Int. J. Heat Mass Transfer. Vol. 34, No. 7, pp. 1783–1790, 1991
Printed in Great Britain

0017-9310/91 $3.00+0.00

Nucleate boiling on two cylinders in line contact

M.-C. CHYU and A. M. MGHAMIS

Department of Mechanical Engineering, Texas Tech University, Lubbock, TX 79409-1021, U.S.A.

(*Received* 20 *February* 1990 *and in final form* 14 *August* 1990)

Abstract—Nucleate boiling from the restricted geometry between two cylinders in line contact is studied. The pool boiling experiment is conducted using water and two small-diameter tubes brought together through either twisting or tying. It is found that nucleate boiling is significantly enhanced in the restricted regions between the two tubes, particularly in those regions with openings facing upward. This enhancement is due to a favorable thermal environment in terms of the liquid temperature profile inside the restricted geometry. This phenomenon is explained based on the well accepted nucleate boiling theory. The difference among data of different tube orientations is also discussed.

1. INTRODUCTION

ENHANCEMENT techniques of nucleate boiling heat transfer have been extensively searched due to the need of upgrading various types of industrial evaporative devices. In their 1978 patent, Schmittle and Starner [1] proposed to enhance nucleate boiling by wrapping a plain tube with a fibrous or stranded material, as shown in Fig. 1. A plain copper tube wrapped with stranded nylon was reported to provide a heat transfer coefficient up to 3.7 times as high as the plain tube. However, a plain tube wrapped with solid copper wire demonstrated a decrease in heat transfer performance compared with that without wrapping. It is suspected that the strands in line contact with each other played an important role in enhancing the nucleate boiling heat transfer in the former case. In this work, nucleate boiling was studied using a test heater composed of two pieces of small-diameter tube in line contact through either twisting (Fig. 2(a)) or binding together with wires (Fig. 2(b)). The tubes were directly heated by d.c. electricity, and the temperature was measured by thermocouples placed inside the tubes. Pool boiling tests were conducted using pure water at atmospheric pressure. Attention was paid to nucleate boiling activity within the restricted regions between the two tubes, as indicated in Fig. 3. The objectives of this study are to understand the mechanism of enhanced nucleate boiling by two cylinders in line contact, and to identify the factors which are important to the boiling performance.

2. EXPERIMENT

Testing was conducted by boiling pure water at atmospheric pressure using a facility as shown in Fig. 4. The facility included a Lexan test vessel (305 mm × 305 mm × 254 mm), a test heater, and auxiliary heaters. The test heaters employed were (a) two tubes twisted together with a pitch of 3 mm (Fig. 2(a)), (b) two parallel tubes tied together at several locations along the length using pieces of wire (Fig. 2(b)), and (c) a single tube. All the tubes were of stainless steel and of the same dimensions, i.e. 1.59 mm (1/16 in.) o.d. and 0.79 mm (1/32 in.) i.d. The tubes were all from the same manufacturer and were found to yield the same boiling heat transfer performance when each was tested as a single tube heater. All three test heaters were 350 mm long. Special attention was given to the double-tube heaters to ensure good contact between the tubes. Thermocouples (gage 30) were inserted into the tubes to monitor the temperatures at half of the heater length. In the case of parallel tubes tied together, the tie wires were located at a sufficient distance from the thermocouples to avoid any influence on the temperature readings due to a change of the boiling surface condition. The test heater was directly heated by d.c. electricity and was held at 80 mm above the bottom of the test vessel simply by the power cables soldered to its ends.

Four auxiliary immersion heaters were employed for initial heating and maintaining the pool temperature at saturation. The disturbance induced by boiling from the auxiliary heaters was shielded from

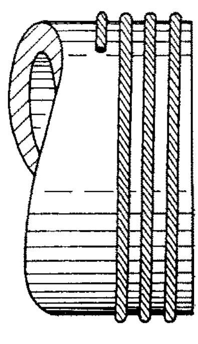

FIG. 1. A tube with wire wrapping.

NOMENCLATURE

Bi	Biot number as in equation (1) [dimensionless]
h_{fg}	latent heat of vaporization [J kg^{-1}]
k	thermal conductivity [W m^{-1} K^{-1}]
q''	heat flux [W m^{-2}]
q'''	heat generation rate per unit volume [W m^{-3}]
R	non-dimensional radius as in equation (1)
r	radius [m]
T	temperature [°C]
ΔT	wall superheat, $T_o - T_s$ [K]
y	coordinate normal to heated wall [m].

Greek symbols

δ	gap width between two tubes as defined in Fig. 8(b) [m]
γ	orientation angle of the two tubes in contact as defined in Fig. 7 [rad or deg]
ρ	density [kg m^{-3}]
σ	surface tension [N m^{-1}].

Subscripts

c	cavity
i	inside wall
l	liquid
o	outside wall
s	saturation
v	vapor
∞	mainstream condition.

the test heater by two pieces of Lexan sheet located on both sides and 70 mm away from the test heater, as shown in Fig. 4. Liquid exchange was allowed over the top of the shield and through the interstices between the shield and the wall of the vessel. This arrangement also effectively maintained the liquid temperature within the shield at saturation without using heavy insulation prohibiting visual observation.

Tests were also conducted with afore-mentioned test heaters placed vertically, using a tall test vessel (450 mm × 254 mm × 254 mm) as shown in Fig. 5, which included four auxiliary heaters separated from the test heater located at the center by a four-walled shield (400 mm × 150 mm × 150 mm).

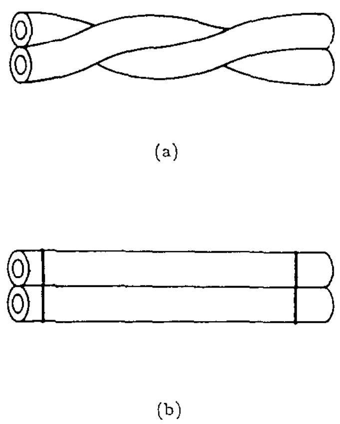

FIG. 2. Two tubes in line contact: (a) twisted; (b) parallel.

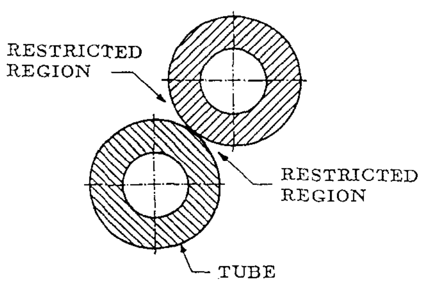

FIG. 3. Restricted geometry formed by two tubes in line contact.

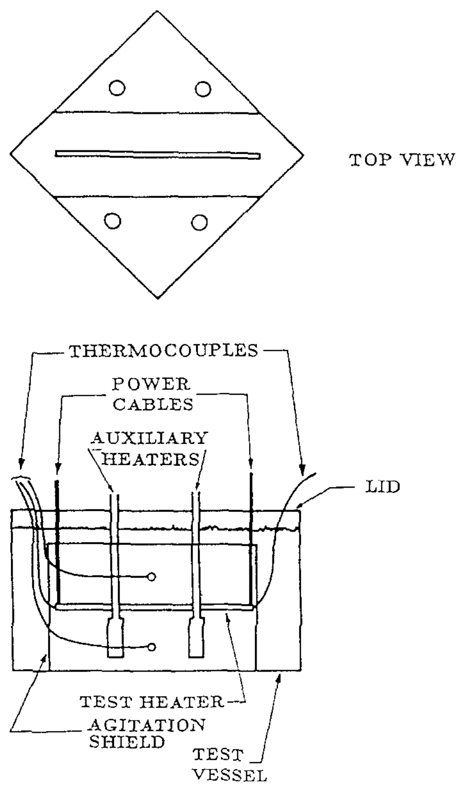

FIG. 4. Test facility for horizontal test heaters.

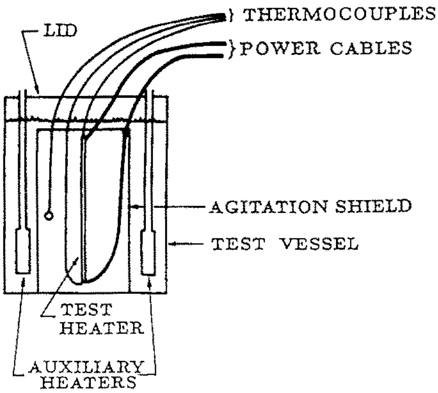

FIG. 5. Test facility for vertical test heaters.

The electricity to the test heater was provided by a d.c. power supply and was monitored by a voltmeter and an ammeter. All thermocouples were of chromel–constantan (E-type) and were monitored by a digital voltmeter. The auxiliary heaters were controlled by a powerstat. A barometer measured the atmospheric pressure in order to determine the saturation temperature.

The test heater was cleaned with acetone prior to each test. Water was first brought to boiling by both the test heater and the auxiliary heaters for at least 3 h to drive away the air content in the system. Boiling water heated and degassed in a beaker was provided periodically to replenish the loss of water since the water vapor generated was not recovered. The variation in the hydrostatic pressure due to change of pool level was taken into account in determining the saturation temperature. The pool temperature monitored by thermocouples placed randomly in the vessel was always within 0.2°C of the calculated saturation temperature based on barometric reading and liquid level.

Data taken during a test were heating power, temperature of the test heater, atmospheric pressure, and height of the water level above the test heater. Heat flux was calculated by heating power divided by the surface area of the test heater. The wall temperature of the heater was determined based upon the temperature measured by the thermocouple inserted into the tube, and the calculated temperature drop across the tube wall. This temperature drop was calculated by considering heat conduction in a hollow infinite cylinder with convective boundary condition on the outside surface and q''' volumetric heat generation in the solid. The solution of the temperature distribution is given as [1]

$$\frac{(T-T_\infty)k}{q'''r_o^2} = \frac{1}{4}\left[\frac{2}{Bi}(1-R_i^2)+1-R^2+2R_i^2 \ln R\right] \quad (1)$$

with $R = r/r_o$ and $Bi = (hr_o)/k$. The temperature difference between the inside and outside surfaces can thus be readily determined as

$$T_i - T_o = \frac{q'''r_o^2}{4k}[R_o^2 - R_i^2 + 2R_i^2 \ln (r_i/r_o)]. \quad (2)$$

The wall superheat, ΔT, was then calculated as the difference between T_o and the saturation temperature. The temperature drop calculated using the above equation was always within 4% of the measured superheat data in the present test range. The saturation temperature was determined based on the pressure at the level of the horizontal test heater, including atmospheric pressure and hydrostatic pressure. In the case of the vertical test, the saturation temperature was based on the pressure at the center of the test heater where the thermocouple was located. The error associated with the heat flux data presented in this work was estimated to be within ± 30 W m^{-2}, and that with temperature data was within ± 0.2°C. Most of the tests presented in this work were repeated, and the data were found to be always reproducible within ± 0.4°C.

3. EXPERIMENTAL RESULTS

Pool boiling tests were conducted using three test heaters under seven different conditions as shown in Fig. 6. Each test heater was tested both horizontally and vertically. The horizontal parallel tubes particularly were tested under two conditions: two tubes placed with one above the other (Case I), and two tubes placed side by side (Case II). The parallel tubes were also tested vertically (Case V). The twisted-tube test heater was tested both horizontally (Case III), and vertically (Case VI). For the purpose of comparison, a single tube was also tested both horizontally (Case IV) and vertically (Case VIII). No boiling crisis was observed in any of the tests presented in Fig. 6.

It was observed in the present tests that a pair of horizontal tubes in line contact, whether twisted, placed side by side, or stacked, start nucleate boiling at a lower superheat, and the fully developed heat transfer coefficient is significantly higher than a single tube. With reference to the data of Case III in Fig. 6, the twisted tubes started generating bubbles at a heat flux as low as 360 W m^{-2} and a superheat of 0.24°C. An interesting phenomenon observed at this point was that the bubbles were generated only at the locations where the two tubes were both on a horizontal plane. This situation can be better explained by considering Fig. 7, in which γ is defined as the angle between the line passing through the centers of the two tubes and the direction of gravity. For two tubes twisted together, the angle γ varies between 0 and π with respect to a coordinate system moving along the axis, namely, the z-direction. During incipient boiling, bubbles were first observed only at the axial locations where γ was $\pi/2$ and from the restricted region having an opening facing upward, as indicated in Fig. 7. In

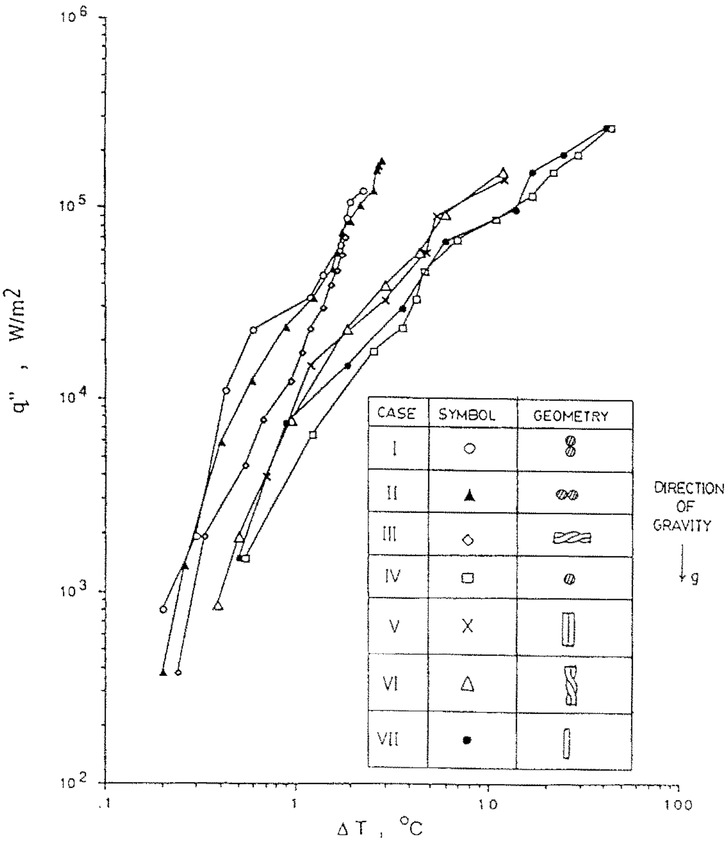

FIG. 6. Boiling heat transfer data.

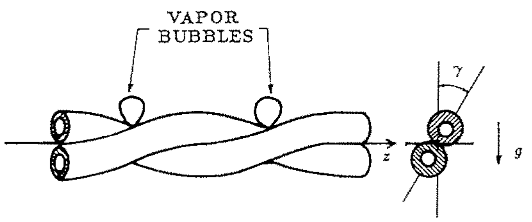

FIG. 7. Bubble formation from twisted tubes at a low heat flux.

fact, at 360 W m^{-2}, bubbles observed were only sitting at these locations without motion. Bubbles started moving at $q'' = 1.87 \times 10^3$ W m^{-2}. At this point, nucleate boiling was observed all over the heated surface; however, bubbles in larger sizes and quantity were generated from the restricted region between the two tubes than elsewhere. The nucleate boiling heat transfer coefficient of the horizontal twisted tubes was always higher than that of the single horizontal tube throughout the test range. Based upon a fixed heat flux, the heat transfer coefficient of the twisted tubes could be as much as about ten times that of the single tube. This figure has, of course, already taken into account the doubled heat transfer surface area of the twisted tubes. The improvement in heat transfer is mainly due to the enhanced nucleate boiling in the restricted region between two tubes in contact, an interesting phenomenon to be further discussed later.

Since bubbles were observed to form first at the locations of $\gamma = \pi/2$ in the twisted tube test, it was of interest to conduct a test with two tubes placed side by side so that γ was $\pi/2$ throughout the length. In this test (Case II, Fig. 6), it was observed that stagnant bubbles were formed in the restricted region facing upward at a low heat flux of 356 W m^{-2} and superheat of 0.20°C. They were similar to those observed on twisted tubes except that they were distributed along the entire contact line. At 1.326×10^3 W m^{-2} heat flux and 0.26°C superheat, many bubbles started to depart from the restricted regions between the two tubes. Even though nucleate boiling was observed from the entire surface of the heated tubes beyond this point, significantly more bubbles were generated from the restricted region facing upward, and the bubbles were larger in size than elsewhere.

In the test with one tube above the other ($\gamma = 0$), stationary bubbles were observed sitting in the restricted regions, which were facing sideward in this case, at a heat flux of 805 W m^{-2} and a superheat of 0.20°C. Bubbles were departing from the surface at 1.81×10^3 W m^{-2}. At 1.03×10^4 W m^{-2}, there was nucleate boiling all over the wall of heated tubes; however, the bubbles were generated at faster rates and in larger sizes from the restricted regions. This phenomenon persisted throughout the test.

In comparison, two stacked tubes demonstrated the highest heat transfer coefficient in the medium heat flux range, which could be as high as four times that of the single tube based on a fixed heat flux. Two tubes placed side by side provided heat transfer coefficients slightly lower; however, the coefficients were still higher than that of twisted tubes. The three double-tube curves converged to one at a high heat flux level.

Tests were also conducted with vertical test heaters, including single tube, two tubes twisted, and two straight tubes placed side by side in contact. First of all, as shown in Fig. 6, data of the horizontal single tube test (Case IV) were close to that of the vertical single tube (Case VII). It was also found that there was no significant difference in the test data between the parallel tubes (Case V) and the twisted tubes (Case VI). These double-tube data demonstrated slightly higher heat transfer coefficients than the single tube only in the high heat flux range, and significantly lower coefficients than the double-tube horizontal test data. The enhanced nucleate boiling from the restricted regions between two horizontal tubes in contact was not observed in the vertical tests.

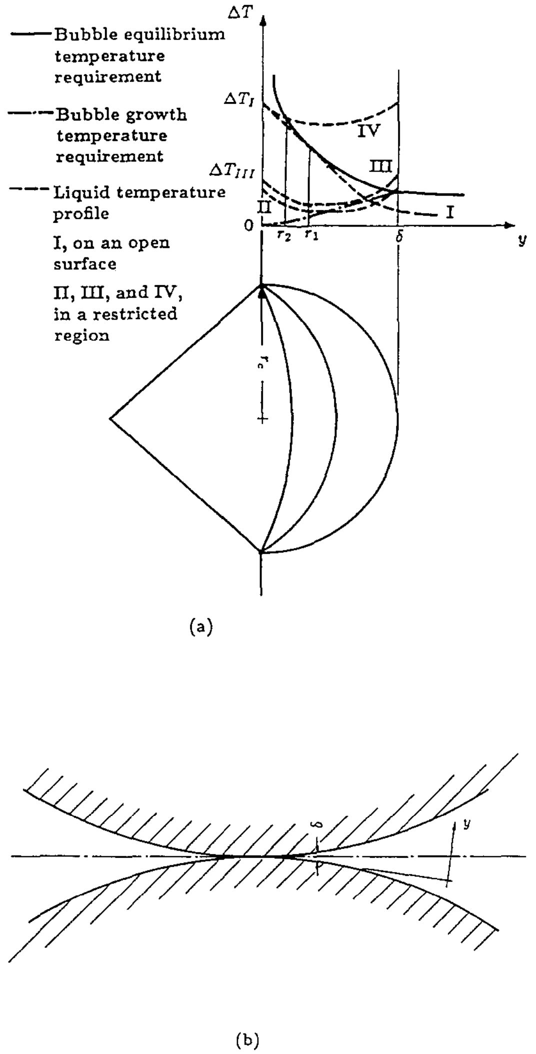

FIG. 8. Nucleate boiling in a restricted region formed by two cylinders in line contact.

4. DISCUSSION

4.1. *Enhanced nucleate boiling in the restricted region*

The present test results show that two horizontal tubes in contact demonstrate better boiling heat transfer performance than the single tube in terms of heat flux and wall superheat required for incipient boiling, and boiling heat transfer coefficient. Visual observation revealed that bubbles start to form at a very low wall superheat between two tubes, and more bubbles continue to be generated from the restricted region than from elsewhere throughout the test. Apparently, the improvement in the boiling heat transfer performance is due to the enhanced nucleate boiling in the restricted region between two tubes. It is thus of interest to study the mechanism of such enhancement.

A number of incipient nucleate boiling models, which describe the condition required for the generation of bubbles, have been proposed [2–6]. Among these models, the one by Bergles and Rohsenow [2] has been most widely accepted. According to their model, on an open surface, a bubble is generated when the liquid temperature profile is tangent to the bubble equilibrium curve. The bubble equilibrium curve is determined based on (a) the mechanical equilibrium of a vapor bubble, i.e. the vapor pressure higher than the surrounding liquid in order to balance surface tension, and (b) the Clausius–Clapeyron relation between the pressure difference and the temperature difference. The result is [7]

$$T_v - T_l = \frac{2T_s\sigma}{h_{fg}\rho_v r_v}. \qquad (3)$$

Nucleate boiling will thus take place when the liquid temperature profile I in Fig. 8(a) is reached. Bubbles will be generated from cavities of radius r_1, provided the residual vapor phase is available to function as nuclei in these cavities.

On the other hand, in a restricted region between two heated walls, the liquid temperature profile is quite different from that near an open surface. Consider the narrow space between two cylinders, as depicted in Fig. 8(b). Even though no attempt was made in this study to measure the liquid temperature profile within the narrow space, at a location where the width of the space is δ, typical liquid temperature profiles are shown by profiles II and III in Fig. 8(a), which are symmetric with respect to the centerline of the restricted space, since both tubes are generating the same heat flux. The temperature of the liquid can increase indefinitely no matter how small the wall heat flux is, provided heat transfer in the direction of the centerline is negligible. During the heating process, the liquid temperature profile would first intersect the bubble equilibrium requirement curve at $y = \delta$ when profile II is reached. This is different from the tangent condition for incipient boiling on an open surface [2]. Liquid temperature meeting the bubble equilibrium requirement at $y = \delta$, however, does not necessarily guarantee incipient boiling. Consider the liquid superheat requirement during the process of growth of a bubble from a cavity of radius δ. During growth, the bubble needs to be exposed to liquid of a temperature profile which meets the bubble equilibrium requirement at all stages. This bubble growth temperature requirement can be determined based on the bubble equilibrium temperature requirement as given by equation (3), and the curvature radii of the bubble at different heights during growth. For a cavity of size r_c, and $y \leqslant r_c$, this radius–height relation is

$$r_v = \frac{r_c^2}{2y} + \frac{y}{2} \tag{4}$$

where r_v is the bubble radius, and y the height of the bubble. The bubble growth temperature requirement is obtained by combining equations (3) and (4)

$$T_v - T_l = \frac{4T_s\sigma y}{h_{fg}\rho_v(r_c^2 + y^2)}. \tag{5}$$

The above equation is qualitatively plotted in Fig. 8(a). To ensure continuous growth of the bubble, the surrounding liquid temperature at the top of the bubble must be always no lower than the bubble's interior temperature; otherwise the growth of the bubble will be limited by condensation at the top. However, the liquid temperature profile II in Fig. 8(a) does not meet this bubble growth requirement, although it meets the equilibrium requirement at $y = \delta$. Formation of a bubble from a cavity of radius δ requires that the liquid be further heated to profile III, which is tangent to the growth temperature requirement of the bubble. This condition of incipient boiling is unique for a thermal environment with a liquid temperature increasing with y, such as a restricted region between two heated walls. Vapor phase could be generated from cavities of sizes larger than δ before temperature profile III is reached. However, the growth and departure of the vapor bubbles could be restricted by the geometry.

After all, nucleate boiling in the restricted region between two heated cylinders can take place at a lower wall superheat than on an open surface. This phenomenon is qualitatively explained by comparing the liquid temperature profiles I and III. The slopes of the two profiles at $y = 0$ are the same; therefore, the two profiles represent the same wall heat flux. The fact that ΔT_{III} is smaller than ΔT_I indicates that at the same wall heat flux, nucleate boiling can take place at a lower superheat in the restricted region than on an open surface. This implies both a lower wall superheat for incipient boiling and a higher heat transfer coefficient of fully developed nucleate boiling. It is also clear that for the same wall superheat level, a wider size range of cavities would be activated in the restricted region than on an open surface. This can be demonstrated by comparing liquid temperature profile I for an open surface, and profile IV for a restricted region, which has the same wall superheat as profile I and intersects the bubble equilibrium curve at $y = r_2$. Under profile IV, cavities of sizes in the range $r_2 < r < \delta$ can generate bubbles, provided vapor nuclei are available, while only one size of cavity, r_1, can be active under profile I. This explains why more bubbles were observed to emerge from the restricted region between the two tubes than from elsewhere, and why two tubes in contact demonstrated higher boiling heat transfer coefficients than a single tube in the present tests.

Even though bubble formation is facilitated in the restricted region, the departure of a bubble is contingent upon the thermal environment to which the growing bubble is exposed. The growth of a bubble can be limited by the cold liquid outside the restricted region, and the bubble maintains a metastable state sitting on the heated wall without either further growth or diminution. A balance of energy is reached between evaporation at the base of the bubble and condensation at the top. This phenomenon was observed at very low heat flux levels for all three cases of tubes in contact in the present experiment. In order to predict visible incipient nucleate boiling as the result of first bubble departure, it is therefore necessary to know the liquid temperature distribution within and in the vicinity of the restricted region. The liquid temperature distribution was neither measured nor calculated for the above qualitative analysis for the following reason. In the present natural convective boiling experiment, the liquid temperature distribution in the vicinity of a restricted region depends on the orientation of the restricted region with respect to the direction of gravity. In a heat transfer tube as shown in Fig. 1, the liquid temperature distribution will be further dependent upon geometrical factors such as the dimensions of the wire wrapping and pitch of wrapping on the tube. Therefore, only qualitative liquid temperature profiles were considered in the above analysis to study how nucleate boiling can be enhanced in the restricted region, and no attempt was made to quantitatively predict incipient nucleate boiling.

4.2. *Comparison among different cases of tubes in contact*

The three cases of horizontal tubes in contact demonstrated close heat transfer performances in the high heat flux range. However, the difference in heat transfer coefficient can be as large as 100% in the lower heat flux range (cf. Cases I and III, Fig. 6). In fact, the enhanced nucleate boiling of all three cases is attributed to the same restricted geometry formed by two tubes in contact. What makes the difference in heat transfer coefficient in the low heat flux range is the orientation of the restricted geometry. When two tubes are in line contact, two restricted regions separated by the contact line are formed. The twisted tubes have the orientation angle γ varying from zero to π for each of the two restricted regions, while two tubes placed side by side have one restricted region facing upward and the other facing downward, and two stacked tubes have both restricted regions facing sideward. Boiling heat transfer is affected by the orientation of the restricted region because the thermal environment within the restricted region at a different orientation is subjected to a different degree of disturbance by the convective flow. Based on the previous analysis with reference to Fig. 8, a greater disturbance by the convective flow makes the liquid temperature profile more difficult to be tangent with the bubble equilibrium curve. The thermal environment is therefore less favorable to nucleate boiling.

It was observed in the present twisted tube test that bubbles are first generated in the restricted regions with openings facing upward. This indicates that the thermal environment within the restricted region facing upward is most favorable to nucleate boiling. This favorable thermal environment, characterized by a special temperature profile of liquid, is provided by the combination of the restricted geometry between two cylinders in line contact and the small temperature gradient at the top of a horizontal tubular heater subjected to an upward buoyancy flow. A downward-facing restricted region is open to the upward buoyancy flow which disturbs the favorable liquid temperature profile inside the region. The superheat required for incipient boiling was therefore higher in such a restricted region.

In the tests with two horizontal tubes placed side by side, nucleate boiling was also observed to be prominently more active in the restricted region facing upward. Since, in this case, there is a continuous upward-facing restricted region all the way along the length of the test heater, the boiling heat transfer coefficient is naturally higher than that of twisted tubes (Fig. 6), which have upward-facing restricted regions only at one location in every pitch.

In the case of two horizontal tubes with one above the other, it was observed that nucleate boiling is enhanced in the restricted regions facing sideward. The heat transfer coefficients of this case (Case I) are better than that of two tubes placed side by side (Case II) in the medium heat flux range, because the former has two restricted regions equally fostering nucleate boiling, while in the latter case, only the restricted region facing upward significantly enhances boiling.

With regard to the vertical test heaters, the restricted geometry formed by two tubes in contact, either twisted or parallel, was observed not to significantly enhance nucleate boiling as it did in the horizontal tests. This is because the buoyancy flow in the direction of the contact line of the test heater can destroy the favorable thermal environment within the restricted region.

4.3. *General discussion*

The present test results reveal the importance of the hydrodynamic effect on nucleate boiling. Nucleate boiling can be significantly enhanced by a favorable thermal environment characterized by a special liquid temperature profile near the heated wall. This environment can be achieved by the combination of a restricted geometry and the right orientation with respect to the direction of convective flow. The restricted geometry studied in this work is formed by two cylinders in line contact. This geometry is unique in that the liquid deep inside the restricted region can easily be heated to a substantial superheat. This geometry was found to foster nucleate boiling particularly if its opening faces in the same direction as the convective liquid motion so that the restricted geometry is not subjected to the disturbance of the convective flow and is exposed to a small temperature gradient on the lee side. In the present study, the restricted geometry with the opening facing upward in a gravity-induced natural convective flow was found to enhance nucleate boiling most remarkably. This information is important to the design of a boiling-enhancing structured surface featuring small cylinders in line contact.

5. CONCLUSION

A study was conducted for nucleate boiling heat transfer from test heaters prepared using two tubes brought together by either twisting or tying. It was found that nucleate boiling is significantly enhanced in the restricted regions formed by two cylinders in line contact, particularly in those regions with openings facing upward. This enhancement is attributed to a favorable thermal environment provided by the combination of the restricted geometry between the two cylinders and a small local temperature gradient on the lee side of the test heater subjected to a gravity-induced natural convective flow. A restricted region facing sideward demonstrated a moderate enhancement, while that facing downward demonstrated little enhancement, because the thermal environment inside the region is disturbed by the convective flow, and the region is exposed to a large local temperature gradient.

Acknowledgement—This material is based upon work supported by the National Science Foundation under Grant CBT 8796290.

REFERENCES

1. S. S. Kutateladze and V. M. Borishanskii, *Concise Encyclopedia of Heat Transfer*. Pergamon Press, New York (1966).
2. A. E. Bergles and W. M. Rohsenow, The determination of forced convection surface-boiling heat transfer, *J. Heat Transfer* **86**, 365–372 (1964).
3. C. V. Han and P. Griffith, The mechanism of heat transfer in nucleate pool boiling—Part I, *Int. J. Heat Mass Transfer* **8**, 887–904 (1965).
4. S. T. Yin and A. H. Abdelmessih, Prediction of incipient flow boiling from a uniformly heated surface, *A.I.Ch.E. Symp. Ser.* **164**, 236–243 (1974).

5. Y. Sudo, K. Miyata, H. Ikawa and M. Kaminaga, Experimental study of incipient nucleate boiling in narrow vertical rectangular channel simulating subchannel of upgraded JRR-3, *J. Nucl. Sci. Technol.* **23**(1), 73–82 (1986).
6. W. J. Marsh and I. Mudawar, Predicting the onset of nucleate boiling in wavy free-falling turbulent liquid films, *Int. J. Heat Mass Transfer* **32**, 361–378 (1989).
7. Y.-Y. Hsu and R. W. Graham, *Transport Processes in Boiling and Two-phase Systems*, Chap. 1. Hemisphere, Washington, DC (1976).

EBULLITION NUCLEEE SUR DEUX CYLINDRES EN CONTACT EN LIGNE

Résumé—On étudie l'ébullition nucléée dans la géométrie limitée entre deux cylindres en contact en ligne. L'ébullition en réservoir est expérimentée avec de l'eau et deux tubes de petit diamètre maintenus ensemble soit enroulés, soit attachés. On trouve que l'ébullition nucléée est significativement augmentée dans les régions resserrées entre les deux tubes, particulièrement dans ces régions qui sont tournées vers le haut. Cet accroissement est dû à un environnement favorable en terme de profil de température du liquide dans cette géométrie restreinte. Ce phénomène est expliqué à partir de la théorie bien acceptée de l'ébullition. La différence entre les données relatives à différentes orientations des tubes est aussi discutée.

BLASENSIEDEN AN ZWEI ZYLINDERN MIT LINIENKONTAKT

Zusammenfassung—Es wird das Blasensieden unter den räumlich beengten Bedingungen zweier Zylinder mit Linienkontakt untersucht. Die Siedeversuche werden mit Wasser an zwei Rohren mit kleinem Durchmesser durchgeführt, wobei ein Rohr das andere umwickelt oder umschnürt. Dabei ergibt sich, daß das Blasensieden in dem eingeengten Gebiet zwischen den beiden Rohren wesentlich verbessert wird—insbesondere in solchen Regionen, in denen eine Öffnung nach oben besteht. Diese Verbesserung ist auf den günstigen Verlauf des Temperaturprofils in der Flüssigkeit im beengten Bereich zurückzuführen. Das Phänomen wird auf der Grundlage der allgemein anerkannten Theorie für das Blasensieden erklärt. Die Unterschiede zwischen den Daten bei verschiedenen Rohrorientierungen werden ebenfalls diskutiert.

ПУЗЫРЬКОВОЕ КИПЕНИЕ НА ДВУХ КОНТАКТИРУЮЩИХ ЦИЛИНДРАХ

Аннотация—Исследуется пузырьковое кипение в пространстве между двумя контактирующими цилиндрами. В экспериментах по кипению в объеме используются вода и две перекрученные или скрепленные трубы с малым диаметром. Найдено, что пузырьковое кипение заметно усиливается в областях, ограниченных обеими трубами, в особенности на учстках с обращенными вверх отверстиями. Интенсификация кипения происходит за счет благоприятных условий, создаваемых профилем температур жидкости. Это явление объясняется на основании теории пузырькового кипения. Обсуждается различие экспериментальных данных, полученных при разных ориентациях труб.