Features of hydraulic modes of low pressure gas networks

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Abstract. In conditions of modern gas supply, the gas parameters are not constant. In this regard, gas appliances operate at different pressures. In operation, the change in the thermal load of the devices is due to fluctuations in the gas pressure in the city network. These oscillations are associated with the gas oscillations at the outlet from the gas regulating station. The main indicator of qualitative combustion of gas in appliances is the completeness of combustion, and this depends on maintaining the nominal pressure. The time during which the combustion process is completed consists of the time necessary for the formation of a gas-air mixture of stoichiometric composition, for heat the mixture to the ignition temperature, and of the time during which the combustible components of the gas react with oxygen.

1 Introduction

When burning a gas-air mixture with a stoichiometric composition, a number of difficulties arise related to the stability of the combustion process. Violation of combustion stability can occur in the case of a flame breakthrough or separation. The threat of a flame breakthrough or separation occurs when the proportion of primary air in an air-gas mixture increases and its composition approximates to stoichiometric. The most stable is the diffusion combustion, when all the air necessary for it enters directly into the combustion zone. Possible limits of stable operation of gas-burning devices are wide. Diffusion of secondary air to the gas flow does not depend on the flow velocity. With an increase in the proportion of primary air, the limits of the stable combustion process are reduced and when the mixture is supplied with a stoichiometric composition, they are decreased so much that a small disturbance of the burner's load leads either to the separation or the breakthrough of the flame [1, 2].

To ensure a stable combustion process, it is necessary to maintain the rate of entry of the gas-air mixture in a certain ratio from the speed of the flame distribution. If these ratios are not observed, the stable operation of the gas burner device is disrupted. Therefore, it is very important to maintain a stable normal pressure. In order to avoid a breakthrough in the flame, the exhaust speed must always be higher than the speed of flame propagation.

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Consumers connect directly to gas networks of low pressure. While maintaining the nominal pressure burners operate steadily without separation and breakthrough of the flame and ensure the completeness of gas combustion with the maximum efficiency factor [3].

Gas pressure fluctuations in aggregates depend on the following factors:

- the magnitude of the calculated pressure drop and the degree of its use in the path of gas from the supply point to the gas-using unit;
- operating mode of gas-using installations;
- method for regulating the gas pressure at the power point of the network [4, 5].

2 Methods

Household gas appliances are available for two nominal gas pressures: $P_{\text{nom}}=1274$ Pa and $P_{\text{nom}}=1960$ Pa.

The maximum gas pressure fluctuations in front of the devices are equal to the calculated differential pressure of the gas for the gas network [6, 7].

Determine the overload of gas appliances based on the standard data for the nominal gas pressure $P_{\text{nom}}=1274$ Pa and $P_{\text{nom}}=1960$ Pa.

$$K_1 = \frac{P_{\text{max}}}{P_{\text{nom}}} = \frac{1764}{1274} = 1,4; \quad (1)$$

$$K_1 = \frac{P_{\text{max}}}{P_{\text{nom}}} = \frac{2744}{1960} = 1,4. \quad (2)$$

Calculate the load of gas appliances based on the standard data for the nominal pressure 1960 and 1274 Pa:

$$K_2 = \frac{P_{\text{max}}}{P_{\text{nom}}} = \frac{980}{1960} = 0,5; \quad (3)$$

$$K_2 = \frac{P_{\text{max}}}{P_{\text{nom}}} = \frac{637}{1274} = 0,5. \quad (4)$$

Based on the maximum fluctuations of the gas pressures before the units, the calculated pressure drop for the network will be equal to

$$\Delta P_0 = P_{\text{max}} - P_{\text{min}} = (K_1 - K_2) \cdot P_{\text{nom}} = (1,4 - 0,5) \cdot P_{\text{nom}} = 0,9 \cdot P_{\text{nom}}. \quad (5)$$

Thus, at a nominal pressure $P_{\text{nom}} = 1274$ Pa, the expected pressure fall is equal to $\Delta P_{\text{exp}} = 0,9 \cdot 1274 = 1147$ Pa.

At a nominal pressure $P_{\text{nom}}=1960$ Pa expected pressure fall is equal to $\Delta P_{\text{exp}} = 0,9 \cdot 1960 = 1764$ Pa..

According to SP 42-101-2003, the estimated total losses of gas pressure in low-pressure gas pipelines (from the gas supply source to the most remote device) are not more than 1800 Pa.

Thus, for gas appliances with a nominal pressure $P_{\text{nom}} = 1960$ Pa, the normative data from SP 42-101-2003 completely coincide, and for gas aggregates with a nominal pressure $P_{\text{nom}} = 1274$ Pa, the value of the calculated drop (1147 Pa) differs significantly from the normative value. In this case, gas appliances will work with overload and underload, that will affect the stability of the units operation.

The equation relating the value of the initial pressure P_{in} in the network, the pressure at the consumer P_{con} and the pressure drop at the design mode ΔP_d [8,9]:

$$P_{\text{in}} = P_{\text{con}} + \beta \Delta P_d, \quad (6)$$

where β is the degree of use of the calculated differential pressure of the gas.

Taking into account the change in the load with respect to the maximum $\left(\frac{Q}{Q_{\max}}\right)^{1.8} = x^{1.8}$ we obtain the equation:

$$P_{\text{in}} = P_{\text{con}} + \beta x^{1.8} \Delta P_d. \quad (7)$$

Assuming the initial pressure in the network to be constant and equal to $P_{\text{in}} = 1.4P_{\text{nom}}$ and assuming the calculated pressure drop of the gas $\Delta P_d = 0.9P_{\text{nom}}$, the equation takes the following form:

$$1.4P_{\text{nom}} = P_{\text{con}} + \beta x^{1.8} 0.9\Delta P_d. \quad (8)$$

Gas pressure in front of consumers' devices is determined from the following expression

$$P_{\text{con}} = 1.4P_{\text{nom}} - \beta x^{1.8} 0.9\Delta P_d = P_{\text{nom}}(1.4 - \beta x^{1.8} \cdot 0.9). \quad (9)$$

3 Results

We determine the values of gas pressure with full use of the calculated pressure difference $\beta = 1$, $\beta = 0.5$ and possible load changes x from 0.1 to 1 (Tables 1, 2, Figure 1).

Table 1. Gas pressure in consumers when the load changes and the degree of use of the calculated differential pressure at $P_{\text{nom}} = 1960$ Pa.

$\beta=1$						
x	0.1	0.2	0.4	0.6	0.8	1.0
P_p, Pa	2705	2646	2391	2038	1568	980
$\beta=0.5$						
P_p, Pa	2724	2696	2575	2391	2156	1862

Table 2. Gas pressure in consumers when the load changes and the degree of use of the calculated differential pressure at $P_{\text{nom}} = 1274$ Pa.

$\beta=1$						
x	0.1	0.2	0.4	0.6	0.8	1.0
P_p, Pa	1758	1720	1564	1325	1019	637
$\beta=0.5$						
P_p, Pa	1771	1752	1674	1554	1401	1210

4 Discussion

Analysis of Tables 1, 2 and Figure 1 shows that the main part of the loads of the gas network does not exceed the maximum permissible values: 1764 Pa at the nominal pressure $P_{\text{nom}} = 1274$ Pa, and 2744 Pa at the nominal gas pressure $P_{\text{nom}} = 1960$ Pa. Thus, for consumers designed for a nominal pressure of 1960 Pa, the gas pressure in front of the gas burners does not exceed the maximum pressure of 2744 Pa for any load change [10,11,12].

Gas consumers whose gas appliances are released at a nominal pressure $P_{\text{nom}} = 1274$ Pa, the gas pressure with a load change will exceed the maximum pressure $P_{\text{max}} = 2744$ Pa, only at a value of $x = 0.1$ and 0.2 the pressure increase will be 1771 and 1752 Pa.

5 Conclusion

Taking into account the change in the pressure of gas-using plants, it is necessary to regulate the outlet pressure from the gas regulating station in accordance with the network load. The initial pressure in the network must be maintained in such a way that the pressure in all modes of operation was equal to the nominal pressure [13, 14, 15].

Fig. 1. The change in gas pressure at different loads and the degree of use of the expected pressure drop.

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