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The analysis of the condensation process impact on the vacuum boiler operating efficiency

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Abstract

The paper represents the research results of the condensation process impact in vacuum volume on the vacuum boiler operating efficiency. The calculation method of the vacuum hot-water boiler taking into consideration heat transfer under condensation is proposed. The studying of the condensation process in vacuum volume makes possible to identify the disadvantages influencing over the vacuum boiler efficient operation. The selection of heat exchange intensification rational methods on the basis of the obtained information makes possible to use the vacuum boiler as a heat source for autonomous heat supply systems in industry.

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Keywords: condensation; pressure; heat transfer; efficiency

1. Introduction

To improve the applying and achieve economically feasible efficiency of energy resources usage is possible due to the development and implementation of new technologies and equipment. The vacuum hot-water boiler not requiring high financial expenses at operation, having simple construction and being safe in use can be offered for the autonomous heat supply systems.

The boiling and condensation processes taking place in vacuum volume of the given boiler have a considerable impact on the vacuum boiler operating efficiency. The heat exchange capacity reduction in vacuum volume resulting from the pressure lowering decreases the device efficiency. The boiling and condensation processes at subatmospheric pressure differ from the processes taking place at atmospheric pressure, therefore, it is necessary to examine the peculiarities of each process to select optimal methods of intensification.

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For a long period of time, no due attention was paid to the condensation processes under the heat and mass transfer equipment operation, the process was supposed not to require the appliance of extended heating surfaces and other intensification methods. In the vacuum boiler condensation is an important process influencing the boiler operating efficiency and it requires more detailed study of the given process peculiarities at subatmospheric pressure. The research of this process characteristics makes possible to define the spectrum of problems and select the heat exchange intensification rational methods. The vacuum hot-water boiler energy efficiency improvement by means of heat and mass transfer intensification in vacuum volume makes possible to construct the medium powered high efficiency industrial sample for the autonomous heat supply system.

The present paper deals with the condensation processes in boiler vacuum volume taking into account the boiling process.

2. The study subject (Model, Process, Device, Synthesis, Experimental procedure, etc.). Condensation process modelling in vacuum volume

The condensation represents the process of vapor (gas) conversion to the liquid or solid state. The heat release at the phase transformation inextricably connects the vapor condensation process with the heat exchange. Condensation can occur in the vapor volume or on the cooled heat exchange surface.

In vacuum boilers the question is about the saturated vapor condensation to the liquid state on the cooled heat exchange surface, providing that the surface temperature is lower than the saturated one at the defined pressure.

The saturated vapors are often condensed on the horizontal tubes external area in vacuum boilers, to define the heat transfer coefficient value is possible according to the formula [1]:

$$\alpha = 0.798\sqrt[4]{\frac{\lambda_l^3 \rho_l^2 g r}{\mu_l \left(t_s - t_w\right) d}} \tag{1}$$

where λ_l is the heat conductivity of the liquid phase; ρ is the density of the liquid phase; g is the gravity acceleration; μ is the dynamic viscosity; t_s is the saturation temperature; t_w is the wall temperature; d is the typical dimension.

There is also a possibility of condensation on the inclined and vertical surfaces.

In case of condensation on the vertical surface, the heat transfer coefficient is calculated using the following formula [1]:

$$\alpha = 0.943\sqrt[4]{\frac{\lambda_l^3 \rho_l^2 g r}{\mu_l \left(t_s - t_w\right) h}} \tag{2}$$

where λ_l is the heat conductivity of the liquid phase; ρ is the density of the liquid phase; g is the gravity acceleration; μ is the dynamic viscosity; t_s is the saturation temperature; t_w is the wall temperature; h is the wall height.

In case of the inclined surface, the gravity acceleration vector projection on an axis *Ox* is necessary to introduce into the basic equation of motion [1]:

$$g_x = g\cos\varphi \tag{3}$$

where φ is the angle formed by the gravity force direction and coordinate axis *Ox*; the axis *Ox* is oriented in the film direction [1].

Consequently, the following formula is obtained for the inclined surfaces [1]: