# Heat from Wood *without noxious emissions*

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For perhaps 2 million years the genus Homo has used cooking fires to process food that would otherwise be indigestible, and provide light and warmth against the chills of the night. The comfort afforded by the radiation from flames has over the millennia imprinted a common perception of wood combustion as red and yellow flames dancing above a pile of faggots sitting on a bed of incandescent charcoal. However in just the last 25 years a spectacular advance in combustion technology has occurred that has the potential to change that perception fundamentally.

In 1989 Joachim Wünning, a German combustion engineer, unexpectedly observed that when an air-staged high velocity gas burner with a self-recuperative secondary air pre-heater was firing into a closed furnace in which the furnace temperature was 1000 $^{o}$C and air preheat was 650 $^{o}$C, no flame could be seen and yet the fuel was completely burned. The CO content was below 1 ppm and $NO_x$ emissions close to zero. The combustion was extremely stable, smooth and noiseless, the furnace atmosphere clear and translucent with a uniform temperature over the whole volume.

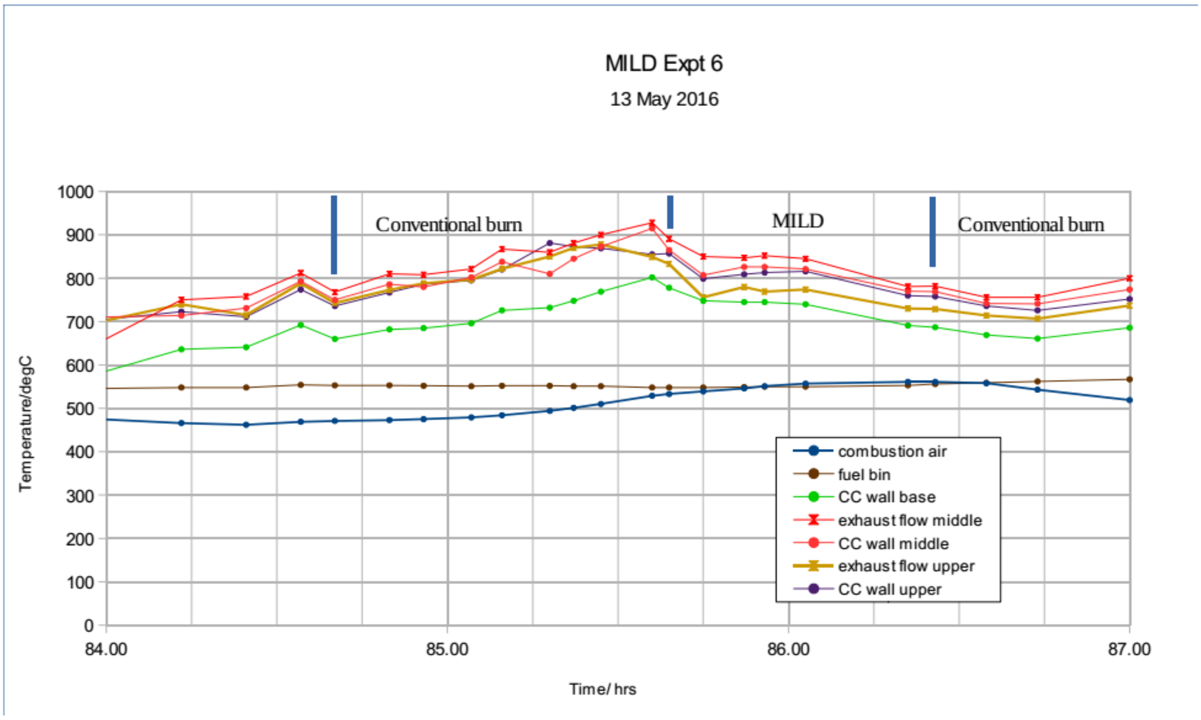
After investigation Wünning concluded that with the strong recirculation of exhaust gas, both the fuel and air jets were being mixed with exhaust gas, and heated and diluted before the fuel and oxidiser came into contact at temperatures above the level for auto-ignition. The lowered oxygen concentration slowed the resulting reaction leading to an extended reaction zone of uniform temperature much lower than the adiabatic temperature of a conventional flame. This technique of flameless combustion, which he called FLOX(® was patented worldwide and is now in application in many fields all over the world. Other terms for the phenomenon are MILD (Medium to Intense Low oxygen Dilution) and HiTAC (High Temperature Air Combustion).

Wünning gives reduction of $NO_x$ emissions as the motivation to apply flameless combustion in many cases, but other reasons for implementing FLOX(® include high thermal efficiencies, high combustion stability, improved homogeneous temperature distribution, reduced thermal stress for the burner, reduced noise, fewer burner failures, fewer restrictions on the choice of fuels due to the combustion stability. MILD is now widely understood to simultaneously offer both improved thermal efficiency and low pollutant levels. In studies involving bio-fuels it has been found that MILD is very tolerant of fuel quality.

With all its virtues could MILD be applied to domestic scale wood burners to vastly improve their efficiencies and emissions? The answer I think is yes. The temperature record of a MILD experiment carried out by the author with a gasifier based burner is shown over-leaf.

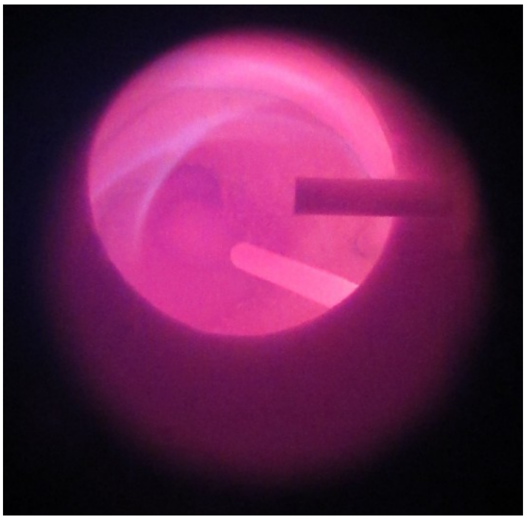
The burner is comprised of three chambers contained within a steel casing about 700 mm wide, high and deep. The first chamber is a fuel bin of 40 litre capacity to take batch loads of billet wood. It is heated by a wall shared with the tertiary chamber which is a plenum space above the secondary chamber, a gas burning cyclone. The burner distributes heat from the exhaust of the secondary chamber in an energy feed-back loop to the gasifying primary chamber, and an air pre-heater for the combustion cyclone. A third heat exchange function is radiative transfer to the steel cook-top which caps the assemblage. The moisture and gases generated in the fuel bin at up to 600 degC are drawn off from near the base as a simple fuel gas of hydrogen, carbon monoxide and nitrogen after passing through a bed of incandescent charcoal where the myriad thermal breakdown products, many of which are quite noxious, have been cracked out by interaction with the charcoal.[a fuel gas?!]. This gas is completely burned in the secondary cyclone at temperatures ranging from 600-1100 degC. A narrow single slotted grate at the base of the fuel chamber allows ash to be cleared.

The graph is a segment of a 4 day run, with peaking power outputs of 4-5 kW. Temperatures at 3 levels in the combustion chamber are shown. These are obtained from thermocouples placed on the cyclone wall or in the exit flow The combustion chamber is a cylinder 225mm deep; the fuel gas enters tangentially at the top, spirals to the bottom and exits up the centre into the tertiary chamber.

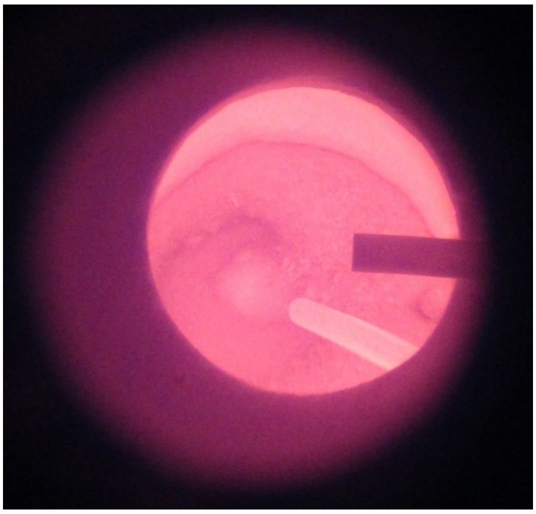



The MILD experiment was started at 84 hr 40 mins by allowing primary air into the fuel chamber through the grate to boost the gasification rate and raise the combustion chamber temperature above 900 degC. At that point a small auxillary charcoal burner was attached to the secondary air inlet, to provide dilutent $CO_2$ to the secondary air flow. The auxillary burner was withdrawn at 86 hr 25 min.

It is apparent that the temperature on the side walls at upper and middle levels is very nearly uniform compared with periods of conventional burning. The case for this as evidence of MILD is strongly supported by images looking into the combustion chamber during this process.



Conventional: combustion of $H_2O$ saturated pine cones



MILD: $O_2$ dilution 6%, excess air 4% $O_2$

Views looking into the base of the combustion chamber, through the tertiary chamber & exhaust port from an 8 mm hole in the top plate of the burner. Three thermocouple thimbles are visible (in order from RHS; exhaust flow upper, CC wall base, exhaust flow middle).