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TECHNICAL ASPECTS OF TILED STOVES CONSTRUCTION

TECHNICKÉ ASPEKTY KONSTRUKCE KACHLOVÝCH KAMEN

Abstract

One of the most important technical properties of the tiled stove is their accumulative capacity. The accumulative capacity is given by more parameters, but most important are thermal-technical properties of ceramic materials. Ceramic materials are as the main element of tiled stove interior design; as well they make the overall exterior appearance. The constructional solution of fireplace and ducts configuration has influence beside technical parameters to whole shape and design of tiled stoves. Based on a detailed examination of constructional solutions and a series of executed tests were determining mutual connection of monitored parameters as an accumulative capacity, efficiency, emission characteristics, performance and dimensional characteristics.

Abstrakt

Jednou z nejdůležitějších technických vlastností kachlových kamen je jejich akumulační schopnost. Ta je dána více parametry, ale nejdůležitější jsou tepelně-technické vlastnosti používaných keramických materiálů. Keramické materiály jsou jak hlavním prvkem vnitřní konstrukce kachlových kamen, tak tvoří jejich celkový venkovní vzhled. Konstrukční řešení ohniště a uspořádání tahů taktéž ovlivňují mimo technických parametrů celý tvar a vzhled kamen. Na základě podrobného zkoumání konstrukčních řešení a řady provedených testů byly stanoveny vzájemné souvislosti sledovaných parametrů jako akumulační schopnosti účinnost, emisní charakteristiky, výkonové a rozměrové charakteristiky.

1 INTRODUCTION

The tiled stove offers to users the ability to use relatively inexpensive, universally available and renewable sources of energy for heating. The need for such offer is very actually. The purpose of the tiled stove is not only a wood burning and creating sense of comfort and romance, but the use of heat produced by combustion for heating the room. The offered equipment must meet current requirements, however, among which stands high efficiency and environmental acceptability. It is necessary to focus attention on the possibility of increasing their effectiveness. It is possible to say, the price increase of fossil fuels is inevitable, and if the consumer not to be too affected by these developments, must use the most reliable option to increase the efficiency of energy use.

Because of decreasing power demands of the thermal source in residential buildings, there are instances where tile stoves, which can cover all heating demands, are the best choice. With their accumulation abilities, they can deliver heat for several hours without adding more wood, thus decreasing the need for refuelling and increasing comfort. Another advantage is that they are not dependent on electrical energy.

The objective of the measurements was to show the influence of a competitive solution on their thermal-technical properties. During measurement were recorded the surface temperatures of

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two types of differently constructed tile stoves (medium-heavy up to heavy constructions). In addition, the influence of the efficiency and the temperature of the burnt gases and the thermal output of the stoves were monitored. The relation between the design and the technical solution of the tile stove was shown by the measured values.

2 INFLUENCE OF TILE STOVES AND THEIR FORM

The basic function of a tile stove is heating. The functional parts of a tile stove influence the form, size and the overall appearance of the stove. During its development the tile stove obtained its characteristic form from its working parts and the material used.

The outside of a single-chamber stove shows it's inside construction. The outside form corresponds to the inside form.

The outside of a "Draught stoves" tile stove resembled a smoke flue (draught).

Figure 1 Room tiled stove called „Draught stoves"

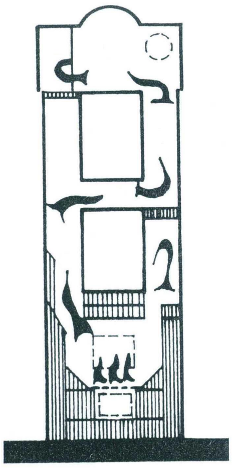


Figure 2 Internal structure of tiled stove called „ Draught stoves "

Further development of the stove made it more compact, the draught units were hidden due to the construction, as well as for practical reasons. The geometry of the fireplace and the arrangement of the draughts had to be changed because various types of fuel were used. Mass production led to a return to smaller tiles. The outside shell no longer reflected the inside construction of the tile stove.

The surface of the tiles was decorated with various ornaments. It was assumed that this increased the surface area of the tile stove through which heat is transferred into the room and increased the output of the stove.

Heat from a high stove rose close to the ceiling, while on the floor it was colder, therefore the body of the stove needed to be lowered.

The next development changed the inside construction of the smoke flue. The flow of flue gases was turned towards the floor; the stove had legs which, in addition to the needs of heavy construction, gave an impression of lightness. Another advantage of using legs on a tile stove was to protect the floor from the heated base of the stove.

Attention was then turned towards thermal-technical problems and the aesthetic properties became less important.

3 EXPERIMENTAL MEASUREMENTS

To determine the effect on the structure and thermal emission characteristics was make extensive set of measurements. The objective of the measurements was to verify and evaluate the thermal-technical properties and behaviour of the ceramic materials, and whole stoves, used to construct wood burning fireplace. This did not involve specifying the basic technical parameters of individual materials, but measurement of the whole fireplace or stove produced from these materials. All the measurements were in accordance with requirements of ČSN EN 12 240.

Traditional ceramic stoves were measured, on which the outside ceramic tile shell was tiled inside with refractory boards and the interface filled with a stove substance. The front and the rear wall is inside a 25 mm thick refractory walling, one side wall is 30 mm and the other 50 mm. A diagram of this construction, known as KK1, is shown in Figure 3.

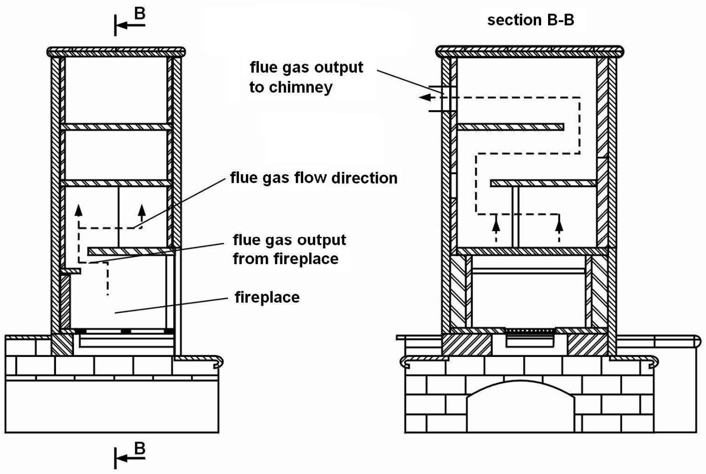


Figure 3 Schematic cross section of the stove and the flow of flue gases – KK1

The second type measured was a stove with a channel flow of flue gases which uses the same construction for the fireplace (the only difference is the upper outlet of flue gases into the flue way). The stove body consists only of ceramic tiles, has thin walls and a relatively stable construction. Its inside space is only heated by radiated heat from the walls of the grate and the flue way. This type of construction is known as KK2 and is shown in Figure 4.

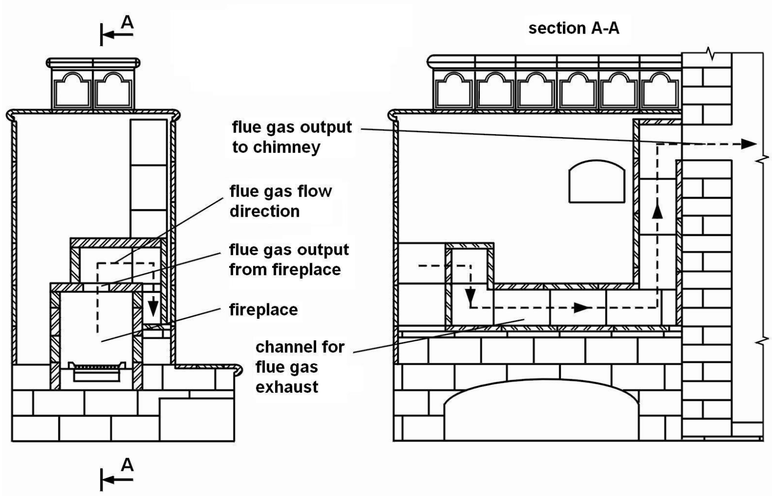


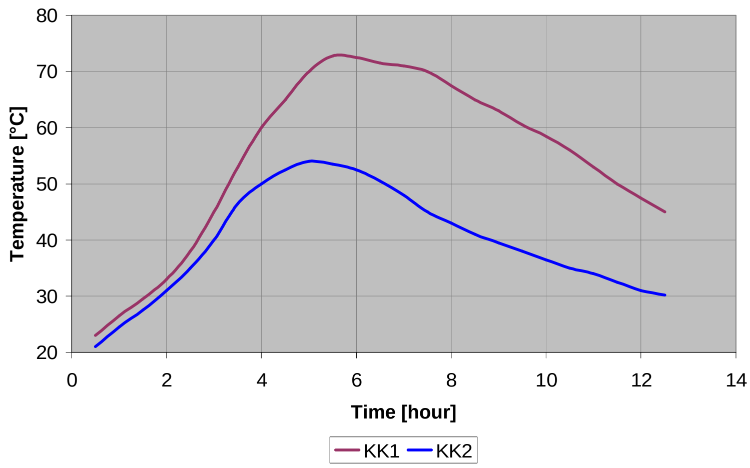
Figure 4 Schematic cross-section of a stove with the flow of flue gases – KK2

To evaluate the results of the tests on two basically different constructions of ceramic stove, the total weight of the ceramic materials used had to be known because this influences the thermal accumulation properties of the stove. The total weight of the KK1 stove is about 630 kg, and the KK2 stove about 490 kg. This weight includes the used fireclay as brick or board, ceramic tiles and the filling material.

For example, the specific thermal capacity of commonly used ceramic materials does not differ significantly and varies around 0.7 $kJ.kg^{-1}.K^{-1}$. Greater individual differences can be found in thermal conductance, the value of which for fire clay is about 1.1 – 1.2 $W.m^{-1}.K^{-1}$ and for a ceramic body about 0.7 $W.m^{-1}.K^{-1}$.

Because of the construction to produce more suitable conditions for transferring heat (the KK1 stove transfers the majority of heat by convection, whereas with KK2 radiation is dominant) the body temperature of the KK1 stove increases faster (maximum thermal gradient 15 °C/hour) than the KK2 stove (10 °C/hour). Therefore the KK1 is heated to the higher temperature of 73 °C than the 55 °C for the KK2. Because of the higher accumulating properties of the used materials and the higher temperature of the KK1, the amount of accumulated heat is significantly higher and, therefore, when heating a room by accumulated heat (without burning wood) this stove can produce more heat (higher temperature and longer time), than the KK2. The KK1's surface temperature cools to 40 °C after about four hours. This measurement was taken by 13 kW heat input of tiled stove. To the stoves was sucked by 5 hours and at hourly intervals.

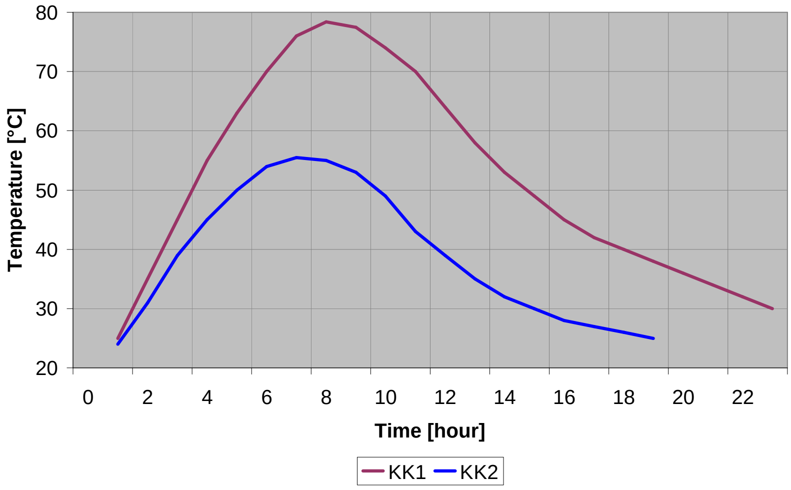
The properties of the stove have a unique effect on the average surface temperature over time, see Graph 1.



Graph 1 Average surface temperatures with power 13 kW

In the other measurement was simulating the normal operation of the stove with a heat input of 11 kW. The stove fuel was supplied at hourly intervals for 8 hours.

The average surface temperatures confirm that the lower heat input power decreases the maximum thermal heating gradient of the KK1 to 10 °C/hour and of the KK2 to 6 °C/hour, the relation between both remains the same. The maximum average surface temperature for the KK1 was increased to almost 80 °C, whereas for the KK2 the increase was omissible. This shows the KK1's greater accumulation ability, whereas these possibilities are exhausted for the KK2. This is confirmed by the cooling curves, see Graph 2. Numerical measurements are given in Table 1



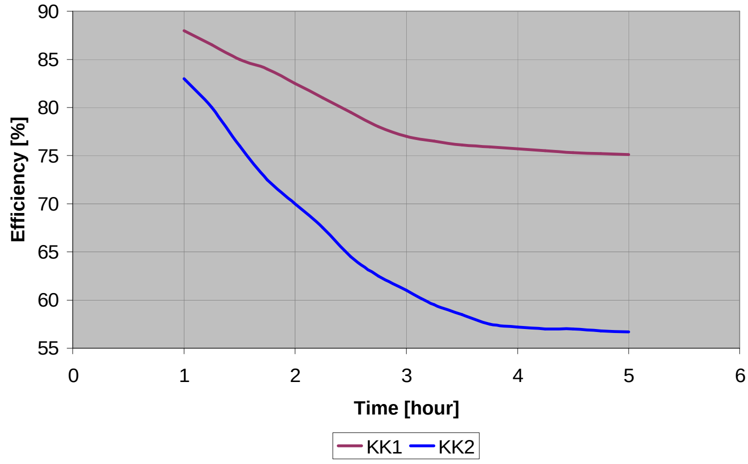
Graph 2 Average surface temperatures with power 11 kW

Table 1 Average values of measured and calculated values at the stove KK1 and KK2

	t flue gases	CO dry	CO n=1	CO O_2=13	n	η	power	input	fuel quan-tity	t room
	[°C]	[%]	[%]	[%]	[-]	[%]	[kW]	[kW]	[kg]	[°C]
KK1 13 kW	121,69	0,16	0,838	0,31	5,283	77,376	10,06	13,00	15,00	21,5
KK2 13 kW	172,17	0,12	0,66	0,25	5,57	65,39	8,5	13,00	15,5	17,00
KK1 11 kW	165,79	0,19	0,98	0,37	5,11	69,54	7,65	11,00	20,00	22,40
KK 2 11 kW	204,62	0,1	0,65	0,25	6,36	54,52	6,00	11,00	20,8	18,00

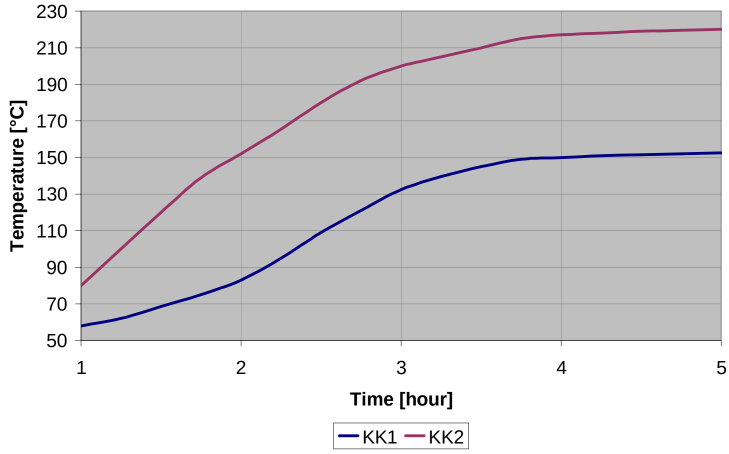
The heating efficiency can be expressed by the efficiency of the stove. Unlike stoves and other combustion equipment that operates continuously, the supply of fuel is not constant and the accumulating properties of the stove's body play an important role.

Graph 3 shows the efficiency of the stove when burning fuel, i.e. during the first five hours of the test. The efficiency of the stove was stated using an indirect method and the only loss which significantly influences it is the loss of physical heat of burnt gases (chimney loss). In the graph the tests last 4 hours because the 1st hour, i.e. the 1st consignment of fuel is the hard to define status of ignition, heating the chimney, etc.



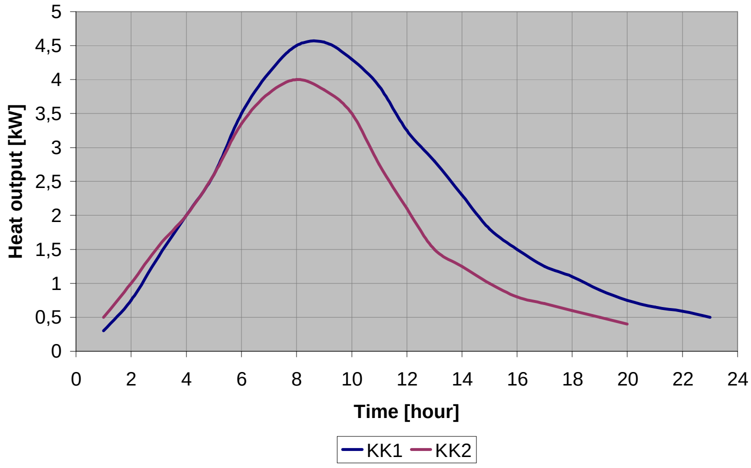
Graph 3 Efficiency of the stove

Graph 4 shows the time flow of flue gas temperature in the chimney.



Graph 4 Time flow of flue gas in the chimney

To evaluate each stove, one of the decisive parameters, in addition to efficiency, is the heat output. The heat output over time is shown in Graph 5



Graph 5 Heat output of stoves KK1 a KK2

The calculated thermal output values during the whole of the test under normal operating conditions show the unique benefits of the KK1 tile stove with heavy walling. The given heat output is the heat for heating the room. When the stove is heating up, the KK2 with its light construction gives a slightly higher heat output and lower heat inertia. However, this is only due to the greater heat-exchange surface area of the stove because the surface temperatures are lower than for the KK1.

It is clear from the above that the construction used determines the thermal-technical properties of the stove. The main advantage of a stove with a medium-heavy or heavy construction is its great heat inertia. Because of the materials used and the great weight, the stove can accumulate a large amount of heat when heating up and transfer the heat when cooling into the room. This result of this principle is high efficiency of the use of the fuel energy higher than at the stove with a light construction, high performance and convenience of use. However, the construction of smoke draughts must ensure the effective transfer of heat from hot flowing flue gases into the ceramic walls. The construction must be carefully selected so that the heat is transferred by convection. Radiation is less suitable and would occur at temperatures which cannot be reached in burning equipment of this type.

This issue is best described by Graph 3, showing the efficiency during comparable tests for both stove constructions when heating by wood, i.e. five or eight hours. When heating up stoves from cold, the ceramic body of the stove acts as a thermal accumulator and receives and stores heat taken from the burnt gases. Therefore, at the beginning, the chimney loss is low and, of course, efficiency is high. During further heating the temperature of the flue gases does not change. However, the temperature of the stove body, the ceramics and heat-exchange areas increases because of the decreasing temperature difference of the flue gases and the ceramics, the intensity of the transfer of heat decreases and the flue gases are less cooled. The temperature of the flue gases at the outlet into the chimney increases, see Graph 4, and, therefore the chimney loss increases and the efficiency of the stove decreases. The heat capacity of the stove is gradually met and the whole system becomes stable according to the conditions of the burning process (fuel, method of adding wood, air regime, and excess air) and the construction of the smoke draughts, showing the intensity of heat transfer, its accumulation and transfer into the surroundings, i.e. heating rooms.

The measurements show that the primary physical properties of the materials used do not determine the main parameters of the stove, but mainly the construction of the stove, its weight/size and the quality of its construction.

4 CONCLUSIONS

To determine the technical aspects of design tiled stove were taken a wide range of measurements of the thermal-technical parameters of two basically different ceramic stoves (medium-heavy and heavy construction) with a fireplace for burning wood. In both cases a grate with the same construction was used with a nominal heat fuel input power of 11 kW.

The measurements showed that the primary physical properties of the materials used do not determine the main parameters of the tile stove, but mainly the stove's construction and the quality of its construction.

This is illustrated by the efficiency during comparable tests of both types of tile stove when heated by wood. But please note that higher efficiency leads to lower fuel consumption with the same heat output, moreover, it can be used for more intensive heating with a higher heat output.

The tests showed that with the same method of heating in the same fireplace, increasing the weight of the ceramic materials by 28 %, increased the total efficiency of the stove by about 23 % and prolonged the radiation time by approximately 50%.

The measurements showed that the construction and also the design of the tile stove influence its technical parameters. The main thermal-technical property of a tile stove is its accumulation capability, which depends on the construction and the quality of the construction, i.e. the overall amount of construction materials. A stove with a medium-heavy construction responds faster to outside conditions, but has lower heat inertia. Heavy construction tile stoves are a dominant element of each room and are characterized by their high accumulation capability and heat inertia.

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