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CRITICAL HEAT FLUX IN A CLOSED TWO-PHASE THERMOSYPHON

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Abstract—An experimental study was made of critical heat flux in a closed two-phase thermosyphon. The effects of inside diameter, heated length, working liquid, fill charge and inside temperature on the critical heat flux were investigated. The present and previously-published experimental data were correlated with expressions already proposed by other investigators but the agreements were not good. Accordingly, a new correlating expression was derived. This expression agrees with the experimental data within ±30% accuracy. Also, discussion of the adequate fill charge is made.

NOMENCLATURE

Bo	Bond number, $d[g(\rho_l-\rho_g)/\sigma]^{1/2}$
d	inside diameter of thermosyphon tube [m]
g	gravitational acceleration [m s^{-2}]
l	length of thermosyphon tube [m]
p	inside pressure of thermosyphon tube (corresponding to saturation pressure of t_{in}) [Pa]
q_c,	critical heat flux based on heated section area [W m^{-2}]
q_{cx}	critical heat flux in axial direction of tube, $q_c 4l_e/d$ [W m^{-2}]
r	latent heat of vaporization [J kg^{-1}]
t_{in}	inside temperature of thermosyphon tube [°C]
V_e^+	dimensionless fill charge: volumetric fill charge divided by the volume of heated section
V_t^+	dimensionless fill charge: volumetric fill charge divided by the total volume of thermosyphon

Greek symbols

μ	dynamic viscosity [N s m^{-2}]
ρ	density [kg m^{-3}]
σ	surface tension [N m^{-1}]
ϕ	dimensionless number: sometimes called the Kutateladze number, $q_c/r[\sigma g\rho_g^2(\rho_l-\rho_g)]^{1/4}$

Subscripts

a	adiabatic section
c	cooled section or critical condition
e	heated section
g	vapor
l	liquid
t	total

1. INTRODUCTION

A CLOSED two-phase thermosyphon is also called a wickless heat pipe. A conventional heat pipe has a wick attached to the inner surface of the tube, since condensate must be returned from the cooled section to the heated section by means of capillary force. The closed two-phase thermosyphon, however, has no wick, so the condensate has to be returned by gravitational or centrifugal forces. Since heat is transferred by utilizing a phase change in both devices, thermal resistance is small and thus a large amount of heat is transferred with small temperature differences. Besides, external power is not necessary to circulate the working fluid, so that many applications such as gas turbine blade cooling [1], electronic component cooling [2], gas-to-gas heat exchanger [3] have been proposed and investigated. In the wicked heat pipe, flow resistance is much larger due to return-flow through the wick matrix. As a result, heat transportation is precluded from a wicking (capillary) limitation at a relatively small heat flux. In the closed thermosyphon, since boiling occurs in the narrow confines of the tube, the critical heat flux is smaller than that of normal pool boiling. It has been indicated, however, that the critical heat fluxes of the closed thermosyphon were about 1.2–1.5 times larger than those of the wicked heat pipe [4]. In addition, the closed thermosyphon is simpler to manufacture, since no wick is required. Although the closed two-phase thermosyphon has these advantages over the wicked heat pipe, it is necessary to predict accurately the critical heat flux for the design of heat transfer equipment using closed thermosyphons, since the critical heat flux is comparatively small. For this reason, many investigations of the critical heat flux have been performed [1, 4–17].

The experiment described in this paper investigates the effects of tube diameter, heated length, working liquid, liquid fill charge and inside temperature on the critical heat flux in the closed two-phase thermosyphon. The present and previously-published experimental data were correlated with expressions already proposed by other investigators but the agreements were not good. Therefore, a new correlating expression was derived on the basis of the result of the dimensional analysis presented by Katto [15].

2. EXPERIMENTAL APPARATUS AND PROCEDURES

A schematic diagram of the experimental apparatus is shown in Fig. 1. As the experimental apparatus and procedures have been reported in detail elsewhere [18], these will only be mentioned briefly. Water, ethanol and Freon 113 were used as working liquids. The thermosyphon tubes were made of brass with dimensions as listed in Table 1. The dimensions of the tubes used in other investigations are also given in Table 1 [1, 6–10]. The locations of the thermocouple hot junctions for measurements of the wall temperature are shown by the symbol × in Fig. 1. Inside temperatures were measured with two thermocouples inserted into brass tubes of 2 mm O.D. which were brazed individually to top and bottom caps.

The experiment was performed as follows: The thermosyphon tube was thoroughly cleaned with benzene, alcohol and finally the test liquid. Then the test liquid was poured into the tube to a volume slightly in

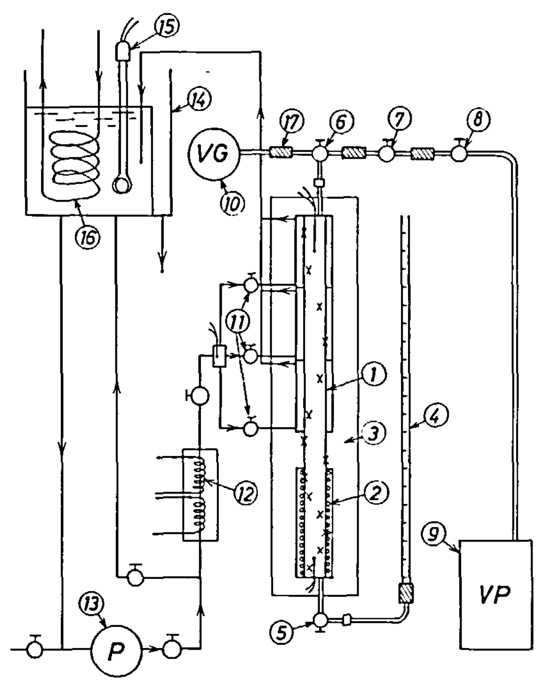

FIG. 1. Schematic diagram of the experimental apparatus. 1. Test tube. 2. Main heater. 3. Insulation. 4. Measuring device for liquid level. 5–7. Vacuum valves. 8. Leak valve. 9. Vacuum pump. 10. Vacuum gauge. 11. Valve for adjustment of cooling water flow rate. 12. Heater. 13. Circulation pump. 14. Head tank. 15. Pipe heater. 16. Copper coil for cooling. 17. Vacuum rubber hose.

Table 1. Range of parametric values for experiments

Test liquid	Investigators	Inside diameter d (mm)	Heated length l_e (mm)	Cooled length l_c (mm)	Total length l_t (mm)	l_e/d	Inside temperature t_{in} (°C)	Symbols
Water	Present work	19.4	300	300	643	15.5	50–100	○
		13.1	300	600	1000	23.0	40–100	⦶
	Nguyen-Chi *et al.* [6]	7.0	160		500	22.9	30–60	○
		10.0	75		500	7.5	12–51	○-
		10.0	160		500	16.0	30–60	○
	Cohen and Bayley [1]	6.35	152.4	609.6	762	24.0	100, 195	●
		12.7	152.4	609.6	762	12.0	100	●
	Harada *et al.* [7]	45.0	3450	2450	6000	76.7	52–105	◐
Freon 113	Present work	19.4	300	300	643	15.5	50–80	□
		13.1	100	600	1000	7.7	35–95	◫
		13.1	200	600	1000	15.3	35–95	⊟
		13.1	300	600	1000	23.0	35–95	⧄
	Fukui *et al.* [8]	21.0	200	200	500	9.5	100, 120, 140	◧
		12.0	200	200	500	16.7	100, 120, 140	◨
		6.3	200	200	500	31.8	100, 120, 140	■
Ethanol	Present work	19.4	300	300	643	15.5	60–100	△
		13.1	100	600	1000	7.7	50–95	⚠
		13.1	200	600	1000	15.3	50–95	▽
		13.1	300	600	1000	23.0	50–95	⩔
Dowtherm A	Suematsu *et al.* [9]	16.7	250	250	600	15.0	180, 260	◇
	Sakhuja [10]	17.27					288, 343	◇
		19.18					269, 307, 343	◇
		23.62					315, 343	◆

Symbols in this table are for Figs. 4–11.

excess of the predetermined value. The air in the tube was removed by a vacuum pump, and the residual air was checked by comparing the top-inside temperature with the bottom-inside and adiabatic wall temperatures after operating the thermosyphon. After that, the heat flux was increased in small steps, while the inside temperature was adjusted to the predetermined value by controlling the flow rate and temperature of the cooling water. The critical condition was determined by observing the temperature excursion of the heated wall. The heat flux when the critical condition was reached, i.e. the critical heat flux, was obtained from the value of electric input minus heat loss. The heat loss was estimated by preliminary experiment and was less than 7% of the electric input. Accurate values of the liquid fill charge were measured after a series of test runs, since a part of the liquid was removed together with the air by the vacuum pump.

3. EXPERIMENTAL RESULTS AND DISCUSSION

3.1. *Critical heat flux*

The relation between the critical heat flux q_c and the dimensionless liquid fill charge V_e^+ is shown in Figs. 2(a)–(c) where the inside temperature t_{in} (the arithmetic average of top-inside, adiabatic wall and bottom-inside temperatures) is taken as a parameter. A sketch of the flow patterns, observed with a glass tube device, is shown in Fig. 3 [18]. With small V_e^+, the condensate on the wall surface of the cooled section flows down in the form of liquid film to the heated section through the adiabatic section as in Fig. 3(a), and breaks down into rivulets at a comparatively small heat flux. When the film break-down occurs, the heat transfer in the break-down area decreases and the wall temperature rises. The wall temperature, however, does not rise continuously but reaches an equilibrium. This is because the break-down heat flux is relatively small and because heat conduction through the tube wall appears gradually to prevail. With the next increase in the heat flux, the wall temperature reaches a higher equilibrium, so it is difficult to determine the accurate value of critical heat flux. Hence, in this experiment, we took the critical heat flux to be when one of the temperatures of the thermocouples embedded in the heated wall rose above about 180°C. The critical heat flux q_c increases with increasing V_e^+ in this region. This region is called the 'dry-out region', since the dry area appears as a result of the film break-down. In the region of V_e^+ over a certain value, q_c is independent of V_e^+ and increases with rising t_{in}. The flow patterns of this region are presumed to correspond to Figs. 3(b) and (c), and the heated wall temperature, which had had a uniform temperature distribution, rose sharply at a lower half position of the heated section when the critical condition was reached. Since the rate of temperature rise of this region was faster than that of the dry-out region, this region is called the 'burn-out region'. Since the critical heat flux is smaller in the dry-out region, the liquid fill charge of the burn-out region should be selected for practical use. Excessive fill charge which is not appropriate, will be discussed later.

Many investigations of critical heat flux in the closed two-phase thermosyphon have been performed, and several correlating expressions have been proposed.

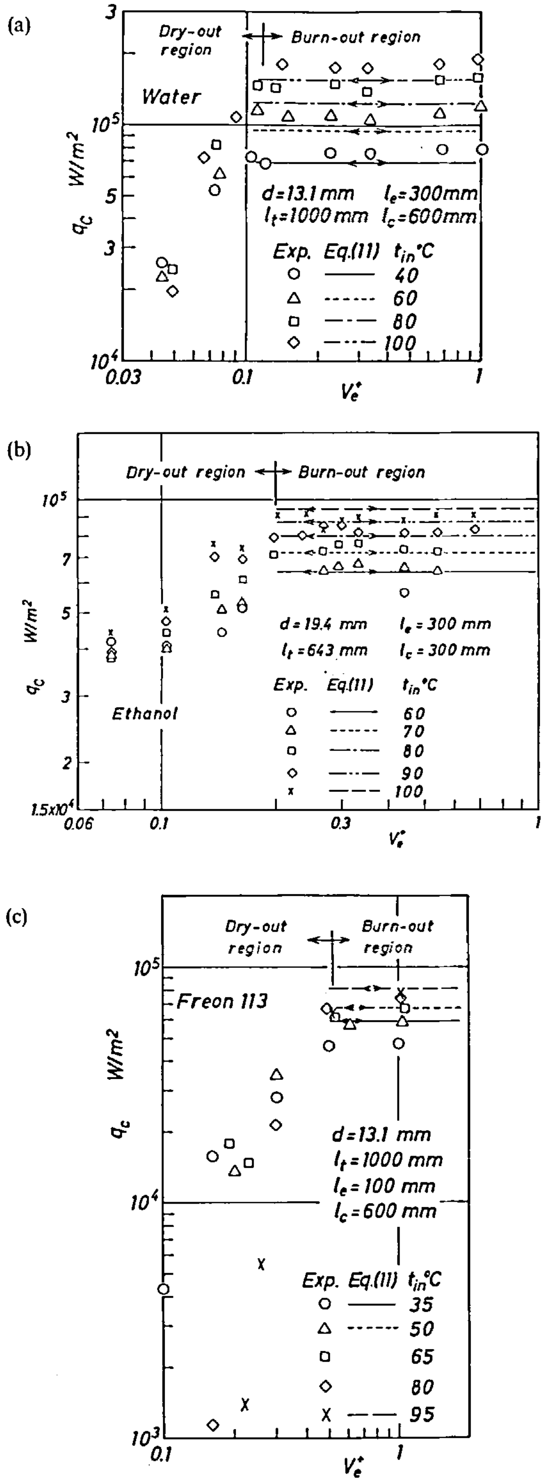

FIG. 2. Relation between critical heat flux q_c and dimensionless fill charge V_e^+.

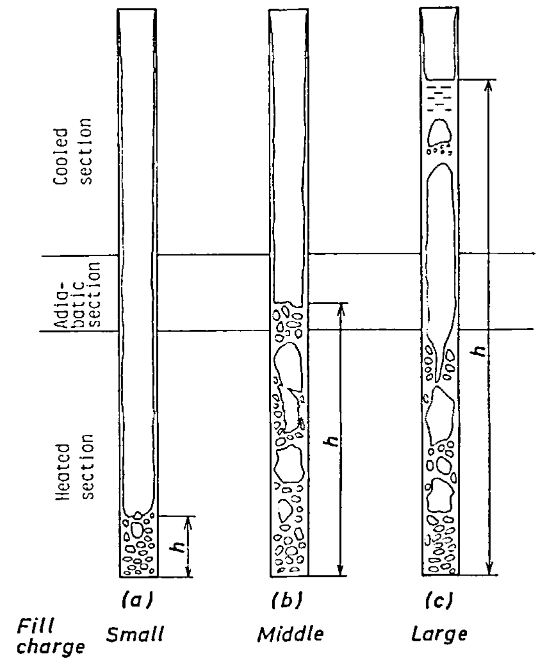

FIG. 3. Flow patterns in the closed two-phase thermosyphon.

Sakhuja [10] reported as follows: When the relative velocity between upward-flow of vapor and downward-flow of liquid exceeds a critical value, a flooding phenomenon occurs and the liquid in the tube is carried up to the cooled section. This is followed by the stoppage of liquid supply to the heated section. As a result, a heat transfer limitation is caused. Hence, Sakhuja proposed equation (1) on the basis of the equation for flooding velocity presented by Wallis [19], and showed that equation (1) agreed with his experimental data.

$$\phi = \frac{C^2}{4}\frac{d}{l_e}Bo^{1/2}/[1+(\rho_g/\rho_l)^{1/4}]^2 \tag{1}$$

where C is the experimental constant and $C = 0.725$. Similarly, Tien and Chung [11] and Nejat [12, 13] proposed equations (2), (3) and (4), respectively

$$\phi = 0.8\frac{d}{l_e}[\tanh(Bo^{1/4}/2)]^2/[1+(\rho_g/\rho_l)^{1/4}]^2, \tag{2}$$

$$\phi = 0.8\left(\frac{d}{l_e}\right)^{0.9}(1-1.5\,Bo^{-1/2}), \tag{3}$$

$$\phi = 0.09\left(\frac{d}{l_e}\right)^{0.9}Bo^{1/2}/[1+(\rho_g/\rho_l)^{1/4}]^2. \tag{4}$$

Gorbis and Savchenkov [14] took account of the influence of the heated wall curvature in Kutateladze's equation [20], which is applicable to pool boiling on a heated flat plate, and they presented the following equation:

$$\phi = C\left(\frac{d}{l_e}\right)^{-0.88}\left(\frac{d}{l_e}\right)^{1.10}(V_t^+)^m(1+0.03\,Bo)^2, \quad 2.0 \leqslant Bo \leqslant 60 \tag{5}$$

where

$C = 0.0215$ and $m = 0.26$ for $V_t^+ \leqslant 0.35$

and

$C = 0.00930$ and $m = -0.74$ for $V_t^+ > 0.35$.

Katto [15] made a dimensional analysis of critical heat flux in confined channels and presented equation (6) using the experimental data of an open thermosyphon obtained by Kusuda and Imura [21]

$$\phi = 0.10\Big/\left[1+0.491\frac{l_e}{d}Bo^{-0.30}\right]. \tag{6}$$

Imura and Kusuda [5] transformed their own equation for flooding velocity [22] and derived equation (7) using the data of the open thermosyphon [21]

$$\frac{q_c}{r(\sigma g\rho_g^2\rho_l)^{1/4}} = 0.0298\frac{d}{l_e}[d(g\rho_l/\sigma)^{1/2}]^{2/7}(\rho_l/\rho_g)^{1/14} \times(\mu_l/\mu_g)^{0.051}[(\sigma/g\rho_l)^{1/2}(\sigma\rho_l/\mu_l^2)]^{1/14}. \tag{7}$$

Bezrodnyi [16] considered the flooding phenomenon and derived the following equation using the critical heat flux in the axial direction of the tube $q_{cx} = q_c 4l_e/d$:

$$\phi\frac{4l_e}{d} = 10.2\left\{\frac{\sigma}{p}[g(\rho_l-\rho_g)/\sigma]^{1/2}\right\}^{0.17} \quad \text{for } \frac{\sigma}{p}[g(\rho_l-\rho_g)/\sigma]^{1/2} \geqslant 2.5\times10^{-5}$$
$$= 1.70 \quad \text{for } \frac{\sigma}{p}[g(\rho_l-\rho_g)/\sigma]^{1/2} < 2.5\times10^{-5}. \tag{8}$$

Harada *et al.* [7] showed that their experimental data were fairly correlated with equation (9) for the flooding velocity presented by Diehl and Koppany [23]

$$\frac{q_c}{\rho_g r}\frac{l_e}{d} = 9.64F(\sigma/\rho_g)^{0.5} \quad \text{for } F(\sigma/\rho_g)^{0.5} \geqslant 0.079$$
$$= 14.1[F(\sigma/\rho_g)^{0.5}]^{1.15} \quad \text{for } F(\sigma/\rho_g)^{0.5} < 0.079 \tag{9}$$

where

$F = 1.58(d/\sigma)^{0.4}$ for $d/\sigma < 0.318$

and

$F = 1.0$ for $d/\sigma \geqslant 0.318$.

When equation (9) is used, all variables should be substituted in the SI units shown in the Nomenclature. Although some of the above equations (1)–(9) were derived under different notions, most have the same functional form as the following equation derived from the dimensional analysis by Katto [15]:

$$\phi = f(d/l_e, \rho_l/\rho_g, Bo). \tag{10}$$

In Gorbis and Savchenkov's equation (5), the influence of d/l_e and V_t^+ are added. Imura and Kusuda's equation (7) includes μ_l/μ_g and $(\sigma/g\rho_l)^{1/2}(\sigma\rho_l/\mu_l^2)$ as dimensionless numbers in addition to those included in equation (10) when $\rho_l \gg \rho_g$ is assumed, but the influence of these

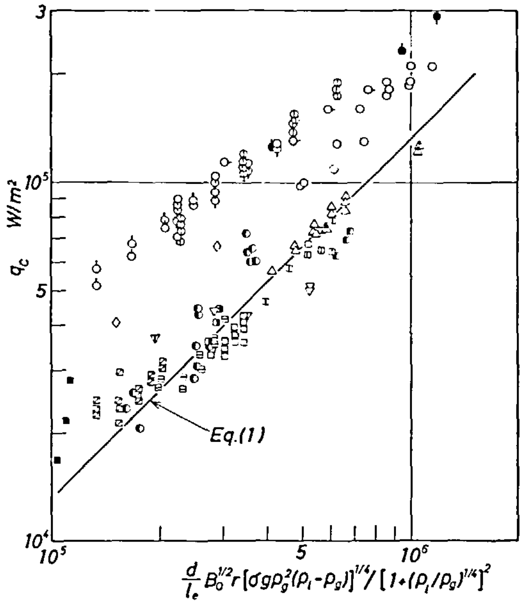

FIG. 4. Correlation with Sakhuja's equation (1).

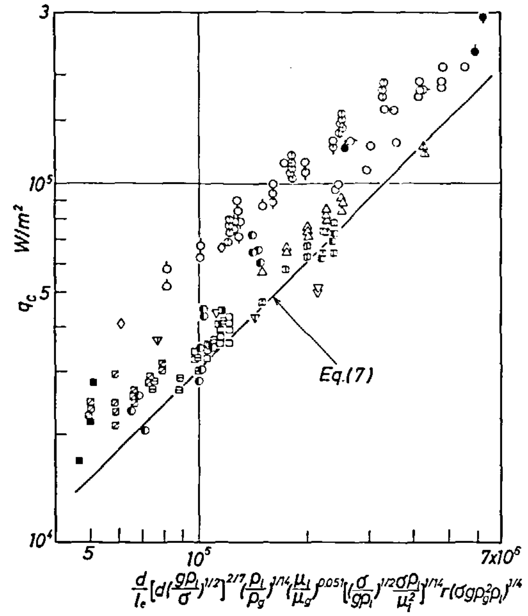

FIG. 6. Correlation with Imura and Kusuda's equation (7).

numbers is weak owing to the small values of their exponents. Equation (7) is therefore similar to equation (10). Only Bezrodnyi's equation (8) includes a dimensionless number different from equation (10). Diehl and Koppany's equation (9) is completely empirical and has no dimensionless form. Since all the above equations are applicable to the data of the burn-out region, the experimental data of this region were correlated with equations (1)–(9). The experimental data listed in Table 1 were correlated with equations (1) and (6)–(9), and the results are shown in Figs. 4–8. Figures 4–6 indicate similar results where most data for water have large values and show a discrepancy from the others. In Fig. 7, the solid line is Bezrodnyi's equation (8), and the experimental data indicate average values about 40% smaller than equation (8). However, if an empirical equation shown by the broken line is considered, a fair correlation can be obtained. In Fig. 8, which shows the result correlated with Diehl and Koppany's equation (9), some of the data for water show larger values than equation (9) and some of the data for ethanol show smaller values. In addition, since the results correlated with equations (2) and (4) are similar to Fig. 4, and since the results correlated with equations (3) and (5) show a very large scatter of data, these four figures are not shown. Figures 7 and 8 indicate fairly good correlations, but the agreements are not good enough. Thus we tried a correlation using the dimensionless numbers included in equation (10). Katto [15] showed the relation $\phi \propto d/l_e$ from vectorial dimensional analysis and this relation is also seen in Figs. 7 and 8. Therefore, the relation between

$$\phi 4l_e/d = (q_c 4l_e/d)/r[\sigma g \rho_g^2(\rho_l - \rho_g)]^{1/4}$$

and Bo is shown in Fig. 9. In this figure, the data with almost equal t_{in} values are plotted in order to keep the values of ρ_l/ρ_g constant. From this figure, the effect of Bo is not recognized, although the scatter of data is considerably larger. The relation between

$$(q_c 4l_e/d)/r[\sigma g \rho_g^2(\rho_l - \rho_g)]^{1/4}$$

and ρ_l/ρ_g is shown in Fig. 10. Some of the data for water obtained by Harada *et al.* [7] and the data for Dowtherm A obtained by Suematsu *et al.* [9] indicate larger values, and some of the present data for ethanol indicate smaller values. But except for the above, the data are correlated with the following equation within

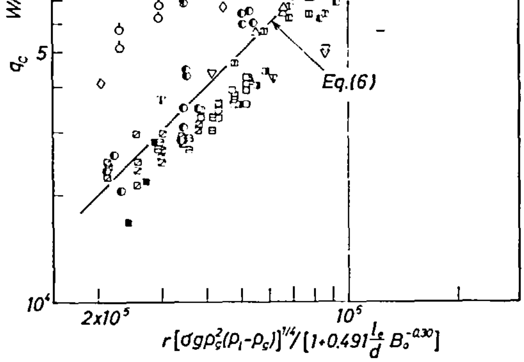

FIG. 5. Correlation with Katto's equation (6).

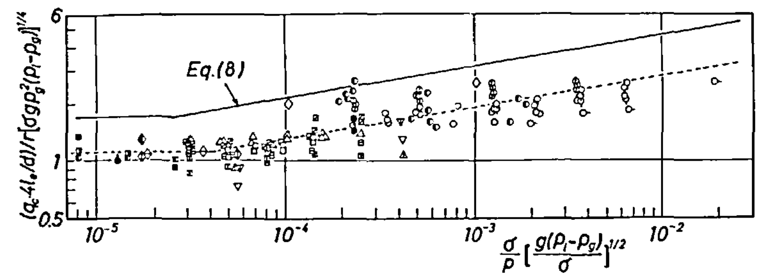

FIG. 7. Correlation with Bezrodnyi's equation (8).

$\pm 30\%$ accuracy:

$$q_c \frac{4l_e}{d} \Big/ r[\sigma g \rho_g^2(\rho_l-\rho_g)]^{1/4} = 0.64(\rho_l/\rho_g)^{0.13}. \quad (11)$$

In Fig. 10, however, the values of the ordinate tend to become constant at small values of ρ_l/ρ_g (or at higher inside pressure) as shown by the broken line. This tendency is also seen in Fig. 7 which shows the result correlated with Bezrodnyi's equation. Hence, the correlating equation may be better if it were divided into two regions like Bezrodnyi's equation (8) at the boundary $\rho_l/\rho_g \simeq 70$. From equation (11) it is considered that the critical heat flux in the axial direction, q_{cx}, rather than q_c has a physical meaning in the thermosyphon with comparatively larger values of l_e/d. The values of q_c calculated from equation (11) are shown in Figs. 2(a)–(c) in order to compare them with the experimental data. The relation between ϕ and $(d/l_e)(\rho_l/\rho_g)^{0.13}$ is shown in Fig. 11, although this is basically the same correlation as in Fig. 10. In the case of a thermosyphon, as described by Katto [15], the critical heat flux is considered to approach the value predicted from Kutateladze's equation (12) [20], as the value of d/l_e increases

$$\phi = 0.12-0.16. \quad (12)$$

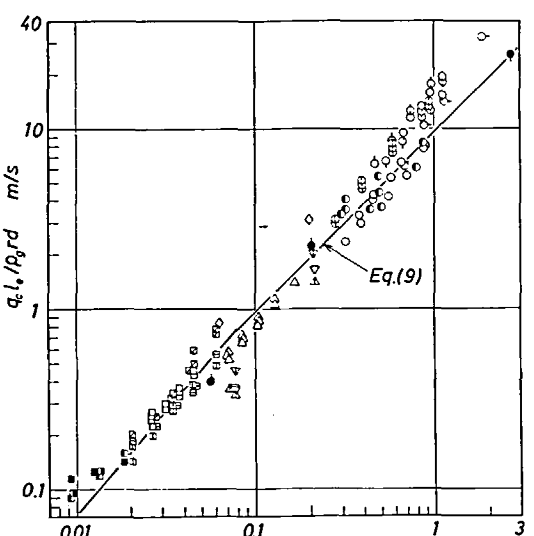

FIG. 8. Correlation with Diehl and Koppany's equation (9).

The following equations approach equation (11) when the value of d/l_e becomes much smaller, and approach equation (12) (assuming $\phi = 0.16$) when the value of d/l_e becomes much larger:

$$\phi = 0.16/[1+(l_e/d)(\rho_g/\rho_l)^{0.13}], \quad (13)$$

$$\phi = 0.16\{1-\exp[-(d/l_e)(\rho_l/\rho_g)^{0.13}]\}. \quad (14)$$

Equation (13) has the same form as Katto's equation (6). Equations (13) and (14) are shown in Fig. 11. Although a definitive statement cannot be made because of a lack of available data for larger values of d/l_e, equation (14) appears to be in closer agreement with the experimental data than equation (13).

3.2. *Liquid fill charge*

The liquid fill charge of the dry-out region is not adequate, since the critical heat fluxes of this region are smaller than those of the burn-out region. The critical heat fluxes of the burn-out region, where the flow patterns correspond to Figs. 3(b) and (c), are independent of the fill charge. However, with such a large fill charge as in Fig. 3(c), the liquid is carried up to the cooled section and subcooled there. As a result, periodic burst boiling takes place, which causes vibration of the thermosyphon device accompanied by a bursting noise [18]. For this reason, excessive liquid fill charge is not appropriate either. Hence, it seems best to operate the thermosyphon so that the liquid–vapor mixture level h is at almost the same height as the heated section or a little higher, as shown in Fig. 3(b). To maintain the level in Fig. 3(b) under operating

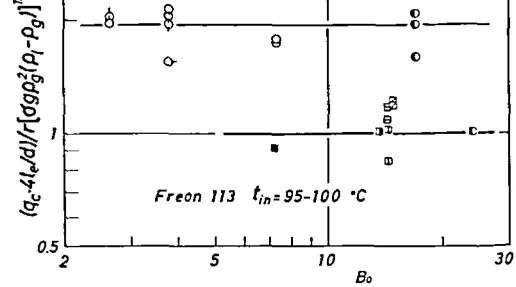

FIG. 9. Effect of Bo number on the normalized critical heat flux.

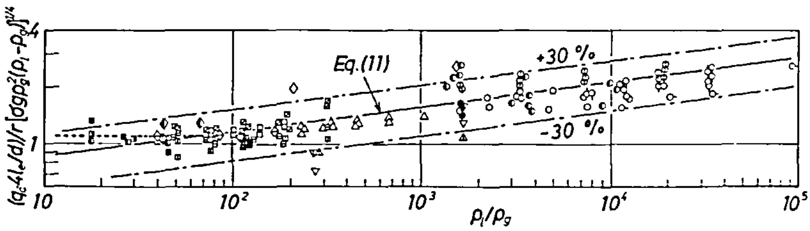

FIG. 10. Effect of ρ_l/ρ_g on the normalized critical heat flux.

conditions, we need to predict how much liquid should be charged into the tube. Larkin [24] and Imura [25] investigated the height of the liquid–vapor mixture level. They first filled a glass tube with a predetermined quantity of water and measured the height of the mixture level raised by introducing various flow rates of air instead of water vapor from the bottom of the glass tube. According to these experiments, $V_e^+ \simeq 1/5–1/3$ seems to be adequate for the liquid fill charge. Harada *et al.* [7] suggested that $V_e^+ = 0.25–0.30$ is desirable. When the sum of the cooled and adiabatic lengths is much larger than the heated length, however, the critical heat fluxes become those of the dry-out region. This is because the liquid exists in the form of film on the wall and as a vapor in the core, which reduces the level of the liquid–vapor mixture. Hence, taking account of the liquid existing as film on the cooled and adiabatic walls and as vapor in the core, we obtain the following equation:

$$V_e^+ = (1/5\text{–}1/3) + \frac{0.8l_c + l_a}{l_e}\frac{4}{d}\left(\frac{3\mu_l l_e q_c}{\rho_l^2 g r}\right)^{1/3} + \frac{\rho_g}{\rho_l}\left[\frac{l_c + l_a}{l_e} - \frac{0.8l_c + l_a}{l_e}\frac{4}{d}\left(\frac{3\mu_l l_e q_c}{\rho_l^2 g r}\right)^{1/3}\right]. \quad (15)$$

Assuming the film thickness to be much less than the radius of the tube, we derived equation (15) from the Nusselt film condensation theory. The second term on the RHS of equation (15) is the quantity of liquid film, and the third term the quantity of vapor [5]. The ranges of V_e^+ calculated from equation (15), into which the value of q_c estimated from equation (11) was substituted, are shown by the arrow in Figs. 2(a)–(c). In Fig. 2(c), where l_e is much less than $(l_c + l_a)$, the liquid fill charge of $V_e^+ = 1/5–1/3$ is not sufficient, but that calculated from equation (15) is. The values (1/5–1/3) of the first term on the RHS of equation (15) are not accurate, since they seem to change with inside pressure, inside diameter, heat flux, physical properties of working fluid, etc. Thus further study is required. As for the effect of inside diameter, since the liquid–vapor mixture level has a tendency to rise with a decrease in the inside diameter [25], a value of about 1/5 should be taken for a tube with a smaller diameter, and a larger value for a larger diameter.

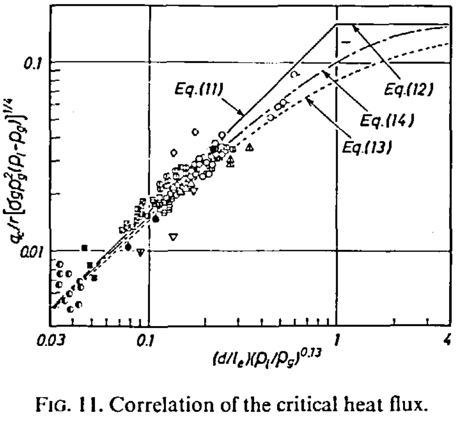

FIG. 11. Correlation of the critical heat flux.

4. CONCLUSIONS

This experiment on the critical heat fluxes in the closed two-phase thermosyphon was performed using water, ethanol and Freon 113 as working liquids. We tried to correlate the present and previously-published experimental data with various correlating expressions. The results are as follows:

(1) Equation (11) was presented as the correlating expression for the critical heat fluxes. The experimental data correlate with this expression to within $\pm 30\%$ accuracy. In addition, equation (14) may be applicable over a wide range of d/l_e values, including large values.

(2) Taking account of the magnitude of the critical heat flux and the operating situation of the thermosyphon, we propose equation (15) as giving values for adequate liquid fill charge.

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FLUX THERMIQUE CRITIQUE DANS UN THERMOSYPHON FERME ET DIPHASIQUE

Résumé—Une étude expérimentale concerne le flux thermique critique dans un thermosyphon fermé et diphasique. On étudie les effets du diamètre intérieur, de la longueur chauffée, du liquide de travail, de la charge de remplissage et de la température interne sur le flux thermique critique. Les données expérimentales tant présentes que déjà publiées sont unifiées par des expressions déjà proposées, mais les accords ne sont pas suffisamment bons, aussi une nouvelle formulation est-elle proposée. Cette expression s'accorde avec les données expérimentales à $\pm 30\%$ près. Une discussion du remplissage correct est faite.

DIE KRITISCHE WÄRMESTROMDICHTE IN EINEM ZWEI-PHASEN-THERMOSYPHON

Zusammenfassung—Die kritische Wärmestromdichte in einem Zwei-Phasen-Thermosyphon wurde experimentell untersucht; dabei war der Einfluß des Innendurchmessers, der beheizten Länge, des Arbeitsfluides, der Füllmenge und der Temperatur im Inneren von Interesse. Es wurde versucht, die hier gewonnenen und früher veröffentlichte Daten mit Hilfe von Beziehungen anderer Autoren zu korrelieren. Die Übereinstimmung war jedoch nicht gut genug. Folglich wurde eine neue Korrelation entwickelt, die die experimentellen Daten mit einer Genauigkeit von $\pm 30\%$ wiedergibt. Außerdem wurde die angemessene Füllmenge diskutiert.

КРИТИЧЕСКИЙ ТЕПЛОВОЙ ПОТОК В ЗАМКНУТОМ ДВУХФАЗНОМ ТЕРМОСИФОНЕ

Аннотация—Проведено экспериментальное исследование критического теплового потока в замкнутом двухфазном термосифоне. Исследовалось влияние на критический тепловой поток внутреннего диаметра, длины нагреваемого участка, рабочей жидкости, степени заполнения и внутренней температуры. Была предпринята попытка описать представленные в работе и ранее опубликованные экспериментальные данные известными отношениями, однако, расхождения были слишком велики. Поэтому предложено новое обобщающее соотношение, описывающее экспериментальные данные с точностью $\pm 30\%$. Обсуждается также вопрос о необходимой степени заполнения термосифона.