ADVANCED HVAC SYSTEMS FOR IMPROVING INDOOR ENVIRONMENTAL QUALITY AND ENERGY PERFORMANCE OF CALIFORNIA K-12 SCHOOLS

Attachment X

Code Action White Papers for Displacement Ventilation and UVC Applications

CONSULTANT REPORT

Prepared For:
California Energy Commission
Public Interest Energy Research Program

Prepared By:
Architectural Energy Corporation

Arnold Schwarzenegger, *Governor*

June 2006
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ADVANCED HVAC SYSTEMS FOR IMPROVING INDOOR ENVIRONMENTAL QUALITY AND ENERGY PERFORMANCE OF CALIFORNIA K-12 SCHOOLS

Final Displacement Ventilation Brochure / Flyer (Recommendation for Code Actions)

CONSULTANT REPORT

Prepared For:
California Energy Commission
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DISCLAIMER

Abstract

This paper/brochure provides information on the need for improved indoor quality, energy use and maintenance in schools and other commercial buildings. A primer on the use of displacement ventilation for improved air quality and energy use in schools and other commercial buildings is provided. Included in this information are the benefits of displacement ventilation, how it works, how to use it in commercial buildings, and its cost. Examples of field test experience on the efficacy of the technology are provided. Recommendations are given for how to assure that the benefits of displacement ventilation are adequately accounted for in building energy codes and guidelines, including modeling requirements and necessary applications information.

Overview

Poor environments in schools influence the health, performance and attendance of students. Many existing school space conditioning systems using conventional mixed ventilation systems fail to provide the indoor air quality, acoustics, and comfort that can produce optimal student and teacher performance. Displacement ventilation (DV) is a cost effective means of providing and optimal indoor environment by delivering cool supply air directly to the occupants in a space. The air is enters the room at about 65 ºF, considerably warmer than with a conventional air conditioning system. The fresh air, supplied near the floor at a very low velocity, falls towards the floor due to gravity and spreads across the room until it comes into contact with heat sources. The cool supply air slowly rises as it picks up heat from occupants and equipment. The warm, picks up contaminants as it rises towards the ceiling where it is exhausted from the space. This vertical airflow pattern near each occupant often referred to as a *thermal plume*, makes it less likely that germs will spread. The air distribution system provides for effective ventilation, since the fresh supply air is delivered directly to each occupant. All this can be provided at a first cost that is comparable to that of less effective conventional mixed ventilation systems that rely on creating fully mixed air in the room.

What are the benefits?

The learning environment will be improved in a way that delivers more fresh air to the students and teacher, while controlling noise and providing comfort. These healthy surroundings should result in improved health, (lowered absentee rates) and better productivity (higher test scores)

- **Indoor air quality** - is improved since the rising thermal plumes also carry away contaminants towards the ceiling exhaust. This air pattern also inhibits transfer of pollutants from one student to another and between the students and the teacher. Improved ventilation effectiveness with displacement ventilation provides better pollutant removal and enhanced indoor air quality than achieved with a mixed ventilation system.

- **Acoustics** – are enhanced due to the low air velocities and the remotely located cooling and delivery equipment aid in designing to ANSI recommendations. This is of particular advantage when compared to unit ventilators or wall-mounted equipment.
- **Maintenance Benefits**- displacement ventilation systems provide servicing benefits compared to systems using mixed ventilation and should result in reduced down-time and service calls
- **Energy Benefits –** displacement ventilation systems provide several energy benefits which are discussed below. A cooling energy savings of 25% to 50% is possible.

How important is indoor air quality?

Evidence strongly suggests that poor environments in schools, primarily due to the effects of indoor pollutants, adversely influence the health, performance and attendance of students and teachers. This evidence links high concentrations of several air pollutants to reduced attendance levels. There is also persuasive evidence that microbiological pollutants are associated with increases in asthma effects and respiratory infections, which are both related to reduced school performance and attendance.[1] Displacement ventilation systems offer an effective, energy-efficient means of delivering fresh air and removing airborne pollutants to improve classroom air quality.

How can displacement ventilation improve classroom acoustics?

The low velocity air leaving the diffuser is very quiet compared to the noisy, inrush of air often experienced with mixed ventilation system diffusers. As a result, building acoustic standards are more easily achieved with displacement ventilation systems. It will no longer be necessary to turn off the air conditioner in the classroom to be able to hear the students and teachers

How will maintenance be improved?

Displacement ventilation systems use remote central or semi-central cooling systems reducing the number of fans and compressors compared to decentralized systems that may use wall mounted units or unit ventilators or dedicated packaged rooftop units for each classroom. The presence of these many fans and compressors increases the potential frequency of service calls and their proximity to the teaching space increase the chance of classroom disruptions. Other issues such as poor indoor air quality, drafts and equipment noise that may result in frequent service calls with mixed ventilation systems should not frequently occur with mixed ventilation systems.

How does it save energy?

There are several reasons behind the cooling energy savings with TDV. First and foremost, the higher supply air temperature (SAT) of 65°F greatly increases potential for free cooling. In some California climates, there are 2,000 hours annually when the outside temperature is between 55 °F and 65°F. This benefit is especially evident in coastal California climates. Secondly, the higher SAT also increases the efficiency of mechanical cooling equipment. There is less "lift" – less work required for the compressor to raise the refrigerant pressure and temperature before it reaches the condenser. Finally, since warmer air is exhausted from the ceiling return, DV systems reduce cooling coil loads. There are two zones in the classroom, a stratified occupied zone and a mixed upper room zone. Much of the heat from the upper part of the room never enters the occupied zone and thus does not have to be removed by the cooling system. Each of these savings contributes to a large cooling energy savings.

What does it cost?

The additional costs of the displacement ventilation systems are for the low-velocity displacement diffusers and for the enhanced compressor capacity control needed to maintain the flow rate and temperature. The displacement diffusers carry a slight cost premium of about \$1 to \$2/ft^2 over a conventional set of four ceiling diffusers per classroom.[2] However, some of this is offset by the simplification of ductwork. In some cases, using displacement ventilation provides an opportunity to downsize cooling equipment, which will offset some of the added diffuser and capacity control cost. Practitioners of these systems have found that construction costs of schools using displacement ventilation are quite comparable to first costs of an average school construction project using mixed ventilation

What are the building requirements?

The primary requirement for displacement systems is a high ceiling. This allows heat and contaminants to be carried away effectively to the ceiling exhaust. A nine-foot ceiling is adequate, but a high ceiling (12 ft) will enhance the benefits of stratification. Air is typically delivered thru two sidewall diffusers installed at the interior corners of the classroom. Each diffuser takes up approximately 6 ft^2 of wall space and about 1 ft^2 of floor space. Shapes and designs are available that integrate seamlessly into the space with diffusers mounted in a corner, positioned under casework or recessed into the wall,
Displacement ventilation allows for simplification of ductwork. For multi-story structures, the floor-to-floor ceiling height does not need to increase for displacement ventilation. If the suspended ceiling is eliminated, this may allow for a reduced floor-to-floor height.

Is a retrofit a suitable candidate?

Any school that meets the minimum requirements – a ceiling height of at least 9 feet – is a suitable candidate for a DV system. One unique requirement for displacement ventilation is a steady supply of cool 65°F air to remove heat and contaminants from the space. Smaller packaged rooftop units typically do not provide the cooling capacity control to maintain a steady supply air temperature. Central systems using either a central chiller or packaged VAV cooling system may be more suitable for a retrofit, since the systems often can be used with only adjustments to the controls.

What about relocatables?

Relocatables often have issues with noise, and could well benefit from displacement ventilation. However, since these are usually conditioned by individual packaged units, these are less suitable for a DV installation. As DV technology becomes more commonplace, manufacturers may offer a displacement ventilation-compatible cooling system as an option.

What kinds of HVAC systems can I use?

The primary requirement that is unique to DV is the warmer 65°F supply air. A central plant system and hydronic coil is the easiest means to control supply air temperature. A three-way valve controls the flow to the coil at the air handler or terminal unit to maintain a steady SAT. A packaged variable-air volume system with multiple cooling stages will also provide for good control of supply air temperature.

Packaged rooftop units serving single classrooms generally do not have the temperature or air flow control required for TDV. However, a system with multiple compressors or a variable-capacity compressor should provide the necessary control.

What about heating?

Heating can be provided through the low-velocity displacement diffusers, but in heating, the goal is a well-mixed space. A morning warm-up sequence that heats the space to the set point prior to occupancy will minimize heating requirements during occupied hours. For colder mountain climates such as Lake Tahoe, a supplemental perimeter heating system may be required to maintain comfort during the colder months.

What about indoor humidity?

Some designers point out that with a higher SAT, the system will not provide for dehumidification. This is correct, but in most California climates, the outside air humidity level (in lb of moisture per lb of dry air) is lower than indoor design conditions throughout the year. Thus, providing outside air ventilation will also serve to dehumidify the space during the cooling season. For some coastal climates, a psychometric analysis should be performed at design wet-bulb conditions, to see if dehumidification is required.

There are several options for removing moisture without lowering the supply air temperature. Return air bypass lowers the SAT off the coil by having a portion of the return air bypass the cooling coil. The warmer bypassed air is mixed with the dehumidified air to achieve the desired 65°F supply. Another option is to use a "run-around" coil, to capture waste heat rejected from the condenser and heat the air downstream of the cooling coil.

What field experience do we have with displacement ventilation?

Displacement ventilation has been used in schools in the Northeast and Midwest since the 1990s, and has recently been installed in demonstration schools in California. Several school examples have been documented where DV systems have made a significant difference in changing the culture, providing fresher air, relief from asthma and other disorders, creating a fresher environment with fewer absences. A teacher in Boscawen, NH suffering from asthma and other complaints with the previous systems had perfect attendance after the displacement ventilation systems were installed.[3] Student absentee rates also fell. In a school in Overland Park, KS, the culture has changed as result of installation of displacement ventilation systems. Where teachers had been complaining of poor indoor air quality they now cannot believe the difference that the new systems have made.[4] In Elk River, Minnesota visitors to a school with displacement ventilation often note that the air seems noticeably fresher than in traditional buildings.[5] In Howell Township in New Jersey 60% lower absentee rates were obtained as a result of use of displacement ventilation systems.[6] Several school districts that have used displacement ventilation systems now specify them as a requirement for new schools and major remodels.

Current Study Sponsored by the California Commission

At the Kinoshita Elementary School in the Capistrano Unified School District in Orange County California displacement ventilation and a standard mixed ventilation system were installed, instrumented and operated in adjacent classrooms. The DV system used a packaged rooftop unit with a variable capacity scroll compressor capable of delivering a continuous flow of 62°F to 65°F supply air. The mixed ventilation system used a standard packaged unit delivering 55°F air to the classroom. .The DV conditioned classroom had consistently lower CO_2 levels at the return than in the occupied zone, illustrating that a stratified room air distribution was created that effectively swept pollutants out of the occupied zone. The acoustics were consistently better for the DV classroom (40-44dBA) compared to the control classroom (48-50dBA). After a calibration period that corrected faulty economizer and room air temperature settings, the DV system cooling savings were 39% for the month of November 2005. Savings were principally due to the extended economizer range of the DV system and the reduction in cooling load in the occupied zone. Teacher feedback has been positive with the teacher in the displacement ventilation system saying; “It’s like walking in fresh air, like being outside all the time. During open house all the other teachers wanted to know when they’re getting one in their classrooms.”

The technology, used in Europe since the 1970s, has also found its way into libraries, casinos, auditoriums, lobbies, atria and other open spaces with high ceilings.

Codes Issues and Recommendations- General

A comprehensive evaluation of codes and standards setting bodies and related organizations that have provisions in their codes and guidelines that could affect the design, deployment and operation of displacement ventilation systems was performed and updated in 2004. The details of that evaluation are provided in the “*Final Code Action Plan [D-4.3b]*”, revised July 16, 2004 and December 1, 2004.[7] This report showed how existing standards and guidelines need to be modified to assure that DV is handled fairly. Recommendations made in this plan applied to the standards, guidelines and program documents and criteria in place at the time the plan was initially developed. Since that time most of these documents and criteria have been updated. In some cases the updates reflect suggestions made in the Final Code Action Plan and may have, in part, resulted from actions taken by the project team to disseminate project results, as well as the information and recommendations in that plan. This white paper attempts to update the issues and recommendations in the Final Code Action Plan to reflect the current state of the technology and the codes, standards and guidelines currently in place.

The main code issues revolve around differences between conventional mixed ventilation systems and displacement ventilation distribution systems with regard to room air temperature stratification and flow patterns, handling of thermal loads, supply air temperature and quantity, control strategies and economizer operation. Code modifications are needed to account for these differences, principally in two areas; the ability of the design case and reference case (to which the design is being compared) to differ in terms of set points and other conditions (supply air temperature, economizer operation, air flow rate, thermostat location and setting); and the need to model stratified room air distribution. The modeling issue has been studied both with the intent of developing simplifications solutions that permit heat balance models such as DOE 2 to successfully simulate DV and with the objective of developing multimode models that handle the differences between mixed systems and stratified systems such as displacement more directly.

Suggested methods for "working around" the short comings of heat balance models were identified as possible: redistribution of internal and envelope heat gains; reduction of the modeled volume of the conditioned space to that of the occupied zone; or establishing vertical thermal zones.[8] Step by step procedures for modeling DV with DOE-2.1a, EnergyPro and eQuest are provided by Energy Design Resources[9] consisting principally of a recommendation that internal loads be apportioned to the return air plenum and the occupied space as follows in Table 1.

Table 1: Percent of the Cooling Load Entering the Conditioned Space

Load Component	Percent to Occupied Space	Percent to Plenum
People	67%	33%
Lights	50%	50%
Equipment	50%	50%

A more rigorous approach is being taken by the University of California at San Diego with funding from the CEC PIER program that has been incorporated into EnergyPlus Calculations. [10] This approach uses a multi-node, multi-plume model that permits vertical temperature gradients to be modeled, effectively simulating the main attributes of displacement ventilation.

The Final Code Action Plan indicated that existing standards needed to be modified to assure that DV is handled fairly. These standards were principally the Energy Code provisions (Part 6) of the State of California Building Code (Title 24) and ASHRAE Standard 90.1 dealing with non-residential building energy use. Other corollary programs, that rely in part on provisions of the California Energy Code (Title 24, Part 6) and ASHRAE 90.1 Standard are the Collaborative for High Performance Schools (CHPS), Leadership in Energy and Environmental Design (LEED®) and Savings By Design. These standards and programs and recommendations for their changes are discussed in the following sections.

The California Energy Code, Title 24, Part 6

The California Energy Code deals with building energy efficiency and provides several paths for code compliance. None of these paths currently permits appropriate consideration of the attributes of DV. Changes are needed to the nonresidential standards and alternative calculation methods (ACM) to enable DV to be credited in the compliance process of Title 24, Part 6. For DV, changes are also needed to permit differences in supply air temperature, supply air flow rate, ventilation effectiveness and economizer operation to be modeled between the design case and reference case. Changes to the ACM are needed to model the temperature stratification inherent in DV operation.

There are several ways of achieving compliance with Title 24, Part 6. The **prescriptive approach** requires that specific criteria be met for building envelope space conditioning lighting and water heating. For the space conditioning system these requirements include sizing to meet loads based on the indoor design conditions, outdoor design conditions, ventilation requirements, occupancy, and start-up safety factors. All criteria must be met to comply using this approach. Since these criteria have been developed for mixed ventilation systems, the prescriptive approach does not provide credit for the distinguishing attributes of displacement ventilation (greater use of economizer operation, higher supply air temperature, better ventilation effectiveness, thermal zoning/room temperature stratification and differences in sizing and controls that permit improved occupant environmental quality and better handling of internal loads).

An alternative approach that can be used is the **performance approach** wherein the building design case being considered is compared to a baseline building reference case. The energy use for the design case cannot exceed the energy use calculated for the reference case. The method of calculating energy use must be approved by the California Energy Commission (CEC). Approved Calculation Methods (ACMs) have default calculations that select reference system characteristics to efficiently handle the energy needs of the subject building. The performance approach is grounded in principles that apply to mixed ventilation systems and therefore uses conditions to analyze the design case (using displacement ventilation) that apply to mixed ventilation systems and not necessarily to displacement ventilation systems. Model conditions are inflexible with regard to supply air temperature, controls, thermal zoning, room air temperature distribution, removal of cooling loads, economizer operation, and ventilation requirements, i.e. the design case input and modeling parameters cannot be adjusted to differ for the design case compared to the inputs and modeling parameters used for the reference case.

Title 24, Part 6 also provides for **approval of Exceptional Designs**, if a building cannot be adequately modeled by an approved calculation method. The applicant can receive a building permit if the CEC feels that: the building cannot be adequately modeled by an approved calculation method and that using an alternative evaluation technique the design complies with Title 24, Part 6; and the design complies with all other legal requirements.

Recommendations for Modifying Title 24

If either the performance approach or the exceptional design provisions are used, it will be necessary to specify an alternative evaluation technique for DV. Important elements of the alternative evaluation technique for displacement ventilation systems should be based on test results as embodied in the final report[11] and design guidelines[12] for this displacement ventilation study which includes corroboration and documentation of the design approach used by Halton[13], application of the Computational Fluid Dynamic Modeling (CFD) results[14]and generalization of the test results to confirm or modify the design guidelines documented in published REHVA and ASHRAE documents[15,16]. The design guidelines[12] discuss methods for determining ventilation requirements, system sizing, control strategies, thermal stratification, how to handle the classroom cooling loads, economizer operation and equipment sizing with DV. The design guidelines have supplemented study results with the pertinent findings from the most recent studies reported in the literature and obtained from colleagues working on displacement ventilation projects. This information is provided to facilitate changes that incorporate DV into the ACM manual. While these changes are in process, the techniques can be used by DV practitioners to help obtain waivers for Exceptional DV Designs and corresponding evaluation methods.

Changes to the ACM manual are needed to properly account for differences between DV and mixed ventilation system performance. The procedure for comparing the baseline case (the reference mixed ventilation system) and design case (the DV system) needs to permit differences in the sizing, control strategies, thermal stratification, supply air temperatures, handing of cooling loads, economizer operation, and ventilation effectiveness in modeling the two systems. The alternative evaluation technique and associated analysis methods should be patterned after that described above for obtaining approval for DV Exceptional Designs.

Eligibility criteria which need to be fulfilled to assure that the DV systems will comply with the proposed ACM changes should include guidelines for minimum, supply air temperature, and maximum diffuser discharge velocity.

Once the ACM manual changes are approved, these changes should be incorporated into the corresponding approved calculation programs[17] by the corresponding vendors. EnergyPlus[18] algorithms, using multiple nodes have recently become available as tools [10] for analyzing displacement ventilation systems. Discussions with modeling experts have indicated that these modules are not readily transferable to DOE 2.1or DOE2.2 and tools based on DOE2 such as Title 24 approved models such as EnergyPro[19]. Based on this cursory assessment it may be desirable to evaluate and subsequently utilize tool such as EnergyPlus for use as an approved ACM.

Work in Progress on Title 24 Revisions

The process for developing the 2008 version of Title 24, Part 6 is well underway. As part of this effort discussions have been held with key California Energy Commission officials involved in the updating of Title 24, Part 6 to inform them of the work ongoing in the CEC PIER Study. This white paper will be submitted to those officials as an extension of those conversations. One of the actions taken as part of the development of the 2008 version of Title 24, Part 6 was to commission a study[18] by EnergySoft LLC that looked at the attributes of displacement ventilation systems including; energy benefits, non-energy benefits, and analysis tools. One of the non-energy benefits cited was the ability to downsize the mechanical system when using displacement ventilation since a large part of the load is exhausted directly from the room without entering the occupied, conditioned zone. The study notes that the current reference method, DOE-2.1E as well its derivatives, are not well suited to modeling displacement ventilation. Newer programs such as EnergyPlus more accurately represent the performance of displacement ventilation systems. Since the process to qualify EnergyPlus as a Reference Method for 2008 standards will take longer than the time permitted by the deadline set for these standards, an approach is taken to write the measure template in a more general format to encompass the current models as well as future emerging products.

The measure template proposes to include an additional option system type in the Nonresidential ACM Manual suggesting that modeling procedures developed by the PIER program and outlined in the study, and corresponding language be included in the ACM manual to allow modeling of these systems. Since different software vendors may approach the problem differently the template provides latitude for modeling with current and future tools.

Suggested language for the Nonresidential ACM Manual acknowledges the use of 63°F to 67° F supply air temperature, delivered at low velocity along the floor. Air is exhausted to the plenum from the space near the ceiling. Heat gain to the occupied/conditioned space versus the portion transmitted directly to the plenum is to be assigned according to the Table 1.

This approach is based on work performed for Energy Design Resources [9] and would permit modeling of displacement ventilation systems with approved ACM tools, namely DOE-2. Another important recommendation is allowing the ACM to model the standard design as the reference system in a new construction situation or the existing systems at it occurs in a renovation situation.

ASHRAE Standards

ASHRAE Standards 55, 62, 113 and 129 as described in the Final Code Action Plan[7] have provisions relating to thermal environment, ventilation rates, room air diffusion, and measuring air change effectiveness respectively that could impact displacement ventilation systems. Since all the provisions of these standards can be met with displacement ventilation systems, no changes are necessary to these standards since they already accommodate the unique attributes of displacement ventilation systems.

ASHRAE Standard 90.1 -2004 [21] provides minimum requirements for the energy-efficient design of buildings except low-rise residential buildings. The main issue in using displacement ventilation systems with ASHRAE 90.1 is that the Standard does not recognize the partitioning of the loads between the occupied space and the return air plenum as shown, for example, in Table 1. As explained in the 90.1 User's Manual[22] this standard provides several paths for complying with providing minimum requirements for the energy-efficient design of buildings except low-rise residential buildings. The EnergyPlus program is specifically cited in the language describing acceptable simulation programs in presenting the Performance Rating Method in Appendix G of ASHRAE Standard 90.1-2004. The Energy Cost Budget (ECB) Method described in Chapter 11 permits the use of simulation programs, specifically citing DOE-2 and BLAST but not excluding other programs. Both the Performance Rating Method and the ECB method permit the use of design systems that could reflect the attributes of displacement ventilation systems while also modeling reference systems that reflect the use of mixed ventilation systems. Use of EnergyPlus as the simulation program would permit the designer to provide the best available evaluation of a building designed with displacement ventilation systems.

It would be desirable for ASHRAE 90.1 to acknowledge the acceptability of a simplified procedure (see Table 1 and the surrounding text) for adjusting the loads in models such as DOE-2 to permit the use of these widely used tools in modeling commercial building systems.

Facilitating these changes will permit designers to take credit for the attributes of displacement ventilation systems in their building designs under ASHRAE 90.1-2004 jurisdiction. It would also facilitate obtaining LEED points in the Energy and Atmosphere (EA1) Credit that is based on ASHRAE 90.1.

The Collaborative for High Performance Schools (CHPS)

CHPS was organized in 1999 by the California Energy Commission, calling together Pacific Gas and Electric, San Diego Gas and Electric and Southern California Edison, to improve the performance of California schools. Out of this partnership, CHPS has grown to include a diverse group of government, utility and school organizations that has produced a set of Best Practice Manuals and achieved national prominence.

CHPS has developed criteria that explicitly define a high performance school. The criteria are most useful as a goal-setting and planning tool. Version 1.0 [23] was published in November 2001. This document has not been updated since that date and as such the information presented in the Final Code Action Plan[7] is current with the exception that the provisions of Energy Prerequisite 1: Minimum Energy Performance have been amended to replace all references to Title 24 -2001 by references to Title 24 -2001. CHPS criteria are similar to the LEED Rating System (see Section below) but there is no interchangeability between the two systems.

To be considered a high performance school, the school must meet all the prerequisites for energy efficiency, water efficiency, site planning, materials and indoor environmental quality and must earn at least 28 points out of a possible 81 points. At least 2 of the points must come from the Energy category. The categories and possible points are as follows: Site - 14 points, Water - 5 points, Energy - 24 points, Materials - 11 points, Indoor Air Quality - 17 points, and District Resolutions - 10 points.

Prerequisites include site code compliance, creating a water use budget, minimum energy performance, system testing and training, storage and collection of recyclables, minimum indoor air quality requirements, acoustics, and comfort compliance. CHPS credits are for superior energy performance, natural ventilation, commissioning, site waste management, recycled materials, certified wood, daylighting, low-emitting materials, pollutant source control, construction indoor air quality management planning, improved acoustical performance, and maintenance planning. Each of the 39 criteria, prerequisites and credit elements described in Volume III of the CHPS Best Practices Manual reference information in other CHPS materials, LEED documents and EPA reports. The scorecard and text in Volume III explain how points can be achieved for each credit criteria.

While displacement ventilation technologies are not specifically addressed in the current CHPS credits, they are being considered in the newest version of Volume III of the CHPS Best Practices Manual[24], that is currently being taken through the public review process. Displacement ventilation could assist in achieving credits in several areas and it is recommended that language be included in the next version of Volume III of the CHPS Best Practices Manual as follows:

Indoor air quality will be enhanced by the vertical plumes that rise from heat and pollutant sources providing a ventilation effectiveness of greater of 1.2 minimizing horizontal flow of contaminants, keeping air fresh in the occupied zone. This is acknowledged by a proposed credit of 2 points in the Indoor Environmental Quality section (EQ2.1 Increased Ventilation Effectiveness) [24] when displacement ventilation is used in at least 90% of the classrooms in a school.

Improved Acoustical Performance (Indoor Environmental Quality 5) will be enhanced due to the low air velocities and low background noise of displacement ventilation mechanical systems and delivery systems. Displacement ventilation systems should therefore be recognized in the recommendations in this section as an option to be explored for achieving 35 dBA maximum (unoccupied) background noise levels in a future version of Volume III of the CHPS Best Practices Manual.

A major benefit that is likely to be realized from the use of displacement ventilation systems will be in the Superior Energy Performance (Energy Efficiency C1) category. In order to achieve appropriate credits in this category the modeling recommendations provided in the Title 24 section needed to be accepted. This would permit the multimode-plume model calculations incorporated into Energy Plus to be used, and the heat balance models such as DOE-2 or EnergyPro to be modified to permit load adjustments to be made that reflect the stratification produced by displacement ventilation systems. The CHPS category Superior Energy Performance includes: 2 points for exceeding Title 24 2005 by 15%, 4 points for exceeding Title 24 2005 by 20%, 6 points for exceeding Title 24 2005 by 25%, 8 points for exceeding Title 24 2005 by 30% and 10 points for exceeding Title 24 2005 by 35%.

Appropriate language should be included in the text in this section of Volume III of the CHPS Best Practices Manual to reflect these modifications. The current version of Volume II of the CHPS Best Practices Manual [25] includes substantially more information on displacement ventilation in Thermal Comfort Guideline TC2, but this information should be further enhanced to include current citations of recent field experience with displacement ventilation in schools design as well as information on available analysis tools as previously described. Some of this information has been included in a draft revision of Guideline TC2: Displacement Ventilation System[26], for the CHPS Best Practice Manual (a deliverable on the current CEC IEQ program). Displacement ventilation should also be cited as a desirable system to be considered in the energy efficiency checklist for HVAC systems in the introduction to Volume II of the CHPS Best Practices Manual[25].

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Leadership in Energy and Environmental Design (LEED®)

The U.S. Green Building Council provides the LEED Rating System as a means of evaluating and certifying the energy and environmental performance of buildings. Version 2.1 as cited in the Final Code Action Plan[7] was issued in November 2002 and revised in March 2003[27]. Version 2.2 was issued in October 2005 [28]and supercedes Version 2.1 for projects registered after January 1, 2006. (For projects registered prior to this date, LEED Version 2.1 remains in effect and the provisions outlined in the Final Code Action Plan[7] still apply.)

There are several levels of certification possible [29] and information on the certification process can be found on the LEED website[30]. Threshold requirements must be met in the following categories: sustainable sites, energy and atmosphere, materials and resources, indoor environmental quality and water efficiency. After these requirements are met, the building can earn credits that result in points being applied to achieve the resulting certification level. The Final Code Action Plan[7] discusses some of the LEED rating requirements and opportunities for credits that apply to the DV systems that were studied in this Program and suggestions for how to obtain these credits.

Changes from versions 2.1 to 2.2 that affect displacement ventilation include reference to current versions of ASHRAE 90.1 -2004, ASHRAE 62.1-2004, and ASHRAE 55-2004 rather than the 2001 versions previously cited. In the Energy and Atmosphere (EA1) Credit, for new buildings, 1 point is given for exceeding ASHRAE 90.1 by 10.5% and 1 point for every additional 3.5% increase in efficiency up to 10 points for exceeding ASHRAE 90.1 -2004 by 42%. For existing buildings 1 point is given for exceeding ASHRAE 90.1 by 3.5% and 1 point for every additional 3.5% increase in efficiency up to 10 points for exceeding ASHRAE 90.1 -2004 by 35%. Provisions are also given for using local codes with demonstrated equivalence to ASHRAE 90.1 -2004.

A corollary area that was changed is EA Prerequisite 1 dealing with commissioning of the building energy systems. The more detailed requirements of EAp1 will be useful in assuring that the assumptions made in the energy calculations are realized in the field.
In the Indoor Environmental Quality area EQ Credit 2, Increased Ventilation, references to ventilation effectiveness have been replaced with a requirement that ASHRAE 62.1-2004 breathing zone ventilation rates be exceeded by at least 30% to achieve a credit of 1 point. Since displacement ventilation systems are often used effectively with 100% outside air this credit should be readily achieved. It is recommended that consideration be given to inserting language in the Potential Technologies and Strategy section in future versions and documentation of the LEED rating system that cite the ability of displacement ventilation systems to provide this credit.

In the Indoor Environmental Quality area EQ Credit 7, Thermal Comfort, references to achieving the requirement of ASHRAE 55-2004, Thermal Comfort Conditions for Human Occupancy, are cited. Since displacement ventilation systems deliver cooling air at a relatively high temperature and low velocity, they are likely to minimize uncomfortable drafts compare to higher velocity, lower supply temperature provided with mixed ventilation systems. It is recommended that consideration be given to inserting language in the Potential Technologies and Strategy section of this credit in future versions and documentation of the LEED rating system that cite the ability of displacement ventilation systems to facilitate the achievement of this credit.

Up to 4 points can be achieved in the Innovation & Design Process (ID*)* credit category for exceptional performance above that set by the LEED Rating System and for innovative performance in green building categories not specifically addressed by LEED. The improved ventilation effectiveness, and indoor air quality in buildings deploying displacement ventilation are not otherwise accounted for in the requirements set by the LEED Rating System and for innovative performance in green building categories and should therefore be should result in some additional credit being imparted to the DV system in the Innovation & Design Process area. It is recommended that consideration be given to inserting language in the Potential Technologies and Strategy section of this credit in future versions and documentation of the LEED rating system that cite the ability of displacement ventilation systems to facilitate obtaining credit pints in this area.

Acknowledging the usefulness of incorporating the load calculation simplifications embodied in Table 1 into ASHRAE 90.1 provisions will permit heat balance tools to be more readily used for flow down to LEED energy use calculations. Some rating officials already accept this partitioning. If ASHRAE 90.1 includes this in their code language no specific additional actions will be required by LEED. In the absence of this acknowledgement LEED officials may want to sanction the acceptability of this method to “rating authorities.”

Savings By Design

This program[31], funded by California’s utility customers and administered by California’s investor-owned utilities and the Sacramento Municipal Utility District, provides design assistance services and financial incentives to help make energy performance a top priority for architects, engineers and building owners. The program was updated in 2006 to include new electric and gas rates to compute benefits. Two approaches are possible, the *Systems Approach* and the *Whole Building Approach*. As noted in the Final Code Action Plan[7] the *Whole Building Approach* is the one most applicable to displacement ventilation.

With the *Whole Buildings Approach,* design assistance, simulation assistance, report preparation and systems integration design assistance are possible. Under the *Whole Building Approach,* the owner incentive is triggered when the overall savings exceeds 10% of Title 24 standards. The whole building owner incentive rate currently in place[32] in 2006 begins at $.10/kWh and $.34/therm at 10% beyond standards threshold and increases to $.25/kWh and $1.00/therm at 30% beyond standards. The owner incentive can reach a maximum level of $150K when savings exceed 30% of Title 24 standards [33]. Design team incentives are triggered when the savings exceed 15% of Title 24 standards and range from $.05/kWh and $.187/therm to $.083/kWh and $.333/therm when savings exceed 30% of Title 24 standards. Design teams can achieve a maximum level of $50K per project when savings exceed 30% of Title 24 standards[34]. Participation procedures, documentation requirements and incentive calculation procedures are provided[32].

In a *Whole Building Approach* analysis, two sets of simulation runs are required for each measure or package of measures. The first set of runs is a Title 24 Compliance run that establishes the Compliance Margin that is used to determine the incentive rate. This set of runs must conform to the ACM rule set, but does not necessarily have to be run with the certified tool, as long as it correctly follows the Title 24 rules. The second set of runs uses real operational characteristics to determine estimated savings which are multiplied by the incentive rate to determine the incentive amount. Some of the assumptions that are fixed in a Compliance Run (such as economizer hours and cooling loads) may be freed up in this set so that a better picture can be obtained of the true savings involved.

Any changes suggested and adopted for Title 24 (See above) would have an impact on the *Whole Building Approach* to Savings By Design. Calculation procedures similar to that suggested for in the methodology surrounding Table 1 should be permitted for use with eQUEST to facilitate computation of incentives for displacement ventilation. Savings By Design should also consider using information such as presented in the Energy Design Resources Brief[2] to inform their participants of the attributes of this technology.

General Recommendations

Evidence exists that displacement ventilation can save energy and improve indoor quality in schools and other commercial buildings. Available field test data as cited in this paper could be supplemented with additional laboratory and field test data that should result in better quantification of the savings attributable to displacement ventilation. This test data could be used to validate the correlations obtained with CFD modeling in Table 1.

Some of this testing could be facilitated by California investor owned utilities under their emerging technologies programs. Correlations providing insight into the performance of displacement ventilation systems as a function of building configuration, HVAC systems types, occupancy and climate would facilitate the incorporation of credits for this technology in the relevant building energy codes and building certification and incentive programs.

Energy modeling needs to continue to be improved to handle the room air stratification that needs to develop to facilitate displacement ventilation system energy and air quality benefits. Validation of the models discussed briefly above should be performed as part of the efforts to obtain more extensive field test data on displacement ventilation systems.

Where Can I Get More Information?

The California Energy Commission's PIER IEQ Program has a Website on displacement ventilation for K-12 schools. http://www.archenergy.com/ieq-k12 Reference 7 below should be accessible on that web site.

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ADVANCED HVAC SYSTEMS FOR IMPROVING INDOOR ENVIRONMENTAL QUALITY AND ENERGY PERFORMANCE OF CALIFORNIA K-12 SCHOOLS

Final UVC Brochure / Flyer (Recommendation for Code Actions)

CONSULTANT REPORT

Prepared For:
California Energy Commission
Public Interest Energy Research Program

Prepared By:
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Arnold Schwarzenegger, *Governor*

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DISCLAIMER

Abstract

This paper provides information on the need for improved indoor quality, energy use and maintenance in schools and other commercial buildings. A primer on the use of ultraviolet radiation for coil cleaning is provided that includes information on the types of UVC systems available, and their sizing, operation, maintenance, safety and cost. Examples of field test experience on the efficacy of the technology are provided. The presence of coil fouling and attendant increase pressure drop and degraded heat transfer and performance are addressed. The possible alternative means of cleaning coils and their attributes are discussed.

Implications of coil fouling and cleaning on relevant building codes are explored with the need for measuring coil degradation and including time-dependent performance in code requirements noted.

Overview

Poor indoor environments in schools influence the health performance and attendance of students. Existing school space conditioning systems have dirty cooling coils, drain pans and plenums that have been fouled by the growth of microorganisms including viruses, bacteria and yeasts and molds. Air passing though and over the dirty coils, drain pans and plenums is likely to be contaminated and could therefore fail to provide the indoor air quality and comfort that can produce optimal student and teacher performance. Microorganism growth can also increase air-flow resistance, and reduce heat transfer, lowering the capacity and energy efficiency of the cooling system. Manually cleaning the coils is a laborious process that only temporarily removes the contaminants.

Using ultraviolet germicidal irradiation, produced by lamps designed specifically for this purpose, can provide continuous, cost-effective coil cleaning. These lamps are designed to emit radiation in the wavelength of 253.7 nanometers that provides the greatest disinfection ability. (The range spectrum of 200 to 280 nm is the “C” range of ultraviolet radiation, hence the term UVC.) The radiation is absorbed by the DNA molecule of the microorganism, producing mutation and deactivation. Thinner walled viruses are most readily deactivated, followed by bacteria and then fungi.

What kinds of UVC systems can be used?

There are three main types of UVC systems that are generally used in buildings: in-duct, upper-room, and air handler systems. In-duct systems provide a high level of ultraviolet radiation sufficient to kill microorganisms in the air flowing past the lamps. Upper room units are installed in occupied rooms above the heads of the occupants, shielded from their view, relying upon personnel movement and heat sources to create currents that cause air flow through the units. They are most often used in rooms with low air turnover. Air handler systems are placed near the cooling coil and drain pan in the delivery plenum and are designed to provide ultraviolet radiation that deactivates microorganisms that would otherwise foul the surfaces of the air handling unit. This irradiation of stationary surfaces has long UVC exposure times and therefore lower intensity requirements than the other types of UVC systems that are trying to disinfect a moving air stream.

Low-pressure UVC systems use lamps that are designed to provide radiation at the 253.7nm wavelength that is most effective in deactivating microorganisms. The lamps use low pressure mercury vapor, operating on the same principles as a fluorescent lamp but differing in not containing phosphors that convert UV to visible light. Another difference is that UVC lamps are made of quartz or soda barium glass which transmits UVC, rather than common glass which does not.

This paper deals primarily with issues related to placement of UVC systems in air handing units in the proximity of the cooling coil and drain pan. In all cases it is recommended that filtration be used in conjunction with the UVC system.

What are the possible benefits of UVC?

- **Indoor air quality** – may be improved since the coils that are continuously cleaned by UVC are thus no longer an incubation site for microorganisms. Air flowing through the coils is not contaminated, resulting in cleaner air being delivered to the classroom.
- **Maintenance Benefits-** may accrue from use of UVC lights to keep coils continuously clean, avoiding the laborious coil cleaning actions that will otherwise be required to return coils to a clean condition.
- **Energy Benefits –** may be provided by ultraviolet lighting that cleans cooling coils, reducing pressure drop, improving heat transfer and increasing system capacity, resulting in overall cooling energy savings.

How important is indoor air quality?

Evidence strongly suggests that poor environments in schools, primarily due to the effects of indoor pollutants, adversely influence the health, performance and attendance of students and teachers. This evidence links high concentrations of several air pollutants to reduced school attendance. There is also persuasive evidence that microbiological pollutants are associated with increases in asthma effects and respiratory infections, both of which are related to reduced school performance and attendance.[1] UVC lights offer an effective means of both reducing energy use and delivering fresh air to improve classroom air quality.

The lamps are designed to clean both the coil and drain pan surfaces in a few hours or a few days[2] and to progressively penetrate between the coil rows and fins with time.

What are the maintenance issues with UVC?

An effective traditional coil cleaning program cleans the coils three to four times per year. Use of UVC lamps can eliminate the need for these costly, laborious cleaning treatments that create system downtime and use chemicals, biocides or pressure washing. Mechanical or chemical washing may also damage coils.

UVC lamps should be inspected to see if they are dirty and cleaned on a regular basis, as needed. Some installations have a view port to permit visual observation of the lamps, without entering the air handling unit. The frequency of cleaning of the UVC lamps depends on the level of filtration and whether the lamps are upstream or downstream of the filter. Some practitioners suggest that if lamps are installed downstream of an effective filter, the lamps will not need to be cleaned at all before they need to be replaced. To clean the lamps, they can be wiped with a soft lint-free cloth (when the lamps are “off”) moistened with isopropyl alcohol or glass cleaner, to assure that the lamps are operating at optimal efficiency. Lamps lose their efficacy with age and are generally replaced annually or whenever the output falls below 70% of the initial output.

Some practitioners of UVC systems recommend manual cleaning of the coils prior to installation and operation of the UVC lamps. This allows the UVC lamps to keep the coil in a continuously clean condition without fear of dispersing deactivated mold and other microorganisms that might otherwise be present if the UVC lamps were used to deactivate microorganisms on a dirty coil and drain pan. Another option that may work for school buildings is to initially operate the UVC system when the building will be unoccupied for a sufficient period such as the summer vacation break to deactivate the organisms and “flush” them from the building prior to occupancy.

How can UVC save energy?

Cooling system energy can be saved by removing microorganisms from the coil, drain pan and plenum area, reducing air-side pressure drop, increasing air-side heat transfer and increasing system capacity.

Lamps are generally operated continuously to achieve the most effective cooling system cleaning and indoor air quality improvement. The resulting lamp energy use must be less than the cooling system energy savings for overall savings to accrue. In a typical installation the installed lamp power could be as low as less than 1% of HVAC system power for large systems and as high as 5% or greater for smaller systems. The savings produced by the lamps need to exceed these levels to achieve net energy savings for the installation.

How should the lamps be sized, located and operated?

Lamps operate most effectively in still air at 25°C**.** Temperatures both above and below 25°C result in reduced lamp performance Lamps are most effective when they are new and clean and lose their efficacy with age and lack of cleanliness. The effect of humidity has little effect on lamp output but germicidal efficacy appears to decrease with increasing relative humidity[3].

Since lamps lose their efficacy with age and operating conditions often differ from optimal, lamps need to be oversized so they can provide effective performance for a reasonable duration in a real world environment of dust, humidity and cooling air flow. Manufacturers will take this into account in providing and locating lamps and reflectors to provide the appropriate lamp intensity for the installation of interest.

Lamps should be operated continuously to prevent growth of microorganisms.

For coil surface cleaning, lamp placement should provide good coverage of the coil face. The travel path of the UV rays should be directly through the gaps between the coil fins. The placement and sizing of the lamps depends on the types of microorganism in the system, the dimensions of the installation and the desired level of disinfection. Many design approaches are available for sizing UVC systems including catalogs, tables, rules of thumb and analytical methods. In general the manufacturer will take the responsibility of sizing the product to meet the conditions required by the application. One manufacturer suggests that 24 inches of high intensity UVC tube length be used for every 4 ft^2 of coil face area and that the ideal distance between the fixture and the coil is half the distance between rows or half the height of a one row coil if it is less than 24 inches.

The International Ultraviolet Association is developing guidelines for UVGI air and surface disinfection systems[4] that includes recommendations on UV lamp sizing to include cooling effects, heating effects, aging, dust accumulation, burn-in, as well as information on safety issues and operation and maintenance of UVC systems. Guidelines for design and installation of surface disinfection systems in new buildings[5] recommends coil selection that avoids corrugated fins and limits fin spacing to 8-12 fins per inch to facilitate penetration of the UV rays into the coil. Combining surface disinfection systems and air disinfection systems is recommended for maximum effectiveness. The latest information from the most current version of these guidelines should be reflected in any codes and standards actions that result from this paper.

What are the safety issues?

Excessive exposure to UVC causes temporary redness and inflammation of the conjunctiva of the eye. Both should resolve within 24 to 48 hours. The cornea is very sensitive to UVC but UVC does not penetrate the cornea, therefore adverse lens or retinal effects are not experienced except for people who have had cataract surgery to remove their lens or cornea.[6] View ports designed to see if the UVC lamps are operating properly or need to be cleaned should be constructed of glass or Lexan since UV does not penetrate either of these materials.

The Illuminating Engineering Society of North America (IESNA) cited the following exposure limits set by the American Medical Association:

UVC Human Exposure Limits	
Exposure Duration	**Exposure Limit**
Continuous	$0.1\ \mu W/cm^2$
7 hours/day	$0.5\ \mu W/cm^2$
10 minutes	$22\ \mu W/cm^2$
2.5 minutes	$90\ \mu W/cm^2$

The American Conference of Governmental Industrial Hygienists (ACGIH) recommends threshold limit values (TLV) for UVC exposure in an 8 hour period of 6.0 mJ/cm^2, equivalent to an irradiance of .2 $\mu W/cm^2$ for an eight hour period and .4 $\mu W/cm^2$ for a 4 hour period. Above this level, erythema (skin redness) and photokeratitus (external eye inflammation) occurs. UV exposure and leakage needs to be minimized. (A tell-tale blue glow provides a clue to UV leakage.)

UVC lamps should be designed to avoid emitting radiation below at the 200nm wavelength that produces ozone.

Plastic-coated wiring can be become brittle when exposed to UV and can create a fire hazard. Glues that hold filter pleats together or to hold the filter to the frame can be degraded by UV. The exposure of UV to these materials must be avoided.

While these hazards are real and care should be taken to avoid unsafe practices, experienced manufacturers and installers are well aware of the safety issues accompanying the use of UVC in occupied buildings and have designed fixtures, safety interlocks, and installation, servicing and operating procedures to avoid any potentially adverse affects that cold occur.

What does it cost?

The initial cost of the lamps and related control equipment and the annual/periodic replacement costs of the lamps are additional costs accrued with the UVC systems. This should be compared to the maintenance costs that will otherwise result from regular chemical, biocidal or pressure cleaning.

Incremental energy use of the lamps must also be considered. Practitioners of these systems have asserted that the additional cost of UVC systems is more that offset by the elimination of costly air handler system cleaning, and incremental coil energy use reduction and that short paybacks are generally achieved.

Furthermore the quantification of the value of reduced absenteeism, and greater learning performance can greatly multiply these benefits. In the end, it may often be the promise provided by using UVC to improve indoor environments and to consequently enhance student and teacher health and productivity that turns the decision in favor of this technology.

What field data has been published on UVC for coil cleaning?

UVC has been used effectively in many commercial buildings including a number of K-12 schools. Examples of the benefits of UVC installation in schools are provided below:

An article on UVC classroom installation in the Capistrano Unified School District in California, claimed reduction in indoor air contaminants (skin cell fragments of 66% and pollen of 50%) and “every 15 to 20 minutes the air in that classroom will be purified resulting in a major improvement over previous conditions”.[7]

The LaPorte Independent School District in Texas installed UVC lamps in a building that had been infected with fungal growth that had been treated with costly cleaning, inspections, and chemical sprays. The UVC installation eliminated the need for these costly, time consuming treatments and provided the ancillary benefit of almost a 10% reduction in energy use compared to a similar facility that had less hours of operation.[8]

The Stepping Stones Center educational and therapeutic facility in Cincinnati, Ohio, used UVC lights to effectively remove mold from an otherwise unusable building.[9]

Examples of use of UVC in other types of commercial buildings include the following: Florida hospital in Orlando, Florida installed UVC lamps in a 27 year old air handling unit and within weeks of the installation, air velocity over the coil more than doubled and pressure drop was reduced by over 60%, saving at least 15% of HVAC energy costs.[10]

Application of UVC in the coil/drain pan area of the HVAC system in an office building in Montreal found a 99% reduction in AHU surface microorganisms, a 25 to 30% reduction in airborne bacteria, a 20% drop in worker absenteeism and a 40% drop in respiratory problems.[11]

Central and South West Corporation of Dallas Texas, installed 170 UVC lamps in the air handlers in their nearly 500,000 ft^2 building in 1998, providing an approximately 28% reduction in air-conditioning system energy use and coils that are free of mold and organic buildup without any use of chemical cleaning or biocidal treatment.[12,13]

Current Study Sponsored by the California Energy Commission

UVC lamp systems were installed in 36 packaged air conditioning units in three school districts across California.[14] Their performance was compared to 18 control units in those school districts over a six week period starting in August 2005. Both packaged rooftop and wall mount type air conditioning units were included in the study. Units that were less than four years old were excluded from the study. The three districts that were included in the study all had year-round schedules. Microbial samples were taken from the surfaces of the cooling coils for each of the units prior to the installation and operation of the UVC lamp systems and also at the end of the test period. Each sample was subjected to fungal and bacterial testing. Results showed that the UVC lamps notably reduced the levels of microbial counts in the evaporator coils in the air conditioning units. (Total fungal and gram positive bacteria reductions from 65 to 100% of colony forming units were found.) Airflow and efficiency measurements were also made on the units and showed a positive trend (1 to 2% improvement in air flow) in reducing pressure drop, and improving air flow but this trend was not statistically significant for the sample size and conditions evaluated.

These study results were somewhat surprising leading us to an investigation of the importance of coil fouling, how this is effected by environmental conditions and the influence of coil cleanliness on system performance. This information follows below along with a description of the pros and cons of alternative coil cleaning techniques.

How Important is Coil Fouling?

Coil fouling is defined as an increase in pressure drop above 100% compared to a new coil. Reduced air flows from coil fouling can cause typical efficiency degradation of less than 5% [15] but can be much greater for marginal or extreme conditions where the units are operating on a steep part of the fan curve or have low refrigerant charge. An analysis of air conditioner coils[16] showed that they were relatively insensitive to low and moderate amounts of air flow reduction due to fouling. When air flow was reduced by 35%, the coil had just a 6% drop in EER with the majority (4.6% of the 6%) occurring in last two years of the coil's twenty year life projection.

Both of these studies indicate that substantial fouling is needed to produce modest (~5%) degradation in efficiency. The level of fouling needed to provide the opportunity to save significant amounts of energy as cited in the Texas and Florida studies[8, 11, 13, 14] is likely to be indicative of humid, warm conditions that have produced considerable microbial growth that may have gone untreated for some time.

Pros and Cons of Coil Cleaning Technologies – The following compares the perceived advantages and disadvantages of traditional coil cleaning methods that use chemicals, biocides or pressure washing to the attributes if UVC lights for coil cleaning. Both types of technologies lacking well-documented quantitative studies of coil degradation and the subsequent benefit of cleaning methods and systems.

UVC Technology

Pros- Surface cleaning is quick and effective. Continuous cleanliness is maintained, sustaining cleanliness benefits. Maintenance (lamp cleaning and replacement) is quick and simple.

Cons- It is unclear how UVC light penetrates well below the surface envelope of the coil to disinfect and clean deep within the coil. UVC only addresses biofouling and does not affect other contaminants. Cleaning could take weeks or months to reach maximum effectiveness. The initial cleaning period may need to be coordinated with breaks/school shutdown periods to avoid transmittal of dead/deactivated organisms into the occupied space.

Traditional Coil Cleaning Technologies

Pros – The coil is cleaned to the full extent that is manually possible immediately after treatment. HVAC technicians are familiar with these technologies, infrastructure exists for their deployment.

Cons- Pressure washing could drive contaminants deeper into the coils. Chemicals and biocides need to be carefully removed to avoid subsequent air contamination. Cleaning can require facility shutdown, disassembly of equipment. The coil cleanliness degrades steadily immediately after initial treatment.

Recommendations

Although building performance standards and certification programs are generally based on the as-designed and as-built conditions there is a tendency for building performance to degrade as the building ages. Degradation of the air handler performance, for example, can be affected by the buildup of dirt and microorganisms on the heat exchanger surfaces with the passage of time. This buildup and consequent fouling and performance degradation is exacerbated in the presence of moisture, mold spores, bacteria and other environmental parameters that encourage the growth of microorganisms.

Several issues should be addressed in response to coil performance degradation. Effort should be made to keep the coil in a clean condition to minimize energy use and maintain systems capacity and building comfort. The building operator should regularly inspect and monitor the condition of the air handler/coil surfaces to assess the degree of biological buildup through visual inspection, presence of odor, increased pressure drop and complaints about insufficient cooling. Language in codes and guidelines should refer to ASHRAE guidelines being developed as SPC 180P[17] to provide minimum inspection requirements that preserve a building's ability to achieve acceptable thermal comfort, energy efficiency and indoor air quality in buildings.

Conditions that produce or are likely to produce substantial coil fouling should require the use of coil cleaning procedures. If ultraviolet lights are used to provide this cleaning then adherence to the guidelines outlined in this paper and those being developed by the IUVA[4, 5] with regard to sizing, location, safety, operation, and maintenance should be required.

Substantial additional field testing is needed to quantify the potential improvement in performance accruing from the use of UVC lights in conditions that could otherwise produce substantial coil fouling. Correlations resulting from this testing could then be factored into the calculations employed to evaluate energy performance in codes such as ASHRAE 90 and Title 24. Once this has been done these calculation procedures could be factored into the LEED® rating system to provide for superior energy performance if UVC is used to maintain an otherwise severely fouled coil in a clean condition. Similarly, credits could be provided in the Collaborative for High Performance Schools (CHPS) to reflect performance enhancements due to UVC implementation.

Applicants for building energy code approval by or certification by guidelines should be made aware of the issues regarding building maintenance and operation in order to maintain the performance of the HVAC system over the life of that building.

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