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RESEARCH OF METASTABLE CONDITIONS AND HEAT - MASS TRANSFER PROCESSES IN MAGNESIUM CHLORIDE SOLUTIONS

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In the given work results of an experimental research of pulsations of temperature on the evaporating surface and in the steam volume of the laboratory evaporator installation are given. Research of the major factors influencing pulsations of temperature in the solution, on the phase boundary and in the steam-gaseous medium is carried out.

Keywords: pulsations of temperature, magnesium chloride solutions, heat - mass transfer, kvazi-elastic periodic force.

At non-stationary boiling of solutions in evaporating apparatuses there are temperature pulsations in the solution, on the phase boundary and in the steam-gaseous medium [1]. This phenomenon has been scantily explored till now. At the same time, its studying represents essential scientific interest as it allows revealing of "thin" mechanisms of the heat and mass transmission phenomena in evaporating, distillation and heat power installations. Simultaneously, research of this phenomenon also represents significant practical interest, supplying a valuable initial material for strengthening equipment calculations as temperature pulsations in combination with the medium corrosive attack can result in a premature failure of the structural materials it has been made of. In the present paper results of an experimental research of pulsations of temperature on an evaporating surface and in the steam volume of the heat-insulated laboratory evaporator system are presented.

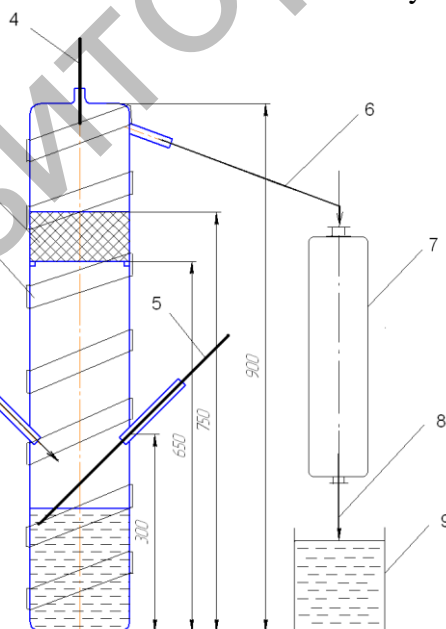


Fig. 1. Experimental installation design. 1 - connecting pipe for supply of initial evaporated solution; 2 - heater tape element; 3 - separator device; 4 - upper thermometer 5 - bottom thermometer; 6 - secondary steam; 7 - capacitor; 8 - condensate; 9 - container for condensate.

It represented a vertically installed sealed insulating quartz glass unit with the diameter 54 mm and height 900 mm, warmed with an electric tape element (in fig. 1. the thermal insulation is not conditionally shown). The temperature on the surface of boiling and in the steam volume was controlled by thermometers with accuracy $\pm 0.1^\circ\text{C}$. The measuring equipment was heat-insulated from the influence of the external temperature effects.

The experimental technique consisted in the following. The equal heat rating was brought to the evaporated solution. Thus the solution temperature in the evaporator system volume was $101\div 102^\circ\text{C}$ (for bidistillate). In the first series pulsations of the temperature of the evaporated pure distillate was investigated at a temperature below the temperature of its intensive boiling ($101\div 102^\circ\text{C}$). In the second series of experiences at the same power input to an evaporated solution pulsations of the temperature solution of MgCl_2 were investigated. For the purpose of devaporation prevention on the installation walls, the installation was warmed all along the length of the steam volume with the tape heating element, that resulting in the temperature of the steam at the steam out connecting pipe being bigger, than the temperature of the boiling liquid since the steam became overheated.

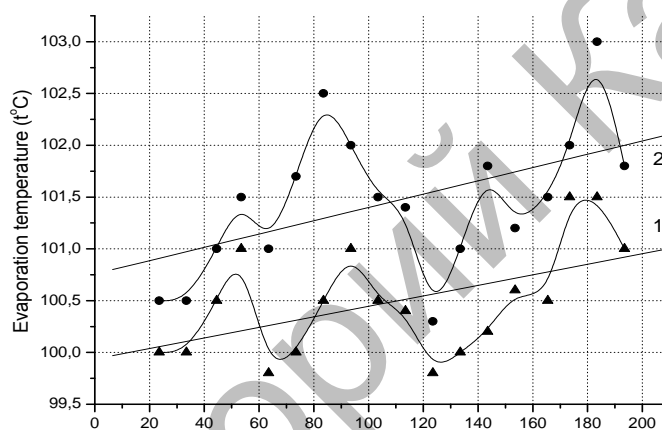


Fig. 2. Change of temperature at vapor out connecting pipe at $p=759$ mm Hg, $V=200$ ml; 1- solution MgCl_2 (concentration 15 g/l); 2- bidistillate.

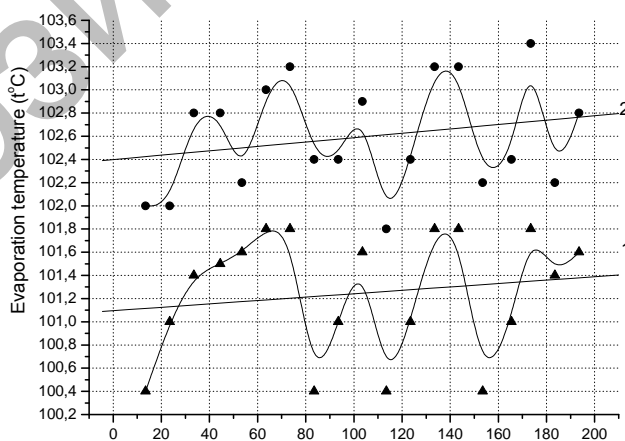


Fig. 3. Temperature change on the solution surface at $p=759$ mm Hg, $V=200$ ml. 1- solution MgCl_2 (concentration 15 g/l); 2- bidistillate.

At definition of the quantity of the steam leaving the heating surface, it is necessary to operate with concepts of thermal loading, temperature pressure and heat emission factor. At the most rough calculations these magnitudes are accepted independent of the position of the heating point along

the length of the pipe, i.e. the calculation is based on the average values of the heat emission factor. The average values do not allow revealing the adverse zones of boiling which result in the local excessive heating of the wall of the evaporator system, reducing durability of its work.

Intensity of the process of steam formation is connected with the thermal loading. Certain spectrums of heat emission, water resistance along the evaporator system match certain thermal loading. Loading change results in moving of spectrums to this or that side. The higher is the thermal loading, the more stretched the longwise pipes spectrums are and vice versa. At the change of thermal loading this spectrum is sweepingly overhauled, while aerodynamic and radiation regimes of heat upping space behave inertly enough [2].

Uncoordinated reorganization of internal and external spectrums at sudden changes of thermal loading and pressure sometimes result in the local excessive heating of the installation even when the general rate of evaporation per unit heating surface and a average number of joules removed from a unit of the surface also increase, the basic part of the evaporating surface being chilled.

The mechanism of the process of steam formation as a molecular dispersion of the solution is carried out in the presence of meshes or the so-called centers of steam formation on heated upped surfaces. Steam bubbles growing in the boundary of the overheated bed of mortar periodically come off the surface and carry away with some portions, or quanta energy.

The physical model and the conditions defining regularities of the process of heat emission, consist of the following:

1. Faltering character of the process of steam formation coming to light in the form of periodic origination of steam bubbles with a certain frequency is supposed. The process of elastic-oscillatory traffic of the enlarging steam bubbles in the presence of a thermal field of the environment defines conditions of existence of the external kvazi-elastic periodic force in the form of pulsing blisters and primary chains.

2. Under the influence of this external kvazi-elastic periodic force when frequency of their own oscillations of the system of the moving steam bubbles and fluid-flow stoppers coincides with the ripple frequency of steam streams, the phenomenon of a resonant pulsation and intensive enlargement of the moving group stream of the total bubbles chain into bigger steam volumes is gained.

3. Enlarged (total) steam bubbles coarsening in the process of traffic result, in turn, in a total pushing effect of a tie-rod on the liquid phase in the whole volume of the pipe.

4. Thrown upwards in bubble expansion fluid-flow stoppers retard speed at the moment of its compression or get return speed and then are thrown again etc.

5. As a result of such air-lift mechanic action both phases possess certain "phase" speeds alongside with their average group velocities significantly different from each other.

In the course of heat-transfer agent boiling it is necessary to distinguish the stage of unsteady boiling from the stage of the developed or stationary boiling. In the boiling initial stage formed steam bubbles on the heating surface at extending to the zone, boundary with the wall condense because of insufficient excessive heating of the boundary layer. New blisters appear, condense again etc. Under these conditions the steam bubble represents the dipole fluctuating with a big frequency and acoustical effect in the limits of audibility [3].

Work of expansion of the steam blister volume is achieved at the expense of the heat going together with the steam from the wall.

At blister condensation negative work of compression with isolation into the liquid medium of heat in the quantity, equivalent to the change of the blister volume is made.

Steam bubbles vibrating on the surface create some kind of a system of the kvazi-harmonious high-frequency injection units irradiating energy into the heated liquid medium in portions, multiple to integers [4]. Such notion about energy generation is also passed round also to the area of the installed boiling. In the developed or installed stage of boiling when the stationary temperature pattern has already been attained in the liquid phase, steam blisters come off the boiling surface and,

rising upwards, carry away matching portions of energy. The temperature, pressure balance and average frequency of the brake-off of blisters along the length of the generating tube vary.

According to it, calorific intensity, oscillation amplitude of the diameter of the blister, kinetic and potential energy undergo a change. It results in existence of the original spectrum of heat emission and the water resistance along the pipes. The above mentioned is connected with the origin of the kvazi-periodic traffic of the steam bubbles coarsening longwise the pipe, as resulting complexes from the resonant affecting of periodically pulsing steam streams from meshes of steam formation [3]. These steam streams, or chains of primary blisters during the initial moment come off the heating surface in a normal direction, and then under the influence of Archimedes' forces and the initial pulse move on a parabola up to merge with the total bubble. As follows from graphs (fig. 2, fig. 3) the temperature ripple amplitude lies over the range of 1-2°C, and the basic part of the pulsations occurs in the temperatures range of 101-103°C. In fig. 2 change of temperature at the vapor withdrawal connecting pipe is presented. From the data presented in fig. 2 it is visible, that the bidistillate temperature ripple amplitude makes 2°C, whereas the ripple amplitude of the temperature of the salt liquid of MgCl₂ makes 1,5°C. Frequency of pulsations of temperature coincides. Comparison of pulsations frequency at vapor discharge pipe and on the solution surface (fig. 2, fig. 3), show that at a jump of the thermal loading heat emission parameters on the surface of fig. 3 are sweepingly overhauled, while hydrodynamic regimes of the heating space behave inertly enough. Thus the temperature ripple amplitude on the solution surface makes 1°C for bidistillate, and 2°C for salt liquid MgCl₂. Analyzing the mechanism of pulsations, it is possible to come to the following conclusions:

1) In pseudo-steady-state conditions of evaporation the influence of the temperature patterns consists in changing of conditions of the origin of the whirlwind convection streams defined, basically by the rising blisters.

2) In non-stationary conditions ($t \leq t_{\text{water boiling}}$) where faltering character of the process of steam formation is supposed, manifested in the periodic origin of steam bubbles with certain frequency, the main role in the course of pulsations is played by the local temperature change of the solution in time. Comparison of the period of pulsations at unstable boiling of the pure distillate and the concentrated solution of MgCl₂ has allowed to determining their conformity. Relative decrease in a ripple amplitude for concentrated solution of MgCl₂ in comparison with the distillate has thus been noted. Change of hydrodynamic properties of the evaporated system can serve as one of the reasons for it. The maximum intensity of pulsations is observed on the evaporation surface, whereas the minimum - at the vapor withdrawal connecting pipe. It can be explained, at the first approximation, by inertia of the heating space regime as well as the influence of the secondary convective currents. Their formation is caused by heat exchange processes between the liquid and the wall, non-stationary hydrodynamic and thermal processes in the evaporated solution.

Despite the small sizes of the laboratory evaporating system and the desire to achieve in it a uniform input of warmth to the wall of the evaporating chamber, intensive pulsations of temperature were observed in it. Presence of such pulsations of temperatures even in the laboratory-scale plant testifies that pulsations of temperatures will be much higher in the industrial evaporator system since conditions of a uniform heat input to the wall are complicated there. At designing industrial evaporator systems it is necessary to pay special attention to the uniformity of a heat input to the wall and the mist eliminator design.

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