New system of fuel combustion and prospects for its application

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In this article I would like to point out the main ideas of our system as well as dwell on some points of our system of fuel combustion that make it different from other systems. Classification of heat-producing devices (heat-generators) with regard to gas flow movement mechanism.

1. The systems with forced gas movement (hereinafter referred to as forced-gas systems) incorporate: convective systems with channels connected in series. Parallel convective systems (including a counterflow system). Combined convective systems; **These systems are used at present all over the world.**

2. The system of free gas movement, to which belong channel-free (bell-shaped) convective systems. **This system was developed by me**.

In furnaces built in accordance with the system of forced gas movement hot gases under the action of chimney draft are running along the channels to the top and to the bottom, to the left or to the right. When hot gases move over the channels their heat energy is used for heating the walls, the gases in this case cool down. The furnace is heated non-uniformly, due to that the danger of crack initiation becomes greater. These furnaces are not provided with any other space for placing the heat exchanger, except for the firebox.

In channel-free-bell-shaped furnaces the convective system consists of bells connected in series. When hot gases being lighter move through the bell, they rise up and are accumulated in the bell where they uniformly warm up the walls or the heat exchanger that is placed inside the bell. Cold gases being heavier are pushed down and pass through the lower part of the bell into another bell or chimney exerting no influence on the heat exchanger.

<u>The system of free gas movement in heating devices as viewed by I. V. Kuznetsov.</u>

Heat-generating devices are built in accordance with the formula "The stove's lower level and the firebox are combined to form a single space creating a lower bell". The essence of the formula is as follows. It concerns fuel combustion in the firebox placed inside the bell and optimal use of extracted heat energy. The conception is aimed at receiving maximum amount of heat from the fuel combustion and using it efficiently; the design of heat-producing device shall meet functional requirements and ensure maximum heat transfer.

The bell is practically a vessel turned upside down.

Let's fill the bell with a portion of hot air. Hot air being lighter will rise up and push colder heavier air out of the bell and will remain there until its heat warms up the bell's walls. As a result we will obtain a system accumulating heat of hot air in a limited space. Hot air moves in the bell due to convection and does not require external energy. If hot air flow is transferred through the lower zone of the bell the latter will accumulate its heat. The heat of hot air will be transferred to the bell's walls and to the heat exchanger placed inside the bell, and the surplus of heat (cooled air) will be exhausted. Water boiler registers, air heater, retort for fuel gasification, etc. can serve as the heat exchangers.

The gas flow that runs in a heat-generating device with any convective system transfers heat energy and products of combustion. In order to understand the difference of gas flow mechanism in forced -and free gas movement system let's imagine that an electric heater is the source of heat. In this case it is not necessary to exhaust the products of combustion. In the system of free gas movement, for example in the double-bell furnace the heat transfer takes place due to natural forces even with a closed damper (without chimney draft). A certain time is needed to transfer heat and in case the bell or the heat exchanger do not have enough time to accumulate the entire heat generated by the electric heater, the surplus of heat in the form of waste hot air, will be transferred to the second bell. The heat transfer in the second bell is made in the same way as the heat transfer in the lower bell.

This process of heat energy transfer reflects the essence of the system's name" "the system of free gas movement". In order to exhaust the products of combustion, if fuel combustion is the source of the heat energy, chimney draft is necessary. It should be pointed out that gas movement inside the bell will be turbulent.

As distinct from the system of free gas movement, the heat energy transfer in the system of forced gas movement is possible only in case chimney draft is available. When hot gases run along the channels their heat warms up the walls while the gases themselves get cooled.

The stove warms up non-uniformly; therefore the probability of crack initiation increases. These stoves are not provided with any other space for placing the heat exchanger, except for the firebox.

So this is the <u>essence</u> of difference in mechanism of transfer and usage of heat energy in the above-mentioned systems.

It should be pointed out that there is a significant difference between the system of free gas movement developed by I.V. Kuznetsov and the system of free gas movement the basis of which was laid down by Professor V. E. Grum-Grzhimailo that was further developed by I.S. Podgorodnikov.

In the system developed by I.V. Kuznetsov the author speaks about " fuel combustion in the bell and optimal use of the extracted energy" whereas in the system developed by V. E. Grum-Grzhimailo and I.S. Podgorodnikov the attention is paid only to the optimal use of extracted energy". The system proposed by I.V. Kuznetsov provides a possibility of creating of infinite number of heat-generating devices of different functional purpose and power including creation of gas-generator-type heat generators of different power using different kinds of fuel (including domestic and industrial waste), and charcoal burning plants. In this case the process of fuel combustion is fully controlled without reducing the efficiency when the plant is operating with reduced power.

One can use any type of fuel that during burning decomposes into volatile part and solid matter and when oxygen from the air is added at high temperature combustion takes place.

The novelty of heat-generators of the system of free gas movement developed by Kuznetsov lies in the organization of fuel combustion in the bell. **The firebox of heat- generator is placed inside the bell and is combined with it to form a single space.** In according to this formula the dry joint should be a must. The dry joint is a vertical crevice of 2-3 cm width connecting the firebox and the bell. The firebox can be different as far as the design is concerned as well as the principle of fuel combustion. This can be the principle of top combustion and the principle of bottom combustion, the principle of back burning, the principle of gas generation, etc. Any type of fuel can be used for combustion. Combustion of fuel in the Russian stove represents the simplest case of fuel combustion in the bell. Burning fuel in this type of bell of big volume do not really allow for optimal fuel combustion. **One should arrange fuel burning in a limited space.**

The gases (combustion gases) are extracted from the heat-generating device of any system by means of natural or artificial draft. If artificial draft is used it is necessary to perform **blasting of additional air** and **create vacuum for gases (blasting-draft)**. With the help of **blasting-draft** it is possible to create both vacuum and excess pressure in the firebox. The surplus of one over the other is harmful. Therefore pressure in the firebox should be equal to atmospheric pressure or a little bit less. The tests in France proved that the heat-generators of the system of free gas movement could operate with depression in the firebox 1mm of water column. Under such conditions **the gas flow**, which is formed **(products of combustion reaction) are subdivided into cold and hot components.** In order to better understand the process let's view the following.

Some features of the bell when **blast-draft are equal** and when cold **air** flow passes through the lower zone of the bell.

1. When cold air flow passes through the lower zone of the bell filled with hot air, the condition of heat inside the bell won't change much irrespective of velocity with which the air flow is running. It is similar to water flowing over the deep.
2. The same will happen if an electric heater is placed inside the lower zone of the bell, and all the incoming heat will be absorbed by the bell's walls and the heat exchanger placed inside.
3. If the heat generated by an electric heater coming into the bell in a certain time unit is not completely absorbed by the heat exchanger and the bell's walls, the surplus of heat is taken away by the flow. In this case the air that has given up its heat is taken away. The amount of heat taken away is not significantly dependent on the flow velocity.
4. If the heat coming into the bell is formed as a result of fuel combustion, then part of atmospheric oxygen coming into the bell is used for combustion, and ballast gases and gases that gave up their heat are extracted from the bell.

Summing up the above-mentioned in item 1-4 one can arrive at the following conclusion.

In case of blast-draft equality in heat-generators of the system of free gas movement the combustion gases are subdivided into separate components in conformance with their heat. Hot gases are coming to the heat exchanger while cold gases are extracted from the bell. The amount of gas supplied beyond the theoretical limits does not reduce the gas flow temperature coming to the heat exchanger.

The products of combustion include carbonic acid, water vapours formed as a result of hydrogen combustion, nitrogen as air component, and excess amount of air that didn't take part in combustion as well as water vapours from evaporation of water normally present in the fuel. These are ballast gases. They do not take part in combustion but only get heated from combustion of carbon and hydrogen, in other words they absorb useful heat. The molecules of the above-mentioned gases are totally independent, that is, they are not coupled with each other (they have their own atomic weight and heat).(И.И. Грингауз «Паровые котлы»,НКЭП СССР, Москва 1940 Ленинград, стр. 53). In the condition of the bell the hottest gases creating the flow rise up, fill in the bell and act on its walls and the heat exchanger. The ballast gases having smaller temperature and a larger weight get down and from there due to blast-draft or chimney draft are exhausted into the atmosphere without coming into the heat exchanger. Contrary to that, in heat-generating devices of forced- gas system the hot gas flow is diluted with ballast gases making its temperature colder. Besides, there is no other space for placing the heat exchanger, except for the firebox. Cold heat exchanger in the firebox reduces the temperature in it worsening the conditions of fuel combustion.

When creating heat-generator in conformance with the above-mentioned formula, supplying optimum amount of primary and secondary air, good mixing of air with fuel, adequate firebox design, separation of flows of hot and cold gases, absence of cold core in the firebox, regeneration, arrangement of combustion catalyst etc. the conditions of combustion change. The temperature in the firebox increases and high-temperature process of combustion is formed, which ensures fuel heating and gasifying at the temperature of approximately 1060 °C at pure combustion.

The influence of ballast gases on the combustion process and fuel calorific value can be traced on an example of acetylene burning when carrying out gas-welding operations.

The calorific value of acetylene will depend on the type of oxidant used. If air is supplied in the combustion zone instead of oxygen, then the temperature of combustion reaction and the energy of extraction from acetylene will be insufficient for metal cutting and welding.

More information on the subject in question is viewed in the articles:

" Fuel combustion and optimum…"http://www.stove.ru/index.php? Ing=0&rs=168,
" Pyrolysis of biofuel…"http://stove.ru/index.php?Ing=0&rs=116,
" Charcoal burning installation…"http://www.stove.ru/index.php?Ing=08&rs=124,
"Heat-generating boilers…" http://www.stove.ru/index.php? Ing=0&rs=126.

The purpose of this article is not only to show theoretical advantages of heat-generating devices built in conformance with the system of free gas movement but it also serves as an invitation for businessmen and organizations that can provide financial and intellectual assistance in creating a center to implement the above-mentioned ideas in world economy.

I consider it necessary to create one or several pilot power-generating devices on which the necessary equipment as well as necessary parameters of the respective components, etc. will be tested.

The result of this work will be development of documentation for various power-generating devices possessing various parameters that will enable to propose power-generating devices of new type to customers.

I. V. Kuznetsov, December 25, 2006

PS.

Comments and questions I receive after publication of the article have shown that I have not quite clear viewed the essence of the topic in all the details. I found some of the questions quite interesting and well-grounded, which are of primary importance in understanding the essence of our system in comparison with other systems of fuel combustion. Some of the questions and my replies are given below.

Here is a commentary of S.M. Mirkis, a stove-setter from St.-Petersburg, who is also the author of" Index of stove and fire-place projects published in Russia within last century" mirkis@cards.lanck.net.

Thank you for informing me about your latest article. I have already included it into "The index…". But I would like to ask you some questions. These questions are not connected with the real stove designs of I. S. Podgorodnikov and his books but they are connected with his thesis. These questions are pointed out in enclosure directly in accordance to the text of his thesis.

I know and believe that you are doing a great thing. But probably I do not understand your text so deeply and probably not only me. Probably you should dwell on the differences more precise. I would be glad if your replies will help me to better understand the text of this very article without making reference to the previous articles of yours.

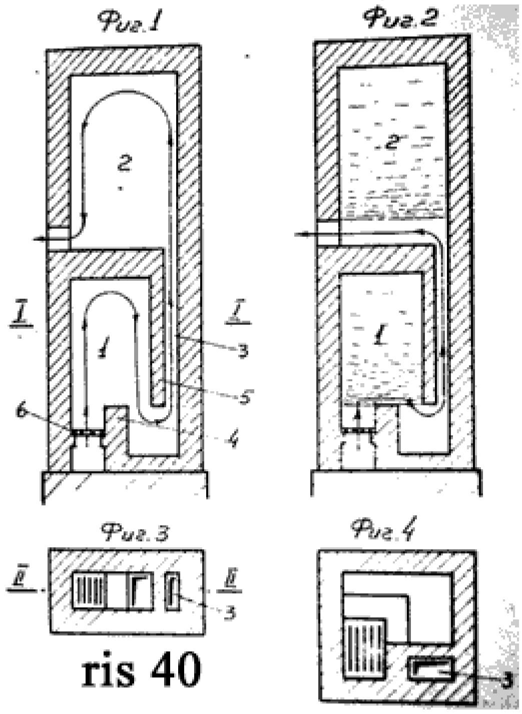
The questions of S.M.Mirkis are included into the text of thesis of I.S. Podgorodnikov *in italics.* My comments and replies are given ***in bold italics***.

Academic degree thesis of Ph.D., engineer I. S. Podgorodnikov, Moscow, 1950

V. HEATING STOVE ”DOUBLE-LAYER BELL”

1. General

In the above-described “Double-bell” stove “free” gas movement has remained but in comparison with the stove of Grum Grzhimailo design its lower part warms up more than its upper part and besides, sooting is excluded in it. It is only possible in case the firebox is overloaded with wood but this overload could be easily avoided if we watch the output holes of the bell through the peep-hole. Red flame tips from the bell holes show that the firebox functions with overload resulting in a certain combustion imperfection. When we increase the firing time by reducing the amount of wood charged for firing and make adjustment of the ash hole or chimney damper we could easily achieve clear combustion (without soot).



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In this case we speak about overstress of specific heat stress of the furnace volume. In this case the firebox is located inside the bell and is not separated from it. The combustion takes place the way it is normally done in traditional Russian stove. “A certain imperfection” of combustion shall be pointed out.

In “double-bell” stove the lower part of the stove is not only better heated during firing in comparison with the upper part but the heat accumulated in the lower part of the stove remains all the time during stove cooling. Thermal conduction from the bottom to the top due to inner gas circulation is impossible.
At the same time “free” gas movement and “gas damper”(when the damper is open the stove cools down slowly) remain and sooting is absent.

The elementary stove diagram is shown on Fig.40. Fig.1 and 2 features the stove section per 2-2, Fig.3; Fig.3 features stove section per 1-1 in Fig.1; Fig.4 features stove section per 1-1 in Fig.1 when the stove is square in plan.

The stove consists of low bell 1 and upper bell 2 interconnected with channel 3, the height of wall 4 of the firebox over the grid is determined by the type of fuel and is approximately 14 cm for coal and 21-28 cm for wood. Such thickness of fuel layer ensures combustion with normal surplus of air. **Wall 5 separating bell 1 from channel 3 starts from the layer of partition wall 4.**(*It seems to me this is an equivalent of ”dry joint”-crevice. Should wall 4 be higher than the wall shown in the drawing, it has to be bored in order to achieve the above specified condition).* Bell 1 is given the respective dimensions *(then text is given from which one may conclude that Podgorodnikov thought not only of the optimum use of the extracted energy but also about fuel combustion in the bell)* **to ensure complete combustion*.* The boundaries used to determine its size, its volume are set in accordance with the following**

considerations. The bell shall have the size, which is not less than the volume that is required to ensure that the stress of the combustion volume shall not exceed the permissible norms.

Due to this consideration its volume has to be increased as much as possible. The boundary limiting this increase is the following assumption. When the volume of the firebox is larger the heat loss in the firebox also increases thus reducing temperature in the firebox. It can go down to such an extent that the temperature in the firebox becomes lower than the temperature of gas ignition, so gases will exhaust through the chimney unburnt. Consequently we deal with heat losses into the chimney with unburnt gases.
So bell 1 shall be big enough so that the stress of the firebox space does not exceed the permissible norms, but not as big so that the temperature of the furnace volume turned to be below the temperature of fuel gas ignition.

Burnt gases through channel 3 are transferred to bell 2 where they cool down to 150-200 ° C and with this temperature they are exhaust by the chimney.
At such design of the lower bell combined with the firebox the low and the upper limits of specific heat stress of the furnace volume shall be observed. The lower limit restricts the increase of the size of the bell combined with the firebox due to worsening of combustion process caused by temperature decrease there. When fuel is burnt in the bell of this type but greater in size it is not possible to achieve optimum conditions for fuel combustion. The same will happen if we place a heat exchanger inside such bell; the temperature of combustion reaction in this case will go down. So we can say that at such construction of the lower bell it is not possible to create an infinite number of heat-producing devices of various functional purpose and power including creation of water boilers and boilers using air heating gas-generator heat-generating devices of various capacity using various types of fuel (including domestic and industrial waste) and charcoal-burning plants.
This could be done only in our system.

Transfer of the lower part of the stove into the bell firebox, *(What is the difference between the phrases: " The firebox of heat-generating plant is placed inside the bell and combined with it to form a single space"?)* the walls of which are used as external walls of the stove itself, ensuring maximum warming-up of the lower part of the stove, maximum accumulation of heat, leaving the rest of the heat for the upper bell.
One should arrange fuel combustion in a restricted volume with the best conditions for fuel combustion and after that transfer the radiated energy to the heat exchanger (for utilization).

In consequence of high temperature and high heat radiation of flame on the walls the lower bell 1 accumulates more than part of the fuel heat. As this heat is concentrated in the bell, it remains in it all the time during which the stove cools down. The heat of bell 1 is transferred through the walls only to the lower parts of the room. The gases don't transfer heat to the upper bell or chimney.
All the heat absorbed by the upper bell remains in it.
In case of **blow of cold heavy air into the firebox it passes into the chimney omitting bells 1 and 2,** *(there is no crevice but when walls 4 and 5 are on the same line it is not required though the function exists)* **filled with hot light air preventing ingress of cold air into the bells** that cool them.

Thus the proposed setting of the stove firstly, distributes the fuel heat in duly way and secondly, prevents it from being exhaust into the chimney in case of cold air blow into the stove during firing or in case of ingress of cold air into the furnace after the firing is over when the damper is not completely tight and thirdly, contributes to combustion improvement.

As a result when heating the room with the help of the proposed stove the temperature difference between the floor and the ceiling, as pilot stoves have shown, is 2-4°, while in stoves with lower heating the temperature difference between the floor and the ceiling is 10-12 °, and in stoves with the upper heating this difference reaches 15 °.

Mention shall be made of uniform heat radiation of the lower part of the stove and their uniform warming-up. The upper part of the stove is warmed up less than the lower one though the heating is also done uniformly due to gas movement in the upper bell. Thus, **when the firebox is bell-shaped the combustion is much better**, *(Again*. What is the difference of phrases: *" The firebox of heat-generating plant is placed inside the bell and combined with it to form a single space"?)* concentrates heat in the lower part of the stove and keeps this heat in the lower part all the time while the stove is cooling down, and when connected with the upper bell prevents the heat from exhaust into the chimney.

The stove shown in Fig. 40 represents the simplest elementary diagram of the double-bell stove.
The firebox volume of Podgorodnilkov's stove occupies the entire lower bell. The lower and the upper limits of specific heat stress of the furnace volume shall be observed. Our system covers only firing volume of the firebox. In our case, we can change the condition of fuel combustion for the better taking advantage of optimization of primary and secondary air supply, good mixing of air with the fuel, adequate design of the firebox, proper separation of hot and cold gas flows, absence of cold core in the firebox, regeneration, combustion catalyst arrangement, etc.
The temperature in the firebox increases and high-temperature combustion process initiates, which ensures warming-up and gasification of fuel at approximately 1060 ° C during clean combustion. This heat is sent to the heat exchanger. We can make any type of bell for any purpose.
Hello Igor,
I am thankful to you for your explanation letting me understand your system better, and the role of crevice in particular.
The role of crevice was previously clear but I thought that it plays the role of "gas damper" that separates the flows. Now after our discussion I understood that its role is much wider. On the one hand, crevice makes it possible to keep a single space of the firebox with the bell and, on the other hand, it provides a possibility to raise up the firebox much higher;(that is the difference from the above-mentioned recommendation of Podgorodnikov, which (the firebox wall) in its turn makes it possible to form firebox volume with a preset heat stress. Thus it becomes possible to avoid limitations with regard to the size of the lower bell, which Podgorodnik was compelled to impose to ensure completeness of combustion and, as you write, to create an infinite number of heat-producing devices of various functional purpose and capacity.
Thank you once again. It was a real pleasure to communicate with you. Personally for me probably this very explanation was just what I needed, which was not available in your article.

With best regards, Semyon Mikhailovich Mirkis.

The Formula of creation of gas-generator heat-producing device is as follows:
" The lower level of gas-generator heat-generating device consists of the firebox and a number of bells combined by means of the firebox to form a single space". Each bell is combined with the firebox through dry joint and an opening in the upper part and is provided with a separate output in the lower part into the chimney, another bell or fume chamber. Each bell can be provided with a heat exchanger in the form of water boiler registers, air heater, retort for fuel pyrolysis, technological materials, equipment, devices, etc. Gas-generator heat-producing device can be of various functional purpose and capacity. For example, gas-generator boiler for private house heating, including that of periodic action.

I declare the above formula **priority inventor's application for method** of creation of power plants the **world's common property**. Those people who would like to use the results of this work should acquire the right for using it by paying certain fee into international fund. The fund activity and appropriation of funds shall be under management and control of international organization and shall be used for development of "free gas movement system". The main task of those people who will be assigned means from the fund is to make the results of carried out work public domain.

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