Thermal conduction properties of metals used for heat flux management in a novel domestic coal stove

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TOPICS

The need for efficient combustion cookstoves

Redefining heat transfer in downdraft combustion cookstoves

Enhancement of cooking by thermal conduction

Principles of construction of the novel bi-planar conducting stove

Further refinements

The need for efficient combustion cookstoves

"Despite progress in the provision of electricity infrastructure, a significant part of the population, 25 % of households, are still without electricity at all and 53% of these use firewood for cooking.

Significantly even 25% of those with access to electricity use firewood for cooking due to the cost. The cost-recovery system, typified by the use of pre-paid meters, leads households to continue using coal and firewood for cooking and heating (with their pollution consequences) because heaters and stoves consume a lot of electricity."

Extract from press release; Patrick Craven (National Spokesperson) Congress of South African Trade Unions, March 2012.

Redefining heat transfer in conventional combustion cookstoves

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- In a conventional coal/wood stove, only a small portion of heat is ultimately available for cooking.
- The remaining heat may be radiated or convected as space heating or is used to maintain draft in the chimney.
- It would be useful if a greater fraction of the heat dissipated as space heating could first be directed to the cooking surfaces.
- How can this be achieved?

How can space heating losses be re-directed through the cooking surfaces?

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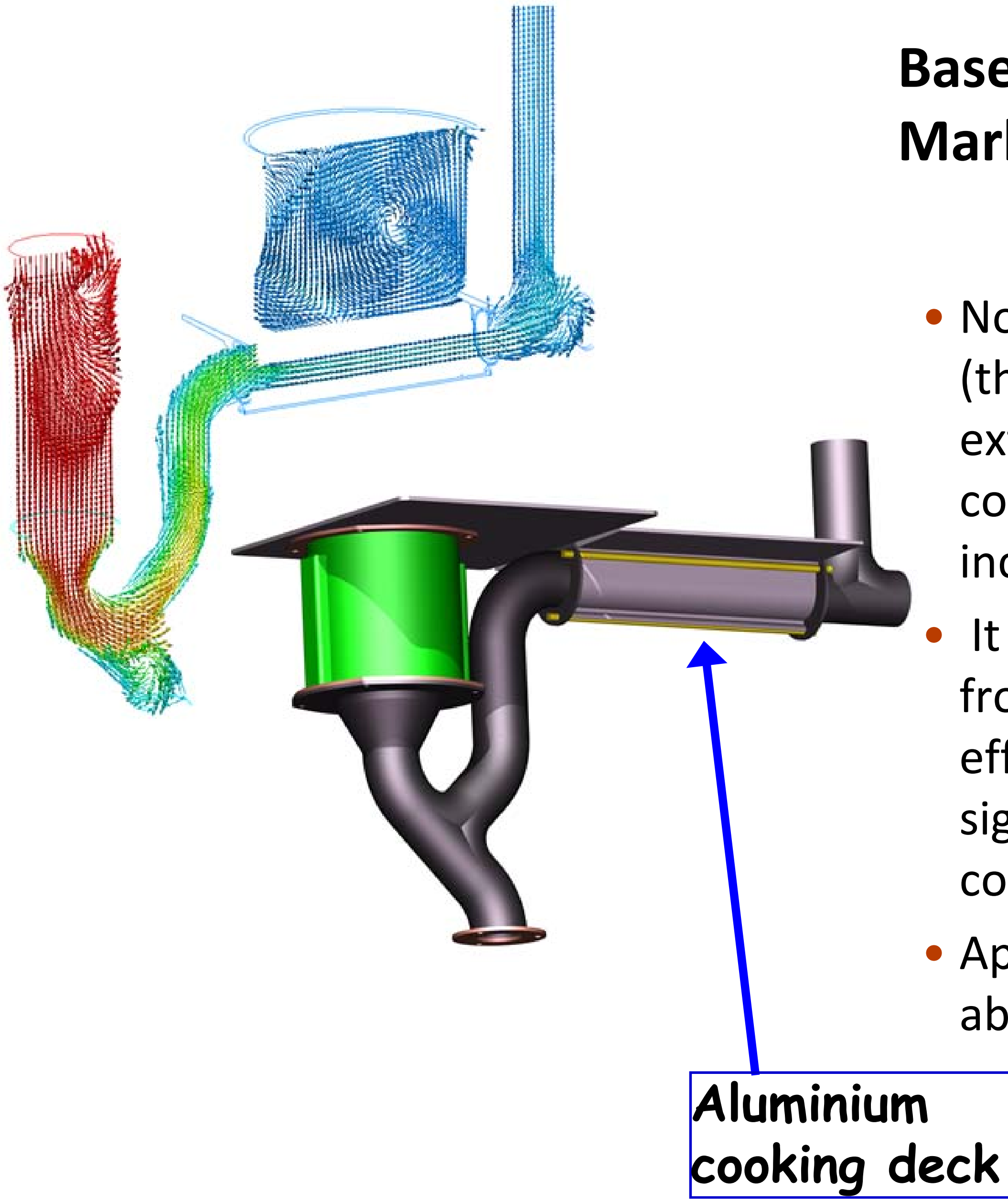
- Posing this question drove a fresh look at how heat is dissipated from the combustion chamber, the stove body and the exhaust pipes.
- This led to a novel approach of using **differential conduction of metals** to lead heat through the solid state directly from the hopper and combustion chamber to the cooking surface, rather than through the inefficient conventional method of heat transfer through convective gas transfer and/or radiation.



Baseline case: SeTAR Centre Mark V Down draft stove

- Novel downdraft two-pot coal stove (the SeTAR Centre BLDD 5) with an extruded, black-anodized aluminium cooking surface of suitable dimension incorporated into the gas path.
- It demonstrates in principle that heat from the coal fire gas stream can cook effectively by conduction alone without significant risk of melting the aluminium components.
- Approximate cooking power 700 Watts, about the same as a small paraffin stove

Comments on features and short comings of the SeTAR BLDD

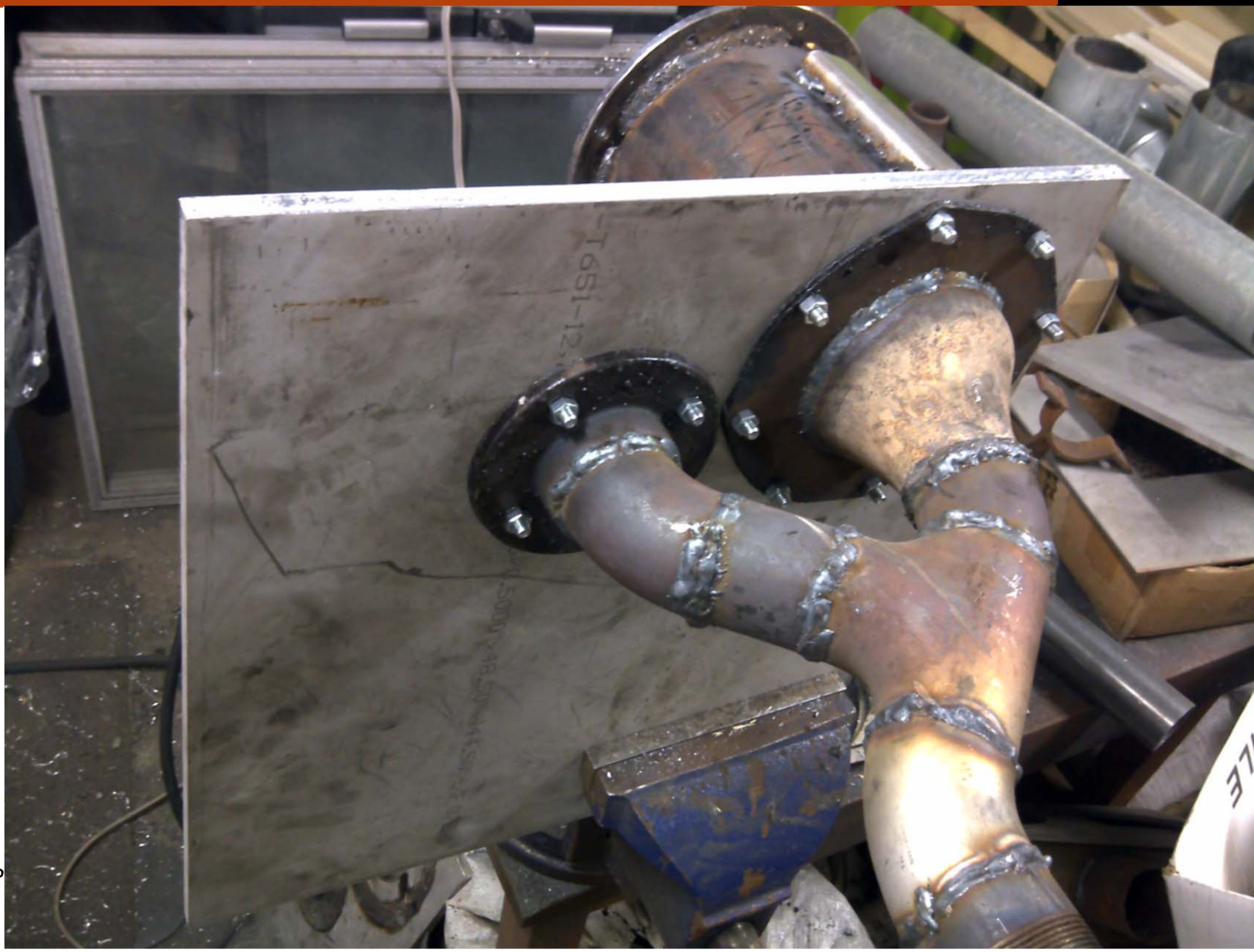
It has been used to demonstrate that disposal of heat from the aluminium cooking surface in the absence of a pot can be managed through a combination of heat exchanger size, efficiency, emissivity and profile.

- However, significant quantities of heat are still available from the pyrolysing fuel hopper and combustion chamber.
- Heat is radiated / convected from the hopper, combustion chamber and the rising gas path to warm the surrounding space
- This heat is welcome for space heating but is not very useful for cooking.

Innovations in choosing metals of different heat conductivities to optimise heat transfer to the cooking surfaces

- By the prudent selection of materials based on their thermal conduction coefficients, heat can be extracted from the hopper and combustion chamber by the use of:
  - Additional flat aluminium plates
  - Thick mild steel for the combustion chamber and stainless steel for other components

Principles of construction – 12 mm aluminium plate inserted between hopper and the combustion chamber



Bottom of the hopper showing the secondary air pre-heater and tangential injection to induce vortex in the combustion chamber

Incidental breaking with convention (Meditations on a split level oven)

- In a multiple plate stove, why should all plates lie in the same horizontal plane?
- Innovation is to break with convention whereby cooking plates are co-planar, in favour of a configuration in which cooking locations (*pot spots*) are at different elevations – bi-planar – designed to maximise heat capture into multiple cooking surfaces.

Co-planar configuration of the SeTAR BLDD 5 (Bottom-Lit Down-Draft) stove

Proof of concept:
bi-planar conductive down draft stove

Pot 1 with 7 litres of water in conventional position in primary plane above hopper.

Two additional pots, 3 L and 1.8 L boiling on aluminium conduction plate in secondary plane

Refinement – adding the aspirational element

Split-level down-draft solid fuel stove

1.1 kW delivered cooking power into the pots – ~20% efficient prototype

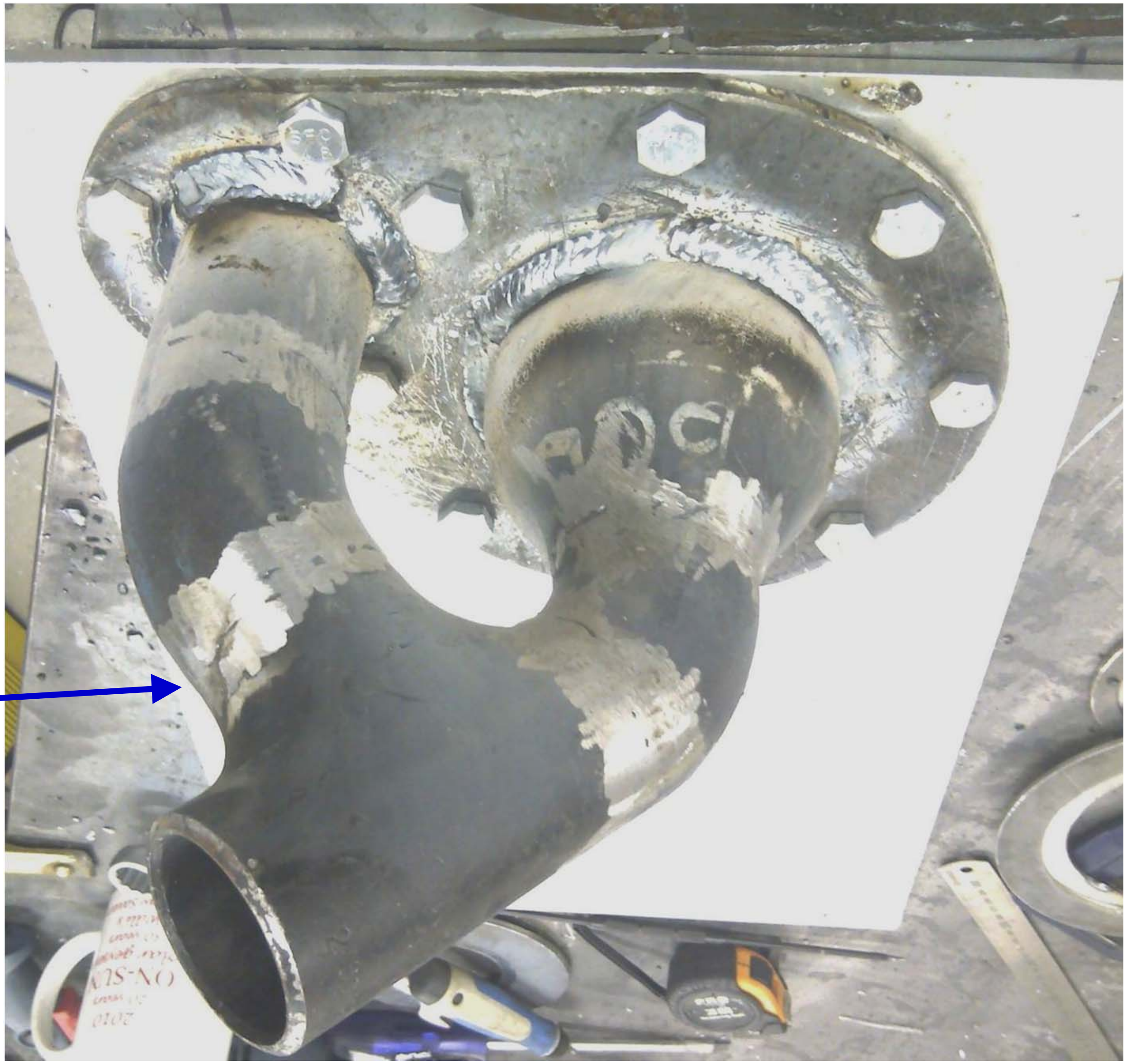
Reflective stainless steel cowl constrains radiative and convective losses, forcing more heat into the conductive plates.

The cowl acts as a protective barrier to prevent user contact with the 400°C hopper.

Further refinements:

Optimising heat transfer to the aluminium plate with thicker and more conducting pipes (mild steel rather than stainless steel)

Underside: Combustion chamber (right) and rising gas path (left)



Conclusions

- The final configuration bi-planar conductive down-draft stove increases the number of pots which can be simultaneously heated.
- The system cooking efficiency is increased.
- In addition to extending the cooking capabilities, manufacturing costs are lowered by eliminating the aluminium extrusion and replacing it with two variously perforated flat plates.
- Further optimisation is possible.
- Overall smoke and CO emissions are lowered for wood and all grades of coal compared to conventional bottom-lit updraft stoves.

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