1. Nucleation in liquids

After reviewing the literature for description of the nucleation in superheated liquids the following conclusions and recommendations have been drawn. The maximum superheating in technical systems is a function of the depressurization velocity and of the produced turbulence. The maximum superheating can be predicted by the Algamir and Lienhard and by the Bartak correlations within an error band of 48.5%. Flashing in short pipes and nozzles leads to critical flows driven by the pressure difference equal to the entrance pressure minus the flashing inception pressure. For the prediction of the maximum achievable superheating, which represents the spinoidal line the Skripov correlation is recommended. The wetting angle is an important property of the polished surface characterizing its capability to activate nucleation sites. For the prediction of the activated nucleation sites the correlation obtained by Wang and Dhir is recommended. The establishing of a vapor film around a heated surface having temperature larger than the minimum film boiling temperature takes a finite time. The availability of small bubbles of noncondensing gases reduces the superheating required to initiate evaporation. Evaporation at lower than the saturation temperature is possible.

1.1 Introduction

Liquids having temperature above the saturation temperature corresponding to the local pressure are called superheated liquids. Superheated liquids are unstable and start to disintegrate. This process is in generally called flashing. The process of rupturing a continuous liquid by decrease in pressure at roughly constant liquid temperature is often called cavitation – a word proposed by Froude. The process of rupturing a continuous liquid by increase the temperature at roughly constant pressure is often called boiling. The fluctuation of molecules having energy larger than that characteristic of a stable state causes the formation of clusters of molecules, which after reaching some critical size are called nuclei. The theory of the nucleation provides us with information about the generation of nuclei per unit time and unit volume of the liquid as a function of the local parameter.
1.2 Nucleation energy, equation of Kelvin and Laplace

Let us abstract from a superheated nonstable liquid a spherical volume, having an initial radius $R_{10}$, a volume $\frac{4}{3} \pi R_{10}^3$, pressure $p$, temperature $T_2$ and density $\rho_2 = \rho_2(p, T_2)$. After some time the selected sphere liquid volume increases due to evaporation to the radius $R_1$ (respectively to the volume $\frac{4}{3} \pi R_1^3$) and reaches a pressure $p'(T_2)$. The pressure inside the bubble is assumed to be uniform because of the small bubble size. The density of the evaporated steam inside the sphere is $\rho^* = \rho^*[p'(T_2)] = \rho^*(T_2)$. The initial and the end spheres have the same mass per definition, therefore

$$\left( \frac{R_{10}}{R_1} \right)^3 = \frac{\rho^*}{\rho_2}.$$  \hspace{1cm} (1.1)

Consequently, the initial volume of the sphere is changed by

$$\frac{4}{3} \pi (R_1^3 - R_{10}^3) = \frac{4}{3} \pi R_1^3 \left( 1 - \frac{\rho^*}{\rho_2} \right).$$ \hspace{1cm} (1.2)

During this expansion a mechanical work

$$4\pi \int_{R_{10}}^{R_1} \left[ p'(T_2) - p \right] r^2 dr = \frac{4}{3} \pi (R_1^3 - R_{10}^3) \left[ p'(T_2) - p \right]$$

$$= \frac{4}{3} \pi R_1^3 \left( 1 - \frac{\rho^*}{\rho_2} \right) \left[ p'(T_2) - p \right]$$ \hspace{1cm} (1.3)

is performed and transferred into total kinetic energy of the surrounding liquid Skripov et al. (1980). In other words, this work is introduced into the liquid. For the creation of a sphere with a free surface, additional work

$$\int_{0}^{R_1} \frac{2\sigma}{r} 4\pi r^2 dr = 4\pi R_1^2 \sigma$$ \hspace{1cm} (1.4)

is needed. The surface tension of water in N/m, $\sigma$, in contact with its vapor is given in Lienhard (1976) with great accuracy by

$$\sigma = 0.2358 \left[ 1 - \frac{T'(p)}{T_c} \right]^{1.256} \left[ 1 - 0.625 \frac{T'(p)}{T_c} \right],$$ \hspace{1cm} (1.5)

where the $T_c$ is the thermodynamic critical temperature (for water $T_c = 647.2$ K). For the region of 366 to 566 K the above equation can be approximated by