# Measuring droplet size

A spray nozzle produces a range of droplet sizes that can often be summarized by a single number. Which single number is appropriate to use to compare the droplet spectrum of several sprays depends on the application.

There are two elements to consider when measuring droplet size

Firstly there will be a spread of droplet sizes within a spray so some kind of average will need to be taken but which type of average is appropriate. Secondly there are different methods for actually analysing sprays and they will produce different results depending on the type of spray. It is important to understand which is being used and particularly to ensure that same method is used when comparing the sprays produced by two different nozzles.

Different averages

**Arithmetic Mean Diameter (D10)**

• The average of the diameters of all the droplets in the spray sample.

**Volume Mean Diameter (D30)**

• The diameter of a droplet whose volume, if multiplied by the total number of droplets, will equal the total volume of the sample.

**Sauter Mean Diameter (D32):**

• 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 (DV0.5)**

• 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.

- DV0.1 would represent the diameter of which 10% of droplets are smaller than and DV0.9 would represent the diameter that 90% of droplets are smaller than.

**Relative span**

Relative span is a measure of how varied the droplet sizes are in a given spray. It is defined as Rs= (DV0.9 – DV0.1)/DV0.5

**Uses of the different terms**

**Sauter mean**

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. Whenever overall surface area is a critical factor in spray performance such as in cooling or gas scrubbing applications then SM diameter is a good comparative tool for deciding which spray will be most effective.

**Mass Volume**

The Mass (Volume) medium diameters might be appropriate when the drift of a fluid is important. When, for example, spraying a toxic material it may be important to ensure that very few droplets are formed below a certain size as smaller droplets are more prone to drift in winds. A spray with a lower Sauter mean diameter could still produce more droplets that are below a certain threshold diameter.

**Relative span**

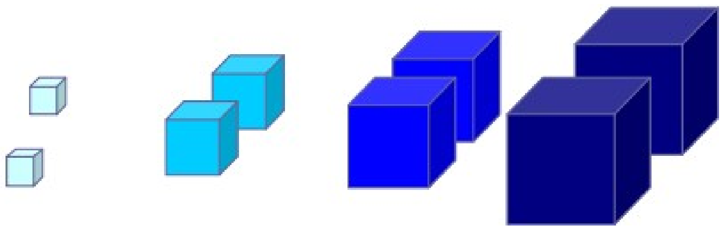
When a very even distribution of spray is required a lower relative span is generally desirable. This is because similarly sized droplets tend to behave in similar ways and follow similar trajectories. If there is a large spread in droplet sizes then there can be a tendency for particles to group in certain areas depending on droplet size. This grouping is inevitable to a certain extent in all sprays but with larger relative span spray the effect is more pronounced resulting is less even fluid distribution.

**<u>How a larger average droplet size can mean the presence of more small droplets</u>**

Too show this phenomena we shall examine two differently composed sprays.  For illustrative purposes, and to make the maths simpler, we shall make each droplet perfect cubes rather than spheres.  The cubes have a sides lengths of 1,2,3 and 4 units. Meaning they have volumes of 1,8,27 and 64 (i.e. $1^3$,$2^3$,$3^3$,$4^3$) units respectively.

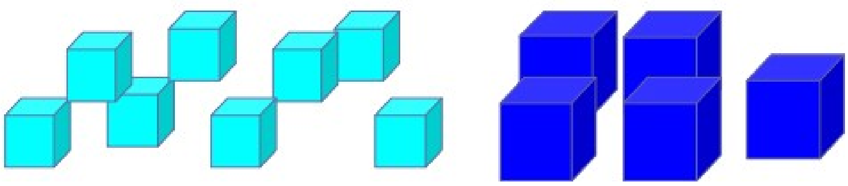
The average droplet size is simply found by multiplying the number of droplets of each size by the side length, adding these totals up and dividing by the total number of droplets in the spray sample i.e. it is a standard arithmetic mean size.

**Spray Sample 1**



| | Droplet size 1 | Droplet size 2 | Droplet size 3 | Droplet size 4 |
|---|---|---|---|---|
| Number of drops | 2 | 2 | 2 | 2 |
| Volume per droplet | 1 | 8 | 27 | 64 |
| Volume contribution | 2 | 16 | 54 | 128 |
| | | | Total Volume | 200 |
| | | | Average drop size | 2.5 |

**Spray Sample 2**



| Droplet size 1 | Droplet size 2 | Droplet size 3 | Droplet size 4 | |
|---|---|---|---|---|
| Number of drops | 0 | 8 | 5 | 0 |

| | | | | |
|---|---|---|---|---|
| **Volume per droplet** | **1** | **8** | **27** | **64** |
| **Volume contribution** | **0** | **64** | **135** | |
| **Total volume** | | | **Total volume** | **199** |
| | | | **Mean Average drop size** | **2.38** |

So we can see that spray 2 has a smaller average droplet size than spray 1 but has no droplets of size 1. If we were selecting a spray purely on mean droplet size and wanted to ensure that there were very few droplets below a certain size then we might be tempted to select spray 1 as its average droplet size is larger.

When considering roughly spherical droplets the mathematics is slightly different but the principle is the same namely a smaller average droplet size does not necessarily mean that there will be more droplets below a certain size. If the spectrum of droplet sizes is wide then the larger droplets present in the mix may drag up the mean droplet size and thus mask the fact that some very small droplets are present in the spray. This may have implications for certain applications.