*1、Before attempting to design any particulate matter collection device, we must obtain information about the particulate matter, airflow, and process conditions. Discuss what information we should obtain and explain how this information affects the particulate matter collection device.*

**Important particulate characteristics include size, size distribution, shape, density, stickiness, corrosivity, reactivity, and toxicity. Gas stream characteristics of importance are pressure, temperature, viscosity, humidity, chemical composition, and flammability. Process conditions include gas flow rate, particulate loading (mass concentration of particles in the gas stream), removal efficiency requirements, and allowable pressure drop.**

Understanding the size distribution of the particles (e.g., $PM_{10}$, $PM_{2.5}$, or ultrafine particles) is crucial. Smaller particles are harder to capture and may require more advanced collection methods, such as electrostatic precipitators (ESP) or fabric filters, while larger particles can be captured using simpler devices like cyclones or gravity settlers. The density of the particulate matter influences the settling velocity and the choice of collection method. Heavier particles tend to settle more easily, and devices such as cyclones or gravity-based separators may be sufficient. Lighter particles may require additional mechanisms like filtration or electrostatic forces. Irregularly shaped particles or those prone to agglomeration may behave differently in airflow, affecting their capture efficiency. Agglomerated particles may be easier to collect in mechanical collectors, while dispersed fine particles require more precise control. The chemical properties of the particles (e.g., corrosive, combustible, or toxic substances) will impact the choice of materials for the collection device, as well as the safety measures required. Devices handling toxic or hazardous particles need to include safeguards like enclosed systems or secondary filtration. Particles with high moisture content may lead to clogging or agglomeration in certain devices. The collection device must be designed to manage wet particulate, often requiring pre-drying systems or self-cleaning mechanisms to prevent buildup.The volume of air that needs to be processed will determine the size and capacity of the collection device. High airflow rates may require larger or more robust systems with multiple stages of collection, while lower flow rates can be handled by smaller devices. Air velocity affects the transport of particulate matter and the efficiency of its capture. Higher velocities can lead to particle re-entrainment in certain types of devices (e.g., gravity settlers), requiring adjustments in design to control airflow speeds. High-temperature airflows can affect the choice of materials for the collection device and influence particle behavior. Some materials may degrade at elevated temperatures, necessitating the use of heat-resistant components. Additionally, temperature can affect the viscosity of particles, especially if they are semi-volatile. High humidity can lead to condensation within the collection system, which may affect particle capture or lead to equipment corrosion and malfunction. The design must account for humidity levels, and in some cases, pre-treatment of the air (e.g., dehumidification) may be necessary.

*2、Try to determine the drag force on a spherical particle moving in dry air with a relative velocity of 0.1 m/s.*

*Known information: dp=1μm, T=373 K, P=1013.25 hPa*

*dry air viscosity =2.18×10$^{-5}$ Pa·s,   dry air density=0.947 kg/m$^3$)*

Solution:

$$RE = \frac{d_p v_r \rho_F}{\mu} = \frac{1 \times 10^{-6} \times 0.947 \times 0.1}{2.18 \times 10^{-5}} = 4.34 \times 10^{-3} < 1$$

Because the particle scale is close to the gas mean molecular free range, a **Cunningham correction** to Stokes is required.

$$\rho = \frac{PM}{RT}$$

$$\lambda = \frac{\mu}{0.499\rho\sqrt{\frac{8RT}{\pi M}}} = \frac{\mu}{0.499P\sqrt{\frac{8M}{\pi RT}}}$$

The molar mass (M/MW) of dry air is about 28.97 g/mol

**Mean free path** of a gas molecule:

$$\lambda = \frac{\mu}{0.499\rho\sqrt{\frac{8RT}{\pi M}}} = \frac{2.18\times10^{-5}}{0.499\times0.947\times\sqrt{\frac{8\times8.314\times373}{3.14\times28.97\times10^{-3}}}} = 8.83 \times 10^{-8}\ m$$

**Cunningham correction factor:**

$$C = 1 + \frac{2\times8.83\times10^{-8}}{1\times10^{-6}}\left[1.257 + 0.4 \times \exp\left(\frac{-0.55\times1\times10^{-6}}{8.83\times10^{-8}}\right)\right] = 1.22$$

Based on **Stokes law** of resistance and **Cunningham correction factor**:

$$F_D = \frac{3\pi\mu d_p v_r}{C} = \frac{3 \times 3.14 \times 2.18 \times 10^{-5} \times 1 \times 10^{-6} \times 0.1}{1.22}$$

$$= 1.68 \times 10^{-11}\ N$$

*(3)A single spherical particle settles in air due to the effect of gravity, and the drag coefficient is known to be in the Stokes regime, and when the two forces of gravity and drag (buoyancy is neglected) are in equilibrium, the expression for the terminal velocity of the spherical particle is?*

When settling under gravity, the forces involved include gravity, fluid buoyancy, and fluid resistance, and the two forces are balanced when buoyancy is neglected.

$$F_G = \frac{4\pi}{3}\left(\frac{d_p}{2}\right)^2 \rho_P g$$

$$F_D = \frac{3\pi\mu d_p v_r}{C}$$

$$F_G = F_D$$

$$v_r = \frac{C\rho_P d_p^2}{18\mu} g$$