УДК 621.311.22

CRISIS OF HEAT IRRADIATION AT BOILING OF UNDERHEATED HYDROCARBON HORIZONTAL COILED PIPE

KELBALIYEV R.F., ISKENDEROV M.Z.

Azerbaijan State Oil Academy

Results of study of crisis of heat irradiation at boiling of underheated toluene in the field of pressures, close to critical in horizontal coiled pipe. Uneven sharing of the temperature of wall on perimeter of horizontal coiled pipes at boiling of toluene is revealed. Dependencies of critical heat flow on working parameters are established.

In steam generation devices arising of the crisis of heat irradiation and spasmodic increase of temperature of metal is possible, and this can destroy the walls of device. There are a lot of works dedicated to study of crisis of heat irradiation. This phenomena basically investigated in direct pipe with saturated liquid which is located away from critical pressure [1-3]. These studies have allowed to reveal the main rules of crisis of heat irradiation. However, study of this complex question is not completed. Data on crisis of heat irradiation in coiled pipe for underheated liquids in the field of pressures close to critical practically are absent, some data is obtained for direct pipes. [4-7].

In this study some results of investigation of crisis of underheated toluene (P_{kr}= 4,24 МПа; $t_{кг}$=320,8^{0}C) in horizontal coiled pipe are given in following limits of changes of operating conditions :

$P/P_{кг}$=0,71-0,95; $\Delta t/t_{кг}$=0,16-0,91; pu=550 kg/(m^{2}s); d_{in}/d_{ext}=4/6;D_{bend}=110mm; l_{heat}=515mm.

The experiments were conducted on experimental plant which is flow circuit. The Description of experimental plant and measurements of single values are provided in [4]. All components of experimental plant are made from stainless steel of 1X18H10T type. Even heating the experimental area was done with the electric current of low voltage. The temperature of liquid and walls were measured by chromel – aluminum thermocouples, with diameters of wire 0,2 mm. In each section on length of horizontal coiled pipe temperature of the wall was measured in lower, upper and lateral forming pipes. On fig. 1. scheme of experimental area of horizontal coiled pipe and location of thermocouples are shown. At the input and output of coiled pipe there are direct vertical areas, in bends a direction of liquid motion changes and there is transition from vertical position to horizontal and from horizontal - to vertical (fig.1).

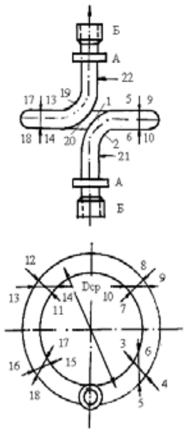

Fig.1. The Scheme of experimental area and locations of thermocouples:
A - lead; B – plenum chamber; 21, 22 - thermocouples, located on direct part of heated area; 1,20-thermocouples, located on external part of perimeter turning points, atthe input and output coiled pipe; 2, 19 -thermocouples, located on internal part of perimeter, turning points, , at the inlet and outlet of coiled pipe; 6,10,14,17- thermocouples, located on upper generator perimeter of area; 5,9,13,18–thermocouples, located on lower generator perimeter of coiled pipe; 3,7,11,15 – thermocouples, located on internal generator perimeter of coiled of coiled pipe; 4,8,12,16- thermocouples, located on external generator perimeter of coiled pipe;

On these areas of coiled pipe there are also changes in intensity of heat exchange. The experiments were conducted under constant operating conditions, but under gradually increasing heat flow. In each experiment heat balance was checked i.e. comparison of heat flow counted on electric power, and flow, perceived by liquid was done. Difference between they do not exceed 3%. The heat flow was calculated on the value of electric power, inaccuracy of its determination was 1,8%. The Crisis of heat irradiation was fixed with uneven increasing of the temperature of wall.
In fig.2 change of the temperature of wall in different forming sections on length of coiled pipe at pressures P=3,0MPa (P/P_{kr}=0,71) is shown.

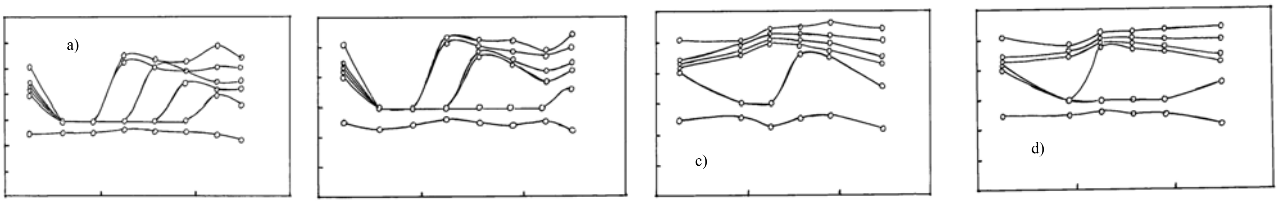

Fig.2. Change of the temperature of wall along the length of pipe in experiments with toluene under P=3,0 МПа; ρu=550 кg/m^{2}s, l_{heat}=515mm, d_{in}/d_{ext}=4/6 mm, t_{ent}=226^{0}C, for different generators : a) upper, b) lower in, c) internal, d) external.
q·10^{-5}, Vt/m^2: 1 - 0.52; 2 - 2.96; 3 - 3.18; 4 - 3.33; 5 - 3.48; 6 - 3.64.

Under the temperature tc<ts (t_s=297^{0}C) there is convective heat exchange of monophase flow according to which temperature of the wall is changing. Under constant operation conditions with the increase of heat flow tc increases and at $t_{wall} \geq t_s$ boiling of liquid is observed and temperature of the wall remains constant. The stable boiling condition of liquid lasts until definite value of q and $x = \frac{h_{mix} - h_s}{r}$ after which crisis of heat irradiation appears and the temperature of wall increases (curve 2 fig.2a). In this experiment for the upper generator of the pipe stable process of heat irradiation process appears at distance x/d=79 from inlet of pipe, and other linear measures crisis of heat irradiations observed. With increase of heat flow crisis of heat irradiation moves to inlet part of pipe and covers bigger length of coiled pipe (curves 2-4 fig. 2a).

The general nature of change tc along length for lower generators coincides with similar patterns established for upper generators of pipe perimeter (fig 2b).
However length of area of stable boiling for upper and lower generators of pipe slightly differs. For instance, under q=2.96·10^5 Vt/m^2 length of area of stable boiling for lower generator forms x/d=111, but upper - x/d=95 (the curve 2 fig.2a,b). With increase of the heat flow a place of increasing the temperature of wall moves against movement of the liquids to inlet elbow of coiled pipe, length of area of stable boiling decreases, but for lower generators it is higher, than for upper. Because of that in these areas of horizontal pipe difference of temperatures between upper and lower generators is observed. In other words, at equal terms a crisis of heat irradiation for these generators appears not in the same section. Under higher values of q arising of crisis of heat irradiation occurs in inlet elbow of pipe, distribution of temperature for lower and upper generators for rest length of pipe coincides. (curve 5 fig.2a,b).

Obviously, temperatures of lateral surfaces of perimeter of coiled pipe will have other values. On fig.2в,g changes of temperature of the wall along length of lateral surfaces for inner and outer generator loop of pipe is presented, which is different from similar values for upper and lower. The deterioration of heat exchange on lower, upper and lateral generators of perimeter of horizontal coiled pipe which can be observed at stable parameters, in different distances from inlet of pipe are well illustrated in fig.2. From these graphs it follows that in horizontal coiled pipe at equal terms of experiment heat irradiation gets worse first at inner lateral surfaces, and after that at upper and lower generators in different distances from pipe inlet.

Dependency of critical heat flow upon regime parameters in area of pressures close to those with under heated liquids is interesting.

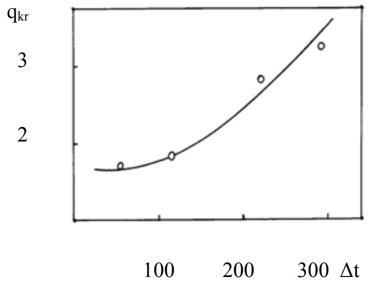

Fig.3. Dependency of critical heat flow upon underheating of liquid in inlet of the pipe. P=4,0 MPa; ρu=550 кg/m^2s, l_{heat}=515mm, d_{in}/d_{ext}=4/6 mm.

On fig.3 dependency $q_{kr}=f(\Delta t)$ for case P/P_{kr}= 0,95 is given. As it can be seen from picture, inclination of these dependencies at lower ($\Delta t < 100^0$C) and higher ($\Delta t > 100^0$C) underheating of liquid are different, and these must be taken into account when establishing the general rule of heat irradiation crisis. Decrease of the value of critical heat flow with increase of liquid pressure also is confirmed in experiments with underheated toluene (fig.4).

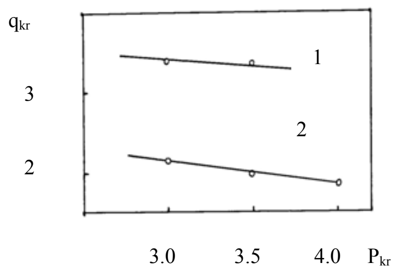

Fig.4. Dependency of critical heat flow upon pressure under different underheatings. ρu=550 кg/m^2s, l_{heat}=515mm, d_{in}/d_{ext}=4/6 mm. Δt,^{0}C: 1-276; 2-85.

Dependency of critical heat flow upon relative enthalpy (fig.5) shows that in the area of pressures close to critical with underheated liquid crisis of heat irradiation appears at negative values of relative enthalpy of toluene.

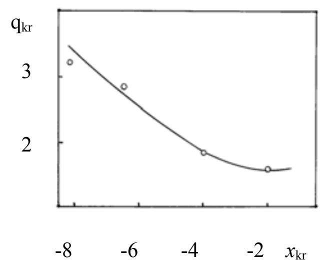

Fig.5. Dependency of critical heat flow upon steam content (the relative enthalpy). P=4,0 MPa; ρu=550 кg/m^2s, l_{heat}=515mm, d_{in}/d_{ext}=4/6 mm.

Obtained results show that study of rules of heat irradiation crisis at boiling of underheated liquid in horizontal coiled pipe in area of pressures close to critical demands further experimental studies with different liquids in broad interval of operating conditions.

CONCLUSIONS

1. New experimental information about heat irradiation at boiling of underheated toluene in area of pressures close to critical in horizontal coiled pipes is obtained.
2. It is revealed that in horizontal coiled pipe under same conditions crisis of heat irradiation on upper, lower and lateral generators of the pipe appears in different distances from inlet of pipe, i.e. not in the one section of the pipe
3. Dependency of critical heat flow upon working conditions is established

MARKING

P - pressure, МПа; t - temperature, ^{0}C; q - density of heat flow, Vt/m^2; d - diameter of pipe, mm; l - length of pipe, mm; x – distance from inlet of pipe, mm; D - diameter of coiled pipe, mm; $\Delta t = (t_s - t_{en})$ – underheating of liquid to temperature of saturation, ^{0}C; $x = \frac{h_{mix} - h_s}{r}$ - relative enthalpy; h_{mix} – enthalpy of mixtures, кDj/kg; h_s – enthalpy of liquids under the temperature of saturation, кDj/kg; r-heat of vaporization, кDj/kg.

---

1. *Дорощук В.Е.* Кризисы теплообмена при кипении воды в трубах. М.: Энергоатомиздат. 1983. 120с.
2. *Тонг Л.* Кризис кипения и критический тепловой поток. М:Атомиздат,1976. 99с.
3. *Кутателадзе С. С.* Основы теории теплообмена. М., Атомиздат, 1979. 456с.
4. *Келбалиев Р.Ф.* Теплоотдача при кипении жидкости в области давлений, близких к критическому // Теплоэнергетика, 2002, №3. С.39-42.
5. *Калбалиев Ф.И., Мамедова Д.П., Искендеров М.З.* Исследование кризиса кипения недогретого толуола.// Труды конференции «Технические и физические проблемы энергетики». Баку. 2002. С.261 – 263.
6. *Келбалиев Р.Ф., Мамедова С.Г., Искендеров М.З.* Кризис кипения при вынужденном движении углеводорода. // Труды XIV Школы – семинара молодых ученых и специалистов. «Проблемы газодинамики и тепломассообмена в энергетических установках». М.: Изд. МЭИ. 2003. Т.1. С. 243 – 246.
7. *Келбалиев Р.Ф., Мамедова Д.П., Искендеров М.З.* Расчетные уравнения критического теплового потока. // Химия и Нефтехимия. Баку. 2003. № 1. С. 68 – 72.

ŞAQULİ İLANVARİ BORUDA QIZMAMIŞ KARBOHİDROGENLƏRİN QAYNAMASINDA İSTİLİKVERMƏNİN BÖHRANI

KƏLBƏLİYEV R.F., İSGƏNDƏROV M.Z..

Şaquli ilanvari boruda, kritik təzyiq yaxınlığında toluolun qaynamasında istilikvermənin böhranı tədqiq edilmişdir. Toluolun qaynamasında şaquli ilanvari borunun perimetrii boyunca divarın temperaturunun qeyri bərabər paylanması müəyy edlmişdir. Kritik istilik yükünün rejim parametrlərdən asılılığı göstərilmişdir.

КРИЗИС ТЕПЛООТДАЧИ ПРИ КИПЕНИИ НЕДОГРЕТОГО УГЛЕВОДОРОДА В ГОРИЗОНТАЛЬНОЙ ЗМЕЕВИКОВОЙ ТРУБЕ

КЕЛБАЛИЕВ Р.Ф., ИСКЕНДЕРОВ М.З.

Приводятся результаты исследования кризиса теплоотдачи при кипении недогретого толуола в области давлений, близких к критическому, в горизонтальной змеевиковой трубе. Выявлено неравномерное распределение температуры стенки по периметру горизонтальной змеевиковой трубы при кипении толуола. Установлены зависимости критического теплового потока от режимных параметрах.