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Experimental Research on a Gas Burner with a Heat-Transfer Enhancer in a Rod Form

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Abstract—The results of an experimental study of a new gas burner that can be effectively used in domestic gas stoves are presented. The presented modified design of a burner with new heat-transfer enhancers made it possible to reduce heat loss to the environment and increase the efficiency of burning natural gas.

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INTRODUCTION

The rising cost of natural resources and energy makes us consider new energy-efficient technologies. Natural gas is no exception. Let us consider the picture from 2016 as an example of the dynamics of natural gas price growth around the world. Prices rose by as much as 24.6% in Belarus, 16.7% in Kazakhstan, 14.8% in Ukraine, and 8.0% in Russia. The highest gas price for the population, as in 2015, was in Sweden: 89.3 rubles/m^3 (in terms of Russian currency). The price was 74.7 rubles/m^3 in Portugal, 70.8 rubles/m^3 in Spain, etc. [1]. In 2017, the average price of natural gas in the countries of the European Union amounted to approximately 0.64 US dollars or 35.5 rubles (per 1 m^3) [2].

Thus, the development of new technologies for the burning of gaseous fuels, as well as the development of more economical burner devices, is essential.

In the face of constant problems with gas prices in some countries, the cost-effectiveness of a gas appliance increasingly affects customer choices. When buying, for example, a household gas stove, the consumer often pays attention not only to the beautiful, modern design but also to the energy-conversion efficiency and the efficiency of natural-gasburning. Here, gas burners are said to play the mail role. In addition, burners that can also be used to heat apartments in extreme residential living conditions should be observed [3].

The purpose of the work is to improve the heat-transfer enhancer of a gas burner and conduct additional experimental studies.

HIGH-EFFICIENCY GAS BURNERS FOR HOUSEHOLD GAS STOVES

In [4], the author developed and presented a gas burner for household gas stoves. A patent search was carried out earlier [3, 5–8]. And the prior art was found such as the burner of Karas V.I. [8]. Table 1 shows the comparative characteristics of energy-saving fire nozzles with various options and a standard thermal power of 1.6 kW [3].

It should be noted that Karas's gas burner contains a mixer with a gas-supply element; a surface with fire holes; and a body bottom with holes, one of which is designed to supply a gas-air mixture; opposite there is an element for the formation of a zone of changing direction of a gas-air jet, e.g., a radiator. The emitter is coated with a catalyst layer, which can be made of a copper-titanium alloy.

Karas's economical gas burner for household gas stoves works as follows. Gas leaves the gas-supply element, e.g., a nozzle, and passes a simplified injection mixer with a limited size and preheats the gas-air mixture.The gas then passes between the holes of the emitter from the firing surface and is burned on the latter, while the gas-air mixture is preactivated by the catalyst on the emitter. The liquid entering the burner body is removed through special openings.

Figure 1a shows the gas burner [4] developed by the author of the article: *1* is gas-supply channel, *2* is housing, *3* is mixing chamber, *4* is head, *5* is clearance, *6* is fire holes, *7* is cover, *8* is rod, and *9* is heat-transfer enhancer. Figure 1b shows a possible embodiment of the cover *7*, which has protrusions *11*. It is also proposed that a heat-transfer enhancer *9* can be placed on the rod *8* inside the confuser *10*.

The problem of the utility model [4]—to increase the efficiency of fuel combustion due to heat recovery from the flame to the flow of unheated gas—is solved. The technical goal of the utility model is to reduce fuel consumption during the operation of a gas burner. This is facilitated by the fact that in the gas burner to ensure heat recovery, the lid is connected to the rod, which is connected to the heat-transfer enhancer. The

Table 1. Test results for the Karas burner

Indicator	Indicator of existing counterparts according to GSTU 2204–93	Performance for various fire-nozzle designs	
		no. 1	no. 2
Burner efficiency	59	70	80
Gas saving relative to analogs with standard efficiency of 59%, %	0	16	30
Gas savings by burner relative to burners of old gas stoves produced in USSR with efficiency of 56% according to GOST 10798–77, %	0	20	35
Content of carbon monoxide in flue gases (standard indicator 0.05%), %	0.5	0.014	0.005
Content of nitrogen oxides in flue gases (standard indicator of 200 mg/m^3), mg/m^3	200	17	5
Estimated price in Ukraine, USD	–	5	12
Principle of operation	–	Traditional burning of gas without catalyst	

cover has protrusions for greater heat absorption from the outside of the flame surface. The surface of the protrusions of the outside cover is insulated to reduce heat loss to the environment. The heat-transfer enhancer is installed inside the confuser, and the flow of gas passing through the confuser increases its speed [4].

This gas burner operates as follows. Gaseous fuels (e.g. natural gas) are supplied through the channel *1* and then mixes with air in the mixing chamber *3* and ignites. Through fire holes *6*, tongues of flame extend beyond the head *4* and mixing chamber *3*. Heat is generated, when the fuel is burned. Some of the heat is transferred to the heated object, e.g., a vessel with water. Other piece of heat is lost to the environment. In this case, in order to reduce such losses, the following system is proposed to accumulate part of the heat: lids *7* are connected by a rod *8* with the heat-transfer enhancer *9*. It is practical to construct these parts with metals (e.g., copper) or metal alloys with high thermal conductivity. Thus, during combustion, some of the heat is absorbed by the cover material *7* transmitted along the rod *8* to the heat-transfer enhancer *9*. Gas passes through the gas supply channel *1*, which is partially heated; heat recovery occurs with heat-transfer enhancement. Heat-transfer enhancers *9* can be made in different forms, e.g., a screw swirl, a tube with artificial roughness, ribs, a porous metal insert, a twisted metal wire, a device that swirls the flow, or a developed surface with recesses and protrusions, etc.

The gas flow is accelerated when the confuser design *10* is used (Fig. 1b), since the flow cross section decreases and there is additional heat-transfer enhancement.

Additional heat accumulation from the outer flame surface is achieved with the use of protrusions *11*, e.g., in the form of petals. A given amount of heat passes from the protrusions *11* to the lid *7* and further along the rod *8* to the heat-transfer enhancer *9*. It is possible to form protrusions *11* with a heat-insulating layer on the outside (not shown in the utility model) to achieve maximum heat absorption from the outer flame surface and minimal heat loss to the environment.

EXPERIMENTAL RESEARCH WITH THE DEVELOPED GAS BURNER

Experiments were carried out on a household gas stove with a gas burner [4], in which the lid was connected to a threaded rod, i.e., the metal rod itself was a heat-transfer enhancer (Fig. 2). All experiments were carried out on the Gazmash gas stove. At the same time, water in different volumes was brought to be boiled in different vessels with a base burner and a new gas burner [4] and the same gas supply. The gas savings from the new design of the burner during experimental studies averaged 6.72% (by volume) [9].

It was hypothesized that more natural gas could be saved with a change in the design of the heat-transfer enhancer of the rod (Fig. 2) with additional fins or longitudinal slot-type gaps (Fig. 3).

In 2016, experimental studies were conducted on an improved gas-burner design with a heat-transfer enhancer in the form of a threaded rod with slot-type gaps. The design significantly increased the efficiency of the gas burner (Fig. 3) [10].

At the same time, the average natural gas savings were 22.14% (by volume). However, it should be noted that the figures obtained during the experiments [10] turned out to be overestimated (the supply of natural gas stopped as soon as bubbles appeared on the water surface, which was observed visually without measuring of temperature).

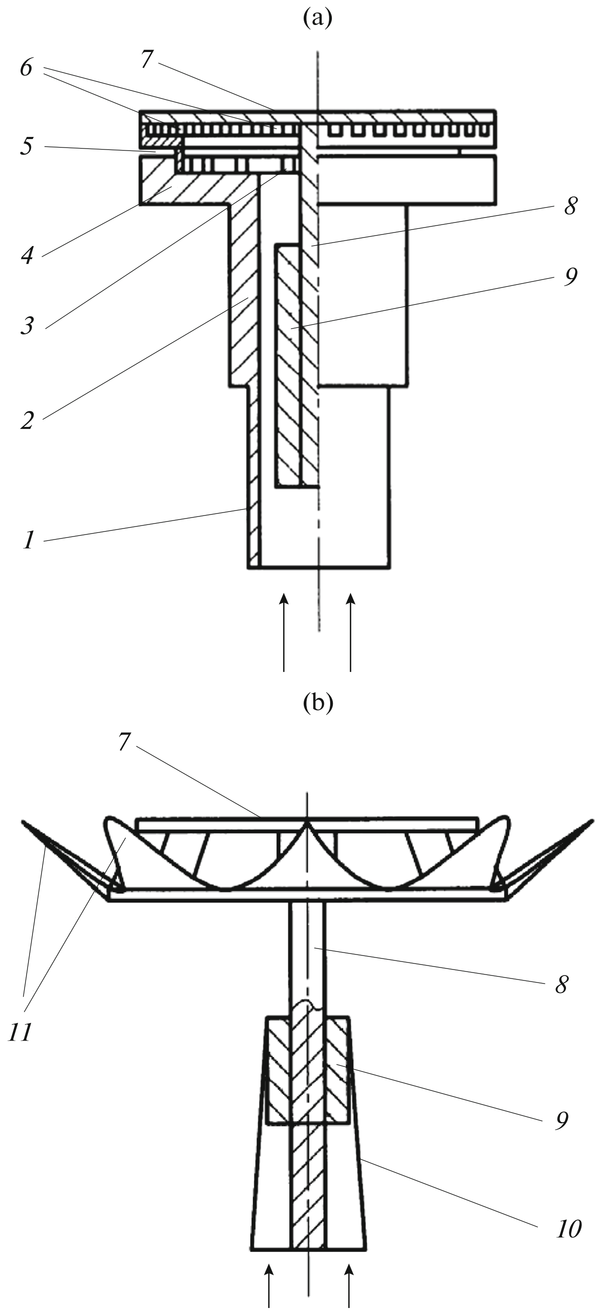

Fig. 1. Gas burners for domestic stoves: (a) with the heat-transfer enhancer, (b) with the confuser and heat-transfer enhancer.

Fig. 2. Gas burner cover for domestic stoves with the heat-transfer enhancer in the form of the thread.

In order to increase measurement accuracy in 2019, an additional series of experimental studies was carried out with a natural gas meter, a timer, and an SP-2 glass kerosene thermometer. The results are summarized in Table 2.

In this case, water of different volumes was brought to boil in different vessels with a base burner and a new gas burner [4] and the same gas supply (medium or maximum). The experimental research technique was as follows. A fixed volume of water was poured into a specific vessel with water (a 1-L mug or a 4-L pot) at room temperature (t_f = 21–22°C). Further, a fresh portion of fuel was automatically ignited (the handle of the gas stove was set either to the average gas supply or to the maximum), the timer immediately turned on; kerosene thermometer SP-2 [11] measured the temperature inside the vessel with water (the thermometer tip was immersed strictly in the center of the water) volume; when the temperature reached 99°C (in order to avoid the appearance of additional inaccuracy, it was decided not to bring the water temperature in the volume center to 100°C), the supply of natural gas abruptly stopped, and the electronic timer turned off. In all experiments, the vessel with water was uncovered.

From Table 2, it follows that the average natural gas savings from a new burner with a heat-transfer enhancer in the form of a threaded rod with longitudinal slot-type gaps is about 14.19% (by volume).

Then, the design of the heat-transfer enhancer underwent some changes, namely, the four parts of the rod were opened towards the end, thus increasing the gap thickness (Fig. 4).

Table 3 shows the results of such experiments with the heat-transfer enhancer in the form of the threaded rod with widening slot-type gaps.

From Table 3 it follows that the average natural gas saving from the new burner with the heat-transfer enhancer in the form of the threaded rod with widening slotted gaps is about 12.85% (by volume). However, it is easy to notice that the natural gas savings were underestimated in experiment no. 7 (Table 3). This is associated with a longer heating time of 3 L of water with an average fuel supply and an uncovered

Fig. 3. Gas burner cover for domestic stoves with the heat-transfer enhancer in the form of the thread and slot-type gaps in the rod.

Fig. 4. Gas burner cover for domestic stoves with the heat-transfer enhancer in form of the rod with a filament and widening slot-type gaps.

water vessel. Therefore, if we disregard the results of experiment no. 7, we obtain 14.2% (by volume).

The GORENJE GI 52 CLI1 gas range, which has an automatic electric ignition and four burners, was selected for experiments conducted in 2019. All experiments were carried with a medium power burner. A SGM G2.5 membrane type gas meter was used to measure the volume of natural gas. It was designed to measure the amount of natural gas in accordance with GOST 5542–87 or liquefied petroleum gas vapors in

Table 2. Results of experiments with gas burners (Gorenje gas stove, medium power burner, heat-transfer enhancer is a threaded rod with longitudinal slot-type gaps)

No. experiment	Name of gas burner	Volume of expended gas, L	Gas supply	Time, min:s	Gas savings, % (by volume)
	Water volume 300 mL (cup)				
1	I	7.5	Ave	6:15	–
	II	6	Ave	5:50	20
2	I	7.5	Ave	8:24	–
	II	6	Ave	5:45	20
	Water volume 500 mL (cup)				
3	I	11	Ave	09:10	–
	II	9.5	Ave	07:10	13.64
4	I	11	Ave	11:52	–
	II	9.3	Ave	10:54	15.45
	Water volume 1 L (cup)				
5	I	20.8	Ave	20:58	–
	II	18.5	Ave	20:41	11.06
6	I	20.8	Ave	24:45	–
	II	18.3	Ave	21:52	12.02
	Water volume 3 L (pan)				
7	I	63.9	Max	22:05	–
	II	58	Max	19:46	9.23
8	I	63.7	Max	21:48	–
	II	56	Max	18:52	12.09

I, conventional burner (cover without heat-transfer enhancer); II, burner with heat-transfer enhancer; ave is average natural gas supply (gas supply knob is turned 45° to left); max is maximum natural gas supply (gas supply knob is turned 90° to left).

Table 3. Results of experiments with gas burners (Gorenje gas stove, medium power burner, heat-transfer enhancer is a threaded rod with widening longitudinal slot-type gaps)

No. experiment	Name of gas burner	Volume of expended gas, L	Gas supply	Time, min:s	Gas savings, % (by volume)
	Water volume 300 mL (cup)				
1	I	8	Ave	9:05	–
	II	6.5	Ave	6:15	18.75
2	I	8	Ave	8:10	–
	II	6.3	Ave	8:01	21.25
	Water volume 500 mL (cup)				
3	I	10.8	Ave	13:08	–
	II	8.8	Ave	8:56	18.52
4	I	11	Ave	12:05	–
	II	9.5	Ave	10:54	13.64
	Water volume 1 L (cup)				
5	I	20.5	Ave	19:18	–
	II	18.5	Ave	21:49	9.76
6	I	20.5	Ave	21:24	–
	II	19	Ave	27:10	7.32
	Water volume 3 L (pan)				
7	I	73	Ave	72:44	–
	II	70.5	Ave	69:54	3.42
8	I	64	Max	21:46	–
	II	57.5	Max	19:25	10.16

accordance with GOST 20448–90, as well as other nonaggressive gases used for domestic and industrial purposes. The meter is designed for operation in climatic conditions corresponding to the design group according to GOST 12997–84 SZ for sizes G1.6 and G2.5. In this case, the nominal gas flow rate of the meter is 2.5 m^3/h, the minimal value is 0.025 m^3/h, and the maximum value is 4 m^3/h. The limits of the permissible basic relative error of the meter during operation in the flow range are (3–5)%. An electronic timer of the Honor smartphone was used to measure the time.

A FLUKE 568 infrared thermometer was used to measure the temperature of the lid and the rod. The temperature measurement range of this thermometer is from –40 to 800°C, the error is ±1°C, and the power source is two AA batteries. The temperature of the rod wall was approximately 235°C, and the surface temperature of the lid was about 260°C. The diameter of the channel was 10 mm, and the diameter of the rod at the base was 6 mm.

The temperature of the heated water was measured with a thermometer [11] with a range of 0 to 100°C, a division value of 1°C, and a basic error margin of ±1°C.

A graph of the dependence of the Nu and RePr numbers was constructed (Fig. 5) based on the obtained data (Tables 2, 3).

Figure 5 shows that all experimental points lie on the same line:

$$\mathrm{Nu} = 0.48\mathrm{RePr},$$

where Nu is the Nusselt number, Re is the Reynolds criterion, and Pr is the Prandtl criterion.

The deviation of this dependence on experimental data does not exceed 1%.

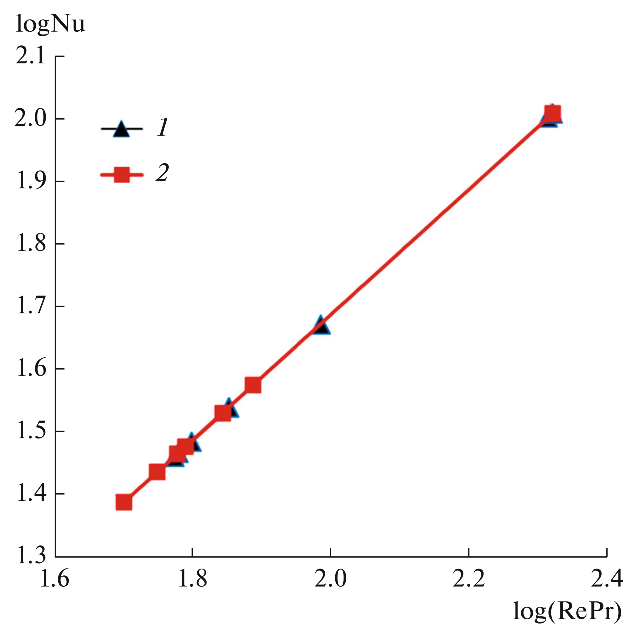

Fig. 5. Research results for the gas burner with the heat-transfer enhancer in the form of the thread with slot-type gaps in the rod: (*1*) longitudinal, (*2*) expanding.

CONCLUSIONS

Experimental studies were carried out for a new gas burner for household stoves that contains in its design the heat-transfer enhancer in the form of the threaded rod with longitudinal slit sections. It was shown that it is possible to reduce the consumption of natural gas via intensive preheating. The results of previous studies were compared with the latest ones. It was found that the use of the heat-transfer enhancer in the form of the simple threaded rod saved only 6.72% (by volume) on average, while the heat-transfer enhancer in the form of the threaded rod with additional longitudinal cuts saved 14.2% (by volume). It is interesting to note that the use of the threaded rod with expanding slotted gaps did not lead to additional fuel savings (average volume).

The heat-transfer formula was obtained for description of heat transfer from the heated rod with the heat-transfer enhancer in the form of the threaded rod with slot-type gaps to the cold gas flow in the supply channel.

The proposed design of the gas burner is easy to manufacture, can be used effectively in domestic gas stoves and in various fields of energy for additional natural gas saving [12].

The results of recent studies indicate the need for a more detailed study of the possible structural schemes and materials for heat-transfer enhancement, as well as additional studies to ensure maximal saving of natural gas.

REFERENCES

1. Ranking of countries by natural gas prices for the population in 2016, 2016. http://luckyea77.livejournal.com/1325864.html.
2. Rating of countries by gas price for the population, 2019. http://svspb.net/novosti/stoimosti-gaza/.
3. Benefits of higher tariffs and new energy-saving options: Burners, 2016. http://congeniator.com/gorelki-i-konforki.
4. Altunin, K.V., Patent RU 129600, *Byull. Izobret.*, 2013, no. 18.
5. Basargin, T.L., Zakharov, L.K., Sundikov, I.I., and Sviridenko, N.A., USSR Inventor's Certificate no. 1216566, *Byull. Izobret.*,1986, no. 9.
6. Bykov, A.N., Krasyakov, I.R., and Krasyakov A.I., USSR Inventor's Certificate no. 1416800, *Byull. Izobret.*, 1988, no. 30.
7. Annenkov, V.Z., Ragozin,Yu.A., Grinenko, G.F., and Dzhulik, P.K., USSR Inventor's Certificate no. 1252549, *Byull. Izobret.*, 1986, no. 31.
8. Karas', V.I., Ukraine Patent 26706, 2007.
9. Altunin, K.V., *J. Eng. Phys. Thermophys.*, 2017, vol. 90, no. 2, p. 480.
10. Altunin, K.V.,*Vestn. Kazan. Nats. Isseled. Tekh. Univ.*, 2017, no. 2, p. 80.
11. *TU (Technical Requirements) 25 11 663-76: Glass–Kerosene Thermometers SP-2, Moscow, 1976; GOST (State Standard) 28498-90: Liquid-in-Glass Thermometers. General Technical Requirements. Methods of Tests*, Moscow 1991.
12. Altunin, K.V., *Razrabotka gorelok povyshennoi effektivnosti dlya teplovykh elektrostantsii* (Development of High-Efficiency Burners for Thermal Power Plants), Kazan: Kazan. Nats. Issled. Tekh. Univ., 2016.