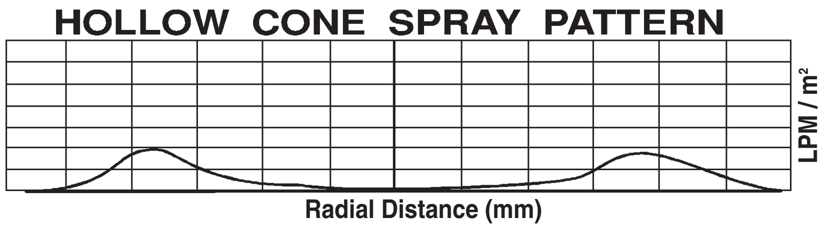
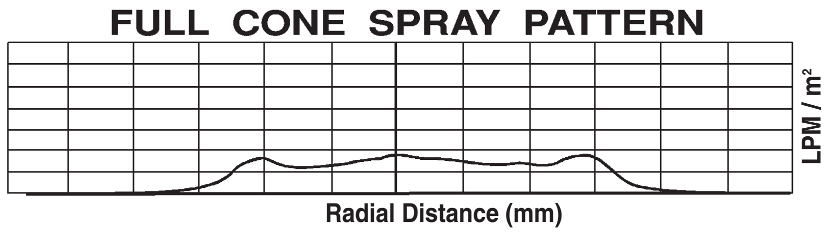
is useful in estimating the pressure a pump will have to supply to a nozzle system:

$$P_{Pump} = P_{Nozzle} + P_{Pipe\ Losses} + \frac{\rho g h}{100000}$$

where:
ρ = density of fluid (kg/m^3)
[water = 1000 kg/m^3]
g = 9.81 m/s^2
h = height of nozzle above pump (m) - negative if the nozzle is below the pump
p = pressure (bar)





A chart of pipe friction losses is presented on page 108. In using the chart be sure to look at the *total* system flow if there are multiple nozzles to be supplied by one pipe. Elbows, tees and other pipe fittings (see p. 108) also contribute to pressure loss and can be significant, especially in short, convoluted runs.

SPRAY ANGLE
The spray angle chosen for a particular application depends on the coverage required.

The spray angle for spiral nozzles is relatively stable over a wide range of pressures, while the spray angle for whirl nozzles tends to decrease as the pressure is increased. For additional information see page 114.

NOZZLE SPRAY PATTERN
The term “Spray Pattern” describes the location and spray density of the liquid emitted from a nozzle. Two examples of pattern measurement are shown above. The height of the curve at any point is the spray density in units of LPM/m^2.

DROPLET SIZE
Droplet size is often critical. Many processes such as gas scrubbing depend on exposing the maximum possible amount of liquid surface to a gas stream. Other applications require that the droplets be as large as possible, such as when the spray must project into a fast moving gas stream.

Exposing the maximum surface area requires breaking the liquid into droplets as small as possible. To get an idea of how this works, imagine a cube of water with a volume of 1 m^3. This cube has a surface area of 6 m^2. If we now split it in two, we expose some of the inner surface and increase the total surface area to 8 m^2. Atomizing the liquid into spheres 1 mm (1,000 microns) in diameter would increase the surface area of this gallon of liquid to 6000 m^2.

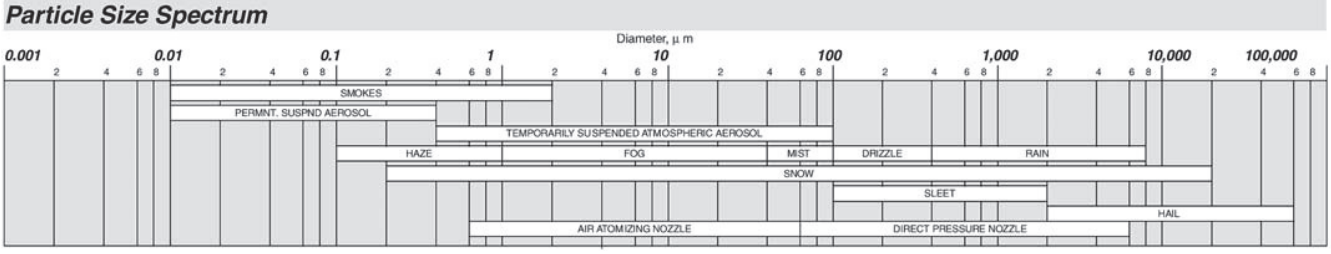
A nozzle actually produces a range of droplet sizes from the solid liquid stream. Since it is inconvenient to list all the sizes produced, droplet size (in microns) is usually expressed by a mean or median diameter. An understanding of diameter terms is essential.

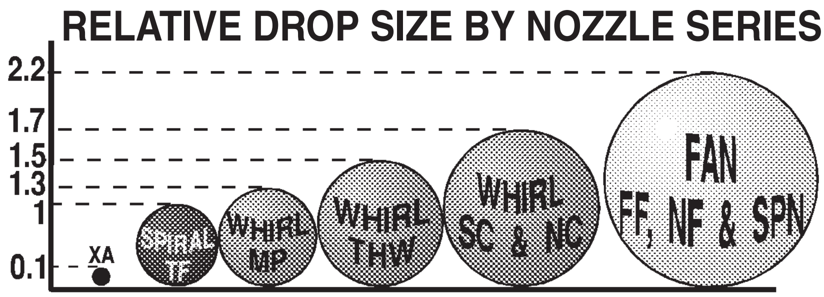
The following definitions are given for the most frequently used mean and median diameters:

Arithmetic Mean Diameter (D_{10})
- The average of the diameters of all the droplets in the spray sample.

Volume Mean Diameter (D_{30})
- The diameter of a droplet whose volume, if multiplied by the total number of droplets, will equal

Particle Size Spectrum





the total volume of the sample.

Sauter Mean Diameter (D_{32}):
- The diameter of a droplet whose ratio of volume to surface area is equal to that of the complete spray sample.

Mass (Volume) Median Diameter (DV_{05}):
- The diameter which divides the mass (or volume) of the spray into two equal halves. Thus 1/2 of the total mass is made up of droplets with diameters smaller than this number and the other half with diameters that are larger.

The Sauter Mean Diameter is one of the most useful ways to characterize a spray. The ratio of volume to surface area for the Sauter Mean is the same as that ratio for the entire spray volume. For this reason, the use of the Sauter Mean is preferred for process calculations.

Whirl nozzles generally produce larger droplets than spiral nozzles, and air-atomizing nozzles such as the XA or SpiralAir Series typically produce the smallest droplets of all.

It is sometimes useful to predict the effect a change in pressure will have on the droplet size produced by the nozzle. For single fluid nozzles the following equation may be used for modest changes in pressure:

$$\frac{D_2}{D_1} = \left(\frac{P_2}{P_1}\right)^{-0.3}$$

TROUBLESHOOTING BASICS

The following are some of the things to look for when a system is not performing as intended:

Nozzle Wear or Corrosion
- may cause excessive flow rate due to enlarged passages
- may increase droplet size
- degrades spray pattern

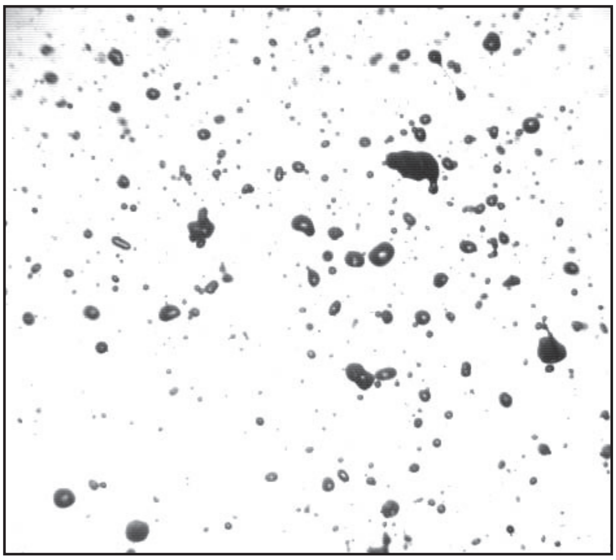
Nozzle Clogging
- low flow rates
- poor spray pattern

Inadequate Pipe Size
- excessive pipe pressure losses leading to low nozzle pressures
- high velocities in headers that disrupt fluid entering the nozzle

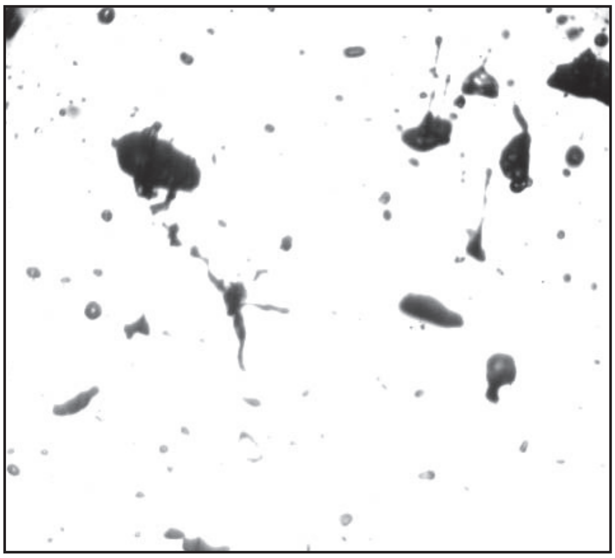
Incorrect Nozzle Location
- poor gas/liquid contact in scrubbers and quenchers
- poor area coverage

Incorrect Nozzle for Application
- drop size too small or too large
- incorrect pattern type

Careful system design and selection of the proper BETE nozzle will minimize spray problems.



Actual droplet images captured using the BETE Model 700 Spray Analysis System.



The BETE Droplet Analyzer is capable of characterizing non-spherical droplets like those seen in this actual image.