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RESEARCH AND CALCULATION OF HIGH-FORCED CAPILLARY-POROUS HEAT EXCHANGER

Abstract. A capillary-porous cooling system for caissons of melting units has been studied, developed and calculated. The experimental type of the mesh porous structure $(2\times0.55)\cdot 10^{-3}$ m is defined. The heat transfer capacity of the cooling system is increased six times. The hydraulic resistance at boiling of water will be 40.4 times less than in mesh heat pipes, and even more so for the wicks of heat pipes with fibrous, powder and ceramic materials. The caisson allows to carry out cooling of furnaces is explosion-proof due to the maintenance of a trace amount of liquid in the porous structure. The system of caisson of the lining of the unit and the cooling scheme of the caisson by a capillary-porous system is presented. The hydraulic resistance in the capillary-porous structure, the criterial heat transfer equation, taking into account the excess fluid, which determines the speed and underheating of the flux, and the heat-storage capacity of the wall, are obtained by us as a result of experimental studies.

Key words: capillary-porous system; hydraulic resistance; cooling system; caisson; heat flux.

1. INTRODUCTION

The capillary-porous heat exchanger is designed to ensure the explosion-proof operation of melting units in metallurgy. It contains a very small amount of liquid, which eliminates the danger of explosion at the burnout of the cooled element. It is also excludes the ingress of water into the melt, which leads to the explosion of the furnace, as in the case for water and evaporative cooling systems, made in the form of caissons.

The next stage of development of the heat exchanger was the study of a capillary-porous structure. To increase the removal of thermal loads, the control of heat transfer processes is used. For this purpose, the separation of the energy of the boiling stream in the porous structure into energy of the thermal wave and the energy of the vapor flow is investigated [1].

For this purpose also, the process of explosive production of a steam germ is simulated.

The next step in controlling heat exchange is the joint action of mass and capillary forces for coolant transport, creating underheating and forced flow velocity in the structure [2]. Also, the system is capable to increase the critical heat loads by an order of magnitude and can be allocated into a separate class of heat exchangers, characterized by high forcing and intensity of heat transfer. In addition, mass forces make it possible to control the shape and intensity of generation of internal characteristics of a boiling stream in a capillary-porous structure and intensify heat transfer processes [3,4].

2. METHODOLOGY

Physical and mathematical models of processes of boiling in a porous structure are developed for all modes of boiling (initial, transitional, developed and crisis (limiting)) [5-8].

Generalization of experimental data on the basis of the theory of similarity and modeling makes it possible to obtain a criterial equation for calculating the heat exchange of boiling and foam flows in porous structures [9] and to create an engineering calculation technique.

We give an example of calculation of such system in relation to the heat exchanger executed in the form of a caisson. The system of caisson of lining (garnissazh lining) of the melting unit is shown in figure 1. The scheme of the caisson with the garnissazh lining consists of: 1 – meling film; 2 – garnissazh;

3 - fireproof packing; 4 – thermal isolation; 5 – outside metal covering; 6 - temperature variation in the thickness of the lining; 7 – viscosity variation in a garnissazh layer; 8 – caisson wall; 9 – caisson. The following designations are accepted: q_{pi} , q_u , q_{env}- - the specific heat flux from a melt; the specific heat flux is carried away by a cooling system; the specific heat flux coming to an environment; t_m , t_{mf} , t_{met} , t_w - temperatures of melting, of melting films, of metal and the protecting wall.

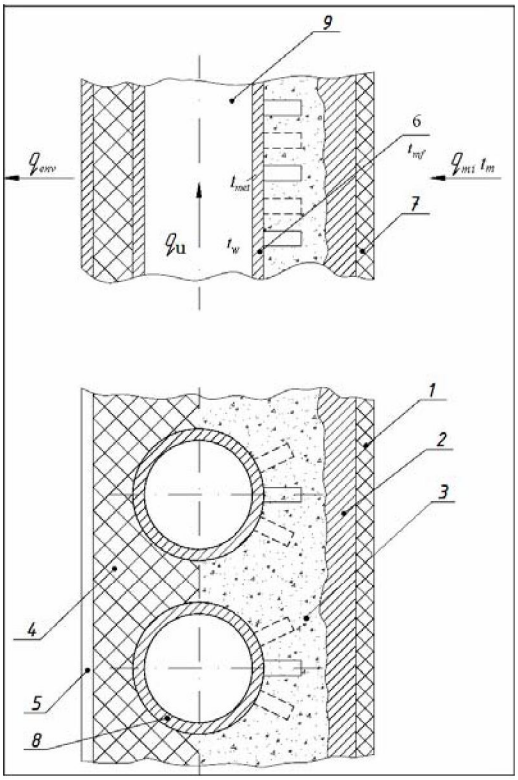

Figure 1 - The scheme of the caisson with the garnissazh lining

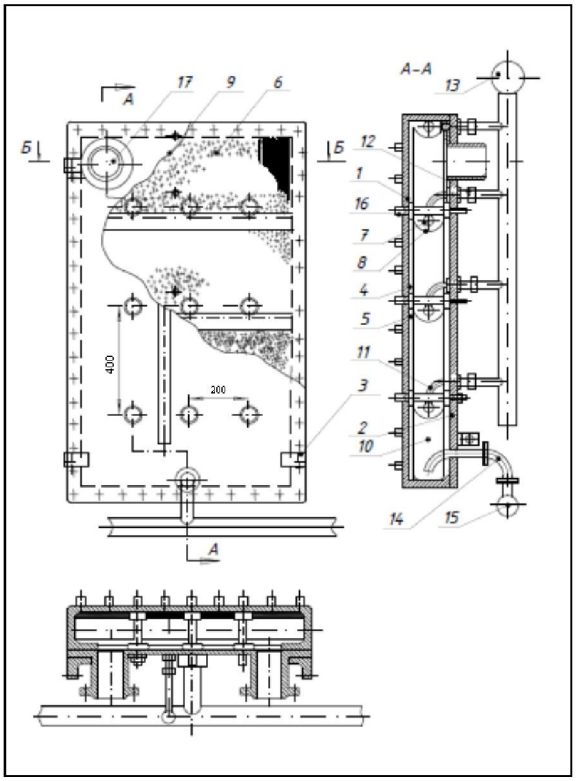

Figure 2 - The cooling scheme of the caisson of a capillary-porous system with struts

Figure 2 shows the cooling scheme of the caisson of a capillary-porous system with stiffening ribs made in the form of struts. It consists of: 1 – housing; 2 – cover; 3 – bolt; 4 – wall; 5 - capillary-porous structure; 6 – plate; 7 – artery; 8 – basket; 9 – opening; 10 – channel; 11, 17 – branch pipe; 12 – pipe; 13, 15 – collector; 14 – siphon; 16 – struts.

It can be seen from figure 2 that a capillary-porous structure has a small thickness (a fraction of millimeters), every second contains a small amount of cooler, which is not dangerous for the formation of an explosive mixture in case of its enter in a melt of furnace.

The design of caissons (figure 2) represents a box-shaped form. It consists of the housing 1 and a removable cover 2, hermetically bolted on perimeter 3. The internal surface of a wall 4 is covered with the capillary-porous structure 5 pressed by perforated plates 6. Arteries 7 are connected to top ends of structure through the end face of which to the cooled surface liquid is supplied by mass and capillary forces. The lower ends of structure are usually free and immersed in baskets 8 where liquid accumulates due to leaks, droplet entrainment or the excess. On a surface of plates the openings 9 are stamped which provide a steam-out from structure in channel 10 and also serve as catchers of the drops which are thrown out from the structure and the flowing-down excess liquid on an external surface of a plate. The artery is connected to a branch pipe 11, with the distributing pipes 12 and a collector 13. The excess of cooling liquid accumulates in the bottom of a caisson and is removed by a siphon 14 in the lower collector 15 and further in the store for return to system. For the purpose of facilitation of a design and preservation of sufficient rigidity, the caissons are provided with struts 16. If the struts made in the form of ribs, they may be located either on the outside or inside the shell and the caisson cover. On a cover, in its upper part,