STOVES WITHOUT SMOKE

Update on activities in Asia

Crispin Pemberton-Pigott

19 November 2016

STOVES WITHOUT SMOKE

Location

Ulaanbaatar, Mongolia

Problem

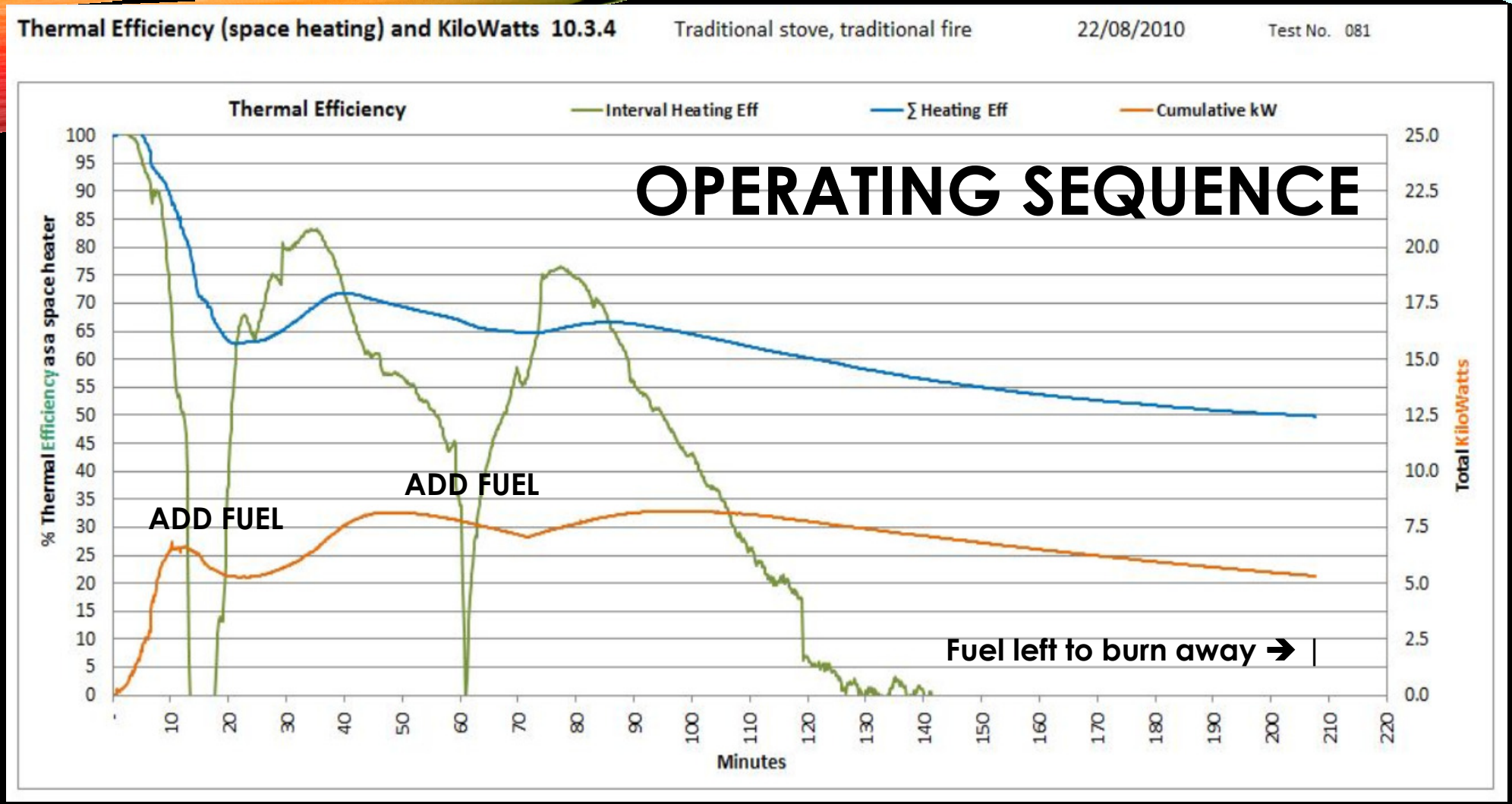
Very bad air quality in the city

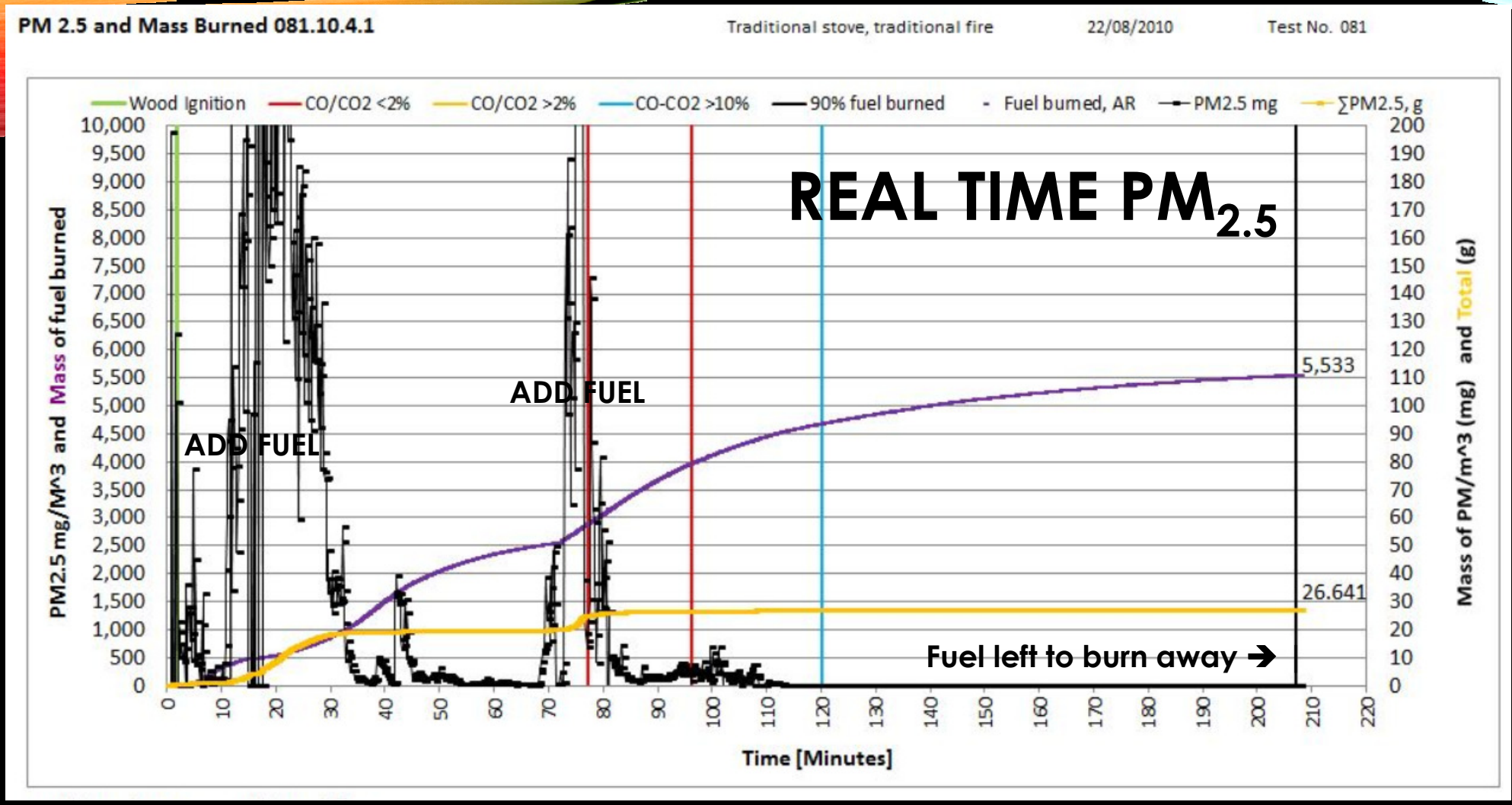
Source

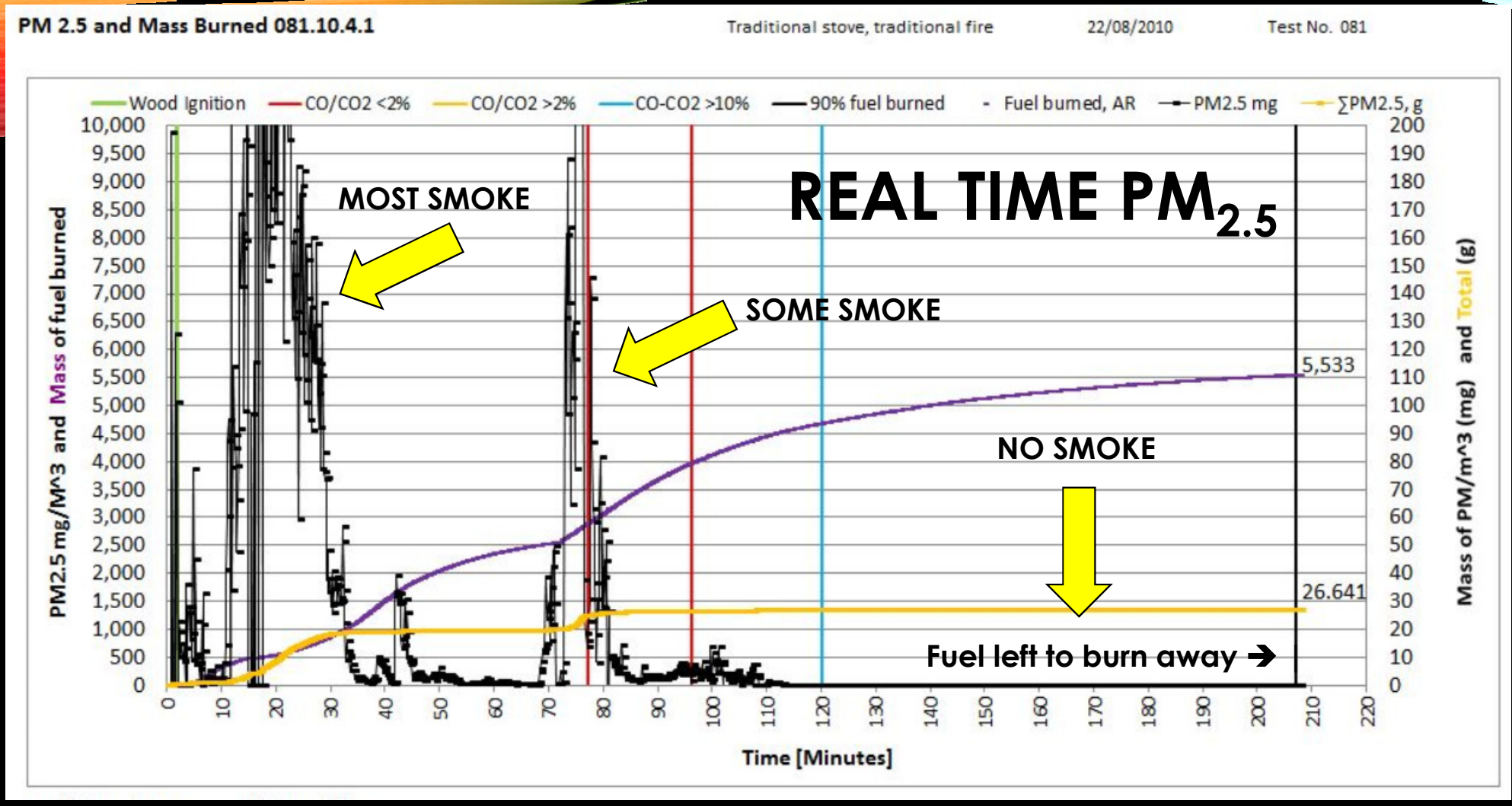
Traditional wood stoves burning coal

Root cause of the problem

Evaporation of volatiles without burning them completely


Thermal Efficiency (space heating) and KiloWatts 10.3.4
Traditional stove, traditional fire
22/08/2010
Test No. 081
Thermal Efficiency
Interval Heating Eff
∑ Heating Eff
Cumulative kW
OPERATING SEQUENCE
% Thermal Efficiency as space heater
Total KiloWatts
Minutes
ADD FUEL
ADD FUEL
Fuel left to burn away ➔


PM 2.5 and Mass Burned 081.10.4.1
Traditional stove, traditional fire
22/08/2010
Test No. 081
Wood Ignition
CO/CO2 <2%
CO/CO2 >2%
CO-CO2 >10%
90% fuel burned
Fuel burned, AR
PM2.5 mg
∑PM2.5, g
REAL TIME PM2.5
ADD FUEL
ADD FUEL
5,533
26.641
Fuel left to burn away ➔
PM2.5 mg/M^3 and Mass of fuel burned
Mass of PM/m^3 (mg) and Total (g)
Time [Minutes]


PM 2.5 and Mass Burned 081.10.4.1
Traditional stove, traditional fire
22/08/2010
Test No. 081
Wood Ignition
CO/CO2 <2%
CO/CO2 >2%
CO-CO2 >10%
90% fuel burned
Fuel burned, AR
PM2.5 mg
∑PM2.5, g
REAL TIME PM2.5
MOST SMOKE
SOME SMOKE
NO SMOKE
Fuel left to burn away ➔
5,533
26.641
PM2.5 mg/M^3 and Mass of fuel burned
Mass of PM/m^3 (mg) and Total (g)
Time [Minutes]

EMISSIONS

Emissions created to deliver heat into the home

Emissions per Net MegaJoule		
PM2.5	**794.28**	mg per Net MJ in the home
CO	**16.61**	g per Net MJ in the home

WHY IS THERE SOMETIMES NO SMOKE ?

What is smoke?

Unburned fuel

Suppose all the fuel is burned

If all the fuel is burned there is completely there is no smoke.

Why is coal said to be 'smoky'?

Because the stoves do not burn all the fuel.

Therefore

The problem is *not* the **fuel**, it is the **combustor**.

WHY DO BIG COMBUSTORS WORK WELL ?

Continuous operation

Homogenised fuel

Homogeneous combustion

Therefore

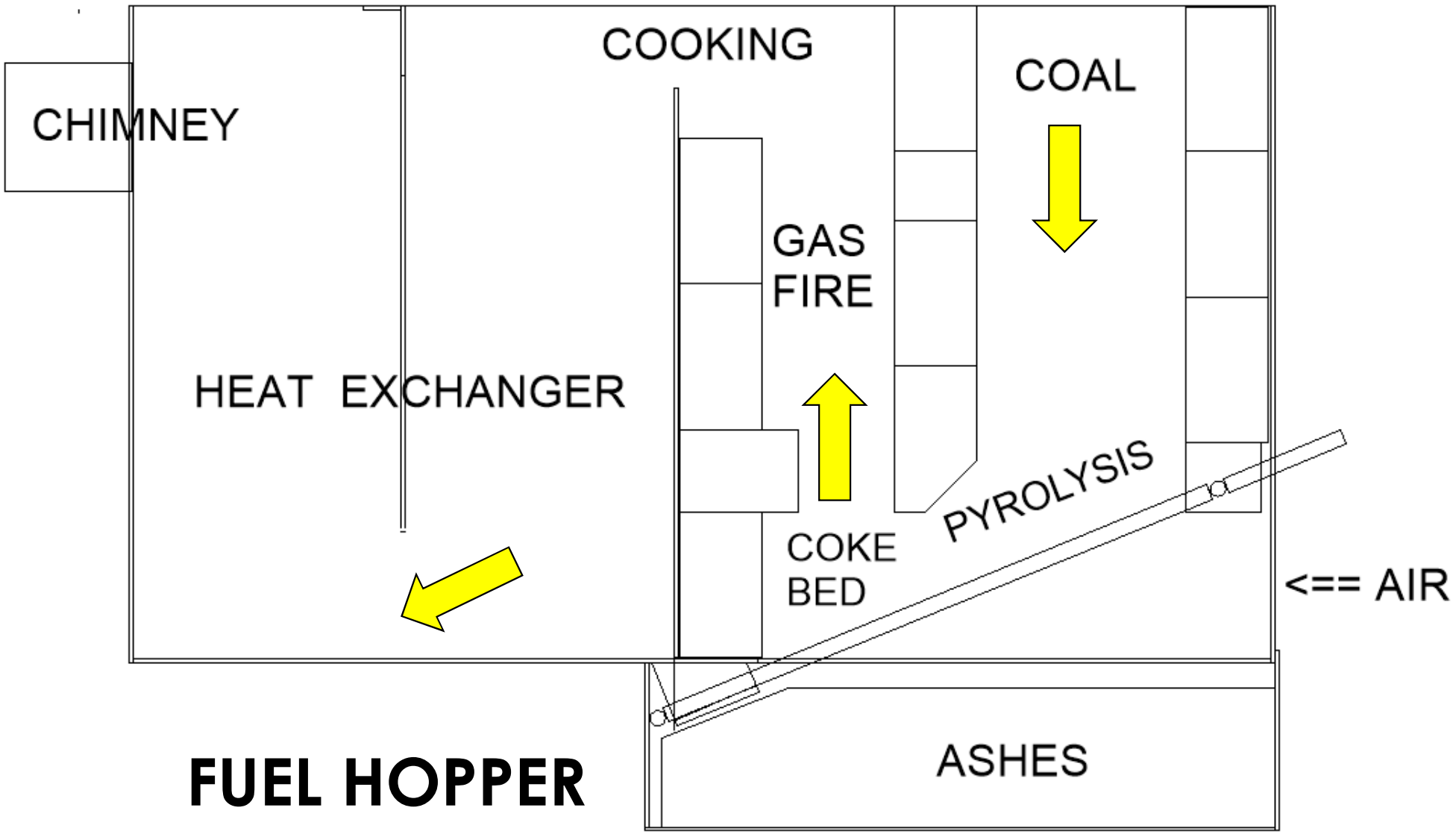
Combustion conditions can be optimised

PROBLEMS FOR STOVES

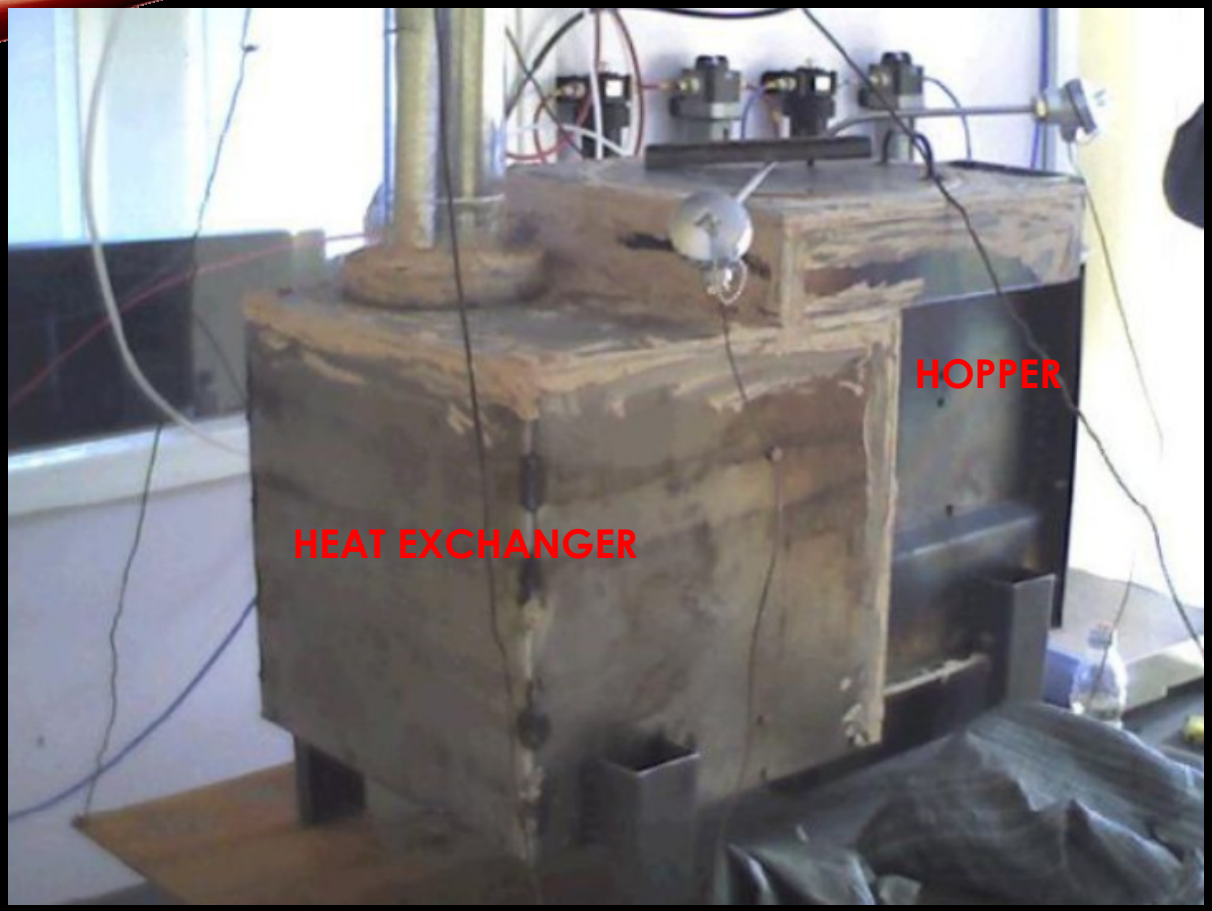
Operation changes during the day

Inhomogeneous combustion
Fuel composition is continuously changing

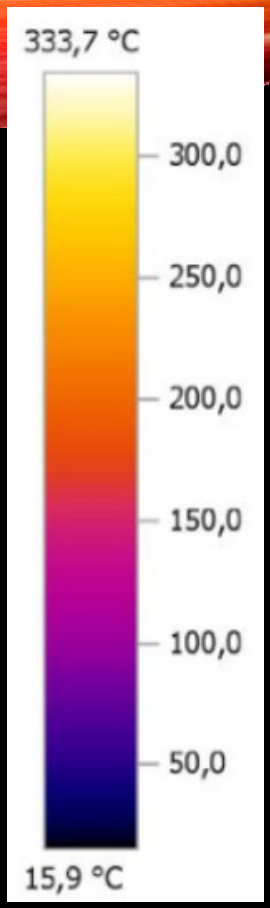
Refueling completely changes the conditions
Fuel is added at different times in different amounts

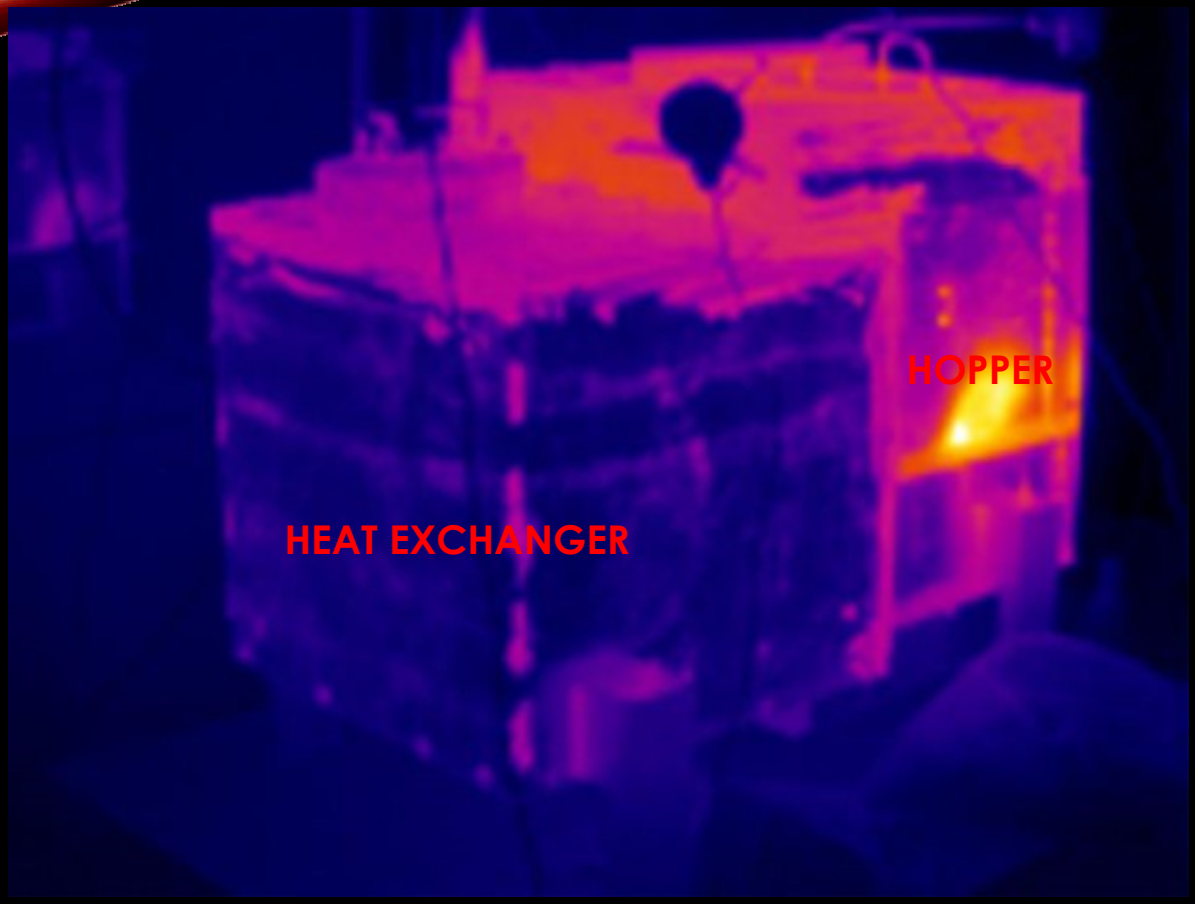

COOKING
CHIMNEY
COAL
GAS
FIRE
HEAT EXCHANGER
PYROLYSIS
COKE
BED
<== AIR
ASHES
FUEL HOPPER

GTZ 7.1



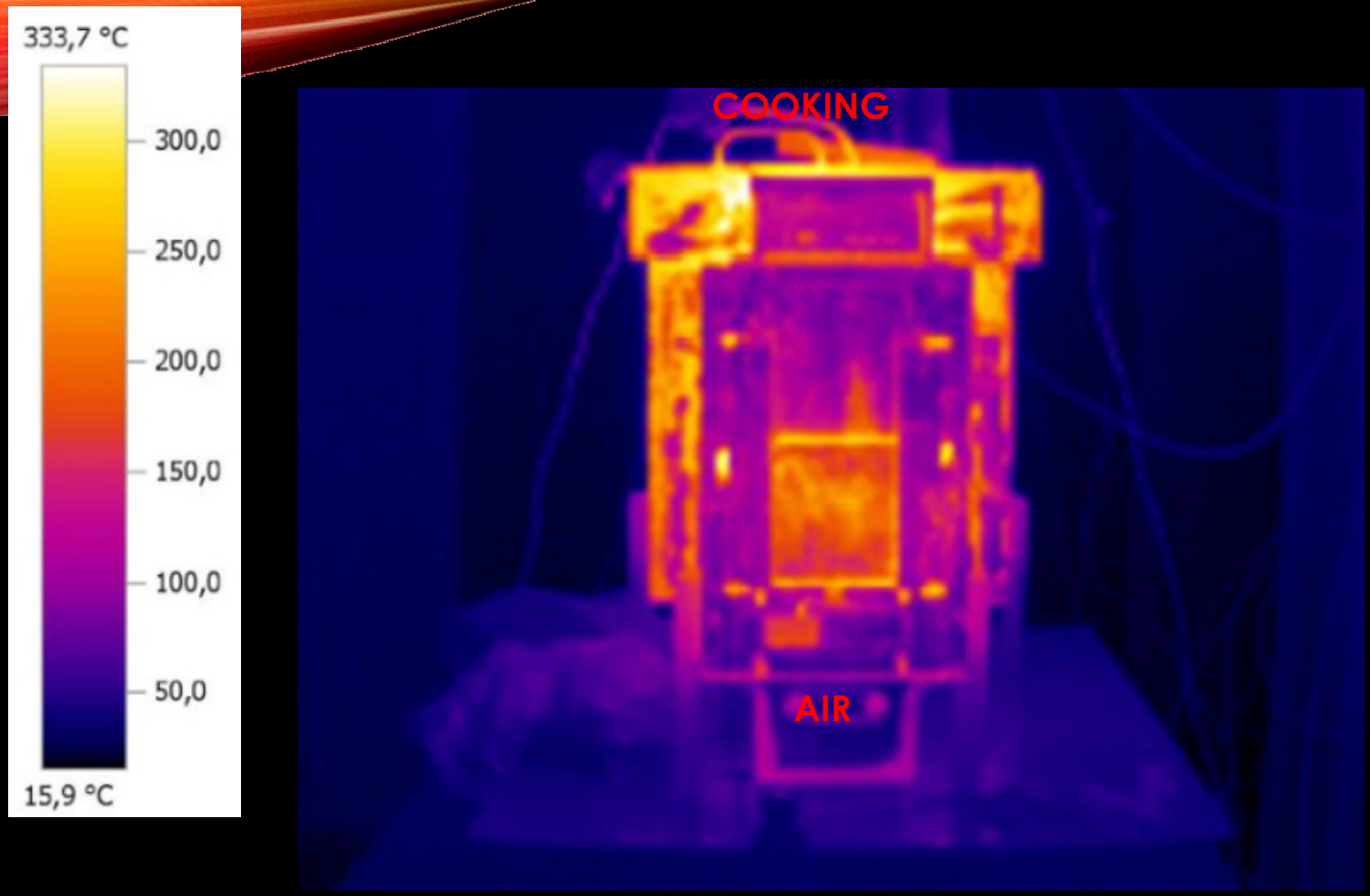
GTZ 7.1

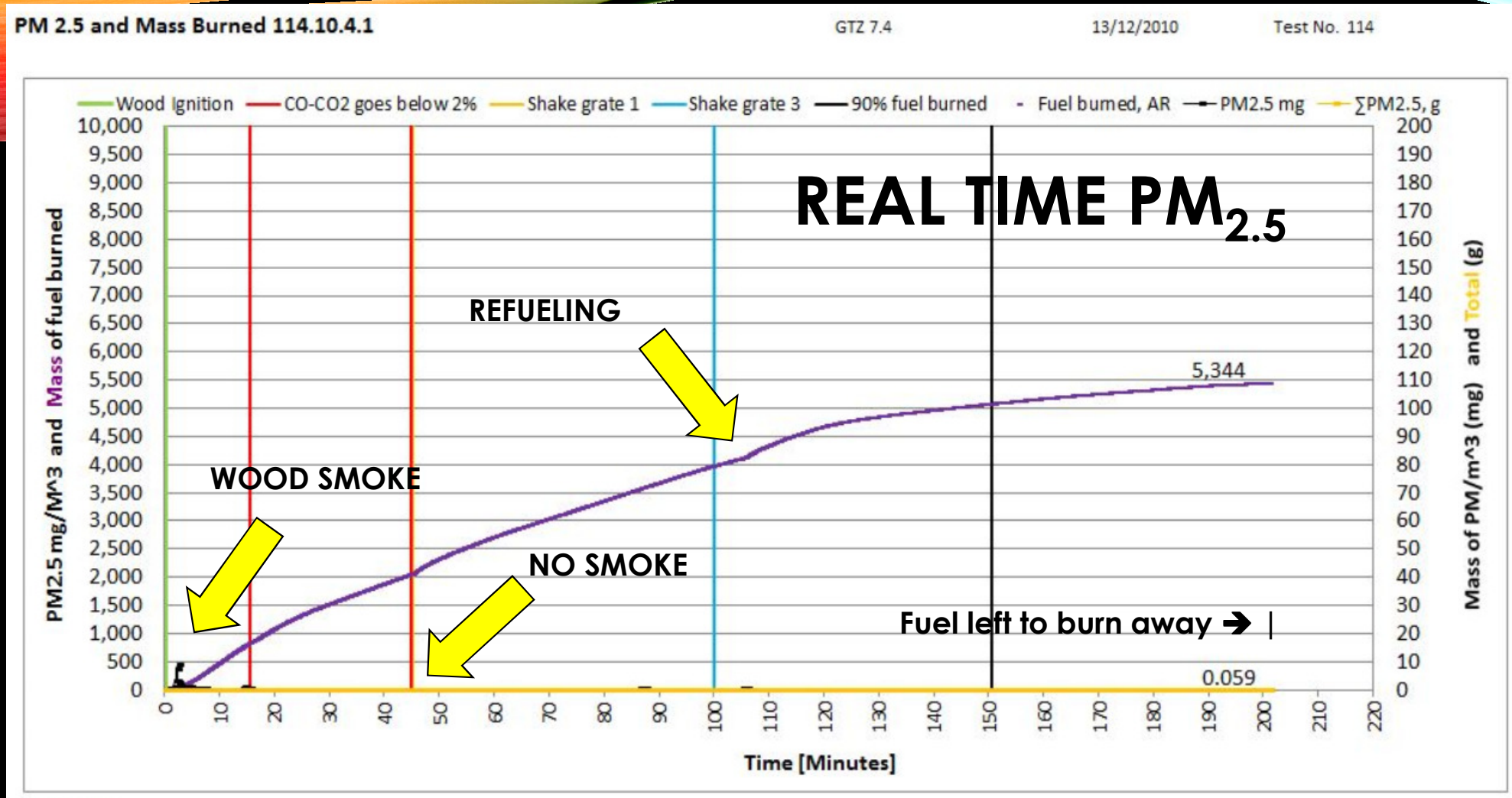

333,7 °C
300,0
250,0
200,0
150,0
100,0
50,0
15,9 °C


HOPPER
HEAT EXCHANGER

GTZ 7.1

GTZ 7.1




PM 2.5 and Mass Burned 114.10.4.1
GTZ 7.4
13/12/2010
Test No. 114
Wood Ignition
CO-CO2 goes below 2%
Shake grate 1
Shake grate 3
90% fuel burned
Fuel burned, AR
PM2.5 mg
∑PM2.5, g
REAL TIME PM2.5
REFUELING
WOOD SMOKE
NO SMOKE
Fuel left to burn away ➔
5,344
0.059
PM2.5 mg/M^3 and Mass of fuel burned
Mass of PM/m^3 (mg) and Total (g)
Time [Minutes]

EMISSIONS

Emissions created to deliver heat into the home

Emissions per Net MegaJoule		
PM2.5	**0.81**	mg per Net MJ in the home
CO	**0.82**	g per Net MJ in the home

EMISSIONS

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Emissions created to deliver heat into the home

Emissions per Net MegaJoule		
PM2.5	**794.28**	mg per Net MJ in the home
CO	**16.61**	g per Net MJ in the home

EMISSIONS

This represents a 99.9% reduction of $PM_{2.5}$ compared with the baseline traditional stove

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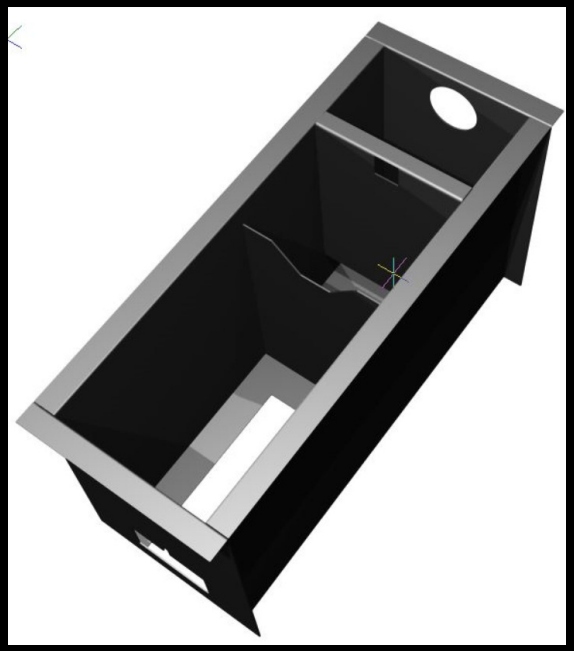
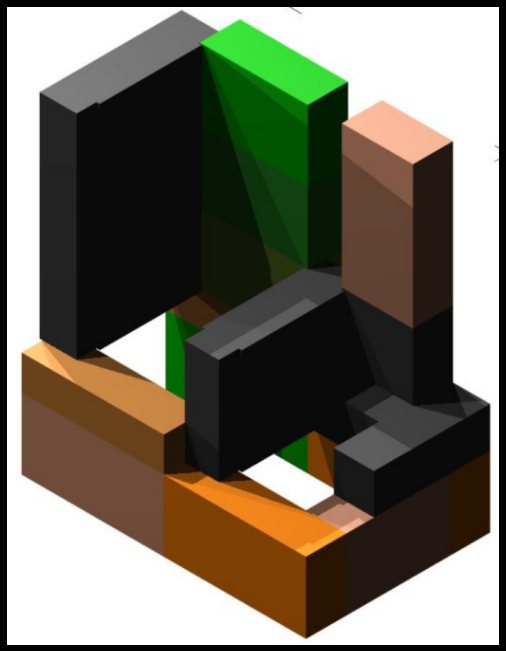
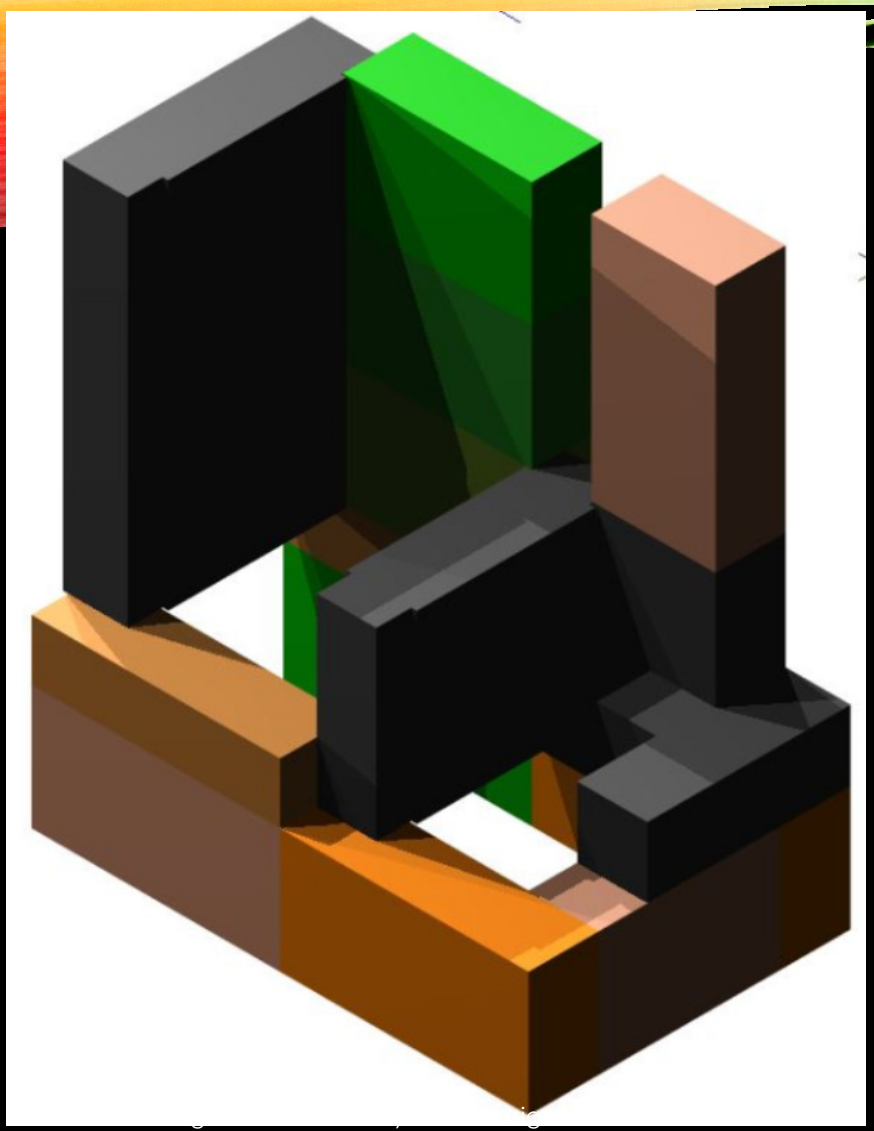
TAJIKISTAN MODEL 4

KYRGYZSTAN MODEL 4







KYRGYZSTAN MODEL 4

Bricks are high temperature Resistant, the type used for lining boilers.

The entire combustion process takes place in a brick chamber.

KYRGYZSTAN MODEL 4

KYRGYZSTAN MODEL 4

COAL CAPACITY 9 KG

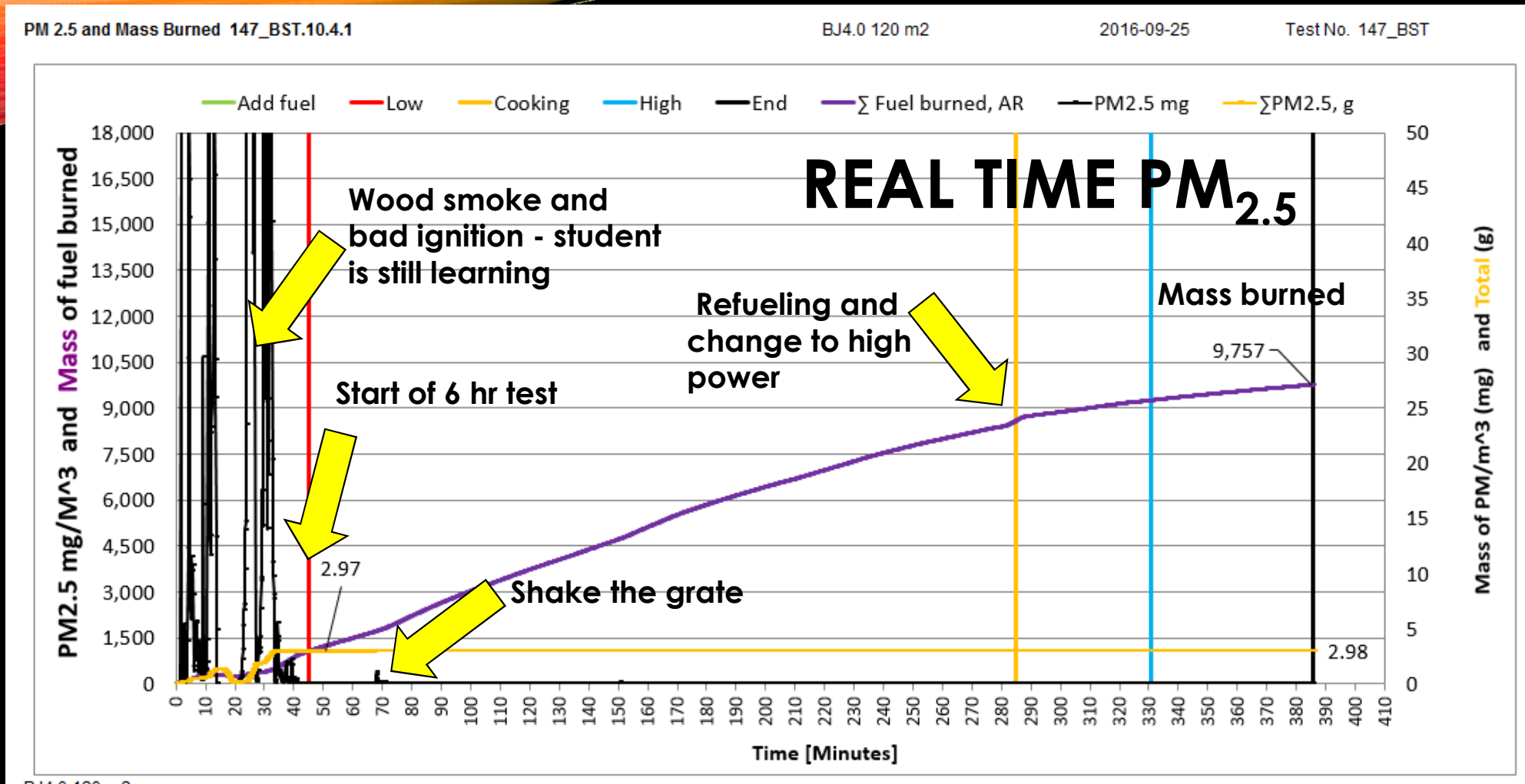
INSTALLED NOV 2016

"IN THE MORNING THE ROOM WAS TOO WARM."

SOLUTION: "CLOSE THE AIR CONTROLLER A LITTLE."

BEIJING MODEL 4

BEIJING MODEL 4


PM 2.5 and Mass Burned 147_BST.10.4.1
BJ4.0 120 m2
2016-09-25
Test No. 147_BST
Add fuel
Low
Cooking
High
End
∑ Fuel burned, AR
PM2.5 mg
∑PM2.5, g
REAL TIME PM2.5
Wood smoke and bad ignition - student is still learning
Start of 6 hr test
Refueling and change to high power
Mass burned
Shake the grate
9,757
2.97
2.98
PM2.5 mg/M^3 and Mass of fuel burned
Mass of PM/m^3 (mg) and Total (g)
Time [Minutes]

EMISSIONS

BJ 4.0

Emissions per MJ delivered into the home

Emissions per Net MegaJoule (Radiant Heating)		
PM2.5	**0.018**	mg per Net MJ in the home
CO	**0.289**	g per Net MJ in the home

Thermal Eff 91.2 %

EMISSIONS

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GTZ 7.1

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EMISSIONS

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GTZ 7.1

Emissions created to deliver heat into the home

Emissions per Net MegaJoule		
PM2.5	**0.81**	mg per Net MJ in the home
CO	**0.82**	g per Net MJ in the home

This represents a 98% reduction of $PM_{2.5}$ compared with the GTZ 7.1

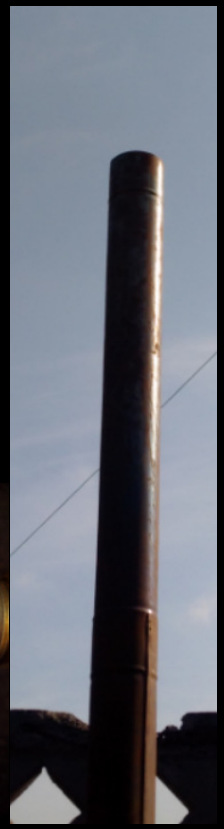
KYRGYZSTAN MODEL 5 LPB

1.0 M² HEAT EXCHANGER

KYRGYZSTAN MODEL 5 LPB

1.0 M² TUBE BOILER HEAT EXCHANGER

KYRGYZSTAN MODEL 5 LPB



THERMAL PERFORMANCE

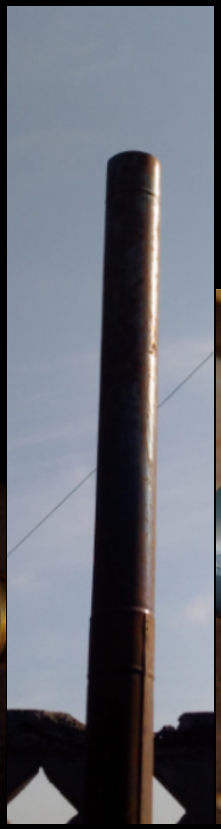
Maximum water heating power 15 kW for 6 hrs
Maximum burn time 24 hrs
Fuel capacity 9 kg
Retail $225

KYRGYZSTAN MODEL 5 LPB

EMISSIONS PERFORMANCE

Low pressure boiler test

No smoke



High power

In the fully developed fire the bricks are very hot.

Flow meter

THANK YOU FOR YOUR PARTICIPATION !

Crispin Pemberton-Pigott





EMISSIONS

BJ 4.0

Emissions per MJ delivered into the home		
Emissions per Net MegaJoule (Radiant Heating)		
PM2.5	**0.018**	mg per Net MJ in the home
CO	**0.289**	g per Net MJ in the home

GTZ 7.1 without ignition

Emissions created to deliver heat into the home		
Emissions per Net MegaJoule		
PM2.5	**-0.134**	mg per Net MJ in the home
CO	**1.52**	g per Net MJ in the home

If the first 30 minutes of the GTZ 7 test are omitted (per the Hebei protocol) the overall emissions are negative.

This is because the stove is cleaning the air as it burns the fuel.