

SEMI F54-1000

TEST METHOD FOR MEASURING THE COUNTING EFFICIENCY OF CONDENSATION NUCLEUS COUNTERS

This test method was technically approved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Regional Standards Committee on July 13, 2000. Initially available on SEMI OnLine August 2000; to be published October 2000. Previously published June 2000.

1 Purpose

1.1 Particle specifications for gases require the use of condensation nucleus counters (CNCs) having specified counting efficiencies. This document provides the test method for determining the counting efficiencies of CNCs.

2 Scope

2.1 This document provides the method for 1) generating an aerosol standard consisting of sodium chloride (NaCl) particles having sizes 0.01 micrometer and larger suspended in air at atmospheric pressure (1×10^5 Pa), 2) controlling the size and concentration of particles in the aerosol, and 3) using the aerosol to determine the counting efficiency of a CNC as a function of particle size. This method is suitable for CNCs having a lower size sensitivity of 0.01 micrometer or larger.

NOTE 1: Suitable test methods for calibrating optical particle counters are contained in ASTM F328 and JIS B 9921.

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

3 Limitations

3.1 This document does not provide the method for adjusting the CNC's counting efficiency.

3.2 This document does not provide the method for determining the CNC's background noise level, maximum concentration limit, or maximum detectable particle size.

4 Referenced Standards

4.1 ASTM standards¹

ASTM D1193 — Standard Specification for Reagent Water

ASTM F328 — Standard Practice for Calibration of an Airborne Particle Counter Using Monodisperse Spherical Particles

4.2 JIS standard²

JIS B 9921 — Japanese Industrial Standard, Light Scattering Automatic Particle Counter

NOTE 2: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *aerosol electrometer* — an instrument that converts the charge flow in an aerosol stream to an electrical current signal.

5.2 *aerosol standard* — an aerosol containing particles of a known size and concentration.

5.3 *coincidence error* — the inaccuracy in a measured particle concentration caused by multiple particles in the optical sensing volume of an instrument.

5.4 *concentration limit* — the maximum concentration of particles in an aerosol to avoid a coincidence error of 10% or greater in an instrument.

5.5 *counting efficiency* — the ratio of the concentration of particles reported by the CNC to that reported simultaneously from the same aerosol by a reference instrument.

5.6 *lower size sensitivity* — the particle size corresponding to 50% counting efficiency for the CNC.

5.7 *monodisperse aerosol* — an aerosol having a narrow distribution of particle sizes. The maximum band width of a monodisperse aerosol is defined in Section 8.7.

5.8 *particle concentration* — the number of particles per unit volume in a gas.

5.9 *polydisperse aerosol* — an aerosol having a wide distribution of particle sizes.

NOTE 3: Additional terminology is contained in ASTM F328 and JIS B 9921.

¹ American Society of Testing and Materials, 1916 Race Street, Philadelphia, PA 19103, USA

² Japanese Standards Association, 1-24, Akasaka 4-chome, Minato-ku, Tokyo 107, Japan

6 Summary of Method

6.1 The measurement is performed using aerosol standards consisting of NaCl particles suspended in air. Aerosols are produced by nebulizing a solution of NaCl in water. After drying and charge neutralization, particles of the required size are extracted from the aerosol using an electrostatic classifier (EC). The concentration of particles in the resulting monodisperse aerosol is then recorded by the CNC and compared to that measured simultaneously by a reference instrument. Examples of suitable reference instruments are described in Section 8.8.

NOTE 4: This method has been shown to provide repeatable results in tests performed in separate laboratories on similar CNCs. Examples of these tests are found in Agarwal and Sem³ and Bartz, et al⁴.

7 Requirements

7.1 The reference instrument must have a proven counting efficiency of not less than 95% over the entire range of particle sizes tested. Low counting efficiency in the reference instrument results in an error in the measured particle concentration. The counting efficiency for the reference instrument must be checked by the manufacturer against a calibrated standard, such as a calibrated aerosol electrometer.

7.2 Coincidence error in either the CNC or the reference instrument causes inaccuracy in the measured particle concentration. The concentration limit for each instrument must be obtained from the manufacturer's specifications. The particle concentration in the aerosol standard must be kept below both concentration limits.

7.3 When an aerosol electrometer is used as the reference instrument, the minimum detectable particle concentration must be obtained from the manufacturer's specifications. A particle concentration below the minimum detectable value will cause inaccurate results. The particle concentration in the aerosol standard must be kept above the minimum detectable particle concentration.

7.4 The transport loss of particles from the EC to the CNC, and from the EC to the reference instrument must be checked. Any disparity in particle transport loss to the two instruments will cause erroneous results. The method for calculating the transport loss of particles in

sample lines is found in Pui, et al⁵. The transport loss must be calculated for each particle size tested. Record all transport loss calculations.

7.5 When an aerosol electrometer is used as the reference instrument, a correction must be made for multiple charging of particles in the aerosol standard. Multiple charging can cause substantial error when measuring particles larger than 0.06 micrometer. The correction factor for multiple charging must be obtained from the manufacturer of the EC. An example of the method for calculating the correction factor is found in Liu and Pui⁶.

8 Apparatus

8.1 *Atomizer* — A sub-micrometer aerosol generator capable of nebulizing a liquid solution. The atomizer must be capable of producing a stable aerosol containing particles as small as 0.01 micrometer after drying.

8.2 *Liquid Trap* — A device which allows free passage of an aerosol stream containing sub-micrometer particles, but which removes the entrained liquid phase by gravitational settling into a reservoir.

8.3 *Diffusion Drier* — A device which allows free passage of an aerosol stream containing sub-micrometer particles, but which dries the aerosol by diffusion of water vapor into a surrounding desiccant medium. The design flow rate of the diffusion drier must at least match the output flow rate of the atomizer.

8.4 *Aerosol Neutralizer* — A bipolar charging device which neutralizes aerosols by producing both positive and negative air ions. The neutralizer must reduce the charge on the particles to the Boltzmann equilibrium level. The design flow rate of the neutralizer must at least match the output flow rate of the atomizer.

8.5 *Bypass Filter* — A high efficiency point of use gas filter. The design flow rate of the bypass filter must at least match the output flow rate of the atomizer.

8.6 *Mixing Vessel* — A device which disperses particles in a flowing aerosol by inducing turbulence.

8.7 *Electrostatic Classifier (EC)* — A device which extracts particles from a polydisperse aerosol according to their electrical mobility. The electrical mobility of a particle depends upon its size and charge. The EC must extract a monodisperse aerosol standard having a

³ Agarwal, J. K. and Sem, G. J. Continuous Flow, Single-Particle-Counting Condensation Nucleus Counter. *Journal of Aerosol Science*, 11: 343-357 (1980)

⁴ Bartz, H., Fissan, H., Helsper, C., Kousaka, Y., Okuyama, K., Fukushima, N., Keady, P. B., Kerrigan, S., Fruin, S. A., McMurtry, P. H., Pui, D. Y. H. and Stolzenburg, M. R. Response Characteristics for Four Different Condensation Nucleus Counters to Particles in the 3-50 nm Diameter Range. *Journal of Aerosol Science*, 16 (5): 443-456 (1985)

⁵ Pui, D. Y. H., Ye, Y. and Liu, B. Y. H. Sampling, Transport, and Deposition of Particles in High Purity Gas Supply System. *Proceedings 9th ICCCS*: 287-293, (1988)

⁶ Liu, B. Y. H. and Pui, D. Y. H. A Submicron Aerosol Standard and the Primary, Absolute Calibration of the Condensation Nuclei Counter. *Journal of Colloid and Interface Science*, 47 (1): 155-171 (1974)

narrow band width. The mobility band width of the extracted aerosol must be no greater than 20% of the mean particle mobility. The method for calculating electrical mobility and mobility band width are found in Liu and Pui⁶.

8.8 Reference Instrument — An instrument which can measure the concentration of particles in an aerosol. The calibration of the reference instrument must have been checked against a calibrated standard within the past 12 months. Calibration and maintenance records for the reference instrument must be maintained. Suitable reference instruments include aerosol electrometers and CNCs having lower size sensitivities below 0.01 micrometer.

8.9 Condensation Nucleus Counter (CNC) or Condensation Particle Counter (CPC) — The particle counter to be used in process gas particle measurements, and for which the calibration check is required. The CNC detects sub-micrometer particles using nucleation and droplet growth of a super-saturated working fluid.

8.10 Tubing — In order to minimize particle losses, all tubing used to transport charged aerosol particles must

be constructed from electrically conductive materials (e.g., stainless steel) and grounded.

9 Reagents and Materials

9.1 De-ionized or distilled water in accordance with ASTM D1193, Type 1 is required to dissolve NaCl for aerosol generation.

9.2 NaCl is required for aerosol generation.

9.3 A supply of dry, oil-free compressed air is required to generate and transport aerosols in the apparatus.

10 Preparation of Apparatus

10.1 The test apparatus is shown in Figure 1. The particle concentration in the aerosol is controlled using a bypass filter. If the flow rate of the monodisperse aerosol from the EC is insufficient to supply the CNC and reference instrument simultaneously, filtered air must be added to the stream. The air must be added to the aerosol upstream of a mixing vessel. If the flow rate of the monodisperse aerosol from the EC is greater than that required to supply the CNC and reference instrument simultaneously, the excess aerosol must be vented.

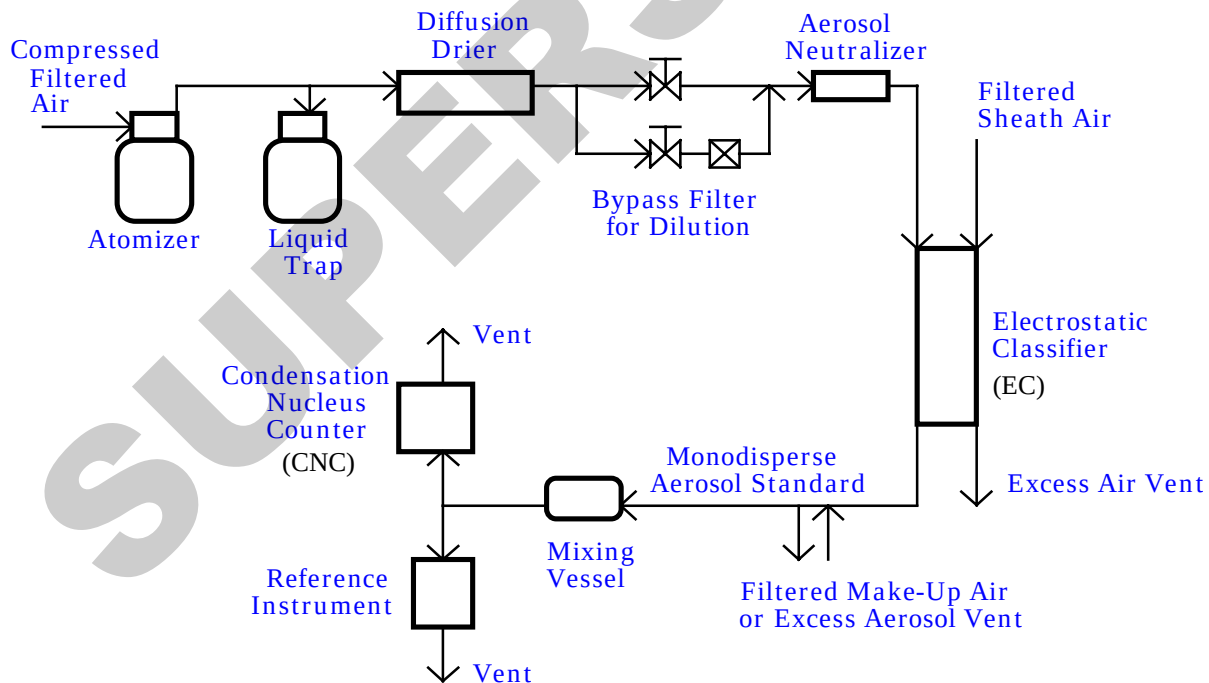


Figure 1
Schematic Diagram of Test Apparatus