:38:46	66.70	27.80	120.00	22.00	0.00	0.60	1.00	3.00	19.20	80.30
8:38:51	67.20	27.90	118.00	28.00	0.00	0.60	1.00	3.00	19.17	80.40
8:38:56	65.80	28.00	117.00	31.00	0.00	0.50	1.00	3.00	19.15	81.10
8:39:01	66.40	28.00	116.00	34.00	0.00	0.40	1.00	3.00	19.18	80.80
8:39:06	67.30	28.00	114.00	36.00	0.00	0.50	1.00	3.00	18.18	80.40
8:39:11	67.00	28.00	116.00	35.00	0.00	0.40	1.00	3.00	19.21	80.20
8:39:16	65.60	27.90	119.00	36.00	1.00	0.60	1.00	3.00	18.25	80.30
8:39:21	66.40	27.80	121.00	37.00	1.00	0.60	1.00	3.00	18.26	79.80
8:39:26	69.40	27.80	120.00	40.00	1.00	0.50	1.00	3.00	19.24	78.80
8:39:31	70.40	27.80	114.00	43.00	0.00	0.40	1.00	3.00	19.19	78.90
8:39:36	71.10	27.70	112.00	43.00	1.00	0.60	1.00	3.00	19.17	78.80

8:39:41	68.90	27.70	109.00	43.00	1.00	0.60	1.00	3.00	19.16	79.80
8:39:46	68.60	27.70	111.00	40.00	1.00	0.60	1.00	3.00	19.21	79.40
8:39:51	71.80	27.80	114.00	38.00	1.00	0.70	1.00	3.00	19.20	78.20
8:39:56	72.70	27.70	116.00	40.00	1.00	0.80	1.00	3.00	19.16	78.20
8:40:01	72.10	27.70	115.00	41.00	1.00	0.80	1.00	3.00	19.17	78.30
8:40:06	71.30	27.70	115.00	40.00	1.00	0.80	1.00	3.00	19.18	78.60
8:45:13	71.40	27.60	138.00	46.00	1.00	1.00	2.00	4.00	19.75	70.20
8:45:18	71.20	27.60	139.00	46.00	1.00	1.10	2.00	4.00	19.76	70.00
8:45:23	71.20	27.50	139.00	46.00	1.00	1.10	2.00	3.00	19.79	69.20
8:45:28	70.40	27.50	139.00	47.00	1.00	1.00	2.00	3.00	19.80	69.60
8:45:33	69.90	27.60	139.00	47.00	1.00	1.10	2.00	3.00	19.83	69.10
8:45:38	70.20	27.50	138.00	47.00	1.00	1.00	2.00	3.00	19.86	68.20
8:45:43	70.50	27.40	139.00	46.00	1.00	1.00	2.00	4.00	19.85	68.20
8:45:48	69.90	27.40	142.00	45.00	1.00	1.00	2.00	4.00	19.84	68.90
8:45:53	69.40	27.50	145.00	44.00	2.00	1.00	2.00	4.00	19.86	68.70
8:45:58	69.50	27.40	146.00	46.00	1.00	1.00	2.00	4.00	19.90	67.60
8:46:03	69.30	27.50	145.00	48.00	2.00	1.00	3.00	4.00	18.90	67.70
8:46:08	69.60	27.50	143.00	51.00	1.00	1.00	2.00	4.00	19.90	67.60
8:46:13	69.30	27.30	140.00	52.00	1.00	1.00	2.00	3.00	19.91	67.50
8:46:18	69.60	27.40	139.00	52.00	1.00	1.00	2.00	3.00	19.91	67.30
8:46:23	69.80	27.50	141.00	49.00	1.00	1.00	2.00	4.00	19.89	67.70
8:46:28	70.30	27.60	143.00	49.00	1.00	1.00	2.00	4.00	19.91	66.90
8:46:33	70.40	27.50	145.00	49.00	1.00	1.00	2.00	4.00	19.90	66.90
8:46:38	70.20	27.60	147.00	48.00	1.00	1.00	2.00	4.00	19.88	67.70
8:46:43	70.50	27.50	150.00	49.00	1.00	1.00	2.00	4.00	19.89	67.20
8:46:48	70.40	27.60	148.00	52.00	1.00	1.00	2.00	4.00	19.96	
8:46:53	70.60	27.60	146.00	53.00	1.00	1.00	3.00	4.00	19.96	
8:46:58	71.00	27.60	146.00	52.00	1.00	1.20	2.00	4.00	19.91	66.50
8:47:03	70.80	27.60	146.00	52.00	1.00	1.30	3.00	4.00	19.89	67.00

8:47:08	70.50	27.70	146.00	51.00	1.00	1.30	3.00	4.00	19.92	66.60
8:52:15	82.40	27.60	167.00	60.00	1.00	1.10	2.00	4.00	19.95	
8:52:20	81.70	27.60	170.00	58.00	1.00	1.10	2.00	4.00	19.81	62.10
8:52:25	78.40	27.60	170.00	58.00	1.00	1.40	2.00	5.00	19.66	67.80
8:52:30	77.10	27.60	164.00	62.00	1.00	1.50	3.00	4.00	19.55	70.70
8:52:35	75.20	27.70	157.00	63.00	1.00	1.50	2.00	4.00	19.51	72.40
8:52:40	74.20	27.70	151.00	63.00	1.00	1.50	3.00	4.00	19.58	71.80
8:52:45	74.80	27.70	148.00	61.00	1.00	1.50	3.00	4.00	19.64	70.50
8:52:50	75.00	27.70	148.00	58.00	1.00	1.50	3.00	4.00	19.67	69.60
8:52:55	74.90	27.70	148.00	57.00	1.00	1.50	3.00	4.00	19.67	69.80
8:53:00	74.30	27.70	149.00	56.00	2.00	1.70	3.00	4.00	19.67	70.20
8:53:05	73.70	27.70	149.00	55.00	1.00	1.70	3.00	4.00	19.73	69.30
8:53:10	73.20	27.70	147.00	55.00	1.00	1.70	3.00	4.00	19.79	68.10
8:53:15	72.60	27.60	146.00	55.00	1.00	1.70	3.00	4.00	19.84	67.30
8:53:20	73.30	27.70	148.00	54.00	1.00	1.70	3.00	4.00	19.85	66.60
8:53:25	72.80	27.80	150.00	53.00	1.00	1.70	3.00	4.00	19.86	66.60
8:53:30	72.70	27.80	153.00	52.00	1.00	1.70	3.00	4.00	18.89	65.80
8:53:35	73.30	27.70	156.00	52.00	1.00	1.70	3.00	4.00	19.90	65.10
8:53:40	73.10	27.60	158.00	52.00	1.00	1.70	3.00	4.00	19.90	65.20
8:53:45	72.10	27.50	160.00	52.00	1.00	1.70	3.00	4.00	19.92	65.30
8:53:50	71.30	27.50	165.00	52.00	1.00	1.70	3.00	4.00	19.96	64.70
8:53:55	70.50	27.50	171.00	51.00	1.00	1.60	3.00	4.00	19.99	
8:54:00	71.10	27.40	175.00	52.00	1.00	1.50	3.00	5.00	20.01	
8:54:05	71.90	27.50	178.00	54.00	1.00	1.60	3.00	5.00	20.01	
8:54:10	72.20	27.50	178.00	57.00	1.00	1.70	3.00	4.00	20.01	
8:59:17	65.90	27.30	305.00	83.00	1.00	0.80	2.00	8.00	20.40	
8:59:22	64.70	27.30	315.00	80.00	1.00	0.90	2.00	9.00	20.39	
8:59:27	62.40	27.30	311.00	84.00	1.00	1.00	2.00	9.00	20.42	
8:59:32	69.30	27.30	263.00	106.00	1.00	0.60	2.00	8.00	20.56	

8:59:37	76.10	27.30	245.00	97.00	1.00	0.90	2.00	7.00	20.37	
8:59:42	74.40	27.30	259.00	80.00	1.00	1.10	2.00	7.00	20.18	
8:59:47	75.00	27.30	259.00	82.00	1.00	1.20	2.00	7.00	20.07	
8:59:52	73.30	27.40	245.00	86.00	1.00	1.30	3.00	7.00	20.00	
8:59:57	72.40	27.40	229.00	87.00	1.00	1.30	3.00	6.00	19.99	62.10
9:00:02	71.80	27.30	220.00	82.00	1.00	1.30	2.00	6.00	19.98	62.90
9:00:07	71.10	27.40	216.00	77.00	1.00	1.40	3.00	6.00	19.99	63.40
9:00:12	70.90	27.50	216.00	74.00	1.00	1.30	2.00	6.00	20.02	
9:00:17	71.60	27.50	221.00	69.00	1.00	1.30	3.00	6.00	20.01	
9:00:22	71.40	27.40	229.00	67.00	1.00	1.30	3.00	7.00	20.02	
9:00:27	70.90	27.40	238.00	65.00	1.00	1.30	3.00	7.00	20.05	
9:00:32	69.70	27.50	245.00	66.00	1.00	1.30	2.00	7.00	20.10	
9:00:37	69.30	27.40	246.00	72.00	1.00	1.20	3.00	7.00	20.13	
9:00:42	69.50	27.30	245.00	74.00	1.00	1.30	3.00	7.00	20.14	
9:00:47	69.80	27.30	246.00	73.00	1.00	1.30	3.00	7.00	20.15	
9:00:52	69.20	27.30	253.00	71.00	1.00	1.20	2.00	7.00	20.17	
9:00:57	68.90	27.40	258.00	72.00	1.00	1.20	2.00	7.00	20.19	
9:01:02	68.60	27.30	265.00	72.00	1.00	1.20	2.00	7.00	20.21	
9:01:07	69.00	27.30	273.00	72.00	1.00	1.10	2.00	8.00	20.22	
9:01:12	68.90	27.30	283.00	73.00	1.00	1.10	2.00	8.00	20.21	
9:06:19	70.20	27.30	390.00	80.00	2.00	1.40	4.00	10.00	20.21	
9:06:24	69.50	27.40	402.00	79.00	2.00	1.50	4.00	10.00	20.22	
9:06:29	69.30	27.50	409.00	81.00	2.00	1.50	4.00	11.00	20.24	
9:06:34	69.20	27.40	410.00	83.00	2.00	1.50	4.00	11.00	20.26	
9:06:39	69.00	27.40	416.00	88.00	3.00	1.50	4.00	11.00	20.29	
9:06:44	68.90	27.30	420.00	92.00	3.00	1.70	4.00	11.00	20.29	
9:06:49	69.10	27.30	427.00	92.00	3.00	1.50	4.00	11.00	20.29	
9:06:54	69.40	27.20	436.00	92.00	3.00	1.50	4.00	12.00	20.29	
9:06:59	69.00	27.30	443.00	94.00	3.00	1.50	4.00	12.00	20.29	

9:07:04	69.20	27.30	449.00	97.00	3.00	1.50	5.00	12.00	20.30	
9:07:09	68.40	27.40	454.00	100.00	3.00	1.50	5.00	12.00	20.33	
9:07:14	68.00	27.40	457.00	102.00	3.00	1.30	4.00	12.00	20.36	
9:07:19	68.20	27.50	458.00	104.00	3.00	1.40	4.00	12.00	20.35	
9:07:24	69.40	27.40	457.00	108.00	3.00	1.40	4.00	12.00	20.37	
9:07:29	80.00	27.50	443.00	115.00	3.00	1.40	4.00	12.00	20.34	
9:07:34	82.70	27.50	433.00	115.00	3.00	1.90	5.00	11.00	20.08	
9:07:39	80.40	27.50	418.00	118.00	3.00	2.10	5.00	11.00	19.88	
9:07:44	77.90	27.50	388.00	124.00	3.00	2.10	5.00	10.00	19.82	59.30
9:07:49	76.40	27.50	359.00	123.00	3.00	2.10	5.00	9.00	19.81	63.00
9:07:54	77.10	27.50	339.00	116.00	3.00	2.10	5.00	9.00	19.79	64.30
9:07:59	76.20	27.50	335.00	106.00	3.00	2.30	5.00	8.00	19.78	64.40
9:08:04	75.30	27.60	339.00	96.00	3.00	2.20	5.00	9.00	19.80	65.50
9:08:09	74.90	27.50	346.00	91.00	3.00	2.10	5.00	9.00	19.82	65.40
9:08:14	74.80	27.50	350.00	89.00	3.00	2.10	5.00	9.00	19.87	65.00
9:13:21	69.30	27.60	510.00	101.00	3.00	1.10	4.00	15.00	20.29	63.90
9:13:26	68.50	27.60	515.00	104.00	3.00	1.00	4.00	15.00	20.32	
9:13:31	73.10	27.70	493.00	119.00	3.00	1.10	4.00	14.00	20.39	
9:13:36	75.10	27.60	476.00	124.00	3.00	1.10	4.00	14.00	20.35	
9:13:41	74.60	27.50	457.00	126.00	3.00	1.10	4.00	13.00	20.26	
9:13:46	73.60	27.50	425.00	128.00	3.00	1.30	4.00	12.00	20.12	
9:13:51	72.70	27.50	389.00	123.00	3.00	1.30	4.00	11.00	20.09	
9:13:56	72.60	27.60	372.00	116.00	2.00	1.40	4.00	10.00	20.10	
9:14:01	71.70	27.60	368.00	105.00	3.00	1.40	4.00	10.00	20.11	
9:14:06	71.40	27.60	374.00	94.00	3.00	1.30	4.00	11.00	20.14	
9:14:11	71.50	27.60	384.00	88.00	3.00	1.30	4.00	11.00	20.15	
9:14:16	71.30	27.50	397.00	84.00	3.00	1.30	4.00	11.00	20.16	
9:14:21	71.00	27.50	406.00	86.00	3.00	1.20	4.00	12.00	20.20	
9:14:26	71.30	27.60	412.00	88.00	3.00	1.10	4.00	12.00	20.22	

9:14:31	71.60	27.50	421.00	88.00	3.00	1.10	4.00	12.00	20.23	
9:14:36	71.50	27.50	432.00	87.00	3.00	1.10	4.00	13.00	20.23	
9:14:41	71.50	27.50	448.00	86.00	3.00	1.10	4.00	13.00	20.23	
9:14:46	71.30	27.60	459.00	89.00	2.00	1.00	3.00	13.00	20.25	
9:14:51	70.60	27.50	461.00	96.00	3.00	1.00	4.00	13.00	20.30	
9:14:56	70.40	27.50	458.00	100.00	3.00	0.90	4.00	13.00	20.32	
9:15:01	70.30	27.60	461.00	100.00	2.00	0.90	3.00	14.00	20.33	
9:15:06	70.40	27.60	471.00	99.00	3.00	1.00	3.00	14.00	20.32	
9:15:11	70.30	27.60	483.00	98.00	2.00	1.10	3.00	14.00	20.32	
9:15:16	69.90	27.60	491.00	101.00	2.00	1.10	3.00	14.00	20.34	
9:20:23	72.10	27.70	438.00	79.00	2.00	1.50	3.00	12.00	20.21	
9:20:28	72.10	27.70	444.00	86.00	2.00	1.50	3.00	12.00	20.25	
9:20:33	72.20	27.80	448.00	91.00	2.00	1.50	3.00	13.00	20.26	
9:20:38	73.20	27.80	457.00	92.00	2.00	1.40	3.00	13.00	20.26	
9:20:43	73.50	27.80	461.00	92.00	2.00	1.50	3.00	13.00	20.26	
9:20:48	72.60	27.90	484.00	90.00	2.00	1.40	3.00	14.00	20.24	
9:20:53	72.20	27.80	505.00	96.00	2.00	1.30	3.00	14.00	20.25	
9:20:58	71.80	27.90	510.00	102.00	2.00	1.30	3.00	14.00	20.28	
9:21:03	71.00	27.90	517.00	105.00	2.00	1.30	3.00	14.00	20.30	
9:21:08	70.30	27.90	512.00	116.00	2.00	1.10	3.00	15.00	20.35	
9:21:13	69.90	27.80	504.00	121.00	1.00	1.10	2.00	14.00	20.38	
9:21:18	70.00	27.80	503.00	120.00	2.00	1.10	3.00	14.00	20.38	
9:21:23	70.10	27.90	513.00	115.00	2.00	1.00	3.00	15.00	20.38	
9:21:28	70.40	27.90	528.00	113.00	2.00	1.10	3.00	15.00	20.37	
9:21:33	70.40	28.00	547.00	112.00	2.00	1.00	3.00	16.00	20.35	
9:21:38	70.50	27.90	570.00	111.00	1.00	1.00	2.00	16.00	20.35	
9:21:43	70.80	27.90	588.00	114.00	2.00	1.10	3.00	17.00	20.36	
9:21:48	70.10	28.00	604.00	118.00	2.00	1.10	3.00	17.00	20.37	
9:21:53	69.60	27.90	607.00	131.00	1.00	1.00	2.00	17.00	20.41	

9:21:58	69.70	28.00	598.00	140.00	2.00	1.00	3.00	17.00	20.42	
9:22:03	69.70	28.00	601.00	139.00	2.00	0.90	3.00	17.00	20.41	
9:22:08	69.70	27.90	612.00	137.00	2.00	0.90	3.00	17.00	20.42	
9:22:13	69.20	28.00	623.00	138.00	2.00	0.90	3.00	18.00	20.43	
9:22:18	69.80	28.00	627.00	144.00	2.00	0.90	3.00	18.00	20.44	
9:27:25	74.10	27.70	399.00	123.00	2.00	1.90	4.00	11.00	20.06	
9:27:30	74.30	27.70	395.00	108.00	3.00	1.90	5.00	11.00	20.06	
9:27:35	74.10	27.60	405.00	96.00	3.00	1.90	5.00	11.00	20.05	
9:27:40	73.10	27.70	426.00	87.00	3.00	1.90	5.00	12.00	20.07	
9:27:45	72.70	27.70	442.00	85.00	3.00	1.90	5.00	12.00	20.11	
9:27:50	72.60	27.70	447.00	86.00	3.00	1.90	5.00	13.00	20.12	
9:27:55	72.40	27.60	462.00	91.00	3.00	1.90	5.00	12.00	20.18	
9:28:00	71.90	27.70	473.00	93.00	3.00	1.70	5.00	13.00	20.20	
9:28:05	70.70	27.70	488.00	92.00	3.00	1.50	5.00	14.00	20.23	
9:28:10	70.80	27.50	505.00	93.00	3.00	1.50	4.00	14.00	20.27	
9:28:15	70.10	27.50	526.00	94.00	3.00	1.40	4.00	15.00	20.29	
9:28:20	68.40	27.60	542.00	100.00	3.00	1.30	4.00	15.00	20.32	
9:28:25	66.20	27.70	548.00	107.00	3.00	1.30	4.00	16.00	20.36	
9:28:30	70.00	27.70	527.00	127.00	3.00	1.00	4.00	15.00	20.48	
9:28:35	71.80	27.50	485.00	140.00	2.00	1.10	4.00	14.00	20.44	
9:28:40	71.40	27.60	463.00	133.00	2.00	1.30	4.00	13.00	20.37	
9:28:45	70.90	27.50	442.00	133.00	3.00	1.40	4.00	13.00	20.33	
9:28:50	70.30	27.60	421.00	129.00	3.00	1.40	4.00	12.00	20.30	
9:28:55	69.70	27.60	410.00	121.00	3.00	1.40	4.00	12.00	20.30	
9:29:00	69.40	27.50	408.00	112.00	3.00	1.30	4.00	11.00	20.31	
9:29:05	68.90	27.60	415.00	109.00	3.00	1.30	4.00	12.00	20.33	
9:29:10	68.80	27.50	425.00	98.00	2.00	1.30	4.00	12.00	20.36	
9:29:15	68.10	27.60	439.00	94.00	3.00	1.10	4.00	13.00	20.40	
9:29:20	67.80	27.60	450.00	94.00	3.00	1.10	4.00	13.00	20.44	

9:34:27	62.80	28.10				3.00	0.70	4.00	3.00	20.54	
9:34:32	65.60	27.10				3.00	0.60	3.00	3.00	20.60	
9:34:37	73.10	28.00				3.00	0.60	3.00	3.00	20.58	
9:34:42	75.70	28.00				3.00	0.80	4.00	3.00	20.37	
9:34:47	74.80	28.10				3.00	0.90	4.00	3.00	20.21	
9:34:52	73.90	28.10				3.00	1.10	4.00	3.00	20.16	
9:34:57	73.50	28.10				3.00	1.10	4.00	3.00	20.15	
9:35:02	73.00	28.10				3.00	1.20	4.00	3.00	20.12	
9:35:07	72.80	28.00				3.00	1.30	4.00	3.00	20.14	
9:35:12	71.50	28.00				3.00	1.30	4.00	3.00	20.16	
9:35:17	70.80	28.00				3.00	1.10	4.00	2.00	20.21	
9:35:22	70.90	27.90				3.00	1.00	4.00	2.00	20.23	
9:35:27	71.40	27.90				3.00	1.10	4.00	3.00	20.23	
9:35:32	70.90	27.80				3.00	1.10	4.00	3.00	20.25	
9:35:37	70.40	28.00				2.00	1.00	3.00	3.00	20.28	
9:35:42	70.20	28.00				3.00	1.00	4.00	3.00	20.30	
9:35:47	69.30	28.00				3.00	0.90	4.00	3.00	20.33	
9:35:52	69.60	28.00				2.00	0.90	3.00	3.00	20.36	
9:35:57	69.80	28.10				3.00	0.90	4.00	3.00	20.35	
9:36:02	69.00	28.20				3.00	0.90	4.00	3.00	20.36	
9:36:07	68.50	28.20				2.00	0.80	3.00	3.00	20.39	
9:36:12	69.00	28.20				2.00	0.80	3.00	3.00	20.41	
9:36:17	69.50	28.10				3.00	0.80	3.00	3.00	20.41	
9:36:22	67.80	28.00				3.00	0.80	3.00	3.00	20.41	
9:41:29	72.60	28.10				3.00	1.10	4.00	4.00	20.23	
9:41:34	72.00	28.20				3.00	1.10	4.00	4.00	20.25	
9:41:39	72.00	28.10				3.00	1.10	4.00	4.00	20.28	
9:41:44	71.80	28.10				3.00	0.90	4.00	4.00	20.31	
9:41:49	72.20	28.10				3.00	0.90	4.00	4.00	20.33	

9:41:54	68.80	28.00				3.00	0.90	4.00	4.00	20.37	
9:41:59	66.20	28.10				3.00	0.80	4.00	4.00	20.42	
9:42:04	73.70	28.10				3.00	0.90	4.00	4.00	20.44	
9:42:09	80.60	28.30				3.00	1.20	5.00	4.00	20.33	
9:42:14	81.10	28.20				4.00	1.50	5.00	3.00	21.13	
9:42:19	78.70	28.20				4.00	1.70	5.00	3.00	20.04	
9:42:24	77.50	28.20				4.00	1.80	6.00	3.00	20.01	
9:45:49	77.60	28.30				4.00	1.70	6.00	3.00	20.02	
9:42:34	76.60	28.30				4.00	1.70	6.00	3.00	20.02	
9:42:39	75.30	28.20				4.00	1.70	5.00	3.00	20.04	
9:42:44	74.80	28.30				4.00	1.70	6.00	3.00	20.06	
9:42:49	74.30	28.20				4.00	1.50	6.00	3.00	20.10	
9:42:54	73.50	28.20				4.00	1.60	5.00	4.00	20.14	
9:42:59	73.40	28.30				4.00	1.50	5.00	4.00	20.19	
9:43:04	73.10	28.40				4.00	1.50	5.00	4.00	20.22	
9:43:09	72.60	28.30				4.00	1.50	5.00	4.00	20.25	
9:43:14	72.20	28.30				4.00	1.40	5.00	4.00	20.27	
9:43:19	72.60	28.30				4.00	1.20	5.00	4.00	20.29	
9:43:24	70.80	28.70				4.00	1.30	5.00	4.00	20.29	
9:48:31	75.00	28.80				3.00	1.30	5.00	4.00	20.26	
9:48:36	74.00	28.80				4.00	1.20	5.00	4.00	20.27	
9:48:41	73.60	28.80				3.00	1.30	4.00	4.00	20.31	
9:48:46	73.30	28.80				3.00	1.00	4.00	4.00	20.33	
9:48:51	71.90	28.80				3.00	1.10	4.00	4.00	20.35	
9:48:56	68.80	28.80				3.00	0.90	4.00	4.00	20.39	
9:49:01	65.60	28.70				3.00	0.80	4.00	4.00	20.47	
9:49:06	64.30	28.70				3.00	0.80	4.00	4.00	20.48	
9:49:11	69.40	28.70				3.00	0.60	4.00	3.00	20.62	
9:49:16	75.70	28.80				3.00	0.80	3.00	3.00	20.54	

9:49:21	78.70	28.90				3.00	1.00	4.00	3.00	20.29	
9:49:26	79.40	28.80				3.00	1.30	5.00	3.00	20.14	
9:49:31	79.20	28.80				3.00	1.40	5.00	3.00	20.08	
9:49:36	78.70	28.80				3.00	1.50	5.00	3.00	20.05	
9:49:41	77.10	28.80				4.00	1.50	5.00	3.00	20.08	
9:49:46	76.30	28.90				3.00	1.30	5.00	3.00	20.13	
9:49:51	76.00	28.90				3.00	1.30	5.00	4.00	20.17	
9:49:56	76.00	28.80				4.00	1.30	5.00	4.00	20.19	
9:50:01	75.60	28.80				3.00	1.30	5.00	4.00	20.20	
9:50:06	75.60	29.00				3.00	1.30	4.00	4.00	20.23	
9:50:11	75.60	28.90				4.00	1.20	5.00	4.00	20.24	
9:50:16	75.30	28.90				3.00	1.20	4.00	4.00	20.24	
9:50:21	75.80	28.90				4.00	1.10	5.00	4.00	20.25	
9:50:26	75.60	28.90				3.00	1.10	4.00	4.00	20.26	

Table O 44: Temperature at pyrolysis chamber for Experiment (viii-1); AVR = 3.83:9.65 (Wood chips)

Mean	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)
	0	0.00	14.5	284.00	29	251.00	43.5	369.00	58	408.00
	0.5	351.00	15	246.00	29.5	389.00	44	369.00	58.5	456.00
	1	349.00	15.5	220.00	30	342.00	44.5	369.00	59	458.00
	1.5	366.00	16	205.00	30.5	297.00	45	370.00	59.5	471.00
	2	352.00	16.5	449.00	31	258.00	45.5	371.00	60	459.00
	2.5	360.00	17	530.00	31.5	235.00	46	371.00	60.5	436.00
	3	353.00	17.5	571.00	32	222.00	46.5	372.00	61	433.00
	3.5	339.00	18	565.00	32.5	205.00	47	374.00	61.5	437.00
	4	344.00	18.5	499.00	33	399.00	47.5	386.00	62	444.00
	4.5	341.00	19	468.00	33.5	320.00	48	347.00	62.5	443.00
	5	332.00	19.5	437.00	34	257.00	48.5	322.00	63	449.00
	5.5	310.00	20	379.00	34.5	229.00	49	259.00	63.5	457.00
	6	311.00	20.5	332.00	35	212.00	49.5	226.00	64	488.00
	6.5	301.00	21	305.00	35.5	347.00	50	220.00	64.5	507.00
	7	302.00	21.5	656.00	36	288.00	50.5	225.00	65	513.00
	7.5	313.00	22	194.00	36.5	245.00	51	232.00	65.5	446.00
	8	306.00	22.5	181.00	37	223.00	51.5	348.00	66	405.00
	8.5	287.00	23	171.00	37.5	238.00	52	445.00	66.5	396.00
	9	281.00	23.5	159.00	38	270.00	52.5	435.00	67	391.00
	9.5	263.00	24	163.00	38.5	260.00	53	417.00	67.5	457.00
	10	255.00	24.5	322.00	39	235.00	53.5	404.00	68	444.00
	10.5	249.00	25	475.00	39.5	222.00	54	398.00	68.5	326.00
	11	235.00	25.5	431.00	40	212.00	54.5	392.00	69	438.00
	11.5	257.00	26	390.00	40.5	270.00	55	372.00	69.5	395.00

12	250.00	26.5	437.00	41	317.00	55.5	320.00	70	353.00
12.5	231.00	27	380.00	41.5	345.00	56	319.00	70.5	316.00
13	220.00	27.5	323.00	42	358.00	56.5	359.00	71	393.00
13.5	208.00	28	292.00	42.5	364.00	57	368.00	71.5	369.00
14	348.00	28.5	271.00	43	368.00	57.5	388.00	72	328.00

Duration, minute	PT, (°C)
72.5	302.00
73	390.00
73.5	428.00
74	399.00
74.5	377.00
75	344.00

Experiment set (viii-2)

Date = 10/1/2013; Sample = About 3 Kg of Wood chips; Methanol = About 3 Liter; AVR = 3.83:9.65

Measurement rate = 5 seconds; Gas time = 2 minutes; Rinse time = 5 minutes; Mean = 1 second; To make the data meaningful, rinse time is neglected

Table O 45: Results of TESTO Experiment (viii-2); AVR = 3.83:9.65 (Wood chips)

Mean	70.53	32.22	278.21	60.33	1.84	0.79	2.59	8.21	20.15	67.85
Time	FT (°C)	AT (°C)	CO (ppmv)	H2 (ppmv)	NO (ppmv)	NO2 (ppmv)	NOx (ppmv)	SO2 (ppmv)	O2 (%)	η (%)
11:56:14	88.50	31.00	3.00	8.00	1.00	0.10	1.00	0.00	20.97	
11:56:19	82.60	31.10	34.00	31.00	1.00	0.10	1.00	1.00	20.39	
11:56:24	78.70	31.20	1104.00	50.00	2.00	0.20	2.00	4.00	19.46	73.30
11:56:29	74.70	31.00	144.00	35.00	2.00	0.40	2.00	5.00	19.22	78.00
11:56:34	71.40	31.00	151.00	13.00	2.00	0.40	2.00	5.00	19.19	79.60
11:56:39	69.80	31.20	150.00	3.00	2.00	0.60	2.00	5.00	19.18	80.50
11:56:44	69.20	31.30	150.00	12.00	2.00	0.40	2.00	5.00	19.20	80.60
11:56:49	69.00	31.30	149.00	19.00	2.00	0.50	2.00	5.00	19.23	80.40
11:56:54	67.70	31.30	146.00	25.00	1.00	0.70	2.00	5.00	19.28	80.50
11:56:59	67.50	31.30	140.00	31.00	2.00	0.80	3.00	4.00	19.33	80.10
11:57:04	67.90	31.20	135.00	31.00	2.00	0.60	2.00	4.00	19.34	79.80
11:57:09	67.00	31.10	132.00	33.00	2.00	0.80	3.00	4.00	19.37	79.90
11:57:14	67.10	31.10	129.00	34.00	2.00	0.80	2.00	4.00	19.41	79.50
11:57:19	67.60	31.10	127.00	34.00	2.00	0.80	2.00	4.00	19.41	79.20
11:57:24	68.40	31.10	126.00	35.00	2.00	0.80	3.00	4.00	19.41	78.90
11:57:29	68.90	31.10	125.00	34.00	2.00	0.80	3.00	4.00	19.39	78.90
11:57:34	68.20	31.10	124.00	34.00	2.00	0.80	3.00	4.00	19.39	79.20
11:57:39	67.20	31.20	118.00	36.00	2.00	0.80	3.00	3.00	19.44	79.10

11:57:44	67.50	31.00	115.00	36.00	2.00	0.80	3.00	3.00	19.48	78.50
11:57:49	66.80	30.90	114.00	34.00	2.00	0.80	3.00	3.00	19.49	78.70
11:57:54	67.60	30.80	117.00	33.00	2.00	0.80	3.00	3.00	19.51	78.00
11:57:59	66.80	31.00	117.00	32.00	2.00	0.80	3.00	3.00	19.51	78.40
11:58:04	65.60	31.20	114.00	34.00	2.00	0.80	3.00	3.00	19.57	78.40
11:58:09	67.30	31.20	112.00	33.00	2.00	0.80	3.00	3.00	19.61	77.00
12:03:16	64.80	31.20	108.00	43.00	0.00	0.60	1.00	3.00	20.09	
12:03:21	64.60	31.00	111.00	41.00	0.00	0.60	1.00	3.00	20.09	
12:03:26	64.80	31.00	114.00	41.00	1.00	0.60	1.00	3.00	20.12	
12:03:31	63.70	31.00	117.00	40.00	1.00	0.60	1.00	3.00	20.13	
12:03:36	64.30	31.00	120.00	41.00	0.00	0.60	1.00	3.00	20.15	
12:03:41	64.60	30.90	122.00	42.00	0.00	0.60	1.00	3.00	20.14	
12:03:46	64.30	31.10	125.00	42.00	0.00	0.60	1.00	3.00	20.14	
12:03:51	64.10	31.10	127.00	44.00	1.00	0.60	1.00	4.00	20.15	
12:03:56	64.20	31.10	128.00	44.00	0.00	0.60	1.00	3.00	20.16	
12:04:01	64.80	31.10	127.00	47.00	1.00	0.70	1.00	3.00	20.18	
12:04:06	64.80	31.20	126.00	47.00	0.00	0.60	1.00	3.00	20.15	
12:04:11	65.40	31.20	130.00	45.00	0.00	0.50	1.00	4.00	20.15	
12:04:16	64.80	31.30	132.00	45.00	0.00	0.60	1.00	4.00	20.16	
12:04:21	64.50	31.30	133.00	47.00	0.00	0.60	1.00	4.00	20.17	
12:04:26	64.40	31.30	131.00	49.00	0.00	0.50	1.00	4.00	20.20	
12:04:31	63.60	31.40	129.00	49.00	0.00	0.40	1.00	3.00	20.22	
12:04:36	63.30	31.50	129.00	49.00	0.00	0.60	1.00	4.00	20.21	
12:04:41	63.50	31.50	129.00	49.00	0.00	0.60	1.00	4.00	20.20	
12:04:46	63.70	31.60	128.00	48.00	0.00	0.60	1.00	4.00	20.22	
12:04:51	63.20	31.60	127.00	48.00	0.00	0.50	1.00	4.00	20.24	
12:04:56	63.30	31.60	126.00	48.00	0.00	0.40	0.00	4.00	20.27	
12:05:01	63.40	31.50	127.00	48.00	0.00	0.40	1.00	4.00	20.27	
12:05:06	63.20	31.50	128.00	48.00	0.00	0.40	0.00	4.00	20.26	

12:05:11	63.50	31.40	129.00	47.00	0.00	0.40	1.00	4.00	20.25	
12:10:18	62.20	31.30	109.00	42.00	1.00	0.60	1.00	3.00	20.45	
12:10:23	62.50	31.40	111.00	43.00	1.00	0.50	1.00	4.00	20.47	
12:10:28	62.60	31.40	111.00	45.00	1.00	0.40	1.00	3.00	20.47	
12:10:33	63.10	31.30	112.00	46.00	1.00	0.50	1.00	3.00	20.47	
12:10:38	63.30	31.30	114.00	45.00	1.00	0.60	2.00	3.00	20.45	
12:10:43	62.60	31.40	116.00	46.00	1.00	0.60	2.00	4.00	20.44	
12:10:48	62.70	31.30	117.00	47.00	1.00	0.60	1.00	3.00	20.45	
12:10:53	63.30	31.20	117.00	47.00	1.00	0.50	1.00	4.00	20.45	
12:10:58	64.40	31.20	117.00	49.00	1.00	0.50	1.00	4.00	20.42	
12:11:03	64.00	31.20	119.00	50.00	1.00	0.60	1.00	4.00	20.39	
12:11:08	63.10	31.30	119.00	50.00	1.00	0.60	1.00	4.00	20.43	
12:11:13	63.00	31.40	115.00	53.00	1.00	0.60	1.00	3.00	20.46	
12:11:18	62.90	31.40	114.00	52.00	1.00	0.60	1.00	4.00	20.47	
12:11:23	62.80	31.30	115.00	52.00	0.00	0.60	1.00	3.00	20.47	
12:11:28	6.10	31.20	116.00	51.00	1.00	0.60	1.00	3.00	20.49	
12:11:33	62.90	31.20	116.00	51.00	0.00	0.60	1.00	3.00	20.47	
12:11:38	63.30	31.40	118.00	51.00	1.00	0.40	1.00	4.00	20.48	
12:11:43	63.40	31.40	119.00	50.00	1.00	0.60	1.00	4.00	20.47	
12:11:48	62.90	31.20	119.00	51.00	1.00	0.60	1.00	4.00	20.46	
12:11:53	62.70	31.20	119.00	53.00	1.00	0.60	1.00	4.00	20.48	
12:11:58	62.80	31.10	119.00	54.00	1.00	0.60	1.00	4.00	20.49	
12:12:03	62.70	31.20	119.00	54.00	1.00	0.60	1.00	3.00	20.48	
12:12:08	62.30	31.20	118.00	54.00	1.00	0.60	1.00	3.00	20.49	
12:12:13	62.60	31.40	117.00	55.00	0.00	0.60	1.00	3.00	20.49	
12:17:20	62.30	31.60	165.00	55.00	1.00	0.40	2.00	4.00	20.57	
12:17:25	62.60	31.60	165.00	53.00	1.00	0.40	1.00	5.00	20.56	
12:17:30	62.70	31.50	166.00	53.00	1.00	0.40	2.00	5.00	20.56	
12:17:35	62.50	31.60	168.00	52.00	1.00	0.40	2.00	5.00	20.56	

12:17:40	62.70	31.40	169.00	54.00	1.00	0.40	2.00	5.00	20.55	
12:17:45	62.40	31.10	170.00	53.00	1.00	0.40	2.00	5.00	20.56	
12:17:50	62.60	31.10	170.00	55.00	1.00	0.40	1.00	5.00	20.57	
12:17:55	62.80	31.20	172.00	55.00	1.00	0.40	1.00	5.00	20.56	
12:18:00	62.40	31.20	174.00	55.00	1.00	0.30	1.00	5.00	20.57	
12:18:05	62.30	31.20	175.00	55.00	1.00	0.40	2.00	5.00	20.58	
12:18:10	62.70	31.20	175.00	56.00	1.00	0.40	1.00	5.00	20.57	
12:18:15	62.70	31.30	172.00	58.00	1.00	0.40	1.00	5.00	20.59	
12:18:20	62.80	31.50	171.00	58.00	1.00	0.40	1.00	5.00	20.58	
12:18:25	62.70	31.60	172.00	57.00	1.00	0.40	2.00	5.00	20.58	
12:18:30	62.50	31.50	173.00	58.00	1.00	0.20	2.00	5.00	20.57	
12:18:35	62.40	31.50	172.00	58.00	1.00	0.30	2.00	5.00	20.58	
12:18:40	62.40	31.30	171.00	58.00	1.00	0.40	1.00	5.00	20.59	
12:18:45	62.60	31.40	168.00	59.00	1.00	0.40	2.00	5.00	20.58	
12:18:50	62.80	31.40	166.00	60.00	1.00	0.40	2.00	5.00	20.58	
12:18:55	62.80	31.30	167.00	59.00	1.00	0.40	2.00	5.00	20.58	
12:19:00	62.80	31.10	166.00	59.00	1.00	0.40	1.00	5.00	20.59	
12:19:05	62.50	31.10	166.00	59.00	1.00	0.40	1.00	5.00	20.58	
12:19:10	62.40	31.10	170.00	57.00	1.00	0.40	2.00	5.00	20.59	
12:19:15	62.50	31.10	173.00	57.00	1.00	0.40	1.00	5.00	20.58	
12:24:22	61.90	30.90	193.00	55.00	1.00	0.30	1.00	6.00	20.63	
12:24:27	62.40	31.00	195.00	55.00	1.00	0.40	1.00	6.00	20.63	
12:24:32	62.10	31.10	199.00	53.00	1.00	0.20	1.00	6.00	20.63	
12:24:37	61.90	31.10	203.00	55.00	1.00	0.30	1.00	6.00	20.63	
12:24:42	62.00	31.10	205.00	55.00	1.00	0.40	1.00	6.00	20.63	
12:24:47	61.90	31.10	203.00	58.00	1.00	0.40	1.00	6.00	20.64	
12:24:52	61.60	30.90	201.00	59.00	1.00	0.40	1.00	6.00	20.64	
12:24:57	62.10	30.80	203.00	59.00	1.00	0.40	1.00	6.00	20.65	
12:25:02	62.10	30.90	205.00	59.00	1.00	0.40	1.00	6.00	20.66	

12:25:07	61.90	30.90	206.00	60.00	1.00	0.30	1.00	6.00	20.65	
12:25:12	61.80	30.90	208.00	60.00	1.00	0.30	1.00	6.00	20.65	
12:25:17	61.90	30.80	208.00	62.00	1.00	0.30	1.00	6.00	20.65	
12:25:22	61.70	30.70	208.00	62.00	1.00	0.20	1.00	6.00	20.65	
12:25:27	60.80	30.70	210.00	61.00	1.00	0.20	1.00	6.00	20.65	
12:25:32	58.70	308.00	211.00	63.00	1.00	0.20	1.00	6.00	20.68	
12:25:37	57.00	30.80	201.00	70.00	1.00	0.20	1.00	6.00	20.73	
12:25:42	56.20	30.70	181.00	76.00	1.00	0.20	1.00	5.00	20.78	
12:25:47	56.50	30.80	155.00	77.00	1.00	0.20	1.00	5.00	20.79	
12:25:52	76.90	30.80	147.00	69.00	1.00	0.50	1.00	4.00	20.47	
12:25:57	79.70	30.90	148.00	65.00	1.00	0.60	1.00	4.00	20.29	
12:26:02	77.00	30.70	183.00	48.00	1.00	0.90	2.00	5.00	19.80	66.70
12:26:07	74.40	30.70	192.00	53.00	1.00	0.90	2.00	6.00	19.69	71.00
12:26:12	73.90	30.70	189.00	56.00	1.00	1.00	2.00	5.00	19.68	71.60
12:26:17	73.70	30.60	188.00	58.00	2.00	1.10	3.00	5.00	19.63	72.60
12:31:24	66.50	30.80	297.00	66.00	1.00	0.60	2.00	9.00	20.49	
12:31:29	66.00	30.70	297.00	68.00	1.00	0.60	2.00	9.00	20.49	
12:31:34	66.00	30.70	296.00	69.00	1.00	0.40	2.00	9.00	20.50	
12:31:39	66.70	30.70	296.00	68.00	1.00	0.60	2.00	9.00	20.49	
12:31:44	66.00	30.80	300.00	68.00	1.00	0.60	2.00	9.00	20.49	
12:31:49	56.60	30.80	305.00	68.00	1.00	0.50	2.00	9.00	20.51	
12:31:54	66.10	30.80	307.00	68.00	1.00	0.50	2.00	10.00	20.51	
12:31:59	66.40	31.00	310.00	70.00	1.00	0.40	2.00	10.00	20.50	
12:32:04	66.70	30.90	314.00	70.00	1.00	0.50	1.00	10.00	20.49	
12:32:09	66.20	30.90	316.00	72.00	1.00	0.50	2.00	10.00	20.50	
12:32:14	65.80	30.80	314.00	73.00	1.00	0.60	1.00	10.00	20.52	
12:32:19	65.60	30.80	311.00	77.00	1.00	0.50	2.00	10.00	20.54	
12:32:24	65.20	30.80	311.00	76.00	1.00	0.50	1.00	10.00	20.53	
12:32:29	56.30	30.70	309.00	79.00	1.00	0.40	1.00	10.00	20.63	

12:32:34	56.30	30.70	245.00	106.00	1.00	0.20	1.00	8.00	20.78	
12:32:39	67.50	30.80	218.00	94.00	1.00	0.30	1.00	6.00	20.66	
12:32:44	78.10	30.70	222.00	77.00	1.00	0.50	2.00	7.00	20.47	
12:32:49	79.60	30.60	233.00	66.00	1.00	0.80	2.00	7.00	20.05	
17:32:54	77.70	30.60	238.00	67.00	1.00	0.80	2.00	7.00	19.79	66.40
12:32:59	76.70	30.60	228.00	72.00	1.00	0.90	2.00	7.00	19.73	68.70
12:33:04	75.80	30.60	222.00	73.00	1.00	0.90	2.00	7.00	19.72	69.40
12:33:09	74.10	30.70	209.00	69.00	1.00	0.80	2.00	6.00	19.72	70.50
12:33:14	71.70	30.90	203.00	66.00	1.00	0.80	2.00	6.00	19.78	69.70
12:33:19	73.00	30.90	201.00	61.00	1.00	0.80	2.00	6.00	19.80	69.60
12:38:26	74.60	30.60	311.00	44.00	2.00	1.10	3.00	9.00	19.88	65.70
12:38:31	74.30	30.60	321.00	47.00	2.00	1.10	3.00	9.00	19.90	65.20
12:38:36	74.30	30.60	328.00	51.00	3.00	1.10	4.00	10.00	19.93	64.50
12:38:41	74.80	30.60	332.00	56.00	3.00	1.10	4.00	10.00	19.97	62.80
12:38:46	75.10	30.80	332.00	59.00	2.00	1.10	3.00	10.00	19.97	62.60
12:38:51	74.80	30.70	332.00	62.00	2.00	1.10	3.00	10.00	19.99	
12:38:56	74.30	30.70	334.00	63.00	2.00	1.10	3.00	10.00	20.03	
12:39:01	73.60	30.60	340.00	61.00	2.00	1.10	3.00	10.00	20.06	
12:39:06	73.30	30.60	341.00	64.00	2.00	1.00	3.00	10.00	20.09	
12:39:11	73.10	30.60	338.00	67.00	2.00	0.90	3.00	10.00	20.11	
12:39:16	73.30	30.60	337.00	68.00	2.00	0.90	4.00	10.00	20.11	
12:39:21	73.20	30.70	341.00	65.00	2.00	1.10	3.00	10.00	20.12	
12:39:26	73.50	30.70	350.00	62.00	2.00	1.00	3.00	10.00	20.12	
12:39:31	73.40	30.70	356.00	65.00	2.00	0.90	3.00	11.00	20.14	
12:39:36	73.30	30.70	354.00	69.00	2.00	0.90	3.00	11.00	20.17	
12:39:41	73.60	30.70	354.00	69.00	2.00	0.90	3.00	11.00	20.19	
12:39:46	73.00	30.70	357.00	67.00	2.00	0.80	3.00	11.00	20.20	
12:39:51	72.50	30.70	362.00	66.00	2.00	0.90	3.00	11.00	20.22	
12:39:56	72.20	30.70	365.00	68.00	2.00	0.90	3.00	11.00	20.23	

12:40:01	72.80	30.60	366.00	70.00	2.00	0.80	3.00	11.00	20.24	
12:40:06	73.00	30.70	372.00	68.00	2.00	0.90	3.00	11.00	20.23	
12:40:11	72.50	30.60	378.00	68.00	2.00	0.90	3.00	12.00	20.24	
12:40:16	72.40	30.60	389.00	72.00	2.00	0.90	3.00	12.00	20.27	
12:40:21	71.90	30.90	387.00	76.00	2.00	0.90	3.00	12.00	20.29	
12:45:28	66.60	30.70	517.00	88.00	2.00	0.60	2.00	16.00	20.53	
12:45:33	62.80	30.70	506.00	96.00	2.00	0.60	2.00	16.00	20.58	
12:45:38	55.40	30.60	441.00	127.00	2.00	0.40	2.00	14.00	20.76	
12:45:43	56.70	30.50	324.00	155.00	1.00	0.30	2.00	10.00	20.84	
12:45:48	62.30	30.60	284.00	124.00	1.00	0.20	2.00	9.00	20.76	
12:45:53	82.10	30.70	285.00	93.00	2.00	0.60	2.00	9.00	20.58	
12:45:58	87.80	30.60	287.00	78.00	2.00	1.10	3.00	9.00	20.04	
12:46:03	84.70	60.60	304.00	64.00	2.00	1.30	4.00	9.00	19.82	64.10
12:46:08	82.40	30.70	315.00	60.00	2.00	1.50	4.00	9.00	19.76	64.20
12:46:13	81.60	30.70	326.00	57.00	3.00	1.50	4.00	9.00	19.73	65.40
12:46:18	81.50	30.90	343.00	54.00	3.00	1.50	4.00	10.00	19.69	66.40
12:46:23	80.90	30.80	352.00	56.00	3.00	1.50	5.00	10.00	19.68	66.90
12:46:28	80.80	30.80	355.00	61.00	3.00	1.50	4.00	10.00	19.73	65.80
12:46:33	80.40	30.70	358.00	61.00	3.00	1.40	4.00	10.00	19.74	65.50
12:46:38	81.10	30.50	365.00	60.00	3.00	1.30	4.00	11.00	19.76	64.50
12:46:43	80.70	30.60	373.00	59.00	3.00	1.50	4.00	11.00	19.78	64.20
12:46:48	80.00	30.70	377.00	60.00	3.00	1.40	4.00	11.00	19.82	63.80
12:46:53	80.00	30.70	378.00	63.00	3.00	1.30	4.00	11.00	19.86	62.60
12:06:58	78.90	30.70	383.00	60.00	3.00	1.30	4.00	11.00	19.90	62.10
12:47:03	79.00	30.80	394.00	58.00	3.00	1.40	4.00	12.00	19.93	61.00
12:47:08	78.70	30.90	407.00	57.00	3.00	1.40	4.00	12.00	19.94	61.00
12:47:13	78.20	30.80	410.00	58.00	3.00	1.30	4.00	12.00	19.94	61.00
12:47:18	77.70	30.70	414.00	61.00	3.00	1.20	4.00	12.00	19.99	
12:47:23	77.30	30.60	417.00	64.00	2.00	1.10	4.00	13.00	20.04	

12:52:30	75.00	31.10	465.00	57.00	3.00	0.80	4.00	15.00	20.25	
12:52:35	74.70	30.90	470.00	60.00	4.00	0.90	4.00	15.00	20.27	
12:52:40	74.90	30.80	473.00	65.00	3.00	0.80	4.00	15.00	20.29	
12:52:45	74.80	30.60	480.00	65.00	3.00	0.80	4.00	15.00	20.31	
12:52:50	73.20	30.60	490.00	64.00	3.00	0.80	4.00	15.00	20.32	
12:52:55	69.10	30.60	484.00	76.00	3.00	0.60	4.00	15.00	20.46	
12:53:00	66.30	30.70	452.00	87.00	3.00	0.70	4.00	14.00	20.46	
12:53:05	64.50	30.70	419.00	94.00	3.00	0.40	4.00	13.00	20.53	
12:53:10	61.70	30.60	385.00	96.00	3.00	0.60	3.00	12.00	20.54	
12:53:15	62.10	30.70	353.00	94.00	3.00	0.60	3.00	11.00	20.58	
12:53:20	82.00	30.60	320.00	94.00	3.00	0.50	3.00	10.00	20.56	
12:53:25	98.90	30.70	296.00	86.00	3.00	1.30	4.00	9.00	20.03	
12:53:30	96.50	30.70	313.00	58.00	4.00	1.90	6.00	9.00	19.58	60.90
12:53:35	92.80	30.70	380.00	25.00	4.00	1.90	6.00	10.00	19.47	65.10
12:53:40	89.80	30.60	474.00	9.00	4.00	1.70	6.00	13.00	19.47	66.00
12:53:45	86.20	30.50	535.00	19.00	4.00	1.70	6.00	15.00	19.55	65.80
12:53:50	84.30	30.50	574.00	38.00	5.00	1.70	6.00	17.00	19.64	64.80
12:53:55	83.40	30.50	605.00	56.00	5.00	1.70	6.00	17.00	19.65	64.80
12:54:00	81.70	30.60	629.00	69.00	5.00	1.70	7.00	18.00	19.71	64.20
12:54:05	81.00	30.60	646.00	84.00	5.00	1.40	6.00	19.00	19.80	62.20
12:54:10	80.40	30.70	641.00	99.00	5.00	1.30	6.00	19.00	19.86	60.70
12:54:15	80.50	30.60	639.00	105.00	5.00	1.30	6.00	19.00	19.90	59.30
12:54:20	80.40	30.60	639.00	105.00	5.00	1.30	6.00	19.00	19.92	58.80
12:54:25	74.30	30.60	632.00	111.00	4.00	1.20	6.00	19.00	20.00	
12:59:32	93.00	30.60	476.00	63.00	3.00	1.30	5.00	14.00	19.50	63.70
12:59:37	90.80	30.60	505.00	64.00	4.00	1.40	5.00	15.00	19.50	64.80
12:59:42	89.10	30.70	519.00	71.00	4.00	1.30	5.00	16.00	19.53	64.90
12:59:47	88.00	30.70	526.00	80.00	4.00	1.50	5.00	16.00	19.61	63.60
12:59:52	87.40	30.70	526.00	86.00	4.00	1.50	6.00	16.00	19.65	62.90

12:59:57	87.00	30.60	533.00	85.00	4.00	1.60	5.00	16.00	19.67	62.80
13:00:02	87.00	30.60	543.00	83.00	4.00	1.70	5.00	17.00	19.68	62.50
13:00:07	85.90	30.70	550.00	85.00	4.00	1.60	5.00	17.00	19.73	61.70
13:00:12	83.60	30.60	555.00	86.00	4.00	1.50	6.00	17.00	19.79	61.30
13:00:17	77.30	30.70	532.00	105.00	4.00	1.30	5.00	17.00	20.09	
13:00:22	80.90	30.80	476.00	120.00	4.00	1.10	5.00	15.00	20.07	
13:00:27	92.10	30.80	460.00	103.00	3.00	1.30	5.00	14.00	19.97	
13:00:32	93.50	30.90	462.00	92.00	4.00	1.40	5.00	14.00	19.71	58.30
13:00:37	90.40	31.00	469.00	84.00	4.00	1.50	5.00	14.00	19.64	62.00
13:00:42	88.90	30.80	475.00	80.00	4.00	1.60	5.00	14.00	19.65	62.60
13:00:47	87.70	30.70	491.00	73.00	4.00	1.50	6.00	15.00	19.65	63.10
13:00:52	86.70	30.70	518.00	65.00	4.00	1.70	6.00	16.00	19.67	63.10
13:00:57	85.50	30.70	547.00	63.00	4.00	1.70	6.00	16.00	19.69	63.00
13:01:02	84.00	30.80	570.00	66.00	4.00	1.70	6.00	17.00	19.77	61.60
13:01:07	83.10	30.90	586.00	72.00	4.00	1.50	6.00	18.00	19.83	60.40
13:01:12	82.50	30.80	599.00	76.00	4.00	1.50	6.00	18.00	19.85	59.80
13:01:17	83.30	30.80	614.00	78.00	5.00	1.50	6.00	18.00	19.88	58.30
13:01:22	83.10	30.70	629.00	77.00	5.00	1.50	6.00	19.00	19.91	57.20
13:01:27	83.60	30.50	638.00	78.00	4.00	1.50	6.00	19.00	19.91	56.80

Table O 46: Temperature at pyrolysis chamber for Experiment (viii-2); AVR = 3.83; 9.65 (Wood chips)

Mean		312.88					
Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)
0	0.00	14.5	235.00	29	197.00	43.5	327.00
0.5	318.00	15	234.00	29.5	481.00	44	295.00
1	360.00	15.5	233.00	30	538.00	44.5	277.00
1.5	382.00	16	231.00	30.5	471.00	45	416.00
2	371.00	16.5	231.00	31	411.00	45.5	457.00
2.5	357.00	17	225.00	31.5	375.00	46	398.00
3	362.00	17.5	226.00	32	360.00	46.5	352.00
3.5	353.00	18	228.00	32.5	335.00	47	322.00
4	330.00	18.5	223.00	33	315.00	47.5	297.00
4.5	340.00	19	222.00	33.5	295.00	48	280.00
5	310.00	19.5	226.00	34	285.00	48.5	255.00
5.5	310.00	20	225.00	34.5	273.00	49	239.00
6	298.00	20.5	221.00	35	265.00	49.5	484.00
6.5	304.00	21	219.00	35.5	264.00	50	532.00
7	293.00	21.5	219.00	36	256.00	50.5	511.00
7.5	286.00	22	219.00	36.5	456.00	51	446.00
8	283.00	22.5	213.00	37	438.00	51.5	409.00
8.5	276.00	23	211.00	37.5	371.00	52	348.00
9	270.00	23.5	210.00	38	332.00	52.5	348.00
9.5	273.00	24	214.00	38.5	290.00	53	323.00
10	269.00	24.5	220.00	39	272.00	53.5	299.00
10.5	261.00	25	209.00	39.5	251.00	54	488.00
11	259.00	25.5	202.00	40	234.00	54.5	437.00
11.5	258.00	26	201.00	40.5	226.00	55	396.00

12	251.00	26.5	205.00	41	214.00	55.5	364.00
12.5	250.00	27	201.00	41.5	428.00	56	310.00
13	248.00	27.5	200.00	42	467.00	56.5	293.00
13.5	247.00	28	198.00	42.5	406.00	57	422.00
14	243.00	28.5	196.00	43	352.00	57.5	464.00

Experiment set (viii-3)

Date = 10/1/2013; Sample = About 3 Kg of Wood chips; Methanol = About 3 Liter; AVR = 3.83:9.65

Measurement rate = 5 seconds; Gas time = 2 minutes; Rinse time = 5 minutes; Mean = 1 second; To make the data meaningful, rinse time is neglected

Table O 47: Results of TESTO Experiment (viii-3); AVR = 3.83:9.65 (Wood chips)

Mean	75.79	30.39	420.06	104.40	3.04	0.94	3.95	12.60	20.03	67.21
Time	FT (°C)	AT (°C)	CO (ppmv)	H2 (ppmv)	NO (ppmv)	NO2 (ppmv)	NOx (ppmv)	SO2 (ppmv)	O2 (%)	η (%)
15:19:30	62.60	31.50	2.00	12.00	1.00	0.00	1.00	0.00	21.00	
15:19:35	77.50	31.10	23.00	29.00	2.00	0.20	2.00	1.00	20.56	
15:19:40	72.40	31.10	96.00	52.00	3.00	0.20	3.00	3.00	19.94	67.20
15:19:45	70.20	31.20	152.00	38.00	3.00	0.20	3.00	5.00	19.78	72.30
15:19:50	68.30	31.20	153.00	7.00	3.00	0.40	3.00	5.00	19.72	74.50
15:19:55	67.50	31.20	141.00	14.00	3.00	0.50	3.00	5.00	19.70	75.30
15:20:00	67.20	31.20	132.00	22.00	3.00	0.60	3.00	4.00	19.69	75.80
15:20:05	66.70	31.30	126.00	26.00	3.00	0.60	3.00	4.00	19.70	76.10
15:20:10	67.20	31.10	123.00	27.00	3.00	0.60	3.00	4.00	19.70	75.50
15:20:15	67.30	31.10	122.00	28.00	3.00	0.80	4.00	3.00	19.67	76.00
15:20:20	65.90	31.10	119.00	27.00	3.00	0.80	4.00	3.00	19.71	76.20
15:20:25	65.60	31.10	116.00	28.00	3.00	0.90	4.00	3.00	19.74	75.90
15:20:30	66.60	31.10	115.00	27.00	3.00	0.90	4.00	3.00	19.74	75.30
15:20:35	65.90	31.00	120.00	23.00	3.00	0.90	4.00	3.00	19.74	75.70
15:20:40	66.90	31.00	122.00	24.00	3.00	0.90	4.00	3.00	19.76	74.30
15:20:45	67.50	31.00	120.00	28.00	3.00	0.90	4.00	3.00	19.74	74.70
15:20:50	67.90	31.10	117.00	28.00	3.00	1.00	4.00	3.00	19.77	73.90
15:20:55	67.70	31.20	115.00	26.00	4.00	1.00	5.00	3.00	19.79	73.80

15:21:00	68.00	31.20	122.00	20.00	4.00	1.10	5.00	3.00	19.80	73.30
15:21:05	68.80	31.20	142.00	12.00	4.00	1.10	5.00	3.00	19.77	73.30
15:21:10	68.90	31.10	168.00	7.00	4.00	1.10	5.00	4.00	19.76	73.30
15:21:15	68.60	31.10	195.00	6.00	4.00	1.10	5.00	5.00	19.78	72.90
15:21:20	69.70	31.00	226.00	8.00	4.00	1.10	5.00	6.00	19.78	72.00
15:21:25	72.30	31.10	255.00	12.00	4.00	1.30	6.00	6.00	19.75	71.00
15:26:32	82.00	31.10	661.00	216.00	4.00	1.10	5.00	19.00	19.59	66.80
15:26:37	81.10	31.50	651.00	220.00	4.00	1.30	5.00	18.00	19.61	67.20
15:26:42	79.40	31.60	645.00	220.00	4.00	1.10	5.00	18.00	19.64	67.50
15:26:47	75.20	31.60	639.00	220.00	4.00	0.90	5.00	18.00	19.69	69.00
15:26:52	68.80	31.60	623.00	227.00	4.00	0.90	5.00	18.00	19.77	70.90
15:26:57	68.90	31.60	586.00	239.00	4.00	0.80	5.00	17.00	19.95	
15:27:02	88.20	31.60	525.00	247.00	4.00	0.90	5.00	15.00	19.98	
15:27:07	94.80	31.70	538.00	207.00	4.00	1.10	5.00	14.00	19.56	61.10
15:27:12	91.10	31.80	641.00	154.00	5.00	1.30	6.00	18.00	19.32	68.10
15:27:17	89.60	31.70	744.00	145.00	5.00	1.30	6.00	21.00	19.26	69.20
15:27:22	87.40	31.60	776.00	176.00	5.00	1.30	6.00	22.00	19.25	70.10
15:27:27	84.50	31.80	765.00	215.00	5.00	1.30	6.00	22.00	19.27	71.20
15:27:32	81.80	31.80	731.00	239.00	5.00	1.10	6.00	21.00	19.35	71.30
15:27:37	79.80	31.80	706.00	248.00	5.00	1.10	6.00	20.00	19.46	70.70
15:27:42	79.60	31.80	683.00	249.00	4.00	1.00	5.00	20.00	19.54	69.40
15:27:47	80.70	31.80	660.00	251.00	4.00	0.90	5.00	19.00	19.60	67.70
15:27:52	81.80	31.70	643.00	248.00	4.00	0.90	5.00	19.00	19.58	67.60
15:27:57	79.80	31.70	633.00	241.00	4.00	0.90	5.00	18.00	19.57	68.80
15:28:02	78.40	31.80	618.00	241.00	4.00	0.90	5.00	18.00	19.63	68.50
15:28:07	78.60	31.80	596.00	240.00	4.00	0.80	5.00	17.00	19.68	67.40
15:28:12	77.00	31.80	585.00	232.00	3.00	0.90	4.00	17.00	19.70	67.90
15:28:17	71.20	31.70	581.00	223.00	4.00	0.90	5.00	17.00	19.74	70.40
15:28:22	67.40	31.70	566.00	223.00	4.00	0.80	5.00	16.00	19.86	70.20

15:28:27	83.20	31.80	523.00	236.00	4.00	0.80	4.00	15.00	20.04	
15:33:34	76.10	31.80	362.00	104.00	2.00	1.10	3.00	11.00	19.79	67.70
15:33:39	75.00	31.90	356.00	107.00	3.00	0.90	4.00	10.00	19.86	66.50
15:33:44	74.90	31.90	357.00	102.00	2.00	0.90	3.00	10.00	19.90	65.60
15:33:49	75.20	31.90	365.00	99.00	2.00	0.90	3.00	11.00	19.91	65.00
15:33:54	75.90	31.90	372.00	98.00	2.00	0.90	3.00	11.00	19.91	64.50
15:33:59	75.60	31.90	377.00	100.00	2.00	0.90	3.00	11.00	19.92	64.40
15:34:04	75.10	31.90	386.00	98.00	2.00	0.90	3.00	11.00	19.93	64.50
15:34:09	75.70	31.90	397.00	98.00	2.00	0.80	3.00	11.00	19.95	63.30
15:34:14	75.90	32.00	404.00	102.00	2.00	0.80	3.00	12.00	19.95	63.20
15:34:19	75.70	31.90	413.00	103.00	2.00	0.90	3.00	12.00	19.96	62.90
15:34:24	75.20	31.80	413.00	109.00	2.00	0.80	3.00	12.00	20.00	
15:34:29	73.80	31.90	408.00	115.00	2.00	0.80	3.00	12.00	20.03	
15:34:34	73.30	31.80	401.00	118.00	2.00	0.80	3.00	12.00	20.06	
15:34:39	73.50	31.90	392.00	119.00	2.00	0.80	3.00	12.00	20.09	
15:34:44	74.20	31.90	394.00	115.00	2.00	0.80	3.00	12.00	20.08	
15:34:49	73.80	32.00	402.00	111.00	2.00	0.80	3.00	12.00	20.05	
15:34:54	72.80	31.90	413.00	108.00	2.00	0.80	3.00	12.00	20.06	
15:34:59	72.90	31.90	412.00	114.00	2.00	0.90	3.00	12.00	20.10	
15:35:04	72.50	32.00	409.00	116.00	2.00	0.80	3.00	12.00	20.13	
15:35:09	72.40	31.90	411.00	115.00	2.00	0.70	3.00	12.00	20.16	
15:35:14	71.70	32.00	411.00	117.00	2.00	0.60	2.00	12.00	20.18	
15:35:19	71.40	32.00	414.00	117.00	2.00	0.60	2.00	12.00	20.20	
15:35:24	71.90	32.10	414.00	119.00	2.00	0.60	2.00	13.00	20.23	
15:35:29	71.70	32.10	413.00	120.00	1.00	0.60	2.00	12.00	20.22	
15:40:36	82.80	31.10	348.00	89.00	3.00	1.50	4.00	10.00	19.48	70.00
15:40:41	81.30	31.20	344.00	89.00	3.00	1.30	4.00	10.00	19.55	69.50
15:40:46	80.50	31.20	336.00	90.00	3.00	1.30	4.00	10.00	19.61	68.80
15:40:51	82.10	31.40	328.00	90.00	3.00	1.30	5.00	10.00	19.63	67.80

15:40:56	81.80	31.30	326.00	87.00	3.00	1.30	4.00	10.00	19.61	68.20
15:41:01	80.50	31.20	326.00	85.00	3.00	1.30	4.00	10.00	19.66	67.90
15:41:06	79.60	31.20	320.00	87.00	3.00	1.30	4.00	9.00	19.75	66.40
15:41:11	80.00	31.20	312.00	86.00	3.00	1.30	4.00	9.00	19.78	65.50
15:41:16	80.30	31.50	312.00	81.00	3.00	1.30	4.00	10.00	19.77	65.60
15:41:21	79.80	31.40	316.00	79.00	3.00	1.40	4.00	9.00	19.77	65.90
15:41:26	79.20	31.30	323.00	77.00	3.00	1.40	4.00	10.00	19.82	65.00
15:41:31	78.30	31.40	326.00	76.00	3.00	1.30	4.00	10.00	19.85	64.60
15:41:36	78.50	31.40	334.00	75.00	3.00	1.30	4.00	10.00	19.88	63.70
15:41:41	78.80	31.30	342.00	76.00	3.00	1.30	4.00	10.00	19.90	62.80
15:41:46	77.60	31.30	350.00	77.00	3.00	1.30	4.00	10.00	19.92	62.80
15:41:51	76.70	31.40	353.00	80.00	3.00	1.30	4.00	11.00	19.97	62.00
15:41:56	76.60	31.60	348.00	87.00	3.00	1.30	4.00	11.00	20.01	
15:42:01	76.60	31.50	342.00	88.00	3.00	1.20	4.00	10.00	20.02	
15:42:06	76.20	31.50	342.00	86.00	3.00	1.20	4.00	11.00	20.03	
15:42:11	75.80	31.30	351.00	81.00	3.00	1.30	4.00	11.00	20.03	
15:42:16	76.00	31.00	367.00	78.00	3.00	1.20	4.00	11.00	20.05	
15:42:21	76.10	30.90	377.00	80.00	3.00	1.10	4.00	12.00	20.06	
15:42:26	76.30	30.80	379.00	86.00	2.00	1.10	3.00	12.00	20.07	
15:42:31	77.10	30.60	384.00	87.00	3.00	1.10	4.00	12.00	20.05	
15:47:38	69.70	30.40	544.00	118.00	4.00	0.60	4.00	17.00	20.29	
15:47:43	54.80	30.10	502.00	140.00	3.00	0.50	4.00	16.00	20.54	
15:47:48	49.00	30.20	340.00	201.00	2.00	0.30	3.00	11.00	20.88	
15:47:53	47.00	30.20	210.00	190.00	2.00	0.20	2.00	6.00	20.80	
115:47:58	49.30	30.30	180.00	140.00	2.00	0.20	2.00	5.00	20.80	
15:48:03	54.30	30.30	202.00	90.00	2.00	0.20	2.00	6.00	20.73	
15:48:08	75.10	30.20	207.00	80.00	2.00	0.30	2.00	6.00	20.68	
15:48:13	84.80	30.10	238.00	55.00	2.00	0.70	3.00	7.00	20.23	
15:48:18	83.60	30.00	296.00	35.00	3.00	1.10	4.00	8.00	19.99	

15:48:23	81.70	29.90	353.00	32.00	3.00	1.10	5.00	10.00	19.89	60.10
15:48:28	80.30	29.80	390.00	40.00	4.00	1.10	5.00	11.00	19.86	61.70
15:48:33	79.80	30.00	413.00	52.00	4.00	1.10	5.00	12.00	19.87	61.70
15:48:38	79.30	29.80	430.00	62.00	4.00	1.10	5.00	13.00	19.88	61.40
15:48:43	77.80	29.80	432.00	74.00	4.00	1.00	5.00	13.00	19.93	61.00
15:48:48	76.50	29.80	425.00	85.00	4.00	0.90	5.00	13.00	20.00	
15:48:53	76.40	29.70	420.00	88.00	4.00	1.10	5.00	12.00	20.04	
15:48:58	76.30	29.70	425.00	87.00	4.00	1.10	5.00	13.00	20.03	
15:49:03	75.90	29.90	435.00	86.00	4.00	1.10	5.00	13.00	20.05	
15:49:08	75.20	29.70	437.00	90.00	4.00	0.90	5.00	13.00	20.09	
15:49:13	74.60	29.60	436.00	94.00	4.00	1.00	5.00	13.00	20.12	
15:48:19	73.80	29.60	436.00	96.00	4.00	0.90	4.00	13.00	20.17	
15:49:23	74.30	29.50	435.00	97.00	4.00	0.90	5.00	13.00	20.20	
15:49:28	73.80	29.50	437.00	97.00	3.00	0.90	4.00	13.00	20.21	
15:49:33	74.30	29.40	441.00	97.00	3.00	0.80	4.00	14.00	20.21	
15:54:40	79.40	29.20	380.00	67.00	3.00	1.10	4.00	11.00	20.04	
15:54:45	79.60	29.30	393.00	65.00	3.00	1.10	4.00	12.00	20.04	
15:54:50	80.00	29.40	404.00	65.00	3.00	1.10	4.00	12.00	20.04	
15:54:55	79.00	29.50	413.00	68.00	3.00	0.90	4.00	13.00	20.06	
15:55:00	78.40	29.40	419.00	71.00	3.00	1.00	4.00	13.00	20.09	
15:55:05	77.90	29.30	421.00	76.00	3.00	1.10	4.00	13.00	20.12	
15:55:10	77.70	29.20	417.00	80.00	3.00	1.00	4.00	13.00	20.13	
15:55:15	77.80	29.10	419.00	80.00	3.00	0.90	4.00	13.00	20.13	
15:55:20	78.10	29.20	427.00	78.00	3.00	0.90	4.00	13.00	20.15	
15:55:25	77.80	29.10	437.00	77.00	3.00	0.90	4.00	13.00	20.17	
15:55:30	77.30	29.10	446.00	79.00	3.00	0.90	4.00	14.00	20.17	
15:55:35	76.60	29.30	453.00	81.00	3.00	0.90	4.00	14.00	20.17	
15:55:40	76.50	29.20	453.00	87.00	3.00	0.90	4.00	14.00	20.19	
15:55:45	76.60	29.10	453.00	90.00	3.00	0.80	4.00	14.00	20.20	

15:55:50	77.40	29.00	460.00	87.00	3.00	0.80	4.00	14.00	20.21	
15:55:55	78.30	29.10	480.00	82.00	3.00	0.80	3.00	15.00	20.19	
15:56:00	77.20	29.00	505.00	80.00	3.00	0.90	4.00	16.00	20.18	
15:56:05	76.40	29.00	519.00	86.00	3.00	0.80	4.00	16.00	20.23	
15:56:10	76.20	29.00	515.00	98.00	3.00	0.80	4.00	16.00	20.26	
15:56:15	76.30	29.00	514.00	101.00	2.00	0.80	3.00	16.00	20.25	
15:56:20	75.80	29.20	519.00	102.00	2.00	0.80	3.00	16.00	20.26	
15:56:25	76.00	29.20	514.00	108.00	3.00	0.70	3.00	16.00	20.28	
15:56:30	75.80	29.20	508.00	110.00	2.00	0.60	3.00	16.00	20.27	
15:56:35	75.90	29.10	514.00	107.00	2.00	0.80	3.00	16.00	20.26	
16:01:42	70.70	29.30	600.00	116.00	2.00	0.40	2.00	20.00	20.47	
16:01:47	63.70	29.30	590.00	124.00	2.00	0.50	3.00	19.00	20.56	
16:01:52	59.40	29.20	481.00	173.00	2.00	0.30	2.00	16.00	20.73	
16:01:57	59.40	29.30	401.00	164.00	2.00	0.30	2.00	12.00	20.66	
16:02:02	63.70	29.20	390.00	134.00	2.00	0.20	2.00	12.00	20.72	
16:02:07	86.40	29.10	341.00	133.00	2.00	0.60	2.00	11.00	20.54	
16:02:12	94.00	29.10	327.00	112.00	2.00	1.10	3.00	10.00	19.98	
16:02:17	91.00	29.20	335.00	92.00	2.00	1.50	4.00	10.00	19.75	58.30
16:02:22	88.50	29.20	351.00	78.00	3.00	1.70	5.00	10.00	19.68	61.70
16:02:27	86.50	29.20	374.00	70.00	3.00	1.70	5.00	11.00	19.66	63.10
16:02:32	85.10	29.20	402.00	65.00	3.00	1.60	5.00	12.00	19.68	63.40
16:02:37	83.60	29.30	422.00	69.00	3.00	1.50	5.00	12.00	19.73	62.90
16:02:42	82.60	29.40	427.00	76.00	3.00	1.50	5.00	13.00	19.79	61.80
16:02:47	82.10	29.40	430.00	79.00	3.00	1.50	5.00	13.00	19.84	60.50
16:02:52	82.60	29.50	437.00	78.00	3.00	1.50	5.00	13.00	19.86	59.60
16:02:57	81.10	29.50	451.00	77.00	3.00	1.50	5.00	13.00	19.90	59.30
16:03:02	80.50	29.50	452.00	83.00	3.00	1.40	5.00	14.00	19.97	57.30
16:03:07	80.20	29.60	451.00	87.00	3.00	1.30	4.00	14.00	20.00	
16:03:12	80.70	29.50	455.00	86.00	3.00	1.30	5.00	14.00	20.01	

16:03:17	80.70	29.50	468.00	83.00	3.00	1.30	4.00	14.00	20.02	
16:03:22	80.50	29.40	480.00	83.00	3.00	1.30	4.00	14.00	20.04	
16:03:27	79.50	29.40	490.00	84.00	3.00	1.30	4.00	15.00	20.06	
16:03:32	78.60	29.20	491.00	90.00	3.00	1.20	4.00	15.00	20.11	
16:03:37	78.30	29.10	482.00	97.00	3.00	1.10	4.00	15.00	20.14	
16:08:44	76.40	29.50	589.00	128.00	3.00	0.80	4.00	19.00	20.38	
16:08:49	75.80	29.40	591.00	125.00	3.00	0.80	4.00	19.00	20.38	
16:08:54	75.50	29.40	602.00	123.00	3.00	0.80	4.00	19.00	20.39	
16:08:59	75.20	29.40	603.00	126.00	3.00	0.80	4.00	19.00	20.41	
16:09:04	74.70	29.40	604.00	127.00	3.00	0.80	4.00	19.00	20.42	
16:09:09	74.40	29.50	606.00	129.00	3.00	0.70	4.00	19.00	20.44	
16:09:14	74.20	29.60	601.00	132.00	3.00	0.60	3.00	19.00	20.46	
16:09:19	74.20	29.70	594.00	134.00	3.00	0.60	3.00	19.00	20.46	
16:09:24	74.30	29.50	600.00	130.00	3.00	0.60	3.00	19.00	20.46	
16:09:29	75.10	29.50	611.00	127.00	3.00	0.60	3.00	19.00	20.45	
16:09:34	75.10	29.50	629.00	121.00	3.00	0.60	3.00	20.00	20.44	
16:09:39	74.30	29.50	645.00	123.00	3.00	0.60	4.00	20.00	20.44	
16:09:44	72.00	29.50	656.00	129.00	3.00	0.60	3.00	21.00	20.45	
16:09:49	66.60	29.50	646.00	141.00	3.00	0.60	3.00	21.00	20.49	
16:09:54	60.80	29.50	575.00	178.00	3.00	0.40	3.00	19.00	20.67	
16:09:59	64.90	19.40	441.00	210.00	2.00	0.40	3.00	14.00	20.75	
16:10:04	80.10	29.40	377.00	181.00	3.00	0.50	3.00	11.00	20.59	
16:10:09	86.70	29.40	377.00	136.00	3.00	0.90	4.00	11.00	20.22	
16:10:14	87.20	29.50	391.00	115.00	3.00	1.40	4.00	12.00	19.97	
16:10:19	86.70	29.50	390.00	105.00	4.00	1.60	5.00	12.00	19.86	57.20
16:10:24	84.90	29.40	394.00	98.00	4.00	1.70	6.00	12.00	19.82	59.80
16:10:29	83.80	29.40	402.00	91.00	4.00	1.70	6.00	12.00	19.83	60.00
16:10:34	82.90	29.50	409.00	88.00	4.00	1.70	6.00	12.00	19.87	59.20
16:10:39	81.70	29.50	415.00	86.00	4.00	1.50	6.00	12.00	19.92	58.60

16:15:46	77.00	29.60	512.00	89.00	3.00	0.90	4.00	16.00	20.32	
16:15:51	77.10	29.40	517.00	89.00	3.00	0.90	4.00	16.00	20.32	
16:15:56	77.20	29.30	538.00	82.00	3.00	0.90	4.00	16.00	20.31	
16:16:01	77.40	29.40	563.00	80.00	3.00	0.90	4.00	17.00	20.31	
16:16:06	76.90	29.30	586.00	83.00	3.00	0.90	4.00	18.00	20.32	
16:16:11	76.10	29.30	603.00	88.00	3.00	0.90	4.00	18.00	20.33	
16:16:16	75.80	29.40	618.00	93.00	3.00	0.80	4.00	19.00	20.36	
16:16:21	75.40	29.60	629.00	99.00	3.00	0.80	4.00	20.00	20.38	

Table O 48: Temperature at pyrolysis chamber for Experiment (viii-3); AVR = 3.83:9.65 (Wood chips)

Mean		355.60					
Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)	Duration, minute	PT, (°C)
0	0.00	14.5	347.00	29	450.00	43.5	427.00
0.5	308.00	15	319.00	29.5	315.00	44	377.00
1	300.00	15.5	284.00	30	258.00	44.5	333.00
1.5	318.00	16	255.00	30.5	229.00	45	299.00
2	279.00	16.5	228.00	31	380.00	45.5	277.00
2.5	301.00	17	217.00	31.5	414.00	46	356.00
3	275.00	17.5	512.00	32	394.00	46.5	453.00
3.5	424.00	18	629.00	32.5	285.00	47	414.00
4	336.00	18.5	583.00	33	246.00	47.5	363.00
4.5	317.00	19	491.00	33.5	343.00	48	323.00
5	272.00	19.5	411.00	34	528.00	48.5	292.00
5.5	405.00	20	370.00	34.5	491.00	49	270.00
6	365.00	20.5	550.00	35	413.00	49.5	256.00
6.5	329.00	21	534.00	35.5	365.00	50	243.00
7	306.00	21.5	444.00	36	325.00	50.5	427.00
7.5	403.00	22	400.00	36.5	286.00	51	480.00
8	397.00	22.5	335.00	37	261.00	51.5	371.00
8.5	351.00	23	291.00	37.5	250.00	52	338.00
9	333.00	23.5	263.00	38	296.00	52.5	300.00
9.5	329.00	24	250.00	38.5	487.00	53	431.00
10	310.00	24.5	238.00	39	493.00	53.5	400.00
10.5	283.00	25	483.00	39.5	443.00	54	338.00
11	265.00	25.5	501.00	40	400.00	54.5	291.00
11.5	421.00	26	394.00	40.5	362.00	55	388.00

12	412.00	26.5	336.00	41	332.00	55.5	341.00
12.5	330.00	27	302.00	41.5	313.00	56	285.00
13	450.00	27.5	268.00	42	295.00	56.5	249.00
13.5	485.00	28	254.00	42.5	403.00		
14	399.00	28.5	446.00	43	521.00		

Table O 49: Mean and standard deviation of pyrolysis chamber temperature

	N	Mean	Std. Deviation	Std. Error Mean
PT_i	200	209.7250	60.32075	4.26532
PT_ii	198	219.5556	69.99880	4.97460
PT_iii	219	227.7671	80.03517	5.40828
PT_iv	325	218.2615	86.88311	4.81941
PT_v	339	301.5221	150.02651	8.14832
PT_vi	383	199.8695	72.12862	3.68560
PT_vii	395	265.5595	95.23124	4.79160
PT_viii	284	330.5246	89.62566	5.31830

Table O 50: Mean and standard deviation of surrounding temperature

	N	Mean	Std. Deviation	Std. Error Mean
AT_i	360	32.4850	2.25391	.11879
AT_ii	360	32.1639	.96063	.05063
AT_iii	432	33.7144	1.63553	.07869
AT_iv	590	33.4403	1.29530	.05333
AT_v	624	32.1476	1.26966	.05083
AT_vi	696	32.7592	1.39617	.05292
AT_vii	718	31.6986	1.31348	.04902
AT_viii	704	30.0425	10.67756	.40243

Table O 51: Mean and standard deviation of exhaust temperature

	N	Mean	Std. Deviation	Std. Error Mean
FT_i	360	194.0956	42.64729	2.24771
FT_ii	360	148.2186	33.50768	1.76601
FT_iii	432	135.5009	45.51132	2.18966
FT_iv	590	159.4908	27.59437	1.13604
FT_v	624	106.2405	16.20466	.64871
FT_vi	696	98.6728	17.89555	.67833
FT_vii	718	85.1221	8.23083	.30717
FT_viii	704	72.3970	7.74969	.29208

Table O 52: Mean and standard deviation of Carbon Monoxide and Hydrogen

	N	Mean	Std. Deviation	Std. Error Mean
CO_i	191	751.6126	212.17663	15.35256
CO_ii	192	394.1250	118.85300	8.57748
CO_iii	192	499.7240	229.77299	16.58244
CO_iv	120	1256.4833	716.69703	65.42519
CO_v	576	285.4896	107.84783	4.49366
CO_vi	456	243.8296	73.63072	3.44807
CO_vii	600	195.0350	50.98928	2.08163
CO_viii	632	333.3165	170.97047	6.80084
H2_i	192	179.0885	84.50458	6.09859
H2_ii	192	87.5781	31.04909	2.24078
H2_iii	192	116.5625	63.28831	4.56744
H2_iv	120	434.2167	264.37407	24.13394
H2_v	576	166.7795	111.45940	4.64414
H2_vi	456	68.6272	26.39808	1.23620
H2_vii	600	60.8600	24.11139	.98434
H2_viii	632	79.8908	42.77252	1.70140

Table O 53: Mean and standard deviation of Nitrogen Monoxide, Nitrogen dioxide and Nitrogen Oxides

	N	Mean	Std. Deviation	Std. Error Mean
NO_i	360	18.3000	5.70286	.30057
NO_ii	360	10.8806	5.18780	.27342
NO_iii	432	10.3171	3.95964	.19051
NO_iv	590	8.5542	4.80622	.19787
NO_v	624	3.7340	1.72594	.06909
NO_vi	696	3.8649	2.15757	.08178
NO_vii	718	2.7730	1.29261	.04824
NO_viii	704	2.2955	1.18822	.04478
NO2_i	360	15.5942	5.75294	.30321
NO2_ii	360	9.4119	3.69157	.19456
NO2_iii	432	8.2400	4.12235	.19834
NO2_iv	590	20.3127	10.32051	.42489
NO2_v	624	8.5853	9.20360	.36844
NO2_vi	696	6.6526	3.31442	.12563
NO2_vii	718	6.4078	2.88910	.10782
NO2_viii	704	.9879	.42775	.01612
NOx_i	360	33.8778	10.35587	.54580
NOx_ii	360	20.3139	7.92611	.41774
NOx_iii	432	18.5625	7.19247	.34605
NOx_iv	590	28.7746	14.08156	.57973
NOx_v	624	11.9824	5.51589	.22081
NOx_vi	696	10.5532	4.92009	.18650
NOx_vii	718	9.1769	4.02304	.15014

	N	Mean	Std. Deviation	Std. Error Mean
NO_i	360	18.3000	5.70286	.30057
NO_ii	360	10.8806	5.18780	.27342
NO_iii	432	10.3171	3.95964	.19051
NO_iv	590	8.5542	4.80622	.19787
NO_v	624	3.7340	1.72594	.06909
NO_vi	696	3.8649	2.15757	.08178
NO_vii	718	2.7730	1.29261	.04824
NO_viii	704	2.2955	1.18822	.04478
NO2_i	360	15.5942	5.75294	.30321
NO2_ii	360	9.4119	3.69157	.19456
NO2_iii	432	8.2400	4.12235	.19834
NO2_iv	590	20.3127	10.32051	.42489
NO2_v	624	8.5853	9.20360	.36844
NO2_vi	696	6.6526	3.31442	.12563
NO2_vii	718	6.4078	2.88910	.10782
NO2_viii	704	.9879	.42775	.01612
NOx_i	360	33.8778	10.35587	.54580
NOx_ii	360	20.3139	7.92611	.41774
NOx_iii	432	18.5625	7.19247	.34605
NOx_iv	590	28.7746	14.08156	.57973
NOx_v	624	11.9824	5.51589	.22081
NOx_vi	696	10.5532	4.92009	.18650
NOx_vii	718	9.1769	4.02304	.15014
NOx_viii	704	3.2599	1.44773	.05456

Table O 54: Mean and standard deviation of Sulphur Dioxide

	N	Mean	Std. Deviation	Std. Error Mean
SO2_i	360	16.1639	5.93918	.31302
SO2_ii	360	9.5472	5.27970	.27826
SO2_iii	432	12.1620	6.68458	.32161
SO2_iv	590	17.2458	16.24574	.66883
SO2_v	624	6.5449	4.47765	.17925
SO2_vi	696	4.6106	2.74412	.10402
SO2_vii	718	4.5682	2.05847	.07682
SO2_viii	704	9.0824	5.20302	.19610

Table O 55: Mean and standard deviation of Oxygen levels at the B2H exhaust

	N	Mean	Std. Deviation	Std. Error Mean
O2_i	360	16.4922	4.04003	.21293
O2_ii	360	18.0531	1.50011	.07906
O2_iii	432	18.6309	1.80691	.08693
O2_iv	590	16.2508	2.73653	.11266
O2_v	624	19.4341	.92707	.03711
O2_vi	696	22.5557	76.54995	2.90162
O2_vii	718	19.8925	.96759	.03611
O2_viii	704	20.0866	.39081	.01473

Table O 56: Mean and standard deviation of B2H combustion Efficiency

	N	Mean	Std. Deviation	Std. Error Mean
Eff_i	356	66.6008	8.26717	.43816
Eff_ii	337	64.4395	8.00003	.43579
Eff_iii	351	61.8581	7.69007	.41047
Eff_iv	585	73.8918	38.62858	1.59710
Eff_v	426	62.3378	8.54552	.41403
Eff_vi	356	64.0301	8.37586	.44392
Eff_vii	332	66.9705	8.68616	.47671
Eff_viii	246	68.4248	6.40609	.40844

APPENDIX P: Statistical Analysis Results for Experiment (vii)

Table P 1: Correlations between pyrolyzer temperature and emissions, combustion efficiency

	PT_vii	CO_vii	H2_vii	NOx_vii	SO2_vii	Eff_vii
PT_vii						
Pearson Correlation	1	-0.146**	-0.269**	-0.337**	-0.217**	-0.205**
Sig. (2-tailed)		0.004	0.000	0.000	0.000	0.000
N	395	395	395	395	395	332
CO_vii						
Pearson Correlation	-0.146**	1	0.603**	0.205**	0.178**	0.130*
Sig. (2-tailed)	0.004		0.000	0.000	0.000	0.018
N	395	600	600	600	600	332
H2_vii						
Pearson Correlation	-0.269**	0.603**	1	0.254**	-0.085*	-0.019
Sig. (2-tailed)	0.000	0.000		0.000	0.038	0.728
N	395	600	600	600	600	332
NOx_vii						
Pearson Correlation	-0.337**	0.205**	0.254**	1	-0.293**	-0.220**
Sig. (2-tailed)	0.000	0.000	0.000		0.000	0.000
N	395	600	600	718	718	332
SO2_vii						
Pearson Correlation	-0.217**	0.178**	-0.085*	-0.293**	1	0.333**
Sig. (2-tailed)	0.000	0.000	0.038	0.000		0.000
N	395	600	600	718	718	332
Eff_vii						
Pearson Correlation	-0.205**	0.130*	-0.019	-0.220**	0.333**	1
Sig. (2-tailed)	0.000	0.018	0.728	0.000	0.000	
N	332	332	332	332	332	332

**, Correlation is significant at the 0.01 level (2-tailed).

*, Correlation is significant at the 0.05 level (2-tailed).

Table P 2: Correlations between pyrolyzer temperature and exhaust temperature of Experimental (vii)

	PT_vii_Special_for_T	FT_vii_Special_for_T
PT_vii_Special_for_T Pearson Correlation	1	0.627**
Sig. (2-tailed)		0.000
N	120	120

** . Correlation is significant at the 0.01 level (2-tailed).

CO variable

Variables Entered/Removed^b

Model	Variables Entered	Variables Removed	Method
1	PT_vii ^a	.	Enter

a. All requested variables entered.

b. Dependent Variable: CO_vii

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.146 ^a	.021	.019	50.88235

a. Predictors: (Constant), PT_vii

ANOVA^b

Model	Sum of Squares	df	Mean Square	F	Sig.
1 Regression	22057.214	1	22057.214	8.520	.004 ^a
Residual	1017482.447	393	2589.014		
Total	1039539.661	394			

a. Predictors: (Constant), PT_vii

b. Dependent Variable: CO_vii

Coefficients^a

Model	Unstandardized Coefficients		Standardized Coefficients		t	Sig.
	B	Std. Error	Beta			
1 (Constant)	211.123	7.593			27.805	.000
PT_vii	-.079	.027	-.146		-2.919	.004

a. Dependent Variable: CO_vii

Variables Entered/Removed^b

Model	Variables Entered	Variables Removed	Method
1	PT_vii ^a	.	Enter

a. All requested variables entered.

b. Dependent Variable: H2_vii

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.269 ^a	.072	.070	25.33706

a. Predictors: (Constant), PT_vii

ANOVA^b

Model	Sum of Squares	df	Mean Square	F	Sig.
1 Regression	19676.910	1	19676.910	30.651	.000 ^a
Residual	252292.888	393	641.967		
Total	271969.797	394			

a. Predictors: (Constant), PT_vii

b. Dependent Variable: H2_vii

Coefficients^a

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
1 (Constant)	82.909	3.781		21.928	.000
PT_vii	-.074	.013	-.269	-5.536	.000

a. Dependent Variable: H2_vii

Variables Entered/Removed^b

Model	Variables Entered	Variables Removed	Method
1	PT_vii ^a	.	Enter

a. All requested variables entered.

b. Dependent Variable: NOx_vii

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.337 ^a	.114	.112	3.49989

a. Predictors: (Constant), PT_vii

ANOVA^b

Model	Sum of Squares	df	Mean Square	F	Sig.
1 Regression	618.414	1	618.414	50.486	.000 ^a
Residual	4813.941	393	12.249		
Total	5432.354	394			

a. Predictors: (Constant), PT_vii

b. Dependent Variable: NOx_vii

Coefficients ^a					
Model	Unstandardized Coefficients		Standardized Coefficients		t
	B	Std. Error	Beta		
1					
(Constant)	12.025	.522			23.025
PT_vii	-.013	.002	-.337		-7.105
					.000
					.000

a. Dependent Variable: NOx_vii

Variables Entered/Removed ^b			
Model	Variables Entered	Variables Removed	Method
1	PT_vii ^a		Enter

a. All requested variables entered.

b. Dependent Variable: SO2_vii

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.217 ^a	.047	.045	1.17339

a. Predictors: (Constant), PT_vii

ANOVA ^b					
Model	Sum of Squares	df	Mean Square	F	Sig.
1 Regression	26.706	1	26.706	19.396	.000 ^a
Residual	541.102	393	1.377		
Total	567.808	394			

a. Predictors: (Constant), PT_vii

b. Dependent Variable: SO2_vii

Coefficients ^a						
Model	Unstandardized Coefficients		Standardized Coefficients		t	Sig.
	B	Std. Error	Beta			
1 (Constant)	4.407	.175			25.169	.000
PT_vii	-.003	.001	-.217		-4.404	.000

a. Dependent Variable: SO2_vii

Variables Entered/Removed ^b			
Model	Variables Entered	Variables Removed	Method
1	PT_vii_Special_ for T	.	Enter

a. All requested variables entered.

b. Dependent Variable: FT_vii_Special_for_T

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.627 ^a	.393	.388	6.44931

a. Predictors: (Constant), PT_vii_Special_for_T

ANOVA^b

Model	Sum of Squares	df	Mean Square	F	Sig.
1 Regression	3184.313	1	3184.313	76.558	.000 ^a
Residual	4908.047	118	41.594		
Total	8092.360	119			

a. Predictors: (Constant), PT_vii_Special_for_T

b. Dependent Variable: FT_vii_Special_for_T

Coefficients^a

Model	Unstandardized Coefficients		Standardized Coefficients		t	Sig.
	B	Std. Error	Beta			
1 (Constant)	71.488	1.701			42.034	.000
PT_vii Special for T	.053	.006	.627		8.750	.000

a. Dependent Variable: FT_vii_Special_for_T

Variables Entered/Removed^b

Model	Variables Entered	Variables Removed	Method
1	PT_vii ^a	.	Enter

a. All requested variables entered.

b. Dependent Variable: η_{vii}

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.205 ^a	.042	.039	8.51382

a. Predictors: (Constant), PT_vii

ANOVA^b

Model	Sum of Squares	df	Mean Square	F	Sig.
1 Regression	1053.618	1	1053.618	14.536	.000 ^a
Residual	23920.113	330	72.485		
Total	24973.731	331			

a. Predictors: (Constant), PT_vii

b. Dependent Variable: η_{vii}

