Perspectives of application of gas deaeration of water in heat-power engineering installations of various purposes

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Abstract. In this article considers a new technologies for low-temperature deaeration of water using natural gas as a desorbing medium. It is shown that these technologies are an effective means of anticorrosion treatment of water in heat power plants of various purposes. It is proved that with the use of low-temperature deaeration by natural gas of make-up water of the heating network and additional boiler feed water, the greatest energy efficiency is achieved. The possibility of applying deaeration of water by gas for anticorrosion treatment of water in district water-heating boiler plants and in autonomous heat supply systems is estimated.

1. New technologies for low-temperature deaeration of water

In the research laboratory "Heat power systems and installations", new technologies for the anticorrosion treatment of water in heat power plants have been developed. Natural gas that does not contain oxygen and carbon dioxide in its composition is used as a desorbing agent [1-3].

The technology of gas deaeration was initially developed for thermal power plants, where it provides a significant increase in the energy efficiency of district heating turbines. The economics of the new technology was estimated from the annual savings of the conventional fuel in the transition from the traditional scheme of water deaeration to the scheme of water degassing with natural gas:

\[
\Delta B = \left( \Delta N_{ch} + \Delta N_{reg} \right) \left( b_c - b_h \right) 10^{-3} - \Delta B_{add} \right) n_h, \tag{1}
\]

where \( \Delta N_{ch} \) – increase in capacity developed by the turbine on thermal consumption, kW; \( \Delta N_{reg} \) – increase in the power produced by the steam of the turbine selections, which is spent for regenerative heating of steam condensate, kW; \( \Delta B_{add} \) – increase in fuel consumption for additional steam generation in the boiler, t/h; \( b_c, b_h \) are specific consumptions of the equivalent fuel for power output in the condensation and heat extraction modes, respectively, kg/(kW·h); \( n_h \) – number of hours of use of the turbine.

In article [4], the energy efficiency of the new technology of degassing the make-up water of the heating network is estimated (Figure 1). The savings are achieved, first of all, by lowering the temperature of the make-up water and return water, which allows increasing the generation of electricity by thermal consumption. The calculation of the energy efficiency of low-temperature deaeration showed that in an installation with a T-100-130 turbine and a 500 t/h boiler with a flow of network water through the network heater of a turbine of 3600 t/h and a feed water consumption of a heat network of 800 t/h, an annual savings of about 4587 t of fuel is achieved.
Figure 1. Flow diagram of degasation of make up water of the heating supply system by natural gas: 1 – steam boiler; 2 – turbine; 3, 4 – lower and upper network heaters; 5 – deaerator; 6 – pipeline of influent water; 7, 8 – inlet and outlet branch for desorbent; 9 – gas pipeline; 10 – accumulator tank; 11 – pipeline for make up water of the heating supply system; 12 – return network pipeline.

Low-temperature deaeration of additional feed water by gas is especially effective in the operation modes of turbines of power plants with small vapor permeations to the condenser (Figure 2). In this case, the new technology helps prevent significant heat losses with the recirculation of the main condensate. The calculation is made for the T-100-130 heating turbine, the main condensate flow in the heating mode is 16 t/h, the condensate temperature is 30°C, the recirculation condensate flow is 150 t/h. The flow and temperature of the initial water for the deaerator are adopted, respectively 150 t/h и 30 ºС.

The values of the heat fluxes through the ejector cooler, the seal steam cooler and the gland heater are taken on the basis of the data [5]: $Q_{ec} = 1.68 \text{ mW}$, $Q_{sc} = 0.67 \text{ mW}$, $Q_{gh} = 2.56 \text{ mW}$. The calculation showed that the total annual savings of fuel using the new solution for the above input data is 2519.78 t.

Figure 2. Scheme of a heating turbine installation with low-temperature gas deaeration of additional feed water: 1 – steam boiler; 2 – turbine; 3 – the condenser; 4 – cooler of the main ejector; 5 – the vapor seal cooler; 6 – gland heater; 7 – low pressure heaters; 8 – deaerator; 9 – pipeline of influent water; 10 – gas pipeline; 11 – pipeline of additional feed water.

However, it was later found out that the scope of gas deaeration is much wider. In particular, it can be used in installations where, for various reasons, it is not possible to use traditional technology using
steam or superheated water as a desorbing agent in atmospheric and vacuum deaerators, and the requirements for anti-corrosion treatment of water are high enough. Let us consider the application of gas deaeration at heat power facilities of this type.

2. District water-heating boiler plants
In these plants, as a rule, vacuum deaerators are used to deaerate the heating water make-up water.

As heating agent in vacuum deaerators, the network water superheated with relatively to the pressure in the deaerator is used because of the absence of steam in the water-heating boiler plants. The main problem with the use of vacuum deaerators in water-heating boiler plants is the inability to provide the technologically necessary temperature regime of vacuum deaeration in the non-heating period and during most of the heating season. For effective vacuum deaeration the temperature of the heating agent – the overheated network water is required not less than 90-100°C, however during most of the year the temperature of the network water does not reach such values. In this regard, most of the water-heating boiler plants do not provide the required quality of the anticorrosion treatment of the make-up water of the heating network.

Since hot water boiler plants in most regions of Russia use natural gas as fuel, it is advisable to use gas deaeration technology in such boiler plants (Figure 3).

![Figure 3](image)

**Figure 3.** Schematic scheme of the deaeration of make-up water by gas in the heating system in a hot-water boiler plant:
1 – hot water boiler; 2 – burner; 3 – gas pipeline; 4, 5 – pipelines of network water;
6 – pipelines of heating water make-up water; 7 – deaerator

In most cases, atmospheric jet-bubbling deaerators are applicable for deaeration by gas in hot water boiler plants [6]. The height of the installation of atmospheric deaerators depends on the temperature of the deaerated water. At a temperature of 104,3°C, typical for the traditional technology of atmospheric deaeration using steam as a heating agent, the required height of the deaerators installation, at which water does not boil on the make-up or feed pumps, is 7-8 m. With low-temperature deaeration by gas, such deaerators can be located practically at any height that is convenient for the layout of the boiler plant.

During the reconstruction of the hot water boiler plant for deaeration by gas, previously installed vacuum deaerators can also be used [7].

3. Autonomous heat supply systems
Autonomous heat supply systems with roofed, attached, separately standing water-heating boiler plants have been widely spread in the last quarter of a century. However, over time, problems associated with the operation of autonomous heat sources began to be identified. One of such problems is caused by the lower reliability of boiler plant operation and the entire autonomous heat supply system because of the increased intensity of internal corrosion of equipment and pipelines of primary and secondary (in case of connecting local heating systems and hot water supply through an intermediate heat exchanger)
circuits. The reason is that the primary and secondary circuits of the autonomous heat supply system are fed by non-deaerated raw water [8].

The impossibility of anticorrosion treatment of water by deaeration in autonomous boiler plants is due to objective factors: the use of atmospheric deaerators is impossible due to the absence of steam used as a desorbing medium, and the use of vacuum deaerators is impossible due to the lack of overheated water of the required temperature (about 100°C or more).

Under these conditions, effective anticorrosion treatment of water for primary and secondary circuits of autonomous heating systems can be carried out by means of deaeration of water by gas, especially since the vast majority of such systems use natural gas as fuel. The basic scheme of water deaeration is similar to that shown in Figure 3, with amendments to the scheme of a particular autonomous heat supply system (single-circuit or dual-circuit).

Gas deaeration of water for autonomous heat supply systems is advisable to be carried out in atmospheric jet-bubbling deaerators of the required capacity. The release of low-capacity deaerators for autonomous systems can be established at the Saratov Power Engineering Plant, the main domestic manufacturer of atmospheric and vacuum deaerators.

References
[1] Sharapov V I, Pazushkina O V and Kudryavtseva E V 2013 Patent RF № 2537656 Method of operation of a thermal power plant IPC F 01 K 17/00
[2] Sharapov V I, Pazushkina O V, Kudryavtseva E V and Kurochkina A S 2013 Patent RF № 2548962 Method for deaeration of water for a thermal power plant IPC C 02 F 1/20
[3] Sharapov V I, Pazushkina O V and Kudryavtseva E V 2016 Energy-Effective Method for Low Temperature Deaeration of Make-up Water on the Heating Supply System of Heat Power Plants Thermal Engineering 63 56–60
[4] Sharapov V I and Kudryavtseva E V 2016 Energy Efficiency of Low-Temperature Deaeration of Makeup Water for a District Heating System Power Technology and Engineering 50 204–7
[5] Shempelev A G 2011 Development, research and implementation of methods for increasing the efficiency of equipment of technological subsystems of thermal steam turbine plants (Kirov: dis. for the degree of Doctor of Technical Sciences) p 379
[6] Sharapov V I and Kudryavtseva E V 2017 Hydrodynamic operating conditions of deaerators on natural gas Energosberezheniye i vodopodgotovka 1(105) 13–6
[7] Sharapov V I 1994 Actual problems of using vacuum deaerators in open heat supply systems Teploenergetika 8 53–8
[8] Khavanov P A 2002 Heat sources of autonomous heat supply systems ABOK 1 14–21