Doubling the power of a wood boiler with fixed grill

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Abstract: The article presents one technological modality of doubling the thermal power of a wood boiler. The base of departure is a wood boiler with fixed grill with a power of 30 kW and a yield of 62%. The technological variant is to increase with maximum 50% of the value of the heat transfer surfaces and modify the water circuit. For this, a FEM thermal transfer simulation program was used. In the first part of the article is presented the initial 30 kW wood boiler with the heat transfer surfaces. With the help of the FEM program, a thermal transfer simulation was performed. The results of the program were compared with those of the technical characteristics of the wood boiler. The authors of the article carried out different simulations with new surface types, changes in the water circuit, heat transfer calculations, fluid flow angles, so that the efficiency reaches over 75%. The design results were put into practice and the new wood boiler was built. The power of the wood boiler reached a maximum of 75 kW. The article presents some of the intermediate stages of execution. The wood boiler was tested in a specialized installation. It can be seen that the efficiency increased by 18%, from 62 to 80 and the thermal power reaches a maximum of 75 kW. The hot water flow is about 60 l/min, a very good value considering the type of wood boiler. Using the experimental results presented in this paper, wood boilers can be designed with much smaller dimensions having the same characteristics of power and water flow.

1. Introduction
Wood boilers represent an alternative for the production of heat ecologically and independently. The modern and ecological technique that has at its basis the use of wood fuel, manages to reach notable performances, having a high yield compared to other modern heating systems.

The wood boiler, from a constructive point of view, is composed of an enclosure with double walls. The wood fuel is burnt inside the enclosure, and the water circulates between the double walls, usually at a distance of 3-7 cm one to the other. The heat generated inside is taken over through the walls by the water that circulates between them. Wood boilers are composed of:

a) The fireplace chamber – the place where the wood fuel is inserted;
b) The fixed grill – the surface on which wood is placed;
c) The inferior chamber – the ash bin;
d) The hot air route – which is composed of more baffles so that the heat of the burnt gases be taken over in the proportion of 90% water;
e) Air ventilation system - insertion of the air necessary for fuel burning;
f) The water circuit – entry of cold water, its direction to the hot areas and discharge.

Because these boilers operate with wood that is not very dry, the thermal yield of the boiler is
pretty low, between 65 – 80%.

The wood fuel is renewable and economic compared to other gas heating solutions, with electric power or fluid fuel.

The maintenance of the equipment is made easily due to the burning process and low quantity of ash produced.

During the last years, the focus was more and more on the development of some new solutions of biomass use by the apparition of briquettes/pellets made of vegetal residues [2, 3]. There is a great diversity of row materials, starting from seed husks, wastes resulted from the technological processes of wood processing, tree trimming, straw from agriculture, etc.

The article presents the increase of power of a wood boiler from 30kW to 75kW by changes of: contact surface, water route or materials used.

2. The increase of thermal transfer surfaces

A wood boiler with fixed grill of 30kW was analysed from the point of view of thermal transfer surfaces and water circuit, cold water entry – hot water exit, see figure 1 (a) and 1(b). For this purpose, the boiler was disassembled and all components were analysed [1]. The boiler was designed (figure 2(a)) and the measured values were entered, resulting the assembly of figure 4. The main connections are:

1) Cold water entry
2) Hot water exit
3) The charge hole of the wood fireplace
4) The fireplace chamber
5) The fixed grill
6) Ash bin
7) Gas discharge

![Figure 1](image-url)

**Figure 1.** The wood boiler: (a) frontal isometric view; (b) anterior isometric view; (c) design frontal isometric; (d) boiler dimensions.
The overall dimensions of the analyzed boiler, with a weight of 84kg, are the following:
- with covers and charge hole - L x l x H = 1260 x 400 x 1025
- L x l x H = 1010 x 380 x 900

Figure 2. The wood boiler: a) without lateral left wall; b) view without left lateral wall.

The detailed analysis allowed the determination of the following dimensions for the main components:

a. The fireplace chamber – 1.74 m²
b. The hot air route – 1.06 m²
c. The fixed grill – round pipes – 0.47 m²
d. The inferior chamber (the ash bin) – 0.82 m²

The total surface of thermal transfer was determined at 4.09 m².

The fixed grill (figure 3) is composed of 6 round pipes with diameter of 42mm inside which water passes.

Inside the burning chamber there are “air nozzles” filled from outside through a natural air vent for the homogenization of fuel burning [2]. The nozzles are practically some orifices performed in the „L” profiles of the boiler walls.

Figure 3. Fixed grill.

The inferior chamber transfers the heat only through lateral surfaces. In the inferior part, a lack of
thermal transfer was acknowledged. The water circuit is achieved only according to the principle of filling from bottom to top of the boiler without taking into account the areas with high temperatures. Because of this, high temperature losses exist, the boiler yield being at the inferior limit [4].

![Boiler design](image1)

**Figure 4.** Boiler design, (a) isometric rear view, (b) detail 1) inside wall; 2) outside wall; 3) distance between walls.

The adequate dimensioning of the boiler, namely of the heating power, represents an important condition for the economic use and appropriate operation of the boiler. The boiler must be chosen so that the nominal power corresponds to the heat loss of the heated space.

Following the analysis of the existing situation, the following changes were proposed and performed:

a) The burning chamber was dimensionally changed, in the sense that the pipe length increased from 600 to 900 mm and 3 more pipes were added, figure 5. Therefore, the values of the thermal transfer surfaces changed.

![Redesigned boiler](image2)

**Figure 5.** Redesigned boiler.

Compared to the initial values, an increased was acknowledged by 55.7% of the thermal transfer surfaces.

The total thermal transfer surface increases to 6.37 m², being distributed as follows:

1.  
2.  
3.  


a. The fireplace chamber – 2.68 m²  
b. The hot air route – 1.63 m²  
c. The fixed grill – round pipes – 0.71 m²  
d. The inferior chamber (the ash bin) – 1.35 m²

3. Change of water circuit
As regards the water circuit, in the initial variant, the entry of cold water was made from the inferior section, at approximately 75 mm from the basis, by the anterior side of the boiler, through the gas discharge wall. The water was pushed through the boiler walls and an optimal route was not created in many cases. It was also acknowledged that the water inside the pipes used as fixed grill was circulating very difficultly. These aspects were noticed and quantified by means of thermal images during boiler operation [5].

Considering those acknowledged, the water circuit was changed in the following mode:
1) The water entry into the boiler was directed completely to the fixed grill by means of some deflectors. This way, the cold water is warming very quickly and the thermal yield increases;
2) The fixed grill was mounted at an angle of 3° from front to the back so that there is a natural discharge slope for the hot water. At a higher angle, the wood tend to slide to the loading hole, making difficult the access to the charge hole;
3) Pipes placed transversally to the boiler were inserted in the superior section of the fireplace. This way, the recovery of an important quantity of heat from the superior area of the fireplace was facilitated and the homogenization of the water temperature in the superior section could be achieved. The pipes mounted transversally were assembled in 2 variants. One parallel to the ground, and in the other variant, the pipes were placed under an angle of 20°. The second variant led to a better result – see figure 6.
4) A fan was inserted that introduce air in the fireplace chamber. The quantity of fuel consumed is much higher and, therefore, the oxygen demand must increase. In the case of the old boiler, the air admission was natural. The fan inserted has a variable speed and, therefore, it produces a variable flow. For this, a sensor was inserted into the boiler, which commands the quantity of air necessary.

The chosen welding procedures used were: WIG and MAG. Considering the operation temperature – 90 – 100°C and the working pressure, 4 – 5 bars, all the welded joints were made by welding the root layer (the first layer) by WIG procedure, and then the second layer, as the case may be, WIG or MAG, according to the strap length [6].

The addition material used was an ER 70S for WIG and G100 for MAG procedure. Because the sheet thickness did not exceed 5 mm and the basic material is S355, pre-heating was not performed.

Figure 6. Image with the new boiler: (a) the fixed grill and the fireplace chamber; (b) semi-assembled boiler.
After the welding of the first layer, checks were conducted by the examination with LP and PM. All non-conformities were remedied. And after the welding of the second layer, the control with LP was performed.

The boiler was assembled and thermally insulated. Then, it was connected to a verification and homologation system (see figure 7).

The values obtained were very good (see figure 8). For example, 22 minutes after the lighting of the fire, the following were obtained:

1) Thermal load: 75.31 kW;
2) Yield 120.5%
3) Cold water temperature – 18.5°C
4) Hot water temperature – 91.8°C
5) Hot water flow – 3.062 m³/h
6) Temperature of burnt gases discharged – 34.9°C

**Figure 7.** Boiler connection.

**Figure 8.** Boiler verification: (a) after 22 min; (b) after 29 min.

### 4. Conclusions

Following the investigations and practical performance, thermal power increase was managed from 30kW to 75kW and yield increase by the increase of the transfer surface by 55% and the change of water route. Such boilers can be redesigned in the future taking into account those listed above.

The wood boiler is intended for the economic and ecologic heating of familial residences, cottages, of small-size factories, workshops and other similar objectives. It is the first choice for those who do not have access to gas, but also a good solution for heating, as modern, practical, ecological and efficient alternative to the wood stove. The wood boiler is capable to use efficiently solid fuel with classical burning, i.e. wood, coal, cox or pellets.

The solid fuel is the most used resource for heating used by us, human beings, a long time, and for many areas of Romania, but also worldwide, it is further the most accessible resource. Therefore, it is easy to understand why heating equipment operating based on solid fuel are still used by a high...
number of persons and why the companies producing them are aiming at making them more and more efficient.

These experimental researches were carried out from the will to improve as much as possible these boilers, and constructive and technological changes were made, such as re-dimensioning of the thermal transfer surfaces and redesign of the water circuit, for the increase of wood boiler power.

The wood boiler is the cheapest, it produces a high quantity of heat, if the wood consumed comes from cutting places, it is ecological, and the costs of maintenance are practically zero. The wood hating is and it will remain the cheapest heating form.

5. References
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