such, the location of $X_{eq}=0$ would not be at z=0, where z represents the direction of flow and z=L (where L is the length of the boiling microchannel) represents the end of the microchannel. On the other hand, the water flow at inlet could also be overheated ($X_{eq}>0$) due to the pre-heating to maintain water temperature before entering the channel;

[0021] 2) Wall superheat T_w-T_{sat} is large enough to start boiling near the inlet of the microchannel, defined as the first 5% of its length;

[0022] 3) q" is constant along the channel periphery and in flow direction.

[0023] The local quality of the convecting flow is needed to estimate the pressure drop in a channel. Knowing the void fraction and vapor quality variation along the channel length, the two-phase pressure drop in the channel can be calculated using the separated flow model of Lockhart and Martinelli [1949][1]. This equation, shown below, breaks up the pressure drop into frictional losses and acceleration from boiling terms,

$$\begin{aligned}\Delta p &= \Delta p_{fr} + \Delta p_{acc} \\ &= \int_0^z \frac{2 f_{lo} G \phi_{lo}^2}{D_h \rho_l} dz + \\ &\int_0^z G^2 \frac{dX}{dz}\left\{\left[\frac{2X}{\rho_v \alpha} - \frac{2(1-X)}{\rho_l \alpha}\right] + \frac{d\alpha}{dz}\left[\frac{(1-X)^2}{\rho_l (1-\alpha)^2} - \frac{X^2}{\rho_v \alpha^2}\right]\right\} dz\end{aligned} \quad (2)$$

[0024] D_h[m]=Hydraulic diameter of the channel

[0025] f_{lo}[−]=Friction factor of the channel when the entire mass flux rate as liquid

[0026] f_l[−]=Friction factor of the channel when the mass flux rate as liquid, G(1−X)

[0027] p_v[kg/m^3]=Density of the vapor phase

[0028] p_l[kg/m^3]=Density of the liquid phase

The terms in equation (2) that aren't defined above need the Martinelli parameter, X, which defines the pressure gradients for the liquid flowing alone over the pressure gradient of the vapor flowing alone,

$$\chi^2=(dp/dx)_l/(dp/dx)_v \quad (3)$$

where p is the local static pressure. The correlation for α in equation (2) for turbulent flow in large pipes is given as

$$\alpha=[1+0.28_\chi^{0.71}]^{-1} \quad (4)$$

[1] Lockhart, R. W. and Martinelli, R. C., "Proposed Correlation of Data for Isothermal Two-Phase, Two-Component Flow in Pipes", Chemical Engineering Progress 45(1), pp. 39-48, 1949.

[0029] The value of ϕ_{lo}^2, the two-phase flow friction multiplier, is dependent upon the friction multiplier for liquid flowing alone ϕ_l^2, the friction factors and local quality,

$$\phi_{lo}^2 = \phi_l^2\left(\frac{f_l}{f_{lo}}\right)(1-x)^2, \quad (5)$$

The friction multiplier for liquid flowing alone is given by the Martinelli-Nelson correlation as,

$$\phi_l^2 = 1 + \frac{C}{\chi} + \frac{1}{\chi^2}. \quad (6)$$

C in equation (6) has terms dependent upon the gas and liquid phase flow regimes

[0030] 20 (liquid-turbulent, gas-turbulent)

[0031] 12 (liquid-viscous, gas-turbulent)

[0032] 5 for (liquid-viscous, gas-viscous).

Lee (2001) suggested a correlation of the coefficient C:

$$C=0.06185\,Re_{lo}^{0.726}, \quad (7)$$

for micro-channels down to D_h~0.8 mm.

[0033] The term "critical heat flux", or CHF, is the local heat flux at which wall temperature can not be maintained due to heat transfer mechanism change from boiling to vapor convection. This results in the formation of a localized hot spot. **FIG. 19** shows the typical boiling curve, with heat flux on the vertical axis and the temperature difference between the wall (T_w) and the saturated fluid (T_s). Smaller values of the temperature difference range have single phase heat transfer and low heat fluxes. There is a threshold temperature difference where nucleate boiling starts and increasing the difference slightly can result in larger heat fluxes, as nucleate boiling starts to occur. CHF occurs when the difference reaches a point where the heat transfer rate changes from nucleate/bubbly flow to local dry out and gas phase resistance starts to dominate heat transfer. CHF can occur before dry-out.

[0034] CHF results in larger hydraulic diameters are fairly well characterized. CHF for saturated fluids are generally a function of the following effects:

[0035] 1. Flow rate: CHF goes up when flow rate is increased for a fixed inlet conditions and geometry

[0036] 2. Pressure: When pressure is increased from ambient pressure the CHF increases to a local maximum and gradually decreases with increasing pressure

[0037] 3. Channel size: CHF increases when channel size increases;

[0038] 4. Channel length: Longer channels lead to lower CHF;

[0039] 5. Vapor quality: Increased vapor quality X leads to smaller CHF;

Channel size and vapor quality are related to average wall heat flux in saturated boiling. Thus, higher process heat flux (average) quickly approaches local CHF via higher vapor generation rate and accumulated vapor amount.

[0040] The boiling number, Bo, is the heat flux nondimensionalized with mass flux and latent heat of vaporization