RECENT DEVELOPMENTS IN THE CLEAN COMBUSTION OF COAL

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THEORY OF SMOKE PRODUCTION 1

- Coal is placed on a fire.
- The coal is heated, giving off volatile gases.
- If the flames do not completely combust the gases produced, the gases cool and condense.
- The result is ‘smoke’ which is condensed volatile matter, combustible gases and unburned carbon.
- Empirical observations indicate: the higher the volatile content of a coal, the more smoke.
- This has resulted in the terms “high quality coal” and “low quality coal”.

THEORY OF SMOKE REDUCTION 1

- Smoke mostly results from the incomplete combustion of volatiles contained in coal.
- Coked coal, is ordinary coal roasted using a process called destructive distillation.
- It has been known for centuries that coking the coal resulted in a low smoke fuel (China 9th Century).
- In the mid 1800's in the UK, train engines were required to "consume their own smoke" so they had to burn coke.
- Coke is hard to ignite and often rejected by householders.
- Removing some of the volatiles creates a 'semi-coked' coal-based fuel; easier to light.

THEORY OF SEMI-COKED COAL

- Making semi-coked or fully coked coal reduces smoke because there is less volatile material available.
- To make coke, coal is "pyrolysed" – heated to a chosen temperature in the absence of air – which boils away some of the volatile materials.
- Simple stoves are able to burn semi-coked coal so they make very little smoke but this improvement comes at a significant fuel cost.
- It is accepted that burning coked coal dramatically reduces smoke.

THEORY OF SMOKE COMBUSTION 1

- Stoves that burn all the volatiles also make virtually no smoke.
- There are at least three ways to do this in a simple domestic stove:
  - Top-lit updraft – ignited on top, coal sitting underneath, flames go upwards.
  - Bottom-lit downdraft – ignited at the bottom, coal added on top, flames go downwards, then upwards.
  - Cross draft – fire at the bottom, coal bunker on one side, flames rise from the other side.

SMOKE COMBUSTION 2
TLUD STOVE

Top-lit updraft pyrolyser (1768)

1 Ignited on top,

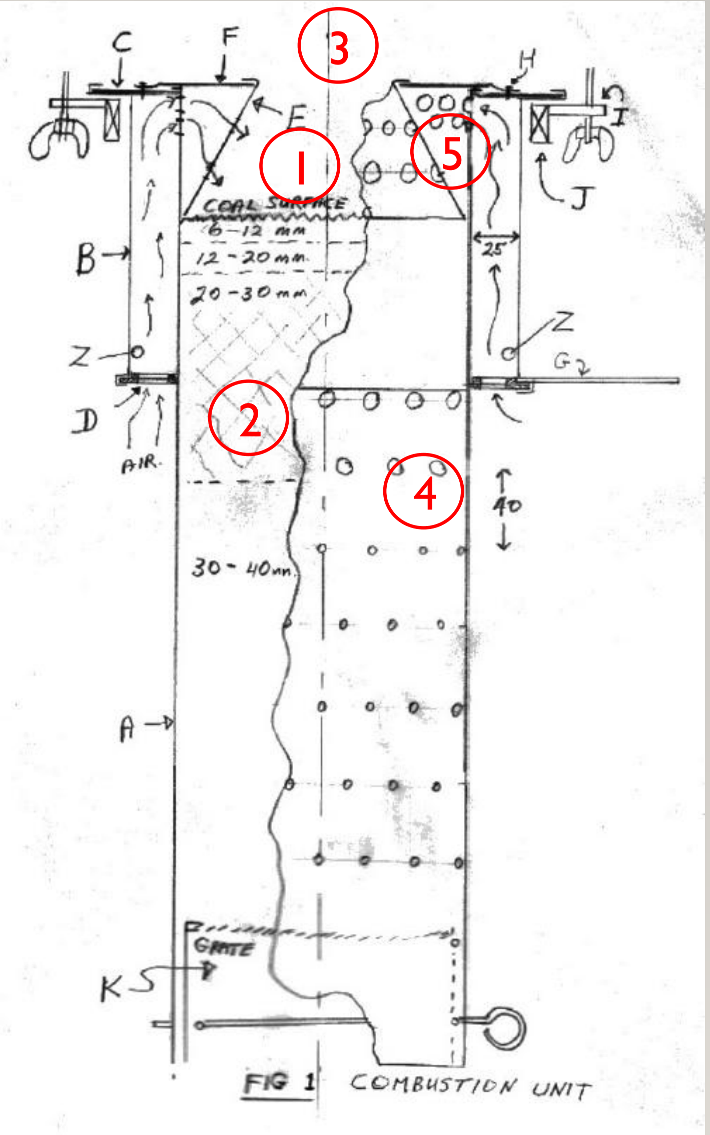
2 Coal is sitting underneath

3 Flames go upwards

4 Primary air

5 Secondary air

Cannot be refueled while burning



John Davies, Packed bed gasifier 2008

SMOKE COMBUSTION 3
DOWNDRAFT STOVE

Downdraft combustor (1688)

1 ignited at the bottom

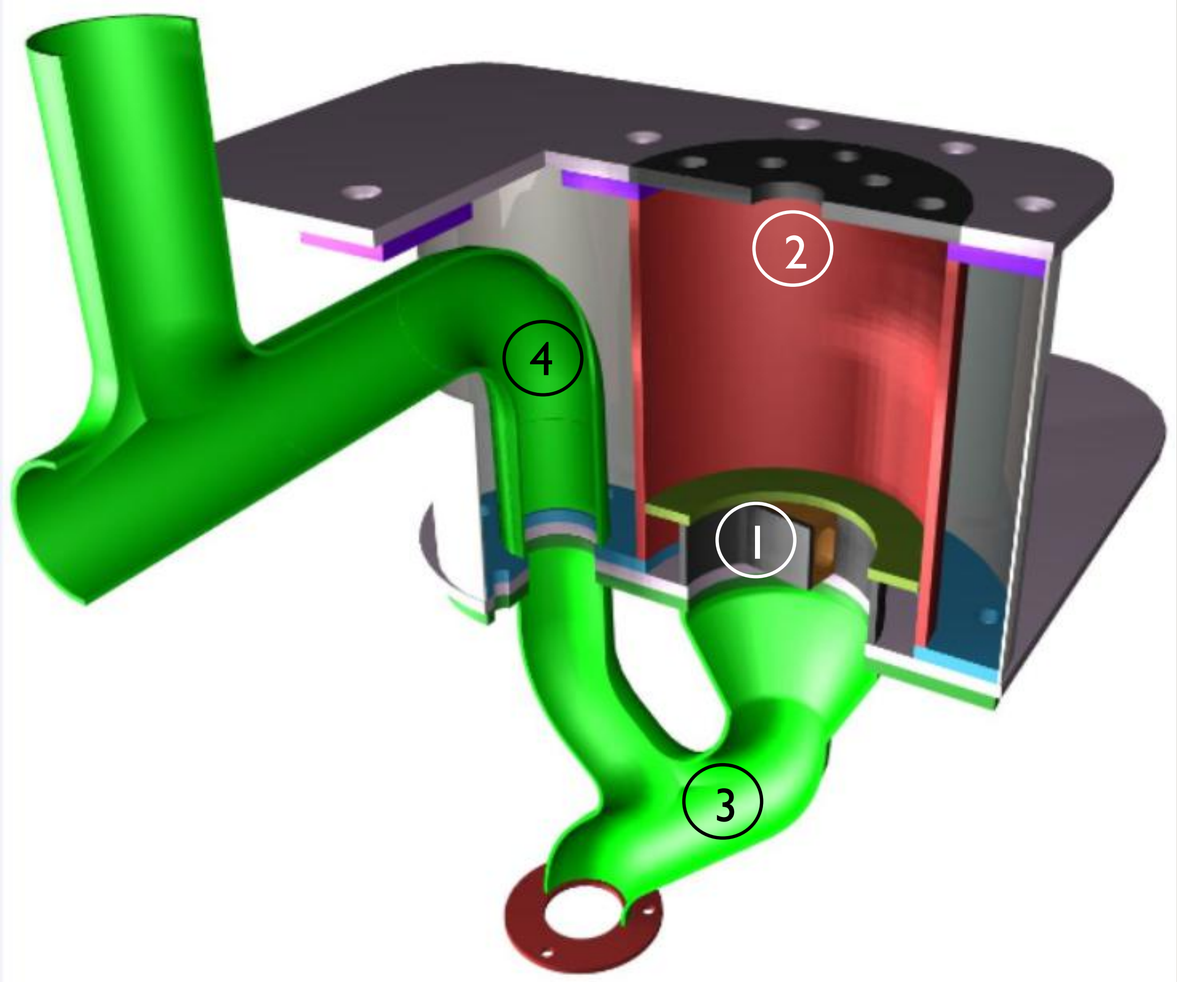
2 coal added on top

3 flames go downwards, then

4 upwards

Cooking is more difficult

CPP - BLDD 6 Downdraft 2012



SMOKE COMBUSTION 4
CROSSDRAFT STOVE

Crossdraft combustion (1742)

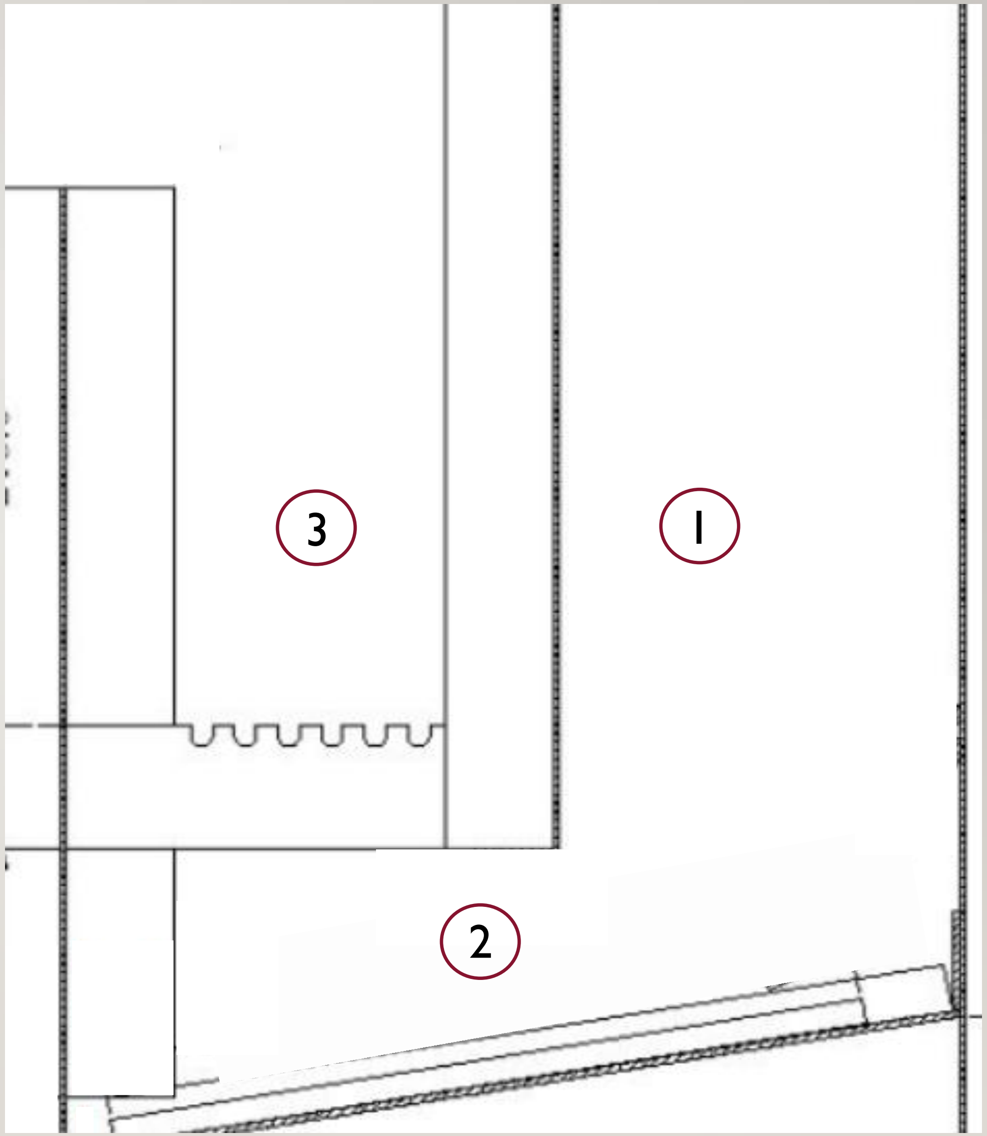
1 Coal bunker on one side,

2 fire at the bottom,

3 flames rise from other side

Cooking and heating easy

CPP – GTZ 7.1, 2010



SMOKE COMBUSTION 5

- All fires are "gas fires".
- All stoves create "smoke" within the fire.
- If the smoke is not burned we see it coming out.
- Some stoves burn most of the smoke – it depends on the stove architecture
- In theory a stove could burn all the smoke
- How?

COMBUSTION ZONES CROSSDRAFT STOVE I

1 Coal

2 Pyrolysing zone

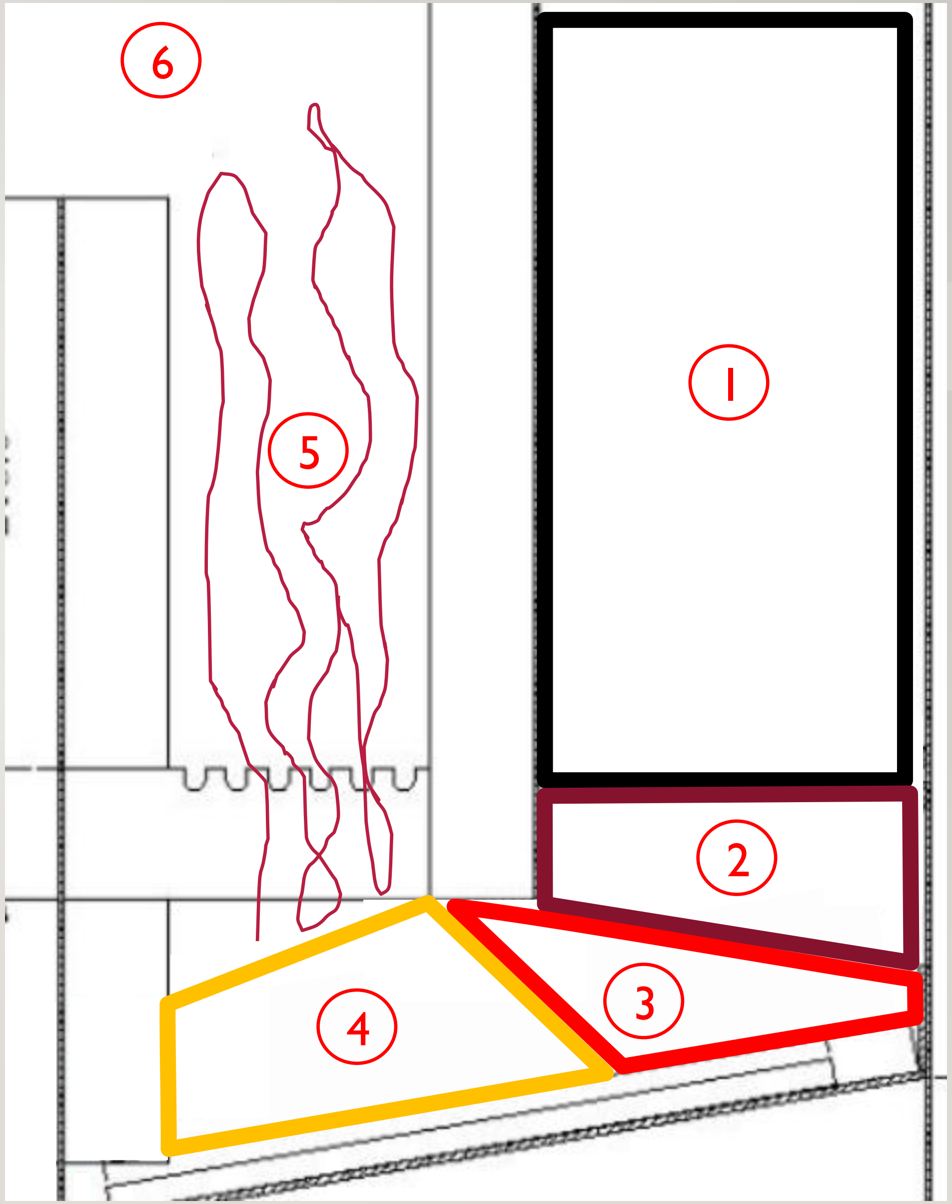
3 Semi-coking zone

4 Coke burning zone

5 Gas burning zone

6 Cooking zone

Can be refueled while burning



COMBUSTION ZONES CROSSDRAFT STOVE 2

All processes continue indefinitely.

It is a miniature semi-coking factory!

1 Raw fuel

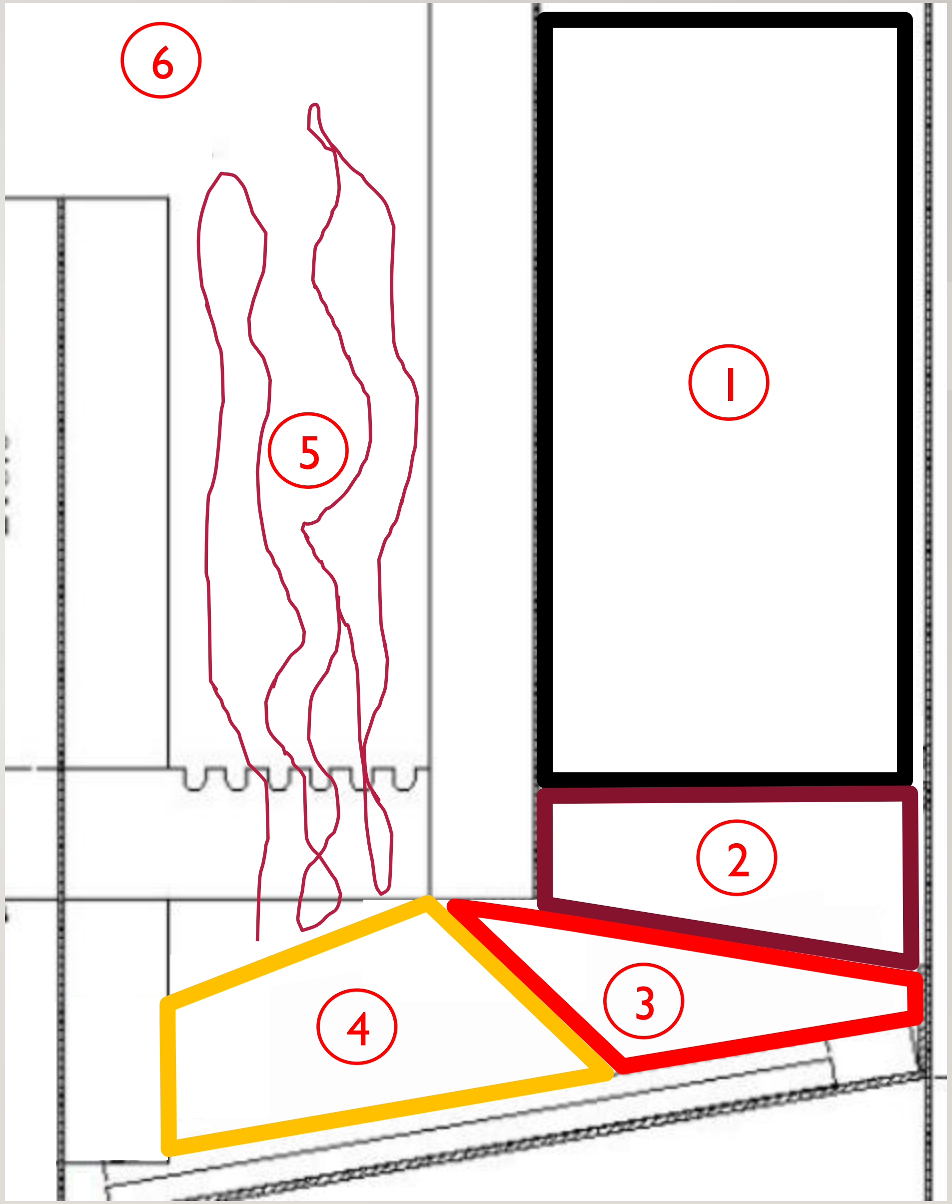
2 Dehydration, devolatilisation starts

3 Semi-coking with lots of smoke

4 Smoke cracking inside the coke

5 Gas burning with secondary air

6 Heat transfer to pot



SUSTAINING CLEAN COMBUSTION I

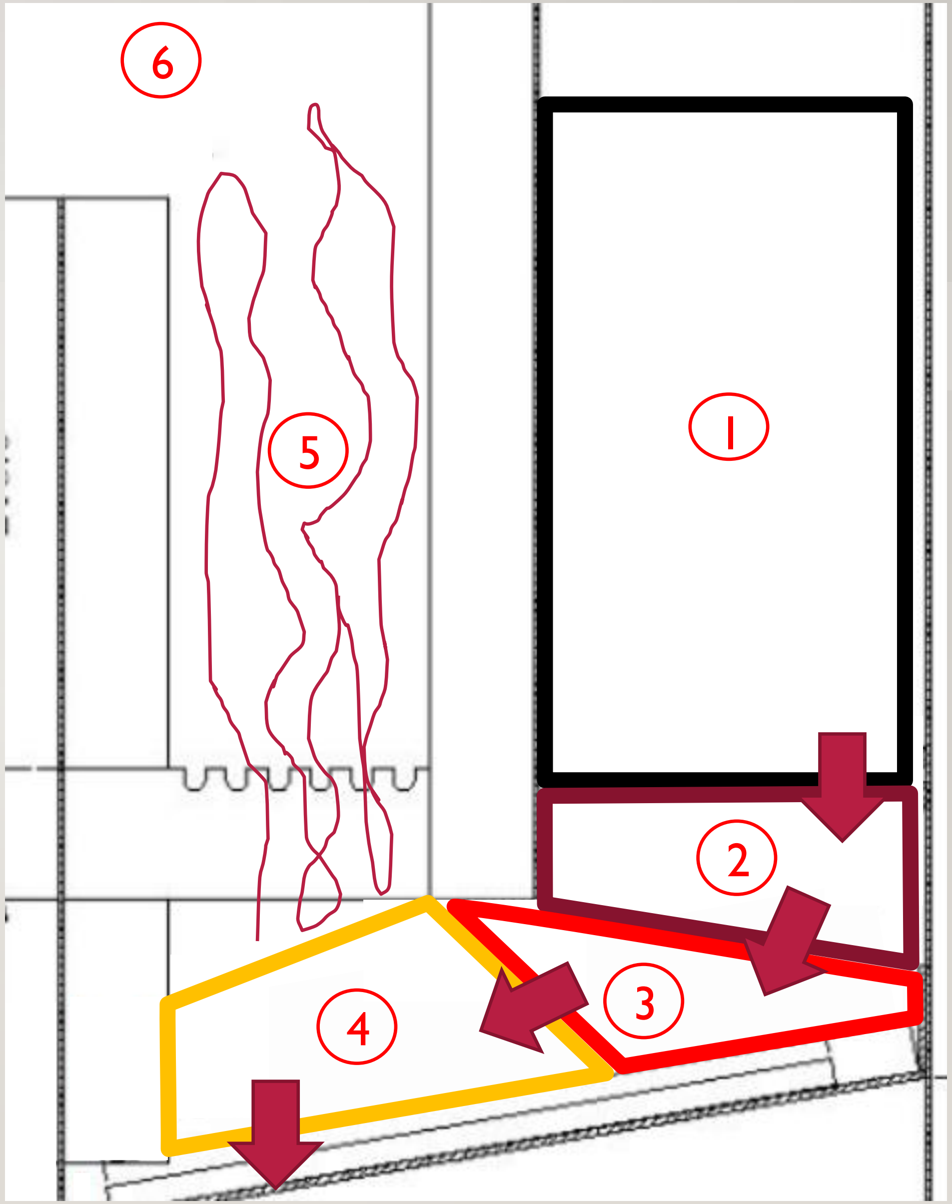
The challenge is to sustain the conditions that give good combustion.

The coke burns and shrinks, dropping ash into the drawer below.

The semi-coked fuel falls into the space.

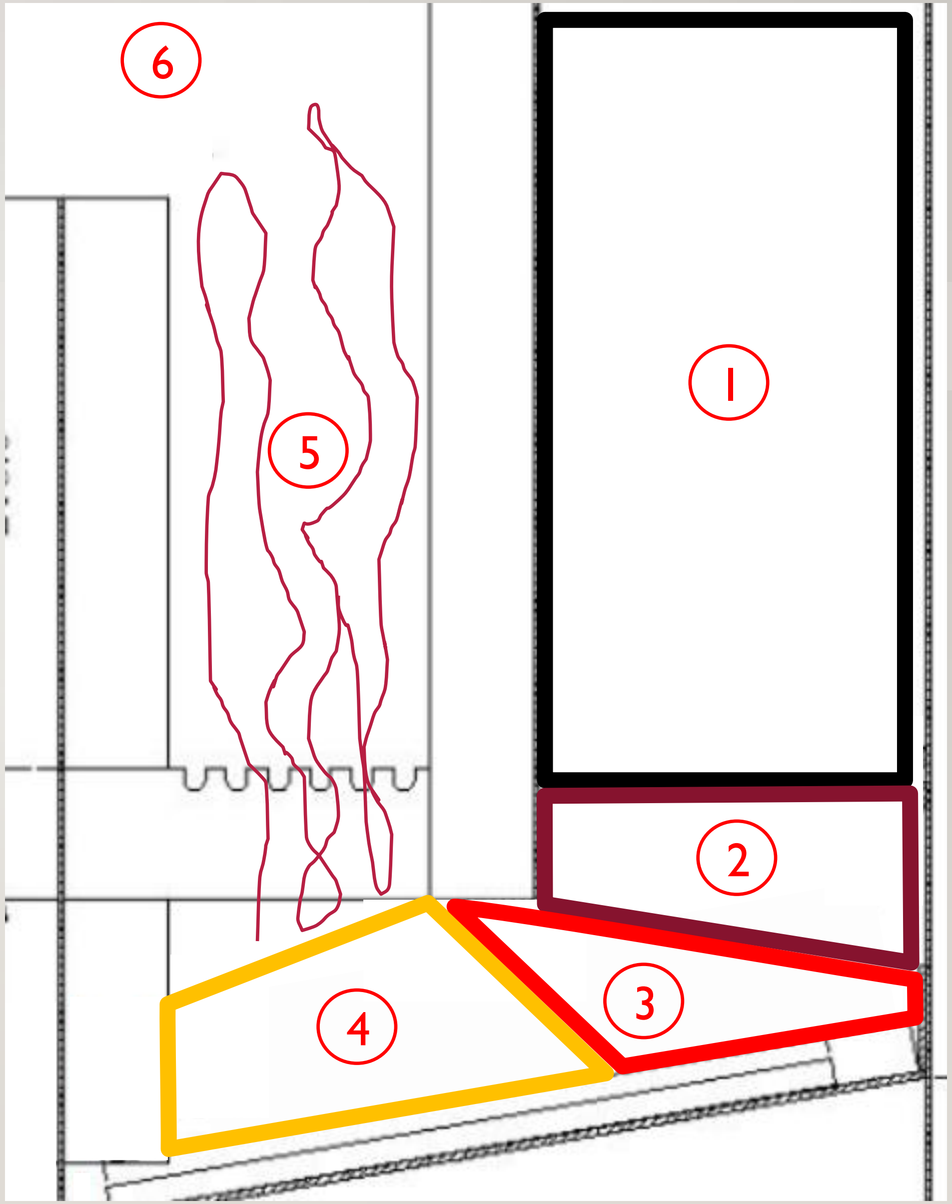
The pyrolysed coal drops onto the grate.

The coal in the bunker falls down.



SUSTAINING CLEAN COMBUSTION 2

- The depth of fuel in (4) determines the level of secondary air.
- The gap under the bridge (3) controls the depth of the fuel, combined with the grate angle.
- The width of the grate sets the firepower level.
- The volume of fuel in the bunker (1) determines the duration of the burn.



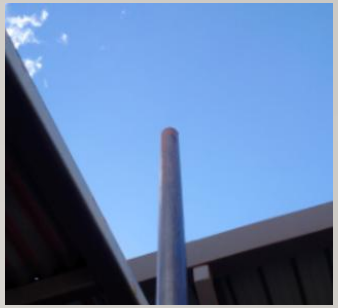
INVENTED LONG AGO…
WHY DO WE STILL HAVE A PROBLEM?

- Wood fire – traditionally: put new wood on top.
- Coal fire refueling replicated wood burning behaviour.
- Large combustion devices do not do this, domestic stoves do (mostly).
- Some progress made with TLUD's – but it has major problems related to continuous burning, emissions can be even worse than baseline if refueled.
- Semi-coking process can be used to create gas in a controlled way (CO and H2).
- Semi-coked briquettes widely used in Europe to reduce the smoke problem.

WHAT TO DO NEXT

- Understand how a crossdraft stove works as a semi-coking coal gasifier.
- Build one and try it using one of the freely available sets of drawings.
- Cooperate with other design teams – many solutions are needed.
- There is a market for larger and smaller versions.
- The required coke bed depth differs from one coal to another – optimise.
- Cooperate with the fuel industry to promote access to the correct sizes of coal.

THANK YOU!



QUESTIONS?