Evaluating Indoor Air Quality with the Fluke 983 Particle Counter

Application Note

Introduction

Over the past several years, indoor air quality (IAQ) has been a much debated and publicized topic, especially as it concerns public health. The EPA (USA Environmental Protection Agency) estimates that we spend approximately 90% of our time indoors, and further studies indicate that indoor air in some commercial settings is up to five times more polluted than outdoor air.

Airborne particulates come in a variety of forms ranging from animal dander, plant pollen, and airborne bacteria, to fiberglass, asbestos, and combustion particles. Motionless, human beings alone shed up to 500,000 particles (é0.3µm) per minute. When active, this level can reach up to 45,000,000 particles per minute. Humidity and temperature play a significant role in the generation rate of these pollutants. To properly identify and troubleshoot IAQ problems, the technician needs a tool that not only reads particle concentrations, but also provides insight into the environment that causes pollutants to grow.

Why Particle Counts Matter

Different locations have varying levels of acceptable particulate concentrations, driven primarily by health and comfort concerns (i.e. homes, offices, paint booths) or contamination (i.e. hospitals, food and beverage plants, cleanrooms). Excessive levels can result in medical conditions such as Sick Building Syndrome, lower productivity, contaminated product, or all of the above. Maintaining acceptable air quality levels may not only lower the costs associated with downtime, but also reduce or remove costs associated with expensive fixes in the future. The first step in establishing an IAQ maintenance program is to determine if a problem currently exists.

IAQ Investigation

An IAQ investigation is the first step in an ongoing maintenance program or in responding to complaints potentially associated with air quality. In either case, the methodology is similar:

1. Conduct a survey of credible staff at the facility. Who has filed complaints, and what are the symptoms? Are those who complained centrally located, or dispersed throughout the facility? The purpose is to gauge the level of toxicity as evidenced by allergic reactions or irritation.

2. Research the building's history. When was the building built and/or remodeled? Have there been any instances of excessive damage, and how were the repairs carried out? What are the maintenance practices within the facility? For example, roof or plumbing leaks may have been repaired, but the underlying water damage may not have been addressed.
3. Perform a physical inspection. Technicians need to be aware of their test environments by considering harmful particulate sources. Within a given location, areas containing exhaust vents, furnaces, cleaning supplies, as well as areas with fresh paint and/or carpeting must be accounted for, especially if present within a complaint area. Are there any odors or visible sources (i.e. mold)?
4. Take air quality measurements. When conducting a complete IAQ investigation, temperature, humidity, CO and CO2 readings should also be taken to identify problems related to inadequate and/or contaminated ventilation, potentially creating a particulate problem. For example, temperature and humidity readings play a key role in identifying mold and bacteria. A location with high relative humidity and higher concentrations of particles 3.0 µm or larger may indicate the presence of mold spores, which should be remediated once identified.

The most efficient procedure for assessing indoor air quality is to obtain several outdoor air readings as baselines, noting where the readings are taken in relation to the facility. At least one of the readings should be from near the building's fresh air intake vent. Note, however, the location of the intake vent to ensure baseline readings are not skewed by pollutant sources, for example, locations near a loading dock. An indoor air particulate "target" is then calculated by modifying the baseline readings by the efficiency of indoor filtering.

Particles tend to diffuse very quickly into the surrounding air, making source identification a challenging task. One method is to take multiple indoor readings, starting with the complaint area first, then moving outwards. As data is collected, take note of any unusual increases in particulate quantity and size. Using the Fluke 983's integrated temperature and humidity sensors, gauge the readings against the accepted parameters (NEN-ISO 7730) for temperature and relative humidity. Compare the particle readings against the outdoor baseline to get a feel for the relative severity of the particulate concentration, and identify hotspots and pathways that may lead to the particulate source. Continue to follow the path of higher concentrations until the source is identified. Once the source is remediated, the area is reassessed to ensure the corrective action addressed the problem.

Multiple tools are often used to carry out such an investigation; however, the Fluke 983 includes both temperature and humidity sensors in a device with a six-channel particle display. Armed with this tool, the technician can conduct a basic IAQ investigation and take appropriate steps to treat the problem.

Interpreting the Data

A correct interpretation of the data requires an understanding of the test area. Is the area residential or commercial? Is the location exposed to tobacco smoke or animals? Is there construction at or near the location? A proper assessment of the environment can help narrow down the list of problem particulates.

Concentration limits vary widely according to the size and type of facility, among other variables. However, a high-level assessment can provide direction on whether or not a problem exists. The following outside air readings provide a high-level point of reference for the technician:

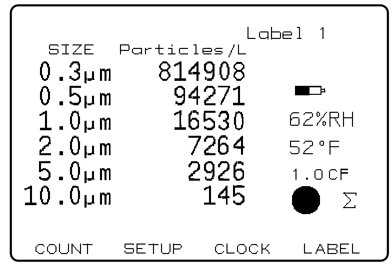

Figure A.

Scenario 1: The particulate levels displayed in Figure B are from a new residence (< 5 years), and do not indicate any concentrations outside of the norm. In a residential setting, particle levels are sometimes higher than outside readings due to more potential particle sources (i.e. pet dander), smaller diffusion area, and often less sophisticated filtration.

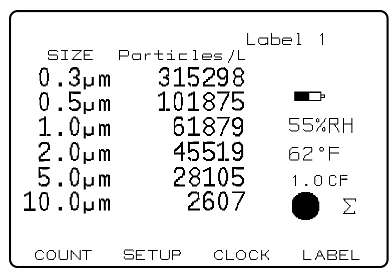

Figure B.

Scenario 2: The particulate levels displayed in Figure C are representative of an average office workspace, and do not indicate any concentrations outside of the norm. In a commercial setting, particle levels should be significantly less than outside readings due to better filtration and better dilution with outside air.

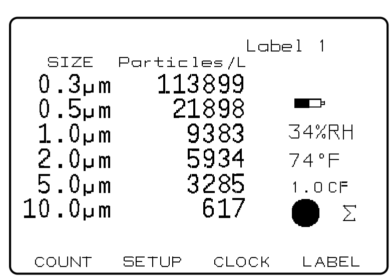

Figure C.

Scenario 3: The particulate levels in Figure D are from an older residential location with visible mold. The readings are significantly higher, and steps should be taken to remediate the mold and address the root cause of the problem.

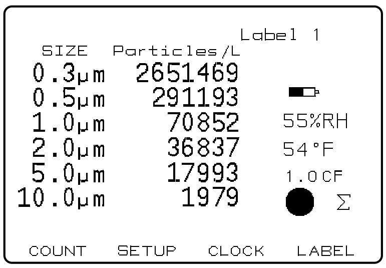

Figure D.

Scenario 4: If the particle source in Scenario 3 is not visible, use particle size tables such as Figure E to identify possible sources. Obtain a sample of the particles and submit to a lab for further analysis.

A Cleanroom Exercise

Cleanrooms are an excellent application for a particle counter. For illustration purposes, let's put the Fluke 983 to the test in evaluating an ISO Class 5 (per ISO 14644-1:1999) cleanroom. To qualify as a Class 5 cleanroom, levels cannot exceed the limits for the class in each particle size stated in the following table:

	Class Particulate Limits					
ISO Classification	**0.1 µm**	**0.2 µm**	**0.3 µm**	**0.5 µm**	**1.0 µm**	**5.0 µm**
	m³	**m³**	**m³**	**m³**	**m³**	**m³**
1	10	2				
2	100	24	10	4		
3	1000	237	102	35	8	
4	10000	2370	1020	352	83	
5	100000	23700	10200	3520	832	29
6	1000000	237000	102000	35200	8320	293
7				352000	83200	2930
8				3520000	832000	29300
9				35200000	8320000	293000

Our test is concerned with the concentration of 0.3 µm particulates in the room. Several 2-liter samples are taken from six different locations inside the cleanroom, with the following results:

	Concentrations (C_1)						Ave. Concentration (AC_1)
Location (L)	**1**	**2**	**3**	**4**	**5**	**6**	
A	750	560	655	730			674
B	1575	1250	750	950	1100	1300	1154
C	1300	850	980	1125	1350	975	1097
D	1150	775	450	825	845	1000	841
E	825	855	730	940	695	925	828
F	1700	1585	1135	900	1725	1210	1376

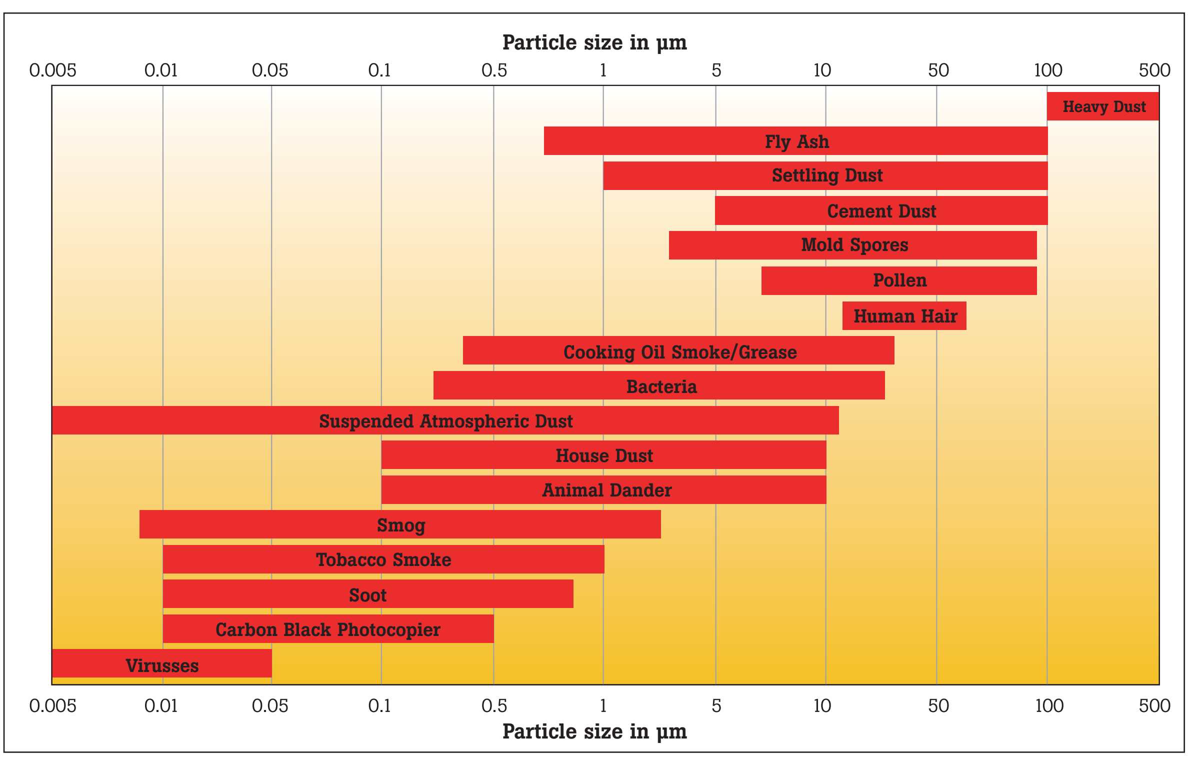

Figure E.

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Making Sense of Particle Counter Features

Using a particle counter is relatively simple; however, understanding the features that distinguish counters can sometimes be a challenge. The following terms are commonly used to describe the accuracy, efficiency, and other attributes of an optical particle counter (OPC).

Count Mode: The count mode defines how the particle counter displays data to the user. Concentration and Totalize are two typical counting modes, and the Fluke 983 adds an Audio mode as well. Concen-tration mode samples a small volume of air then calculates the value based upon the volume setting (cm3 or ft3) in the counter. Totalize mode allows the user to view actual particle counts as they accumulate until the end of the sample. Audio mode is useful when searching for areas with particle levels that exceed predefined parameters. Once levels are exceeded, the counter audibly notifies the user.

Zero Count: Zero count is a measure of the particle counter's accuracy, and should be taken prior to use and periodically thereafter, or when sampling error is suspected. The zero count filter is attached to the particle counter per the manufacturer's instructions, then the counter is run for 15 minutes. The counter should not have detected more than one particle greater than 0.3 µm in a five-minute period.

Coincidence Loss: Coincidence loss occurs when two particles cross the counter's light beam simultaneously, creating a single pulse and resulting in a single particle count. This type of error occurs more frequently as the concentration of particles increases within the sample. Per FED-STD-209E, coincidence loss must be less than 10%.

Counting Efficiency: The probability that the counter will sense and count a particle passing through the sample volume. Counting efficiency is a function of size up to a minimum sensitivity threshold, above which all particles are sensed and counted. A counting efficiency of 50% at the most sensitive threshold is typically considered optimal, and facilitates consistent comparisons between counts from OPCs and those of higher-resolution instruments.

Sensitivity: A device's ability to detect small particle sizes at a certain counting efficiency. The Fluke 983 detects 0.3 µm at 50% counting efficiency.

Resolution: A device's ability to detect minute differences in particle sizes. Sensor resolution is affected by the uniformity of illumination across the sample volume, variations in flow rate, and the relative quality of the optical system. A misaligned sensor or failing laser diode will contribute to poor resolution.

Calibration: A set of operations or actions taken to establish the relationship between the measured values obtained through a device and the values of the corresponding parameters as defined in a standard. The Fluke 983 is calibrated using PSL (polystyrene latex) spheres, widely used due to their uniform size and light-refraction properties.

NIST traceable: Traceability is a characteristic of a measurement or standard and its relationship to stated references, which are often national or international standards. The PSL spheres used in the Fluke 983 calibration process can be traced to NIST (National Institute of Standards and Technology) standards.

The individual readings are well within the limitations for the cleanroom; however, we can take the following steps to determine the statistical validity of the readings:

Step 1: Calculate the mean average particulate concentration

$M = (AC_1 + AC_2 + AC_3 + AC_4 + AC_5 + AC_6) / L$

$995 = (674 + 1154 + 1097 + 841 + 828 + 1376) / 6$

Step 2: Calculate the standard deviation of the averages

$SD = (\sqrt{(AC_1 - M)^2 + \ldots + (AC_6 - M)^2}) / (L-1)$

$116 = (\sqrt{(674-995)^2 + (1154-995)^2 + (1097-995)^2 + (841-995)^2 + (828-995)^2 + (1376-995)^2}) / (6-1)$

Step 3: Calculate the standard error of the mean of the averages

$SE = SD / (\sqrt{L})$

$47.36 = 116 / (\sqrt{6})$

Step 4: Establish the upper confidence limit (UCL)

	Upper Control Limit (UCL) Factor for 95% confidence								
# Locations	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9+**
95% UCL	6.31	2.92	2.35	2.13	2.02	1.94	1.9	1.86	NA

UCL = M + (UCL Factor * SE)

1,087 = 995 + (1.94 * 47.36)

The resulting mean count for all locations is within the requirements of a Class 5 cleanroom.

The Fluke 983 provides particulate data over six channels on a single display, allowing the technician to view all readings at a glance. Though the cleanroom exercise focused on 0.3 µm particulates, the single display would immediately alert the technician to anomalies in other particle size concentrations.

Particle Counting in Perspective

The key to a successful IAQ investigation is to be aware of the environment as a whole. Location, building history, complaints, and measurable factors such as temperature and humidity, can play a key role in uncovering IAQ problems. When using a particle counter, be aware that a particle's source may only be a symptom of a much larger issue looming under the surface. Remediation of the source may not address core problems of poor filtration, ventilation, or excessive moisture. Left unchecked, these conditions will cause the same symptoms, or worse, to reoccur with certainty. The Fluke 983 is a powerful, rugged, and easy to use tool to assist the technician in identifying particulate problems and authenticating the efforts to address their root causes.

Fluke. *Keeping your world up and running.*

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