Designation: E 799 – 92 (Reapproved 1998)

Standard Practice for Determining Data Criteria and Processing for Liquid Drop Size Analysis[1]

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1. Scope

1.1 This practice gives procedures for determining appropriate sample size, size class widths, characteristic drop sizes, and dispersion measure of drop size distribution. The accuracy of and correction procedures for measurements of drops using particular equipment are not part of this practice. Attention is drawn to the types of sampling (spatial, flux-sensitive, or neither) with a note on conversion required (methods not specified). The data are assumed to be counts by drop size. The drop size is assumed to be the diameter of a sphere of equivalent volume.

1.2 The analysis applies to all liquid drop distributions except where specific restrictions are stated.

2. Referenced Documents

2.1 *ASTM Standards: ASTM Standard:*

E 1296 Terminology Relating to Liquid Particle Statistics[2]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *spatial*, *adj*—describes the observation or measurement of drops contained in a volume of space during such short intervals of time that the contents of the volume observed do not change during any single observation. Examples of spatial sampling are single flash photography or laser holography. Any sum of such photographs would also constitute spatial sampling. A spatial set of data is proportional to concentration: number per unit volume.

3.1.2 *flux-sensitive*, *adj*—describes the observation of measurement of the traffic of drops through a fixed area during intervals of time. Examples of flux-sensitive sampling are the collection for a period of time on a stationary slide or in a sampling cell, or the measurement of drops passing through a plane (gate) with a shadowing on photodiodes or by using capacitance changes. An example that may be characterized as neither flux-sensitive nor spatial is a collection on a slide moving so that there is measurable settling of drops on the slide in addition to the collection by the motion of the slide through the swept volume. Optical scattering devices sensing continuously may be difficult to identify as flux-sensitive, spatial, or neither due to instantaneous sampling of the sensors and the measurable accumulation and relaxation time of the sensors. For widely spaced particles sampling may resemble temporal and for closely spaced particles it may resemble spatial. A flux-sensitive set of data is proportional to flux density: number per (unit area × unit time).

3.1.3 *representative*, *adj*—indicates that sufficient data have been obtained to make the effect of random fluctuations acceptably small. For temporal observations this requires sufficient time duration or sufficient total of time durations. For spatial observations this requires a sufficient number of observations. A spatial sample of one flash photograph is usually not representative since the drop population distribution fluctuates with time. 1000 such photographs exhibiting no correlation with the fluctuations would most probably be representative. A temporal sample observed over a total of periods of time that is long compared to the time lapse between extreme fluctuations would most probably be representative.

3.1.4 *local*, *adj*—indicates observations of a very small part (volume or area) of a larger region of concern.

3.2 *Symbols:Symbols—Representative Diameters:*

3.2.1 ($\bar{D}_{pq}$) is defined to be such that:[3]

$$\bar{D}_{pq}{}^{(p-q)} = \frac{\Sigma_i D_i^{\,p}}{\Sigma_i D_i^{\,q}} \tag{1}$$

where:

$\bar{D}$ = the overbar in $\bar{D}$ designates an averaging process,
$(p - q)\ p > q$ = the algebraic power of $\bar{D}_{pq}$,
p and q = the integers 1, 2, 3 or 4,
D_i = the diameter of the ith drop, and
Σ_i = the summation of $D_i^{\,p}$ or $D_i^{\,q}$, representing all drops in the sample.
$0 = p$ and q = values 0, 1, 2, 3, or 4.

$\Sigma_i D_i^{\,0}$ is the total number of drops in the sample, and some of the more common representative diameters are:

[1] This practice is under the jurisdiction of ASTM Committee E-29 on Particle Size Measurement and is the direct responsibility of Subcommittee E29.04 on Liquid Particle Measurement.

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[2] *Annual Book of ASTM Standards*, Vol 14.02.

[3] This notation follows: Mugele, R.A. and Evans, H.D., "Droplet Size Distribution in Sprays," *Ind. Engnrg. Chem.* Vol 43, No. 6 (1951), pp. 1317-1324.

$\bar{D}_{10}$ = linear (arithmetic) mean diameter,
$\bar{D}_{20}$ = surface area mean diameter,
$\bar{D}_{30}$ = volume mean diameter,
$\bar{D}_{32}$ = volume/surface mean diameter (Sauter), and
$\bar{D}_{43}$ = mean diameter over volume (De Broukere or Herdan).

See Table 1 for numerical examples.

3.2.2 D_{Nf}, D_{Lf}, D_{Af}, and D_{Vf} are diameters such that the fraction, f, of the total number, length of diameters, surface area, and volume of drops, respectively, contain precisely all of the drops of smaller diameter. Some examples are:

$D_{N0.5}$ = number median diameter,
$D_{L0.5}$ = length median diameter,
$D_{A0.5}$ = surface area median diameter,
$D_{V0.5}$ = volume median diameter, and
$D_{V0.9}$ = drop diameter such that 90 % of the total liquid volume is in drops of smaller diameter.

See Table 2 for numerical examples.

3.2.3

$$\log(\bar{D}_{gm}) = \Sigma_i \log(D_i)/n \qquad (2)$$

where:
n = number of drops,
D_{gm} = the geometric mean diameter

3.2.4

$$D_{RR} = D_{VF} \qquad (3)$$

where:
f = $1 - 1/e \approx .6321$
D_{RR} = Rosin-Rammler Diameter fitting the Rosin-Rammler distribution factor (See Terminology E 1296)

3.2.5 D_{kub} = upper-boundary diameter of drops in the kth size class.

3.2.6 D_{klb} = lower-boundary diameter of drops in the kth size class.

4. Significance and Use [4]

4.1 These criteria[4] and procedures provide a uniform base for analysis of liquid drop data.

5. Test Data

5.1 Specify the data as temporal or spatial. If the data cannot be so specified, describe the sampling procedure. Also specify whether the data are local (that is, in a very small section of the space of liquid drop dispersion), and whether the data are representative (that is, a good description of the distribution of concern). Report the fluids, fluid properties, and pertinent operating conditions.

5.1.1 A graph form for reporting data is given in Fig. 1.

5.2 Report the largest and smallest drops of the entire sample, the number of drops in each size class, and the class boundaries. Also report the sampling volume, area, and lapse of time, if available and applicable.

5.3 Estimate the total volume of liquid in the sample that includes measured drops and the liquid in the sample that is not measured. (The volume outside the range of sizes permitted by the measuring technique might be estimated by graphical extrapolation of a histogram or by a curve fitting technique.)

5.4 The ratio of the volume of the largest drop to the total volume of liquid in the sample should be less than the tolerable fractional error in the desired representation. See Table 1. All of the drops in the sample at the large-drop end of the

[4] These criteria ensure that processing probably will not introduce error greater than 5 % in the computation of the various drop sizes used to characterize the spray.

TABLE 1 Sample Data Calculation Table

Size Class Bounds (Diameter in Micrometres)	Class Width	No. of Drops in Class	Sum of D_i^r in Each Size Class[A] D_i	D_i^2	D_i^3	D_i^4	Vol. % in Class[B]	Cum. % by Vol.
240–360	120	65	19.5×10^3	5.9×10^6	1.8×10^9	$1. \times 10^{12}$	0.005	0.005
360–450	90	119	48.2	19.6	8.0	3	0.021	0.026
450–562.5	112.5	232	117.4	59.7	30.5	16	0.081	0.107
562.5–703	140.5	410	259.4	164.8	105.2	67	0.280	0.387
703–878	175	629	497.2	394.7	314.5	252	0.837	1.224
878–1097	219	849	838.4	831.3	827.6	827	2.202	3.426
1097–1371	274	990	1221.7	1513.7	1883.2	2352	5.010	8.436
1371–1713	342	981	1512.7	2342.1	3641.1	5683	9.687	18.123
1713–2141	428	825	1589.8	3076.1	5976.2	11657	15.900	34.023
2141–2676	535	579	1394.5	3372.5	8189.2	19965	21.788	55.811
2676–3345	669	297	894.1	2702.8	8203.5	24999	21.826	77.637
3345–4181	836	111	417.7	1578.2	5987.6	22807	15.930	93.567
4181–5226	1045	21	98.8	466.5	2212.1	10532	5.885	99.453
5226–6532	1306	1	5.9	34.7	348.5	1534	0.547	100.000
Totals of D_i^r in $\Sigma\kappa$ entire sample		= 6109 $D_{N0.5}$ = 1300	8915.3×10^3 $\bar{D}_{10}$ = 1460	16562.6×10^6 $\bar{D}_{21}$ = 1860 $\bar{D}_{20}$ = 1650	37729.0×10^9 $\bar{D}_{32}$ = 2280 $\bar{D}_{31}$ = 2060 $\bar{D}_{30}$ = 1830 $D_{V0.5}$ = 2540	100695×10^{12} $\bar{D}_{43}$ = 2670		

$\frac{348.5}{37729} = 0.009$ Relative Span $= (D_{V0.9} - D_{V0.5})/D_{V0.5} = (3900–14200/2530 = 0.98$

Worst case class width $\frac{669}{2676 + 3345} \times 0.21826 = 0.024$

Less than 1%, adequate sample size

Adequate class sizes

[A] The individual entries are the values for each κ as used in 5.2.1 (Eq 1) for summing by size class.
[B] SUM D_i^3 in size class divided by SUM D_i^3 in entire sample.