A Nanoparticle Nebulizer for Generation of Aerosolized Colloid Particles with Reduced Influence by Non-Volatile Residue

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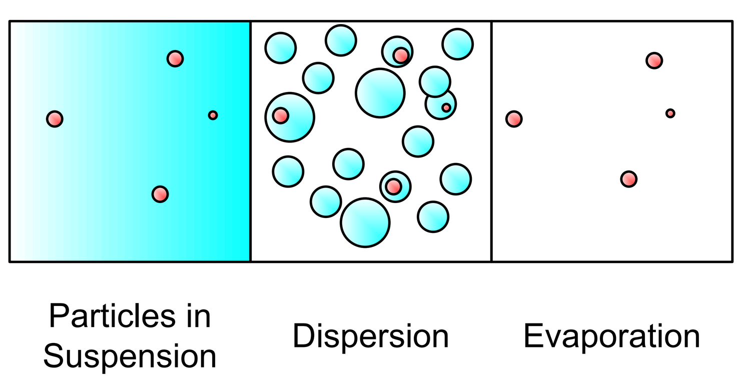
Abstract

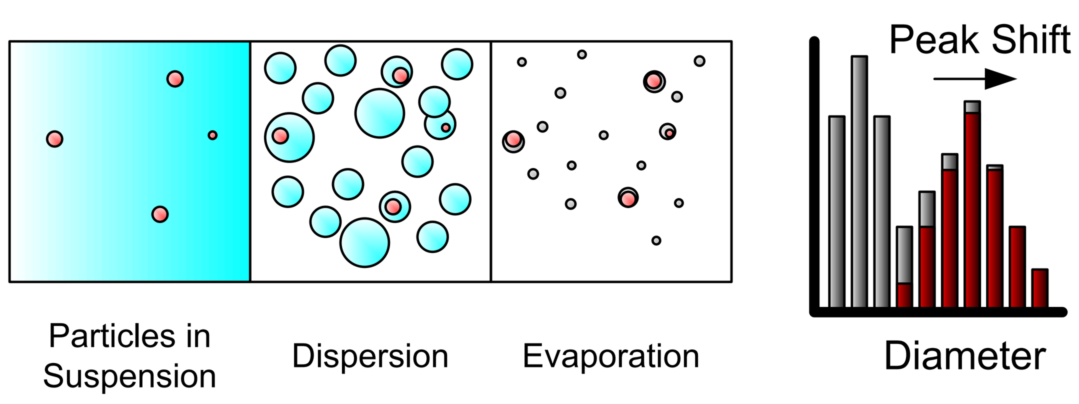
Dispersion of colloid nanoparticles into an aerosol first requires nebulization of the colloid into fine droplets and subsequent evaporation of the solvent from them. Following solvent evaporation, droplets that did not contain a colloid particle form particles composed of non-volatile solvent residue. Droplets that do contain colloid particles result in aerosolized colloid particles with a coating of non-volatile residue. To reduce the interference by non-volatile residue particles as well as effect on the colloid particle properties (surface chemistry, size), it is desirable to create droplets containing a low volume of solvent. This is especially true for aerosolization of nanoparticles that approach the size of the non-volatile residue particles. Nebulization is typically accomplished using either pneumatic or electrospray methods. While electrospray methods do provide sufficiently small droplets (~0.3 µm), there are several limitations to the method including poor long term stability and necessity for a conductive solvent. Common pneumatic nebulizers create droplet distributions with a peak diameter near 2.0 µm which leads to a significant amount of non-volatile residue interference in the aerosol. We present a new commercially available pneumatic nebulizer that is designed to produce a high number concentration of small droplets with a peak diameter less than 0.5 µm. We compare the performance of this nebulizer with existing aerosolization methods for a variety of colloids. We also show additional applications of this device for monitoring colloid concentrations in dilute systems such as ultrapure water systems and in liquid filter efficiency testing.

Introduction

- The properties of particles in hydrosols (colloids) are commonly measured by dispersing the colloid particles into a gas (aerosolization)



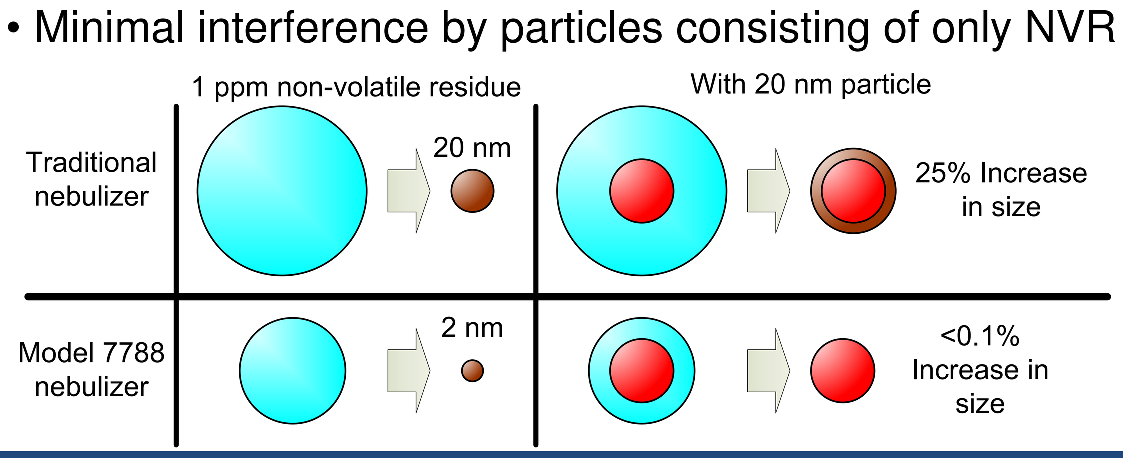
- Primary methods for aerosolization include Nebulization (pneumatic spraying of colloid) and Electrospray (electrohydrodynamic spraying)
- Electrospray is not suited for all colloids and are anecdotally unstable over long periods
- Nebulization using traditional devices typically creates droplets on the order of 2 µm
- Non-volatile residue (NVR) in the solvent creates a particle which is proportional to the diameter of the droplet
- As colloid particle sizes approach the size of the residue particles, the resulting aerosol particles no longer represent the particles in it



- Goal: Design a pneumatic nebulizer which reduces the effect of non-volatile residue on the resulting aerosol

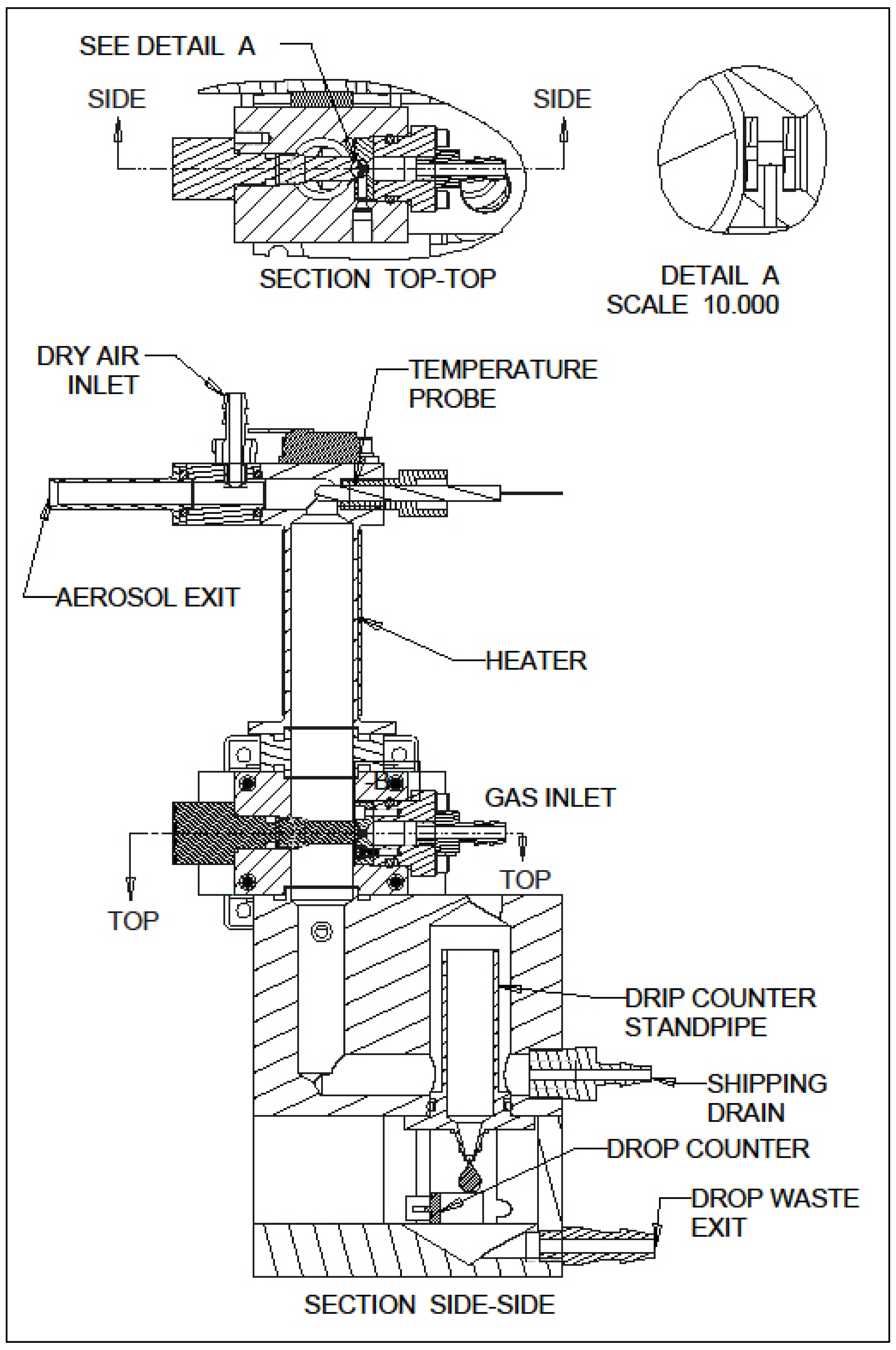
Instrument Design

- Maximum non-volatile residue 1 ppm (typical of many HPLC grade solvents)
- Less than 0.1% change in 10 nm particle diameter due to residue
- Minimal interference by particles consisting of only NVR



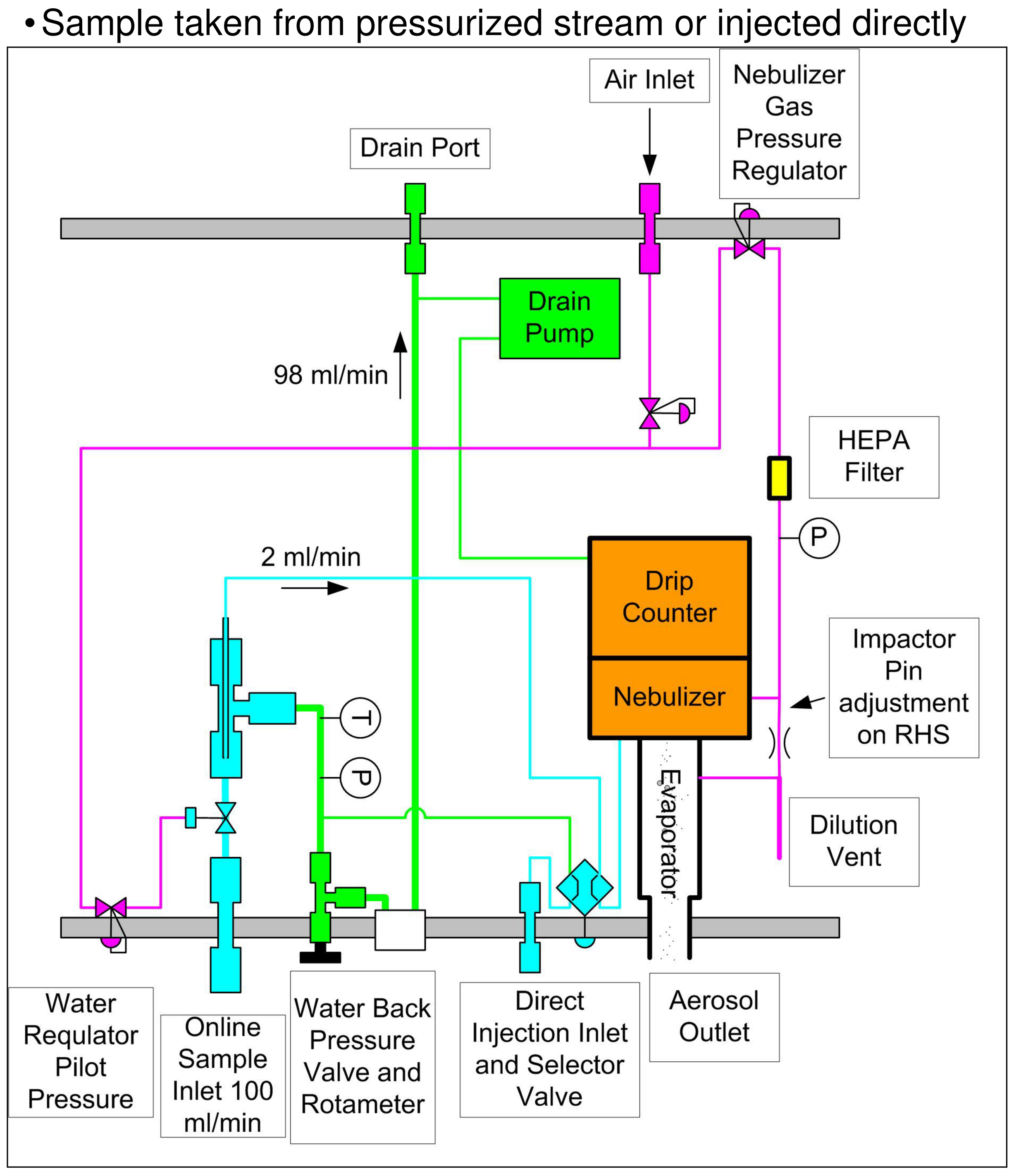
Nebulizer Geometry

- High purity materials of construction - minimize additional NVR contribution
- Swept flow paths - minimize dead spaces
- Confined air-liquid mixing area – Transfer maximum gas energy into breakup of liquid
- Ball end inertial impactor – Large droplet removal



Plumbing and Electrical

- Evaporator and nebulizer temperature control
- Monitor Sample pressure and temperature
- Sample taken from pressurized stream or injected directly



LiquiTrak® Model 7788 Nanoparticle Nebulizer

- Manufactured by Fluid
- Measurement Technologies Inc.

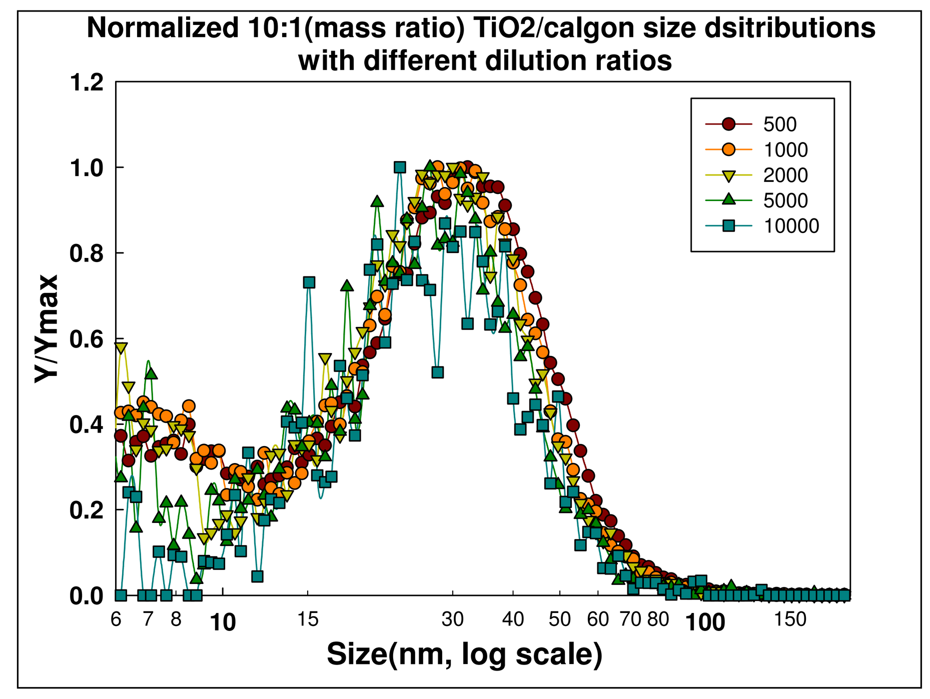
LiquiTrak® Liquid Nanoparticle Sizer (LNS)

- Model 7788
- Model 7780 LNS Dilution Module
- Scanning Mobility Particle Sizer

Patent US 8,272,253, US 8,573,034, US 7,852,465

Online Dilution

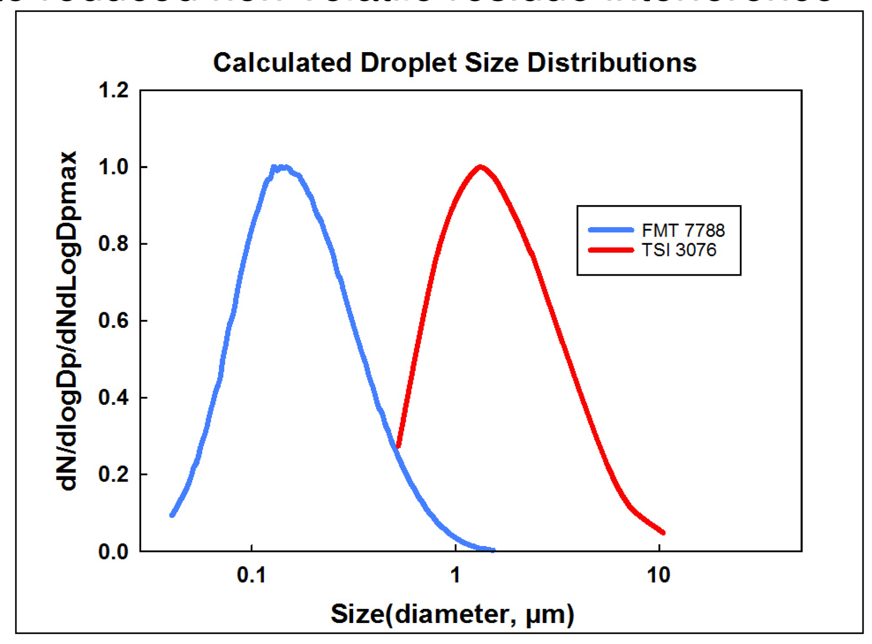
- Online dilution of sample will lower the peak diameter of non-volatile residue particles
- Minimizes contamination from sample vials
- Useful to lower NVR resulting from stabilizers with minimal coagulation due to short diluted residence time.



Results

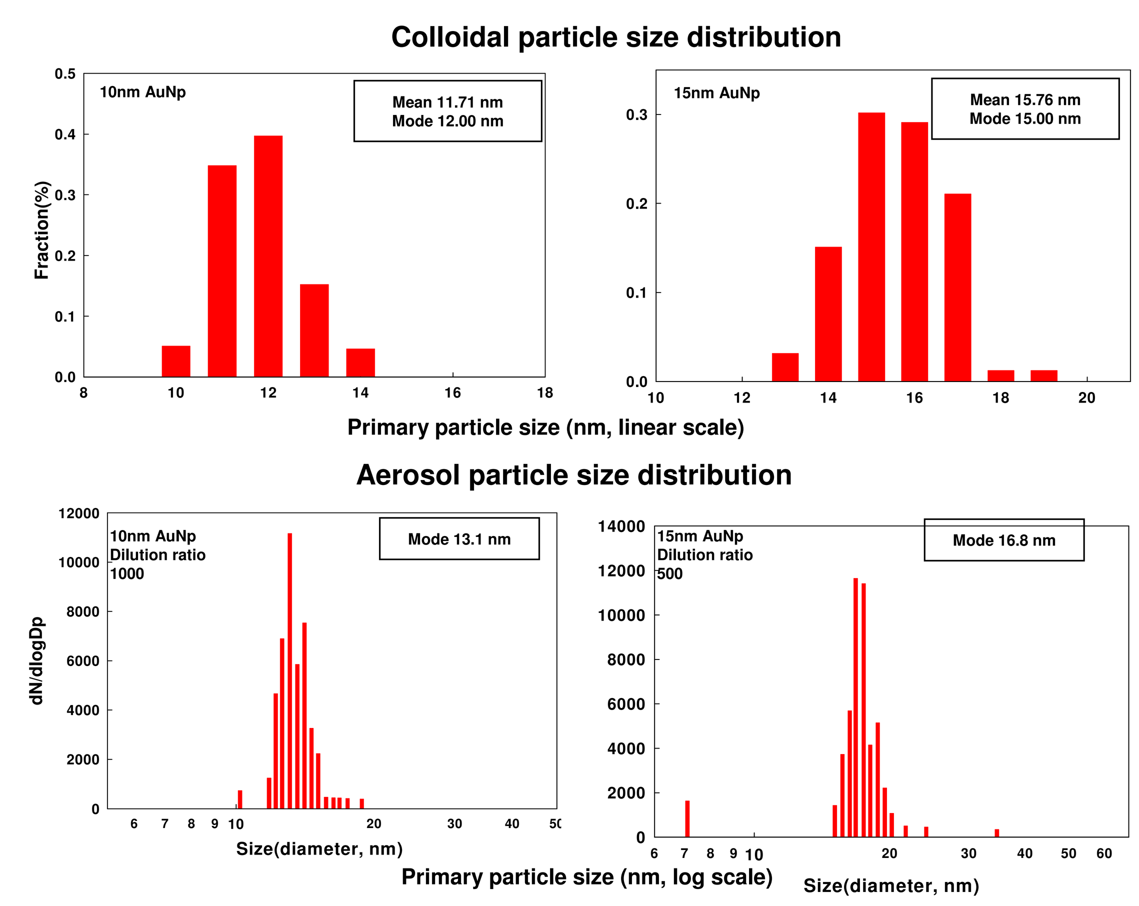
Nebulized Droplet Distribution

- Significant reduction of the peak droplet diameter
- Leads to reduced non-volatile residue interference



Aerosolization of colloid particles

- Aerosol size distribution measured with a Scanning Mobility Particle Sizer (LNS system)
- Good agreement shown between aerosol particle size distribution and colloid size distribution



Liquid Filter Testing

- Nanoparticle nebulizer output particle concentration measured using a condensation particle counter with a 50% detection efficiency at 10nm
- Downstream cumulative (>10 nm) colloid particle concentration measured throughout filter challenge