Energy Efficient Humidity Control in Older Schools

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SUMMARY

Schools with low summer cooling loads due to minimal summer activities often elect to deactivate heating, cooling and air conditioning (HVAC) systems to save energy. Some of these schools experience surface mold growth caused by elevated relative humidity. Eight schools with summer mold growth were investigated to identify contributing factors. HVAC systems and building envelopes were evaluated and site history was documented. Critical factors responsible for mold growth varied between schools. These included overcooling, negative building pressurization, control sequences promoting damp conditions and excessive ventilation. De-activation of HVAC systems was not a factor in some cases. Options for avoiding these conditions and their relative costs are discussed. Mitigation measures generally improved energy efficiency.

INTRODUCTION

Schools in the United States are generally vacant for a two month summer vacation, often with HVAC systems de-activated in unoccupied areas to conserve energy. Mold may grow on walls, floors, furniture and contents in schools with periods of hot, humid weather. Recommendations for controlling building dampness to prevent mold growth include maintaining an average surface relative humidity below 80% over a 30 day period and keeping the dew point low enough to avoid surface condensation (ASHRAE, 2009).

METHODOLOGIES

Eight schools in Maryland, USA with a history of summer mold growth were included in the study. The schools were out of session between mid-June and mid-August, with air conditioning generally off in vacant areas to conserve energy. The objective of this study was to identify critical factors triggering mold growth. Available documentation was reviewed for each school, including HVAC plans, building automation trend logs, maintenance tickets, and schedules for HVAC system operation and building activities. Site investigation compiled the information listed in Table 1.

Table 1. Variable evaluated in study schools.

HVAC Systems	Building Conditions
Control system operation sequence	Locations of suspect mold growth
Thermostat calibration in problem areas	Areas with “bowed” ceiling tiles
Chilled water temperature set point	Water infiltration from leaks
HVAC units for excessive condensation	Condensation – active and water staining
Outside air damper control	Building pressurization
Exhaust fan operation	Openings in building envelope
Outside air damper positions when exhaust fans deactivated	Site orientation
Chilled water pipe insulation for mold or condensation	Solar Loading

The authors then formulated hypotheses that might explain mold growth. The hypotheses were evaluated for consistency with observed and reported conditions. Energy implications of identified deficiencies were evaluated and strategies for preventing mold growth were developed.

Onsite investigation was conducted while school maintenance personnel were drying affected areas and remediating mold growth. Because conditions responsible for mold growth were no longer present, moisture-related measurements were not included in this study.

RESULTS

Six schools had a history of elevated humidity occurring throughout the building every summer. In these schools, mold growth was localized to rooms where relative humidity had been highest and, in some cases, where solar exposure was most limited (i.e., north or shaded exposures). The remaining two schools had experienced a one-time episode of mold growth throughout the building due to over-cooling. While each school had a variety of deficiencies contributing to damp conditions throughout the building, the authors identified the following to be critical factors for mold growth:

Deactivated HVAC Systems during Hot, Humid Weather (five schools). Under this condition, no dehumidification was provided during the summer vacation.

Outside Air Dampers Remaining Open (three schools). The pneumatic main air pressure setting opened unit ventilator outside air dampers to 100% when the room temperature was near the 24°C cooling set point. Unconditioned outside air can infiltrate the building under this condition.

Unit Ventilators Valves Remaining Open (three schools). HVAC sequences of operations typically have open control valves when systems are off for during cold weather. In two-pipe systems, these valves may remain open in the cooling season with HVAC fans off and the chiller running, allowing chilled water to flow through the coils. Humid outside air leaked around the damper forming condensation inside and on the outside of the unit ventilator, on surrounding floors and on the underside side of nearby furniture.

Over-Cooling (two schools). Failure of HVAC controls resulted in very cold areas with moisture condensing on surfaces throughout the school. Over-cooling also occurs where thermostats are set too low.

Negative Building Pressure (three schools). Exhaust air significantly exceeded supplied outside air, allowing infiltration of humid air through openings in the building envelope (i.e., unsealed penetrations, small cracks and dampers).

Incorrect Building Automation Schedules (two schools). In these cases, the chillers shut down after-hours while supply air and/or exhaust fans continued to run.

Operating HVAC Systems in Unoccupied Areas (three schools). Under this condition, humid ventilation air contacts cold surfaces. This occurred where custodial staff operated HVAC systems in vacant areas to facilitate floor re-waxing, then left the system running after work was completed. It also occurred where summer school classes were held, and HVAC systems ran on a normal schedule even though occupancy was limited to half the classrooms for half the summer. Providing ventilation when not required introduces damp air with very little dehumidification.

Failed Chilled Water Pipe Insulation Vapor Barriers (five schools). Vapor barriers which are not fully sealed allow warm moist air to migrate into the insulation. Water then evaporates into rooms from wet insulation and underlying surfaces.

Reduced Solar Loads (four schools). At these sites, rooms with mold issues were on a northern exposure, resulting in low cooling loads. Where HVAC operated, coils did not operate in a range to provide dehumidification.

Ongoing Leaks (two schools). Water infiltration, pipe leaks, and high water tables can introduce excess moisture into the building, with subsequent evaporation increasing the dew point.

Equipment Malfunction (two schools). These included broken dampers, motors, thermostats and other controls resulting in failure to dehumidify the air.

Other potential contributors to summer mold growth were chilled water supply temperature set too high for dehumidification, doors and windows left open for extended periods of time, and failure to dry areas after cleaning.

DISCUSSION

Based on these findings, summer mold growth cannot solely be attributed to the issue of de-activating HVAC systems. One or more of these conditions was also present in mold growth schools with HVAC off:

- Negative building pressure with openings to the exterior and/or outside air dampers remaining open with fans off
- Chilled water flowing into unit ventilators with fans off
- Evaporation of excess water from wet chilled water pipe insulation

Table 2 lists significant sources of high humidity, corrective measures, capital and maintenance costs and energy impacts.

Table 2. Options for correcting humidity control deficiencies.

0 = None, 1 = Low, 2 = Medium, 3 = High, +/- = Variable		Costs		Energy Impact	
		Capital	Mainte-nance	Savings	Cost
Problem: HVAC systems off in summer mode					
a	Run HVAC system on normal schedule	0	1	–	3
b	Run HVAC system short duration each day	0	1	–	2
c	Install dehumidifiers in problem areas	0	2	–	1
Problem: Excessive outside air introduced by HVAC system					
a	Reduce HVAC in unoccupied rooms to brief cycle each day	0	1	2	–
b	Run fans at low speed when HVAC system is activated	0	0	1	–
c	Correct minimum damper position	0	1	1	–
d	Correct sequence of operation	0	1	1	–
e	Disable exhaust and outside air intake during summer mode	1	0	2	–
f	Install motion sensors/controls to disable outside air intake when area unoccupied	1	1	3	–
g	Install DDC controls sequence for summer low occupancy	2	0	2	–
Problem: Extreme over-cooling due to control system failure					
a	Restore normal operations	1	0	3	–
b	Calibrate thermostats	0	2	1	–
Problem: Outdoor infiltration due to negative building pressure					
a	Deactivate unnecessary exhaust fans and increase outside air	0	1	1	–
b	Seal exterior wall openings	1	0	1	–
c	Ensure outside air dampers close when fans are off	1	0	1	–
d	Re-balance the system	3	0	+/-	+/-
Problem: Chilled water flow in unit coils with unit fans off					
a	Program system to close chilled water valve if unit fan is off	0	1	1	–
b	Schedule chiller plant and associated units “on” at same time	0	0	–	2
c	Install DDC system with 2-way valves to close valve when off	3	1	1	–
Problem: Chilled water temperature not at design					
a	Reduce temperature to improve dehumidification	0	0	1	–
b	Increase temperature to control condensation	0	0	–	1
Problem: HVAC runs after-hours					
a	Restore start/stop controls	0	2	3	–
Problem: Wet chilled water pipe insulation					
a	Dry insulation and repair seals	0	2	0	–
b	Replace pipe insulation	3	0	2	
Problem: Limited solar exposure					
a	Install dehumidifier	0	1	–	1
b	Leave lights on	0	0	–	1
Problem: Water infiltration from leaks (roof, plumbing, etc.)					
a	Repair leaks and dry area	0	0	–	–
Problem: HVAC system design provides limited dehumidification					
a	Replace HVAC systems	3	1	–	3

Issues contributing to mold growth in schools where HVAC systems were at least partially operated included:

- Excessive ventilation
- Overcooling
- Negative building pressure
- Chilled water temperature not maintained at design set point
- Start/stop control failures

The authors recommended various options for resolving critical factors associated with summer mold growth. These included:

- Reduce negative building pressure by adjusting outside air intake and exhaust flow rates.
- Disable the outside air dampers and exhaust fans through the building control system in summer unoccupied mode.
- Close chilled water valve when fan is off.
- Operate portable dehumidifiers when needed to supplement dehumidification by the HVAC systems.
- Replace water damaged insulation.
- Prioritize preventative maintenance and repairs of HVAC equipment in buildings subject to mold growth.

Corrective measures were in the process of being implemented at the time of manuscript preparation.

While improving IAQ is commonly assumed to require additional energy use, Table 2 indicates that improved humidity control can, in many cases, lower energy use. While reinstating a normal daily HVAC schedule increases energy use, a reduced operating time can be sufficient to prevent mold growth (Cummings et al., 2005). Additional costs of HVAC operation should be balanced against that for remediating mold growth.

CONCLUSIONS

1. Six schools had a history of elevated dew points throughout the building every summer, with mold growth occurring in the rooms where relative humidity was highest and/or surface temperatures were the lowest. Two schools had recently experienced a one-time episode of mold growth throughout the building due to over-cooling.

2. Critical factors promoting mold growth were:
    - Deactivated HVAC systems during hot, humid weather (five schools)
    - Outside air dampers remaining open (three schools)
    - Over-ventilation (two schools)
    - Negative building pressure (three schools)
    - HVAC air system valves remaining open (three schools)
    - Incorrect building automation schedules (two schools)
    - Operating HVAC systems throughout building with limited activity (three schools)
    - Failed chilled water pipe insulation vapor barriers (five schools)
    - Reduced solar loads (four schools)

- Ongoing leaks (two schools)
- Equipment malfunctions (two schools)

3. Mold growth associated with excessive humidity can be prevented by attention to HVAC operation.

4. Mitigation of the following deficiencies contributing to mold growth is likely to reduce energy use:
   - HVAC control settings allow excessive humidity
   - Over-ventilation
   - Over-cooling
   - Negative pressurization
   - Chilled water pipe condensation

5. A reduced HVAC operating time in vacant areas can be sufficient to prevent mold growth, while minimizing additional energy use. Additional energy cost should be balanced against that required to remediate re-occurring mold growth.

RECOMMENDATIONS

1. Reduce excessive dew points in schools, where feasible, by:
   - Limiting normal HVAC operation to periods when areas are actually occupied.
   - Running HVAC in unoccupied areas on a limited schedule, providing enough dehumidification to prevent mold growth.
   - Limiting HVAC use by Maintenance to the time required to dry wax or carpet, and consider using portable dehumidifiers and fans as an alternative.
   - Adding a mode of operation to Energy Management Systems which disables outside air intake and exhaust when running HVAC in unoccupied areas.
   - Activating outside air dampers by motion sensors, with outside air dampers closing when the room is occupied.
   - Sealing penetrations through the building envelope to prevent outside air infiltration.
   - Programming Energy Management schedules to include a mode where outside air intake and exhaust are disabled while the HVAC system is in occupied mode.

2. Enhance preventative maintenance of schools subject to summer mold growth by:
   - Assigning high priority to HVAC repairs.
   - Identifying critical factors contributing to elevated dew points and implement corrective measures, where feasible.
   - Monitoring classroom conditions regularly during the summer and immediately implementing additional control measures at the first sign of excessive dampness.

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