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Study of the working process of an experimental sample of a safe burner of a household gas stove developed on the basis of moisture-absorbing materials

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Abstract. The most common cause of a household gas explosion in a residential area is a gas leak from the stove burner. Even a small amount of gas can cause a fire with subsequent uncontrolled combustion. The number of explosions on the territory of the Russian Federation in multi-apartment residential buildings associated with the leakage of household gas is growing every year. As a result of the analysis of the designs of existing gas stoves and the main causes of gas leakage, a hypothesis was put forward, suggesting that one of the burner elements should be made of a moisture-absorbing material that can serve as a blocker for the channels of gas entering the environment when wet. The conducted studies have shown the operability of a burner with a working body made of expanded perlite. At this stage of the experiments, the following combination will be the optimal combination of structural elements: the weighted average size of expanded perlite is 0.5 mm, the divider is filled with working fluid by 40%, the number of outlets in the burner cover is 20 pcs.

1 Introduction

In recent years, the number of incidents that occurred in residential premises and related to the leakage of household gas mixture has been steadily increasing [9]. Taking into account the massive gasification of residential premises on the territory of Russia, which is at least 68%, the relevance of the development of security systems aimed at preventing gas leaks is beyond doubt [2].

The most common cause of household gas explosions in residential premises is a gas leak from the stove burner. Even a small amount of gas can cause a fire, followed by a transition to uncontrolled burning. When the volume of the room is filled by 10-15%, the probability of an explosion sharply increases [2]. The cause of ignition of the gas mixture may be accidental phenomena of an exogenous or endogenous ignition source.

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The status of the issue. According to official statistics provided by the VNIIPO of the Ministry of Emergency Situations of Russia, for the period from 2017 to 2021, the number of explosions on the territory of the Russian Federation in residential apartment buildings associated with the leakage of household gas increased from 11 to 32. At the same time, it should be noted that from year to year there is an increase in emergency situations associated with gas mixture explosions. The number of fires caused by malfunctions and improper operation of gas stoves increased from 1,133 in 2017 to 1,361 in 2021.

Taking into account the massive gasification of residential premises on the territory of Russia, which is at least 68%, the relevance of the development of security systems aimed at preventing gas leaks with the possibility of installing such systems on gas stoves already in operation is beyond doubt [2, 10].

2 Materials and Methods

As a result of the analysis of the designs of existing burners [3, 4, 5, 6] of gas stoves and the main causes of gas leakage, a hypothesis has been put forward suggesting that one of the elements of the burner should be made of a moisture-absorbing material capable of serving as a blocker of gas flow channels into the environment when wet [5].

The aim of the work is to study the working process of a gas stove burner containing a moisture-absorbing material as a blocker of gas-conducting channels.

Analysis of the designs and working process of gas stove burners [patents, foreign article] a burner consisting of a flame divider 1, a locking ring 2, a lid 3 and a moisture-absorbing filler - a working fluid was developed (Figure 1).

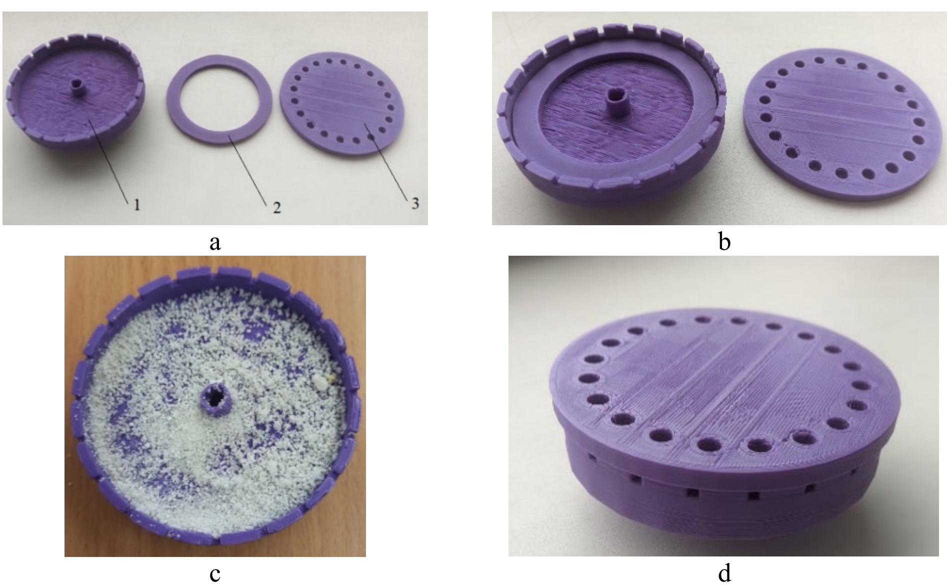

Fig. 1. Components and design of the experimental sample of the burner: a – the structural elements of the burner; b – the assembly scheme of the burner; c – the working fluid (expanded perlite); d – the burner assembly.

As a hygroscopic material, igneous rock was used – expanded perlite [GOST 10832-2009 "Sand and crushed stone perlite expanded], the water absorption of which by weight can reach 125%.

The burner works as follows. In case of flame damping due to the filling of the burner, the liquid interacts with the perlite, which is located in the burner divider. The process occurring with a layer of expanded perlite can be divided into two stages:

1. perlite having a density below the density of water is raised above the bottom of the divider;
2. perlite increases in volume when liquid is absorbed.

Thus, the perlite layer lifts the protective ring that covers the openings in the divider and the lid through which the gas enters the environment.

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At the first stage of experimental studies, the issue of the influence of the following factors on the working process of the burner was studied: the granulometric composition of the expanded perlite (working fluid), the mass of the expanded perlite, the volume of the liquid in contact with the working fluid and the time of the liquid exposure to the working fluid.

Measuring cylinders, beakers, laboratory glasses and flasks were used for the research (GOST 1770-74 (ISO 1042-83, ISO 4788-80) Measuring laboratory glassware], analytical scales VL-224B, construction ruler GOST 427-75 Measuring metal rulers, Mechanical stopwatch: SOPpr-2a-2-010 (GOST 5072-72 Mechanical stopwatches).

Before each experiment, a control measurement of humidity was carried out. Samples for the determination of humidity were taken in accordance with a well-known technique [7, 8]. Humidity was determined by thermosetting the samples in a drying cabinet. The humidity value was determined by the formula:

$$W = \frac{m_1 - m_i}{m_1} \cdot 100\% , \tag{1}$$

where m_1 – weight of the material before drying, kg; m_i – weight of the material after drying, kg.

To obtain objective results, the sample for analysis was selected so that it could be used to evaluate the parameters of the entire batch of material. For this purpose, the average sample was taken in at least 5 different places in each batch of the finished product. The materials from each recess were thoroughly mixed to obtain an average sample, while the presence of impurities was monitored. About 0.2 kg of the product was taken from the mixed mass in at least 5 different places and placed in a polyethylene bag with a label. Similarly, the selection of the source material was carried out.

The granulometric composition of the starting material and the finished product was determined three times by sieving 0.1 kg of each average sample taken on a classifier [7,8]. The weighted average particle size was calculated by the expression:

$$L = \frac{\sum_{i=1}^{n} D_i M_i}{\sum M_i}, \tag{2}$$

where D_i – average particle size in the i-th group, mm; M_i – mass of particles in the i-th group, kg; ΣM_i – sample weight, kg.

3 Results and discussion

At the first stage of research, a search experiment 4^2 was implemented to determine the characteristics of the working fluid (expanded perlite) as a blocker of gas-conducting channels.

The expanded perlite was placed in a prepared container and filled with a different volume of liquid (water), after which the change in the level of the resulting mixture and the change in the volume of the working fluid itself were measured.

The following optimization criteria were selected: x1 – fraction (weighted average particle size) of expanded perlite, which varied from 0.5 to 1 mm; x2 – mass of expanded perlite, which varied from 5 to 10 grams g; x3 – volume of water (100 and 200 ml); x4 – time (60 and 120 s). As a response, y1 is the total height of the mixture, mm; y2 is the height of the expanded perlite layer, mm. The air temperature during the tests is +22 °C.

The research results are presented in the form of three-dimensional diagrams (Figure 2)

Analysis of the obtained results shows that the peak values of the studied parameters are achieved with the maximum taken mass of expanded perlite and with the minimum taken weighted average particle size, while the volume of water and the time of the test did not affect the result.

Also, the results of the first stage of experimental studies have shown that the expanded perlite does not fully possess the declared properties of water absorption.

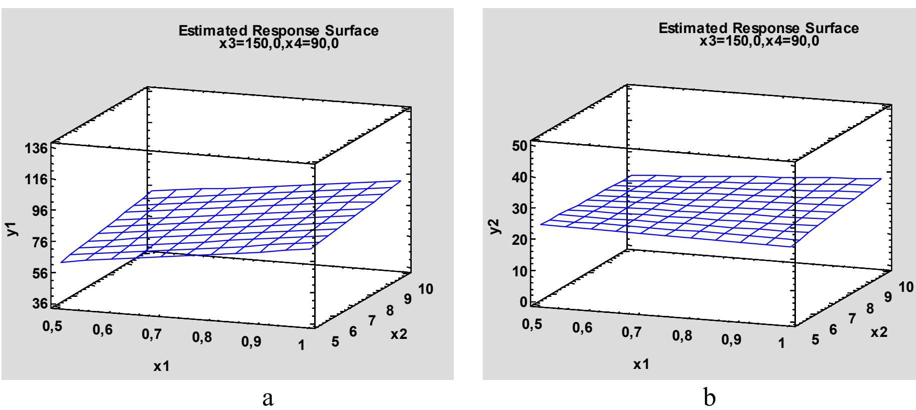

Fig. 2. The influence of the studied factors on: a – the total height of the mixture of the working fluid with the liquid; b – the height of the layer of expanded perlite.

At the second stage of the research, the matrix of experiment 42 was implemented. The influence of the number of holes in the lid of the burner and their diameter, the level of fullness of the burner divider with expanded perlite and the volume of the liquid used was studied. As a response, the value of the displacement of the ring 1 affecting the overlap of the gas-conducting holes was chosen.

The factors had the following numerical values: x1 – the number of holes in the lid of the burner, 10 and 20 pcs.; x2 – the diameter of the holes in the lid of the burner, 3 and 5 mm; x3 – the level of filling of the flame divider with expanded perlite, 40 and 80%; x4 – the volume of water, 12.5 and 25 ml. The following factors were chosen as the investigated factor: y1 – displacement of the flat ring, mm. The air temperature during the tests is +22 °C.

Thus, according to the set of parameters, it can be concluded that the best combination of these parameters should be recognized as a combination of the largest of the studied number of holes in the lid of the burner with the maximum volume of water considered and the lowest level of filling of the flame divider with expanded perlite. Graphically, the results are presented in Figure 3.

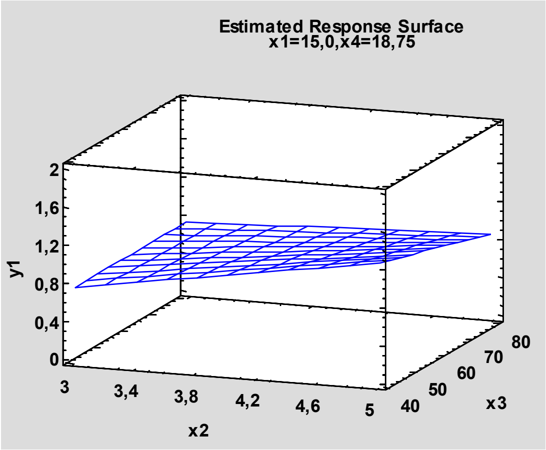

Fig. 3. The influence of the studied factors on the movement of the ring along the walls of the divider.

The experiment was carried out as follows: expanded perlite with a weighted average size of 0.5 mm (the optimal value determined at the first stage of experimental studies) was placed in a divider with a filling of 40 or 80% of the volume of the divider. A movable ring was placed on the working body, which, when moving upward, overlaps the gas-conducting holes in the lid and divider. When pouring the prototype of the burner, the liquid through the holes in the lid and divider interacted with the working fluid, which increased in volume and moved the ring along the walls of the divider. The amount of movement of the ring in the divider was measured.

The analysis of the obtained results shows that the peak values of the studied parameters are achieved with the minimum taken level of occupancy of the flame divider with expanded perlite (x3=40%) and with the maximum number of holes taken (x1=20) and the volume of water (x1=25 ml), while the diameter of the holes in the lid of the burner had no obvious effect on the result of the experiment.

A significant advantage of the studied prototype of the burner over known designs is the possibility of its use both in newly developed plates and in already operated plates without making changes to their design.

4 Conclusion

The conducted studies have shown the operability of the burner with a working body made of expanded perlite. At this stage of the experiments, the optimal combination of structural elements will be the following combination:

1. the weighted average particle size of expanded perlite is 0.5 mm;
2. filling the divider with a working fluid by 40%;
3. the number of exhaust holes in the lid of the burner is 20 pieces.

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