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INTERMITTENT PHENOMENA IN THE BOILING TWO-PHASE BOUNDARY LAYER

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Abstract—In order to investigate statistical properties of temperature fluctuation in a boiling two phase boundary layer the corresponding intermittency functions, which describe liquid, vapor and interface region at an individual fixed point, have been defined. In water boiling on a horizontal surface the temperature fluctuation was measured with microthermocouple and the signal was processed through the digital computer with the detector function specified for liquid, vapor and interface region. The results obtained confirm that the temperature fluctuation in the boiling two phase layer can be divided into three parts corresponding to individual regions and that its statistical distribution depends on the properties of respective systems. It has also been shown that the temperature fluctuation in the interface region is determinative and corresponds to the temperature changes in the liquid layer surrounding vapor bubble growth. Amplitude distribution in the liquid region changes its form with the distance from the wall as a result of the change in the intensity of turbulence at different distances. The probability density distribution in the vapor region shows very small amplitude fluctuation and is almost constant for all distances.

NOMENCLATURE

$I(x, t)$, intermittence function for region P;
γ, average volumetric vapor fraction in region P;
$J(x, t)$, intermittence function for region S;
β, average volumetric liquid superheat fraction in region S;
T, temperature;
ΔT, liquid superheat;
T_0, saturation temperature;
θ, temperature fluctuation;
G, $= \frac{\partial T}{\partial t}$, temperature time derivative;
t, time;
Δt, sampling time;
σ, standard deviation of the temperature probability distribution;
σ_g, standard deviation of the temperature time derivative probability distribution;
q, heat flux;
$\Delta N^S, \Delta N^T, \Delta N^P$, number of the time intervals with amplitude T_i in the regions of superheat liquid, surrounding liquid and vapor phase, respectively;
N, total number of time intervals in a single realization;
δ, distance of the microthermocouple from heated surface;
x, distance from the liquid–vapor interface.

INTRODUCTION

DUE TO the fact that the essential mechanism of turbulent heat transfer relies on the field variable fluctuation in the boundary layer it is very important for us to understand statistical properties of these variables.

The knowledge acquired by investigation of statistical properties of field variables has led us to construct different models of the turbulent heat-transfer mechanism in boundary-layer theory. From these models we have learned that fluctuations of field variables in the boundary layer are strongly dependent on the transport processes within the layer. The statistical parameters of the field variables fluctuation have shown definite correlation between the field variables in the thermal boundary layer which describe the mechanism of transport processes.

The boiling process is a heat-transfer process characterized by one additional field variable as compared to the turbulent convection heat transfer. This means that in addition to temperature, pressure and velocity, density is also a field variable in the thermal boundary layer. It is already known that many typical boiling parameters, such as bubble diameter, bubble frequency, roughness of the heating surface, contact angle, etc. also have statistical nature. Since these parameters are closely correlated with density in the two-phase boundary layer, it is evident that this variable will also have statistical character. Present knowledge of the statistical properties of field variables in the two-phase boundary layer is very limited. It appears that even the classical statistical method for space and time averaging of field variables in the two-phase boundary layer requires additional assumptions in order to obtain corresponding average values. In order to learn more about statistical properties of the field variables in the two-phase boundary layer, an attempt was made to measure and analyze temperature fluctuations and their statistical characteristics [1–3]. The liquid superheat in the two-phase boundary layer is known as a driving thermodynamic potential for the heat transfer process, so that the temperature field in the two-phase system is one of the essential parameters controlling the boiling process. In this respect, the aim of our investigation of statistical properties of temperature fluctuation in the liquid–vapor system is to study the mechanism of boiling heat transfer.

2. LIQUID SUPERHEAT FLUCTUATION

A typical example of liquid superheat fluctuation at a fixed point of the two-phase boundary layer with boiling on the horizontal surface is shown in Fig. 1. By

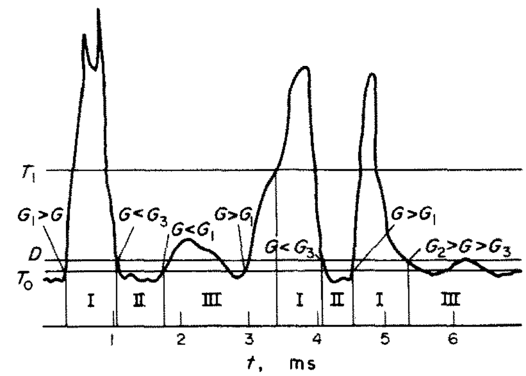

FIG. 1.

comparing this histogram with the film from a high-speed camera, three different characteristic time periods could be distinguished. The period marked "I" corresponds to the time the hot junction of the thermocouple spent in the liquid superheat layer surrounding the bubble during its growth. Period "II" represents the time for which the thermocouple is in the vapor, and period "III" determines the time which the hot junction spent in the surrounding liquid. It is obvious that the thermocouple will read alternatively liquid superheat, surrounding liquid and vapor temperature. The boundary between these regions in the two-phase boundary layer is determined by two parameters: the temperature level and the rate of temperature change between the regions.

Each region has its own particular temperature fluctuation, characterized by corresponding rate of temperature variation. The temperature variation in the liquid superheat boundary layer is canonical in character, and thus a sudden temperature increase in the layer is followed by a decrease which obeys the same functional relation. This points out deterministic nature of temperature variation in the liquid superheat layer. Since temperature fluctuations in the vapor are very small, their dispersion will also be small. Further, it follows that the vapor region will be characterized by small amplitude fluctuation. It is certain that temperature variation in the surrounding liquid is due to turbulent mixing induced by fluid motion in the two-phase boundary layer. These characteristic features of each region justify criteria selection for determination of the intermittency function, which would describe the region to which an individual fixed point of the two-phase boundary layer belongs.

3. DEFINITION OF THE INTERMITTENCY FUNCTION FOR TEMPERATURE FLUCTUATION IN THE TWO-PHASE FLOW

Generally, the intermittency function at the point $M(x)$ for the region D is defined by

$$I(x,t) = \begin{cases} 1 & M(x) \in D \\ 0 & m(x) \notin D. \end{cases}$$

In the case of a two-phase boiling system, with three different regions, liquid superheat layer S, surrounding liquid T and vapor P, the intermittency function can be defined as follows: first, let us consider the intermittency function for the region P. By definition, it is

$$I(x,t) = \begin{cases} 1 & M(x) \in P \\ 0 & M(x) \notin P \end{cases}$$

so that

$$\gamma = \lim_{t_0 \to \infty} \frac{1}{t_0} \int_{t_1}^{t_1+t_0} I(t)\,dt \quad \text{for} \quad x = x_0.$$

In order to specify the period of time the point $M(x)$ spends in the region S and T, we have to introduce a new intermittency function, defined as follows:

$$J(x,t) = \begin{cases} 1 & M(x) \in S \\ 0 & M(x) \notin S \end{cases}$$

so that

$$\beta = \lim_{t_0 \to \infty} \int_{t_1}^{T_1+t_0} J(x)\,dt \quad \text{for} \quad x = x_0.$$

If the temperature fluctuation is

$$T(x,t) = T(x) + \theta(x,t)$$

we can define the average $T(x,t)$ value for the separate regions. For the region P it is

$$\overline{T(x)+\theta(x,t)}^P = T^P = \lim_{t_0 \to \infty} \frac{1}{t_0} \times \int_{t_1}^{t_1+t_0} I(t)|T+q(t)|\,dt \quad \text{for} \quad x = x_0,$$

for the region S

$$\overline{T(x)+\theta(x,t)}^S = T^S = \lim_{t_0 \to \infty} \frac{1}{(1-\gamma)\beta t_0} \times \int_{t_1}^{t_1+t_0} |1-I(t)|J(t)|T+q(t)|\,dt \quad \text{for} \quad x = x_0$$

and for the region T

$$\overline{T(x)+\theta(x,t)}^T = T^T = \lim_{t_0 \to \infty} \frac{1}{(1-\gamma)(1-\beta)t_0} \times \int_{t_1}^{t_1+t_0} |1-I(t)|\cdot|1-J(t)||T+\theta(t)|\,dt \quad \text{for} \quad x = x_0.$$

On this basis, the temperature fluctuation in the two-phase system is

$$\begin{aligned} \theta(x,t) = {} & I(x,t)|T(x)^P + \theta(x,t)^P| \\ & + |1-I(x,t)|J(x,t)|T(x)^S + \theta(x,t)^S| \\ & + |1-I(x,t)||1-J(x,t)||T(x)^T + \theta(x,t)^T| \\ & - \gamma(t)T(x)^P - |1-\gamma(x)|\cdot\beta(x)\cdot T(x)^S \\ & - |1-\gamma(x)||1-\beta(x)|T(x)^T. \end{aligned}$$

Further it follows that the mean square value of the temperature fluctuation at any point of the two-phase system is

$$\overline{\theta^2(x)} = \gamma(x)\cdot\overline{|\theta(x)|^2}^P + |1-\gamma(x)|\cdot\beta(x)\cdot\overline{|\theta(x)|^2}^S + |1-\gamma(x)||1-\beta(x)|\overline{|\theta(x)|^2}^T + \gamma(x)|1-\gamma(x)||T(x)^P - T(x)^T| + \beta(x)|1-\beta(x)||T(x)^S - T(x)^T|$$

where

$$\overline{\theta^2(x)}^P = \lim_{t_0\to\infty}\frac{1}{\gamma t_0}\int_{t_1}^{t_1+t_0} I(t)\theta^2(t)\,\mathrm{d}t$$

$$\overline{\theta^2(x)}^S = \lim_{t\to\infty}\frac{1}{(1-\gamma)\beta t_0}\times\int_{t_1}^{t_1+t_0}|1-I(t)|\cdot J(t)\cdot\theta^2(t)\cdot\mathrm{d}t$$

$$\overline{\theta^2(x)}^T = \lim_{t_0\to\infty}\frac{1}{(1-\gamma)(1-\beta)t_0}\times\int_{t_1}^{t_1+t_0}|1-I(t)|\cdot|1-J(t)|\cdot\theta^2(t)\cdot\mathrm{d}t.$$

4. CRITERIA FOR DETERMINATION OF THE INTERMITTENCY FUNCTION

In each particular case determination of the intermittency function depends on the character of the phenomena under consideration. The method usually employed relies on the selection of properties of each region sufficiently different to be used as criteria for discrimination of an individual region. The analysis of intermittent phenomena in turbulent fluid flow is based on different forms of the detection function. These are defined in accordance with the type of flow under consideration. Table 1 presents some forms of the detection function used in the investigation of intermittent phenomena in the turbulent flow.

It should be emphasized that the form of detection function should be such that it represents the selective criterion for determination of the time spent by the measuring instrument in a particular region. This means that each region can be recognized by the property of its detector function. For the two-phase boundary layer in bulk boiling on the horizontal surface, it is obvious, from the nature of the phenomena, that the superheat temperature has different properties in any particular subsystem, i.e. liquid superheat layer S, surrounding liquid T and vapor P.

Table 1.

Townsend [4]	$\left(\frac{\partial u}{\partial t}\right)$
Kovaszny *et al.* [5]	$\left(\frac{\partial^2 u}{\partial x\,\partial t}\right)$
Hekley and Keffer [6]	$\left\|\frac{\Delta u_1}{\Delta t}\right\| + \left\|\frac{\Delta u_2}{\Delta t}\right\|$
Zarić [7]	$u\cdot\left\|\frac{\partial u}{\partial t}\right\|$.

Temperature at a point $M(x)$ is a continuous function of time the absolute value of which changes on crossing from one region to the other. It should be noticed that the temperature of the liquid superheat layer always corresponds to the temperature which immediately follows the exit of the point $M(x)$ from the vapor or liquid phase. The momentum of the point $M(x)$ crossing from one region to the other, i.e. from P to S and T, is determined using the characteristic temperature time derivative corresponding to this jump. Also, the cross over from the superheat layer to the surrounding liquid, is determined by the appropriate temperature time derivative connected with the heat-transfer process between these two regions. This means that the heat stored in the liquid superheat layer is partially transferred to the surrounding liquid by heat conduction establishing corresponding to rate of temperature change between regions in the two-phase boundary layer. A similar case exists in crossing from the surrounding liquid to the superheat layer region. From this description of the phenomena on the boundary between regions, it follows that the intermittency function of the temperature fluctuation in a two-phase boundary layer can be obtained using the detector function $(\partial T/\partial t)$. In order to obtain non-biased results, additional criteria are introduced which arise from particylarity of temperature fluctuation in the boiling two-phase system. Namely it is known that the temperature of the vapor phase is not liable to fluctuation and corresponds to the saturation temperature; at the same time, fluctuations in the liquid superheat layer correspond to those observed at the highest temperature in the system. It further follows that besides temperature time derivative the criteria for determination of the intermittency function should also include the temperature level. Thus, the detection function for the temperature fluctuation in the two-phase boundary layer will be: T and $\partial T/\partial t$. The limiting values of the detection functions should satisfy the condition that the probability distribution error be the same for each region. Two limitations for the temperature levels have been introduced in this analysis: saturation temperature (T_0) and superheat temperature (T_1). The limiting values for the temperature time derivative $G = \partial T/\partial t$ are determined by three characteristic temperature time derivative values: for the entry in the superheat layer G_1, the entry in the surrounding liquid G_2, and the entry in the vapor phase, G_3.

Characteristic temperature levels are determined as follows: temperature T_0 corresponds to the saturation temperature for a given pressure; temperature T_1 corresponds to the saturation temperature increased for the double value of amplitude probability standard deviation, i.e. $T_1 = T_0 + 2\sigma$.

The limiting values for the temperature time derivatives were determined in the following way: the temperature time derivative for the entry in the superheat layer G_1 is equal to the double value of the standard deviation of the temperature time derivative probability distribution, $G_1 = 2\sigma g$. The temperature time derivative for entry in the surrounding liquid was determined experimentally, $G_2 = 0.2$ grad/m s. The temperature time derivative for entry in the vapor phase is $G_3 = 1.5\,\sigma_g$. Having in mind physical picture of two-phase boundary layer, the boundary between regions was determined using the limiting values of the detector function. For this purpose conditions for the crossing of the point $M(x)$ from one region to the other have been defined. Conditional sampling of the temperature signal obtained with a microthermocouple and recording the intermittency functions were performed applying the following criteria:

(1) The temperature signal will correspond to the liquid superheat layer until the following conditions are satisfied:

for $T_0 < T < T_1$ with
(a) $G \leqslant G_3$ it enters the vapor phase
(b) $G_2 < G < G_1$ it enters the surrounding liquid.

(2) The temperature signal will correspond to the temperature of the vapor phase until the following conditions are satisfied:

for $T > T_0$ with
(a) $G > G_1$ it enters the superheated layer
(b) $0 < G < G_1$ it enters the surrounding liquid.

(3) The temperature signal will correspond to the temperature of the surrounding liquid until the following conditions are satisfied:

for $T > T_1$ with
(a) all values of G it enters the superheated layer

for $T_1 > T > T_0$ with
(a) $G > G_1$ it enters the superheated layer

for $T < T_1$ with
(a) $G \leqslant G_1$ it enters the vapor phase.

Although in this analysis we have used detector functions which allowed discrimination of different regions on the basis of these criteria, there is still need for further investigation of the other detector functions. This might be especially important for the investigation of the other two phase systems.

5. EXPERIMENTAL PROCEDURE FOR THE ANALYSIS OF TEMPERATURE FLUCTUATION IN THE TWO-PHASE BOUNDARY LAYER

Temperature fluctuation measurement was performed in bulk boiling on the horizontal surface. The apparatus is shown and described in the paper [8]. Measurement was made at atmospheric pressure and surface heat flux $q = 19.73$ W/cm^2 and $q = 25.17$ W/cm^2. A Chromel–Alumel microthermocouple ϕ 12.5 μm, but-welded, was used. The static and dynamic characteristics are identified [9]. The position of the hot junction in relation to the heating surface was determined by an adequate micrometric positioning device. Temperature fluctuations were measured at five different positions of the thermocouple $\delta = 0.5$, 1.5, 2 and 3 mm. The analogue signal from the microthermocouple was multiplied 2675 times and recorded on magnetic tape with a speed of 1.524 m/s (60 in/s). Recording time for each position of the thermocouple was $T_0 = 60$ s and presents a single realisation.

The analog signal recorded on magnetic tape was reproduced with the speed of 0.381 m/s (15 in/s), and thus real time was multiplied by a factor of 4. This enabled a decrease in sampling time by the same factor. The real sampling time was $\Delta T = 5 \times 10^{-4}$ s. Every signal was converted into digital form and fed onto magnetic tape of CDC-3600 computer. In this manner, all realizations were converted into digital form and recorded on magnetic tape for analysis.

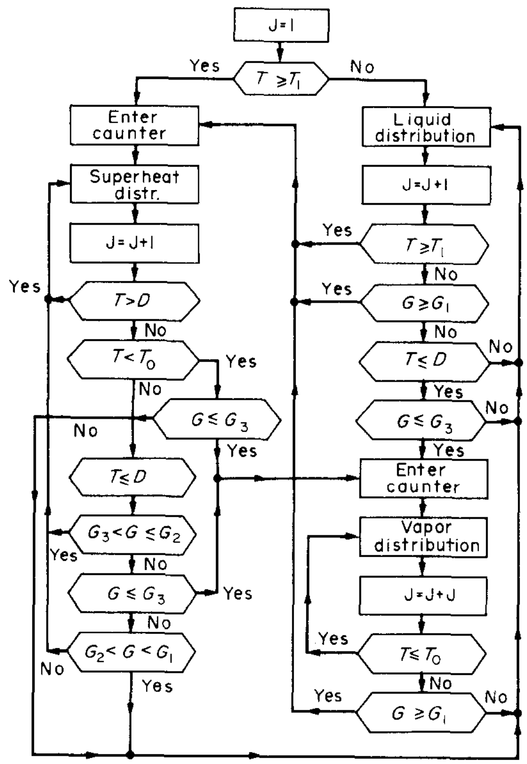

FIG. 2.

Further analysis of the digital signal was performed according to a computer program, the flow sheet of which is presented in Fig. 2. The first part of operations consists of the determination of the mean value of T for the whole realization and calculation of the probability density function. After this operation, the conditional criteria for the intermittency function are applied, and the corresponding part of the signal belonging to the particular subsystem is obtained. Calculation of the probability density functions for each subsystem was the next operation on the flow sheet. At the end of this analysis, the mean values of the temperature in every particular subsystem are calculated, $\bar{T}^S$, $\bar{T}^P$, $\bar{T}^T$ and $\bar{T}$. In Fig. 3 a typical signal is shown and the corresponding intermittency function are obtained.

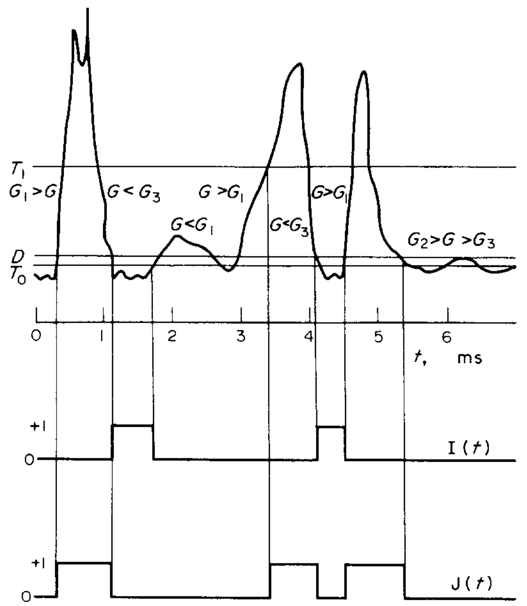

FIG. 3.

6. RESULTS

From the definition of intermittency function, $I(t)$, follows, that the mean value of this function $\gamma(x)$ is the volumetric fraction of the vapor phase at point $M(x)$. Figure 4 shows the distribution of the void fraction in the boiling boundary layer obtained by this analysis.

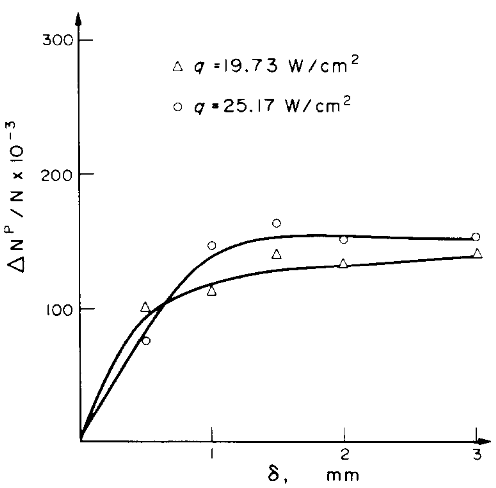

FIG. 4.

The distribution of the temperature probability density at the distance $\delta = 0.5$ mm is given in Fig. 5. Corresponding intermittency functions are obtained when criteria for conditional sampling are applied to the temperature fluctuation signal. This enables to obtain intermittency function $I(T)$ and $J(t)$. The corresponding part of the signal for each subsystem is obtained in turn by multiplying the intermittency function by the temperature fluctuation signal. The probability density function of temperature fluctuation for each subsystem obtained at five different

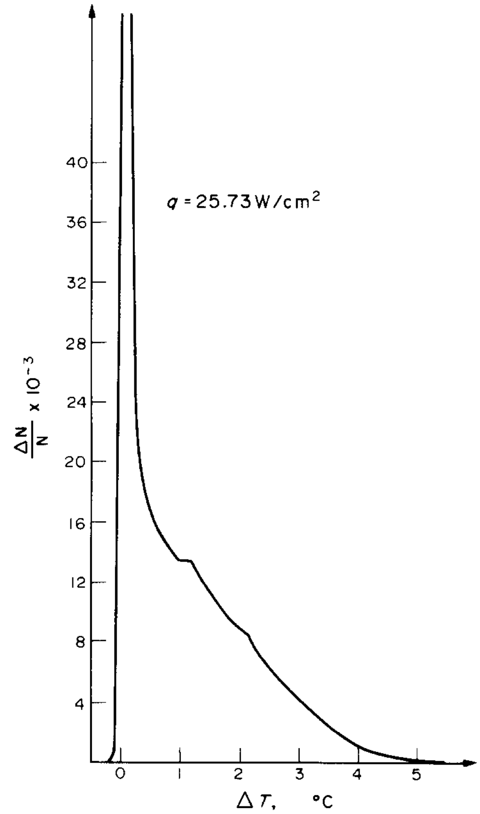

FIG. 5.

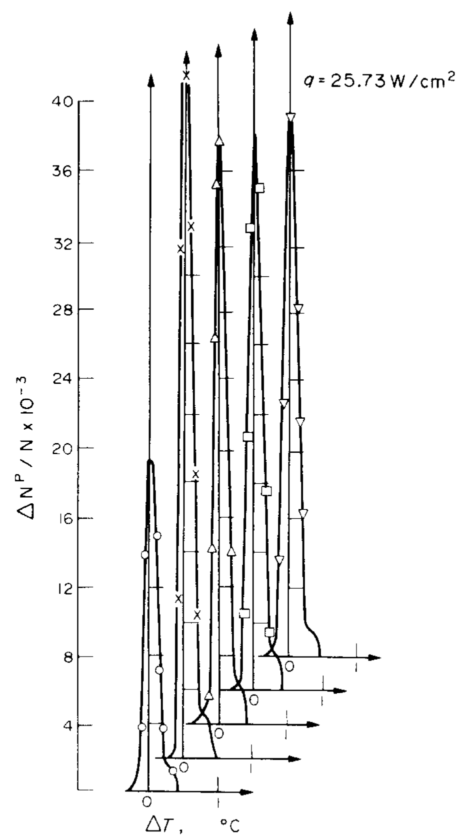

FIG. 6.

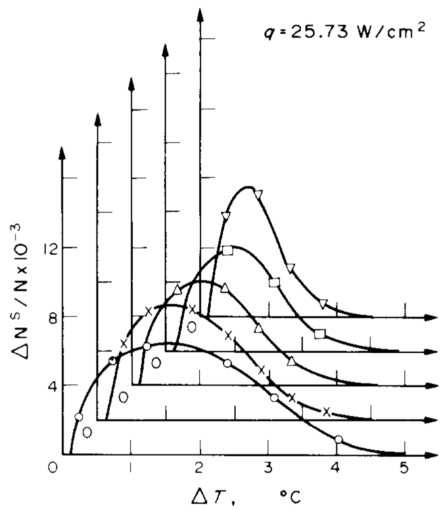

FIG. 7.

of entries in the superheat layer is also assumed, because the character of the probability density distribution in the superheat layer region is very similar to the probability density distribution obtained for the canonical temperature fluctuation. Taking advantage of the number of canonical temperature variations available, it was possible to determine a temperature distribution corresponding to the mean canonical function of the temperature variation in the superheat layer. This analysis was applied to temperature fluctuation at the heat fluxes $q = 19.73\,\mathrm{W/cm^2}$ and $q = 25\,\mathrm{W/cm^2}$. The temperature distributions for these two heat fluxes are shown in Fig. 8. These results confirm that our initial assumption of the canonical temperature fluctuation in the liquid superheat layer is justified. It should be mentioned that the obtained temperature distribution in the liquid superheat layer corresponds only to the distant temperature distribution from the liquid–vapor interface. But even with

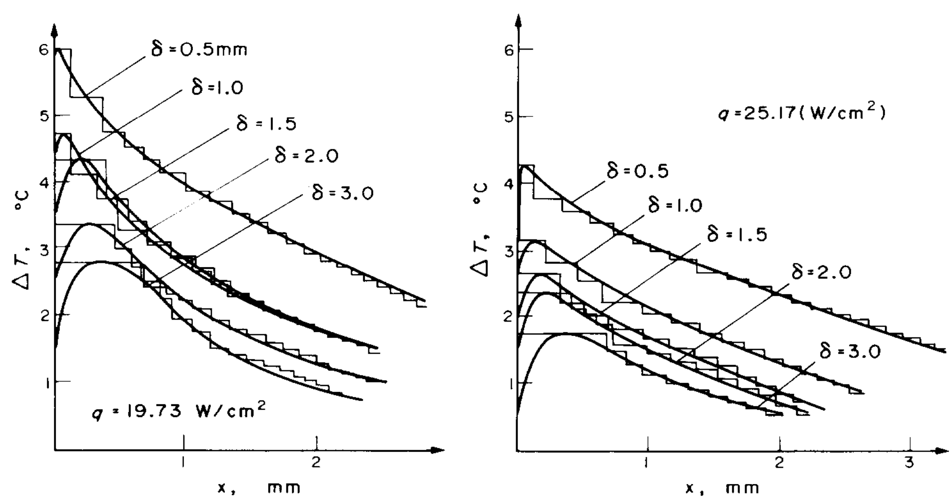

FIG. 8.

distances from the heated wall is given in Figs. 6, 7 and 9.

From Fig. 6, where the probability density distributions of the temperature fluctuation in the vapor region is shown, it can be seen that the amplitude fluctuation in vapor is very small and the dispersion is almost constant for all distances from the wall. The latter can be explained by the noise existing in the signal, which also does not depend on the distance from the wall. The small probability density distribution distortion at superheat temperature is obviously the result of a deficiency of criteria applied in the conditional sampling. When the number belonging to this distortion is compared with the total number of amplitudes in the vapor phase, it can be seen that the error obtained is less than one percent.

Figure 7 shows the probability density distribution of the temperature fluctuation in the liquid superheat layer. It should be mentioned that in the process of analyzing the signal counting, counting of the number

a deficiency, the obtained temperature distribution in the liquid superheat layer is a statistically averaged temperature distribution experimentally obtained under conditions which could be accepted as a realistic process.

In Fig. 9 the probability density distribution of the temperature fluctuation in the surrounding liquid region is shown for five different distances from the heated wall. It can be seen that the probability density distribution changes its forms with varying distances from the wall. It is especially pronounced that higher momentums are different for each distribution depending on distance from the wall. This is probably a result of the change in the intensity of turbulence at different distances from the wall.

From the heat transfer point of view, the change in the mean temperature difference between individual subsystems depending on distance from the wall is certainly of great interest. Figures 10 and 11 show the change of $\overline{\theta^2}^P$ and $\overline{\theta^2}^T$ as a function of distance.

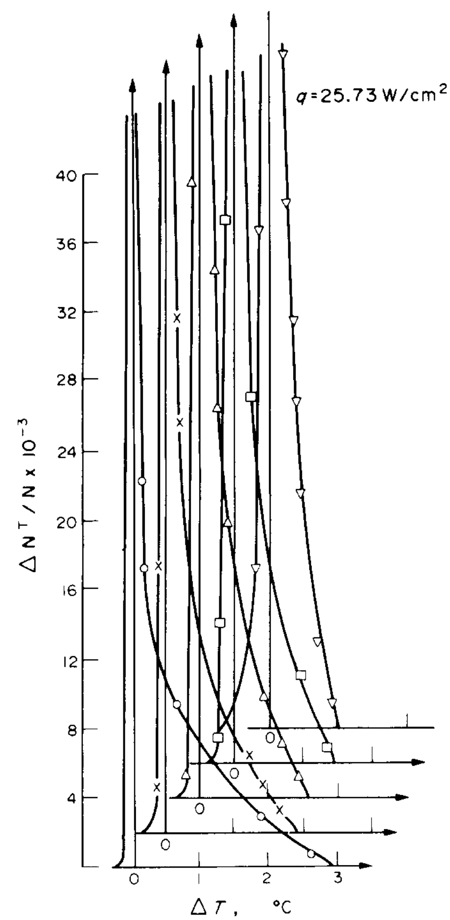

FIG. 9.

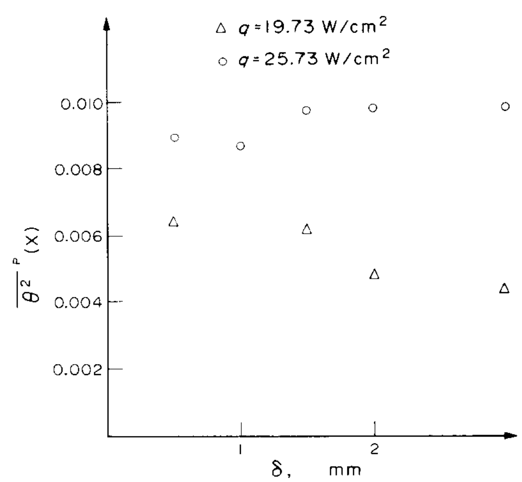

FIG. 10.

As was pointed out earlier, it can be seen that the value of $\overline{\theta^{2}}^{P}$ is very small in comparison with the corresponding value of $\overline{\theta^{2}}^{T}$. Also, $\overline{\theta^{2}}^{P}$ is constant at all distances from the wall while $\theta^{2^{T}}$ changes with distance. This also confirms that the intensity of turbulency changes with the distance, as would be expected.

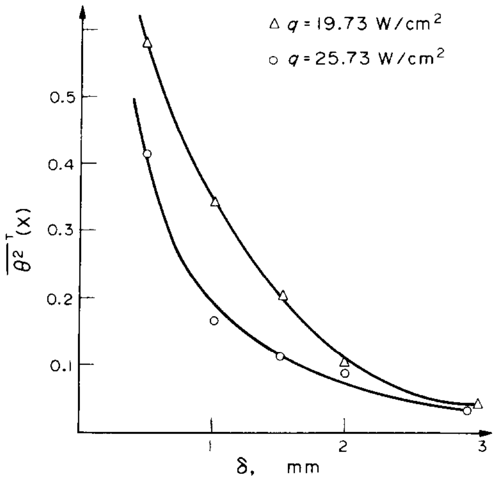

FIG. 11.

7. CONCLUSIONS

The results obtained show that the following conclusions can be drawn on the use of the detector function as defined in the paper.

(1) The use of the detector function in the analysis of the temperature fluctuation in a boiling two-phase layer makes it possible to obtain separate probability distributions for each observed region.

(2) The temperature fluctuation in the interface region is determinative in its character and corresponds to the change of the temperature field during the bubble growth.

(3) The temperature fluctuation in the surrounding liquid depends on the turbulence intensity in the boundary layer.

(4) The temperature fluctuation in the vapor phase is very small and independent of the distance from the heated wall.

(5) Use of the detector function for determination of separate regions in the two-phase system allows determination of the local average volumetric fraction of individual phases.

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PHENOMENE D'INTERMITTENCE DANS LA COUCHE LIMITE BIPHASIQUE D'EBULLITION

Résumé—Pour étudier les propriétés statistiques de fluctuation de température dans une couche limite biphasique d'ébullition, on définit les fonctions d'intermittence qui décrivent en un point fixe la région liquide, vapeur ou d'interface. Dans l'ébullition d'eau sur une surface horizontale, la fluctuation de température est mesurée avec un thermocouple et le signal est analysé par un ordinateur avec un détecteur de fonction spécifique pour le liquide, la vapeur et la région d'interface. Les résultats obtenus confirment que la fluctuation de température dans la couche diphasique peut être divisée en trois parties correspondant à des régions individuelles et que la distribution statistique dépend des propriétés des systèmes respectifs. On montre aussi que la fluctuation de température dans la région d'interface est déterminante et qu'elle correspond à des changements de température dans la couche liquide autour de la bulle de vapeur. La distribution d'amplitude dans la région liquide change de forme avec la distance à la paroi, en corrélation avec le changement d'intensité de turbulence. La densité de probabilité dans la région de vapeur montre une très petite fluctuation d'amplitude et elle est pratiquement constante à toute les distances.

SCHWANKUNGSERSCHEINUNGEN IN DER SIEDENDEN ZWEI-PHASEN-GRENZSCHICHT

Zusammenfassung—Zur Untersuchung statistischer Eigenschaften von Temperaturschwankungen in einer siedenden Zwei-Phasen-Grenzschicht wurden die entsprechenden Intermittenzfunktionen definiert, welche Flüssigkeits-, Dampf- und Phasengrenzflächengebiet an einem einzelnen, festen Punkt beschreiben. In Wasser, das an einer horizontalen Oberfläche siedet, wurde die Temperaturschwankung mit einem Mikrothermoelement gemessen; das Meßsignal wird in einem Digitalrechner mittels einer Prüffunktion für das Flüssigkeits-, Dampf- und Phasengrenzflächengebiet weiterverarbeitet. Die Ergebnisse bestätigen, daß die Temperaturschwankung im siedenden Zweiphasengebiet in drei Teile eingeteilt werden kann, die eigenen Gebieten entsprechen und daß ihre statistische Verteilung von den Eigenschaften der betreffenden Systeme abhängt. Ebenfalls wurde gezeigt, daß die Temperaturschwankung im Grenzflächengebiet ausschlaggebend ist und der Temperaturänderung in der Flüssigkeitsschicht um eine wachsende Dampfblase entspricht. Die Verteilung der Amplitude im Flüssigkeitsgebiet ändert ihre Form mit dem Wandabstand infolge der Änderung der Turbulenzintensität bei verschiedenen Abständen. Die Wahrscheinlichkeits-Dichteverteilung im Dampfgebiet zeigt sehr kleine Amplitudenschwankungen und ist beinahe für alle Abstände konstant.

ЯВЛЕНИЕ ПЕРЕМЕЖАЕМОСТИ В КИПЯЩЕМ ДВУХФАЗНОМ ПОГРАНИЧНОМ СЛОЕ

Аннотация — С целью изучения статистических характеристик пульсаций температуры в кипящем двухфазном пограничном слое определены соответствующие функции перемежаемости, которые используются для описания областей жидкой и паровой фаз, а также границы раздела в отдельной фиксированной точке. При кипении воды на горизонтальной поверхности пульсации температуры измерялись с помощью микротермопары, сигнал преобразовывался в цифровую форму и обрабатывался с помощью вычислительной машины, причем детектирующая функция задавалась отдельно для каждой из рассматриваемых областей. Полученные результаты свидетельствуют о том, что пульсации температуры в кипящем двухфазном слое можно разделить на три группы, соответствующие каждой отдельной области, и что их статистическое распределение зависит от свойств соответствующей системы. Показано также, что пульсации температуры на границе раздела являются детерминированными и соответствуют изменениям температуры в слое жидкости, окружающей растущий пузырек пара. Распределение амплитуды в жидкой фазе изменяет свою форму с увеличением расстояния от стенки в результате изменения интенсивности турбулентности. Распределение плотности вероятности в паровой фазе свидетельствует о весьма незначительных пульсациях амплитуды и является почти неизменным на всех расстояниях от стенки.