Designation: F 660 – 83 (Reapproved 1993)

Standard Practice for Comparing Particle Size in the Use of Alternative Types of Particle Counters[1]

This standard is issued under the fixed designation F 660; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice provides a procedure for comparing the sizes of nonspherical particles in a test sample determined with different types of automatic particle counters, which operate on different measuring principles.

1.2 A scale factor is obtained by which, in the examination of a given powder, the size scale of one instrument may be multiplied to agree with the size scale of another.

1.3 The practice considers rigid particles, free of fibers, of the kind used in studies of filtration, such as: commercially available test standards of quartz or alumina, or fly ash, or some powdered chemical reagent, such as iron oxide or calcium sulfate.

1.4 Three kinds of automatic particle counters are considered:

1.4.1 Image analyzers, which view stationary particles under the microscope and, in this practice, measure the longest end-to-end distance of an individual particle.

1.4.2 Optical counters, which measure the area of a shadow cast by a particle as it passes by a window; and

1.4.3 Electrical resistance counters, which measure the volume of a particle as it passes through an orifice in an electrically conductive liquid.

1.5 This practice also considers the use of instruments that provide sedimentation analyses, which is to say provide measures of the particle mass distribution as a function of Stokes diameter. The practice provides a way to convert mass distribution into number distribution so that the meaning of Stokes diameter can be related to the diameter measured by the instruments in 1.4.

1.6 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

F 661 Practice for Particle Count and Size Distribution Measurement in Batch Samples for Filter Evaluation Using an Optical Particle Counter[2]

F 662 Method for Measurement of Particle Count and Size Distribution in Batch Samples for Filter Evaluation Using an Electrical Resistance Particle Counter[2]

F 796 Practice for Determining the Performance of a Filter Medium Employing a Single-Pass, Constant-Rate, Liquid Test[2]

3. Summary of Practice

3.1 After calibrating an automatic particle counter with standard spherical particles, such as latex beads, the instrument is presented with a known weight of filtration-test particles from which is obtained the data: cumulative number of particles, ΣN, as a function of particle diameter, d; and a plot of these data is made on log-log paper.

3.2 The plot from the results of one kind of instrument is placed over the plot from another and one plot is moved along the particle-diameter axis until the two separate curves coincide. (If the two separate curves cannot be made to coincide, then this practice cannot be used.)

3.3 The magnitude of the shift from one diameter scale to the other provides the scale-conversion factor.

3.4 Any of the three particle counters in 1.4 can provide the frame-of-reference measurement of particle diameter.

3.5 An alternative reference is the Stokes diameter, as mentioned in 1.5.

4. Significance and Use

4.1 This practice supports test methods designed to evaluate the performance of fluid-filter media, for example, Practice F 796 wherein particle size distributions are addressed and at the same time this practice provides a means to compare size measurements obtained from several different types of instruments.

4.2 The factor for converting one kind of diameter scale to another is only valid for the specific test particles studied.

5. Apparatus

5.1 *Automatic Particle Counters*:

5.1.1 Any, or all, of the three types are employed:

5.1.1.1 *The Image Analyzer*—This instrument counts particles by size as those particles lie on a microscope slide. In this

[1] This practice is under the jurisdiction of ASTM Committee F-21 on Filtration and is the direct responsibility of Subcommittee F21.10 on Liquid Filtration.
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[2] *Annual Book of ASTM Standards*, Vol 14.02.

practice, size means the longest end-to-end distance. This diameter, in the examples to follow, is designated d_e.

5.1.1.2 *The Optical Counter*—This instrument measures the area of a shadow cast by a particle as it passes a window. From that area the instrument reports the diameter of a circle of equal area. This diameter is designated d_o. See Practice F 661.

5.1.1.3 *The Electrical Resistance Counter*—This instrument measures the volume of an individual particle. From that volume the instrument reports the diameter of a sphere of equal volume. This diameter is designated d_v. See Method F 662.

5.2 *Sedimentation Instruments*—These instruments provide a measure of the mass distribution of particles (as opposed to the number distributions determined in 5.1). This diameter, the Stokes diameter, is designated d_s .

6. Procedure

6.1 Calibrate each particle counter with standard, spherical particles, following the instructions of the manufacturer of the counter.

6.2 Present a known mass of particles to the counter. That is, with the image analyzer present a known mass of particles to a field of view; and, with the other counters present a liquid suspension with a known mass concentration of particles.

6.3 In counting particles at the small-diameter end of the spectrum, present at least three different, relatively small, masses of particles. In counting particles at the large-diameter end, present at least three different, relatively large, masses.

6.4 After obtaining the counts (6.3) correct them all to reflect the count of a common mass. For example, correct all counts to show particle distribution for each milligram of solids. Plot the counts in the manner of Fig. 1.

6.5 From these plots select the true number distribution; show it as a solid line as shown in Fig. 1.

NOTE 1—It is important to deduce the optimum raw count to look for during the examination of a liquid where the mass concentration of particles is not known. The manufacturers of each counter specify the maximum count per unit volume of liquid that is meaningful. If the count exceeds this maximum limit, dilute the sample with clean liquid. (*Clean* liquid means that where the particle count is less than 10 %, or preferably less than 1 %, of the sample count.) Alternatively, if the sample shows a count so low that a meaningful count of large particles is not obtained, examine a larger sample.

6.6 Compare the Fig. 1 type plot obtained with one particle counter to the plot(s) made from another counter (or other counters). Follow the example of Fig. 2.

6.7 Now, choose one counter to provide the frame-of-reference measure of diameter. Relate other diameter scales to that "standard." For example, if from the present example of Fig. 2, the d_e scale is the standard, then,

$$d_e = 1.30\, d_o \tag{1}$$

and

$$d_e = 1.72\, d_v \tag{2}$$

or

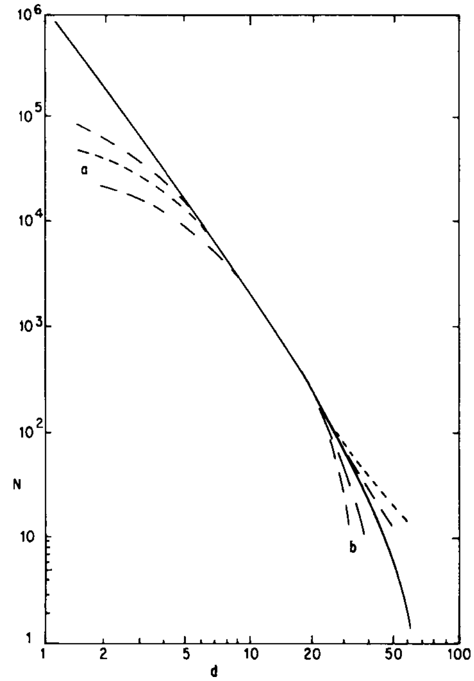
$$d_o = 0.769\, d_e \tag{3}$$

and

$$d_v = 0.581\, d_e \tag{4}$$

6.8 In those cases where measurements of particle-size distribution are based on mass (rather than number), in Fig. 3, convert the Fig. 3 type data to Fig. 1 type data by the following technique:

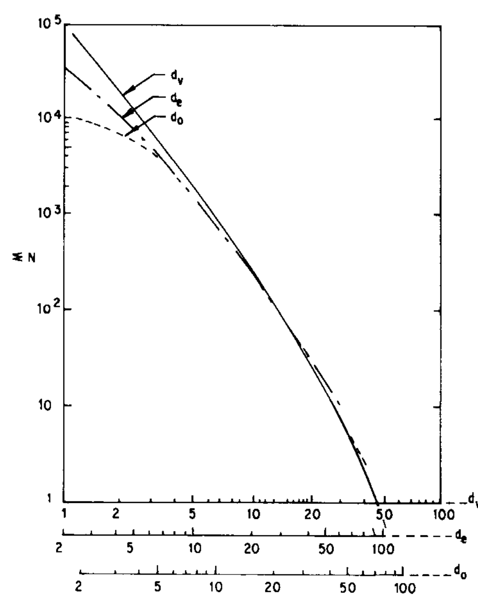
6.8.1 Divide the diameter scale of Fig. 3 into portions so



ΣN	=	cumulative number of particles per unit mass of powder
d	=	particle diameter (see 5.1)

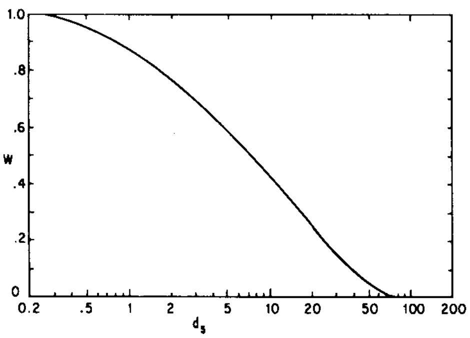
The solid line represents the "real" count. The broken lines represent failures to obtain correct counts because of either presenting too many particles to the counter, *a*, or of presenting too few, *b*.

FIG. 1 Example of Particle Counts



ΣN	=	cumulative number of particles per unit mass of powder
d	=	particle diameter, µm (see 5.1)

FIG. 2 Example of a Blend of Particle Counts Obtained with Different Counters



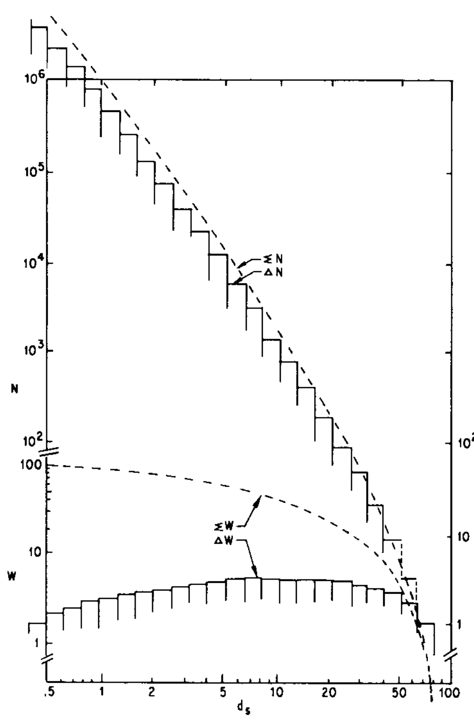
ΣW = cumulative mass of particles per unit mass of powder
d_s = Stokes diameter of a particle, µm

FIG. 3 Example of a Particle-Size Distribution Obtained by Sedimentation Analysis

that there are ten equally wide portions per decade. That is, one portion will be in the diameter scale of 1.00 to 1.26 µm, the next will be in the range 1.26 to 1.59 µm, etc. That is to say, follow the example in Method F 662, where the factor of 1.26 is, in fact, the cube root of 2, that is, 1.25992.

6.8.2 Replot the Fig. 3 data to obtain the ΣW curve and the ΔW bar chart of Fig. 4.

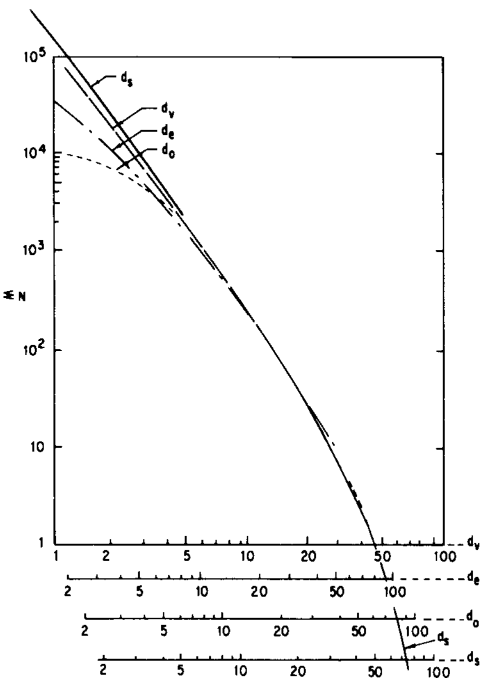
6.8.3 Now, since the diameter scale has been divided into portions where for an equal weight of particles in two adjacent diameter ranges the smaller range will contain twice as many particles, employ this 2.0 factor to convert the ΔW bar chart into the ΔN bar chart; then subsequently draw the ΣN curve.



ΣW = cumulative mass of particles per unit mass of powder, from Fig. 3
ΔW = mass fraction of particles in each diameter range (deduced from ΣW)
ΔN = relative number of particles in each diameter range (deduced from ΔW)
ΣN = cumulative number of particles
d_s = Stokes diameter of particles, µm

FIG. 4 Example of Converting a Weight Distribution into a Number Distribution

6.9 Superimpose the ΣN curve of Fig. 4 over the curves of Fig. 2, to obtain, in the present example, Fig. 5. See, from Fig.



ΣN = cumulative number of particles per unit mass of test powder
d_s = Stokes diameter, µm
d_v = diameter of sphere of equal volume
d_e = longest end-to-end distance
d_o = diameter of circle of equal area

FIG. 5 Blend of Fig. 2 and the ΣN Curve of Fig. 4

5, that

$$d_e = 1.60\ d_s \tag{5}$$

or

$$d_s = 0.625\ d_e \tag{6}$$

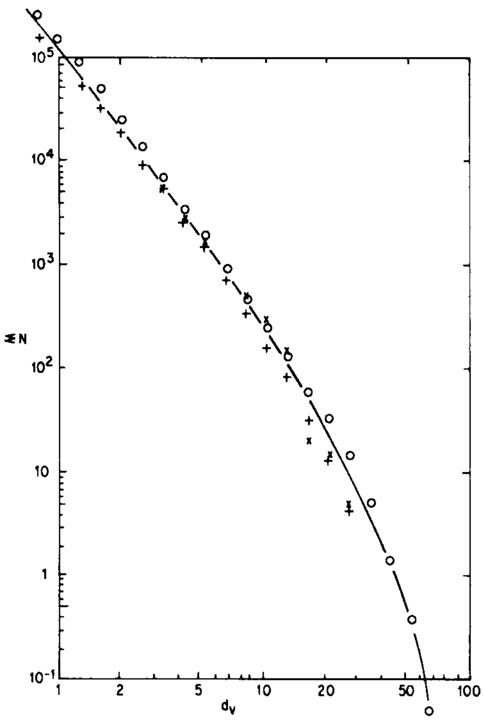
7. Precision

7.1 The examples presented here to explain this practice are results of actual work where different investigators, using different instruments, examined a common lot of quartz test dust.[3]

7.2 Fig. 6 shows the agreement achieved among three investigators, each of whom employed an electrical resistance counter; Fig. 7 shows the agreement among three investigators who employed optical counters.

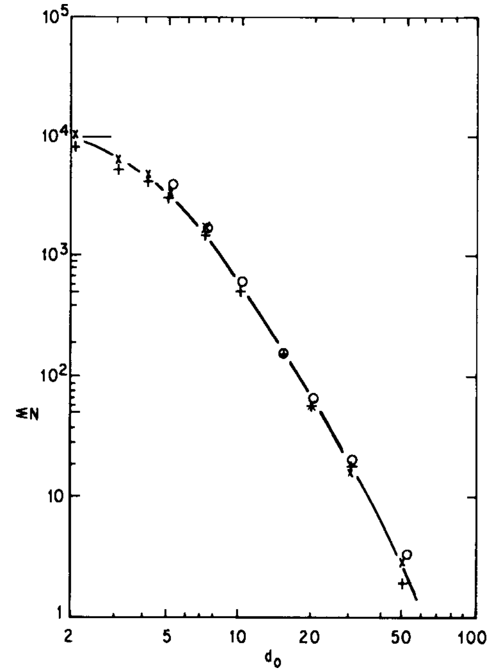
7.3 While the factors reported in 6.7 and 6.9 (for converting one diameter scale to another) are shown as three significant figures, such implied precision is not justified by the present data.

[3] Johnston, P. R., and Swanson, R. R., "A Correlation Between the Results of Different Instruments Used to Determine the Particle-Size Distribution in AC Fine Test Dust," *Powder Technology,* Vol 32, No. 1, pp. 119–124.



ΣN	=	cumulative number of particles per millilitre in a slurry containing 5 mg/L
d_v	=	particle diameter, µm, when instrument is calibrated with standard latex beads

FIG. 6 Particle-Size Distribution in Lot 121 of AC Fine Test Dust as Determined by Three Separate Investigators, in Different Laboratories, Each Employing an Electrical Resistance Counter



ΣN	=	cumulative number of particles per millilitre in a slurry containing 5 mg/L
d_o	=	particle diameter, µm, when instrument is calibrated with standard latex beads

FIG. 7 Particle-Size Distribution in Lot 121 of AC Fine Test Dust as Determined by Three Separate Investigators, in Different Laboratories, Each Employing an Optical Particle Counter

7.4 From the blend of data in Fig. 5 it is obvious that such conversion factors are valid only over a finite range of particle diameters, depending on which instruments are involved.