Capabilities of the Flow-Focusing Monodisperse Aerosol Generator

Model 1520

Application Note FMAG-001 (US)

Contents

Principle of Operation

The Model 1520 Flow-Focusing Monodisperse Aerosol Generator (FMAG) produces highly monodisperse aerosols in the range of 0.8 to ~10 µm. The flow focusing allows the user to adjust the diameter of the liquid jet while operating the liquid with a low pressure (i.e., less than 2 psi).

It achieves a high degree of monodispersity by using a vibrating crystal to break up a liquid jet into identically-sized droplets. The droplets are neutralized by a corona ionizer, and dilution air dries these droplets into particles with number concentrations in the range of $10^2 – 10^3$ #/cm^3.

Key Components

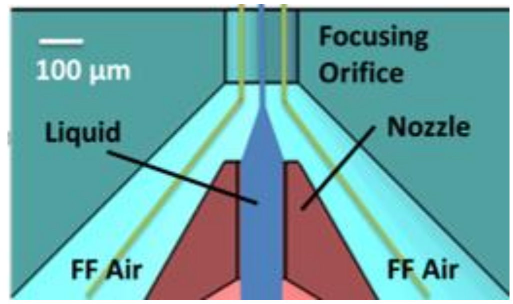
<table>
<tr><td>Syringe Pump</td><td>Provides a steady flow of the solvent, which carries the dissolved (or suspended) material that will form the final particles. Ultrapure water and methanol are the recommended solvents.</td><td rowspan="3">

Figure 1
Cross-sectional diagram of the aerosol generation mechanism within the Model 1520 FMAG</td></tr>
<tr><td>Crystal</td><td>A piezo crystal vibrates at a user-controlled frequency, which is responsible for generating monodisperse droplets.</td></tr>
<tr><td>Nozzle</td><td>Located atop (and coupled to) the crystal, the 100 µm-diameter nozzle determines the initial diameter of the liquid jet. The crystal's vibration is imparted to the liquid jet as it exits the nozzle.</td></tr>
<tr><td>Flow-Focusing Air</td><td colspan="2">Labeled “FF Air” in Figure 1, the flow-focusing air surrounds the liquid jet as it exits the nozzle, and squeezes the jet to a smaller diameter.</td></tr>
<tr><td>Focusing Orifice</td><td colspan="2">The 150 µm orifice emits the flow-focusing air and the liquid jet into the dilution air flow. Upon exit, the jet breaks up into droplets, which are dried into solid or liquid particles by the dilution air flow.</td></tr>
</table>

Results

Particle Size Distributions

The figures below show results obtained using the FMAG to aerosolize suspended materials, dissolved solids, and dissolved liquids. All size distribution measurements were made using the TSI® Model 3321 Aerodynamic Particle Sizer® (APS™) Spectrometer.

Aerosolizing Suspended Materials

The FMAG may be used to generate pre-existing solid particles, such as polystyrene latex spheres (PSL) or certain test dusts (i.e., Silica particles). As long as the particles can be stably suspended in a liquid that is compatible with the FMAG, successful aerosolization is likely.

Figure 2 shows size distributions of 3 µm, 5 µm, and 10 µm PSL aerosolized using the Model 1520 FMAG, and measured using the Model 3321 Aerodynamic Particle Sizer™ (APS™) Spectrometer. Geometric standard deviations for these three peaks are 1.06, 1.02, and 1.05, respectively. The 10 µm PSL peak is shown amplified by a factor of 100.

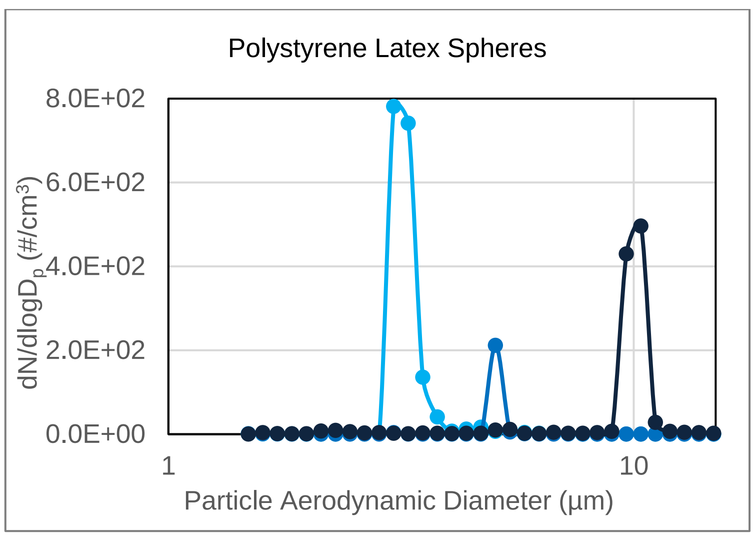


Figure 2
Size distributions of 3 µm, 5 µm, and 10 µm polystyrene latex spheres (PSL) aerosolized by the FMAG

Aerosolizing Dissolved Materials

Solids – Ammonium Sulfate

A wide variety of solid materials may be aerosolized from a solvent-dissolved state. Recommended compounds include ammonium sulfate, sodium chloride, and sucrose.

Figure 3 shows three size distributions of particles generated by the FMAG using ammonium sulfate solutions of differing concentrations. Left to right, the geometric standard deviations (as measured by the APS) of these three distributions are 1.06, 1.07, and 1.06, respectively. In this plot, the second of the three peaks is shown at 10% of its original magnitude.

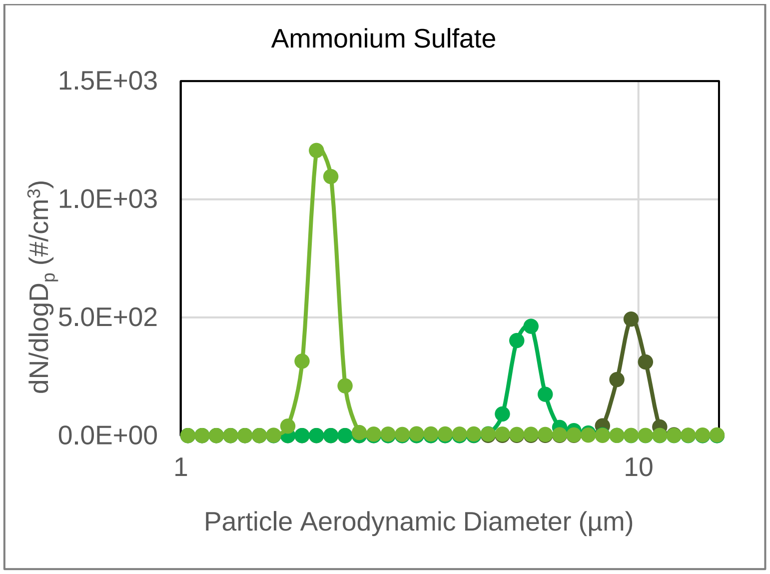


Figure 3
Size distributions of ammonium sulfate particles generated by the FMAG

Liquids – Glycerol

Liquid particles (which may also be referred to as *droplets*) can also be generated by the FMAG. Numerous applications call for aerosols of oleic acid, emery oil, or corn oil. These materials can be aerosolized by dissolving them in methanol at a known concentration.

Figure 4 shows three particle size distributions of glycerol particles generated by the FMAG using a solution of glycerol in methanol. Left to right, the geometric standard deviations of these distributions (as measured by the APS spectrometer) are 1.06, 1.06, and 1.04 respectively. In this plot, the second and third peaks are shown at 100 times their original magnitude.

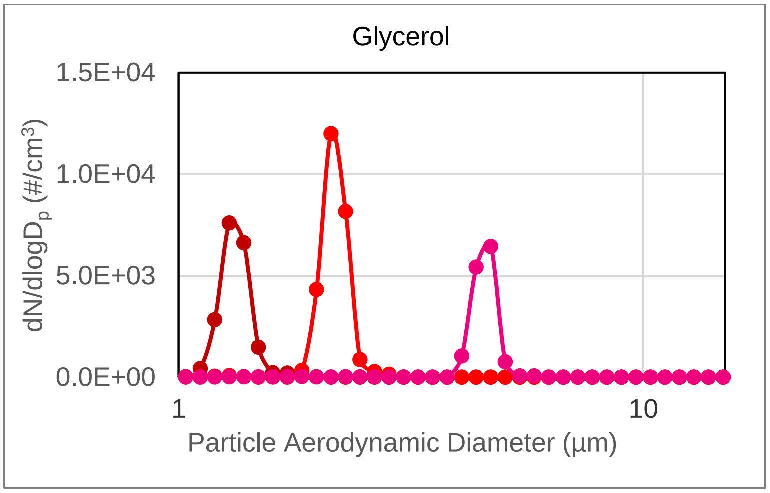


Figure 4
Size distributions of glycerol particles generated by the FMAG

The FMAG can successfully generate monodisperse particles from glycerol—a more viscous substance—as well as other liquids such as oleic acid.

Size Accuracy of FMAG-Generated Aerosols

The volume-equivalent diameter of FMAG-generated particles can be calculated easily from three parameters: the solution volume concentration, vibrating frequency, and liquid flow rate.[1]

Figure 5 shows the relationship between the theoretical and measured aerodynamic sizes of the FMAG-generated aerosols for which size distributions are shown in Figures 2 to 4. The data points in Figure 5 are color-coded to Figures 2 to 4.

All data points in Figure 5 fall within the ± 5% envelope, indicating that the FMAG's particle generation is very accurate with respect to the final particle size after complete solvent evaporation.

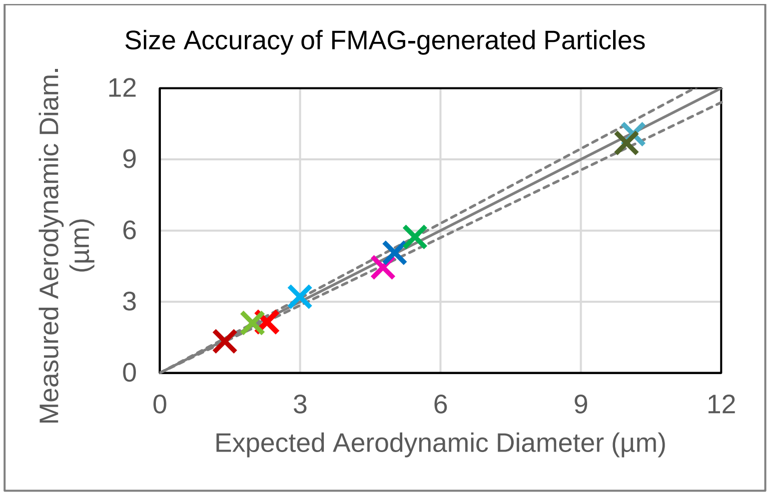


Figure 5
Size accuracy of FMAG-generated particles. The dashed lines indicate ± 5% around the 1:1 line

Effective density values used for calculation of expected aerodynamic diameter were 1.05, 1.67, and 1.26 g/cm^3 for Figures 2 to 4, respectively, and applied shape factors were 1.0, 1.07, and 1.0, respectively.

While optical sizing instruments are common, the quality of the data they generate can be significantly influenced by the optical properties of the particles. Some applications may call for particles that do not have well-understood optical properties. In such cases, aerodynamic sizing is likely to produce the highest quality data.

Summary

The Flow-Focusing Monodisperse Aerosol Generator by TSI/MSP® generates highly monodisperse aerosols of highly accurate particle diameter in the range of 0.8 to ~10 µm. The instrument is easy to use, requires very little maintenance, and changing from one particle recipe to the next can be done in a matter of minutes. Recommended solvents include ultrapure water and methanol, and a wide variety of particle types are compatible with these solvents.

If the FMAG is of interest to you, please feel free to contact TSI® Incorporated. We will be happy to discuss your application with you to see if the FMAG is a good fit for your needs.

References

1. Duan, H.; Romay, F.J.; Li, C.; Naqwi, A.; Deng, W.; Liu, B.Y.H. (2016) Generation of monodisperse aerosols by combining aerodynamic flow-focusing and mechanical perturbation, *Aerosol Science and Technology*, **50:1**, 17-25, DOI: 10.1080/02786826.2015.1123213

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