REAL-TIME HVAC FILTER EFFICIENCY TESTING USING OPTICAL PARTICLE COUNTERS

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ABSTRACT
The National Institute for Occupational Safety and Health (NIOSH) has undertaken a long-term performance test of heating, ventilation, and air-conditioning (HVAC) system filters. This testing is being conducted at the NIOSH facility in Morgantown, WV in an air handling unit (AHU) that services the animal quarters. The six-pocket bag filters in this AHU have been replaced with higher efficiency mini-pleat V-Bank™ filters and have been monitored monthly for filtration efficiency. This study required the development of a method to determine the actual HVAC filtration efficiency using optical particle counters (OPCs) while the system was in operation. OPCs were used to collect particle counts in 15 different particle size ranges from 0.30-0.40 µm to >20 µm. Instruments are placed upstream and downstream of the filter bank and data were collected over several days. Filtration efficiency was determined for submicron to supermicron particles averaged over the sampling period.

INDEX TERMS
HVAC Filters, Filtration, HVAC Filter Efficiency, Optical Particle Counters.

INTRODUCTION
The National Institute for Occupational Safety and Health (NIOSH) has undertaken a long-term performance study of heating, ventilation, and air-conditioning (HVAC) system filters. This study is being conducted at the NIOSH facility in Morgantown, WV in an air handling unit (AHU) that services the animal quarters. The HVAC is a constant volume system, with a heat recovery and preheat/chilled water coil. This system operates 24 hours a day, seven days a week, and is 100% outside air, all return air is exhausted. The facilities personnel from the Office of Administrative and Management Services and researchers within the Laboratory Research Branch undertook this project to determine the best performing filters for the system.

Currently ANSI/ASHRAE Standard 52.2-1999 evaluates the performance of HVAC filters in the laboratory based on the penetration of a potassium chloride test aerosol through a filter mounted in a test duct. A recent paper (Kern and Jackson, 2000) indicated that the ASHRAE 52.2-1999 test might not be indicative of real-life filter performance over the actual life of the filter. The authors believe that the type of filtration material is the biggest factor in whether a filter maintains its efficiency over time. Their data indicate that fiberglass filter media maintains its efficiency while synthetic filter media (like polypropylene) will lose its efficiency due to the discharge of its electrostatic enhanced media.

Our study of HVAC filter performance first required the development of a method to determine the actual HVAC filtration efficiency using optical particle counters (OPCs) while the system was in operation. Six-pocket bag synthetic filters already installed in the system were first evaluated; they were replaced with higher efficiency fiberglass mini-pleat V-Bank™ filters.

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METHODS
A portable OPC (Portable Dust Monitor model No. 1.108, Grimm Technologies, Ainring, Germany) was used with an optional temperature, relative humidity, and air velocity sensor (model 1.154) to measure particulate concentration as a function of particle size. The unit was also equipped with an isokinetic sampling probe (model 1.152) that samples air at a flow rate of 1.2 L/min. These instruments determine particle size based upon the amount of light scattering by individual particles. They count particles in 15 different size channels from 0.30-0.40 µm, 0.40-0.50 µm, 0.50-0.65 µm, 0.65-0.80 µm, 0.80-1.0 µm, 1.0-1.6 µm, 1.6-2.0 µm, 2.0-3.0 µm, 3.0-4.0 µm, 4.0-5.0 µm, 5.0-7.5 µm, 7.5-10 µm, 10-15 µm, 15-20 µm and >20 µm. The challenge aerosol was the ambient particulate or dust that enters the HVAC system from the outdoor air intake.

During our investigation, one OPC was placed upstream of the filter bank to count dust particles with the sampling inlet facing the air steam. Another OPC was placed downstream of the filter bank and both measured particle number concentrations for each size channel, air velocity, relative humidity and temperature. These data were logged every minute. To avoid instrument-to-instrument variability biasing the results, several identical instruments were tested in the laboratory and two were selected that produced comparable data. This set of OPcs was used for data collection in the AHU under normal operating conditions for a period of several days at monthly intervals to monitor filter performance with time.

The data collected from the OPcs were downloaded to a portable computer and placed in a spreadsheet for analysis. Filter penetration is the ratio of the downstream particle counts ($C_{down}$) to the upstream particle counts ($C_{up}$). Filtration efficiency is calculated via the following relationship:

$$\text{Filtration Efficiency (\%) = 100 \left( 1 - \text{Penetration} \right) = 100 \left( 1 - \frac{C_{down}}{C_{up}} \right)}$$

RESULTS
The OPC used in this investigation counted aerosols in 15 different size particle ranges from 0.30-0.40 µm to >20 µm. The average filtration efficiency of the filter bank is presented as a function of root mean diameter particle size for each OPC channel (see Table 1).

<table>
<thead>
<tr>
<th>HVAC Filter Type and Duration in AHU</th>
<th>Average Filtration Efficiency (%)</th>
<th>OPC Channel Root Mean Diameter (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.35</td>
<td>0.45</td>
</tr>
<tr>
<td>Six-Pocket Bag Filter @ 9 months</td>
<td>25</td>
<td>28</td>
</tr>
<tr>
<td>V-Bank Filter - New</td>
<td>70</td>
<td>74</td>
</tr>
<tr>
<td>V-Bank Filter @ 1 month</td>
<td>63</td>
<td>69</td>
</tr>
<tr>
<td>V-Bank Filter @ 2 months</td>
<td>67</td>
<td>73</td>
</tr>
<tr>
<td>V-Bank Filter @ 3 months</td>
<td>62</td>
<td>66</td>
</tr>
<tr>
<td>V-Bank Filter @ 4 Months</td>
<td>61</td>
<td>64</td>
</tr>
</tbody>
</table>

As seen in Table 1, the V-Bank™ filters initially provided a 40% increase in filtration efficiency for submicron (for particles less than 1 µm) particulate over that of the six-pocket
bag filters they replaced. After 4 months, the V-Bank™ filters efficiency has dropped about 10% for submicron particulate. For particles greater than 3 µm, all filters provided filtration efficiency of essentially 100%.

DISCUSSION
The six-pocket bag filters (DriPak 2000 synthetic extended service filter, AAF International, Louisville, KY) in use at the onset of our study were ASHRAE 52.2 rated at 90-95% with a total surface area of 2.0 square meters and had a recommended service life of 9 to 12 months. When these filters were tested after nine months of usage, filtration efficiency was lower than anticipated. When filters age, a filter cake is expected and should have increased efficiency. This observed reduction in efficiency is probably related to the fact that these filters rely on electrostatic attraction, which diminishes over time with exposure to ambient aerosols (Kern and Jackson, 2000 and Blackford, et al, 1986). Thus as a follow up, we plan on collecting additional data to determine what the actual service life of these filters are when new and tested in a similar AHU under real-world conditions.

The V-Bank™ filters (Aerostar FP mini-pleat filters, Filtration Group, Joliet, IL) each have a surface area 17.9 square meters and are wet laid micro-fiberglass. Their surface area is much higher than those of the bag filters. Further, they rely solely on mechanical filtration with no electrostatic enhancement. The manufacturer has provided no ASHRAE 52.2 efficiency rating.

It should also be noted that all ventilation filters were properly sealed in their frames in the filter bank to prevent any leakage around the filter media. This was evaluated with a visual inspection of the filter bank.

CONCLUSIONS AND IMPLICATIONS
These data show that an in situ characterization of ventilation filters by OPCs can be a useful methodology in determining the performance of HVAC system filtration. The V-Bank™ filters have maintained their level of efficiency for supermicron particles during the initial 4 months of this study. According to the manufacturer, these filters have a service life of 2 years; we plan to continue monitoring their efficiency monthly until the end of their service life. Objective real-world data such as this is needed to establish maintenance schedules for filter replacement and offer improved indoor air quality by better filtration of building air.

DISCLAIMER
Mention of company names or products does not constitute endorsement by the Centers for Disease Control and Prevention.

REFERENCES