# Gas Measurements and Characterization of Wood Combustion in Two Moving Grate Boilers

**Narges Razmjoo, Hamid Sefidari, Michael Strand**

Departement of Bioenergy Technology,
Linnaeus University, Växjö, Sweden

*19 November 2013*

Linnæus University

# Outline

- Introduction
- Method
  - Furnace description
  - Fuel
  - Procedures
- Results and discussion
  - Temperature analysis
  - Species profiles
- Conclusions
- Acknowledgments

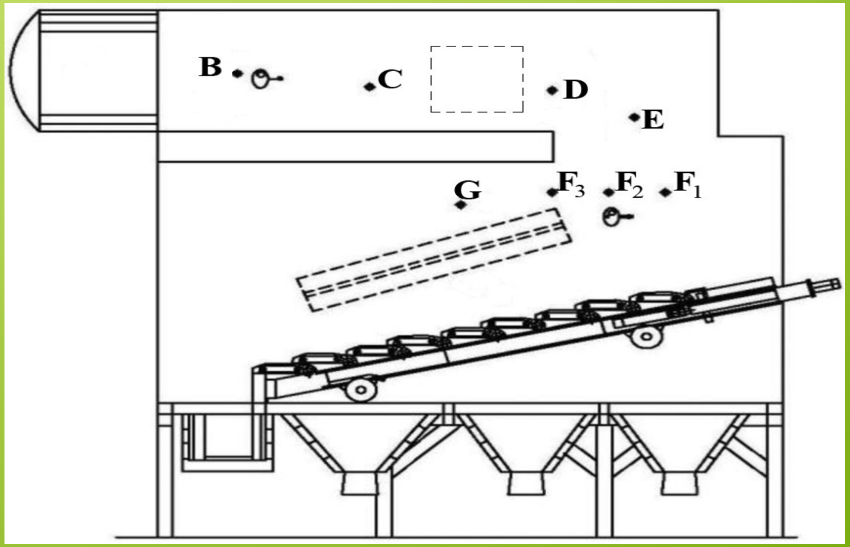
# Introduction

- Combustion of biomass is one of the main conversion routes.
- The use of grate-fired systems has been regarded as a popular combustion technology to burn woody biomass.
- High degree of fuel flexibility, and can be fueled entirely by raw biomass.
- Detailed information about distributions of temperature and gas species within the furnace provides valuable insights into the combustion process.
- There is a noticeable lack of in-situ measurement characterizations of grate boilers in the literature.
- In this study, characterization of gaseous emissions during wood combustion in the furnace has been carried out.


Linnæus University

# Furnace description

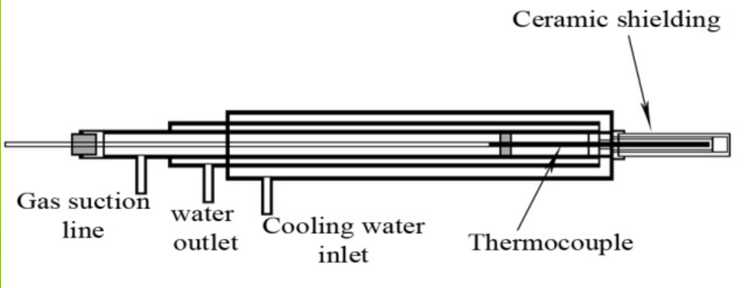
- Two reciprocating grate boilers with maximum thermal capacity of 4 MW (Rörvik) and 12 MW (Boxholm).
- A stoker pushes the fuel forward onto a sloping and moving grate.
- The primary air is distributed from three wind-boxes into the combustor.
- The leftover ash falls under the grate in a water bath.
- Combustible gases leaving the bed upward mix with the secondary air and flue gas.
- After the turn, flue gas passes through a cylindrical-shaped channel in which tertiary air is supplied (Rörvik).
- Hot flue gas is then conducted into the heat exchanger tubes.




Linnæus University

# Experimental method and fuel

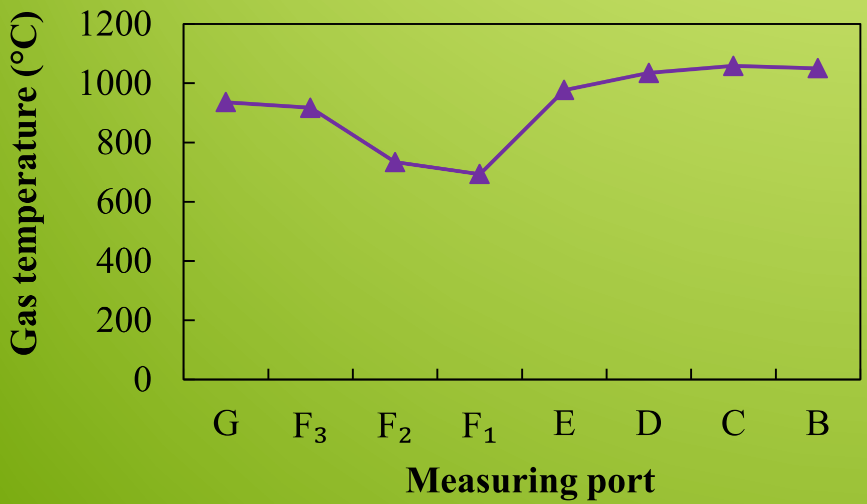
- The fuel was forest waste with a mixture of wood chips, bark and sawdust from sawmill and a moisture content of 53%, and 37 % volatiles.
- Local temperatures and concentrations of gases (NO, CO, and $O_2$) were measured in the central part of the furnace at different ports.
- A water-cooled stainless steel probe 1.5 m in length and a type-K thermocouple were applied.
- High flow of quenched samples were drawn with a suction fan.
- The dry gas was sent into two IR-analysis spectrometers.
- Filter and probe clogging were the main problematic issues during the measurements due to the harsh environment above the fuel bed.
- The probe and the filter were cleaned frequently by blowing high-pressure air through them.

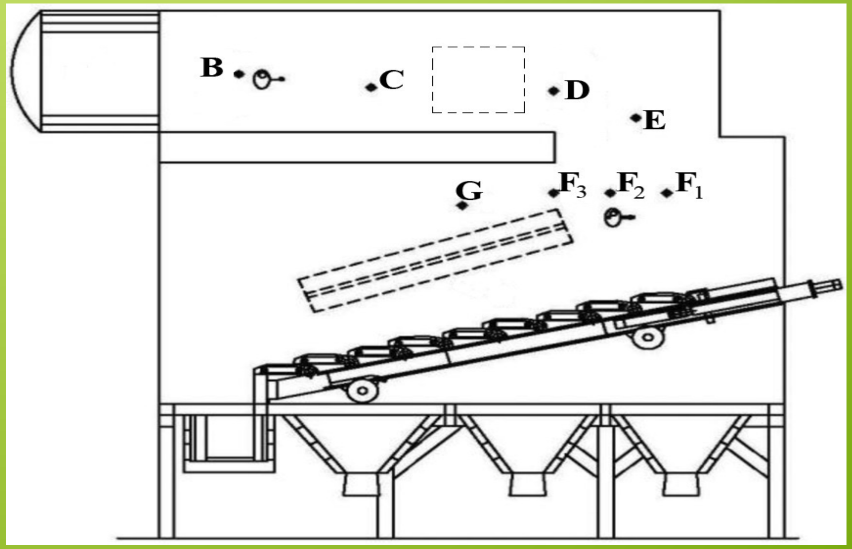



Linnæus University

# Rörvik Furnace
## Temperature measurements

- Port $F_1$ is located close to the bed surface and furnace feed entrance.
- Relatively low temperature since the moisture evaporation process is being the main phenomenon and large fluctuations in the range of 260-520 °C near $F_1$.
- Local instabilities in the bed of fuel cause variations near $F_1$.
- The temperatures near ports $F_3$ and G are almost equal with an average value of approximately 930 ° C since secondary air is introduced to these regions.
- The average temperature near in the secondary chamber is about 1050 ° C.
- The progress of combustion inside the fuel bed along the grate can be implied by the growing sequence in temperature levels from ports $F_1$ to B.

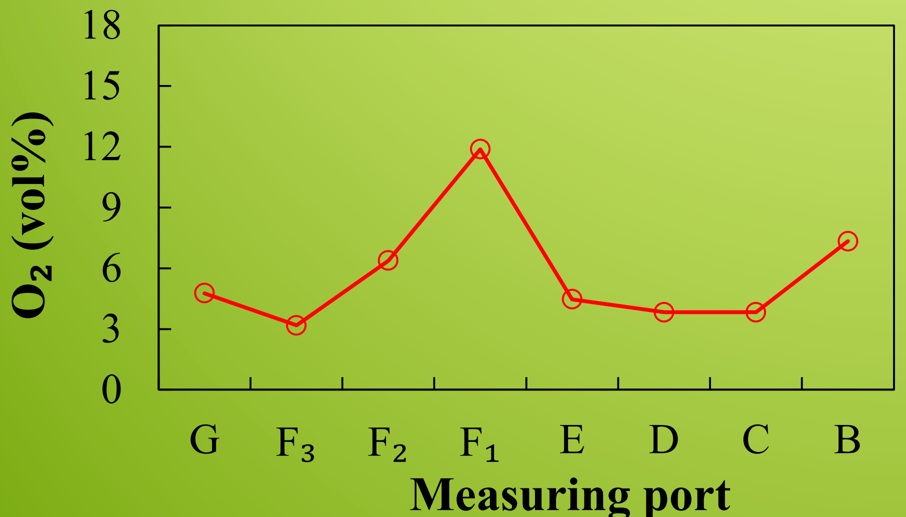


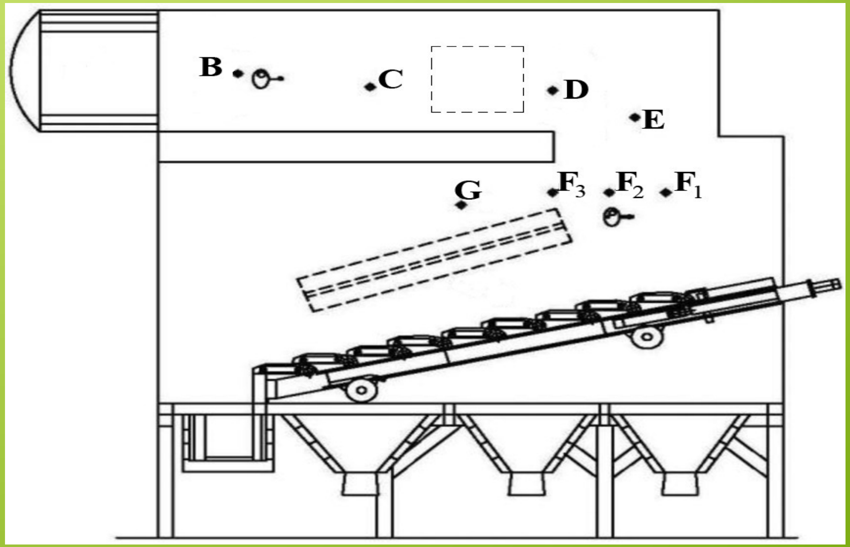




Linnæus University

# Gas analysis (oxygen)

- Concentrations of oxygen near ports $F_3$ and G are 3 and 5 vol%, respectively.
- Concentration of oxygen near port $F_2$ is around 6.5 vol%.
- High $O_2$ content near port $F_1$ varies from as low as 13 to as high as 15 vol% is because the oxidation reaction of released volatiles near port $F_1$ doesn't take place significantly.
- Concentration of oxygen near ports E, D, and C is around 4 vol%.
- Oxidizing conditions are dominant throughout the entire furnace due to high oxygen availability.

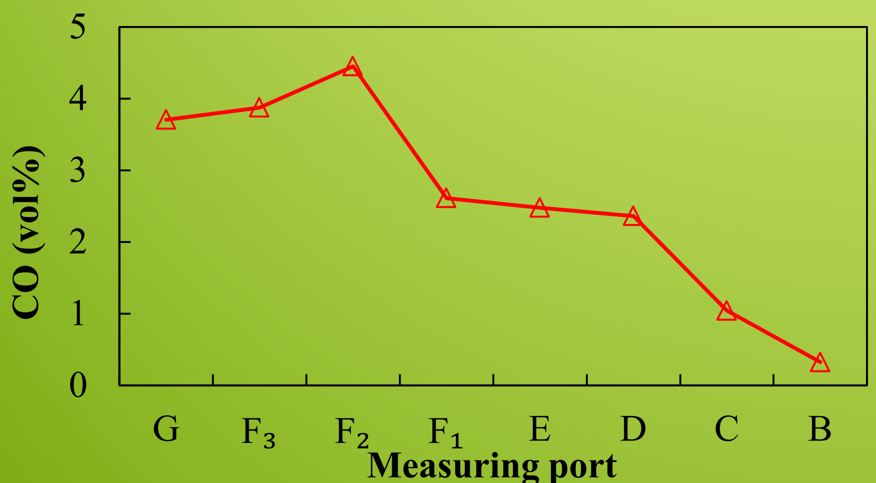


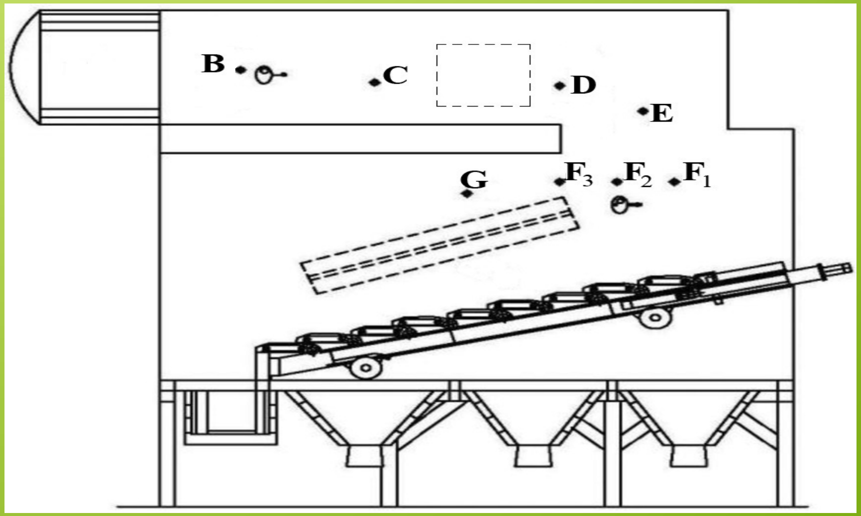




Linnæus University

# Gas analysis (CO)

- CO and NO concentrations are normalized to 13%vol ($CO_2$+CO+$CH_4$).
- CO concentration in the regions near ports $F_3$ and G are about 3.7 vol %.
- High concentration of CO at port $F_2$ (4.6 vol %) reveals poor combustion conditions in this section (pyrolysis and gasification mainly occur).
- Low temperature and the bad mixture between oxygen and volatiles in this region lead to a low conversion of CO (3.5 vol%).
- CO concentration has a descending trend along the path from port E to B (especially from D to C).
- The oxidation of CO continued in the vertical shaft of the boiler downstream of position B.

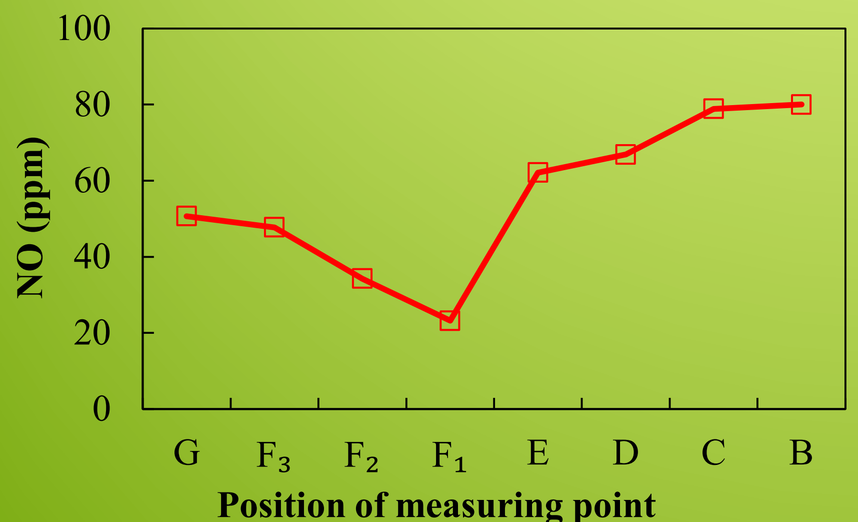


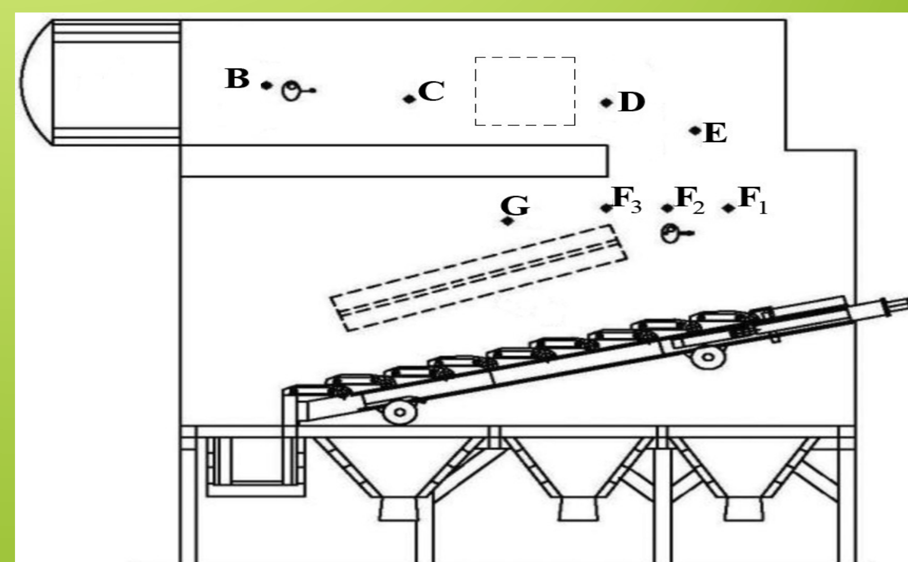




Linnæus University

# Gas analysis (NO)

- NO concentration is about 30, 50 and 52 ppm near ports $F_2$, $F_3$ and G, respectively.
- High concentrations of N-volatiles (HCN and $NH_3$ ) are expected to be released from the fuel bed during devolatilization stage.
- Low NO concentration of about 16 ppm near port $F_1$ is due to low oxidation of N-volatiles.
- NO concentration increases from port $F_1$/$F_2$ to port B, and the geometry of the furnace provides an active oxidizing region near port E which results in high formation of NO from N volatiles.




Linnæus University

# Conclusion

- Oxidizing conditions were dominant throughout the entire furnace due to high availability of oxygen.
- CO concentration has a descending trend along the gas flow path.
- Temperature varies between 450 to 1100 °C in the whole furnace and high temperature regions in the secondary chamber are formed as a result of the heat released through oxidation of CO, hydrocarbons, hydrogen, and soot.
- The geometry of the furnace provides an active mixing region above the bed surface and in the transition section, where high concentrations of NO are formed.

# Acknowledgement

The authors acknowledge financial support from Stiftelsen för kunskaps- och kompetensutveckling and the technical and financial support of Bioenergigruppen AB, E.ON Värme Sverige AB, and Hotab Eldningsteknik AB.


## ***Thanks for your attention***

Linnæus University