CleanAir Engineering
500 W. Wood Street
Palatine, IL 60067-4975
800-627-0033
www.cleanair.com

Choosing the Right Particle Sizing Instrument for the Application

For emissions measurements, the EPA has kept the techniques and calculations as simple as possible by choosing aerodynamic particle diameters. This would suggest one of the previously mentioned in-situ sampling methods.

There is no single sizing technique that is superior in all applications. The instrument selected for an application must be suitable for the material to be measured and for the environment in which it is to be used. It must also provide data to meet the specific needs of the application. This may mean fast, repeatable analyses, or it may mean high-resolution and very accurate results. The determination of particle size distribution is seldom the actual objective. Determining how particle size affects something else is usually the reason for the measurement. In this regard, the characteristic actually being measured and related to size may be more important that size, but size is the conventional way to express the characteristic.

For example, sizing particulate matter exiting a power plant stack may be performed using in-situ impactors via CARB Method 501. But, what actually may be of interest is the deposition mechanism. In this case, size is a way of expressing sedimentation velocity and the sedimentation size (Stokes size) may be of more value.

It should be noted that all of the discussed techniques assume spherical particles. Measuring an attribute arising from a non-spherical particle, then reducing the data from those measurements using spherical model will introduce error. The magnitude of error depends on the technique and the data reduction methods.

The bottom line is: Different techniques are likely to produce different size results for the same sample, and all of them are likely to be correct.

What Particle Size Measurement Techniques are Available?

Various laboratory techniques are available. Each technique will have its own conditions and possible constraints. If these constraints are ignored, the accuracy of reported size data can be significantly affected. They are discussed in the following pages.

Sieve Analysis

This technique continues to be used for many measurements because of its simplicity, cost effectiveness and ease of interpretation. Methods may be simple shaking of the sample in sieves until the amount retained becomes constant or the sample may be washed through with a non-reacting liquid (usually water) or blown through with an air current. This technique is often used for determining Silt content of Road Dusts in accordance with methodology discussed in AP-42. It's also used to determine size fractions for milled coal and limestones.

CleanAir Engineering
500 W. Wood Street
Palatine, IL 60067-4975
800-627-0033
www.cleanair.com

The technique depends on the particles falling through square holes in a mesh sieve tray (see photo of a sieve tray to the left). This is a physical size measurement, not an aerodynamic description of the particles.

The resultant data are not relatable to settling velocity of particles.

Technique Advantages

This technique is well-adapted for bulk materials. A large amount of materials can be readily loaded into eight-inch diameter sieve trays. Two common uses in the power industry are wet-sieving of milled limestone and dry-sieving of milled coal.

Milled limestone is generally analyzed in accordance with EPRI Method G1[1].

Milled Coal is generally analyzed in accordance with ASTM Method D197-87 (Reapproved 2007).

Technique Disadvantages

The most obvious disadvantage is that the smallest practical sieve size (400 Mesh) is 37 µm, and many applications are concerned with much smaller sizes than this.

The amount of energy used to separate size ranges is arbitrarily determined. Over-energetic sieving can cause attrition of the particles. Insufficient energy can fail to break down loose agglomerates.

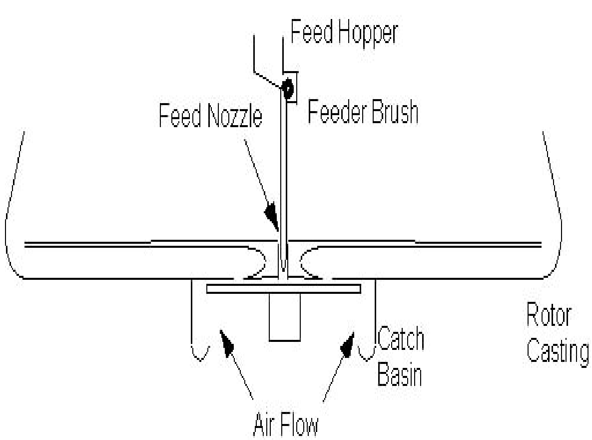
Air Elutriation (Bahco™) Analysis

Most collection devices are sized using Stokes particle size distribution data. A good deal of this work was generated years ago using data from a Bahco™ Centrifugal Classifier. The Bahco is the particle sizing device recommended by the Industrial Gas Cleaning Institute to determine particle size and collection efficiency of mechanical collectors. It was also the device used to gather data for the Electric Power Research Institute's Electrostatic Precipitator Model (ESP Computer Model). Operation and calibration of the Bahco™ is described in the American Society of Mechanical Engineers Power Test Code 28[1].

CleanAir Engineering
500 W. Wood Street
Palatine, IL 60067-4975
800-627-0033
www.cleanair.com

The Bahco™ Centrifugal Classifier is a combination air centrifuge-elutriator consisting of a rotor assembly driven by a totally enclosed electrical motor. The sample is introduced into a spiral shaped air current flowing toward the center. The spiral current of air has suitable values of tangential and radial velocities so that a certain part of the sample is accelerated by the centrifugal force toward the periphery of the whirl, the other part of the sample is being carried by the air current toward the center of the whirl by aerodynamic means. The size, shape and mass of the particles individually determines which direction they will take in the air current.

By varying the air flow, it is possible to change the terminal velocity limit of division and thus the material can be divided into a number of fractions with limited terminal velocity ranges. The instrument has eight calibrated throat spacing rings for eight different air flows. These throat spacing rings are set for flow rates that nominally separate particles into eight size ranges between one and twenty-five micrometers.



Technique Advantages

This technique is well-adapted for bulk materials and is non-destructive.
Each cut-point can be recovered for future size-respective chemical analysis and/or characterization.
Particle size is determined as a function of settling velocity in an air stream (as opposed to some other fluid).
Particle density measurements will allow determination of Stokes diameters.

Technique Disadvantages

A bulk sample (about 8-10 grams) must be obtained.
The technique is a fairly time-consuming manual feed method.
The actual ASME test method has been withdrawn due to obsolescence. Instrument calibration materials are therefore generally not available.

X-ray Sedimentation Technique

Another common analytical technique is X-Ray Sedimentation. Clean Air has used Micromeritics Analytical Services to perform these types of analyses. This technique takes advantage of the natural tendency of particles to separate by size as they settle through a liquid medium.

A homogeneously dispersed mixture of solid sample and liquid is next circulated through the cell. The solid particles absorb some of the X-ray energy, which again is measured, this time to establish a value for full scale attenuation. Agitation of the mixture is ceased and the dispersion is allowed to settle while X-ray intensity is monitored. During the sedimentation process, the largest particles are first to fall below the measuring level, and each mass measurement

CleanAir Engineering
500 W. Wood Street
Palatine, IL 60067-4975
800-627-0033
www.cleanair.com

represents the cumulative mass fraction of the remaining fine particles. Gradually, finer and finer particles settle out, ultimately clearing the measuring zone of suspended particles and allowing the X-ray beam to again pass through the cell unattenuated.

Technique Advantages

This technique is well-adapted for bulk materials.
Particle size is determined as a function of settling velocity.
Particle density measurements will allow determination of Stokes diameters.

Technique Disadvantages

A bulk sample (about 2-5 grams) must be obtained.
Samples must be dispersed in a liquid medium, which could cause dissolution of some components. This could alter the size distribution.
X-rays will not count carbon or organic particles.

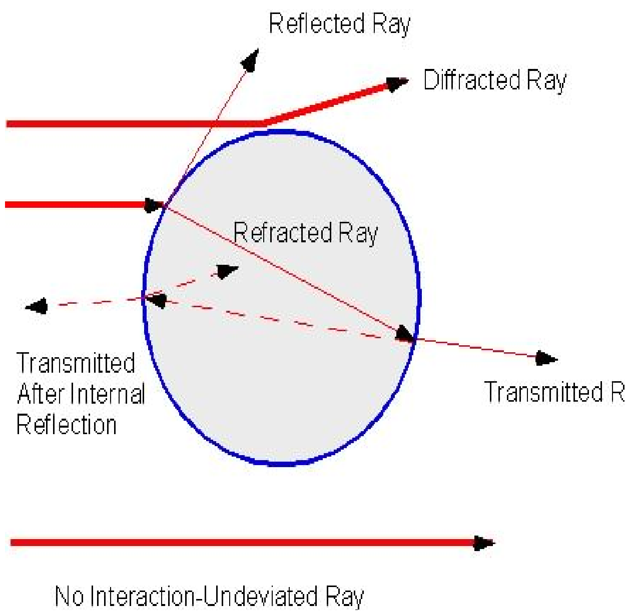
Light Scattering Technique

Laser light scattering methods use Mie and Fraunhofer Theories to determine particle size distribution from a light scattering pattern. Clean Air Engineering has experience with more than one vendor capable of analyzing samples using this technique. These include Malvern Instruments, Microtrac and Micromeritics Analytical Services. All three vendors have the capability of analyzing either wet or dry samples.

Mie theory provides the fundamental light scattered by an individual particle is a function of the scattering pattern produced by spherical particles of a specific size. The intensity I is a function of the angle Θ, wavelength Λ, the particle size x, and the optical properties of the system (specifically, the index of refraction n of the particle relative to the suspension medium).

The wavelength of the incident light is a design constant, and relative index of refraction is an input parameter determined by the sample material and suspension medium. Therefore, the intensity of the scattered light I is a function of the remaining variables Θ and x, the scattering angle and particle size, respectively.

Clean Air has most often used this technique for characterization of gypsum particles in scrubber slurries. In fact, many customers specifically call for this technique. It is also very useful for analyzing paint solids.



Technique Advantages

These instruments can measure particle sizes from 0.1 to 1,000 µm in just minutes.
These types of instruments are readily adaptable for on-line sampling of particle-laden streams.
Mie theory assumes spherical particles, much like the Stokes theory.

Technique Disadvantages

A bulk sample (about 2-5 grams) should be obtained.
Particle morphology (e.g. particle color and/or refractive index) can alter the measured size distribution.
The resultant data are not relatable to settling velocity of particles.

CleanAir Engineering
500 W. Wood Street
Palatine, IL 60067-4975
800-627-0033
www.cleanair.com

Electroresistance Counting Techniques

An example of this is the Coulter Counter, which measures the momentary changes in the conductivity of a liquid passing through an orifice that occurs as individual non-conducting particles pass through. The particle count is obtained by counting pulses, and the size is dependent on the size of each pulse.

Clean Air Engineering has experience with more than one vendor capable of analyzing samples using this technique. These include Micromeritics Analytical Services, Beckman-Coulter and Particle Technology Labs, Ltd.

This technique has been used with success on control device outlet filter catches with very low grain loadings. As little as 100 mg on a filter catch have been characterized for particle size distribution.

Technique Advantages

These instruments can generally measure particle sizes from 0.4 to 400 µm.
Works well with small sample aliquots (e.g. as little as 100 mg). Capable of counting and sizing particles at concentration levels not detectable by other technologies.
Particle color or refractive index does not affect results.

Technique Disadvantages

This technique depends on cross-sectional area of particles as they pass through an orifice. Particle orientation can affect the measured size.
Fibrous filters can interfere with the analysis. Teflon membrane filters can minimize these interferences.

CleanAir Engineering
500 W. Wood Street
Palatine, IL 60067-4975
800-627-0033
www.cleanair.com

The resultant data are not relatable to settling velocity of particles.

Optical Counting Methods

Computer controlled scanning electron microscopy (CCSEM) is an efficient technique to obtain particle size distribution. Manual microscopy techniques do not allow measurement of a significant number of particles for most data requirements. Newer computer programs allow automation and the counting and sizing of thousands of individual particles.

Clean Air has used RJ Lee Group as a subcontractor for this type of analysis on all sorts of samples. The electron beam can also be coupled with energy dispersive fluorescence to determine particle chemistry in the same analysis. A specific advantage of this technique is the characterization of individual particles using a narrow beam.

Technique Advantages

These instruments can generally measure particle sizes from 0.4 to over 100 µm. Works well with small sample aliquots (e.g. as little as 100 mg). Capable of counting and sizing particles at concentration levels not detectable by other technologies.
It is not limited by either the refractive index or the light scattering properties of the sample.
CCSEM is able to measure the size of individual particles in agglomerations, whereas light scattering techniques can not.
Individual particle morphology and chemical composition can be determined when the analysis is coupled with energy dispersive fluorescence.

Technique Disadvantages

The technique can be more expensive than other available methods.
The resultant data are not relatable to settling velocity of particles.
Fibrous filters can interfere with the analysis. Teflon membrane filters can minimize these interferences.

---

[1] Determining the Properties of Fine Particulate Matter: Power Test Codes. American Society of Mechanical Engineers, New York, New York. 1996.