

Evaporation of macrolayer in nucleate boiling near burnout

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Abstract—The mechanism of nucleate boiling heat transfer near burnout has been investigated by studying the evaporation of the liquid macrolayer underneath the vapor mass. It is proved that heat conduction across the macrolayer and evaporation at the free surface is *not* a mode efficient enough to account for the major portion of heat transfer. The alternative model proposed is a macrolayer primarily consumed through evaporation of much thinner microlayers at the bottom of vapor stems penetrating the macrolayer. Analysis based upon the proposed mechanism shows that the macrolayer does not totally dry out in a vapor-mass cycle before boiling crisis. Other mechanisms accountable for the consumption of the macrolayer are also discussed.

INTRODUCTION

THERE has been photographic evidence [1-3] showing that nucleate boiling at high heat fluxes near burnout is characterized by a liquid layer in existence between the heating wall and the vapor mass, as depicted in Fig. 1. The liquid layer is penetrated by numerous vapor passages. According to the observation reported by Gaertner [1], this occurs in the heat flux range between $0.6q_c'$ and q_c' . Similar flow patterns were also observed in transition pool boiling [4] and forced convective flow boiling [5]. This liquid layer between the vapor mass and wall has been termed the macrolayer to permit a distinction from the microlayer which is known as the liquid film, generally thinner, between an individual bubble and the heating wall during nucleate boiling at low heat flux [6].

The role the macrolayer plays at high heat fluxes in terms of its contribution to total heat transfer is not clear. It has been suggested that the liquid film vapor-

izes on the heating wall and supplies the overlying vapor mass with vapor [2]. Since a higher pressure needs to be maintained inside the vapor mass during the growth period in order to do work to displace the surrounding liquid and this pressure also exerts on the wall, there cannot be liquid supplied to the film from the surroundings when the vapor mass grows. Liquid is drawn in only when vapor mass departs. A new vapor mass is subsequently established and grows by evaporating the liquid layer underneath.

In attempting to describe the behavior of the macrolayer, Katto and Yokoya [2] calculated the time required to vaporize the macrolayer by this lumped formulation

$$t = \frac{\rho b h_{fg}(1-a)}{q''} \quad (1)$$

with a the ratio of the cross-sectional area of the vapor passages to the total area covered by a macrolayer. This equation is simply based on the balance between the latent heat and sensible heat for a liquid mass at saturation, without considering the transient effect. It assumes that all the heat goes to the liquid-vapor interface where evaporation takes place immediately after heat transfer begins. However, when a layer of saturated liquid is heated from below, a certain amount of heat is required to superheat the liquid until a temperature gradient is established in the layer to support the heat transfer. By assuming negligible convective heat transfer due to small thickness, the time required for the development of this temperature profile can be calculated by solving a one-dimensional transient heat conduction problem as follows:

$$\frac{\partial T}{\partial t} = \alpha \frac{\partial^2 T}{\partial x^2}, \quad 0 < x < b, t > 0 \quad (2a)$$

with the initial condition

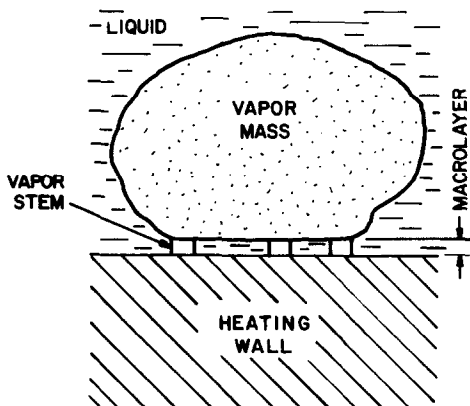


Fig. 1. Macrolayer/vapor mass configuration of nucleate boiling at high heat fluxes.

NOMENCLATURE

a	ratio of the cross-sectional area of the vapor passages to the total area, A'/A [dimensionless]	t	time [s]
A	area covered by the portion of macrolayer evaporated by one vapor-stem microlayer [m^2]	T	temperature [$^{\circ}\text{C}$]
A'	cross-sectional area of a vapor stem [m^2]	ΔT	superheat, $T - T_s$ [K]
b	liquid layer thickness [m]	x, y	distance [m]
c_p	specific heat of liquid [$\text{J kg}^{-1} \text{K}^{-1}$]	X	non-dimensional distance, x/b .
D	diameter of vapor stem [m]	Greek symbols	
h_{fg}	latent heat of vaporization [J kg^{-1}]	α	thermal diffusivity of liquid [$\text{m}^2 \text{s}^{-1}$]
Ja	Jakob number, $c_p(T_w - T_s)/h_{fg}$	δ	non-dimensional location of the thermal layer boundary
\dot{m}	mass flow rate [kg s^{-1}]	ρ	density [kg m^{-3}]
q''	heat flux [W m^{-2}]	τ	non-dimensional time, $\alpha t/b^2$.
s	location of liquid-vapor interface [m]	Subscripts	
S	non-dimensional location of liquid-vapor interface, s/b	c	critical
		e	evaporation
		s	saturation
		w	wall.

$$T(0, x) = T_s, \quad 0 < x \leq b \quad (2b)$$

and boundary conditions

$$T(t, 0) = T_w, \quad t \geq 0 \quad (2c)$$

$$T(t, b) = T_s, \quad t \geq 0. \quad (2d)$$

As depicted by the initial condition, the film is at uniform saturation temperature at the beginning. The boundary conditions are constant wall temperature and saturation temperature at the free surface. The solution is given as [7]

$$\frac{T(t, x) - T_s}{T_w - T_s} = 1 - \frac{x}{b} - \frac{2}{\pi} \sum_{n=1}^{\infty} \frac{\sin n\pi(x/b)}{n \exp(n^2\pi^2\alpha t/b^2)}. \quad (3)$$

The above solution is composed of a steady-state solution and a transient term in the form of an infinite series. The temperature profile becomes more and more linear with time. However, theoretically it takes an infinitely long time to reach the linear temperature profile. The progress of the temperature profile in a layer during thermal development is plotted in Fig. 2. It is shown that the temperature profile is very close to linear for $t > b^2/\pi\alpha$. Therefore, the approximate time required to reach the steady-state temperature profile can be taken as

$$t = \frac{b^2}{\pi\alpha}. \quad (4)$$

For water boiling at atmospheric pressure near burnout, the film thickness measured by Gaertner [1] is about 0.1 mm. The time required for thermal development is readily calculated, using the above equation, as being 0.02 s. For a typical vapor-mass

cycle period of about 0.06 s, as reported in ref. [2], it takes 30% of the cycle period for the liquid layer to become thermally developed. During this period of thermal development, as most of the heat goes to superheating the liquid layer, only a small portion of the heat can be transferred to the interface and only a small amount of liquid evaporated. As a result, Katto and Yokoya's [2] approach is considered oversimplified since the effect of thermal development is not included.

Equation (1) was also used recently by Bhat *et al.* [8] to calculate the time for macrolayer evaporation. In addition, an attempt was made to consider the effect of transient heating. They presented a model in

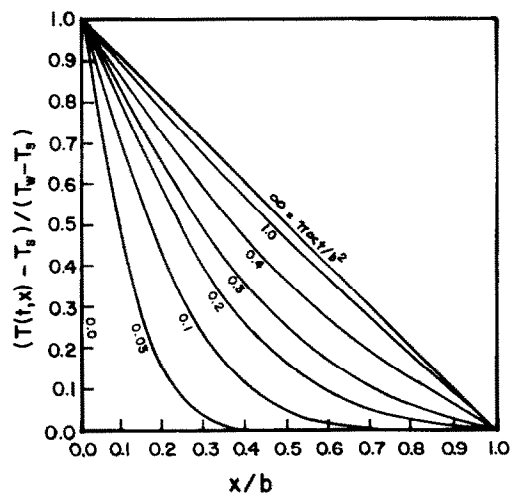


FIG. 2. Progress of temperature profile in a film during thermal development.

which a liquid layer at an initial uniform supersaturated temperature was suddenly subjected to the saturation temperature at the free surface. The initial temperature of the liquid layer was that of the heating wall; this was assumed to be the situation at the end of the waiting period in a vapor-mass cycle. A solution based on constant liquid layer thickness was then derived. The temperature profile was shown to evolve from a uniform supersaturated wall temperature toward a linear steady-state profile with saturation temperature at the interface. Apparently this was a process of losing enthalpy. Since there was heat input from the wall, the liquid layer had to lose enthalpy through the interface. However, because there was no temperature gradient in the vapor phase to support the heat conduction out of the liquid layer, the enthalpy had to be dissipated through evaporation. Therefore, there must have been a decrease in liquid layer thickness due to evaporation at the interface throughout the process, and thus it was really a moving-boundary conduction problem that needed to be solved. The solution by Bhat *et al.* [8] based on constant layer thickness does not properly describe the behavior of the macrolayer.

Bhat *et al.* [8] did present a model to take into account the decrease of macrolayer thickness. However, this model was based on a questionable linear temperature distribution in the liquid layer during evaporation. When a layer of superheated liquid is subject to a saturated interface condition, rapid evaporation or flashing will immediately take place and the layer thickness decreases at a fast rate. The decrease of thickness can be so fast that the liquid temperature never reaches a linear profile. Therefore, the assumption of a linear temperature distribution in the model by Bhat *et al.* is suspect. In addition, their model has been found to be based on further contradictory assumptions. In one equation, $db/dt = -q''/(\rho h_{fg})$ (equation (8) of ref. [8]), it was assumed that all the heat transfer from the wall was dissipated through evaporation at the interface. The liquid layer thickness was then calculated as a function of wall heat flux and time. However, in another equation, $q'' = k\Delta T/b$ (equation (9) of ref. [8]), the heat conduction rate through the layer to the vapor phase was calculated using Fourier's law. These two equations conflict with each other in that if there is a balance between the wall heat flux and latent heat transfer, there must be no conductive heat transfer from liquid to vapor at the interface.

Based on their analysis, Bhat *et al.* [8] suggested that heat conduction across the macrolayer between the vapor mass and the heating wall accounted for the major portion of heat transfer for pool boiling at high heat flux. Nucleate boiling was suppressed within the macrolayer and playing a less important role in heat transfer. However, Gaertner [1] considered that heat was transferred primarily through evaporation at the interface of the vapor passages in the macrolayer. Katto and Yokoya [2] reported that the high heat

transfer rate was attributed to the nucleate boiling in the macrolayer. Yu and Mesler [6] measured the transient surface temperature near burnout and found that nucleate boiling did occur in the macrolayer and accounted for the repeated brief surface temperature drops. Nucleate boiling is suppressed only in a short period just before the macrolayer evaporates completely, because evaporation from the very thin liquid layer keeps the surface temperature low. Apparently there are major discrepancies among the mechanisms proposed concerning the evaporation of the macrolayer.

Since major defects have been found in the analysis by Bhat *et al.* [8], the analysis may have yielded an incorrect estimation of conductive heat transfer across the macrolayer leading to an erroneous conclusion concerning the heat transfer mechanism. If heat conduction across the macrolayer and evaporation at the free surface is the major mode of heat transfer, as suggested by Bhat *et al.*, what is the function of the vapor passages in the macrolayer? How can the vapor passages exist without being flooded by the surrounding liquid if there were no strong vapor flows pushing the liquid away? It is therefore necessary to clarify the role which conduction across the macrolayer plays in the overall heat transfer in order to gain a better understanding of the mechanism of nucleate boiling near burnout. As pointed out by Moissis and Berenson [9], because of different two-phase flow configurations involved, it seems that no single analytical model can describe nucleate boiling well for the entire range of heat flux. A successful model for nucleate boiling in the high heat flux region relies upon an in-depth understanding of the behaviors of macrolayer and vapor mass because they are indeed the main features of the prevailing flow configuration near burnout. By the same token, these behaviors ought to have a direct bearing on the mechanism of boiling crisis as well.

ANALYSIS

In order to clarify the role that conduction across the macrolayer plays, the following one-dimensional transient moving-boundary conduction problem simulating evaporation of a liquid macrolayer is solved. This analysis is based on the assumptions that (a) the effect of the vapor passages in the liquid macrolayer is negligible, (b) the macrolayer attains a uniform superheated temperature which is the same as that of the wall at the end of the waiting period, and (c) the temperature at the liquid-vapor interface drops to the saturation value when a vapor mass overlies the macrolayer and starts to grow, while the wall temperature remains constant throughout the cycle.

Based upon the above assumptions, the evaporation of a macrolayer during the growth period can be calculated by solving a one-dimensional, one-region, phase-change problem as follows:

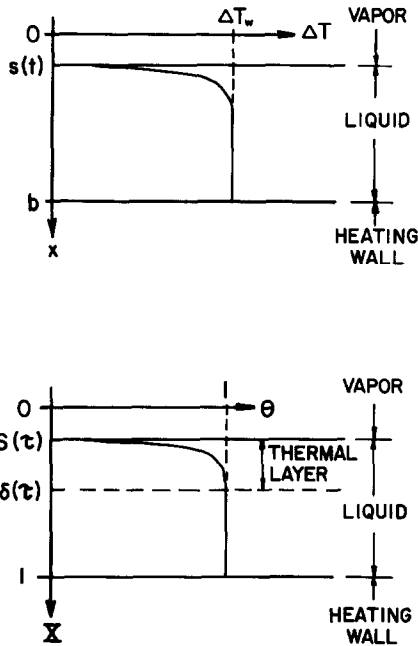


FIG. 3. Analysis of macrolayer evaporation neglecting the effect of vapor passages.

$$\frac{\partial^2 \theta}{\partial X^2} = \frac{\partial \theta}{\partial \tau} \quad \text{in } S(\tau) < X < 1, \tau > 0 \quad (5a)$$

$$\theta = 1 \quad \text{at } \tau = 0, 0 < X < 1 \quad (5b)$$

$$\theta = 1 \quad \text{at } X = 1, \tau > 0 \quad (5c)$$

and at the liquid-vapor interface

$$\theta = 0 \quad \text{at } X = S(\tau) \quad (5d)$$

$$Ja \frac{\partial \theta}{\partial x} = \frac{dS}{d\tau} \quad \text{at } X = S(\tau) \quad (5e)$$

where

$$\theta = \frac{T - T_s}{T_w - T_s} \quad (5f)$$

$$X = \frac{x}{b} \quad (5g)$$

$$\tau = \frac{\alpha t}{b^2} \quad (5h)$$

$$S = \frac{s}{b} \quad (5i)$$

with the coordinate systems depicted in Fig. 3.

No exact solutions are available for the phase-change problems of a medium with finite thickness [10, 11]. The integral method is applied here to obtain an approximate solution for this problem. First, a phenomenological thermal layer in the liquid is defined as the distance beyond which there is no heat flow and the initial temperature field remains undisturbed. Hence, at the boundary of the thermal layer, the following conditions hold:

$$\theta = 1 \quad \text{at } X = \delta(\tau) \quad (5j)$$

$$\frac{\partial \theta}{\partial X} = 0 \quad \text{at } X = \delta(\tau). \quad (5k)$$

The differential equation (5a) is then integrated over the thermal layer to remove the derivative with respect to the space variable. This yields the following energy integral equation after applying the boundary conditions as given by equations (5d), (5j), and (5k):

$$-\frac{\partial \theta}{\partial X} \Big|_{X=S} = \frac{d}{d\tau} \left(\int_S^{\delta} \theta dX \right) - \frac{d\delta}{d\tau}. \quad (6)$$

For the above equation, a suitable temperature profile over the thermal layer is chosen to be

$$\theta(X, \tau) = 1 - \left(\frac{\delta - X}{\delta - S} \right)^n, \quad n \geq 2 \quad (7)$$

where n is a dimensionless integral index to be specified. This profile satisfies the boundary conditions (5d), (5j), and (5k). The location of the interface $S(\tau)$ is taken to be of the same form as that of the exact solution for the semi-infinite solidification problem, namely, Neumann's solution [10]

$$S(\tau) = 2\lambda\sqrt{\tau}. \quad (8)$$

In addition, the location of the thermal layer boundary $\delta(\tau)$ is assumed to have the same form as $S(\tau)$, as the movements of S and δ are closely related; thus

$$\delta(\tau) = 2\beta\sqrt{\tau}. \quad (9)$$

The parameters λ and β are determined by two relations obtained from substituting the assumed expressions of θ , S and δ into equations (6) and (5e); this yields

$$\lambda = Ja \left[\frac{n}{2(n+1)(1-Ja)} \right]^{1/2} \quad (10)$$

$$\beta = [(n+1) - nJa] \left[\frac{n}{2(n+1)(1-Ja)} \right]^{1/2}. \quad (11)$$

The time required for the liquid layer to be completely vaporized, or the dryout time, t_e , is obtained by setting $S(\tau_e) = 1$; thus

$$t_e = \frac{\tau_e b^2}{\alpha} \quad (12)$$

$$= \frac{(n+1)(1-Ja)}{2nJa^2} \cdot \frac{b^2}{\alpha}.$$

In the above equation, the thickness of the macrolayer, b , as reported by Gaertner [1] for saturated water boiling at atmospheric pressure, remains at 0.6 of the vapor stem diameter, D , near burnout

$$b = 0.6D. \quad (13)$$

Gaertner and Westwater [12] have measured the average diameter of the vapor stem, and the data have been correlated as [8]

$$D = 8.09 \times 10^4 q''^{-1.4225}, \quad (14)$$

Based on the two equations above, the macrolayer thickness as a function of heat flux is expressed as follows:

$$b = 4.854 \times 10^4 q''^{-1.4225}. \quad (15)$$

RESULT AND DISCUSSION

The dryout time of the macrolayer is calculated for water boiling at atmospheric pressure using equation (12). It is shown that the time required to vaporize the entire macrolayer is much greater than the measured vapor-mass departure cycle period. For instance, the calculated dryout time for a superheated water layer at the heat flux of $1.62 \times 10^6 \text{ W m}^{-2}$, using equations (12) and (15) and taking $n = 2$, is about 2.5 s, while the measured average vapor-mass cycle period reported by Katto and Yokoya [2] is only 0.06 s. In other words, the time required for the entire macrolayer to evaporate is about 42 times the vapor-mass cycle period. Calculation using equations (5h), (8), and (10) shows that only about 15% of the superheated macrolayer is evaporated during a vapor-mass cycle if the liquid layer evaporates only by heat conduction across its thickness. Note the time required for superheating the macrolayer has not yet even been considered. This suggests that heat conduction across the macrolayer and evaporation at the free surface is *not* the major heat transfer mode accountable for evaporation of the macrolayer near burnout.

Bhat *et al.* [8] apparently overestimated the heat conduction across the liquid layer. This led to their conclusion that heat conduction across the liquid macrolayer accounted for the major portion of heat transfer near burnout. Based on this, they further suggested nucleate boiling within the macrolayer might be suppressed and thus play an unimportant role in heat transfer. The result of the study by Yu and Mesler [6] was cited to support their point of view. Yu and Mesler did report suppression of nucleate boiling in the macrolayer underneath the vapor mass. However, this happened only in a short period just prior to complete dryout of the liquid layer when the layer was very thin. Nucleate boiling did take place in the macrolayer before this and was considered by Yu and Mesler to account for the repeated brief drops in local surface temperature.

ALTERNATIVE MODEL

Since the present analysis has revealed that heat conduction across the macrolayer does not account for a significant heat transfer, an alternative model is proposed for nucleate boiling heat transfer near burnout. By and large, latent heat transport has to be responsible for the major portion of the heat transfer, because neither convection in the macrolayer nor conduction by the vapor phase can be significant. It is suggested in this alternative model that a very thin

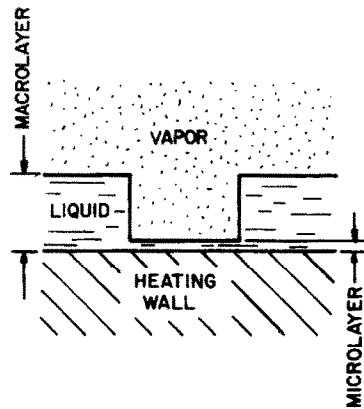


FIG. 4. Evaporation of microlayer in the macrolayer.

liquid layer evaporates at the bottom of each vapor stem in the macrolayer and provides a highly efficient mode of heat transfer.

The heat transfer contribution of vapor stems has never been considered in any analysis. Gaertner [1] suggested evaporation mainly took place at the vapor-liquid interfaces of the stems. However, it is considered that evaporation at the interface of the stem cannot account for much more heat transfer than the free surface of the macrolayer except close to the heating wall. The present model proposes that at the bottom of the vapor stem, due to the wetting capability of the liquid, there is a thin liquid layer covering the heating wall, as depicted in Fig. 4. This is supported by the reasoning that, without the thin liquid layer, the heating surface underneath the stem would be in contact with vapor resulting in local overheating. With a thin layer of liquid, the surface can be effectively cooled by evaporation. Evaporation of this thin layer of liquid should account for a significant contribution of heat transfer near burnout. This layer is very thin compared with the macrolayer, and is thus termed the microlayer.

Yu and Mesler [6] first proposed evaporation of the microlayer underneath tiny bubbles in the macrolayer to explain the repeated drops in local surface temperature they observed. A vapor stem in the macrolayer is simply a coalescence of bubbles generated from a nucleation site which happens at high heat fluxes when the bubbling frequency is high. Generally, as observed by Zuber [13] in nucleate boiling tests, bubbles are isolated and do not interfere with one another at low heat fluxes; as the heat flux increases, the process of vapor removal from the heating surface changes from an intermittent to a continuous fashion as the isolated bubbles coalesce into continuous vapor columns. Evaporation of the microlayer at the bottom is considered to be the major source of vapor flow in the column. Without this liquid layer, the nucleation site, where the vapor column stems from, would dry out and there would be no nucleate boiling thus no vapor column. Microlayer evaporation should also occur at the bottom of a vapor stem in the macrolayer

near burnout. The microlayer is continuously supplied with liquid through the edge and evaporates at the liquid-vapor interface, thus consuming the macrolayer liquid in a highly efficient fashion. The high mass rate of vapor flow pushes the surrounding liquid away and keeps the vapor stem from being flooded.

Since the microlayer is very thin, the time needed for thermal development is negligible. The time required to evaporate the entire macrolayer can be calculated by considering an element including a vapor stem and the surrounding macrolayer to be evaporated through the microlayer at the bottom of the stem (Fig. 4). Since heat conduction across the macrolayer has much higher resistance, all the heat transfer from the wall is assumed to go through the microlayer and to dissipate by evaporation. The energy balance at the interface of the microlayer yields

$$q'' A = \dot{m} h_{fg} \quad (16)$$

with A the cross-sectional area of the element. The liquid mass evaporates at the rate

$$\dot{m} = \frac{\rho b(A - A')}{t_c} \quad (17)$$

where A' is the surface area covered by the microlayer. By substituting equation (17) into equation (16), the dryout time t_c can be solved. It is interesting to find this yields an equation identical to equation (1) which was developed by Katto and Yokoya [2] simply based on a lumped treatment of the macrolayer. Their result incidentally coincides with the present analysis since a lumped model, as pointed out in the Introduction, is physically oversimplified. The idea of consuming a macrolayer through microlayer evaporation was not mentioned at all in their work.

The dryout time t_c is readily calculated using equations (1), (15), and the experimental result of $a = 1/9$ reported by Gaertner and Westwater [12] for nucleate boiling of saturated water at atmospheric pressure near burnout. The density of the superheated liquid in equation (1) is evaluated at the wall temperature corresponding to a particular heat flux as given by the boiling curve. The boiling curve presented in ref. [1] is used in the present calculation. The latent heat of vaporization is evaluated at the saturation temperature because it is the temperature at which evaporation takes place. The result exhibited in Fig. 5 shows that the calculated dryout time is close to the measured vapor-mass cycle period. At the heat flux of $1.62 \times 10^6 \text{ W m}^{-2}$, the calculated t_c is about 0.09 s compared with the measured vapor-mass cycle period of 0.06 s [2].

The above calculation shows that the macrolayer is not completely evaporated during the vapor-mass cycle. In fact, if the macrolayer dries out, the area underneath the vapor mass becomes in contact with vapor and thus results in local surface overheating. Once the dry patch is formed, it would be difficult for

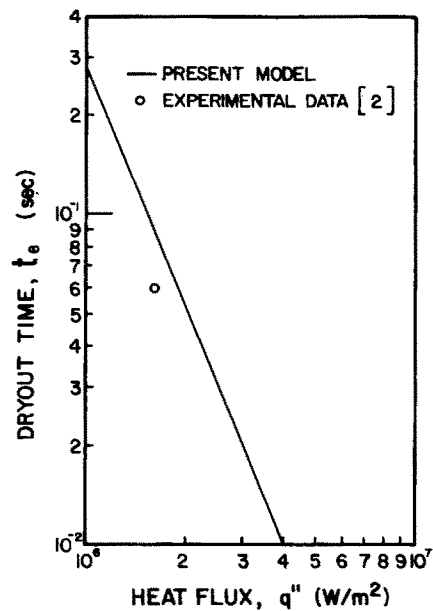


FIG. 5. Calculated dryout time of macrolayer.

the incoming liquid to rewet because of the high local surface temperature. Experimental evidence has shown that the rewetting velocity of the liquid decreases with the dry wall temperature [14]. The surface thus precipitates into boiling crisis as the number and area of the dry patches increase. Before boiling crisis, only a portion of the macrolayer repeatedly consumes and replenishes in each vapor-mass cycle. Boiling crisis occurs when the heat flux is so high that the entire macrolayer is consumed in a cycle.

In addition to microlayer evaporation, evaporation at the interfaces of the vapor stems very close to the heating wall may account for a certain amount of macrolayer consumption. Other minor mechanisms of macrolayer consumption are discussed as follows. It has been reasoned by Katto and Yokoya [2] that the pressure inside a growing vapor mass must be higher than the surroundings in order to do work to displace the liquid. Due to this pressure, not only is there no liquid supplied to the macrolayer, but also is liquid squeezed out of the layer through the edge. Therefore, the macrolayer is also thinned through this pressing action by the vapor mass.

Furthermore, the macrolayer is also consumed through entrainment of liquid droplets in the vapor flows to the vapor mass. Liquid droplets were shown in the vapor mass in the photographs presented by Katto and Yokoya [2]. Kirby and Westwater [3] observed a small bubble initiated in the macrolayer, grew in the vapor mass, and then burst. Liquid droplets generated through bubble bursting could strike on the liquid wall encompassing the vapor mass and be absorbed. More liquid splashing from the macrolayer is expected at higher heat fluxes.

CONCLUSIONS

It is shown in this study that heat conduction across the macrolayer and evaporation at the free surface is not a mode efficient enough to account for the major portion of nucleate boiling heat transfer near burnout. An alternative model is proposed as macrolayer being consumed primarily through evaporation of much thinner microlayers at the bottom of vapor stems penetrating the macrolayer. Comparison between an analysis based upon the proposed model and experimental data shows the macrolayer does not totally dry out in the vapor-mass cycle before boiling crisis. In addition to microlayer evaporation, the macrolayer can be consumed through evaporation at the interfaces of vapor passages close to the heating wall, thinning due to the pressure of vapor mass during growth, and liquid splashing.

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EVAPORATION D'UNE MACROCOCHE EN EBULLITION NUCLEEE PRES DE LA CRISE

Résumé—Le mécanisme du transfert thermique par ébullition nucléée près de la crise est étudié à partir de l'évaporation de la macrocouche liquide au-dessous de la masse de vapeur. Il est prouvé que la conduction de chaleur à travers la macrocouche et l'évaporation à la surface libre n'est pas un mode suffisamment efficace pour prendre en charge la majeure partie du transfert de chaleur. Le modèle alternatif proposé est une macrocouche consommée à travers l'évaporation de microcouche plus fines à la base de poches de vapeur pénétrant la macrocouche. Une analyse basée sur ce mécanisme proposé montre que la macrocouche ne peut pas s'assécher totalement dans un cycle vapeur-masse avant la crise d'ébullition. On discute aussi d'autres mécanismes acceptables pour la consommation de la macrocouche.

DIE VERDAMPFUNG DER MAKROSCHICHT BEIM BLASENSIEDEN NAHE DER KRITISCHEN WÄRMESTROMDICHTEN

Zusammenfassung—Der Mechanismus des Wärmeübergangs beim Blasensieden nahe der kritischen Wärmestromdichte wurde an Hand der Verdampfung der Flüssigkeits-Makroschicht unter der Dampfmasse untersucht. Es wurde bewiesen, daß der Vorgang von Wärmeleitung durch die Makroschicht und Verdampfung an der freien Oberfläche nicht in der Lage ist, den Großteil der Wärme zu übertragen. Das alternativ vorgeschlagene Modell ist eine Makroschicht, die vorrangig durch die Verdampfung von sehr viel dünneren Mikroschichten am unteren Ende von Dampfzweigen, welche die Makroschicht durchsetzen, aufgezehrt wird. Eine auf den vorgeschlagenen Mechanismen basierende Analyse zeigte, daß die Makroschicht vor der Siedekrise nicht vollständig in einem Dampfmassenkreislauf austrocknet. Andere für das Aufzehren der Makroschicht ursächliche Mechanismen werden ebenfalls diskutiert.

ИСПАРЕНИЕ МАКРОСЛОЯ ПРИ ПУЗЫРЬКОВОМ КИПЕНИИ В ОКОЛОКРИЗИСНОМ СОСТОЯНИИ

Аннотация—Механизм пузырькового кипения вблизи кризиса кипения изучался на примере испарения жидкого макрослоя под паровой массой. Показано, что механизмов теплопроводности через макрослой и испарения на свободной поверхности не достаточно для объяснения переноса основной части тепла. Предложена альтернативная модель, согласно которой макрослой выкипает путем испарения значительно более тонких микрослоев на дне паровых капилляров, его пронизывающих. Анализ, проведенный с использованием предложенного механизма, показывает, что этот макрослой не пересыхает полностью до наступления кризиса кипения. Рассматриваются также другие механизмы, объясняющие испарение макрослоя.