Masonry Heaters and the Clean Burning of Wood

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Abstract - When we are heating with a renewable form of energy - wood - we must realize that wood must be considered as a gas, when burnt. To attain total combustion and clean exhaust gases, the combustion temperature must be high and because of this the burning must accur rapidly. In order to get a heating cycle of 24 - 48 hours, the heater must be able to accumulate the energy released in rapid combustion. To control the thermal stresses, the heater must be correctly designed, and made of the right materials - clay based mortar and solid brick.

Fire, brick and ovens have all played an essential part in the development of human cultures. Man has employed fire everywhere in the world to lend comfort to his daily life, but in a cold climate like that of Finland, fire and the ability to master its use has been an absolute necessity, a foundation of civilization. Man is able to survive in a cold climate, eskimos, but to attain a higher level of civilization warmth is an absolute necessity.

In very early times and later also in Europe, man usually built his house using stone. If it was necessary to heat the house, an open fire was used. Radiant heat from the fire accumulated in the massive walls. This way of living was also adopted in Scandinavia by the wealthy.

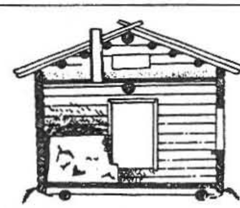
In Finland the evolution has been a little different. Originally we dwelt in tents with an open fire in the middle. If the fire went out, it rapidly became cold. The same hand-to-mouth mentality governed also the provision of food. Men had to go hunting all the time.

About the year 1000, at the end of The Viking Era the life of the Finns was changed dramatically by two innovations stemming from the east, from Russia. The first was the log cabin. Because it is possible to accumulate very little heat in the wooden walls, this type of house is usable in a cold climate only in combination with second innovation, the accumulating heater. The very earliest form of accumulating heater was simply a pile of stones, under which a fire was burnt rapidly, and the heat accumulated in the stones.

Fig. 1
A. A pile of stones - an accumulating heater
B. A log cabin with a wood heater

A

B



The life of the Finns became more stable, and a very important development was the possibility to use this new source of heat for drying grain in order to store enough food for the long winter. Agriculture in this climate immediately became more profitable, using these new means. Social life was dramatically altered. There was some spare time left to men - time to think - and even in Finland, some sings of culture could be seen. It is actually our opinion that the use of the stone rage stove, in which wood could be burned fast, is the basis of culture in Finland. Today the majority of the population of the world, north of 60° latitude are Finns. Our civilization is maintained by good heating methods.

We have been using this heat-storage wood-burning system now for 900 years, and feel able to assure you that the benefits of the clean and rapid burning of wood are inescapable.

To understand the difference in the ways of burning wood, we must first examine solid fuel. Fuels with a very great geological age, like coal, contain very little hydrogen, most of the energy is in the solid material. Coal can be burnt slowly and at a lower temperature. Still, high efficiencies can be achieved and the exhaust gases are fairly clean. A coal-burning stove can be small, and the fuel can be kept burning over a long period, giving out warmth all the time.

But coal is not however a renewable form of energy. That is why it is better to use the younger solid fuels, renewable in 1-30 years. These contain carbon, hydrogen and hydrocarbons. Two thirds of the energy-content of wood is in the gases, so we ought to consider wood as a gas. Total combustion occurs only at a very hight temperature. To achieve this high temperature, we must burn the fuel very rapidly. Most of the gases ignite at temperatures above 500 °C.

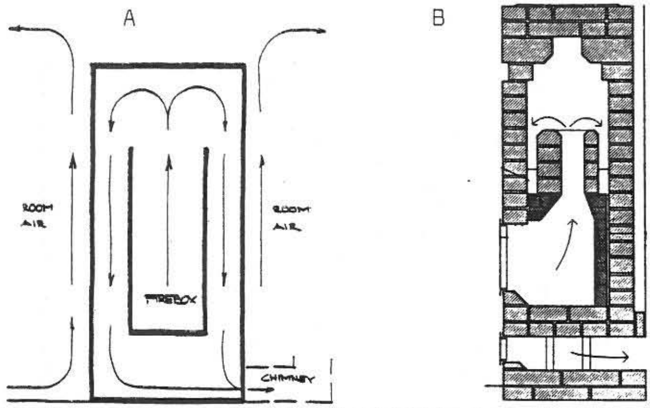
Five kg of wood can be burnt in 30 minutes, and about 40 kW can be released over that period. This is far too much for a modern one-family house, which needs on an average only 3-5 kW heating effect in the Finnish climate. So the surplus energy must either be dumped or accumulated. To be able to store so much energy the heater must be both high and massive.

The other reason why the wood-burning heater must be high is that wood burns with a very long flame. Whilst a coal flame is about 3-50 cm, the wood-burning is 150-200 cm. Thus it is obvious that a heater cannot be effeciently run on different types of fuel. In order to absorb all the heat, the channels containing fast flowing gases must be about 300-400 cm long before the gases reach the chimney flue.

Fig. 2

A. The contra-flow principle

B. A traditional Finnish contra-flow heater



A very good solution to these problems has proved to be the masonry wood heater, and especially the contra-flow type of a masonry stove. This system is a Swedish innovation, which has been used and developed in Finland over a period of a century. The contra-flow principle achieves an entively natural way of burning and heating. We allow the gases to rise from the firebox, and then allow the gradually cooling gases to give up their heat in their passage down the channels. Finally the convection currents start moving along the heater surface.

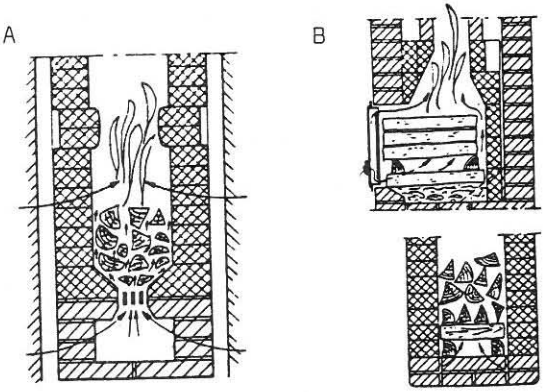
This type of heater has a very high efficiency of 85-90 %, and an extremely long life time of 50-80 years. To attain such high efficiency we require a high combustion temperature, and to attain this high temperature we require the correct airflow to both of the different combustion processes - first primary air to the cindery and then secondary air to the gases. Primary air can be led under the burning layer through the grate and secondary air should be led over the burning layer. To attain complete combustion, it is advisable to also have a secondary combustion space.

Fig. 3

Primary and secondary airflow to the firebox

A. Using grate

B. Using a double skin cast iron door



It must be understood that very rapid combustion necessarily causes high thermal stresses in a masonry heater. Recalling however, the long lifetime of these stoves, it is obvious that these stresses can be kept under control. On the one hand, the construction of the heater must be correct. This means that the sections warmed up at different rates are totally separated from each other. For example the firebox is separated from the outer shell of the heater. On the other hand, the correct combination of brick and mortar is vitally important. Our experience is that only a clay-based mortar, combined with solid brick, forms a combination strong yet flexible for a masonry wood heater. Otherwise cracking and fissures easily occur. This type of mortar expands almost as much as brick, and is strong yet flexible to tolerate a certain amount of movement.

Because of the short burning period and the demand for a heating cycle of 24-48 hours we have been developing a new type of heater which has an especially massive, double-skin construction. This means that inside the frame of the heater is the firebox as normal, and outside the frame is an outer shell. With this construction we can lengthen the heat-discharge period and we don't have too high temperatures on the outer surface of the heater. The double skin construction also gives us more possible finishes for the outer appearance of the heater - both as to form and surface. For example glazed tiles can be used.

The temperatures within the heater are vary greatly between the different parts. In the firebox the temperature is about 600 °C, immediately above it 900 °C, at the top of the heater the gases are 600 °C, and when they reach the bottom of the heater they have lost most of their energy, and the temperature is 200 °C. At the connection to the chimney flue, smoke should be at 180 °C, and at the top of the chimney 70-130 °C. The surface of a single-skin heater can be 75 °C, in a double-skin heater 45 °C.

Fig. 4

Temperatures in a contra-flow, accumulating heater, which has large doors. This type can be run with doors open to get an open fire-place feeling.

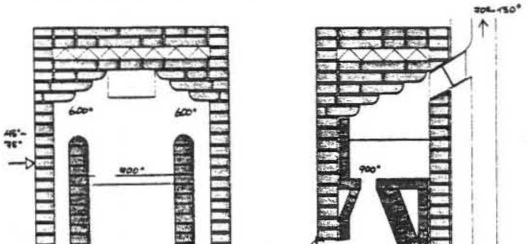
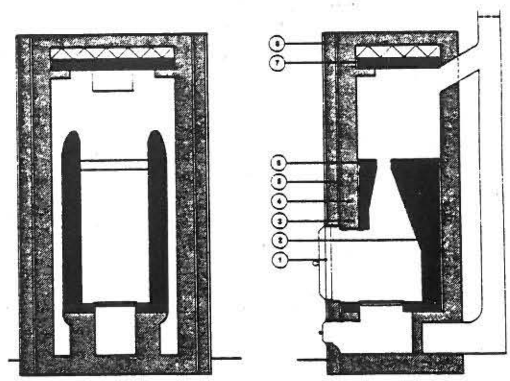


Fig. 5

A double skin heater
1. Cast iron doors
2. Firebox
3. Frame of the heater
4. Clay based mortar and solid brick
5. Outer skin
6. A throat leads to the second combustion chamber
7. Fireproof castable
8. Glazed tile or plaster



In Finland some very active research is going on, concerning energy saving in general and especially wood-burning heaters. Tampere University of Technology and the building materials industry have organised a joint research group. Its main purpose is to maintain the high standard of products, brick, mortar, fireproof materials, and metal parts, and to develop the design of the heaters.

It is probably not possible to get the efficiency any higher, and we always have had a very clean burn with clean exhaust gases. We could however design the heaters to be easier to build and use. We are designing heaters which perform well as a part of a combined heating system which uses, for example, electrical, energy and passive solar energy. We are also designing greater masonry cookingstove for the modern kitchen, to give tha family cook possibilities and pleasure. A stove which produces domestic hot water while cooking the soup has been tested. Our group is studying solutions for heaters in modern one-family houses. Other projects are also underway.

Fig. 6
A contra-flow type bake oven

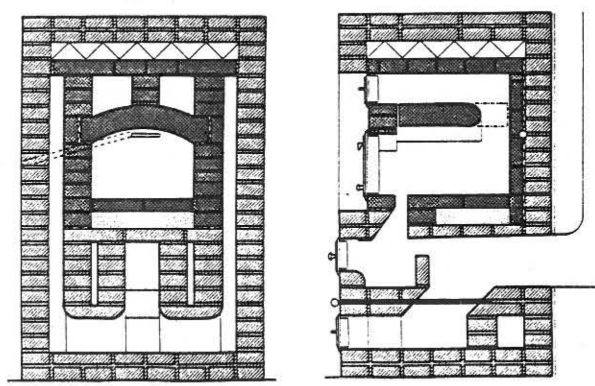
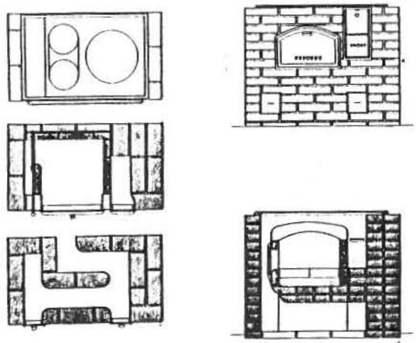


Fig. 7

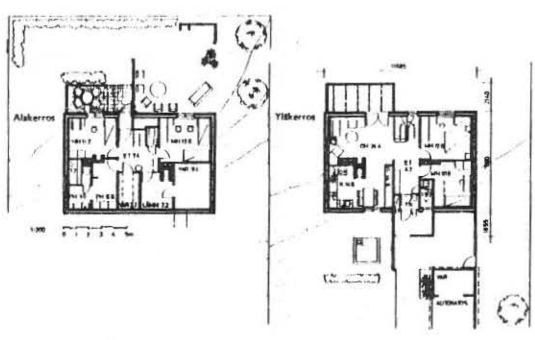
A wood-burning masonry cookstove with bake-oven and possibility to produce domestic hot water



We feel that even though there is a very long wood-burning heater tradition in Finland, we still have a great need for research. Both heater users and builders have an acute need for precise and reliable construction recommendations. We are quite confident that the results of our work will provide them with the technical information in a practical form.

Fig. 8

A one-family house designed to be heated with wood



Basement Main level