INVESTIGATION OF WALL TEMPERATURE REGIMES OF VERTICAL DIRECT AND COIL HORIZONTAL STEAM-GENERATING TUBES UNDER BOILING OF LIQUIDS

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ABSTRACT

The experimental examinations a temperature regime in is vertical direct and horizontally coil steam-generating tubes. The temperature of a wall of a coil in comparison with a direct tube grows monotonously and a little bit more feebly in the field of pressures, close to critical, at crisis of a convective heat transfer.

I. INTRODUCTION

The making of new equipments and chilling of their heating surfaces at major of heat fluxes is one of the basic problems of modern technique

The reliability of thermal power equipment is instituted in basic temperature of their walls. Therefore at designing and operation of thermal power equipment it is necessary to maintain a normal temperature regime of a wall. In a steam-generating equipments at infringement of regime operating originating crisis of a convective heat transfer and jump ascending of temperature of metal is possible, that can shatter walls of the equipment.

Boil of a fluid in direct and the coil the figurative tubes has found wide applying in technique. The concern introduces learning process of boil at fluxion of a underheated fluid in the field of pressures, close to critical, where the thermophysical properties of a saturated fluid are essentially inflected. For example, density and viscosity are moderated, the heat capacity is incremented, interfacial tension and vaporization heat aspire to zero value. The performances at boil of a fluid in these requirements can differ from usual, relevant to boil in major volume. Therefore processes at boil of a saturated and underheated fluid are expedient for exploring separately.

II. MAIN TEXT

In the given article some features of crisis of a convective heat transfer are considered at boil of a underheated toluene (P_{cr} = 4.24 MPa, t_{cr}= 320.8 ^{0}C) and water (P_{cr} = 22.12 MPa, t_{cr}= 374.3 ^{0}C) in a vertical direct and horizontal coil figurative tubes.

The specification statement of experimental installation, procedure of carrying out of experience and the measurings of separate quantities are given in [1]. All clusters of experimental installation are made of stainless steel of the mark(grade) 1Kh18N10T. The uniform heating of an experimental lease came true by an electric current of low tension. The temperatures of a fluid and wall were measured chromel-alumel thermocouples with a wire diameter of 0.2 mm. In each section on length of a horizontal coil temperature of a wall was measured on the inferior, upper and lateral generator tube. On a fig. 1 the plan of an experimental lease and arrangement of thermocouples are shown. On inlet and escaping of a coil are available direct vertical leases, in elbows current of traffic of a fluid is inflected and comes true transition from vertical standing to horizontal and from horizontal - to vertical. On these leases of a coil the intensity of heat transfer is inflected also.

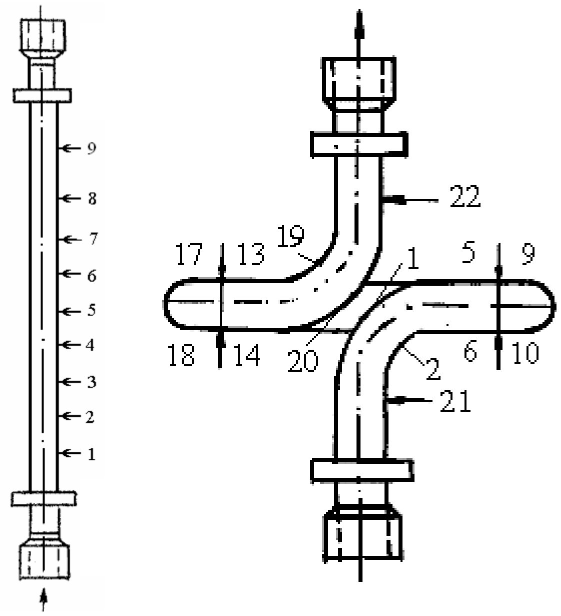

Fig. 1. The plan of an experimental lease and arrangements of the thermocouples:

The experience were spent at stationary values regime parameters, but a heat flux was incremented at gradually . In each experience the heat balance was tested, i.e. the comparison of a heat flux counted on electrical power, and stream perceived by a fluid was yielded. The distinction between them did not exceed 3 %. The inaccuracy of evaluation of a heat flux on value of electrical power was estimated in 1.8 %.

The crisis of a convective heat transfer was fixed by jump pinch of temperature of a wall.

In a fig. 2 the diagrams of a temperature variation of a wall on length of a tube are introduced at pressure $P/P_{cr} = 0.9$. As follows from a fig. 2 at moderate heat fluxes and tc < ts temperature of a wall on length of a tube is inflected monotonously, that corresponds to legitimacies of heat convection of a single-phase stream (curve 1). With magnification of a heat flux she reaches(achieves) value of saturation temperature of water, and on the diagram of dependence $t_c = f$ (x/d) the horizontal lease BV, reference for process of boil (curve 2) is formed. At particular value of a heat flux a burn-out tracking with impairment of a convective heat transfer and sharp ascending of temperature of a wall (a lease VQ).

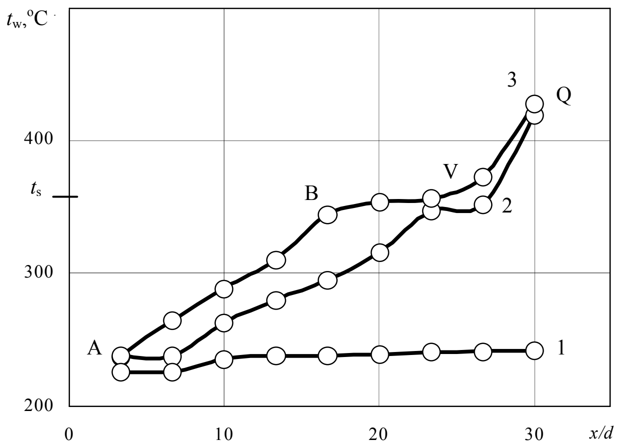

Fig. 2 Changes in the wall temperature along the length of the tube in experience with water at P = 20.0 MPa; ρ*u* = 614 kg / (m^{2}s); d_{ins}/d_{outs}= 8.0/6.0 mm; l_h - 200 mm; q·10^{-5}, W/m^2: 1 - 22.33; 2 - 28.44; 3 - 31.66.

Coil tubes in comparison with direct tubes are characterized by higher intensity of a convective heat transfer, that allows to reach in them by higher heat of intensity. Prior to the beginning boil, i.e. at single-phase heat transfer convection by pinch of a heat flux (at stationary values regime parameters) both for cold, and for a heated fluid tc on an initial direct lease of a tube up to an input elbow is slashed, and after rotational displacement on all generator of perimeter of a horizontal coil grows, that is learnt well enough [2, 3]. A convective heat transfer at boil of a fluid in a coil tubes, and also its private questions - transition from a convective heat transfer to the advanced surface boil, crisis of a convective heat exchange and others, specially at about critical pressure of a fluid are explored very little. Therefore concern introduces learning temperature schedules of coils of a figurative tube at boil of a fluid in the field of pressure, is close to critical (fig. 3). The results of examinations demonstrate, that both for a cold fluid, and for a wall, heated a temperature variation, on length of a coil on top and bottom generator differ from values on lateral surfaces.

For presentation of dependence tc = *f* (x/d) for the inferior and upper surfaces of a tube are illustrated on one diagram (fig. 3). It is visible, that on an initial lease on an input elbow temperature of a wall is slashed, and in mid-range of a coil there is an inconvertible process of boil. On a terminating part of a tube the crisis of a convective heat transfer is observed. In further with magnification of a heat flux the drop of temperature of a wall on an input elbow, diminution of length of a lease of inconvertible boil and propagation of temperature of a wall on a target lease of a coil is observed.

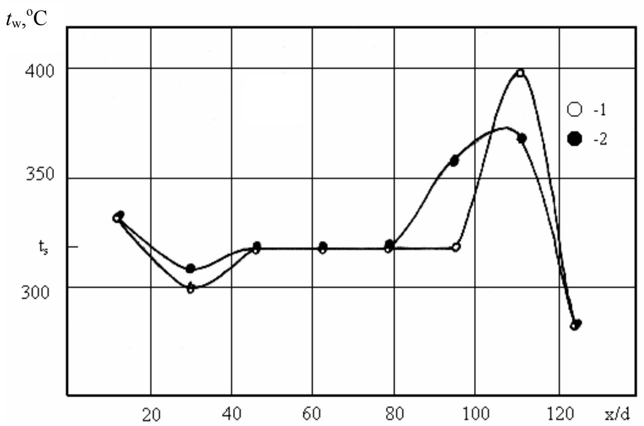

Fig. 3 Changes in the wall temperature along the length of the coil tube in experience with toluene at *P* = 4.0 MPa, ρ*u* = 550 kg/(m^{2}s), l_h= 515 mm, d_{in}/d_{out}= 4/6 mm, t_{in}=261 ^{0}C, q = 1.57·10^5, W/m^2. 1 - lower, 2 - upper element.

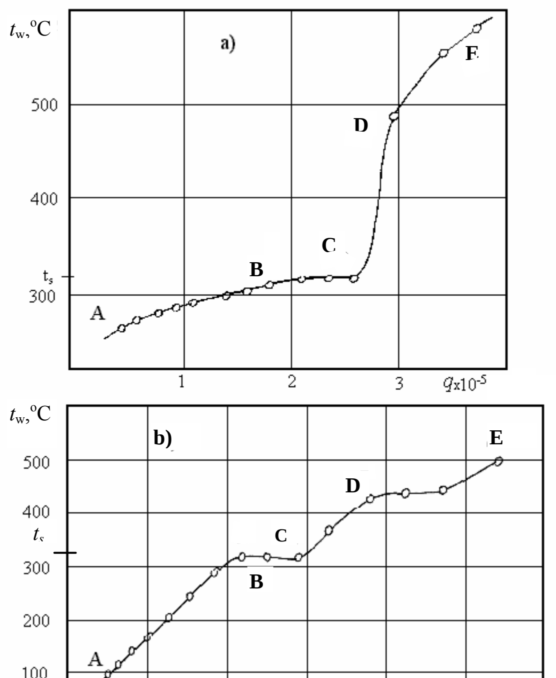

Fig. 4 Temperatures of the wall vs. heat flux density with a toluene: (a) - direct tube, P = 4.0 MPa, ρ*u* = 520 kq/(m^{2}s), l_h= 500 mm, d_{ins}/d_{outs}= 4/6 mm; (б) - coil tube, P = 4.0 MPa, ρ*u* = 550 kq/(m^{2}s), l_h= 515 mm, d_{ins}/d_{outs}= 4/6 mm.

The curves introduced in a fig. 3, walls, describing a temperature variation, at boil of a fluid in a horizontal coil tube, differ from similar, received for a direct vertical tube. It is known, that in a direct tube the crisis of a convective heat transfer is tracked by jump ascending of temperature of a wall, though in the field of pressures, close to critical, the magnification of temperature of a wall at crisis carries smoothly varying delayed character [1]. In a horizontal coil the ascending of temperature of a wall in this area of pressures is expressed more feebly, than in a direct vertical tube.

For clear representation of this phenomena in a fig. 4 the dependences $t_w = f(q)$, received in experience with a toluene are given at $P/P_{cr} = 0.94$ for section of a vertical tube x/d = 62 and for upper generator of a horizontal coil at x/d = 62. In requirements $t_w < t_s$ the heat convection of a single-phase stream (lease AB) takes place. At $t_w = t_s$ there is a boil of a fluid and temperature of a wall remains to a stationary value (lease BC). The crisis of a convective heat transfer is tracked by ascending of temperature of a wall (lease CDE). The comparison of a curve $t_w = f(q)$ for a direct vertical tube and horizontal coil demonstrates, that in the field of pressures, close to critical, at crisis of a convective heat transfer temperature of a wall of a coil grows monotonously and a little bit more feebly.

III. CONCLUSION

The experimental examinations a temperature regime in is vertical direct and horizontally coil steam-generating tubes. The temperature of a wall of a coil in comparison with a direct tube grows monotonously and a little bit more feebly in the field of pressures, close to critical, at crisis of a convective heat transfer.

IV. NOMENCLATURE

t- temperature,^{o}C; *P*- pressure, MPa; *q*-heat flux, W/m^2; *u*- velocity, m/sec; ρ- density, kg/m^3; ρ*u*- mass velocity, kg/(m^{2}s); *d*- diameter, mm; *x* – distance from the inlet of the tube, mm; *l* – length, mm.

Subscripts and superscripts: w — wall; h — heated; in — inlet; ins – inside; outs — outside; cr – critical; s – saturation.

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