HEAT AND GAS SUPPLY, SEWERAGE, BUILDING CONSTRUCTION OF WATER RESOURCES PROTECTION

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RESTORATION OF GAS HEATING STOVES

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Statement of the problem. When supplying gas to households of towns and rural areas using stove heating, furnaces commonly use natural gas instead of solid fuel, usually with the preservation of periodic heating (short-term fuel combustion with heat accumulation in a masonry oven and a long break, during which the oven emits heat to the room air). However, the disadvantages of such furnaces are low thermal efficiency of fuel use, slow heating rates, increased fuel consumption and time-consuming maintenance. Another drawback of these furnaces is the fact that the ventilation of the furnace volume occurs by smoke channels, and this leads to the cooling of a furnace and reducing efficiency.

Results and conclusions. The use of gas heating stoves continuous combustion reduces the metal consumption of gas distribution networks by 1.7—2.2 times. The proposed scheme of restoration of heating furnaces saves up to 15 % of gas fuel.

Keywords: natural gas, efficiency, gas heating furnaces, restoration, saving.

Introduction

The use of such a perfect fuel as gas in log heating furnaces enables the creation of more user-friendly furnaces as well as makes them more automated.

Furnace gas heating offers the following advantages:

- lower installation costs compared to other heating systems;
- easy maintenance;

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- use of materials available locally on the construction site;
- autonomous heating of individual premises along with ventilation;
- a relatively high efficiency coefficient;
- optimal conservation and use of heat released by fuel;
- a furnace can be hermetically sealed;
- low steel intensity (only for doors, latches, sometimes the frame).

The Academy of Communal Households [1, 2] pointed out the major advantages of the use of continuous burning furnaces. Continuous furnace heating employs not only special furnaces including factory-manufactured ones (АКХ-14, АКХ-СМ-1, etc.) but other structures of heat accumulating furnaces using gas fuel can also be switched to the continuous burning mode.

Operation of a continuous burning furnace does not involve significant changes in temperature thus resulting in a longer life cycle. The temperature on heat-transferring furnace surfaces is not over 70 ^{0}C [1, 2] and is maintained to be stable.

Periodic heating involves uneven heating of a furnace surface, which adversely affects a surface layer (plasterwork).

Continuous burning furnaces do not need control of heating of a furnace masonry that is essential for periodic furnaces. The temperature on the internal masonry surface is not over 300 ^{0}C, therefore continuous burning furnaces do not need a heater to be lined up with firebrick.

While a furnace is in the continuous burning mode, the amount of combustion products per hour decreases due to a lower gas consumption per hour. The length and surface of periodic furnace channels is developed based on the calculation of the absorption of a daily heat storage over 1-3 hours of heating (one-off heating) or half daily heat storage (two-time heating). As a result, continuous burning of released gases is lower than for periodic heating thus causing an average increase of 10% (Fig. 1b) in the efficiency coefficient over a heating period.

According to the health and safety regulations in the gas industry and fire safety guidelines, periodic furnaces require ventilation of the furnace volume and chimney holes to avoid explosive gas-air mixture forming. Forced furnace blow in between heatings using ventilation holes in a chimney valve causes a 15% loss of the heat accumulated by the furnace during heating. Therefore, switching a furnace into continuous burning leads to an increase in the efficiency coefficient by an average of 25%.

According to the Academy of Communal Households named after K.D. Pamfilov [3, 4], an average annual efficiency coefficient of gas heating furnaces operated in the continuous burning mode is η_{cb} = 81 - 83 % (Fig. 1a). Therefore the use of gas heating furnaces in the continuous burning mode is most important for providing gas fuel sustainability and lower gas consumption for heating of

$$K = \frac{\Delta\eta}{\eta_{cb}} = \frac{0,25}{0,82} = 0,31\ (31\ \%).$$

A 24-hour operation of a heating furnace removes adverse effects of air temperature oscillations in premises. According to [5], the amplitude of temperature oscillations of the air inside during furnace heating is accepted to be as large as ±3 ^{0}C. In actual conditions, when thermal resistance of fillers is not sufficient and furnace heat transfer is uneven, the actual amplitude of temperature oscillations reaches 5—10 ^{0}C. Hence furnaces made into continuous burning generate a heat mode similar to that for central heating.

A 24-hour gas consumption contributes to a significant decrease in the unevenness of daily gas consumption and is efficient in reducing steel intensity of gas distribution networks.

According to [1, 2], continuous burning mode of heating furnaces helps to reduce steel intensity of gas distribution networks by at least 30 % and more.

This kind of the operation of furnaces causes combustion products to cool off considerably in non-insulated chimneys and in chimney caps with possible condensation [8] due to small gas consumptions per hour (0.1—0.4 m^3/h) and low temperatures of combustion products (70—100 ^{0}C). In order to prevent condensation on the internal surface of chimneys, the latter should be insulated by laying an internal asbestos cement chimney according to the guidelines [1, 6, 7]. In order to switch furnaces into continuous burning in Ltd. "Giproniigaz" lower-power gas injection burners УГОП-II-4 were designed for continuous burning of furnaces УГОП-II-4 with a heat exchange 3.2 kilowatt.

1. Reasons behind converting of furnace heating

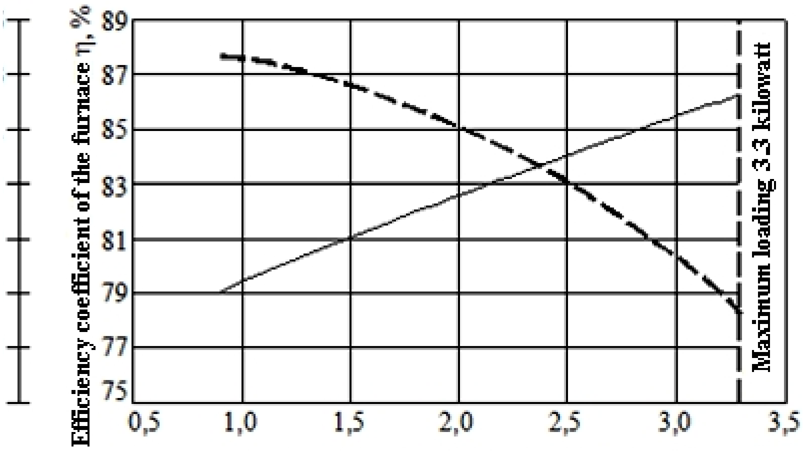
Let us consider a heating furnace ОПТ-8. It is used in moderately cold climates. An average heat exchange of the furnace per hour in two-time heating of 2.5 hours per hour is Q_{av}^h = 3500 Watt.

The gas consumption of a heating furnace per year is given by the formula

$$V_{year} = \frac{Q_{ср}^{ч}}{\eta \cdot Q_{р}^{н}} \cdot \frac{t_{в} - t_{ср.о.п}}{t_{в} - t_{н}} \cdot \tau_{о.п.}, \quad (1)$$

where Q_{av}^h is an average heat exchange of a furnace per hour, kJ/h; η is an average efficiency coefficient of a heating furnace per hour in periodic heating; $Q_p^н$ is a heating power of 35600 kJ/m^3; $t_в$ is the air temperature in the premises, ^{0}C; $t_н$ is a design temperature of the outside air (temperature of five cold days), ^{0}C; $t_{ср.о.п.}$ is an average temperature of the outside air over the heating season, ^{0}C; $\tau_{о.п.}$ is the length of a heating season, h.

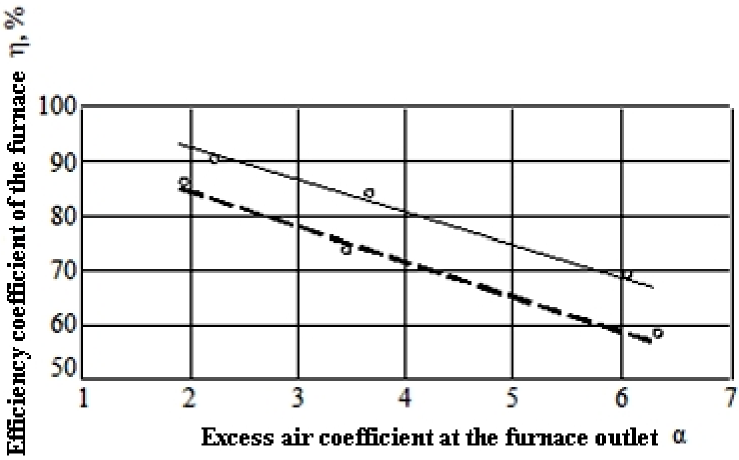
a)



——— efficiency coefficient of the furnace η;

— — . excess air coefficient α

b)



——— continuous burning with the load of 2.36 kilowatt;

— — . two-time heating with the load of 15.2 kilowatt

Fig. 1. Results of heating experiments in a gas heating furnace ($Q_{ср}^{ч}$ =3.3 kilowatt) [2]:

a) dependence of the efficiency coefficient and excess air coefficient on the heat loading of the furnace in continuous burning; b) dependence of the efficiency coefficient on the excess air coefficient in periodic and continuous burning

There are the following original data used in the calculations:

$t_в = 20\ ^0C$; $t_н = -27\ ^0C$; $t_{ср.о.п.} = -5\ ^0C$; $\tau_{о.п.} = 5000$ h;

$Q_р^н = 35600$ kJ/m^3; $Q_{ср}^ч = 12600$ kJ/h; $\eta = 0.57$.

As a result, $V_{year} = 1643$ m^3/year.

When furnaces are switched to continuous burning, gas consumption drops by 1.3 times or in an absolute expression is

$$\Delta V_{year} = V_{year} - \frac{V_{year}}{1,3} = 379 \text{ m}^3\text{/year.}$$

With the gas price c_g = 8 roubles/m^3 operational costs saved per year are $c_g \cdot \Delta V_{year}$= 3032 roubles/year.

Capital investments into the restoration of a furnace as it is switched to continuous burning (replacement of a furnace cap into a lower-power one and insulation of a chimney) according to financial report calculations are K = 5100 roubles with the following payback period of a furnace restoration

$$z = \frac{K}{c_г \cdot \Delta V_{year}} = \frac{5100}{3032} = 1,6 \text{ years.}$$

The use of continuous burning furnaces significantly reduces a gas consumption per hour and thus design loads of gas distribution networks. A reduction in design loads is largely dependent on heating modes in current periodic heating (one-off heating, two-time heating, multiple heating).

In order to identify a minimum amount of heating and thus a maximum reduction in a gas consumption per hour, heat resistance of premises in periodic furnace heating was calculated. The calculation model of heated premises was a room of a one-storey residential building with the area of 20 m^2. The walling of the premises have the following construction characteristics:

– exterior wall (F = 12 m^2) is laid with silicate brick with an internal insulation layer plastered from inside with a sand-lime cement mix;

– floor (F = 20 m^2) is a log slab board, insulated ferroconcrete slab;

– mattress partitions (F = 45 m^2);

– double glazing (F = 4.5 m^2).

The calculations were performed for two levels of thermal wall protection:

– for existing buildings at a minimum thermal protection level according to health and safety regulations;

– for newly constructed buildings at a higher level of thermal protection according to health and safety regulations.

The calculations were differentiated according to three climate zones of building:

– moderately warm area (the temperature of five cold days is $t_н$ = -20 ^{0}C);

– moderately cold area ($t_н$ = -30 ^{0}C);

– cold area ($t_н$ = -40 ^{0}C).

A heat supply source was a typical heating furnace ОПТ-8 with the following technological characteristics:

– an average heat exchange of a furnace per hour in one-off heating of 2-3 hours is $Q_{av}{}^h$ = 2320 Watt per day. The coefficient of cyclic heat exchange is M = 0.6;

– an average heat exchange of a furnace per hour in two-time heating of 2-3hours is $Q_{av}{}^h$ = 3510 per day. The coefficient of cyclic heat exchange is M = 0.23.

The calculations were performed according to the guidelines [4]. The results are shown in Table.

As Table suggests, two-time heating of furnaces complies with health and safety regulations for temperatures of heated premises ($A_{tв} < \pm 3$ ^{0}C) in all climate zones of building operation for existing as well as a higher level of thermal wall protection. One-off heating provides a necessary temperature mode of premises of buildings only with a higher thermal protection level used in moderately warm and moderately cold climate zones.

The diameter of the gas pipes of low-pressure gas distribution is given by the formula

$$d = a^{0,21} \cdot V^{0,368} \cdot \left(\frac{l}{\Delta P}\right)^{0,21}, \qquad (2)$$

where d is the diameter of the gas pipe, cm; α is a proportionality coefficient depending on a gas composition; V is a design gas consumption, m^3/h; l is the length of the gas pipe, m; Δp are pressure losses in the gas pipe (pressure drop), Pa.

Let us introduce the following: V_{cb} is gas consumption per hour for heating furnace in continuous burning; V_{cb} is gas consumption per hour for heating furnaces in periodic heating.

The following ratio connects the above parameters:

$$\frac{V_{pb}}{V_{cb}} = K_h^{\max} = \frac{T}{z_н}, \qquad (3)$$

where $K_h^{\max}$ is a coefficient of a maximum per hour in periodic heating; $z_н$ is the time of furnace heating; T is the heating-break time.

Table

Heat resistance of premises in furnace heating

Climate zone	Thermal protection level of buildings	Amplitude of oscillations of internal air temperature $A_{tв}$, C^0	
		One-off heating ($M = 0.6$)	Two-time heating ($M = 0.23$)
Moderately warm $t_н = -20^0 C$	Existing thermal protection level	5.2	2.0
	Higher thermal protection level	2.7	1.1
Moderately cold $t_н = -30^0 C$	Existing thermal protection level	5.7	2.2
	Higher thermal protection level	3.1	1.2
Cold $t_н = -40^0 C$	Existing thermal protection level	6.4	2.5
	Higher thermal protection level	3.8	1.5

Considering (3)

$$V_{pb} = K_h^{\max} \cdot V_{cb} . \tag{4}$$

Then for continuous burning:

$$d_{cb} = a^{0,21} \cdot V_{cb}^{\ 0,368} \cdot \left(\frac{l}{\Delta P} \right)^{0,21} . \tag{5}$$

Similarly, for periodic heating:

$$d_{pb} = a^{0,21} \cdot \left(K_h^{\max} \cdot V_{cb} \right)^{0,368} \cdot \left(\frac{l}{\Delta P} \right)^{0,21} . \tag{6}$$

The ratio of the diameters of gas distribution pipes according to (5) and (6):

$$\frac{d_{пн}}{d_{нт}} = \left(\frac{K_ч^{\max} \cdot V_{нт}}{V_{нт}} \right)^{0,368} = \left(K_ч^{\max} \right)^{0,368} = \left(\frac{T}{z_н} \right)^{0,368} . \tag{7}$$

For heating $z_н = 3$ hours the reduction in the diameter (steel intensity) of gas distribution pipes is

– for two-time heating at $T = 12$ h:

$$\frac{d_{pb}}{d_{cb}} = \left(\frac{12}{3}\right)^{0,368} = 4^{0,368} = 1,7\,;$$

– for one-off heating at $T = 24$ h:

$$\frac{d_{пн}}{d_{нт}} = \left(\frac{24}{3}\right)^{0,368} = 8^{0,368} = 2,2\,.$$

2. Restoration of gas furnaces

In practice a furnace volume is ventilated through smoke ducts, which causes the furnace surface to cool off and the efficiency coefficient to drop. Forced blow of smoke ducts in between heatings causes an average of 15 % loss of the heat accumulated by the furnace masonry during heating.

Practical operation of gas furnaces suggests that periodic heating causes local overheating in the firebox. Heating with an open chimney valve causes lifting of combustion materials resulting in them entering the heated premises through loose areas. In order to prevent combustible gas from accumulating in the valve in between heatings, holes with the diameter of 12—15 mm are drilled. However, this type of the valve structure helps the furnace to be ventilated and lose heat with the air coming through the drilled holes in the valve into the chimney.

Restoration seeks to enhance operational possibilities of gas heating furnaces. For the ventilation of the furnace volume it is suggested that a special air duct is used which connects the firebox and chimney suction (Fig. 2).

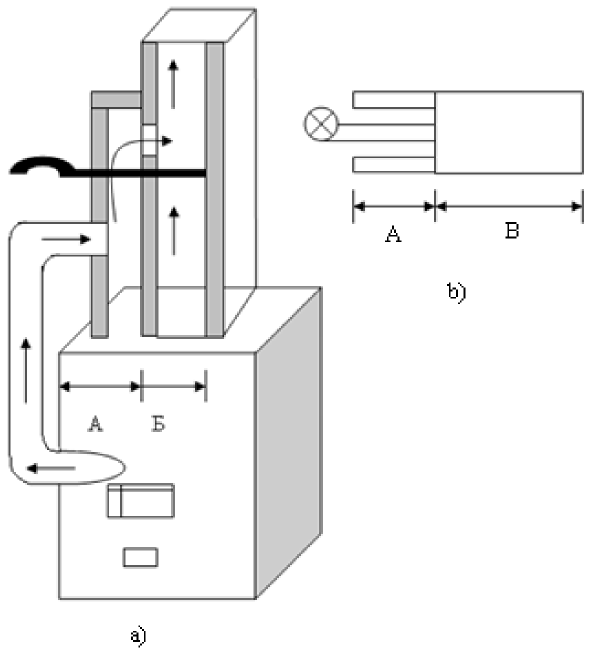


Fig. 2. Ventilation of the firebox of a gas heating furnace: a) general view of the furnace; b) valve

There are two holes in the chimney suction: for combustion products and ventilation air. The chimney suction is fitted with a valve with a plate which is both solid and hollow. Prior to heating, the valve is moved out of the suction to make room for combustion products leaving ducts to enter the chimney. At the same time the solid part of the valve closes the hole for a bypass duct.

Therefore there is no possibility for combustion products to move from the firebox into the chimney through the bypass duct passing the ducts. At the end of heating the valve is moved into the suction. The solid part of the valve blocks the hole for combustion products coming out of the chimney while the hollow part opens the hole for the ventilation air. Therefore when the valve is closed, the furnace ducts do not contact the outside air, which helps to conserve the heat accumulated with the masonry during heating.

Conclusions

1. The use of gas heating furnaces of continuous burning reduces steel intensity of gas distribution networks by 1.7—2.2 times [9]. This provide a sufficient reduction in steel intensity of distribution networks of residential areas under construction and opens up new possibilities of gas networks.

2. The open air duct only ensures ventilation of the furnace volume thus preventing explosive gas and air mix from forming. The scheme of the restoration of the furnace saves up to 15 % of gas fuel. Extra expenditure involved in it pays back within 2.7 years [9]. The research materials were used to obtain an invention patent [10].

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