

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

Attachment VIII Displacement Ventilation and UVC Training EdSpec Models

Prepared For:

California Energy Commission
Public Interest Energy Research Program

Prepared By:

Architectural Energy Corporation



Arnold Schwarzenegger, *Governor*

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CALIFORNIA ENERGY COMMISSION

Prepared By:

Architectural Energy Corporation
John Arent

Submitted By:

Vernon Smith
Program Director
Boulder, Colorado
Commission Contract No. 500-03-030

Prepared For:

Brad Meister
Commission Contract Manager

Ann Peterson

PIER Buildings Program Manager

Nancy Jenkins

Office Manager

ENERGY EFFICIENCY RESEARCH OFFICE

Martha Krebs, Ph.D.

Deputy Director

**ENERGY RESEARCH AND DEVELOPMENT
DIVISION**

B. B. Blevins

Executive Director

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EdSpec Model for Displacement Ventilation
HVAC Applications

CONSULTANT REPORT

Prepared For:
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Prepared By:
Morton H. Blatt



Arnold Schwarzenegger, *Governor*

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CALIFORNIA ENERGY COMMISSION

Prepared By:
Morton H. Blatt
Energy Utilization Consultant

Submitted By:
Vernon Smith
Program Director
Boulder, Colorado
Commission Contract No. 500-03-003

Prepared For:
Brad Meister
Commission Contract Manager

Ann Peterson
PIER Buildings Program Manager

Nancy Jenkins
Office Manager
ENERGY EFFICIENCY RESEARCH OFFICE

Martha Krebs, Ph.D.
Deputy Director
**ENERGY RESEARCH AND DEVELOPMENT
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EdSpec Model for Displacement Ventilation HVAC Applications

This report provides information that permits school facility officials to include displacement ventilation systems in their Educational Specification in K-12 schools in California.

Information on displacement ventilation benefits and experience can be found on the CEC website¹ and in a recently published article in *Engineered Systems* magazine.² Briefly, displacement ventilation uses low velocity cooling air delivered at around 65°F along or near the floor to create thermal plumes when they reach a heat source such as person or a piece of equipment. The plumes carry heat to the ceiling where it is exhausted from the space resulting in a stratified room air temperature profile. Indoor contaminants are often created by the same people and equipment sources as the heat and are thus entrained in the plume and also exhausted from the room. The resulting stratified room air temperature profile provides both a more comfortable and healthier environment in the occupied zone. The higher temperature and pollutant levels commonly in the occupied zones are now elevated to the space between the occupied zone and the ceiling where they can be readily exhausted. Displacement ventilation provides acoustic benefits (because of the low velocity diffusers), reduced energy consumption (lower fan motor speeds and greater economizer use) and indoor air quality benefits (because of the stratification).

Educational Specifications often known as EdSpecs are used as guidelines for planning and construction of school facilities that provide comfortable, healthy, productive learning environments. A brief review of EdSpecs in Connecticut, Vermont, Pennsylvania, Idaho, North Carolina, Colorado as well as EdSpecs for the two districts (Dry Creek Joint Elementary School District and Capistrano Unified School District) in California that hosted the testing of displacement ventilation systems in Project 2 revealed a wide range of detail with regard to acknowledging the need for better space conditioning. These results describe the desired attributes of a good space conditioning system, and suggest or specify practices or options to be considered or followed. The following examples are provided, in order of increasing detail to address the spectrum of EdSpec needs.

The first example does not deal specifically with HVAC systems and just states that:

- **The school design shall provide a comfortable learning environment.**

A bit more detailed generic example would be:

- **The building shall be equipped with an HVAC system that provides, zone control, economizer operation, comfort and good acoustics.**

Further recommendations are provided in a statement such as:

- **The District would expect that various options would be evaluated and the HVAC systems most beneficial to the users of the building and the District would be selected for implementation.**

EdSpec Model for Displacement Ventilation HVAC Applications

In addition to this language the EdSpec could go into some detail as to what HVAC system has worked well for the District and as such should be included in this evaluation.

For example this could read:

- **The District would expect that various options would be evaluated and the HVAC systems most beneficial to the users of the building and the District would be selected for implementation.**
- **The District has been pleased with the Kinoshita Displacement Ventilation System for the following reasons:**
 1. **Energy efficiency, energy costs**
 2. **Acoustics**
 3. **Indoor air quality, health, freshness**
 4. **Comfort**
 5. **User control**

The following example deals with displacement ventilation in greater detail. The areas of main concern addressed in the example are those most likely to be useful to a wide range of school districts in deploying displacement ventilation systems. These areas include facility requirements, acoustic requirements, HVAC/DV system specifications and climate constraints.

Facility Requirements:

- **Minimum ceiling height of 9 feet.**
- **High performance windows, preferably double-pane, low- ϵ (emissivity), to minimize radiant heat loss and cold downdrafts.**
- **Floor space allocation for at least two low-velocity diffusers per classroom (each can be on the same wall near the corners of the room), with each diffuser taking up about 1.5 ft² of floor space and 5 ft² of wall space. For very large spaces with a linear floor dimension greater than 35 feet four diffusers are recommended with an additional two diffusers on the opposite wall.**
- **Avoid stationing occupants within 2 to 4 feet of the diffuser.**
- **Exhaust should be located at or near the ceiling.**
- **Thermostats should be at least 6 to 8 feet from the nearest supply diffuser.**
- **Tight envelope requirements with insulation exceeding Title 24 requirements if the low velocity displacement diffusers are to be used for heating.**

Acoustics Requirements:

- The low velocity (40 to 70 ft/min) diffusers used with displacement ventilation can help meet ANSI S12.60 Acoustics Standards and the Collaborative for High Performance Schools criteria that both recommend a background noise level of 35dBA or less for core learning spaces.
- Specify diffusers that will provide a Noise Criteria rating of NC 27 or better.

HVAC System Requirements:

- Control supply air temperature to within 3°F of the set point (~65°F), this will typically require a level of control that cannot be achieved with single stage packaged units. This will typically require a system with multiple cooling stages or a variable speed compressor. Systems with only two cooling stages may meet this requirement if hot-gas bypass is used at low load conditions. Typically this will often require a programmable controller or control capable of discharge air temperature control.
- Control of the space temperature should be maintained by varying the supply air volume, supply air temperature, or both. A constant air volume system is possible but a variable air volume (VAV) system is recommended as the preferred control strategy.
- Variable-speed drive capable to reducing fan speed and fan power during part-load conditions. VAV control is preferred for several reasons: it saves energy, it promotes stratification in the space, which is one source of the energy benefits of DV, and it reduces indoor noise levels and the potential for drafts during reduced air flow.
- When using the low-velocity diffusers for heating, a supply air temperature of 80-90°F is recommended. This requires a low heating stage (35 MBH) when using gas heating.
- For systems that do not provide 100% outside air, an integrated, fully-modulating economizer (not two-position) with either differential dry-bulb or differential enthalpy control (preferably factory-installed, but could be an original equipment add-on).
- A low-ambient setting is recommended for the economizer, so that the outside air is blended with return air to maintain the minimum required supply air temperature when the outside air temperature falls below 60°F.

Optional HVAC Systems Features:

- With VAV control, the economizer should incorporate an adjustable minimum damper position, so that the outside air volume can be maintained as the fan speed is reduced.
- Demand-controlled ventilation can save energy when the displacement ventilation system provides good ventilation effectiveness by reducing the required amount of outside air intake to provide good air quality in the breathing zone. The CO₂ sensor should be located in the occupied zone of the space.
- The supply air temperature reset set point can be reset higher during low load conditions, thus extending the range of economizer cooling.
- The HVAC system may need to be augmented with additional heating dehumidification and cooling capability to meet the diverse needs of the extreme heat, cold and humidity that could be present in some locations in California. The section below addresses those issues.

Climate-Related Issues and Approaches:

- Provide a perimeter heating system in climates such as Truckee where the winter design dry bulb temperature is lower than 15°F. For all other climates in California, if the building meets Title 24 requirements, the heating needs can be met by supplying air at 80 to 90°F and 1100 ft³/min through the low-velocity displacement ventilation diffusers.
- Humidity control issues may be of importance for Southern California coastal climates or in areas where heavy irrigation requirements or other moisture sources could create high humidity. Indoor moisture sources can be very important in this regard, as well. Consider augmenting the displacement ventilation system with ancillary humidity control equipment or techniques when the absolute humidity would otherwise be greater than the indoor design limit recommended by ASHRAE 55-2004 (of .012 lbs of moisture per lb of dry air) for more than 10% of the time. Humidity control options to be considered should include return air bypass, mixed air bypass, runaround coils and condenser or exhaust air heat recovery.
- The displacement ventilation systems should be able to handle the cooling loads of all classrooms built to Title 24 requirements without need for an auxiliary cooling system. Displacement ventilation systems should be able to handle cooling loads of up to 25 BTU/hr-ft².

EdSpec Model for Displacement Ventilation HVAC Applications

The next level of detail regarding displacement ventilation systems specifications and application guidelines are beyond the scope of this report. This information is provided in a companion document that is available from the project web site.¹ Parallel documents on ultraviolet lights for coil cleaning are also available on that site.

¹ California Energy Commission's PIER IEQ Program website www.archenergy.com/ieq-k12.

² Arent, John, et.al. "The Right Place for Displacement," *Engineered Systems*, pp56-62, April 2006.

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

Model EdSpec for Ultraviolet Lights for Coil Cleaning

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Prepared For:
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Prepared By:
Morton H. Blatt



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CALIFORNIA ENERGY COMMISSION

Prepared By:
Morton H. Blatt
Energy Utilization Consultant

Submitted By:
Vernon Smith
Program Director
Boulder, Colorado
Commission Contract No. 500-03-003

Prepared For:
Brad Meister
Commission Contract Manager

Ann Peterson
PIER Buildings Program Manager

Nancy Jenkins
Office Manager
ENERGY EFFICIENCY RESEARCH OFFICE

Martha Krebs, Ph.D.
Deputy Director
**ENERGY RESEARCH AND DEVELOPMENT
DIVISION**

B. B. Blevins
Executive Director

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Model EdSpec for Ultraviolet Lights for Coil Cleaning

This report provides information that permits school facility officials to decide whether and how to include ultraviolet lighting systems for coil cleaning in their Educational Specification in K-12 schools in California.

Information on ultraviolet lighting for coil cleaning can be found on the CEC website¹ and in a recently published article in *Engineered Systems* magazine.² Briefly, ultraviolet radiation in the “C” wavelength range (UVC) has been used to irradiate dirty air handling system components to deactivate microorganisms on the coils and drain pans of these systems. The UVC is designed to clean both the drain pan and outer coil surfaces in a few hours or a few days, depending on the irradiance levels, and progressively penetrate into between the coil rows and fins with time (within a few weeks or months based on anecdotal data) to clean within the coils³. The objective in removing the microbiological contamination in cleaning the coils is to reduce the pressure drop and enhance the air-side heat transfer, improving the system energy efficiency. Another benefit that has been claimed is improved indoor air quality, apparently caused by reduced entrainment of microbes into air passing over the coil before it enters the room.

The benefits of ultraviolet lighting for coil cleaning are (in a retrofit situation) achieved by returning coil performance to the as-built condition or (in a new building situation) by maintaining the coil in a continuously clean condition. As addressed in the article in *Engineered Systems* magazine², the available data make it unclear whether coils get dirty enough in the California environment to make cleaning a cost-effective proposition. There is however anecdotal data that indicates that using ultraviolet light in the “C” spectrum (UVC) to clean coils that have been heavily fouled by coils in environments that promote heavy microbial growth can be beneficial. There is also well-designed research that has provided evidence in office buildings that UVC coil cleaning carries over into the workspace with reduced airborne microorganisms and improvements in health and attendance.

Installation of UVC lights for coil cleaning in schools can help save energy, enhance indoor air quality and improve maintenance.

Educational Specifications often known as EdSpecs are used as guidelines for the siting and construction of school facilities that provide comfortable, healthy, productive learning environments. A brief review of EdSpecs in Connecticut, Vermont, Pennsylvania, Idaho, North Carolina, Colorado as well as EdSpecs for the two districts (Dry Creek Joint Elementary School District and Capistrano Unified School District) in California that hosted the testing of displacement ventilation systems in Project 2 revealed a wide range of detail with regard to acknowledging the need for good space conditioning, describing the desired attributes of a good space conditioning system, and suggesting or specifying practices or options to be considered or followed. The following examples are provided, in order of increasing detail to address the spectrum of EdSpec needs for a district that is considering or has decided to utilize UVC lights for coil cleaning.

The first example does not deal specifically with HVAC systems and just states that:

- | |
|--|
| <ul style="list-style-type: none">• The school design shall provide a comfortable learning environment. |
|--|

Model EdSpec for Ultraviolet Lights for Coil Cleaning

A bit more detailed generic example would be:

- **The building shall be equipped with an HVAC system that provides, zone control, economizer operation, comfort and good acoustics.**

Further recommendations are provided in a statement such as:

- **Various HVAC options should be evaluated and the HVAC systems most beneficial to the users of the building and the District should be selected for implementation.**

In addition to this language the EdSpec could go into some detail as to what HVAC system has worked well for the District and as such should be included in this evaluation. For example this could read:

- **Various HVAC options should be evaluated and the HVAC systems most beneficial to the users of the building and the District should be selected for implementation.**
- **UVC Systems for coil cleaning are a desirable option for the following reasons:**
 - 1. Improved indoor air quality,**
 - 2. Better student and teacher health,**
 - 3. Higher test scores (enhanced student-teacher productivity)**
 - 4. Enhanced HVAC system energy efficiency, reduced energy costs**

The following example deals with UVC for coil cleaning in considerably more detail. The areas of main concern addressed in the example are those most likely to be useful to a wide range of school districts that have had or anticipate having coil fouling problems and resultant indoor air quality problems. Those Districts should consider deploying UVC systems to solve anticipated problems. They may want to perform some before and after testing to check to see if their problems have been solved or that their objectives have been achieved in deploying ultraviolet lighting systems. These areas include climate, maintenance, HVAC/UVC system requirements, and safety issues.

Climate and Environmental Issues:

- **Consider coil-cleaning technologies if fouled coils and indoor air quality seem to be a problem in the District. Reduced airflows from coil fouling can cause performance problems under extreme contamination conditions and marginal performance conditions. Fouling/microbial contamination is more severe when moisture, and warmth and sources of microbes are more prevalent.**
- **Most California climates have relatively benign dry environments with regard to microbial growth.**

Maintenance and Operational Issues:

- Lamp output degrades with age and buildup of dirt.
- Install a view port to permit visual observation of the lamps without entering the air-handling unit.
- Set up maintenance program when UVC lamps are installed.
 - This should include regular inspections of the lamps to see if they are dirty and consequent cleaning with a soft lint-free cloth.
 - It should also include replacement of lamps annually or whenever their output falls below 70% of their initial output.
- Consider manual cleaning of the coils prior to installation of the UVC lamps.
- Operate lamps continuously to assure that growth of microorganisms is prevented.
- Safety interlocks should disable lamps prior to performing work on the UVC system.

HVAC/UVC System Requirements:

- Use UVC lamps to keep coils continuously clean rather than traditional coil cleaning methods that use chemical and biocides, often require facility shutdown and only provide intermittent cleaning.
- Place lamps where there is ample space in the air-handling unit, a good line of sight to the coil, and the opportunity to avoid exposing materials that are sensitive to degradation from UVC light.
- Placing lamps downstream of the cooling coil usually provides a direct line of sight to the drain pan affording an opportunity to disinfect that source of moisture and microbial growth.
- For coil cleaning the travel path of the UV rays should be directly through the gap between the coil fins.
- Filtration should be used in conjunction with the UVC system.
- Design approaches may be used that rely upon catalogs tables, analytical methods and rules of thumb. Sizing and placement of the lamps depends on the types of microorganisms in the system, the dimensions of the installation and the desired disinfection level. To be safe, rely on manufacturers to size and locate their lamps to achieve your desired specifications and objectives.
- Refer to a UVC Buyer's Guide, maintained by the International Ultraviolet Association (IUVA) to get manufacturers information and product information and catalogs to help select a UVC manufacturer and product.

Safety Issues:

- **Avoid direct exposure to filters containing glue and to plastic-coated wiring.**
- **Avoid direct and excessive exposure to UVC light that can cause temporary skin redness (erythema) and inflammation of the conjunctiva of the eye, both of which should only last 24 to 48 hours. Sizing and placement of the lamps depends on the types of microorganisms in the system, the dimensions of the installation and the desired disinfection level.**
- **Safety interlocks should be installed to disable the lamps when access doors to ports are opened to prevent unnecessary exposure to the UVC light.**
- **View ports should be designed to see if the lamps are operating properly and should be constructed of glass or Lexan since UV does not penetrate either of these materials.**

The next level of detail regarding ultraviolet lighting systems specifications and application guidelines are beyond the scope of this report. This information is provided in a companion document that is available from the project web site.¹ Parallel documents on displacement ventilation are also available on that site.

¹ California Energy Commission's PIER IEQ Program website www.archenergy.com/ieq-k12

² Blatt, Morton, et. al., "Ultraviolet Light for Coil Cleaning in Schools," *Engineered Systems*, pp50-60,95 March 2006.

³Kowalski, Wladyslaw, "UV Cooling Coil Disinfection," The Pennsylvania State Indoor Environment Center, for American Air and Water, September 1, 2005.