Atmospheric Aerosol Physics, Physical Measurements, and Sampling

General Sampling Considerations

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Member of Leibniz Association

ECAC
European Center for Aerosol Calibration

WCCAP
World Calibration Centre for Aerosol Physics

TROPOS
Leibniz Institute for Tropospheric Research

Aerosol Sampling

General Sampling Consideration

These Recommendations are based on the WMO-GAW & ACTRIS:

- Sample air should be brought into the laboratory through a vertical stack.
- The aerosol inlet should be well above ground level (5-10 m) for regional sampling sites in level terrain.
- The aerosol inlet must provide a high inlet sampling efficiency for the required particle size range.
- PM_{10} inlets should be used, while TSP inlets are NOT recommended anymore.
- The recommendation is to measure at a relative humidity below 40%.

GAW Report No. 227:WMO/GAW Aerosol Measurement Procedures, Guidelines and Recommendations, 2nd Edition2016

Sampling under Extreme Conditions

Special sampling requirements are needed for sites:

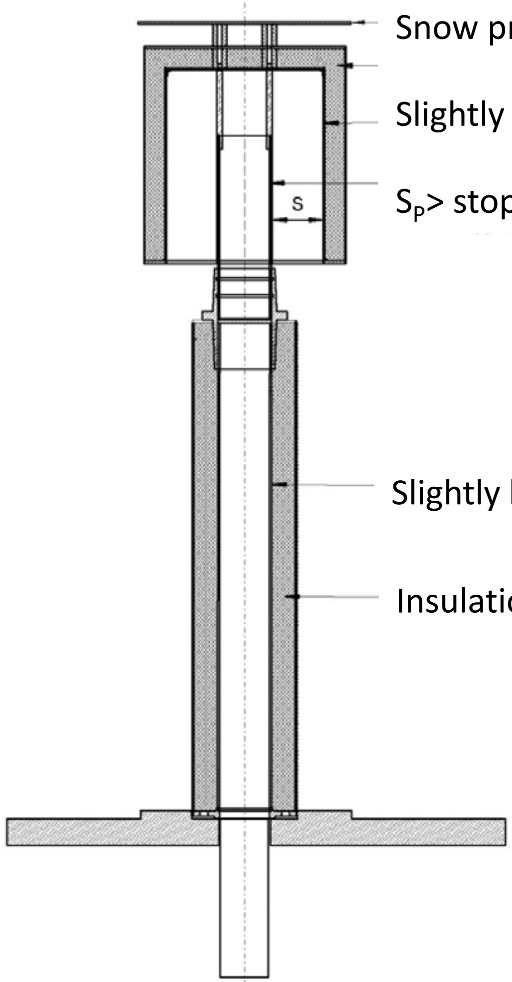
- in tropical and sub-tropical environments
  - → high dew point temperature
- in cold environments (Arctic and Antarctica)
  - → freezing inlets
- on mountains, which are frequently in cloud
  - → whole air vs interstitial inlet

Sampling under Extreme Conditions

- Heated whole air inlet for sites which are frequently in cloud or fog or/and freezing conditions.
- Cloud droplets are drawn into the inlet and evaporated.
- Cloud droplets and interstitial aerosol particles are sampled → whole air inlet

$$\tau_P = m_P \cdot B = \frac{\rho_P \cdot D_P^2 \cdot C_C}{18\eta}$$

$$s_P = u_G \cdot \tau_P$$



Isokinetic Aerosol Sampling

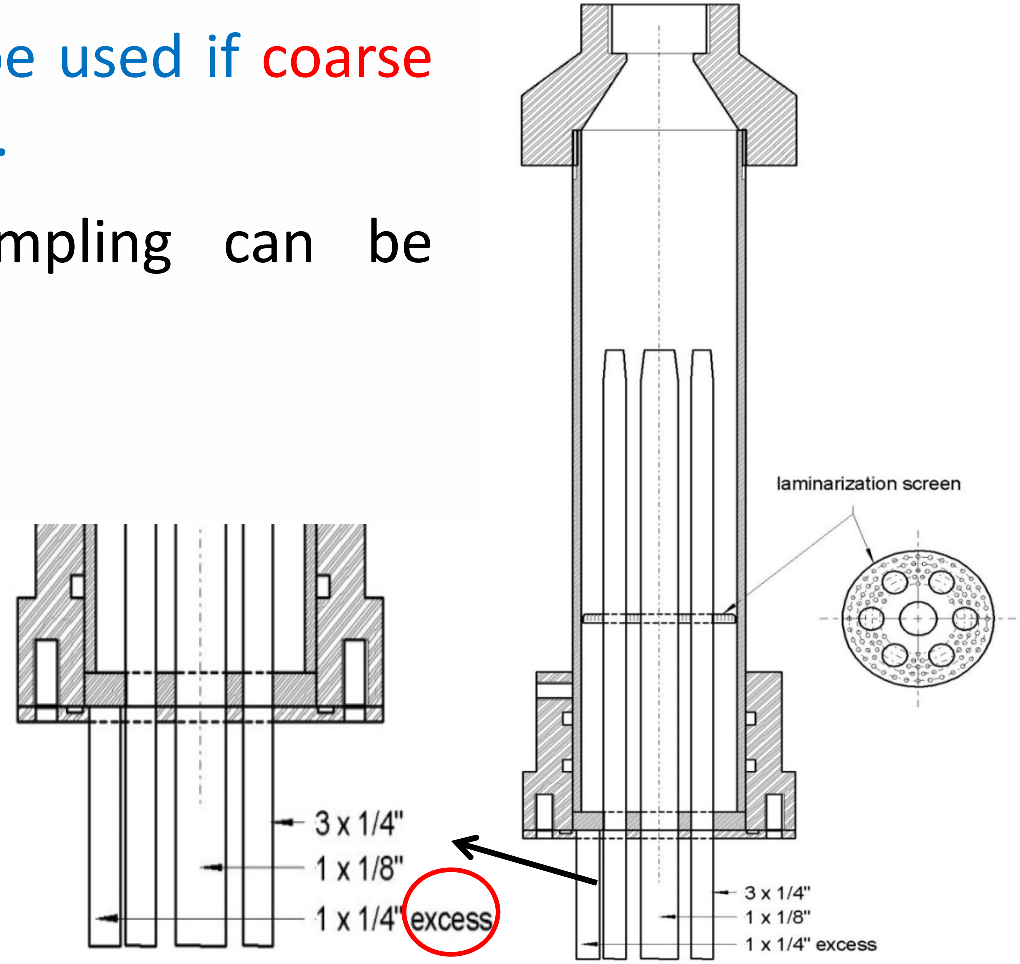
An isokinetic aerosol splitter should be used if coarse particles are sampled or characterized.

The particle over- und under sampling can be neglected if:

$$\text{Stk} \le 0.01$$

$$0.2 \le \bar{u} / u_0 \le 5$$

$$\text{Stk} = \frac{\tau_P \cdot u_P}{D_{\text{pipe}}}$$



Aerosol Drying

Why Aerosol Drying

- With increasing relative humidity, aerosol particles take up water a function of size and solubility.

- This effect can be significant for measurements of particle number size distributions or light scattering coefficients.

- The RH should be <40% to be able to compare e.g. physical and optical aerosol measurements (particle growth <5% in diameter).

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Aerosol Drying

- No dryer is needed, if T_{room} will be higher than 22°C (72°F) and the T_{dew} never exceeds 10°C (50°F).

- A aerosol dryer is needed for each instrument, if the T_{dew} will be higher than 10°C (50°F) and always below the T_{room}.

- The whole inlet flow has to be dried before entering the room, if the T_{dew} will be occasionally above the T_{room}.

Aerosol Drying Methods

Aerosol diffusion dryer

A diffusion dryer works on the base of silica.

- Advantage: no dry air is needed
- Disadvantage: has to be changed frequently

Membrane dryer

A membrane dryer (e.g. Nafion) is based on the principal that water vapor is transported through a membrane surrounded by a counter flow with low humidity.

- Advantage: no frequent changes are needed
- Disadvantage: a dry air supply (or vacuum) is needed

Aerosol Drying Methods

Dilution

The aerosol is diluted with dry particle-free air.

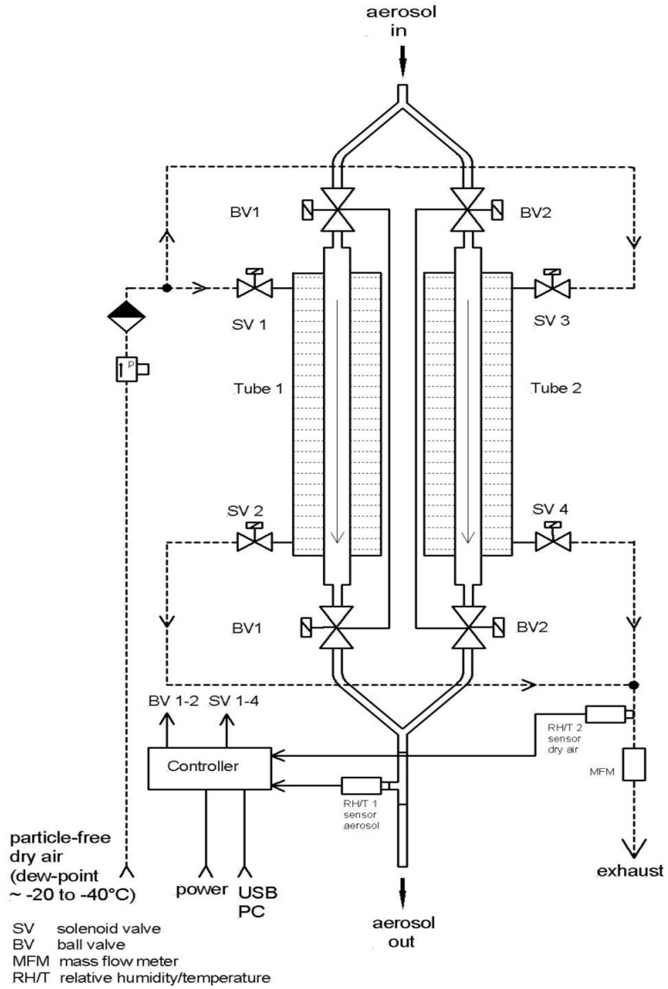
- Advantage: easy way to dry
- Disadvantage: The dilution ratio has to be exactly known. High ratios may create high uncertainties.
- Dilution is the recommended method for tropical and subtropical observatories

Heating

Heating is NOT recommended to avoid evaporation of semi-volatile particle material.

Automated Aerosol Diffusion Dryer

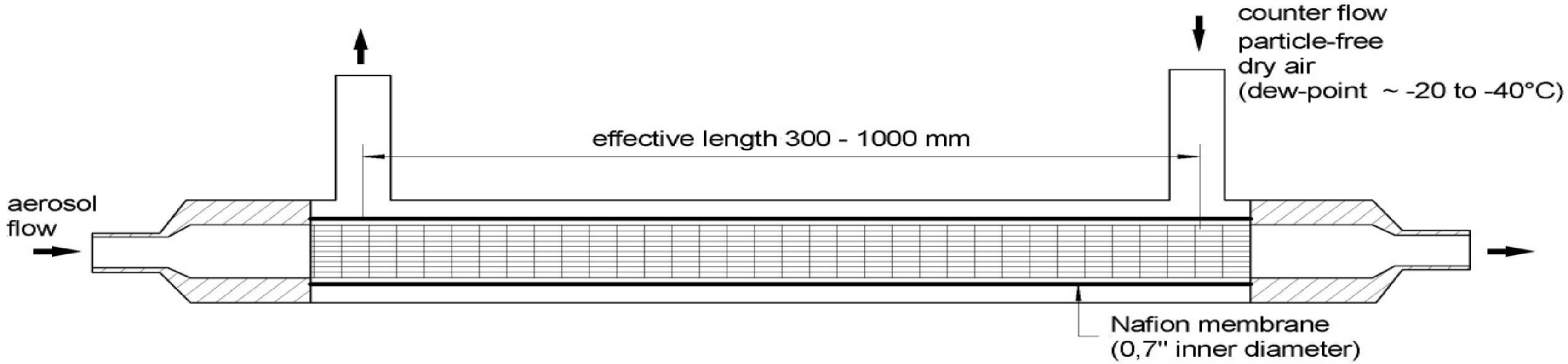
- Automatic aerosol diffusion dryer based on silica.
- Advantage: silica has to not be changed
- Disadvantage: dry air is needed



Tuch, T. M. et al. (2009). Design and performance of an automatic regenerating adsorption aerosol dryer for continuous operation at monitoring sites. AMT **2**, 417-422.

Aerosol Membrane Dryer

- A membrane dryer (e.g. Nafion) is based on the principal that water vapor is transported through a membrane, which is surrounded by a counter flow with low relative humidity.
- Advantage: no frequent changes are needed
- Disadvantage: a dry air supply is needed (or high vacuum)
- Below: a custom-designed Nafion dryer



Aerosol Particle Losses

Aerosol Particle Losses

Particle losses in pipes and instruments can occur due to:

- Sedimentation in horizontal or sloping pipes (coarse particles)
- Inertia in bends (coarse particles)
- Diffusion to the wall (ultrafine particles)
- Electrostatic forces (charged particles, mainly ultrafine)

Losses: Ultrafine Particles < 100 nm

- Pipes should be kept as short as possible.
- Only conductive tubing (e.g. stainless steel) should be used.
- The pipe should be designed for a laminar flow
  - Constant aerosol flow: Change in tube diameter → no change in diffusional losses
  - Constant tube diameter: Adjust aerosol flow to Re=2000, if possible
- Turbulent flows should be avoided, because of higher diffusional particle losses.

Losses: Coarse Particles > 1 µm

- Pipes should be vertically orientated.
- In cases when horizontal or sloping pipes cannot be avoided, the air flow should be high.
- Bends should be avoided.
- Highly turbulent flows cause increased inertial losses.
- An isokinetic sampling should be considered.