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Experimental investigation of geyser boiling in an annular two-phase closed thermosyphon

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Abstract—Geyser boiling in a vertical annular two-phase closed thermosyphon was experimentally studied. The effects of the heat load, condenser temperature, degree of liquid fill and length of the evaporator on the characteristics of the geyser boiling were investigated in detail for both water and ethanol as working fluids. Flow visualization at light heat load clearly illustrates the process of geyser boiling. It also indicates that it occurs more frequently and irregularly at high heat load. The wall temperature measurement dictates that the period of geyser boiling is shorter at a higher heat load, a shorter evaporator length and a smaller liquid fill. Additionally, the heat transfer coefficient is found to increase approximately linearly with the heat load on a logarithmic scale. An empirical equation was proposed to correlate the data for the heat transfer coefficient. A criterion was suggested for the occurrence of geyser boiling based on the present data.

1. INTRODUCTION

A closed two-phase thermosyphon is known as a wickless heat pipe. In constructing the device, a small quantity of liquid is filled into a closed tube occupying a fraction of the tube's inside space. Heat is input through the evaporator section at the lower end, causing the inside liquid to evaporate or boil. The generated vapor, being lighter, moves upwards and condenses at the low temperature condenser section, which is at the upper end. Acting by gravity, the condensate falls back to the evaporator end along the pipe wall. Due to effective latent heat transfer associated with the phase change processes, a large quantity of heat is transferred from the evaporator end to the condenser end with a relatively small temperature difference between them. However, the use of this device is often hindered by various limits such as dry-out of liquid film and flooding of counter-current liquid–vapor flow, and by the geyser boiling.

Heat transfer in the thermosyphon is considered to be affected by many factors, such as (1) the type of the working fluid, (2) the quantity of the working fluid, (3) tube geometry, (4) ratio of the evaporator length to the condenser length, (5) heat flux and (6) operating pressure (or corresponding saturation temperature). Various heat transfer limits occur as a result of the dry-out of liquid film in the evaporator. When the heat input to the evaporator is relatively high, intensive liquid film evaporation causes the vapor flow to move upwards, quickly, exceeding the flooding limit. The drying out of the liquid film may result from liquid droplet entrainment from the liquid film by the interfacial shearing effect of high speed vapor flow, resulting in the entrainment limit. When the tube is filled with a large quantity of working fluid, a peculiar phenomenon is noted. Under certain thermal conditions a large amount of working fluid is periodically propelled from the evaporator to the condenser section with a significant velocity. This fast-moving liquid results in oscillating heat transfer and produces a strange sound in the thermosyphon. In an extreme case, it may damage the container wall. This peculiar phenomenon is the so-called geyser boiling effect or blow-up phenomenon of the thermosyphon.

In view of the complicated hydrodynamic and thermal processes, the heat transfer performance of a two-phase closed thermosyphon is mainly explored by experimental measurement. Lee and Mital [1] noted that the heat transfer coefficient is very sensitive to the operating pressure and in fact rapidly increases with pressure. A similar conclusion was reached by Imura *et al.* [2]. They further noted that the optimal fill quantity is in the range of 10–20% of the inside volume of the tube. Bezrondnyy and Elekseyenko [3] find that optimal heat transfer performance can be obtained when the fill quantity is over 50% of the evaporator volume. Undeveloped boiling occurs in

NOMENCLATURE

A	outside surface area of the inner tube	V^+	fill ratio: volumetric fill charge divided by the volume of the heated section.
l_h	length of the evaporator		
p	pressure		
Q	heat transport rate	Greek symbol	
q''	heat flux	α	heat transfer coefficient.
T	temperature		
T_c	temperature of the cooling water circulating over the condenser end	Subscripts	
		h or w	of evaporator
		v	vapor.

the heat-supply zone at a low heat load, while at a high heat load developed boiling prevails [4].

By using an annular thermosyphon with a glass outer cylinder, Andros and Florschuetz [5] visualized the flow patterns in the device. For small and intermediate fills, four basic flow regimes were observed in the evaporator section for increasing heat load: a smooth continuous film with surface evaporation, breakdown of the smooth continuous film into a series of stable rivulets, a wavy film with unstable rivulets, and a wavy film with bubble nucleation occurring in the unstable rivulets. Obviously, at a very high heat input, complete dry-out in the evaporator results. Similar flow visualization was conducted by Rosler *et al.* [6].

The heat transfer coefficient in the condenser is normally derived from the Nusselt solution for filmwise condensation [2, 5, 7]. Based on 2529 data points, Grob [8] classified the heat transfer processes in the evaporator into a two-phase natural convective regime (undeveloped boiling) and a nucleate boiling regime (developed boiling).

Information on the critical heat flux is essential in the safe operation of the thermosyphon. Bezrodnyi and Beloivan [9] suggested that the heat transfer capacity of the device is limited by the liquid film dryout in the evaporator, resulting from the flooding or entrainment limit at low liquid fill and by the geyser boiling at high liquid fill. In addition, the maximum heat flux significantly increases with the operating pressure. Correlations for the critical heat flux have been proposed by Imura *et al.* [10] and Feldman and Srinivassan [11]. They found that an optimum liquid fill is reached between 18% and 22% of the thermosyphon volume.

Effects of the pipe inclination on the heat transfer performance were examined by Semena and Kiseelev [4], Feldman and Srinivassan [11], Negishi and Sawada [12] and Groll and Spendel [13]. Maximum heat transfer occurs when the inclination is between 20° and 40° for water and more than 5° for ethanol [12]. Also, Groll and Spendel noted that maximum heat flux results at an inclination of around 40°.

Heat transfer performance of the device at high pressure and near critical state has been studied by Gross and Hahne [14, 15]. Their results indicate that the optimum pressure for the overall performance is reached when the reduced pressure is between 0.9 and 1.0.

Various operating limits such as dry-out, burn-out, entrainment and flooding limits have been the focus of several investigations [16–21]. Maximum heat transfer rate due to entrainment limit was derived by Tien and Chung [16]. Nguyen-Chi and Groll [17] pointed out that, in a short thermosyphon with a small diameter, dry-out and burn-out limits prevail, while flooding or entrainment limit is normally encountered in a long device. Fukano *et al.* [18, 19] observed significant oscillation phenomena in a large pipe with moderate fill. A regime map was presented to characterize the dry-out, boiling and oscillation limits in terms of dimensionless liquid and vapor superficial velocities. The oscillation phenomenon was attributed to the alternate flooding and deflooding processes. Bezrodnyi and Volkov [20] studied the influence of the two-phase compressible effects on the stability of the liquid film in counter-current liquid–vapor flow.

The geyser boiling was investigated in detail by Casarosa *et al.* [22] and Negishi [23] through analyzing the time variations of the evaporator and condenser wall temperatures. This interesting but detrimental phenomenon is conjectured to be resulting from the pulse boiling at low (subatmospheric) pressure. Under that condition the nucleation bubble can grow to a very large size. At a certain time this bubble explosively expands along the axis of the thermosyphon, pushing the liquid column above it towards the condenser end with a considerable speed. The liquid then falls down to the evaporator and gets heated. As the liquid gets enough superheat, the next bubble appears and grows, initiating another cycle. At a high thermal load, the frequency of the geyser boiling increases. Increasing the operating pressure results in a lower intensity of the boiling.

The above literature review clearly indicates that the effects of various parameters on the detailed processes of the geyser boiling are still poorly understood. In particular, the flow structure during the dashing motion in geyser boiling is not known. In addition, a criterion for the occurrence of the geyser boiling has not yet been established. In an initial attempt to delineate the characteristics of geyser boiling, we perform

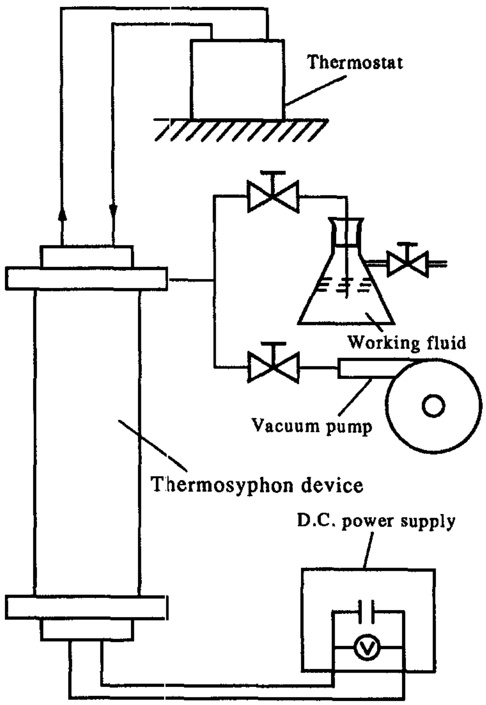

Fig. 1. Schematic diagram of the experimental system.

an experimental study to visualize the flow during geyser boiling and measure the frequency of the blow-up phenomenon.

2. EXPERIMENTAL APPARATUS AND PROCEDURES

A major objective of this study is to observe geyser boiling in a closed two-phase thermosyphon. To achieve this objective, an annular thermosyphon with a transparent outer tube was designed and constructed. Distilled water was chosen as the working fluid. The schematic diagram of the experimental system is shown in Fig. 1. The details of the test section are schematically shown in Fig. 2. The inner tube was made of a hollow SS304 stainless steel cylinder of 3.2 cm O.D. with 0.12 cm wall thickness. Precision-bore glass, 5.3 cm O.D. and 0.16 cm thickness, was used for the outer envelope. Each end cap consisted of three pieces, all made of steel, and was sealed with O-rings between the cap and the inner and outer cylinders. Viton O-rings were used to avoid material compatibility problems. Several small holes were opened in the top cap to allow for the liquid filling, placement of temperature and pressure probes, and the pumping of the air out of the annular space by a vacuum pump. The overall working length of the device was 55 cm. The evaporator and condenser sections were, respectively, 14 and 31 cm long.

The heater assembly was made of a stainless steel sheet, a copper bar and a copper block. It was pressed into the inside space of the lower end of the inner tube. Good thermal contact between the heater and the evaporator was achieved by using silicon grease covering the heater surface. Meanwhile the heater surface was covered by a thin mica piece to prevent electricity leaking to the inner steel cylinder. Direct current was passed through the heater by a d.c. power supply which was a 5 V and 2000 A rectifier. To maintain the condenser section at a constant temperature, a low temperature thermostat was employed to circulate liquid water through the section. The temperature of the section was maintained within ± 0.5°C.

A pressure transducer and a thermocouple were placed inside the condenser end to measure the saturated pressure and temperature of the system. Drastic temperature variation during geyser boiling was detected by gluing a number of calibrated thermocouples on the inner tube wall. The time histories of the temperature from the thermocouples were recorded by a data logger.

In order to reduce heat loss through the glass envelope and avoid the moist air condensing on the envelope during testing, the air surrounding the glass envelope was maintained at a temperature approximately equal to the saturation temperature of the system. This was accomplished by encompassing the device with an acrylic chamber through which heated air was passed. The heat loss through the heater to the ambient was estimated by measuring the temperatures of the copper block and ambient air.

The experimental procedures can be briefly described in the following. First, the air in the annular space between the inner and outer tubes was taken out by a vacuum pump. The air pressure was kept at a relatively low value of 0.01 torr by carefully sealing all the connections and insertions. Thus, the non-condensable gas effect was eliminated. Secondly, a predetermined degased amount of liquid water or ethanol was filled into the device. Next, the power supply was turned on and set at the required current and voltage. Meanwhile, low-temperature liquid water from the thermostat was circulated through the condenser section to maintain its temperature. For a given liquid fill and a fixed condenser temperature, the input power level was adjusted to a particular range in which geyser boiling occurs. Finally, flow visualization and temperature measurement were started after the initial transient had passed. This initial transient time is about 2–3 h. The process of the geyser boiling was recorded by a video camera and a still camera.

3. RESULTS AND DISCUSSION

As indicated above, the main objective of the present study is to investigate the effects of various parameters on the characteristics of geyser boiling. In the light of practical applications, water and ethanol were chosen as the working fluids. The evaporator section length was selected as 14 and 19 cm. The condenser temperature varied from 5 to 30°C and

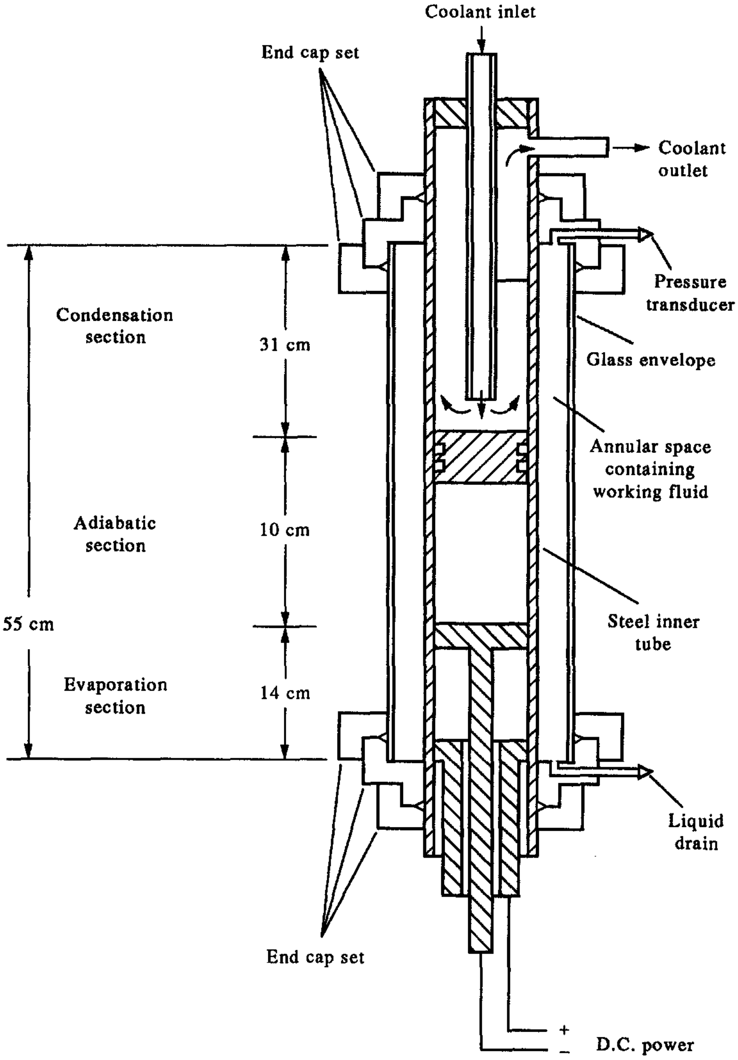

Fig. 2. Schematic diagram of the test section.

liquid fill from 30 to 140% of the evaporator volume. Heat input was adjusted to cause the geyser to boil.

3.1. *Results for a water-filled thermosyphon*

Results for a typical case at low heat load can be clearly seen in Fig. 3 for the temporal variations of the condenser and evaporator wall temperatures for a water-filled thermosyphon with $l_h = 14$ cm, $V^+ = 100\%$, $T_c = 5°C$ and $q''_h = 0.018$ W cm^{-2}. The thermocouples TC2 and TC10 were, respectively, 3.1 and 22 cm from the bottom and top of the thermosyphon. A qualitative picture of the geyser boiling process can be deduced from these results. In the initial stage the quiescent single-phase liquid water in the evaporator gradually heated up and was set into motion by thermal buoyancy. As the wall superheat was high enough to initiate the bubble nucleation, a single bubble emerged at the most active nucleation site. This bubble grew quickly to a very large size, comparable to the tube diameter, causing the evaporator wall temperature to drop sharply. The condenser stayed at a low temperature, except when some liquid was pushed up by the growing bubble from the evaporator to the condenser. An abrupt rise in T_c occurred as the hot liquid originally in the evaporator arrived at the condenser. The following drop in T_c was due to the fall back of the liquid to the evaporator. Note that the liquid, before falling down, was also cooled by the condenser. This cold liquid cooled the evaporator as it reached the lower end. Then this cold liquid again gradually heated up and initiated another cycle. Thus, zigzag and spike-like temperature variations were seen in the evaporator and condenser walls, respectively. A close inspection of these figures indicates that the sudden drop in the evaporator wall temperature T_e occurs a little earlier than the sudden rise in the condenser wall temperature T_c, which is consistent with the process of the geyser boiling described above. The results also suggest that the drastic flow motion across the whole device only occurs

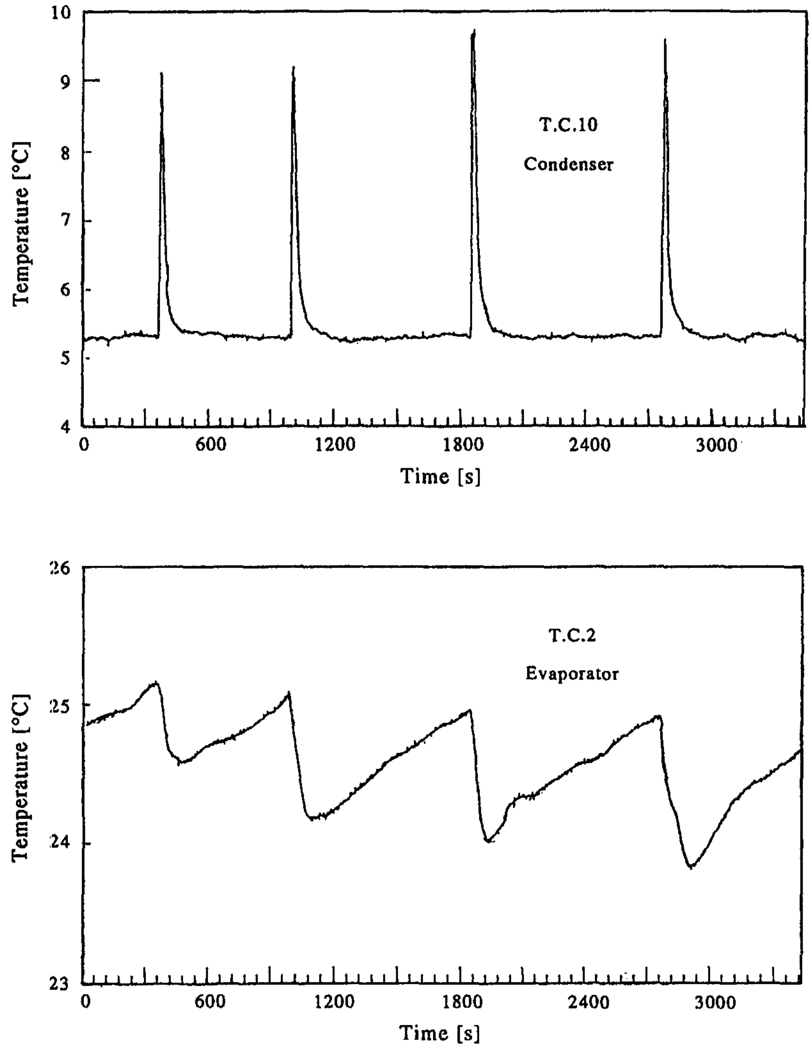

Fig. 3. The time variations of the condenser and evaporator wall temperatures for $q''_w = 0.018$ W cm^{-2}, $T_c = 5$°C, $V^+ = 100\%$ and $l_h = 14$ cm in a water-filled thermosyphon.

in a rather short duration, with the remaining time dominated by the single-phase nature convection. The period of the cycle is about 840 s.

The process of geyser boiling described above is further supported by the flow visualization shown in Fig. 4 for another typical case with $q''_w = 0.16$ W cm^{-2}, $T_c = 30$°C, $V^+ = 100\%$ and $l_h = 14$ cm. Note that the liquid remains quiescent in the evaporator for a long period of time, as in the situation shown at $t = 0$ s in Fig. 4. Here the time $t = 0$ is chosen to denote an arbitrary time instant during the quiescent period. No gas bubble appears in the liquid. At a certain time instant a single gas bubble is seen somewhere in the bottom region of the evaporator ($t = 0.12$ s in Fig. 4). The bubble is often first seen in the bottom corner region, near the intersection of the evaporator end and bottom cap. The bubble grows very quickly to a size comparable to the evaporator volume and the liquid right above it is also quickly expelled upwards. The large pressure difference between the vapor inside the bubble and that in the condenser section causes the expelled liquid to move at a high speed. Note that the liquid hits the top cap of the device at $t = 0.33$ s. Then the liquid falls back to the evaporator, which is clearly seen in the photographs at $t = 1.12$ and 1.41 s. Finally, the liquid calms down towards a quiescent state at $t = 2.5$ s, and a geyser boiling cycle is completed. The above observation of the geyser boiling is qualitatively similar to some earlier studies [22, 23].

The effects of the heat load on the characteristics of the geyser boiling are displayed by plotting the time variations of the condenser wall temperature in Fig. 5 for water, with $V^+ = 100\%$, $T_c = 20$°C, $l_h = 14$ cm and q''_w varying from 0.051 to 0.348 W cm^{-2}. These results clearly indicate that the geyser boiling occurs more frequently at a higher heat load. Specifically, at $q''_w = 0.051$ W cm^{-2} the period of the geyser boiling is approximately 510 s. The period is considerably reduced to about 17 s when q''_w is raised to 0.348 W

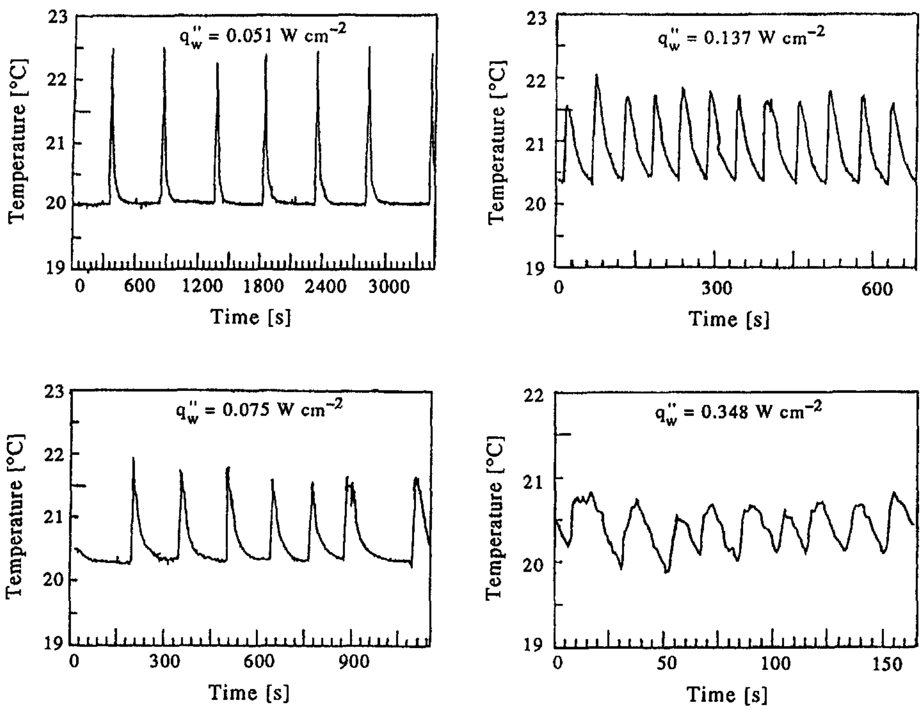

Fig. 5. The time variations of the condenser wall temperatures for various heat loads at T.C.10 for $T_c = 20°C$ and $V^+ = 100\%$ in a water-filled thermosyphon with $l_h = 14$ cm.

cm^{-2}. Note that the temperature oscillation at the highest heat load considered here shows a little irregularity. This results from the multiple bubble nucleation on the evaporator wall at this high heat input and the liquid in the evaporator are found to be in vigorous irregular motion. The corresponding evaporator wall temperature variations given in Fig. 6 clearly support this viewpoint. To further enhance our understanding of the effects of the heat load, flow visualization of the geyser boiling at high q''_w is also conducted. Figure 7 demonstrates the results for $q''_w = 1.89$ W cm^{-2}. Note that at this heat load the wall superheat in the evaporator is well above that required for onset of boiling, and hence a number of small bubbles are often seen in the liquid, as evident from the photograph at $t = 0$ s in Fig. 7. The liquid is rather unstable and never in a quiescent state, such as that seen at light heat load. Sometimes a large bubble may form. It pushes the liquid only a short distance above (photograph at $t = 1.0$ s) and in the meantime another large bubble forms at the bottom end. This late formed bubble grows and pushes some liquid upwards. Meanwhile the liquid expelled by the first bubble starts to fall back. The resulting flow is rather complex, which is clearly shown in the picture at $t = 2.0$ s. At $t = 2.0$ s a third bubble is seen in the bottom end. This bubble then grows and pushes the liquid above it to above half-height of the thermosyphon. Similar trends can be observed for various liquid fills.

Next, the influences of the condenser temperature are examined. The results indicate that, in general, the period of the geyser boiling cycle is shorter when the condenser is at a lower temperature (operating pressure). Besides, the oscillation amplitude is slightly smaller for a high condenser temperature. This trend is observed for various liquid fills. But the effects of the condenser temperature become mixed for $l_h = 19$ cm. No simple trend can be identified. The results for various liquid fills suggest that at a small liquid fill the frequency of the geyser boiling is higher, but the amplitude of the oscillation is smaller. The effects of the evaporator length on the characteristics of the geyser boiling are revealed by comparing the results for $l_h = 14$ and 19 cm. The results indicate that the period of the geyser boiling is shorter for a shorter evaporator section with a smaller oscillation amplitude.

Quantitative data for the variation of the period of the geyser boiling with the heat load and condenser temperature for various liquid fills and evaporator length are of value in using the device. Some of these results are demonstrated in Figs. 8 and 9 for two different liquid fills. It is noted that, at given T_c and V^+, the period decreases almost linearly with q''_h. For the liquid fill $V^+ = 100\%$ and evaporator length $l_h = 14$ cm, the period only slightly depends on the condenser temperature, except at high heat load. Similar results are seen when $V^+ = 50\%$ and $l_h = 19$ cm. The situation is completely different for a liquid fill of $V^+ = 50\%$ and evaporator length $l_h = 14$ cm; the period varies significantly with the condenser temperature, especially at a light heat load [Fig. 8(b)]. A similar situation is noted for the case with $V^+ = 100\%$ and $l_h = 19$ cm.

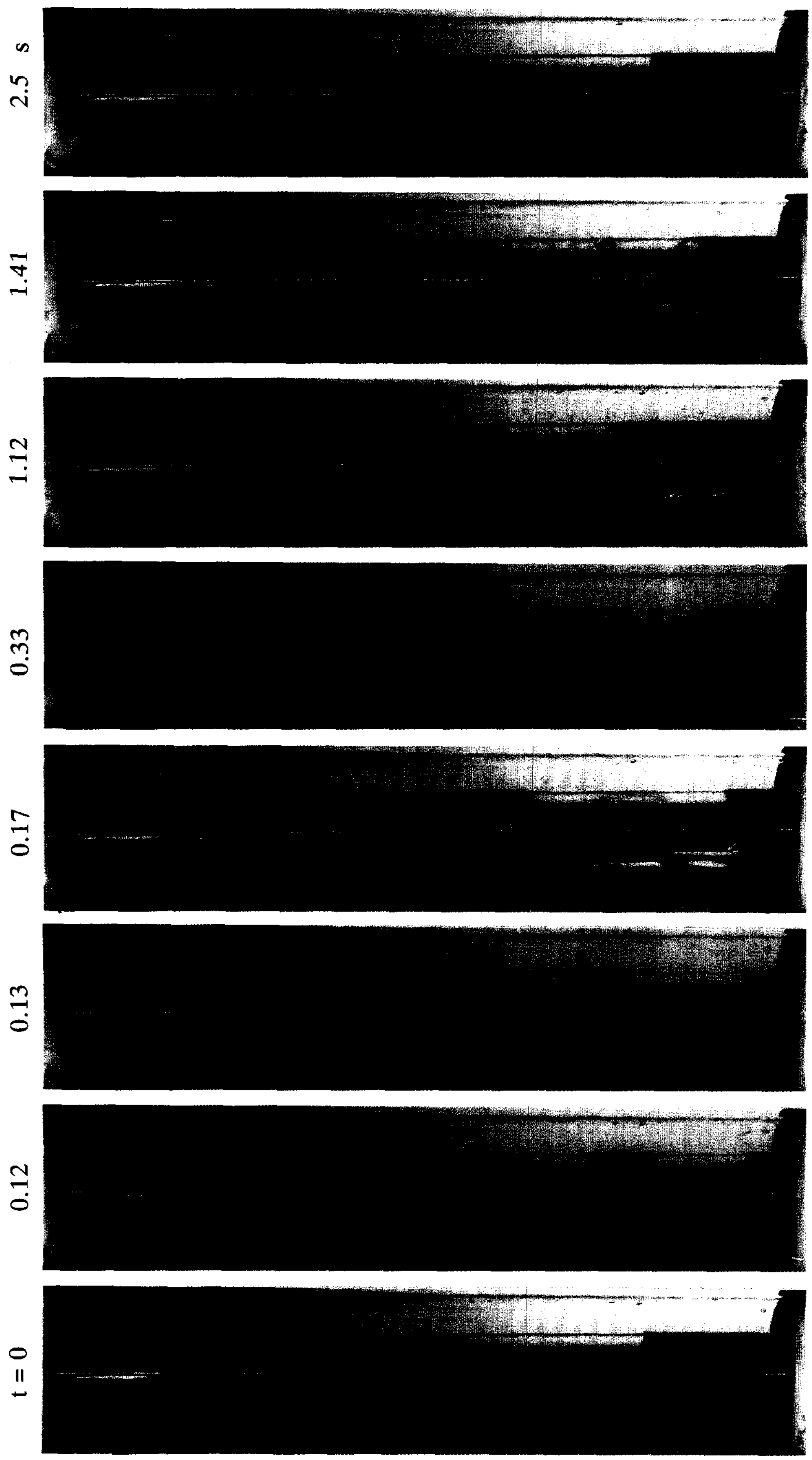

Fig. 4. Photograph of the process of geyser boiling for $q''_w = 0.16$ W cm^{-2}, $T_c = 30$°C, $V^+ = 100\%$ and $l_h = 14$ cm.

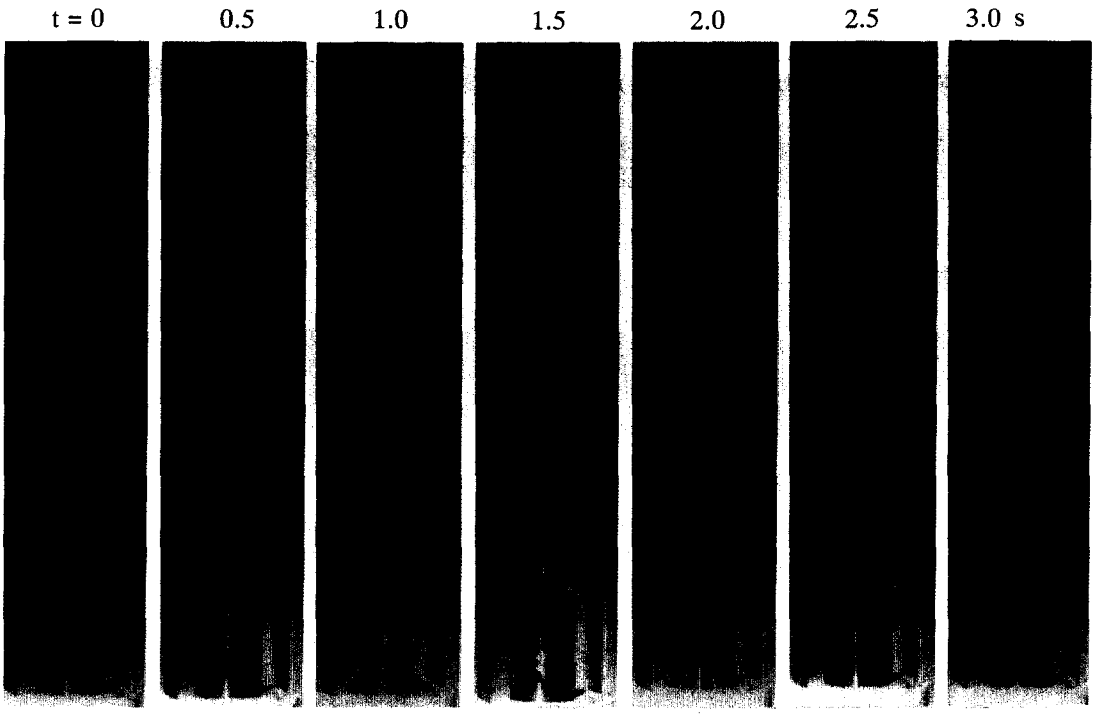

Fig. 7. Photograph of the process of geyser boiling for $q''_w = 1.89$ W cm^{-2}, $T_c = 25°C$, $V^+ = 100\%$ and $l_h = 14$ cm.

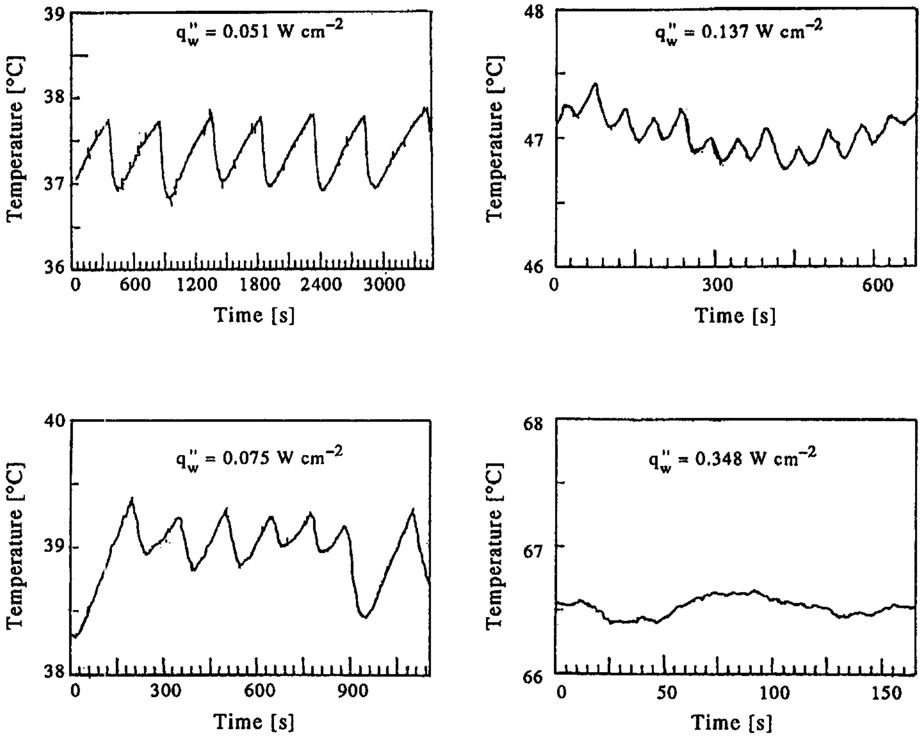

Fig. 6. The time variations of the evaporator wall temperatures for various heat loads at T.C.2 for T_c = 20°C and V^+ = 100% in a water-filled thermosyphon with l_h = 14 cm.

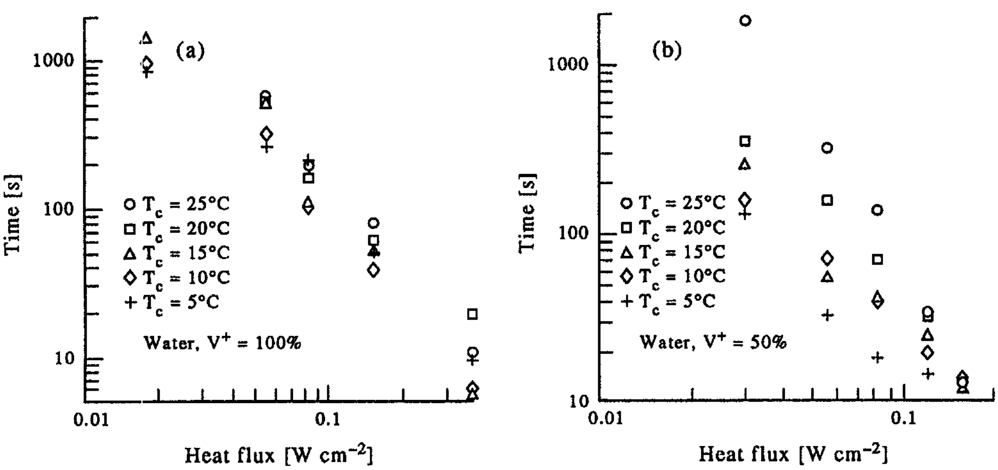

Fig. 8. Effects of heat load and condenser temperature on the period of the geyser boiling for (a) V^+ = 100%, and (b) V^+ = 50% in a water-filled thermosyphon with l_h = 14 cm.

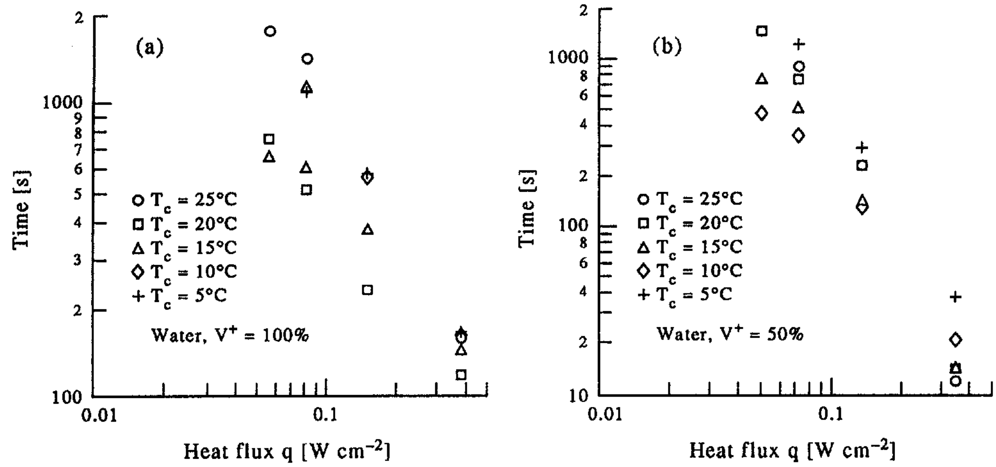

Fig. 9. Effects of heat load and condenser temperature on the period of the geyser boiling for (a) $V^+ = 100\%$, and (b) $V^+ = 50\%$ in a water-filled thermosyphon with $l_h = 19$ cm.

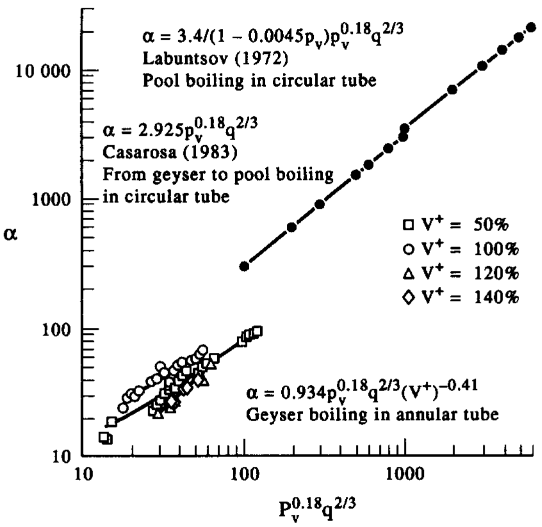

Fig. 10. Heat transfer coefficient versus heat load and pressure for $l_h = 14$ cm in a water-filled thermosyphon.

The mean heat transfer coefficient of the device is calculated by

$$\alpha = \frac{Q/A}{\bar{T}_h - \bar{T}_c} \tag{1}$$

where Q is the net total heat input, A is the inner surface area of the evaporator section and $\bar{T}_h$ and $\bar{T}_c$, respectively, stand for the mean wall temperatures of the evaporator and condenser sections. The results are shown in Fig. 10 for $l_h = 14$ cm. The uncertainty in measuring α is estimated to be about 5%. Our data were correlated, based on the least square method, by the equation

$$\alpha = 0.934 p_v^{0.18} q_h''^{2/3} (V^+)^{-0.41} \tag{2}$$

where the units for α, p_v and q_h'' are, respectively, W m^{-2} K^{-1}, bar and W m^{-2}.

The measured overall heat transfer coefficients for various parameters show that, at given T_c and V^+, the heat transfer coefficient increases almost linearly with q_w'' in logarithmic scale. A close inspection of the data reveals that the heat transfer coefficient is slightly larger for a smaller liquid fill for $l_h = 14$ cm, while the opposite is true for $l_h = 19$ cm. The dependence of the heat transfer coefficient on the condenser temperature is nonmonotonic.

As the liquid fill is respectively fixed at $V^+ = 50$, 100, 120 and 140%, the range of heat load for the occurrence of the geyser boiling is shown in Table 1, with the evaporator length $l_h = 14$ cm. It is noted that the range of heat load is slightly wider when the condenser is at a lower temperature and the device is at a high liquid fill. The parametric range for the occurrence of the geyser boiling based on these data can be expressed as

$$0.73 < p_v^{0.18} q_h''^{2/3} (V^+)^{-0.41} < 750. \tag{3}$$

3.2. *Results for an ethanol-filled thermosyphon*

Results for a typical case can be clearly seen in Fig. 11 for the time variations of the condenser and evaporator wall temperatures for an ethanol-filled thermosyphon with $l_h = 14$ cm, $V^+ = 100\%$, $T_c = 25$°C, and $q_w'' = 0.03$ W cm^{-2}. Contrasting these results with those in Fig. 3 indicates that the process of geyser boiling for ethanol is qualitatively similar to those for water. But the oscillation amplitudes in T_h and T_c for ethanol are much smaller. The period of the geyser boiling cycle for this typical case is about 235 s. The results for various heat loads also suggest that the frequency of the geyser boiling is higher at a higher heat load. Results for $T_c = 20$°C indicate that, at $q_w'' = 0.018$ W cm^{-2}, the period of a geyser boiling is approx. 175 s, while the period is considerably reduced to 18 s when q_h'' is raised to 0.044 W cm^{-2}. Though this trend resembles that for water, the period is much more sensitive to heat load for ethanol.

Table 1. The ranges of heat load to the evaporator for the occurrence of the geyser boiling in a water-filled thermosyphon with l_h = 14 cm

T_c	V^+	$q''_{w\,min}$ (W cm^{-2})	$q''_{w\,max}$ (W cm^{-2})	V^+	$q''_{w\,min}$ (W cm^{-2})	$q''_{w\,max}$ (W cm^{-2})
5°C	100%	4.27×10^{-3}	3.058	50%		3.194
10°C	100%	1.42×10^{-3}	2.694	50%	1.34×10^{-4}	1.73
15°C	100%	8.13×10^{-3}	2.386	50%	3.0×10^{-4}	0.947
20°C	100%	0.0183	2.202	50%	0.0175	0.588
25°C	100%	0.012	2.086	50%	0.025	0.224
5°C	120%	3.2×10^{-2}	4.05	140%	0.07	4.5
10°C	120%	4.1×10^{-2}	3.32	140%	7.2×10^{-2}	3.61
20°C	120%	6.3×10^{-2}	2.31	140%	8.6×10^{-2}	2.62

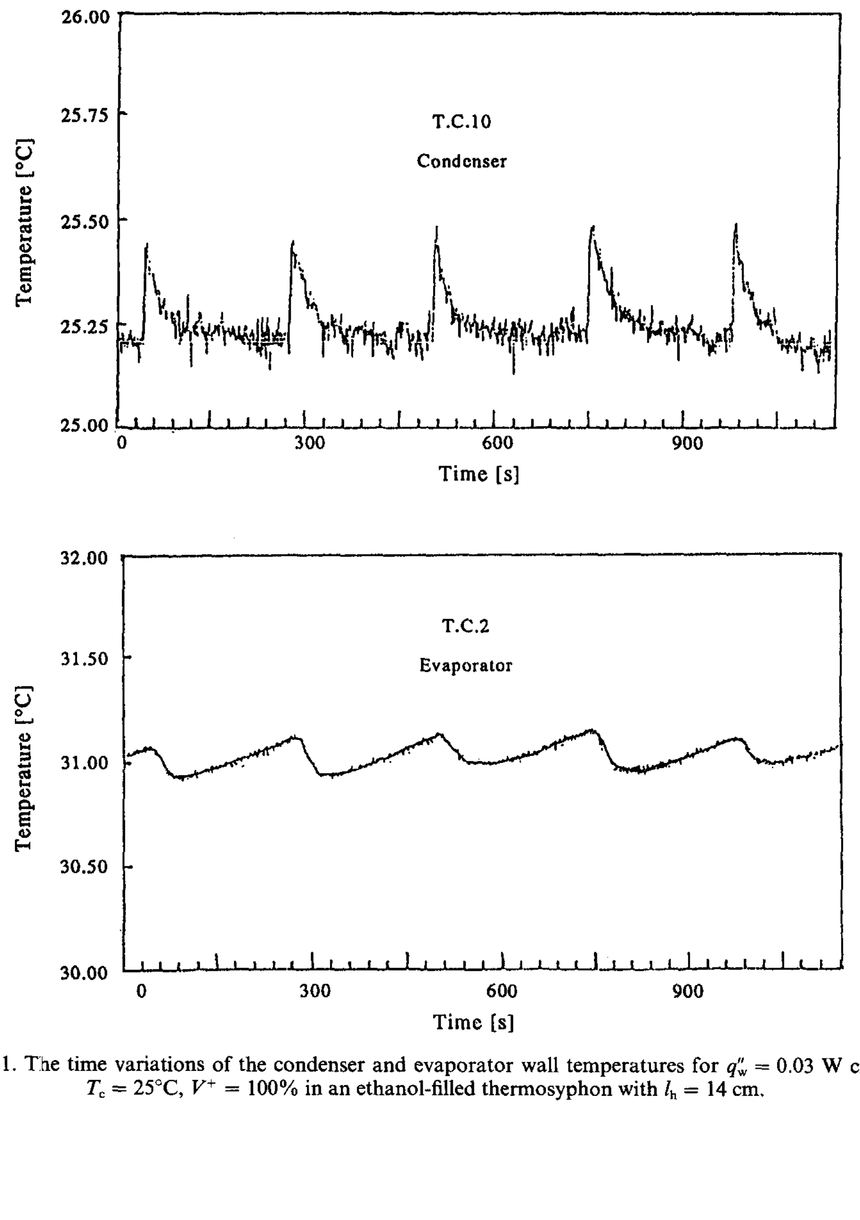

Fig. 11. The time variations of the condenser and evaporator wall temperatures for q''_w = 0.03 W cm^{-2}, T_c = 25°C, V^+ = 100% in an ethanol-filled thermosyphon with l_h = 14 cm.

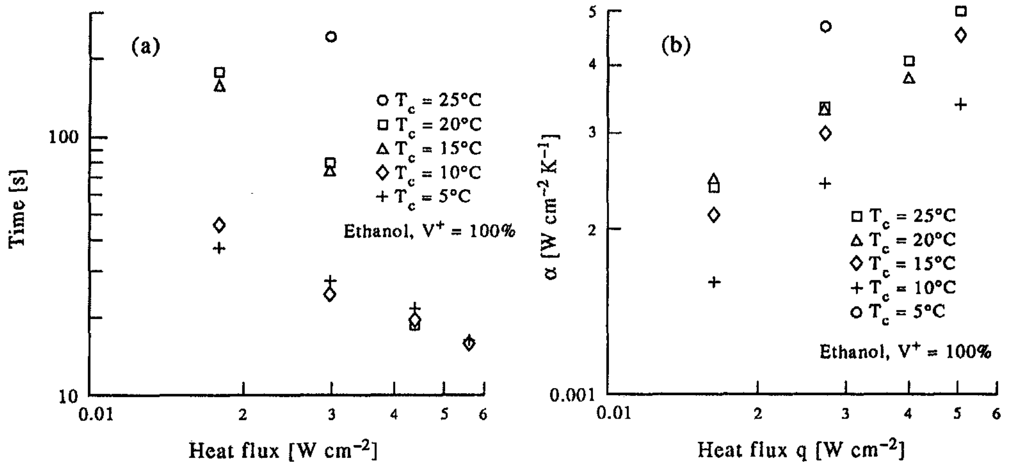

Fig. 12. Effects of heat load and condenser temperatures on (a) the period of the geyser boiling, and (b) the heat transfer coefficient for $V^+ = 100\%$ and $l_h = 14$ cm in an ethanol-filled thermosyphon.

The effects of the condenser temperature were also examined in the study. The results indicate that the period of geyser boiling is shorter when the condenser is at a lower temperature. Again the effects of the condenser temperature are much more pronounced for ethanol. Finally, it was noted that, in the experiments with ethanol as working fluid, no geyser boiling was observed when the liquid fill V^+ was at 50% and 30%.

Quantitative data for the variations of the period and heat transfer coefficient of the geyser boiling with the heat load and condenser temperature are demonstrated in Fig. 12. It is noted that the period varies significantly with the condenser temperature at low heat load and the heat transfer coefficient increases almost linearly with q''_w at a given T_c. The smallest heat transfer coefficient is noted at $T_c = 10°C$. The ranges of the heat load for the occurrence of the geyser boiling are much narrower than those for water.

4. CONCLUDING REMARKS

Geyser boiling in a vertical annular two-phase closed thermosyphon has been studied experimentally with water and ethanol as working fluids. The effects of the heat load, condenser temperature (operating pressure), liquid fill and evaporator length were investigated in detail. The measured data for the evaporator and condenser wall temperatures indicate that the period of the geyser boiling is shorter for a higher heat load, a smaller liquid fill, and a shorter evaporator length. A nearly linear increase in the mean heat transfer coefficient was noted for the increases in the heat input in the logarithmic scale. A correlation equation was proposed for the heat transfer coefficient. Besides, it was noted that, in the thermosyphon containing ethanol, the geyser boiling occurs in a narrower range of the heat load.

In the course of our study we realized that some improvement is needed in the near future. Detailed flow visualization is required to improve basic understanding of the fluid flow and heat transfer process in the device. The effects of the tube inclination on the geyser boiling should be investigated.

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