Protecting the HVAC System During Construction: An Industry Standard of Care for Contractors

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SUMMARY

The relationship between construction activities and an increased risk of microbial contamination and degradation of air quality in new building construction and renovation projects was studied. Poorly designed or installed ventilation systems and inferior workmanship during construction were determined to have an adverse impact on the performance of the building ventilation system. This presentation will provide guidelines to protect HVAC system components during building construction and renovation projects and for building commissioning procedures for building ventilation systems. It also underscores the importance of educating the building owner on proper operation and maintenance of building mechanical systems as part of the building commissioning and transfer process.

INTRODUCTION

Heating, ventilation and air conditioning (HVAC) system components often collect significant amounts of debris and particulates during construction activities within a building. A faulty or contaminated HVAC system can lead to poor humidity and temperature control and cause degradation of indoor air in the building. Newly installed HVAC systems or those in buildings undergoing renovation must be protected before the system is permitted to operate and should be verified to be clean [1]. Protecting HVAC system components from water, dust and debris during construction activities is the major control method to prevent degradation of indoor air quality and microbial contamination. Building commissioning procedures should include quality assurance testing of the ventilation system, prior to building transfer to the owner, to ensure that it is properly tested, and balanced and functioning according to building design parameters. A systematic approach is required to address reported ventilation problems during the warranty period. This presentation describes an industrial hygienist’s role in building construction and renovation, from project planning through testing, and the contribution an industrial hygienist can make to protect HVAC systems from airborne contaminants during construction.

METHODS

The focus of this presentation is on protecting building HVAC systems. Major considerations to prevent adverse impacts on the performance of the building ventilation system are presented by the author based on microbial investigations and case studies involving construction of commercial and residential buildings located throughout North America and the Pacific Rim.
The HVAC system includes the interior surfaces of a building’s air distribution system that services conditioned indoor spaces and/or occupied areas. This includes the entire building ventilation air conveyance system. The return air grilles; return air ducts to the air handler unit (AHU); variable air volume boxes; interior surfaces of the induction, convection, fan-coil units and the AHU; and mixing boxes, heat exchangers, condensate drain pans, humidifiers and dehumidifiers, supply air ducts, fans, fan housings, fan blades, air wash systems, spray drift eliminators, turning vanes, filters, filter housings, reheat coils, ductwork, and supply diffusers are all considered part of the HVAC system. Protecting the integrity of the HVAC system in construction starts with proper building and ventilation system design. Proper building design includes choice of proper building materials; specifications for building construction with detailed attention to critical tasks such as waterproofing, vapor barriers and HVAC systems; procedures for reviewing plans and specifications with explicit consideration of water infiltration and potential mold-related exposure from construction materials, methods, and HVAC system requirements; and procedures for reporting building design weaknesses that can cause water intrusion during construction.

Moisture control in building ventilation design requires diligent engineering. The temperature and relative humidity in climate-controlled areas of the building should be designed within a range considered both comfortable and healthy according to consensus guidelines[2]. Design of the HVAC system, natural airflow, and temperature fluctuations can also help to control moisture condensation and humidity on jobsites. Proper design starts with appropriate material selection. Some materials are more amendable to cleaning during and after construction. For example, unlined galvanized sheet metal and borosilicate glass ducts are corrosion-resistant and cleanable, compared to other duct material, such as fiberglass ductboard and flex duct. Flex duct is extremely difficult to clean because it contains a tremendous amount of surface area inherent in its expandable accordion design. Anti-microbial silver ion-based paints are available to coat sheet metal to minimize mold growth in ductwork[3].

Contractors should provide detailed shop drawings and specifications for the building envelope, including exterior cladding, roofs, windows, walls, doors, and interfaces between the building features and the HVAC system components. For example, Figure 1 shows an exterior wall cavity prior to closing on a multi-story residential construction site. The wall cavity is clean, with no organic debris and minimal dust. This is especially important in places where you have condensation buildup; for example, around the package terminal air conditioning (PTAC) unit housing. PTAC units should be snugly fitted and sealed in the wall with weatherproof silicone sealant, and have flashing and drainage to the exterior for proper condensate pan overflow.

![Figure 1](image1.png)
Figure 1. PTAC unit housing in multi-story residential building.
Strategies to protect HVAC systems during construction are broadly categorized into proper ventilation system design, quality construction methods and work practices, and adequate building commissioning procedures. Design should include easy access to HVAC components, which is essential for proper maintenance and inspection of HVAC systems. Access doors or panels must be provided for all components including ductwork, plenum walls, drain pans, upstream and downstream areas of filters and fan coil units, and terminal boxes [4]. Construction work practices must include proper sequencing of work to protect work-in-progress and to ensure that porous materials, such as fiberglass-lined duct, are installed after the roof structures are dried-in and the building envelope is intact. The time between material delivery and installation should be minimal. Contractors should place emphasis on protection of building materials delivered to and stored at the jobsite from water, dust and debris, and mold growth. Figure 2 demonstrates poor work practices as evidenced by water damage to stockpiled fiberglass duct wrap stored outdoors and exposed to ambient conditions and inclement weather.

Pre-construction planning should include implementation of weather protection plans in project schedules. For example, tenting of the building envelopes using polyethylene sheeting in building construction is a control strategy routinely used to protect exterior wall assemblies during damp, rainy seasons in the U.S. Pacific Northwest.

Because water availability is one of the most critical factors controlling microbial amplification in indoor environments, prompt correction and elimination of water intrusion/moisture sources are imperative. Protecting HVAC system materials and components, and work-in-progress from water, moisture, construction dust and debris is critical to prevent microbial growth and degradation of indoor air. Figure 3 shows proper storage of an AHU in a large commercial building prior to installation, i.e., elevated above the concrete slab floor to protect from water intrusion and covered to shield from construction dust and debris. Figure 4 shows a 30-centimeter diameter branch entry opening to a duct near a supply drop, covered with black plastic, to protect the ductwork interior during construction. Equipment and material movement and a lack of adequate space on construction jobsites can also result in physical damage to HVAC system components. Stored materials and work-in-progress on HVAC systems should be inspected on a daily basis and safeguarded from physical damage.
Proper location of outdoor air intakes (OAI) and cooling towers are of special concern. The location of the OAI can significantly affect the nature of outdoor bioaerosols that enter a building. Rooftop OAI are especially vulnerable to bioaerosol sources such as cooling towers, sanitary vents, building exhausts, and standing water. Cooling towers located close to or directly upwind of OAI are potential bioaerosol sources. To minimize entrainment of cooling tower mist, it is recommended that OAI and other building openings be located at least 7.5 meters and preferably 15 meters upwind of, and horizontally separated from, cooling towers [5]. Even OAI placement at this distance does not ensure that aerosols in the exhaust air / drift will not be entrained. Airflow patterns and prevailing wind direction are important factors affecting drift entrainment. Install drift eliminators on cooling towers to intercept water droplets where air is discharged to limit dissemination of bacteria, such as *Legionella*, from water-cooled heat transfer systems. The cooling tower shown in Figure 5 is constructed of materials that can be readily disinfected and is located in an area that is remote from building air intakes, and easy to inspect and maintain.
Building renovations performed without proper planning and design can also result in degradation of indoor air caused by moisture problems and subsequent mold growth. An indoor air quality study in the United States in 2001 found that some indoor air quality problems in office buildings are the result of contractor errors and omissions including inappropriate balancing and reassessment of HVAC systems during building renovation or modification [6].

Contractors should reduce exposure to liability by contract review, proactive risk transfer methods, and independent third-party construction oversight. Contracts should be carefully reviewed to verify that they: adequately protect the contractor from construction defects or negligence of subcontractors; specifically address the responsibility for repairs; and contain enforceable language providing for indemnification of damages. Contractors should document activities at certain critical stages of construction to establish proof of proper construction practices. Superintendents should take photographs of work-in-progress to document conditions during construction, for example, prior to closing ceiling plenums and wall cavities and covering work with interior finishes, furnishings and contents. Damaged materials should be properly marked and replaced during construction, as shown in Figure 6. Comprehensive field notes and inspection checklists should be retained on file for the project. Contractors should require subcontractors to provide documentation that materials and HVAC system components are installed per manufacturer’s instructions and engineering design drawings. All of this documentation will be valuable in mitigating damages and associated costs. In addition, third-party consultants should be retained to perform independent peer review of the HVAC system design and to make inspections during construction. They should document HVAC system commissioning procedures and inspect the completed project prior to transfer to the owner.
DISCUSSION

Post-construction activities should include final cleaning of all interior finishes and functional testing of building mechanical systems. Protect the HVAC system from dust, dirt and water during construction and make certain it is clean afterwards. Cleaning is the final defense in managing indoor environmental quality and preventing microbial contamination. After the areas of source management and building operations have been addressed, cleaning is still necessary. The importance of this was demonstrated in a year-long study of cleaning effectiveness in a multi-use building without evident infrastructure problems. The routine use of high efficiency vacuum cleaners, damp dusting, and improved cleaning products – particularly in high traffic areas – along with attention to leaks and spills, resulted in meaningful decreases in particulate and microbial contamination [7].

Building commissioning procedures of the completed project should include quality assurance testing of the HVAC system to ensure that it is properly tested and balanced and functioning according to building design parameters. Procedures and methodologies for documenting and verifying the performance of HVAC systems according to design are published by the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) [8]. Replace pre-filters and filters on all air moving equipment in the HVAC system after construction is completed. Filters should be of the highest grade compatible with the HVAC system and the air handler fan – with a 50% to 70% dust spot efficiency rating. Ensure that complex computer-controlled systems for building ventilation have been properly programmed. Operate the HVAC system for 7 to 14 days to stabilize its operation prior to building occupancy.

In addition to these guidelines, testing the HVAC system for acceptance by the owner may include a microbial risk assessment performed on various HVAC system components most susceptible to contamination during construction – including supply air ductwork and plenums, heat exchangers, air washers and humidification devices, AHUs, filters, drain pans, and outdoor air intakes. The assessment should always be performed by a qualified environmental health professional, such as a Certified Industrial Hygienist (CIH), with experience in potential health implications of indoor contaminants, including microbial growth and a familiarity with commercial and residential HVAC systems. If needed, based
upon the results of the microbial assessment, remedial action should be taken prior to occupancy of the building. The risk assessment should include a visual inspection of HVAC system components to ensure that they are clean and dry – with no signs of water intrusion, physical damage, or mold growth – and microbial sampling of a representative portion of the building and HVAC units. Procedures to verify cleanliness of the HVAC system proposed by the author should include:

- A visual inspection should be conducted to make certain HVAC system components are clean after construction with no residual dust or visible contamination. Test and balance the system per industry standards. Observations of airflow and pressure differentials should be made after system startup.

- Fungal spore samples should be collected pre-HVAC system operation. The system should then be turned on for 60 to 120 minutes to stabilize its operation, followed by the collection of post-HVAC system fungal spore samples from several random areas of the building. Pre-HVAC and post-HVAC samples should also be collected in areas of the building where the highest building occupant load or population density is expected. Air sampling is performed using a calibrated air sampling pump operating at 28.3 LPM. Fungal spore samples should be collected from the ambient indoor air and the outdoor air intake. One sample should be collected from the ambient indoor room air; another at a supply air diffuser; and another near the outdoor air intake. An additional outdoor sample should be taken at ground level outside the building for reference control purposes. Each sample should be collected for two minutes. The microbial samples should be analyzed by an Environmental Microbiology Accredited Laboratory using cultured methods or Quantitative Polymerase Chain Reaction (Q-PCR) analysis. Although more costly, Q-PCR analysis appears to be the most likely technology to be used in the future because it provides very rapid turnaround and greater accuracy, sensitivity, and precision in identifying microbial species present; but conventional techniques are also acceptable. Microbial air samples are interpreted by comparing the types, distribution and levels of fungal spores found in pre-HVAC system operation samples to post-HVAC system operation samples and to outdoor control areas. General guidelines for interpretation of fungal spore data specify that indoor levels of mold spores should be less than outdoors. The biodiversity of fungal spores indoors should also be similar to outdoors. The levels of mold spores and fungal genre in the post-HVAC samples should be less than and similar to those in the pre-HVAC samples.

- Sampling of cooling towers and domestic water supplies for the presence of *L. pneumophila* and other waterborne bacterial pathogens is also recommended. The location of the OAs and air pathways within the building should be identified and evaluated to prevent aerosolization of *Legionella*-containing water droplets in the building. Water samples should be collected using sterile sampling containers with Sodium Thiosulfate preservative provided by an AIHA-accredited laboratory. Samples should be analyzed for the presence of *Legionella* using a combination of culture analysis and Deoxyribonucleic Acid (DNA) sequencing.

Third-party inspections should be performed by qualified professionals to review shop drawings and to inspect the integrity of the building envelope during and after construction – to identify any defects that could cause potential problems with water intrusion, moisture accumulation, mold growth or structural integrity. A systematic approach for addressing reported problems and customer complaints during the warranty period should be developed.
to help prevent small problems from becoming big. Educate the building owner on proper operation and maintenance of all building systems. Train the building owner’s property management and building engineers/maintenance staff on preventive maintenance of the HVAC system; humidity control; ventilation of moisture producing processes; inspections and maintenance of the building envelope; and operation of the plumbing, heating, fire sprinkler and mechanical systems, including outside irrigation and landscaping. Train building maintenance staff in mold prevention methods for the new building after completion. Prompt attention to water intrusion should be emphasized with the owner and maintenance staff to prevent and minimize costly structural damage and mold growth, and to increase the life span of the building.

Air quality can be enhanced by properly designed, operated and maintained building ventilation systems. Fanger suggested that air quality be defined by the extent to which human requirements are met [9]. Sources of contaminants and the effectiveness of control measures, including HVAC systems, should continue to be evaluated to assess indoor air quality after building occupancy.

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REFERENCES