Roots of Mold Problems and Humidity Control Measures in Institutional Buildings with Pre-Existing Mold Condition

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ABSTRACT

Humidity control and mold in buildings has become an increasingly important problem. Once a building has experience mold growth on walls, ceilings, and other surfaces, it does not take long-term exposure to moisture for mold to re-grow in the building. Some commercial buildings on the Texas A&M University (TAMU) campus have suffered with humidity problems for many years. The Continuous Commissioning (CC^{SM}) group of the Energy Systems Lab in collaboration with the Utilities Office of Energy Management, and the TAMU Physical Plant, was dispatched to perform Continuous Commissioning on these commercial buildings in order to find viable solutions to the humidity problem. The CC group performed extensive field tests and analysis on building air handling unit (AHU), exhaust systems, building construction, and the Energy Management Control System (EMCS). Based on the field studies and analysis, a four-category (Design, construction, building retrofits and alterations, and poor maintenance) system was set up to classify sources for high humidity problems. This paper presents the investigation and follow-up efforts, which identified reasons and corrective measures for the high humidity levels in these buildings, turning these inefficient and humid commercial buildings into comfortable environments. Recommendations for dealing with such possible problems are provided.

INTRODUCTION

Over the last fifteen years it has become apparent that moisture and humidity control problems exist in commercial buildings. The causes of these problems can be complex and involve many aspects of building design, construction and maintenance (Harriman 2001). Improper humidity control inside a building can lead to occupant discomfort, people feeling sick, building deterioration, and the development of mold, mildew or odors.

At Texas A&M University the Utilities Energy Office and the CC group of ESL have been called upon to solve many of the humidity problems around the campus. The group has worked on all types of buildings including dormitories, offices, laboratories, theaters, and many others. Many of the buildings commissioned to do this work have experienced the existence of not only high levels of humidity but also have been positively identified mold. Mold in buildings is a serious problem since previous studies indicate that it can lead to or aggravate health problems including headaches, breathing difficulties, allergic reactions, and aggravation of asthma systems (United States Environmental Protection Agency, 2001).

Many of the problems leading to mold and inadequate humidity control can easily be identified and prevented. A four-category system will be presented along with examples of Texas A&M buildings in which will help classify humidity problem causes. Since most of these buildings had experienced some type of mold growth it is also important to understand what mold is (how it acts) and most importantly how it can be prevented or eliminated.

MOLD

Over the last fifteen to twenty years, as building ventilation standards have changed, there has been a growing concern for mold and mold prevention. Monetary problems due to mold clean up, worker's compensation, and building restorations have becoming a major concern for the HVAC industry. In order to control and eliminate mold one must first know some basics about mold.

Mold is a fungus. It is all over the world and it is crucial to the earth's ecosystem since it breaks down trees and other natural wastes. Mold is microscopic in size and travels through the air. Its' survival is directly dependent on humidity, temperature, and limited exposure to ultraviolet light. As a result, different species of mold live in temperature ranges from just above freezing to just below the boiling point of water depending on the ideal conditions for growth of that particular mold species. In a particular place and building there could be hundreds of different species of mold. When temperature and humidity conditions change, one species of mold dies and is quickly replaced or outgrown by the best suited species to take its place (Harriman, 2001; United States Environmental Protection Agency, 2001).

Since mold travels through the air and most buildings do not have direct sunlight, the best way to prevent its development is to maintain adequate relative humidity levels inside a building. Penicillin mold, for example, starts to grow when relative humidity levels rise around the area of seventy eight percent (Harriman, 2001), at which it thrives on surfaces with condensation present. According to ASHRAE the optimal building comfort level ranges from 30-60 percent (ASHRAE, 1989)

Once mold has grown and can be easily identified with the human eye, it has already grown a protective layer called mycelium. This protective layer allows the surface in which the mold is growing to be kept moist. Due to this protective layer, mold is very difficult, if not impossible, to completely remove from a building once it is present. When mold is treated by ultraviolet light or toxic chemicals such as bleach, only the top layer of the mold is usually killed. If the original spore is unaffected, it will continue to live on the surface in a dormant state. Once there is additional moisture present, the mold will again reproduce and develop (Harriman, 2001; United States Environmental Protection Agency, 2001)

CAUSES OF HUMIDITY IDENTIFICATION

Humidity control has been a major concern in areas that experience warm temperature and high humidity concentrations. Excess humidity cannot only cause discomfort for the building's occupants but it can also allow for the growth of mold in these buildings. ASHRAE standard number 62 states that an office environment should have a relative humidity in the range of 30 to 60% (ASHRAE, 1989). There are many causes for lack of humidity control in commercial buildings. Most of these causes can be avoided if a concerned effort is made to control the amount of relative humidity inside a building. Some of these causes can be prevented before the building is built by having adequate and proper design of the HVAC system. Other ways to prevent the lack of humidity control are adequate building alterations and proper maintenance. The probable causes for the lack of humidity control were analyzed and presented in four major categories (table 1). Table 1 on the next page lists several buildings with humidity control problems at Texas A&M University in which the CC group has performed field studies and provided solutions. Listed are the building names, the type of building, and the source of the humidity problem.

Category 1: Design

The first of these categories, the one in which an engineer has the most control over, is HVAC design. A building should be designed properly to provide a comfortable environment so that its occupants will be able to conduct their duties. The building should be provided with the proper type and kind of equipment for it to be properly cooled or heated. It is also crucial for a building to have a positive differential pressure to the outside atmosphere. If the building is negative, the engineer will have no control as to what type of air will be drawn into the building making it impossible to control the humidity level. Figure 1 shows that 31 percent of TAMU buildings with humidity problem were categorized as having a design problem.

Another important factor in HVAC design is the building's respective location. It is necessary take into account the position of the building with respect to wind direction, speed, and outside air humidity content. The engineer should try to minimize any direct openings to the outside to control infiltration.

The CETTI building's two stairwell pressurization relief grills are located at the top of each stairwell. They are directly linked to the outside with no dampers installed to control the infiltration of outside air. These grills and therefore the stairwells are affected by winds coming in from the east, south and west. This air comes from the Gulf of Mexico area and is rich in moisture. Additionally, any strong wind current will overcome the building's stairwell pressure and blow humid air into the building.

Table 1: Humidity Problem Identification for Different Buildings of TAMU

Building Name	Building Type	AC Area (ft^2)	Humidity Problem			
			Design	Construction	Retrofit and Alterations	Poor Maintenance
CETTI	Office	157,840	X	X	X	X
McFadden	Dorm	62,160	X	X		X
Kruger Hall	Dorm	112,140		X		X
Rudder Dorm	Dorm	67,290			X	X
Richardson Petroleum	Lab (10th Floor)	11,370	X			
WERC Basement	Office	44,400				X
Chemistry 72	Lab	63,000	X	X		
Doherty	Lab and Office	42,340		X		X
Chemistry 86	Lab	115,800				X
Kleberg Building	Lab and Office	165,030				X
Beutal Building	Hospital	54,600				X
Coke	Office	24,500	X	X		X
Sbisa	Dining Hall	137,900	X	X		X
Biohazard/Containment lab	Lab	96,000				X
Small Animal Clinic	Clinic	103,400				X
Memorial Student Center	Office/Cafeteria	368,930				X
Bio/Bio	lab	166,000			X	X
Teague Building	Office/lab	63,510				X
Data Processing Center	Computer lab/Office	30,460				X
Jack K. Williams Administration Building	Office	62,400	X	X	X	X

This was a major contributing factor to the humidity problem in CETTI.

Another building with humidity problems was the Richardson Petroleum Building, in which a lecture hall had experienced high relative humidity levels and mold was starting to become evident on walls, tables, and chairs. People were upset with the room conditions. The computers and equipment were moved out of the lecture room because the humidity levels could have damaged them. Measurements in the room indicated temperatures near the comfortable range of 70-72°F but relative humidity near 80%. (Chen, etc. 2000).

A single-zone air handling draw-through unit configuration served the lecture hall. Out of all of the all air handling systems, the single-zone air handling system is perhaps the simplest and most common type of system. The unit is controlled to respond to the room conditions as indicated by a room thermostat. No reheat coil was designed for this system, so dehumidified primary air or recirculated room air could not be reheated if the cooling coil was opened for humidity control.

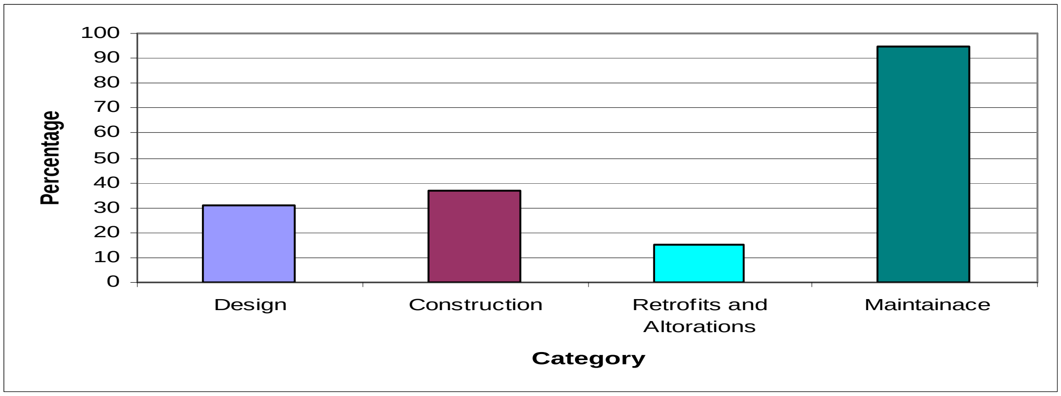

Figure 1: Percentage Category breakdown for Texas A&M University Buildings with Humidity Problem

The original design data of the AHU and the measured air condition data both prove that the cooling capacity and supply airflow volume is adequate for actual sensible load, but not latent load. The single-zone AHU system with no reheat capacity originally chosen was not adequate for the space due to the lack of humidity control. This is because the current AHU system cannot handle the space humidity level. Different geographic locations have different ratios of latent load to sensible load and different AHU types have different advantages. The ratio of latent load to sensible load should be considered as a criterion to design the HVAC system and select equipment for different climates (Harriman, Plager and Kosar, 1999).

Category 2: Construction

Sometimes the way a building was designed or planned is not the way it was ultimately built. During construction, there are some "last minute" changes and compromises that have to be made on the spot. Some building material could be substituted for others or improper sizes may be used, which can result in imperfections in wall sizes and seals. Such problems can be seen in many buildings throughout the Texas A&M University campus. Figure 1 shows that 37 percent of TAMU buildings with humidity problems were categorized as having a construction problem. These imperfections over time have caused some major humidity problems in both dormitories and commercial buildings (Chen, etc. 2000).

An example of a construction problem is the CETTI building. Like most buildings, large fire water stand pipes run all the way from the first floor to the top of each stairwell. These pipes are very long and have to be pieced together by a bracket system. At CETTI the brackets were placed very close to the wall that is shared between the stairwell and the mechanical room. The position of the pipe and the steps in the building process made it difficult for an adequate sealing between the walls. As a result, inadequate sealing of the stairwells and the overall negative pressure of the adjacent mechanical caused the stairwells to experience negative pressures relative to the outside. As a consequence, when outside weather conditions are right, warm humid air is drawn into the stairwell allowing for the reproduction and growth of mold.

An additional building on campus with such a problem was Krueger Hall. Krueger Hall had the distinction of being a building plagued by humidity issues. The ceilings in many of its bathrooms were "weeping" to the point that water was raining on the occupants. This condensation problem had no obvious cause since room humidity levels were not excessive. Removal of the lighting fixtures in one such bathroom revealed that the crawl space above the bathroom was filled with very hot (90°F), very humid (95%) air that was condensing on all the available surfaces with temperatures below the air's dew point. The condensate moisture would then leak into the bathrooms below. Careful examination of the crawlspaces uncovered numerous pathways for this humid air through the large unsealed holes originally cut for piping. These gaps allowed the humid air to freely migrate from the steam tunnel to the rest of the building. Once the humid air came in contact with a cold surface, it would condensate (Chen, etc. 2002).

Another dormitory on campus also experienced similar humidity problems due to poor construction was McFadden Hall. This dormitory had many complaints for both resident comfort and humidity. Measurements inside the bedrooms indicated relative humidity levels as high as 80 percent.

Part of the problem with this building was the fact that chase access doors were too small to seal off the chase from the space air. Similar gapping passages were found throughout the building. These gaps combined with the negative differential pressure between the bathrooms and the exhaust chase caused conditioned air to be sucked into exhaust chases, failing to reach the rooms.

This problem was a building problem since the doors used to close the chase were not of proper size. This allowed for gaps to be present along the chase leading to a lack of fresh air inside the bathrooms and bedrooms causing further humidity problem.

Category 3: Building Retrofits and Alterations

Once a building has been in place for several years changes have to be made to it in order to better fulfill its purpose, for example, a conference room has to be changed into four new offices or a classroom has to be converted into a computer or server room. There are also advancements in the technology utilized in the office environment. Offices must now have fast and reliable Ethernet connections. There is also the need for additional telephone lines for fax machines and other office equipment. All this wiring has to be directed and distributed throughout the building. In order for this to be done, electrical conduit has to be run through walls and from floor to floor. Often the breaks made in walls and ceilings are not properly sealed. It is really not an aesthetic problem since most of these holes are made above false ceilings and hidden from public view, however these holes combined with pressure differential are enough to allow for undesired flow through the building. For the TAMU buildings with humidity problems, 15 % were categorized as having been caused by retrofits and alterations (figure 1).

This was extensively seen in the CETTI building. Built in the 1980s, construction retrofits and alterations had to occur to account for the upgraded information technology equipment installed. Ethernet wiring had to be distributed thought out the building, which resulted in breaks the walls for wiring conduit. Since these breaks were not sealed correctly, it allowed for undesired airflow throughout the building. In particular, breaks found in mechanical rooms, which shared a wall with one of the stairwells, sucked humid outside air into the stairwell. This was a major factor for the growth of mold in the building.

Category 4: Poor Maintenance

One of the main causes of mold within buildings is poor maintenance. In large institutions such as Texas A&M University, where there is a large number of buildings to maintain, regular scheduled maintenance is often delayed in order to fix new and last minute complaints from building occupants. As a result, problems that could have been prevented begin to accumulate. In some instances problems will not be fixed until complaint calls are made to the maintenance office (Chen, etc. 2000; Chen, etc. 2002). Figure 1 shows that 95 percent of TAMU buildings with humidity problem were categorized as having some type of maintenance problem. This is by far the category with the highest cause for lack of humidity control and also the easiest to prevent.

In the example of CETTI, the main problems for the CC group were with the AHUs. When the building was first turned over to the group, a general building inspection was done. It was discovered that all the AHUs needed new belts and that filters needed to be changed immediately. Fresh air supply measurements were taken for second through eighth floors, which indicated that the building was receiving 1500 CFM below design requirements.

Another building with maintenance problems was McFadden Hall. This dormitory mentioned previously had high levels of humidity inside bathrooms and bedrooms. Relative humidity levels reached the 80 percent mark and residents constantly complained about comfort. Upon careful inspection of the building, it was discovered that all the outside air grills were partially or completely obstructed, effectively forcing the units to circulate only inside air. As a result of the building being operated very negative, untreated air was entering through any possible door or gap possible. This problem could have easily been corrected by proper maintenance and inspection of HVAC equipment.

An additional dormitory on campus with humidity control problems was Rudder Hall. In comparison with other buildings, Rudder Hall was a basic problem and could have very easily been prevented. During inspection, it was noticed that two outside air AHUs designed to dry out the outside air and provide the building with positive pressure were discovered to be off-line due to component failures. It was further noticed that the coiling coils were still active, flowing chilled water. Even with the air-handling units off, airflow was detected through the units due to the negative pressure in the building, which was being cooled by the active cooling coils. Simultaneously, untreated air was infiltrating through doors and cracks of the building. Once the hot, humid air came in contact with the cool ductwork fed by the "off-line" AHUs, it condensed and dripped onto the below hallway.

Humidity control problems could easily have been prevented with proper air handling unit maintenance and inspection. Once one of the components was not working properly it should have been replaced and the humidity problem would have been avoided. The fact that both outside air AHUs were not working goes to prove that proper maintenance was not performed on these buildings.

With increasing concern for energy savings, many buildings are now on time and schedule controls. These methods of energy savings are great especially for commercial buildings such as offices that are not occupied at night or during the weekend. However, when these practices are exercised there is risk of not getting the correct air balance for the building. In an effort to conserve energy all or most of the AHUs are switched off reducing the amount of air being supplied to the building. The exhaust systems are usually not automatically turned off and run continuously throughout the night and during the weekend. As a result, the building experiences a negative pressure during these off-peak times. When a building is subjected to a negative pressure it will suck in untreated air from the outside or air will infiltrate throughout the building. Therefore it is important to keep a positive air balance at all times, regardless of the building usage. This can be achieved without having all the AHUs and still saving energy.

Other maintenance problems in buildings that are often overseen are leaking water pipes. These might not be a major break but over a period of time, a dripping or leaking water pipe will create enough moisture for mold to get their food source and multiply.

It is very important to take care of these simple maintenance problems since, according to the environmental protection agency, it is advised to not let surfaces be wet or damp for periods longer than forty eight hours to prevent the growth of mold.

RECOMMENDED CORRECTIONS

The best way to eliminate problems of humidity control is prevention. An adequately designed building should consider humidity control as one of the top priorities. Once a building has been built there are a few corrective actions that should be followed.

Elimination of Mold

Even though mold can't be completely eliminated and killed, it can be set back to its "dormant" state. The best way to do this is by using ultraviolet light or special chemicals such as bleach. Replace any furniture that has tested positive for mold as well as wallpaper and carpets. Remember that just because the mold has been cleaned off does not mean that it has been eliminated. In fact, as explained before, mold will not be completely eliminated and problems will continue to arise if excessive moisture persists.

Identification of Source

Once the mold has been cleaned off and eliminated as much as possible, it is time to find the source of the problem. There are multiple sources for humidity problems, and a thorough investigation should be conducted.

As seen before in the case of the CETTI building, there are often many different causes for lack of humidity control. It is important to identify all of them since there might not be just one root to the problem.

Taking Action

Finally, after all the possible sources for the problem have been identified, it is important to correct the problem as soon as possible since mold can resurface causing additional problems and cost. One of the best ways to keep humidity from reaching undesired levels is to make sure that a building's differential pressure to the outside stays positive at all times. Always keep up with regular scheduled maintenance and fix humidity problems as quickly as possible. When all corrective actions have taken place, it is very important that proper maintenance and service is conducted in the building. As it has been mentioned before, 95 percent of TAMU buildings with humidity problems were categorized as having poor maintenance as part of the problem. This is one of the factors that can easily and inexpensively be corrected. Timely and corrective maintenance can go a long way to keep a building comfortable and free of humidity problems. Remember that once mold has been spotted in a building it will not take a long for the problem to return.

In the example of the CETTI building the CC group recommended that several corrective actions be taken. First, replace the relief dampers in each of the stairwells with sealing gravity dampers. This will allow the stairwell to be sealed from the outside humid air while allowing for pressurization relief in case of an emergency. Properly seal all breaks and gaps on the stairwells walls, mechanical room, and electrical rooms and provide additional outside air supply to each of the buildings floors. It was determined during investigation that the best way to do this in this case was by reducing the fan pulley size, thereby increasing the fan flow rate.

For the Richardson Petroleum building, a reheat coil was installed in the duct system and the cooling coil valve was fully opened. The problem in Krueger Hall was corrected by fully shutting the doors between the primary hot water loop tunnel and the crawl space to isolate hot air from the tunnel to the building. All the utility chase gaps were sealed off to prevent air infiltration into the building and the crawl space vents were opened. Similar actions were taken in McFadden hall in which chase access doors were replaced to correctly seal off the gaps around the chase area. Foam insulation was used to seal around piping penetrations. Finally in Rudder Hall the outside air AHUs were brought back online and the positive differential pressure to the outside was obtained.

Much needed maintenance was done in all the buildings. In all AHUs the old dirty filters were replaced, and loose belts were either tightened or replaced. A good cleaning of the cooling coils was performed and insulation was provided where it was missing.

CONCLUSION

Causes for lack of humidity control and the development of mold come from many different sources. They are related to every stage of a buildings life from the original design to construction to retrofits to poor maintenance. The source classification system presented in this paper will provide a tool for easier cause identification.

The existence of mold in a building is a serious concern and should be treated immediately. The easiest way to deal with the mold problem is to prevent it by having a properly designed building HVAC system and to keep it performing adequately with proper maintenance. Once mold has been identified in the building, it should be treated and high relative humidity concentrations should strongly be avoided.

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