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# POOL BOILING HEAT TRANSFER IN A CONFINED SPACE

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Abstract—Pool boiling heat transfer in a confined space has been studied for vertical narrow annuli with closed bottoms. Experiments were performed for Freon-113, acetone, and water at 1 atm. for annuli with heights of 25.4 and 76.2 mm, and gap sizes of 0.32, 0.80 and 2.58 mm. Three boiling regimes are identified through visual observation. The importance of the Bond number is also demonstrated. When the Bond number is less than unity, the isolated deformed bubble regime occurs at low heat flux and the coalesced deformed bubble regime is observed at high heat flux. For Bond numbers slightly larger than unity at high heat flux, nucleation on the heated surface has been observed. The general behavior of the boiling curves and the heat transfer mechanisms of these boiling regimes are presented and discussed.

## NOMENCLATURE

$B_l$, modified boiling number, defined in equation (5);
$Bo$, Bond number for the gap, defined in equation (4);
$D$, diameter of the annulus, measured from the middle of the gap;
$g$, acceleration of gravity;
$Gr_x$ Grashof number, $\beta g x^3 \Delta T/\nu^2$;
$h$, heat transfer coefficient;
$h_{fg}$, latent heat of evaporation;
$k_l$, thermal conductivity of the liquid;
$L$, length of the annulus;
$Nu_x$, Nusselt number, $hx/k_l$;
$Pr$, Prandtl number, $\nu/\alpha$;
$q_w$, heat flux at the heated wall;
$s$, gap size of the annulus;
$T_w$, wall surface temperature;
$T_{sat}$ saturation temperature of the fluid;
$V$, characteristic slug bubble rising velocity at the inertial dominant condition, defined in equation (6);
$x$, axial location, measured from the bottom of the tube.

Greek symbols
$\alpha$, thermal diffusivity of liquid;
$\beta$, thermal expansion coefficient of liquid;
$\nu$, kinematic viscosity of liquid;
$\rho_g$, density of vapor;
$\rho_l$, density of liquid;
$\sigma$, surface tension of liquid to vapor.

## INTRODUCTION

POOL boiling in open spaces has been studied extensively in the past but knowledge on the effect of confinement on pool boiling heat transfer is still very limited. Consider the situation when boiling occurs in the liquid filling the space between two walls. When the distance between the walls is large, any bubble generated rises upwards in its natural form. When the distance between the walls is less than the diameter of the natural bubbles, the bubbles will be squeezed and deformed. The boiling phenomenon is expected to be different from the conventional open-pool boiling, and the boiling curve will also deviate from the conventional results.

Pool boiling in confined spaces may occur in many practical heat transfer devices. In vertical shell-and-tube steam generators, the heated tubes penetrate through the holes of the tube-sheet plate with a clearance in between. A very narrow crevice exists between the heated tube and the tube-sheet plate with the bottom end of this narrow crevice welded closed. Pool boiling occurs in this confined space. The knowledge of the boiling heat transfer at this confined condition is of great importance to the estimation of the dryout and the thermal-induced corrosion of the tubes near the tube-sheet plate [1]. The pool boiling heat transfer in a confined space is also of significant importance to the liquid cooling at the inside of gas turbine blades. In both cases, the confined space is in a form of a vertical gap with an open top and a closed bottom where nucleation sites may exist naturally.

Katto and Yokoya, and Katto *et al.* [2, 3] investigated boiling heat transfer in the confined space in saturated water on a horizontal flat plate. A movable optical assembly was placed above the horizontal heated surface with a small gap in between. It was observed that the boiling in the narrow gap had a high heat transfer coefficient which was attributed to the existence of the thin liquid film under the squeezed bubbles. Jensen *et al.* [4] performed experiments of boiling on a horizontal tube which was constrained by an annular shroud at its outside. The measured heat transfer coefficient was also high, and was explained by thin film evaporation.

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Ishibashi and Nishikawa [5] conducted experiments of boiling in vertical narrow annuli. Both the top and bottom ends were open. It was suggested that two boiling regimes exist: the isolated bubble regime and the coalesced bubble regimes with different heat transfer characteristics, respectively. Kusuda and Imura [6] performed experiments with subcooled and saturated liquid for boiling heat transfer in vertical tubes and annuli with closed bottoms. The heat transfer coefficient at boiling was reported to be independent of the length and diameter of the heated-tube. However, the annuli were made of unheated cores and heated external shrouds. The visualization of boiling had to be performed in separate tests.

In the present study systematic investigation of pool boiling heat transfer is performed in narrow vertical annuli with closed bottoms. Different gap sizes and heights of the annuli are studied for Freon-113, acetone, and water. A wide range of heat flux is considered and includes the cases beyond dryout. Since the heat transfer behavior is closely associated with the boiling phenomena in the confined space, visualization and heat transfer measurement are conducted simultaneously to provide a better understanding of the heat transfer mechanisms. Boiling curves and boiling regimes are presented and discussed.

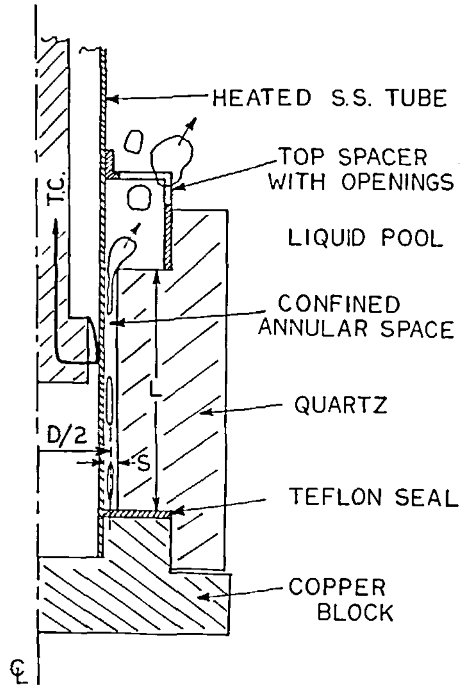


FIG. 1. Schematic of the test section.

## EXPERIMENTAL

### *Apparatus and procedure*

Experiments are performed in the pools of Freon-113, acetone, and distilled, demineralized water. The electrically heated tube was placed inside a hollow quartz cylinder. A small separation was maintained between the tube and the cylinder. The annulus was closed at the bottom and open to the pool at the top. The overall test assembly is shown in Fig. 1.

The heated section was made of stainless steel 304 seamless tube with 0.71 mm wall thickness, 25.4 mm O.D. and 101.6 mm heated length. The top of the heated tube was thermally shrink-fitted to a copper tube which had the same O.D. but a 1.42 mm wall thickness. The bottom end of the heated tube was shrink-fitted to a copper block. The stainless steel tube was heated with direct current. The heat flux is calculated from the measured electric current and resistance of the thin wall test section using a shunt and a digital voltmeter.

The hollow quartz cylinders were milled to the dimensions of 63.5 mm outside diameter with the inside diameters 26.04, 27.00, and 30.56 mm to form different gap sizes with respect to the heated tube. Both the inside and the outside surfaces of the quartz were polished to a 50–80 finish and was clear enough to see through. Three of the annuli tested were 76.2 mm long with gap sizes 0.32, 0.80, and 2.58 mm, respectively. There was another short one with a 25.4 mm length and a 0.32 mm gap. The bottom of the annuli is sealed with a Teflon ring. Two positioners at the top and the bottom of the quartz were used to maintain the concentric position of the quartz cylinder with respect to the heated tube.

The liquid pool was constructed from a Pyrex glass pipe with a 101.6 mm I.D. and a 457.5 mm length. The generated vapor during boiling experiments was released to a separate condenser. The liquid level was maintained at 100 mm above the top of the annulus by periodically adding the make-up liquid to the pool. The saturation temperature of the pool was maintained by an immersion heater. Before each experiment the liquid was degassed by boiling for one hour at low heat flux.

The inner-wall temperature of the heated tube is measured by two thermocouples 180° apart at the same elevation. Two type-K ungrounded stainless steel sheathed thermocouples with 0.81 mm diameter were pressed against the inner-wall by springs with a force of 0.48 N. The natural convection inside the tube is suppressed. The thermocouples were calibrated, but the temperature reader only had an accuracy of $\pm 0.28$ K. Since the two readings are always about the same, only one of the readings is used as data. The outside surface temperature was calculated from the steady-state heat conduction equation.

The same heating tube was used for all the tests. The tube surface was polished before each test with #320 sandpaper. The nucleation sites at the bottom of the annulus were formed naturally between the Teflon seal and the copper block. In the present study, the variation of wall superheat in the upper half of the test section is always very small. In order to avoid the minor details of the results, the thermocouples were permanently located 12 mm below the top opening of the narrow annulus. All the data reported here are for this representative location. The steady-state data were taken approximately 3 min after the change of heat flux in experiments.

The occurrence of critical heat flux is defined when the wall temperature at the measuring location increases continuously in an excursion. Usually, the bottom of the crevice contains a small pool of liquid at this moment. Although the critical heat flux may initiate at a particular location, different from the measuring position, it is likely that the measuring location will also observe the excursion within 3 min. Since the excursion is usually very slow, the power is shut off before the temperature reaches 95°C. The repeatability of critical heat flux is very good. The details of the experimental set-up and procedure have been described in ref. [7].

## RESULTS

*Boiling curves*

In the present investigation, relatively extensive studies are performed for Freon-113. First of all, the open-pool boiling in Freon-113 is conducted. This is done by removing the quartz shroud from the test section. At very low heat flux, natural convection appears as the dominant heat transfer mode. The natural convective heat transfer of a vertical cylinder with large Prandtl number has been described as [8]

$$Nu_x = 0.508\,[Pr/(0.92+Pr)]^{1/4}(Gr_x Pr)^{1/4} \quad (1)$$

where $x$ is the distance measured from the bottom of the cylinder. Although equation (1) is for a free cylinder, it is interesting to compare it with the present data of a cylinder with a block at the bottom. As shown in Fig. 2, the experimental data appear to be close to equation (1) with an error of 10%.

The boiling hysteresis of the open tube is shown in Fig. 2. The overshoot of wall temperature occur at heat up process; the boiling curve changes smoothly at cool down process. The nucleate boiling curve of the open tube is also shown in Fig. 2 with a limited number of data points. The critical heat flux is not reached in this open tube experiment because the available heating power is not sufficient to get to the critical heat flux. When nucleate boiling occurs, as shown in Fig. 2, the heat flux increases with the wall temperature in a form of

$$q_w \alpha (T_w - T_{sat})^3. \quad (2)$$

The pool boiling data of Yilmaz and Westwater [9] for a horizontal copper tube of 6.4 mm O.D. heated by steam in Freon-113 are also plotted in Fig. 2. Although these two experiments are for tubes at different orientation with respect to gravity and possibly with different surface conditions, the boiling curves are in parallel.

The boiling of Freon-113, acetone, and water in a confined space was studied for different gap sizes and heights. The experimental conditions are summarized in Table 1, together with the corresponding Bond numbers which will be discussed later. The detailed information on critical heat flux is reported in ref. [1]. In this paper, the highest point of each boiling curve denotes the condition of critical heat flux.

The boiling curves of Freon-113 are presented in

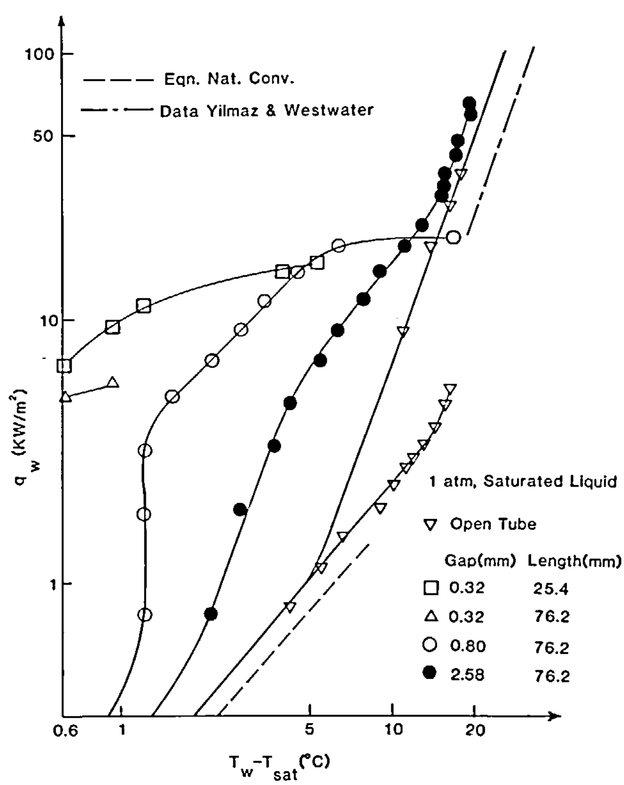


FIG. 2. Boiling curves of Freon-113.

Table 1. Summary of the experimental conditions*

| Geometries | | | Bond numbers | | |
|---|---|---|---|---|---|
| Tube diameter (mm) | Gap (mm) | Length (mm) | Freon-113 | Acetone | Water |
| | 0.32 | 76.2 | 0.300 | 0.197 | 0.127 |
| 25.4 | 0.32 | 25.4 | 0.300 | 0.197 | |
| | 0.80 | 76.2 | 0.757 | 0.495 | 0.319 |
| | 2.58 | 76.2 | 2.44 | 1.60 | 1.03 |
| | Open pool | 101.6 | ∞ | ∞ | ∞ |

*1 atm., saturated liquid, closed-bottom annuli.

Fig. 2. At the same heat flux, the wall superheat reduces as the gap size decreases. That means the heat transfer coefficient increases when gap size decreases. However, the critical heat flux is also reduced. In terms of the shape of the boiling curves, several different regimes can be identified. For the case of a large gap (2.58 mm), the boiling curve at high heat flux is in parallel with the open-pool results but with a higher heat transfer. For a narrow gap (0.80 mm for example), three different regimes are observed. At very low heat flux the boiling curve is almost vertical. The increasing of heat flux does not affect the wall superheat. With a higher heat flux the wall superheat increases as the heat flux is increased. The relationship is almost linear,

$$q_w \alpha (T_w - T_{sat}). \tag{3}$$

At even higher heat flux the boiling curve shows a very small slope with a severe increasing of wall superheat with little addition of heat flux. This leads to dryout in the confined space.

For the case of a narrow gap (0.32 mm), the boiling curve has a low wall superheat that only the regime of the vertical boiling curve and the regime of near-dryout condition are observed. The vertical boiling curve in this case can not be measured exactly because the measured wall superheat is 0.6 K which is very close to the uncertainty of this experiment. It is also interesting to point out that the boiling curve of the narrow gap (0.32 mm) with a short height (25.4 mm) shows the same general behavior as the long one (76.2 mm). The only effect of the shorter height is to have the near-dryout regime of the boiling curve occur at a higher heat flux, and reaches a higher critical heat flux at a higher temperature.

The boiling curves of acetone are shown in Fig. 3. The open tube tests were not performed for acetone and water. Equation (1) is shown in Fig. 3 for reference. The boiling in the large gap (2.58 mm) starts with a vertical boiling curve and goes through the regime of a linear boiling curve and, finally, shows a shape parallel with the conventional open-pool boiling curve. For smaller gaps, all the curves contain only two regimes—the vertical boiling curve and the near-dryout conditions.

The boiling curves of water are presented in Fig. 4. The curves are similar in nature to the results of acetone. The result of a large gap (2.58 mm) also

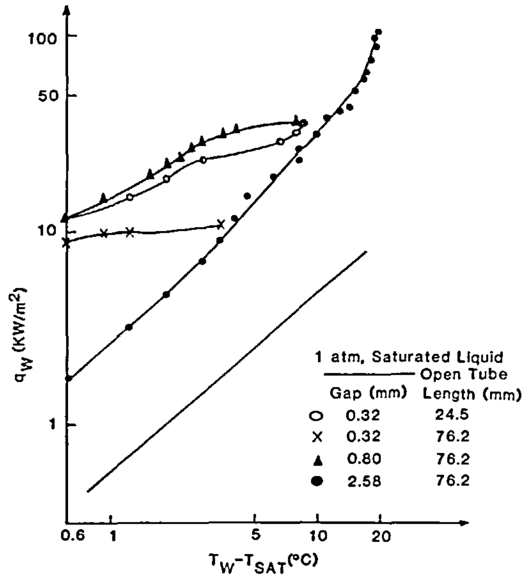


FIG. 3. Boiling curves of acetone.

contains a linear boiling curve, but the critical heat flux also occurs at this regime. The results of small gaps are essentially similar in nature to the results of acetone.

*Bond number*

As described in the last section, when the gap size of the annulus is decreased the effect of space confinement to boiling heat transfer increases. The more the confinement, the more the boiling curve shifts away from that of the open-pool. Boiling in a confined space is mainly characterized by the deformation of the bubbles. The bubble deformation can be characterized

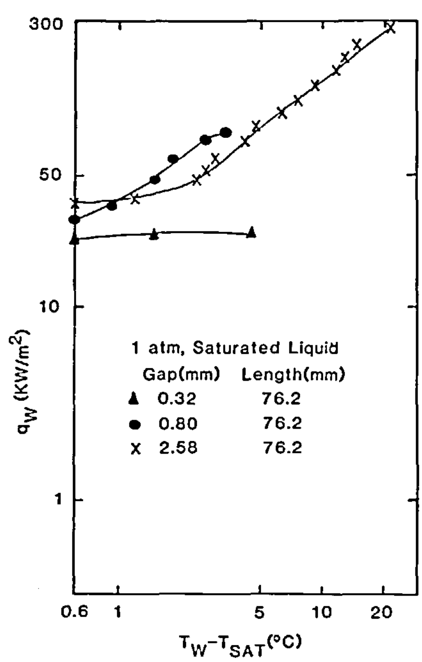


FIG. 4. Boiling curves of water.

by the ratio of the gap size and the nominal bubble departure diameter, which is generally known as the Bond number

$$Bo = s/[\sigma/g(\rho_l-\rho_g)]^{1/2}. \quad (4)$$

The Bond numbers corresponding to all the experimental conditions are listed in Table 1. It is reasonable to expect that the effect of confinement on boiling heat transfer may become significant if the Bond number of the gap is of the order of unity or less. Among the present experiments of the three fluids with the same geometry, the tests using water give the lowest Bond number while the tests using Freon-113 give the highest Bond number. This is because the nominal diameter of the departure bubbles for water is the largest, while the nominal bubble diameter of Freon-113 is the smallest. Comparing all the boiling curves in terms of their corresponding Bond numbers, it is observed that the shapes of boiling curves vary consistently with the change of Bond number. Generally speaking, the smaller the Bond number the less the wall superheat, and the greater the similarity of the boiling curve to a straight vertical line. Although the Bond number appears to be the most important parameter to characterize the effect of space confinement on the shape of a boiling curve, it is difficult to correlate the boiling curves with the variation of Bond number in terms of equations.

*Visualization*

In the present study, the boiling phenomena has been observed through the transparent quartz shroud. Cine film was also used to make systematic records for comparison. At low heat flux, bubbles are generated from the nucleation sites existing between the copper block and the Teflon seal near the bottom of the annulus. These nucleation sites are allowed here because this is also the typical situation occurring in many practical applications. With the presence of these nucleation sites the geysering phenomenon [10] has never been observed in the present study. With the addition of wall heat flux the boiling phenomena evolve through the following stages:

1. *Isolated deformed bubbles.* This occurs at the condition of small gap and low heat flux when the boiling curve appears as a straight vertical line. Generally, the shape of the bubbles is a half circle with a flat bottom as shown in Fig. 5(a). Thin liquid films exist between the squeezed bubble and the walls. Due to the addition of heat, the bubbles enlarge while rising upwards. At low heat flux, only a small fraction of the heated surface is covered by these isolated bubbles; at higher heat flux, more of the heated surface is covered by bubbles.

2. *Coalesced deformed bubbles.* At a higher heat flux the wall superheat increases linearly with the heat flux as described in equation (3). Due to the high heat flux at the surface the rising bubbles expand rapidly. The bubbles rise with a stop-and-go pattern, and merge or interact with other surrounding bubbles as shown in

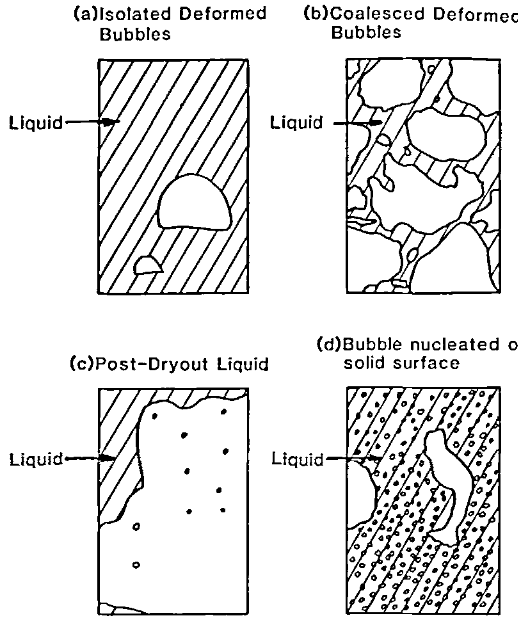


FIG. 5. Boiling phenomena in the confined space.

Fig. 5(b). It is likely that temporary dryout may occur under the expanding bubbles; however, due to the strong agitation and interaction the liquid will quickly rewet the surface. Since the thin film evaporation is still effective when the surface is wet, no bubble nucleation appears on the heated surface. Most of the surface is covered by the up-rising coalesced deformed bubbles with the liquid flowing downwards in between.

3. *Near-dryout and post-dryout conditions.* When the heat flux is close to the dryout value, the liquid films flow downwards along both of the surfaces with the vapor flowing upwards in between them. The liquid film on the unheated wall may extend to the bottom of the annulus; however, the liquid film on the heated surface evaporates extensively and possibly dries up. The dried area on the heated surface may be rewetted frequently by the liquid film on the unheated wall through surface waves which bridge the gap, or by the liquid pushed from the expanding bubbles at the liquid pool which is accumulated at the bottom of the annulus. Therefore, a stable temperature at the heated surface can still be maintained.

Beyond the dryout heat flux the temperature of the heated surface rises in a transient. Since the dryout heat flux in a confined space is usually not very high, the temperature excursion rate is, therefore, relatively slow. At this moment, the liquid on the outside of the crevice can hardly get into the crevice. Standing waves at the liquid–vapor interface are observed near the top of the crevice as shown in Fig. 5(c). Occasionally the wave breaks up, and some droplets are ejected into the crevice. The droplets evaporate while descending to the bottom. The outgoing vapor provides sufficient flow to maintain the standing wave at the top of the crevice.

4. *Nucleation under slightly deformed bubbles.* When

the gap is large (e.g. 2.58 mm) and the heat flux is high, the bubbles are slightly deformed and nucleation occurs on the heated surface. The generated bubbles at the surface may merge with the existing deformed bubbles. The phenomenon is illustrated in Fig. 5(d). To some extent, this is a mixed condition of open-pool boiling and confined space boiling. The heat flux variation is proportional to $(T_w - T_{sat})^3$ but with a higher heat flux than the conventional open-pool boiling curve.

## DISCUSSION

At the condition of low Bond number and low heat flux, the boiling is in the isolated deformed bubble regime. The measured superheat of the wall temperature is in the range of 0.56 K. This low value of superheat is sufficient to maintain the stability of the deformed bubble in the confined space. For example, the required superheat for a flattened Freon-113 bubble to maintain dynamic equilibrium in a gap of 0.32 mm is estimated to be only 0.03 K. On the other hand, the heat transfer at the isolated deformed bubble regime is mainly dependent upon the effective evaporation of a thin liquid film between the bubble and the heated wall. Therefore sufficient heat transfer occurs at low superheat.

At low heat flux, the isolated deformed bubbles cover only a small fraction of the heated surface. From the movie record, the averaged heat flux under the bubbles is evaluated from the rate of change of bubble sizes. Together with the measured area of the heated surface which is covered by bubbles the total heat transfer rate to all the bubbles can be evaluated. This value is found to be within 13% of the measured heat input to the surface at various heat flux levels. Therefore, most of the heat released from the surface contributes to the evaporation of the deformed bubbles. The increasing of surface heat flux simply increases the fraction of the surface area covered by deformed bubbles but with little change of the wall superheat.

At higher heat flux the coalescence of deformed bubbles happens. Since the deformed bubbles at the high heat flux condition already cover the majority of the heated surface, rapid evaporation causes violent merging and interaction among the deformed bubbles. Due to the high heat flux, temporary dryout may occur locally and increases the wall superheat; therefore, the heat flux varies linearly with wall superheat.

The boiling phenomena near dryout and beyond dryout is similar to the counter-flow phenomena of liquid and vapor in the annulus. The critical heat flux at this condition can be correlated following the flooding analysis [1]. To some extent, the boiling phenomena near dryout condition would be also dependent upon the geometric dimension of the testing condition.

When the Bond number is slightly higher than unity and the heat flux is high, nucleation may be observed under the slightly deformed bubbles. The higher heat transfer rate as compared with open-pool results have been explained in ref. [11], for water in the annulus with both ends open, as the effect of increased turbulence of the two phase mixture in the confined space.

Generally, the boiling regime in a narrow annulus with a closed bottom can be described in terms of the Bond number, which characterizes the effect of geometric confinement, and a boiling number, which characterizes the effect of confinement to bubble dynamics. This boiling number is defined as

$$B_l = \frac{q_w L}{h_{fg} \rho_g s V} \tag{5}$$

and

$$V = [gD(\rho_l - \rho_g)/\rho_l]^{1/2} \tag{6}$$

where $V$ is the characteristic bubble rising velocity in the annulus. In the present study this modified boiling number may be described as the ratio of the characteristic time of bubble rising through the crevice $(L/V)$, to the characteristic time of bubble expansion $(q_w/h_{fg}\rho_g s)^{-1}$ in the crevice. The boiling regime map of isolated deformed bubbles, coalesced deformed bubbles, and nucleation under slightly deformed bubbles are plotted from the data base of the present study in Fig. 6 in terms of the boiling number and the Bond number. It appears that the isolated deformed bubble regime occurs when the Bond number is less than unity at all the heat fluxes below the critical heat flux. The nucleation under slightly deformed bubble happens when the Bond number is larger than unity but at high heat flux condition. The coalesced deformed bubble regime may happen when the Bond number is slightly larger than unity and at low heating condition that the nucleation beneath the coalesced bubble does not occur. It may also happen when the Bond number is slightly less than unity and at high heating condition that bubbles expand violently and coalesce. Of course, when Bond number is very large the boiling will be the same as that of an open-pool. From Fig. 6 it can be observed that the boiling regime is mainly dependent upon the Bond number (larger or less than unity), but relatively less dependent upon the amount of heating in the crevice.

## CONCLUSION

Pool boiling heat transfer in a confined space is studied for vertical narrow annuli with closed bottoms for various gap sizes, fluids, and heat fluxes. The Bond number is found to be important in characterizing the boiling behavior. Three boiling regimes are identified: (1) Isolated deformed bubble regime occurs when the Bond number is less than unity and at low heat flux. The boiling curve is vertical with heat transfer mainly through thin film evaporation. (2) Coalesced deformed bubble regime happens when the Bond number is less than unity and the heat flux is high. The boiling curve is of linear form with possibly temporary dryout under the deformed bubbles. (3) Nucleation under slightly

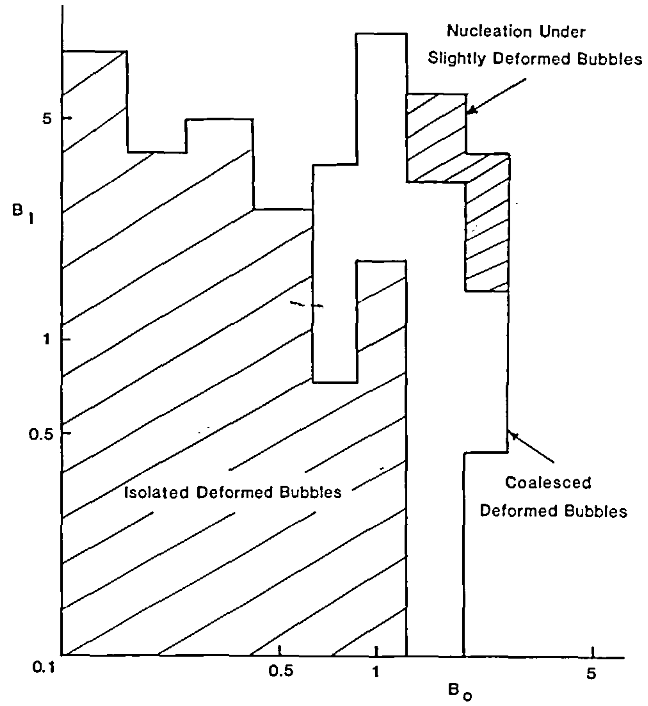


FIG. 6. Boiling map as a function of Bond number and boiling number.

deformed bubbles occurs when the Bond number is slightly larger than unity and at high heat flux. The boiling curve is of cubical form but with high heat transfer rate due to the significant agitation of the two phase mixture in the confined space.

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## TRANSFERT THERMIQUE DE L'EBULLITION EN RESERVOIR DANS UN ESPACE CONFINE

Résumé—Le transfert thermique par ébullition dans un espace confiné est étudié pour des espaces annulaires étroits, verticaux et fermés par des fonds. Les expériences portent sur Freon-113, acétone et eau à 1 atm, dans des espaces annulaires de 25,4 et 76,2 mm de hauteur, d'espace 0,32, 0,80 et 2,58 mm. On identifie par visualisation trois régimes d'ébullition. On démontre aussi l'importance du nombre de Bond. Quand le nombre de Bond est inférieur à l'unité, le régime de bulle isolée et déformée apparaît à faible flux thermique et le régime de bulles coalescentes est observé à haut flux thermique. Pour des nombres de Bond légèrement plus élevé que l'unité, à grand flux, on observe la nucléation sur la surface chauffée. Les courbes d'ébullition et les mécanismes de transfert thermique de ces régimes d'ébullition sont présentés et discutés.

## WÄRMEÜBERGANG BEIM BEHÄLTERSIEDEN IN EINEM GESCHLOSSENEN RAUM

**Zusammenfassung**—Der Wärmeübergang beim Behältersieden in einem geschlossenen Raum wurde für vertikale enge Ringspalte mit verschlossenen Enden untersucht. Versuche wurden für Freon-113, Aceton und Wasser bei einem Druck von 1 atm, Spalthöhen von 25,4 mm und 76,2 mm und Spaltbreiten von 0,32; 0,80 und 2,58 mm durchgeführt. Durch visuelle Beobachtung wurden drei Siedebereiche identifiziert. Der Einfluß der Bond-Zahl wird erläutert. Ist die Bond-Zahl kleiner als eins, so tritt bei niedrigen Wärmeströmen der Fall getrennter deformierter Blasen auf, während bei hohen Wärmeströmen der Fall zusammenhängender deformierter Blasen beobachtet wird. Für Bond-Zahlen, die nur wenig größer als eins sind, wurde bei hohen Wärmeströmen Blasenbildung an der Heizfläche beobachtet. Die Charakteristik der Siedekurven und der Wärmetransport-Mechanismus dieser Siedebereiche wird erläutert und diskutiert.

## ТЕПЛОПЕРЕНОС ПРИ КИПЕНИИ В БОЛЬШОМ ОБЪЕМЕ ЖИДКОСТИ В ЗАМКНУТОМ ПРОСТРАНСТВЕ

**Аннотация**—Исследован теплоперенос при кипении в большом объеме жидкости в вертикальных узких кольцевых каналах с закрытыми торцами. Эксперименты проводились с фреоном-113, ацетоном и водой при давлении 1 атм в каналах высотой 25,4 и 76,2 мм при величине зазоров 0,32; 0,80 и 2,58 мм. Путем визуальных наблюдений установлено 3 вида режимов кипения. Исследовано также влияние числа Бонда. При значениях числа Бонда меньше единицы наблюдается режим отдельных деформированных пузырьков, когда тепловой поток имеет небольшую величину, и режим сливающихся деформируемых пузырьков, когда тепловой поток имеет большую плотность. При значениях числа Бонда, несколько превышающих единицу, и большой плотности теплового потока наблюдалось зарождение пузырьков на поверхности нагрева. Описан общий характер кривых кипения и механизмов переноса тепла при таких режимах и проведен их анализ.