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Cooling Coil Ultraviolet Germicidal Irradiation

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A previous IEQ Applications column[1] reviewed the then-current literature on the use of ultraviolet germicidal irradiation (UVGI) to control biological growth on cooling coils and other components of air-handling units. In addition to reducing potential sources of air contaminants, this technology has long been claimed to yield significant energy use-related benefits by decreasing the airside flow resistance of cooling coils while increasing their airside heat transfer coefficients. At the time, however, not a single peer-reviewed publication could be found that reported rigorous measurements of these effects.

The few trade magazine articles that had been published on the subject reported impressive, but incompletely documented, results. In the ensuing six years, there has been progress toward a clearer understanding of the capabilities of coil UVGI as a result of several recently published peer-reviewed studies. This column updates the previous one by summarizing key findings of these investigations.

As noted in the 2011 column,[1] UVGI cooling coil treatment has been the subject of prior research, but these studies only investigated changes in microbial populations on cooling coil and air-handling unit surfaces. Reports of energy use impacts are limited to a few anecdotal accounts that make very optimistic performance claims that are not well documented or repeatable.

Since then, researchers have published results of field studies at two U.S. sites (Tampa, Fla., and State College, Pa.) in the U.S.[2] and a site in Singapore,[3,4] and results of one laboratory study in Boulder, Colo., in the U.S.[5] The field studies reported before and after UVGI treatment results for coils that initially had varying degrees of fouling, while the laboratory study used an apparatus containing two identical coils, one treated with UVGI and the other untreated.

Bahnfleth and Firrantello[2] installed commercial coil UVGI systems sized per manufacturer recommendations. In Tampa, the system was installed downstream of the coil. This is the preferred location because it also permits irradiation of the condensate pan. In State College, the installation was upstream due to access issues and the observed location of fouling. Instrumentation was installed to record air- and water-side data including temperature, flow rate, air humidity and airside pressure drop across the cooling coils.

They selected sites partly to provide a clear contrast in climates that might be expected to result in different levels of impact for coil UVGI. Tampa, on the Gulf Coast of Florida at a latitude of 28°N, is hot and humid with year-round cooling loads that could be expected to keep cooling coils wetted most of the time. State College, Pa., at 41°N in the northeastern United States, is a temperate climate in which cooling systems may only operate during seven or eight months of the year with lighter dehumidification loads and several months during which the coil is dry. The specific cooling coils in these locations were selected because they had heavy, visible fouling. This was done in preference to studying better maintained coils to increase the likelihood that there would be a clear effect from coil UVGI.

The air-handling unit at the Tampa site was variable air volume, serving a science classroom building, while the State College air handler was a constant volume unit serving a fitness facility. Both had six-row chilled

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FIGURE 1 Tampa, Fla., downstream cooling coil surface fungal colonies before coil UVGI (left) and after 13 months of coil UVGI (right).[2]

water coils. Fin spacing was 8/in. (0.315/mm) and 11/in. (0.433/mm) for Tampa and State College, respectively. Baseline data were collected at each site for several months prior to energizing the UVGI systems and then for several months afterward.

Due to miscommunication, the owner chemically cleaned the State College coil just prior to the start of data collection, but it was decided to proceed with the protocol, although this site was no longer directly comparable with the other and less impact of coil UVGI was expected.

Analysis of data from the Tampa site indicated that mean airside pressure drop through the coil decreased by just under 22% after one month of UVGI operation, while overall heat transfer coefficient increased by almost 15%. Changes in the appearance of downstream surface fouling, as well as the surfaces of tubes and fins, were evident after coil UVGI was energized (*Figure 1*), but residues of fungal colonies remained on the coil after months of irradiation.

The State College site, after cleaning, experienced a mean pressure drop reduction of 1.3% to 1.4% and a mean increase in overall heat transfer coefficient of 45% to 50%. The results from Tampa are encouraging in that significant improvements in both flow resistance and heat transfer were observed that saved more energy than was consumed by the UVGI system. The less positive results at the State College site were likely due to combined effects of climate, heavy non-biological fouling, and the unplanned cleaning. The individual effects, unfortunately, cannot be determined from the data collected.

Yi, et al.,[3,4] used a similar setup, protocol and data analysis procedures to those of Bahnfleth and Firrantello[2] in their study of coil UVGI in a Singapore laboratory. Located at a latitude of 1.3°N, Singapore has a year-round hot-humid climate that varies little from month to month. The studied system underwent regular maintenance that included coil cleaning and was not fouled to a degree that was visibly obvious. Coil UVGI was installed downstream of the coil. The study system had an eight-row chilled water coil with 10 fin/in. (0.394/mm) spacing.

They reported[3] mean pressure drop reduction of 13% and an overall heat transfer coefficient increase of 10%. Fan energy use during the study period decreased by 9%, and savings in fan energy were 39% greater than lamp energy use. Further analysis of heat transfer impacts[4] showed that coil UVGI resulted in a chilled water temperature difference increase of 0.4°C to 0.6°C (0.7°F to 1°F) and a corresponding decrease in chilled water flow rate of 8.0% to 11.9%.

Luongo, et al.,[5] constructed a laboratory system in Boulder, Colo., with identical parallel chilled water coils, one of which was irradiated, and one of which served as a control. In Boulder's temperate, dry climate, there was little latent load to support biofouling on the test coils, and the results showed a correspondingly low impact of coil UVGI. Average heat transfer coefficient increased by 3.0% to 6.4% with a relatively high uncertainty of ±2.7%, and impact on pressure drop was negligible. Luongo and Miller[6] have also reported on microbial measurements in this system and their relationship to latent load.

Overall, these initial studies suggest that the benefits claimed for coil UVGI are real, but, as is often the case, they may be considerably smaller in typical applications than has been claimed in anecdotal reports. This is not to say that such dramatic impacts do not occur, but they probably are not typical. Both Bahnfleth and Firrantello[2] and Yi,[7] conducted economic analyses based on equipment cost, operating cost, avoided conventional maintenance and electric cost savings.

Bahnfleth and Firrantello[2] also estimated the monetized benefit of air disinfection by a system designed for coil UVGI. Space limitations do not permit a detailed discussion of their findings here, but they suggest that coil UVGI can be cost-effective under some conditions—those conducive to heavy, continuous biofouling—but not in others—climates with low humidity and limited cooling seasons. They found that, from an economic perspective, the collateral air quality benefit and savings from avoided conventional maintenance could be greater than energy cost savings, which mainly result from reduced fan energy use.

The failure of coil UVGI to completely remove preexisting biofouling indicates that cleaning by other methods prior to treatment with UVGI is needed for retrofit applications. More investigations of coil UVGI under a wider range of operating conditions are needed to provide a clearer picture of their performance and economic value, but these new studies provide support for this technology that is already in fairly widespread use.

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