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Modification of Aerosol Size Distribution by Complex Electric Fields

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Analyses by the writer suggested that electric fields could modify perceived odor and particulate distribution (Frey 1968). In an experiment to test this possibility, it was found that passing animal room air through a complex electric field in the supply duct reduced the perceived odor intensity by a half (Frey 1983). In another experiment using particle mass and laser light scattering measures, it was found that passing air through electric fields substantially decreased the respirable aerosol concentration in a room (Frey 1984). The differences were significant at the .001 level.

In view of these findings, the experimentation reported here was undertaken to determine the mechanism of the effect. Tobacco smoke was used in this experiment, since it consists of respirable size particulates and gasses that are well characterized and can be generated in a simple reliable manner. Since seventy percent of the particulates in mainstream smoke are filtered out by the lungs, sidestream smoke was used. This is the unfiltered smoke emitted from an idling cigarette, cigar, or pipe. Hoegg (1972) found that seventy-five percent of sidestream particles remained suspended in a test chamber after 2.5 hours. They had a median size of 0.7 microns with no particles greater than 2 microns. Thus, sidestream smoke was used to explore how specific electric fields in a duct influence the size distribution of particulates in a room.

METHODS AND MATERIALS

The testing was carried out in a room 4 meters by 11 meters by 2.5 meters high. The room had its own closed circuit air handling system which allowed the fifty percent recirculation used in this experimentation. Air entered the room through a pair of slot supply diffusers near the ceiling centerline, passed down through the room, and exited into a duct through a pair of slot return grills at the bottom of the walls that were parallel to the diffuser slots. In the duct, the air passed sequentially through a smoking device, a 55 percent filter, a blower, three electric field screens, and then re-entered the room through the supply diffusers. The room air change rate was

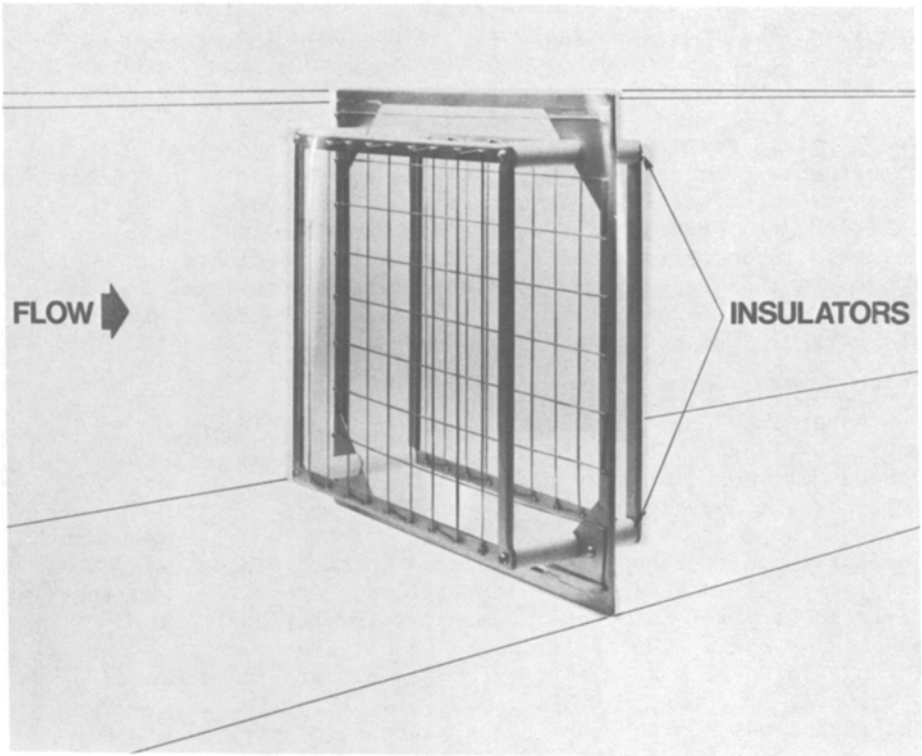

Figure 1. Electric field screens.

10 per hour with fifty percent recirculation. The air supply was filtered through activated alumna to remove moisture. The temperature ranged about 70°F with a relative humidity less than 3 percent. The air in the room was purged to the outside between test runs and said runs were separated by at least two days.

The three electric field screens shown in Figure 1 (A, B, and C with A upstream) were installed in the duct. Screens A and C were 53 x 45 cm and screen B was 55 x 51 cm. Screens A and C consisted of vertical bands of 0.33 cm braided wire 4.5 cm apart on centers. The bands on screen B were horizontal and 5.5 cm apart. The screens were spaced 7.6 cm apart. Electric field generators supplied a 700 V pp, 177 kHz signal that was applied to screen B and also a 25 kV DC signal that was applied to screens A and C. The current was less than 3 ma. Prior experiments showed that no ozone is produced by this system.

The smoke was generated by burning cigarettes in a smoking device in the duct. For a seventy-five minute period in each run a mean rate of 1044 mg/min of airborne burned cigarette products was produced. This mean was calculated from the pre-burn weight of the cigarettes burned less the ash and butts remaining from each run. No run deviated more than 7 percent from this mean.

Two particle measuring instruments were used concurrently in the experiment. One was a Royco, Inc., Model 218 Particle Monitor, which measured particle concentration and size by light scattering. Particles of 0.5 micron diameter and larger can be detected in concentrations up to 10 million particles per cubic foot. Particle size range threshold is selectable and includes 0.5 micron and larger, 1.0 micron and larger, and 2.0 microns and larger. The instrument has a sampling flow rate of 0.01 CFM.

The other instrument used was a California Measurements, Inc., Model PC-2 Aerosol Particle Analyzer, which measures particle concentration and size by mass. It is a 10-stage cascade impactor with quartz crystal microbalance mass monitors in each stage. Two unsealed crystals, one for particle collection and one for temperature sensing, are used in each stage. By use of a crystal pair with the same temperature characteristics, the reference crystal nulls out any temperature effect on the sensing crystal. The nominal aerodynamic diameters (50% cutoff) for particles of a mass density of 2 g/cm^3 are, in microns: 0.05, 0.1, 0.2, 0.4, 0.8, 1.6, 3.2, 6.4, 12.5, and 25.0. The instrument was set for continuous, automatic sampling of the air, with sampling periods of 180 seconds. This instrument provided a printout of the frequency and mass for each stage at the end of each 180 second sampling period throughout each test run. The two instruments were located on surfaces 45 cm high on opposite sides of the room 90 cm from the wall.

During each 90-minute test run, there was no smoke introduced into the air for the first 15 minutes. During the next 20 minutes, the smoking of the cigarettes began and the smoke distribution in the room was allowed to stabilize. During the remaining 55 minutes, the smoking was held at an essentially constant rate. Thus, the primary data for the analyses was the last 55 minutes of each experimental run.

A counterbalanced experimental design was used with the electric fields off for days 1 and 4 and on for days 2 and 3.

RESULTS AND DISCUSSION

In accordance with the experimental design, the days 1 and 4 data (field off) gathered after smoke levels stabilized were combined and the days 2 and 3 data (field on) were combined.

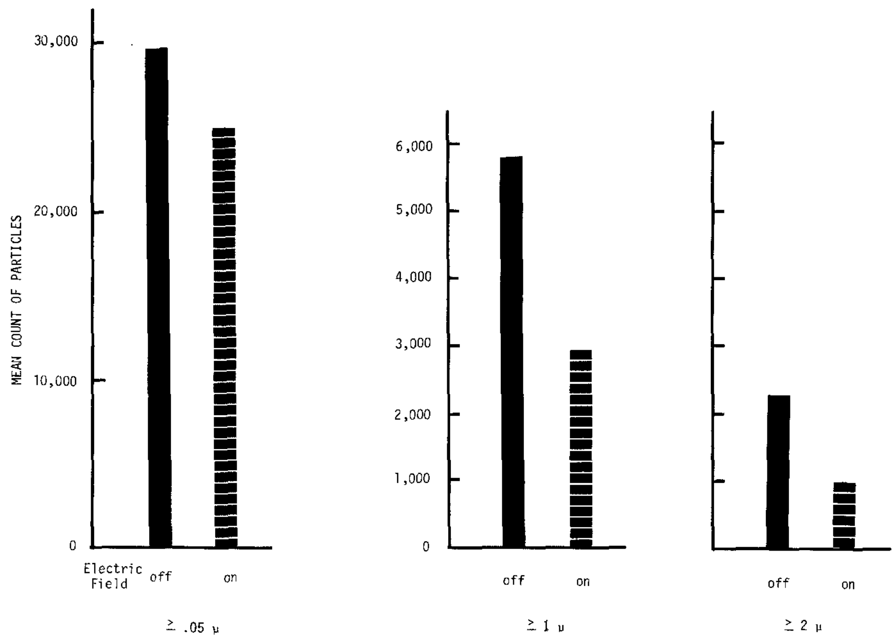

Figure 2. Comparison of mean particle counts in the electric field on vs. off conditions.

The mean counts of the on vs off data for each particle size and larger (0.5 micron, 1 micron, 2 microns) are shown in Figure 2. The statistical analysis of these data show that the mean particle count of size 0.5 micron and larger for the field off condition was 30,013 and for the field on it was 24,882. This difference is statistically significant at the .01 level ($t = 3.63$). The mean particle count of size 1 micron and larger for the field off condition was 5,638 and for the field on it was 2,653. This difference is significant at the .01 level ($t = 3.53$). The mean particle count of size 2 microns and larger for the field off condition was 2,466 and for the field on it was 1,217. This difference is significant at the .01 level ($t = 2.99$).

Statistical tests of the cascade impactor data obtained before smoking began (during the first 15 minutes) showed that there were no significant differences between runs in the number of particles at the various sizes. Thus, all testing started from the same pre-smoke baseline.

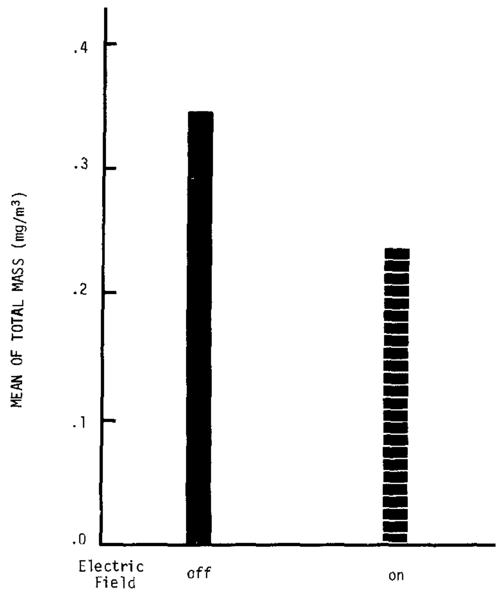

Figure 3. Comparisons of mean masses in the electric field on vs. off conditions.

The first objective in analyzing the cascade impactor data was to see if the results from the two instruments were consistent. Since one instrument operates by light scattering and the other operates by mass measurement, one would expect substantial, though not complete, correlation in the results.

The Royco instrument measured all particulates in the air 0.5 microns and larger. A comparable set of data from the cascade impactor was obtained by summing the data from the first seven stages of the impactor, which includes all particulates 0.4 microns and larger. The mean mass for the electric field on condition, day 2 and 3 data, was significantly less than that for the off condition, day 1 and 4 data, ($t = 3.03$, $p < .005$). This difference is shown in Figure 3. Thus, both instruments indicated that the electric field in the duct was significantly decreasing the particulate concentration in the room.

The crystals for two of the ten stages, the 0.05 micron and the 0.1 micron, overloaded during the last 35 minutes of some of the runs. In the following statistical analyses in which data from those two stages are included, the analyses were done without

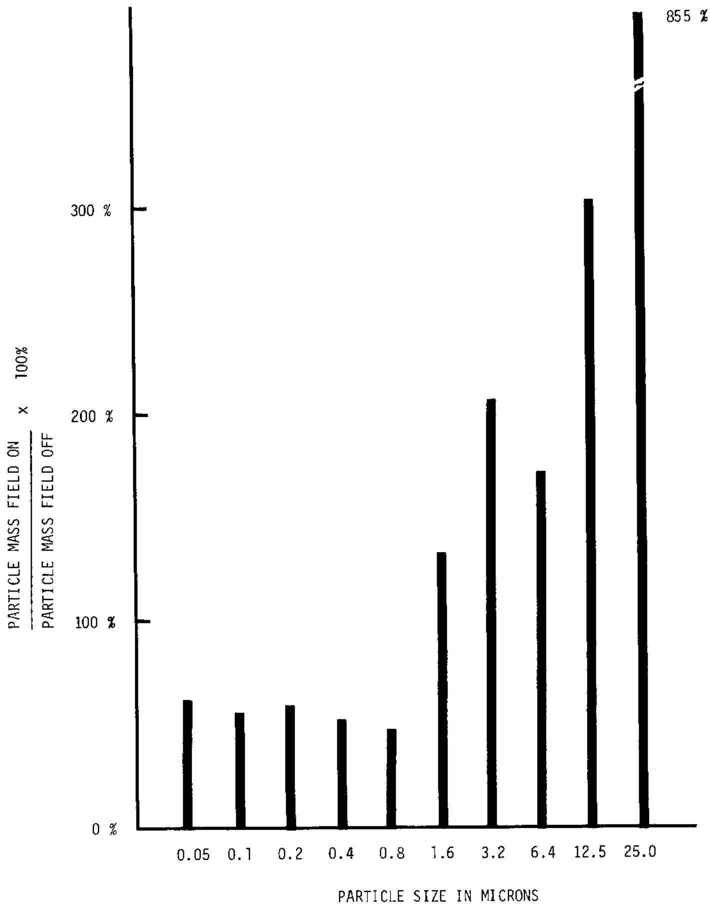

Figure 4. Percent decrement or increment in particle mass with the electric field on when compared against the electric field off data as the baseline. The field off data would all be 100%. The difference in mass between on and off conditions at each particle size are statistically significant, except at the 1.6 microns size.

the data obtained from those two crystals during the time they were overloaded. This minor loss of data had no influence on the conclusions drawn.

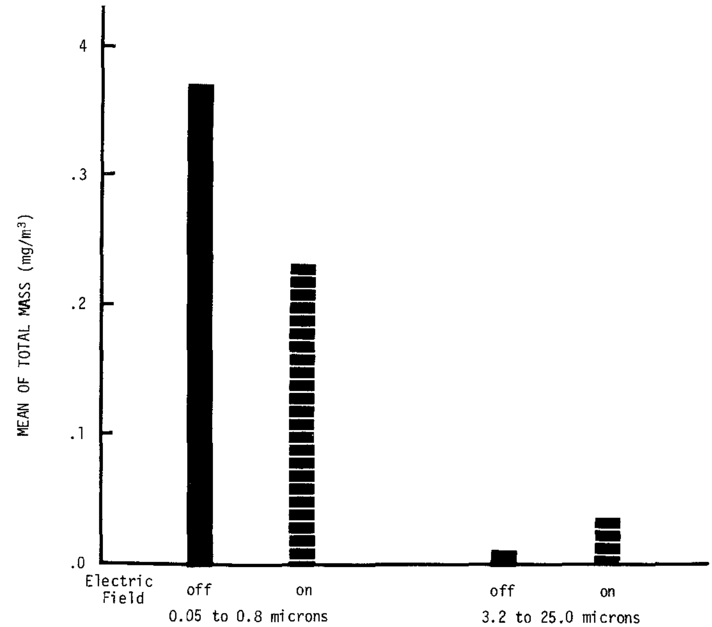

Figure 5. Comparison of mean mass in the electric field on vs. off conditions.

A statistical analysis using the data from all ten stages was carried out. The results were comparable to what was found with the seven stages; there were differences and they were significant ($t = 5.02$, $p < .005$).

Statistical analyses were also done stage by stage. These showed that the operation of the in-duct electric field substantially reduced the mass of small particulates in the air and slightly increased the mass of large particulates. This relationship is shown in Figure 4 as percent decrease or increase in mass from the mass determined in the no-electric field condition. The difference between field on vs off data at each stage was statistically significant except for the 1.6 microns stage data.

Since the 1.6 microns size seemed to be the transition point, it was used as a break point in further analyses. The mean mass for the small particles (0.05 to 0.8 microns) was calculated. For the electric field on condition, it was 0.232 mg/m^3; and for the off condition, it was 0.378 mg/m^3 as is shown in Figure 5.

Thus, the operation of the electric field reduced the mass of small particles in the room air to 61 percent of what it was in the field off condition.

The mean mass for the large particles (3.2 to 25.0 microns) was calculated. For the electric field on condition, it was 0.033 mg/m^3; and for the off condition it was 0.009 mg/m^3. Thus, the operation of the electric field increased the mass of the large particles in the air to 367 percent of what it was in the off condition.

Note that the loss of small particle mass is not balanced by the gain in large particle mass. The gain of 367 percent in large particle mass in the field on condition accounts for only 6 percent of the mass lost in small particles. The other 94 percent of the decrement in small particle mass is going elsewhere. In view of the fact that there is a significant increase in large particles, this data could be interpreted to indicate that this 94 percent of small particle mass that is unaccounted for is being deposited in the filter.

In sum, the statistical analysis of the Royco data indicated that the operation of these specific electric fields in the duct significantly reduced the particle count in the room. The statistical analyses of the cascade impactor data supports that conclusion and adds further information that suggests a mechanism for the effect. The shift in particle size can be interpreted as the operation of the electric field causing the small particles to coalesce into larger particles which are more readily trapped in the filter. If this is what is happening, there are significant implications for controlling contamination.

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