

# Evolution of Size and Temperature of Droplets in the Process of Bulk Condensation

N.M. Kortsenshteyn<sup>1</sup>, A.K. Yastrebov<sup>2</sup>

<sup>1</sup>G.M. Krzhizhanovsky Power Engineering Institute, Moscow, Russia

<sup>2</sup>Department of Low Temperatures, Moscow Power Engineering Institute, Moscow, Russia

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Presenting author email: ars48@yandex.ru

In various studies of bulk condensation temperature of droplets is often assumed to be equal to temperature of gaseous phase or to saturation temperature at vapor pressure. We compared results which have been obtained with use of these assumptions and in general formulation (Korstenshteyn and Yastrebov, 2012). However we assumed that all droplets have the same temperature, but the equation of heat balance for a single droplet shows that its temperature depends on its size. In this work we consider temperature distribution of droplets in the process of bulk condensation.

We proposed the modification of the kinetic equation for distribution function of droplets. This modification does not require the assumption of equality of all droplets' temperature. The distribution function is defined as derivative of droplets' number by their radius and temperature. The modified kinetic equation is written as follows:

$$\frac{\partial f}{\partial t} + \frac{\partial(\dot{r}f)}{\partial r} + \frac{\partial(\dot{T}f)}{\partial T} = \frac{I}{\rho} \delta(r - r_{cr}) \delta(T - T_s) \quad (1)$$

Here  $f$  is the distribution function of droplet sizes and temperatures,  $r$  is the droplet radius,  $\dot{r}$  is the droplet growth rate,  $\dot{T}$  is the rate of variation of droplet's temperature,  $I$  is the nucleation rate,  $\rho$  is the density of two-phase mixture,  $\delta$  is the delta function,  $r_{cr}$  is the critical droplet radius, and  $T_s$  is the saturation temperature. The rate of variation of droplet's temperature can be found as follows:

$$\dot{T} = 3 \frac{(L - C_{pm}(T - T_m)) \rho' \dot{r} - q}{\rho' C' r} \quad (2)$$

Here  $L$  is phase transition heat,  $\rho'$  and  $C'$  are density and specific heat of liquid,  $C_{pm}$  and  $T_m$  are specific heat and temperature of gaseous phase, and  $q$  is interphase heat flux. This formula was obtained from the equation of heat balance for a single droplet. There is droplet's temperature  $T_0$  for which value of  $\dot{T}$  is equal to zero. In this case all the heat released at condensation on the surface of droplet is transferred to the gaseous phase. For free molecular regime both growth rate and interphase heat flux do not depend on droplet's size, so the temperature  $T_0$  is the same for all droplets.

Testing of proposed modification was carried out for the problem of condensational relaxation at instantaneous creation of supersaturated state. We considered the mixture of cesium (vapor) and argon (non-condensable gas). This mixture was taken as example of free molecular regime of droplets'

condensational growth. The initial temperature of mixture was 560 K, the partial pressure of vapor was 10 times higher than saturation pressure at this temperature.

We obtained results of numerical solution with and without taking into account temperature distribution of droplets. These results are almost identical because temperature of most of the droplets is close to the average one. The value of  $\dot{T}$  is inversely proportional to the size of droplets. The size of newly formed droplets is equal to the critical one which is very small at initial supersaturation ratio at beginning of relaxation. The rate of temperature variation is very high for newly formed droplets, and their temperature becomes equal to  $T_0$  within a very short time (about  $10^{-8}$  s). So results obtained with use of the same temperature of all droplets should be close to ones obtained with use of the modified kinetic equation. Example of temperature distribution function  $f_T$  is shown in Figure 1. This function is defined as integral of the distribution function of droplet sizes and temperatures by droplet size. It can be seen that number of droplets with temperature between  $T_0$  and  $T_s$  is very small in comparison with number of droplets with temperature  $T_0$ , so their influence on the average temperature of droplets can be neglected. The problem of condensational relaxation can be solved with use of the same temperature of all droplets. Our numerical results confirm the efficiency of the proposed modification of the kinetic equation.

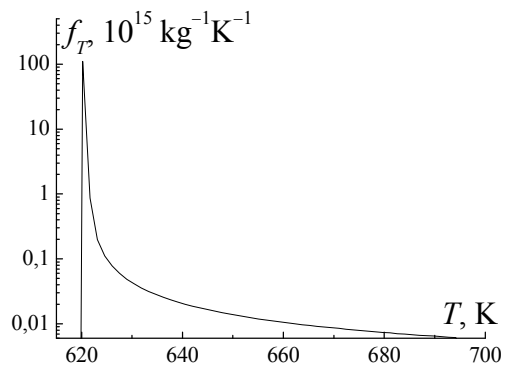


Figure 1. Example of temperature distribution function.

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