Advances in European cord wood testing and policy

Workshop on
Pellet Stove Design Challenge
Brookhaven National Laboratory 6-8 April 2016

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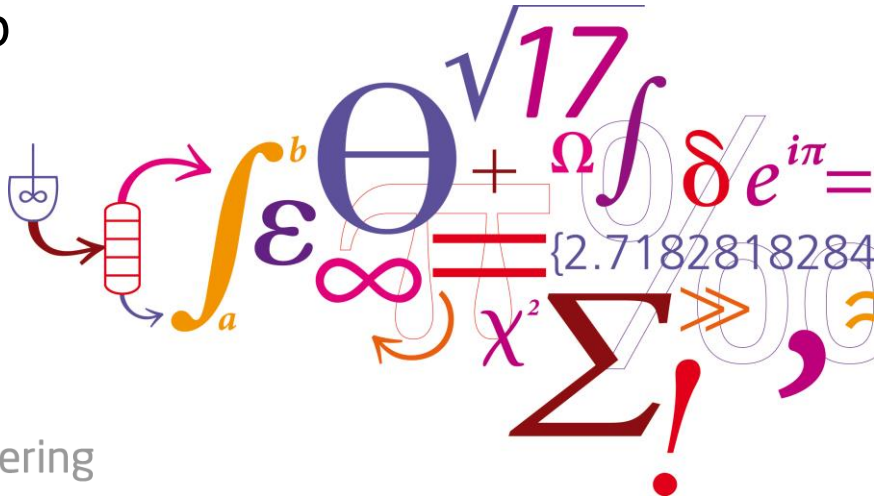


DTU Chemical Engineering
Department of Chemical and Biochemical Engineering

Intelligent Heat System

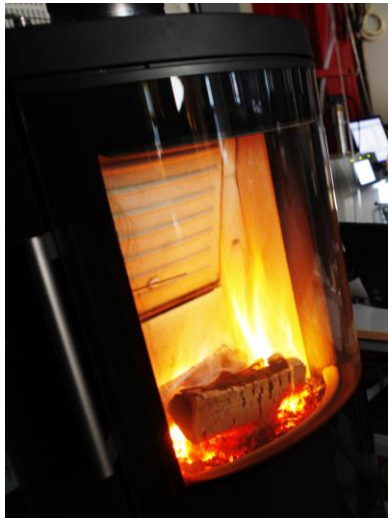
High-energy efficient wood stoves with low missions

- Collaboration between HWAM A/S and DTU Chemical Engineering
- Periode 2011 – 2016
- EUDP - project

  (Energy Technology Development and Demonstration Program)

Development of a new automatically controlled wood stove with:

- High energy efficiency
- Reduced emissions (CO, particles etc.)
- High comfort for the wood stove users



Main results

- *A new advanced control system has been developed based on experiments conducted at experimental facilities at HWAM og DTU Chemical Engineering*
- *HWAM has launched an automatically controlled wood stove on the market*
- *Field and laboratory tests have shown reduced emissions and higher efficiency for stoves with the control system*

Content

- Background for the project – why an automatic control system?
- Concept of the automatically controlled wood stove
- Our results from
  - Field tests
  - Experiments at the wood stove set-up at DTU Chemical Engineering

Regulation and legislation

New wood stoves are approved according to national and European standards.

Standards:

Approval of Wood stoves	**Eff. (%)**	**CO (mg/ Nm³)**	**PM (mg/Nm³)**	**PM (g/kg)**	**OGC (mg/Nm³)**
Danish Statutory of order	-		<40	<5	<150
Danish Statutory of order (from 2017)	-		<30	<4	<120
Swan label (optional)	≥76	≤1250		<3	<100
Swan label (from 2017)	≥76	≤1250		<2	<100

The emissions can be much higher when the stoves are used by ordinary wood stove users

Challenges

This is due to challenging conditions when using a wood stove:

- batch firing in a small combustion chamber
- use of different wood types and wood log sizes
- combustion air flows and the fuel load are manually controlled

Difficult to achieve an optimal combustion

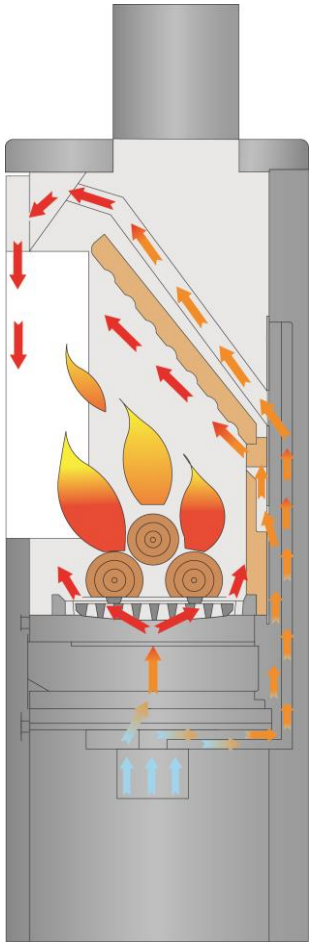
Improved technologies

Modern stoves with air staging:

Three combustion air inlets:

- Primary air at the bottom (ignition)
- Secondary air at the top of the front window (air-wash, second combustion)
- Tertiary air at the back wall (high temperature gas combustion)

However, well-designed stoves can also cause high emissions and low efficiency



Field tests – measurements at stoves in private homes

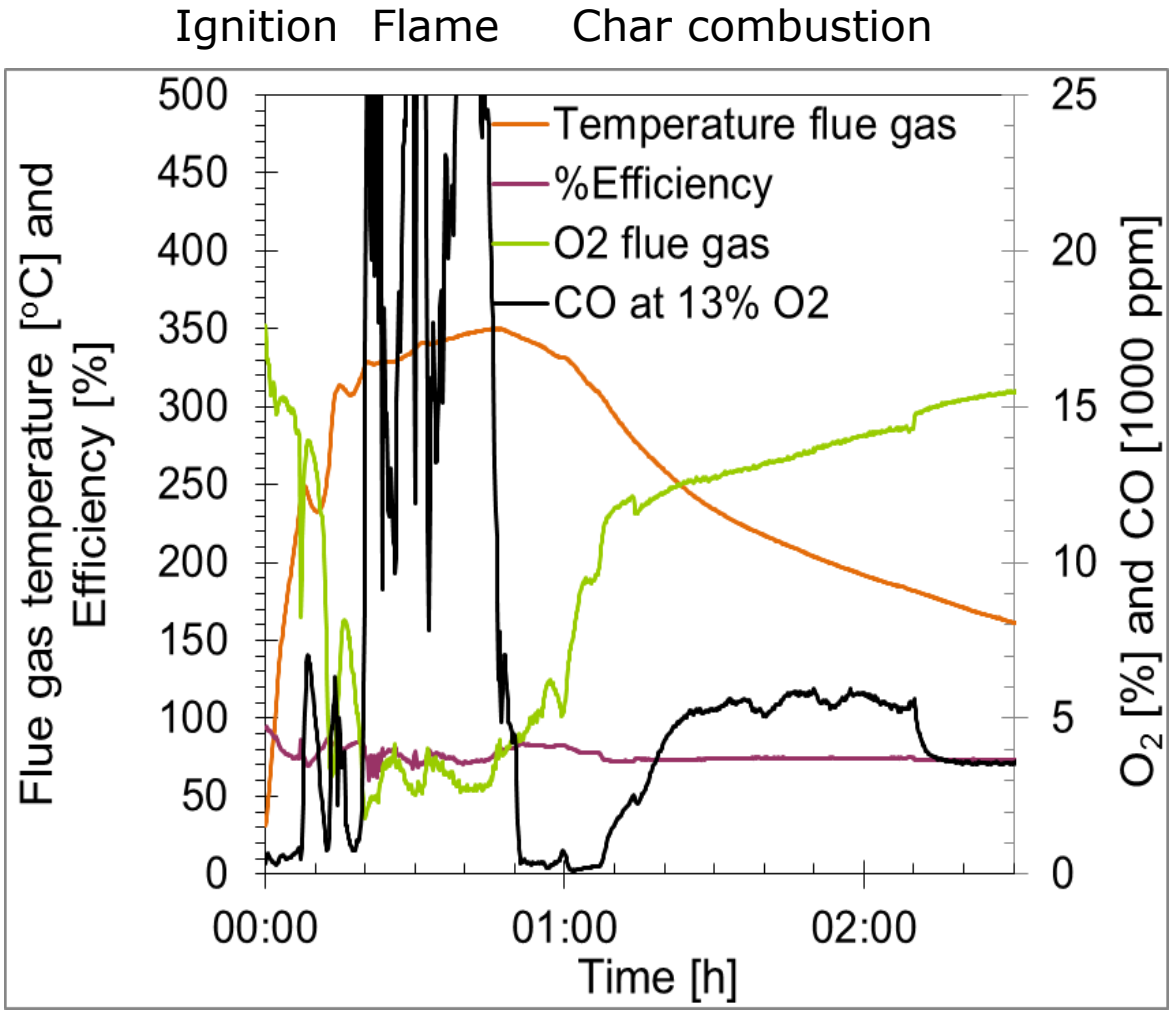
Field tests in six private homes

Measured 1 week:

- Existing (modern) stove
- Automatically controlled wood stove
- O_2, CO_2, CO, flue gas temp.
- Amount of wood
- Temp. in– and outdoor

It is difficult to control manually the combustion air flows in an optimal way.

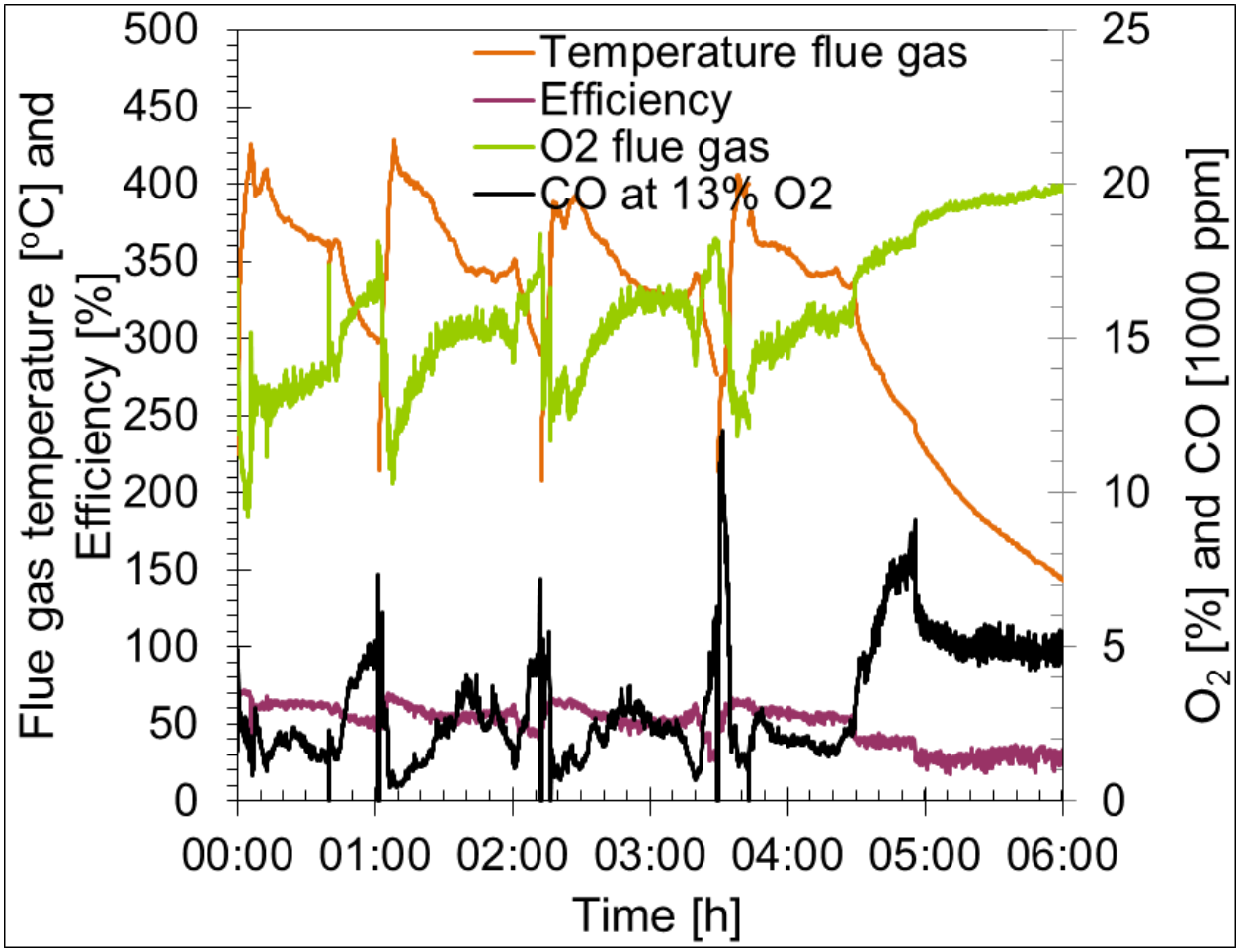
Manually controlled wood stove – 1



One combustion cycle

Lack of combustion air in the flame phase and too much air in the char combustion phase

Manually controlled wood stove – 2



Four combustion cycles

High excess air and temperature in both the flame phase and the char combustion phase

Automatically controlled wood stove

Modern wood stove

+

Air box (3 motor-controlled valves and a software program)

+

Process control (the process parameters are the O_2 concentration and the temperature in the flue gas)

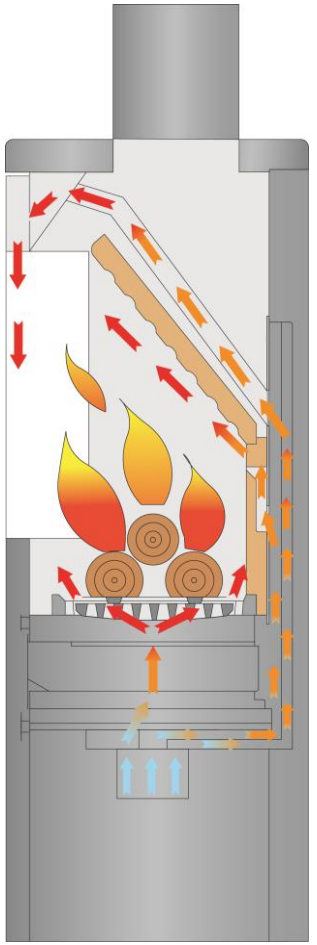
+

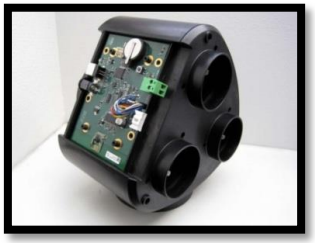
Remote control to starts the combustion and set the room temperature

Control of the air supply

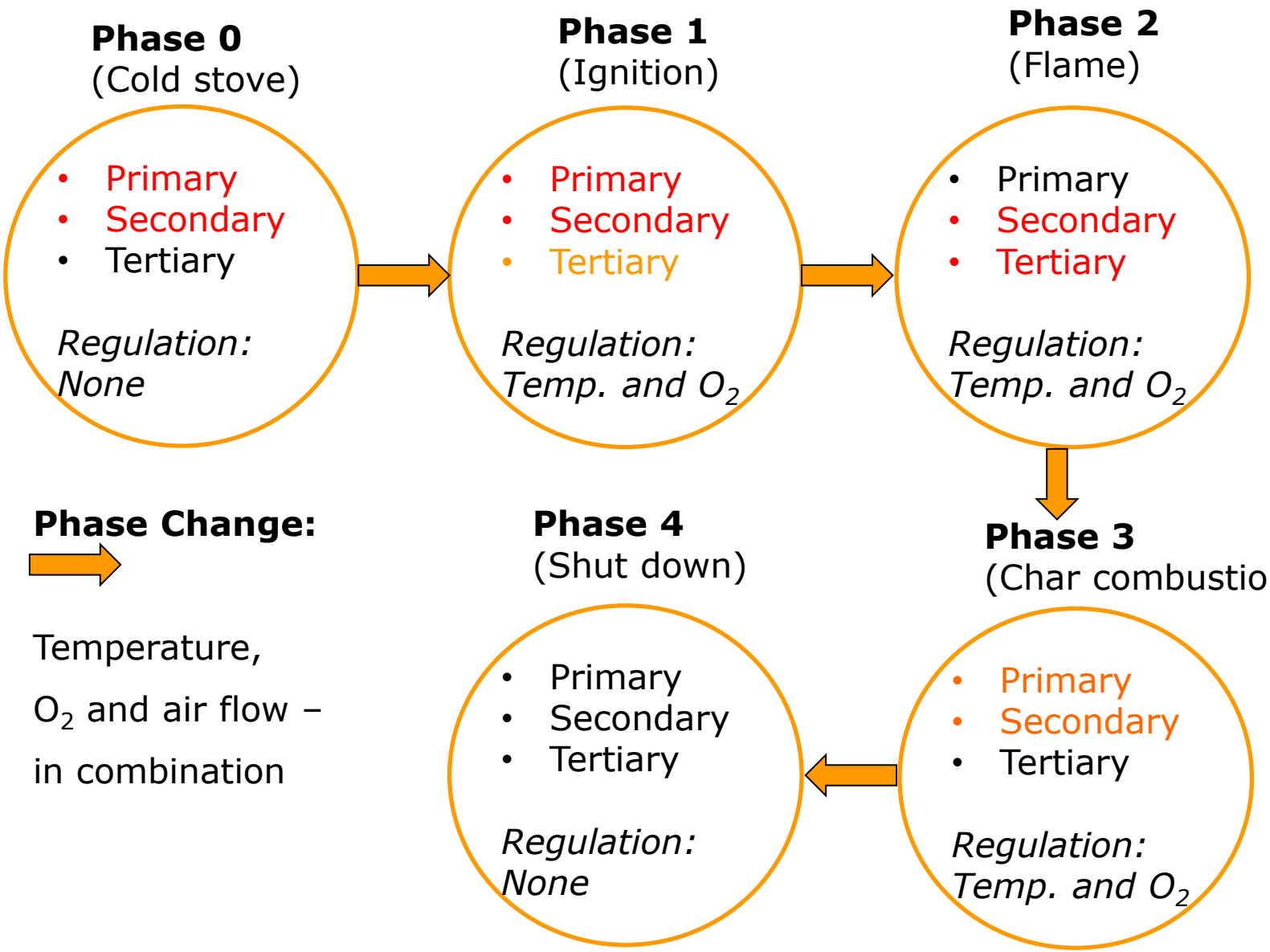
The three air inlets are automatically controlled by

- a software program based on the definition of *five combustion phases*
- and the process parameters – measured *temperature and O_2 in the flue gas*

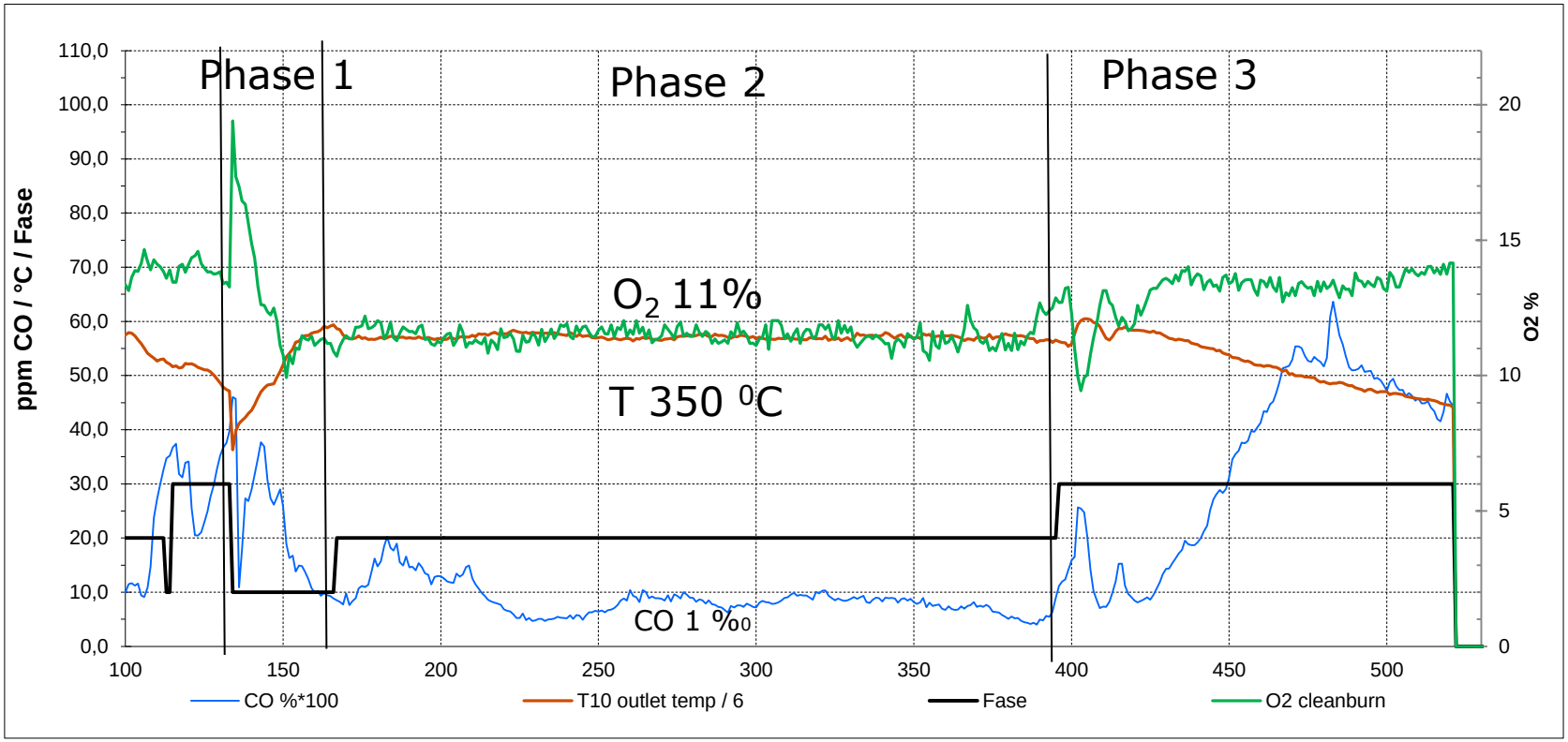




Overall concept of the software



Standard combustion cycle



Temperature and O_2 concentration constant and optimal during most of the combustion cycle

<u>Phase 1:</u>

- Ignition of wood
- A few minutes

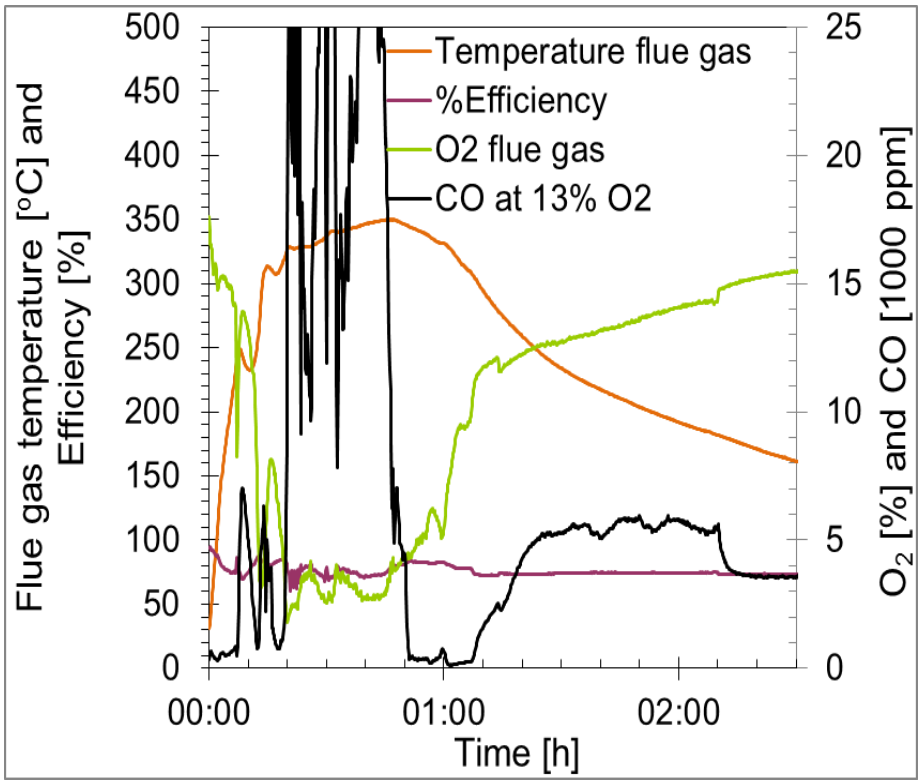
<u>Phase 2:</u>

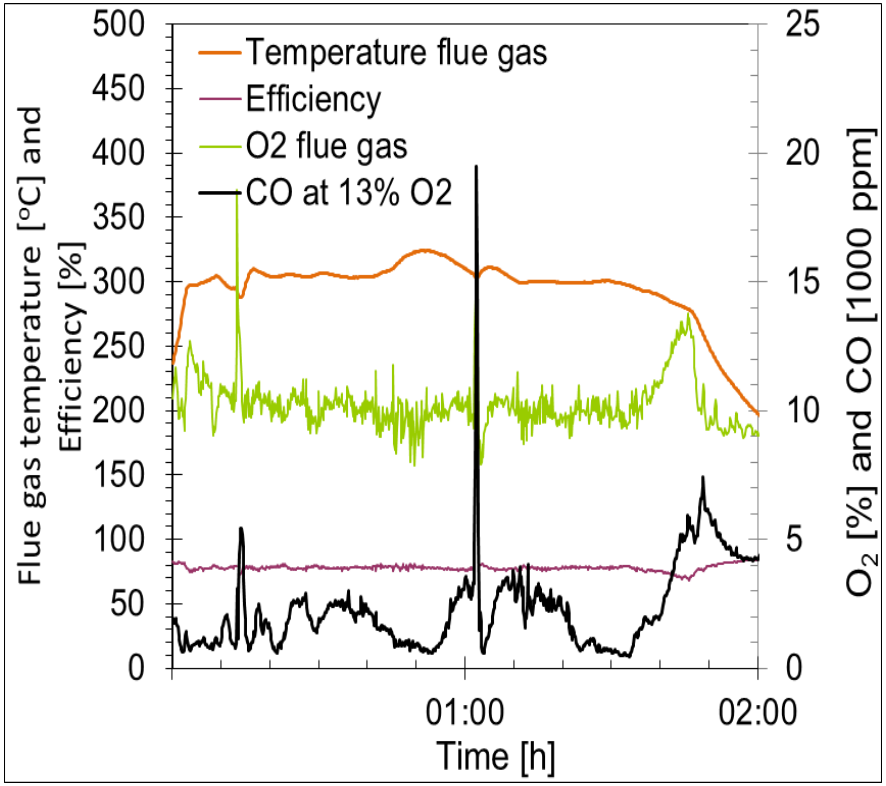
- Combustion of pyrolysis gases
- Intensive combustion with flames
- 25 - 30 minutes

<u>Phase 3:</u>

- Combustion of char
- The combustion intensity deceases
- The temperature decreases, the O_2 and CO emission increase

The same user





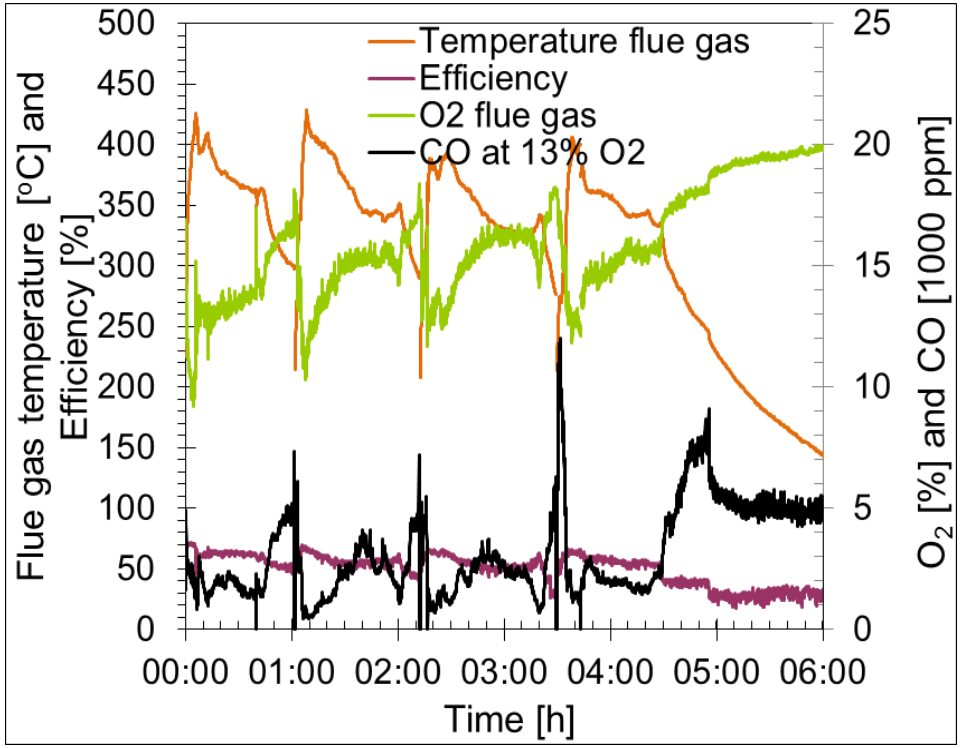
Manually controlled

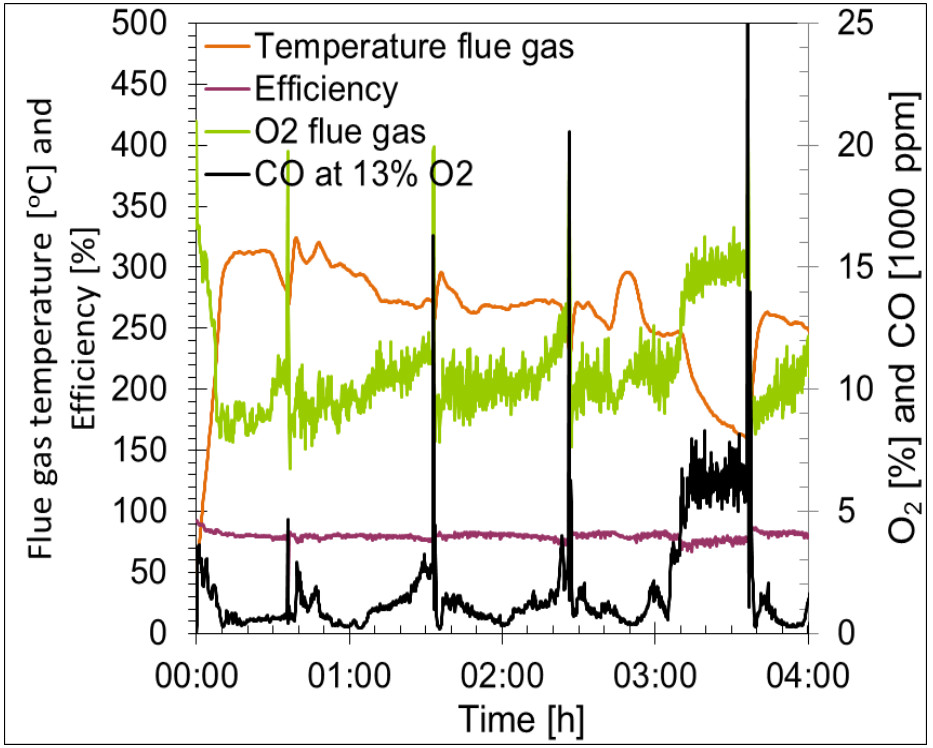
Lack of combustion air in the flame phase and too much air in the char combustion phase

Automatically controlled

Stable O_2 and temperature, and low CO

The same user





Manually controlled

High excess air and temperature in both the flame phase and the char combustion phase

Automatically controlled

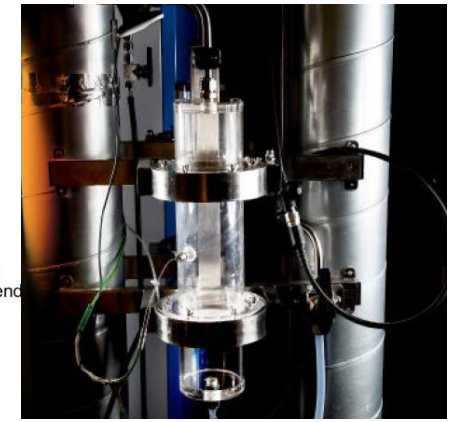
Lower and optimal O_2 and temperature, and *much* higher efficiency

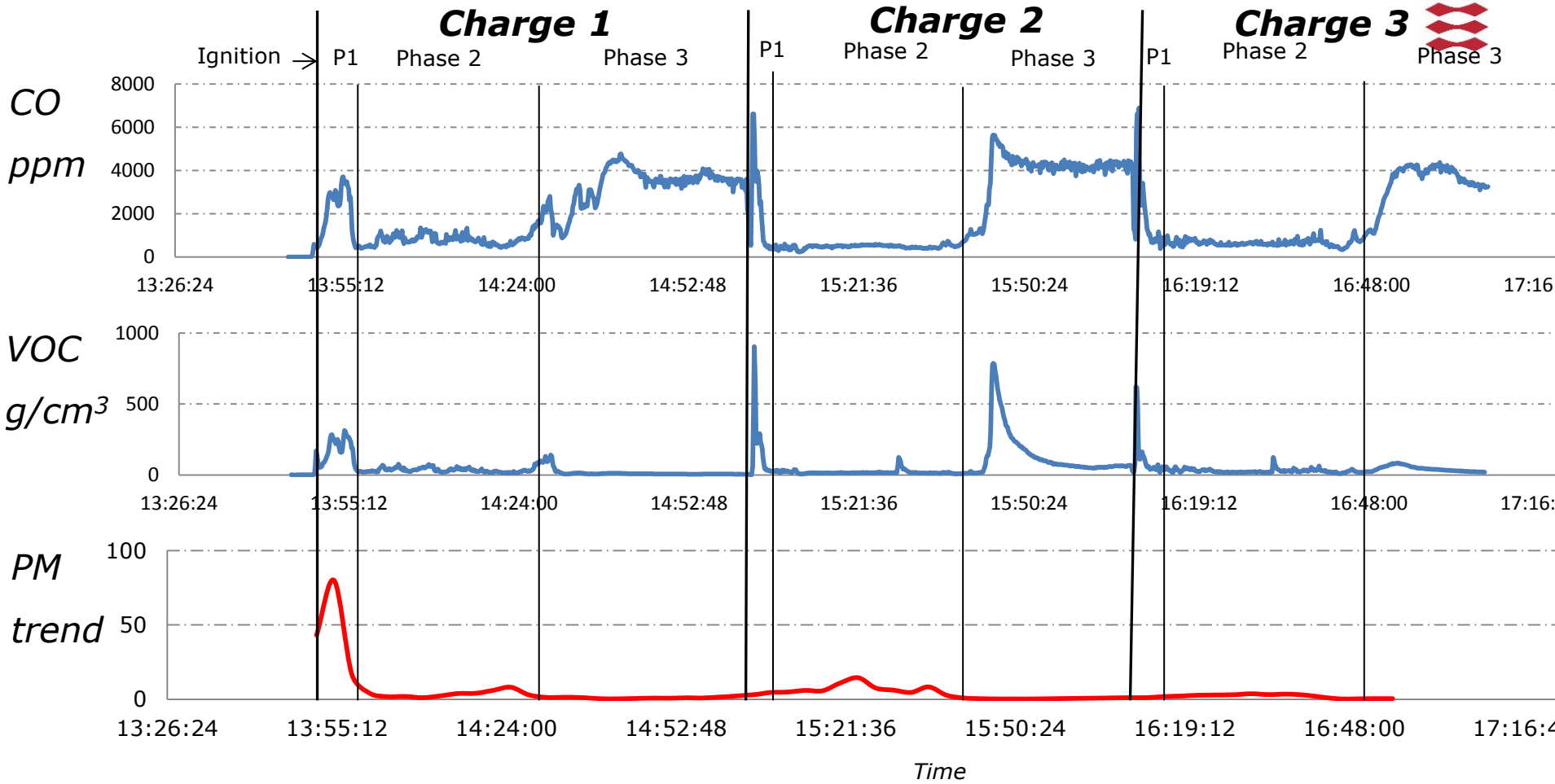
Experimental setup

Including: woodstove, stack, dilution tunnel, sampling sites, filters for particle collection and panel for gaseous analysis.

PM measurements:

- Filter collection based on the Noweigan Standard NS-3058
- Scanning mobility particle sizer (SMPS)





- Increase in CO/VOC/PM in phase 1
- PM peak but low CO/VOC in phase 2
- Increase in CO (VOC) but low PM in phase 3

PM composition

- Condensable organic compounds
  Example hexane (T_{boil} = 69 ^{o}C)
  Example benzene (T_{boil} = 80 ^{o}C)
  Initial release of volatiles from fuel
  Temperature/mixing in the combustion zone

- Soot/Black carbon
  High temperature & O_2 lean formation
  Potentially caused by insufficient mixing

Charge 1: 1.8 ± 0.2 g / kgdry

Charge 2: 1.8 ± 0.8 g / kgdry

Charge 3: 1.4 ± 0.4 g / kgdry

Charge 4: 0.5 g / kgdry

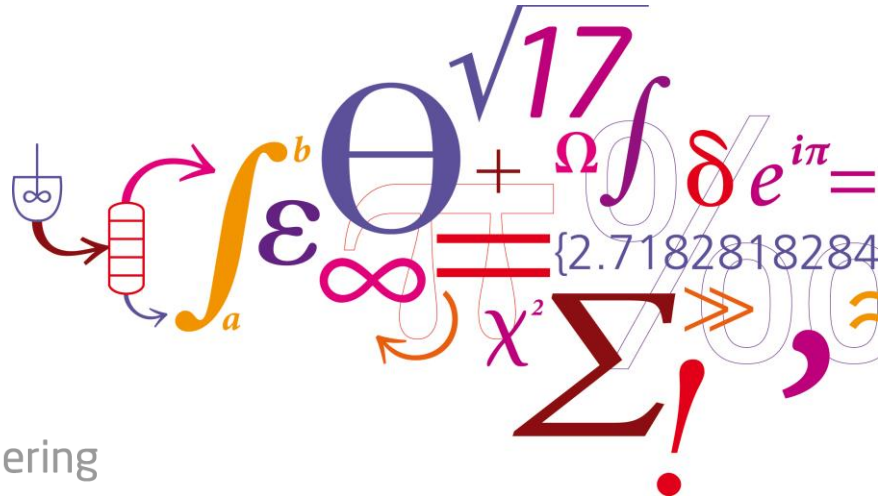
Charge 1

Charge 2

Conclusions

- An automatically controlled wood stove, HWAM IHS, has been developed and launched on the market.
- Results have shown significantly reduced emissions and high efficiency for the automatically controlled stoves compared to manually controlled stoves.
- The new control system ensures improved stove operation - also when used by private wood stove owners.

Thanks for your attention



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