How Monitoring the Behavior of HVAC Systems Can Support Filter Performance Assessment

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SUMMARY
A ducted air system is a common way to heat and cool an occupied building. Most devices in such systems - fans, ductwork, coils, chillers, etc. - have well-described relations to building thermal requirements and thermal characteristics. However, for one device category, air filters, the relation to thermal and other factors is poorly developed. Thermal requirements change filter airflows by season, but filter performance depends primarily on the combination of outdoor aerosol size distribution and concentration, the desired indoor air quality, and the numbers and activities of people in the building spaces. Filter pressure drop normally increases during its operating life, which complicates filter performance and affects other system elements. Fully instrumented studies of actual filter-containing systems over extended time periods are needed to develop the relationships between characteristics of a system and its energy usage, capital costs and operating costs. This includes the characteristics of indoor and outdoor particles affecting the performance of the air filters in the system.

KEYWORDS
Air filter performance, Ventilation systems, Air filter pressure drop, Particulate matter removal, HVAC operating costs

1 INTRODUCTION

Building HVAC system design today is performed by computer applications, which can simulate the thermal characteristics of structures and the detailed behavior of the HVAC system elements needed to provide desired indoor conditions. Such programs calculate solutions for a wide range of climates and system operating conditions. The outputs of design programs give the energy consumption due to system elements, allowing designers to minimize both energy use and system capital and operating costs. These convenient design procedures, however, are not yet available for an important system element: air filters. This absence is largely due to the complexity of filter media and particle capture processes.

Progress has been made in describing filter media structures, mostly based on analysis of scanning electron microscope images of media. (Gassemieh, 2002) Once the geometry of a filter medium is established, computational fluid dynamics (CFD) can calculate the details of the gas flow through the inter-fiber spaces, and the paths of individual aerosol particles through the medium. Particles that collide with fibers usually stay attached to the fibers, and become potential particle collectors themselves. Thus, it is possible to simulate the particle collection efficiency of filter media, including the buildup of particles in the media, and the increase in pressure drop across the media as particles accumulate. The computer power needed to do these CFD calculations is, however, quite large.

Comparison of simulated pressure drops to measured values always needs to confirm the validity of CFD simulations. These comparisons should be made for operating conditions covering expected ranges. In the case of an air filter in a building, operating conditions vary widely.

Both outdoor and indoor particulate source characteristics are constantly changing. Airflow velocity, temperature and relative humidity at the filter media face change as thermal requirements change. If the behavior of a filter system is to be simulated accurately, the values of these particulate and gas properties need to be found for the building location as a function of time, by hour, day, and month.

2 METHODS

The HVAC system in our study (Noussan, 2017) included the air handling unit, heat recovery exchanger, and ducts serving a 1500 m^3 lecture hall at the Politecnico di Torino. Up to 400 students occupied the hall intermittently. Data were gathered and recorded at 15-minute intervals for most of the period from January 2012 to March 2017. Recorded data included: gas temperature, relative humidity, and flow velocity in the supply-air, recirculation, and discharge ducts for the hall; pressure rise and power draw for both recirculation and main flow blowers; CO_2 concentrations in the hall supply and return air flows; pressure drops across the prefilters and fine filters in the AHU; and particle counts and particle size distributions upstream and downstream of the fine filter only. Particle measurements employed optical particle spectrometers (OPS). Blowers operated at fixed speeds; hence, airflow rates changed as the pressure drop of the air filters increased with dust accumulation.

The data collection system interacting with the OPS calculates the variance for each particle-size channel count for each sample taken. The manufacturers of the standard instrumentation used for all other measurements provided each instrument’s accuracy. Hourly or seasonal variances and relations between the measured variables can be calculated from the data sets obtained from yearlong studies.

3 RESULTS AND DISCUSSION

Our analysis of the energy use data shows that the metabolism of the hall occupants provides approximately half the thermal energy in this system. Not surprisingly, the electrical power usage is a linear function of the indoor-outdoor temperature differential. Understanding the impact of air filter pressure drop is helped by "normalizing" filter pressure drop data, which converts measured values to what would have been observed if the air flowing had a reference density. Particle concentrations in the outdoor air delivered to the system could be approximated from $PM_{2.5}$ data available from nearby monitoring stations, and size distributions can be approximated from the $PM_{2.5}$ sampler properties. Blower efficiency varies with flow volume and properties of the air it moves, thus affecting energy usage.

4 CONCLUSIONS

Many parameters of an HVAC system, plus the time-dependent characteristics of the aerosols from outdoor and indoor sources, are needed for accurate simulation of air filter performance in such systems. To establish the relations between parameters and filter performance, we need extensive and fully instrumented studies of actual building spaces with occupant activity. These studies must extend over all seasons, and be made in a wide variety of locations, to yield procedures useful to system designers in general.

5 REFERENCES

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