

Supporting Information for

**Experimental and numerical investigation of a condensation
particle counter challenged by particles with varying
wettability to working liquid**

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A. Derivation of Heat and mass transfer model in the condenser

The condenser, in which the test particles are activated, is modeled in a two dimension cylindrical view. The length of the condenser is 0.1 m and the internal diameter is 5 mm.

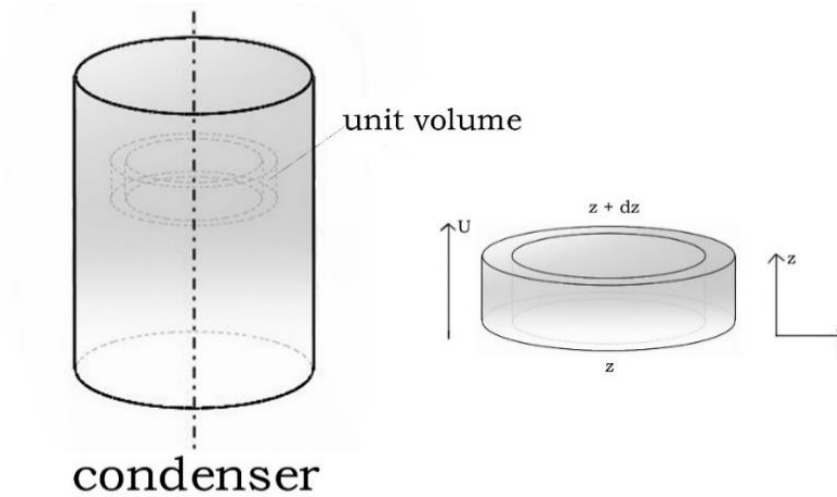


Fig. A1 The cylindrical control volume of the condenser.

The heat and mass transfer model of the condenser complies with Fourier's law, Fick's law, energy conservation law, and mass conservation law. For simplicity, a number of assumptions were made: steady temperature field, constant physical properties, axisymmetric temperature field, negligible viscous dissipation and a fully developed laminar flow without turbulent mixing. The enthalpy increment within the control volume is $u_r \cdot 2\pi r dr \cdot \rho \cdot c_p \cdot \frac{\partial T}{\partial z} dz$, while the radial and axial heat transfer are $2\pi r \cdot dz \cdot \lambda \frac{\partial}{\partial r} \left(\frac{\partial T}{\partial r} \cdot r \right) \cdot dr$ and $-2\pi r \cdot dr \cdot \lambda \frac{\partial}{\partial z} \left(\frac{\partial T}{\partial z} \right) \cdot dz$ respectively. Thus the energy balance equation is as follows:

$$2\pi r \cdot dz \cdot \lambda \frac{\partial}{\partial r} \left(\frac{\partial T}{\partial r} \cdot r \right) \cdot dr - 2\pi r \cdot dr \cdot \lambda \frac{\partial}{\partial z} \left(\frac{\partial T}{\partial z} \right) \cdot dz \quad (A1)$$

$$= u_r \cdot 2\pi r dr \cdot \rho \cdot c_p \cdot \frac{\partial T}{\partial z} dz$$

Since the temperature gradient along the radial direction is much larger than that of axial direction, the term $[2\pi r \cdot dr \cdot \lambda \frac{\partial}{\partial z} (\frac{\partial T}{\partial r}) \cdot dz]$ can be safely neglected. The final energy conservation equation for a micro control volume can be written as follows:

$$u_r \frac{\partial T}{\partial z} = \alpha_t \cdot \frac{1}{r} \frac{\partial}{\partial r} (r \frac{\partial T}{\partial r}) \quad (A2)$$

Where r, z refer to radial and axial coordinates; α_t is the thermal diffusivity: $\alpha_t = \frac{\lambda}{\rho \cdot c_p}$; ρ is the density of air; c_p is the specific heat capacity of the air; u_r is the velocity at position r , which is calculated according to the Poiseuille's law. The fully developed laminar flow in a pipe is calculated as follows:

$$u_r = 2U \left[1 - \left(\frac{r}{R} \right)^2 \right] \quad (A3)$$

Where U is the average velocity through the whole condenser.

With Fick's law and energy conservation law, the equations for the CPC partial pressure and particle concentration are similar with T, α_t replaced by p_v, D_{vg} and $N(D_P), D(D_P)$, respectively. The values of $D_{vg}, D(D_P)$ are vapor diffusivity and particle diffusivity. As mentioned previously, the axial energy conduction driven by axial temperature gradient is negligible. Similar assumptions are applied to axial diffusion of working liquid vapor and particle concentrations, and their partial differential equations are as follows:

$$u_r \frac{\partial p_v}{\partial z} = D_{vg} \cdot \frac{1}{r} \frac{\partial}{\partial r} (r \frac{\partial p_v}{\partial r}) \quad (A4)$$

$$u_r \frac{\partial N(D_P)}{\partial z} = D(D_P) \cdot \frac{1}{r} \frac{\partial}{\partial r} (r \frac{\partial N(D_P)}{\partial r}) \quad (A5)$$

B. Introduction of the classical Kelvin theory

The classical Kelvin theory was widely used in existing CPC models, which relates the effect of surface tension to the equilibrium partial pressure of a curved-surface liquid, and this introduced the most fundamental concept of the activation theory, namely Kelvin diameter (D_k) (Stolzenburg and McMurry, 1991),

$$D_k = \frac{4\gamma M}{\rho_b R T \cdot \ln S} \quad (\text{B1})$$

Where γ is the surface tension; M is the molecular weight; ρ_b is the butanol density; R is the universal gas constant; T is the droplet temperature; S is saturation ratio and $S \equiv \frac{p_v}{p_{sat}(T)}$; p_v is the partial pressure of the working fluid; $p_{sat}(T)$ is the saturated vapor pressure over the flat surface at temperature T . Kelvin diameter D_k indicates the droplet equilibrium diameter that neither evaporates nor grows, and as the particle diameter is larger than this equilibrium diameter the particle would grow rapidly to detectable sizes, thus the activation rate k can be regarded as infinity. Conversely, the activation rate k is assumed as zero when the particle diameter is smaller than the equilibrium diameter.

REFERENCE

Stolzenburg, M.R. and McMurry, P.H. (1991). An ultrafine aerosol condensation nucleus counter. *Aerosol Sci. Technol.* 14: 48-65.