Natural draft for better biomass burning cookstoves

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NATURAL DRAFT FOR BETTER BIOMASS BURNING COOKSTOVES

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ABSTRACT
In the laboratory of the Woodburning Stove Group at the Eindhoven University of Technology, much of the research effort is focused on developing stoves in which the wood fuel is completely burned. The products of complete wood combustion, carbon dioxide and water vapour, pose neither pollution nor health problems to either user or surroundings. To bring about clean combustion, novel ways of conducting the burning process are being developed, such that the evolution of volatiles can be kept under control and air can reach the places where it is needed. The sole motive force available for moving air or combustion gases is natural draft. In this paper a number of experimental wood burning cookstoves is discussed, in which use is made of natural draft.

KEYWORDS
Biomass fuel, natural draft, woodburning cookstoves, clean combustion.

INTRODUCTION
Woodburning cookstoves, designed at universities, to be used in developing countries should ideally use less wood to accomplish a given cooking job than the traditional stoves they pretend to improve upon. In addition, the improved stoves should produce less environmental pollution and be user friendly, to use a modern cliche. Next to the specific fuel consumption, the pollution aspect has received a fair deal of attention in the Eindhoven based Woodburning Stove Group. The solution is sought, not in chimneys (that only bring the pollution out of the house into the environment), but in clean combustion. There is no reason why wood, predominantly consisting of the non poisonous chemical elements Carbon, Hydrogen and Oxygen, should not be capable of burning up completely (except for the ash), producing such non polluting substances as carbon dioxide and water vapour. The quest for clean combustion is a technological challenge.
Since good combustion is a matter of the right temperature, transport of air to the combustion zone, mixing of fuel and oxidant and removal of combustion products, part of the solution has to do with inducing flow in gases. Extraneous...
Woody means for moving air and combustion gases being absent, all gas flow must be induced through natural draft. This paper describes some of the attempts by the group to realize clean combustion of wood.

WOOD AS A FUEL

Wood is a difficult fuel for the following reason. Roughly 80% of the original dry mass of wood, upon heating to a moderate temperature of 250°C, is expelled in the form of gases, vapours and finely divided droplets, leaving behind a solid remains called charcoal. The so-called volatiles represent roughly 60% of the original combustion value of the wood.

AVAILABLE DRAFT

Chimney draft is the underpressure resulting from the difference in weight of a vertical column of combustion gas and an equally tall column of ambient air. Classically, chimney draft is used to draw air into the combustion space of the stove and, after part of the heat of combustion is used, to expel the combustion gas into the environment, some distance away from those enjoying the fire.

Fig. 1. Specific chimney draft for gas temperatures to 1450°C. The top pair of curves is for sea level, the upper curve of each pair is for an ambient temperature of 20°C, the lower for 30°C. The middle pair of curves is for an altitude of 2000, while the lowest pair is for an altitude of 5000 m.

The principal variables in draft are the temperature and the height of the column. A simple expression was derived, giving the specific draft (Pascal per meter vertical chimney length) as a function of ambient temperature, gas temperature and altitude. As the draft also depends on the composition of the gas, numerical values in the formula were taken from stoichiometric combustion gas of pure carbon. This gives the worst-case condition (densest gas e.g., least specific draft) for most combustion gases one is liable to come across.
\[ q = 3153.14 \left( \frac{1}{T_a} - 1.0875/T_g \right) \exp\left( -0.0340032/T_a \right) \]  
(1)

Where:
- \( q \) specific draft [Pa/m]
- \( T_a \) Ambient temperature [Celsius]
- \( T_g \) temperature of hot gas [Celsius]
- \( z \) altitude [m]

There is one other case we can come across, especially in newer stoves viz the specific draft of hot air. Equation (1) in this case simplifies to:

\[ q = 3153.14 \left( \frac{1}{T_a} - 1/T_g \right) \exp\left( -0.0340032/T_a \right) \]  
(2)

In Fig. 1 specific chimney draft is plotted against gas temperature for several altitudes and ambient temperatures.

**EXPERIMENTAL STOVES**

During the past years several experimental stoves have been constructed in which some hypothesis for clean burning was tested. The most important fact to emerge was that clean combustion of biomass on a small scale was proven a possible dream. In the following discussion of their salient features we follow the chronological order in which they were conceived and tested.

**Tubular Stove**

In late 1979 the first experimental stove was built with the express purpose of looking into the influence of secondary air when it is injected into a stream of volatiles. This became the so-called Tubular stove. It consists of a steel burner pot with a perforated bottom, a depth of 420 mm and an inside diameter of 90 mm. At a height of 250 m from the bottom the wall is perforated with six rows of holes of 4.4 mm diameter. The burner pot is let into a wider pipe, closed at the bottom and provided with two inlets such that the lower inlet controls the primary and the other controls the secondary air supply (see Fig. 2). Primary air enters through the perforated bottom through natural draft of the hot gases in the burner pot. The secondary air flows under its own buoyancy on being heated by the outer wall of the burner pot as well as through the natural draft of the column of hot combustion gases above the holes inside the burner pot. In the experiments it was demonstrated that secondary air can, under circumstances, bring about complete combustion of the volatiles liberated during pyrolysis of wood in the higher layers of the fuelbed. It also became clear that fairly rarely all conditions for complete burning could be met.

**Rocket Stove**

Early in 1984, work began on the so-called Rocket stove, first built by Mr. Larry Winiarsky at the Aprovecho Institute, (Eugene Oregon, USA) in 1983. In this tall stove natural draft ensures vigorous burning. The stove can burn...
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\[
\text{Pa/m} \quad \text{Celsius} \quad \text{Celsius}
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rocket stove, first built by Mr. Eugene Oregon, USA) in 1983. In s burning. The stove can burn fairly long straight sticks. Preliminary work proved that this stove can be controlled by varying the number of sticks burning simultaneously. It burns rather clean and reacts quickly to operation of the controls. Performance, including combustion could be improved by further work on locations for admitting secondary air and on control of primary air. Fig. 3 shows an advanced model that has not yet been built, in which the primary air flow can be set to burn the char at an arbitrary rate, providing an ambience of hot gas for charring the sticks. Air, warmed in the annular space between the inner and outer pipe is directed into the volatiles generated by the sticks. This stove certainly merits further investigation as it appears the only reasonably clean burning stove that can burn sticks.

Session 5.2.

In the summer of 1984 the so called Aldestove was designed, in which the concept of staged combustion of volatiles is used, just as it is supposed to occur in the multiwick kerosene burners (Romp 1937). The primary air flows up through the grate under influence of the natural draft in the burner pot. The secondary air rises as a result of absorbing heat from the outer wall of the burner pot. The secondary air is split into two partial flows, one rising into the central air pipe, to issue from the perforations in the central cylinder, the other going to the perforated part of the burner pot wall. Experiments, burning wood, showed the stove's capability of clean burning. However, the stove needs very careful tending and the range of control appears poor. During clean burning a pan can be placed on this stove without blackening.

Aldestove

In 1985 an improvised stove was built and used to test some assumptions concerning downdraft combustion of wood on a grate. Encouraged by the test results, an experimental downdraft stove was built in 1986, Fig. 5 showing its main features. When the stove is in operation, the chimney draft induces air to flow downward through the fuelbed supporting combustion of the fuel on the grate. The fire on the grate is of such intensity that the combustion zone

Fig. 3 Rocket stove

Fig. 4 Aldestove
tends to travel upward quite rapidly until the top surface of the fuelbed is alight, providing a source of pure radiative heat. Next to its potential as a clean grill, this stove has a potential as a two pan stove, enabling simultaneous cooking in two locations viz. one pan above the fire, the other just above the chimney. Figure 6 shows the relative concentration of carbon monoxide during operation of the stove.

CONCLUSIONS
The most heartening fact to emerge from the research, briefly described above, is that several roads seem to lead to clean combustion of wood in experimental domestic cookstoves. Natural draft is applied in novel ways, either bringing preheated air into contact with volatiles or to create vigorous and complete combustion upstream from the place of utilisation of the heat. In the case of the downdraft stove which at present looks the most promising, a disadvantage is that the stove body has to withstand high gas temperatures and needs good insulation in order not to lose too much heat on the way from the fire to the pan. Figure 6 shows the capability of the downdraft stove of very clean burning on the one hand and its sensitivity to being overcharged with fuel on the other. Clearly much more work has to be done before a clean burning biomass cookstove will appear on the market.

REFERENCES