
The Basics of HVAC Systems in Humid Climates— What Goes Wrong and Why

David MacPhaul, P.E.

ABSTRACT

Following a few simple rules when designing heating, ventilating, and air-conditioning (HVAC) systems for humid climates can help avoid the catastrophic failures seen in such buildings as Florida's Martin and Polk County courthouses in the early 1990s. These buildings suffered through rampant mold growth, complaining occupants, and escalating remediation costs, all because the HVAC system designers did not understand what is required to produce a successful building in a humid climate. Ultimately, designers and contractors of these buildings were held liable for millions of dollars in remediation costs, which exceeded the original construction costs of the buildings.

UNDERSTANDING THE FUNCTIONS OF THE HVAC SYSTEM

In any climate, the HVAC system designer must consider the four basic functions of the HVAC system:

- Comfort control (temperature, relative humidity, and air motion)
- Ventilation
- Contaminant control
- Pressurization

By design, these functions overlap. For example, ventilation helps provide contaminant control and pressurization. In humid climates, two of these functions are essential—providing proper dehumidification (a component of comfort control) and positive pressurization—to avoid moisture problems.

DESIGNING FOR PROPER DEHUMIDIFICATION

Dehumidification, or removal of moisture from the supply air, is accomplished in most buildings by cooling the air below its dew point and condensing moisture from the air. In a typical building, the supply air is cooled to about 55°F at the air handling unit. When this air is provided to the occupied space and warmed to a room temperature of 74°F, the resulting relative humidity in the space is 55 to 60 percent, which is comfortable for occupants and well below the 70 percent relative humidity threshold for mold growth. This process is illustrated on the psychrometric chart in Figure 1.

Designing a system to handle both the latent (moisture) and sensible loads is taught to, but not necessarily well understood by, most HVAC system designers. However, much has been written recently to increase HVAC engineers' understanding about the problems typically associated with dehumidification in humid climates. For example, Stanke (2000) discussed the problems that commonly used constant-vol-

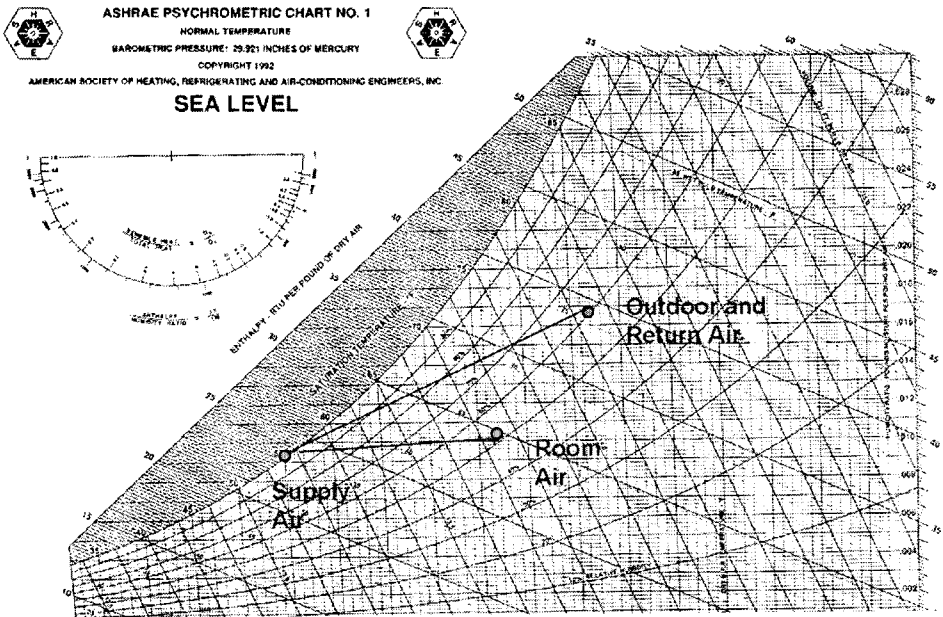


Figure 1. A Typical Cooling Process Shown on the Psychrometric Chart
 Source: ASHRAE Handbook of Fundamentals, 1997 Edition.

ume air handling systems have with dehumidification in the Trane Company *Engineer's Newsletter* (Volume 29, No. 24, 2000). In the *Dehumidification Handbook* (2000), Harriman describes the information HVAC system designers should know to avoid dehumidification problems in buildings. Dehumidification problems typically occur because these systems control based on sensible loads and, under part-load conditions, moisture loads may be the largest cooling loads on the system.

DESIGNING FOR PROPER PRESSURIZATION

Pressurization in buildings is the second, and equally important, issue for producing successful buildings in humid climates. A building must be positively pressurized relative to the outside; that is, some conditioned air from inside the building must exfiltrate through the envelope to the outside. Unfortunately, the required methods for providing proper pressurization are not well understood among the HVAC design community.

Positive pressurization is normally achieved by providing more outdoor, or makeup, air to a building than is exhausted from the building. An HVAC designer typically provides 10 to 15 percent more outdoor air to a building through the air handling units than is exhausted through restroom, kitchen, or laboratory exhaust systems.

HVAC designers often treat the building as one large open vessel where air can move freely between zones, believing that the makeup air will go where it is needed in the building. Figure 2 illustrates the common understanding of pressurization in buildings.

In reality, buildings do not function as open areas at all. Fire walls, floors, shafts, and other full height walls create a series of pressure zones, or vessels, within a building. Depending on how the makeup air and exhaust air are distributed throughout the building, most buildings function similar to the building shown in Figure 3, containing both positively and negatively pressurized areas relative to the outside. Infiltration and exfiltration are rampant in the building.

The Florida Solar Energy Center (FSEC), in *Uncontrolled Air FloZV in Non-Residential Buildings* (1996), coined the term "the smart-air syndrome," describing the belief that air will go to where it is needed, rather than where it is distributed.

Areas that are positively pressured tend to exfiltrate excess outside

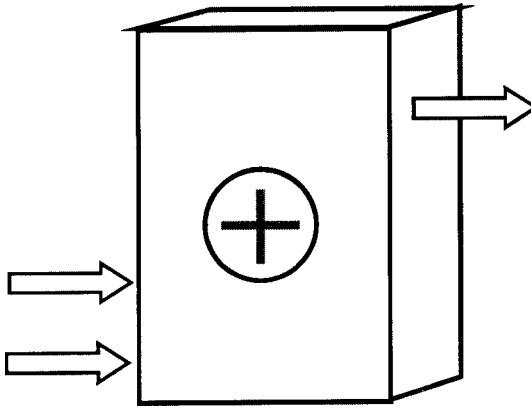


Figure 2. The Common Understanding of Building Pressurization

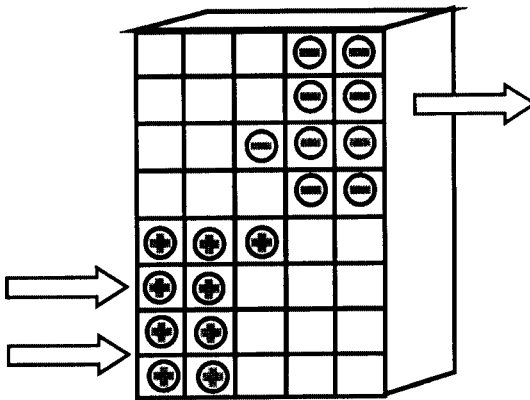


Figure 3. The Actual Pressurization in Most Buildings

air, and areas of negative pressurization have large amounts of infiltration. At best, this infiltration and exfiltration can cause a tremendous energy waste to cool and dehumidify the extra outside air. In the case of infiltration, when moist outside air comes into contact with cool building surfaces inside the wall cavity, condensation and moisture accumulation will occur. The amount of moisture accumulation can be quite large. For example, the infiltration of 1 cubic foot per minute (cfm) of outdoor air in Orlando, Florida, can bring in nearly 20 gallons of unwanted moisture per year. In its worst case, infiltration will create severe humidity problems, mold growth, and deterioration of building materials.

When designers refer to the American Society of Heating, Refrigerating, and Airconditioning Engineers (ASHRAE) *Handbook of Fundamentals* (2001) about pressurization in humid climates, it states “Negative pressures of the indoor space should be avoided.” For designers in humid climates, negative pressurization relative to the outside, with its resultant infiltration, *must be avoided*.

CASE STUDY DEMONSTRATING POOR PRESSURIZATION

The following case study of a hotel in southern Florida illustrates what happens when the rules for proper pressurization are not followed. Hotels make excellent examples because they contain a large number of pressure zones (each room in a hotel is surrounded by fire-rated full height walls) and generally contain their HVAC systems within the room. In this case, a hotel began to suffer from mold growth, and odors were noted soon after construction was completed.

Figure 4 shows the design of the hotel HVAC and exhaust systems. The guest room is served by a packaged terminal air conditioner (PTAC) installed in a sleeve through the outside wall. A continuous toilet exhaust fan serving a pair of rooms on each floor is located on the roof. The PTAC unit is scheduled to provide 70 cfm of outdoor air, and 50 cfm is exhausted through the bath fan.

Twenty-five cfm of makeup air per guest room is provided through the air handling system serving the corridor. This makeup air provided to the corridor is intended to serve as a safety factor. Assuming at least half of the PTAC units would be in operation at any given time, 50 cfm of corridor makeup air would be available to transfer under the guest room door undercut into a guest room with the PTAC unit off, providing the makeup air required for the exhaust system.

To test the designer’s assump-

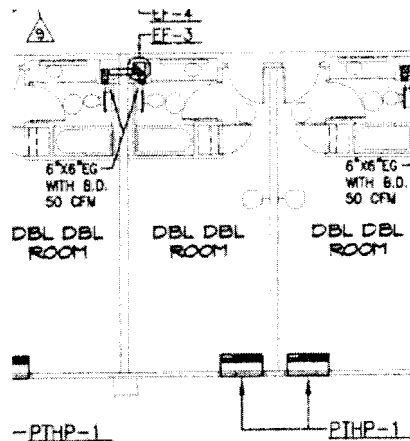


Figure 4. The Layout of the Hotel HVAC System

tion after the hotel began to develop humidity and mold problems, we measured pressures relative to the outside in the guest room and corridor while sequentially shutting down the rooftop-mounted bath exhaust fans. Figure 5 shows the pressures in the corridor and guest room. The relative pressure is graphed against the ratio of corridor makeup air to exhaust air.

In this case, the corridor reaches a neutral pressurization when the ratio of makeup air to exhaust air is 1.7. The guest room never reaches a positive pressurization, even when the ratio of makeup air to exhaust air is nearly 3. Upon further examination, although the test-and-balance report indicated the exhaust system was properly balanced, significant leakage of air into the exhaust ducts was occurring. Unfortunately, this is a problem that is typical in many buildings. Even with the leakage, the final ratio of corridor makeup air to guest room exhaust air is above 2, and positive pressurization is not achieved as required.

In this case, the owner responded to the humidity problems as soon as they began occurring, and problems were limited through short-term

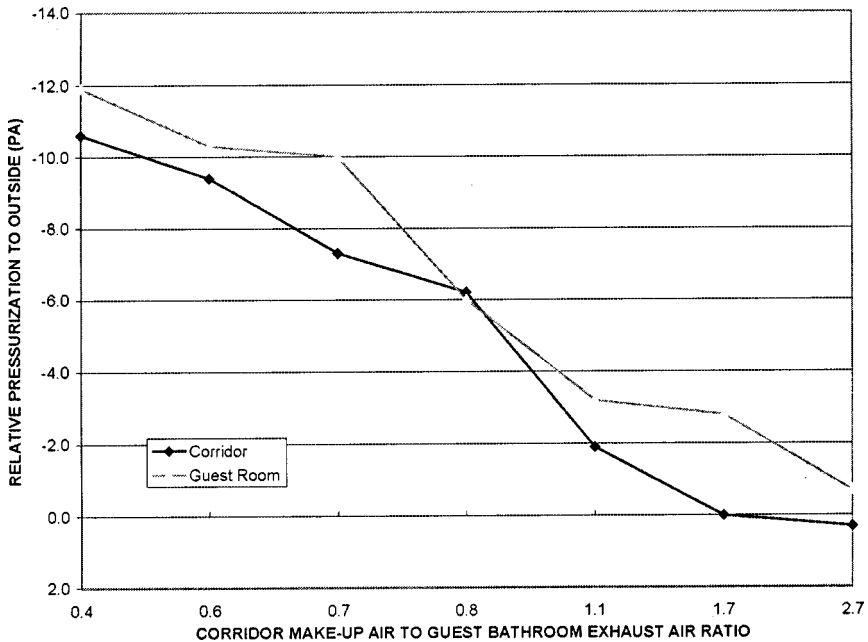


Figure 5. Relative Pressurization of The Guest Room and Corridor.
Source: CH2M HILL, February 1, 2002,

corrective actions.

If the owner had waited to correct these problems, serious mold growth and damage could have occurred. Figure 6 shows the results of waiting through one summer season before correcting the problems—large amounts of mold growth on the backside of the gypsum wall board. This piece was removed from the partition wall between rooms, approximately 4 feet from the perimeter wall. Extensive and costly remediation work was required at this hotel.

CONCLUSIONS

Providing proper dehumidification and maintaining positive pressurization in all zones of a building is critical to ensuring the success of the building in a humid climate. While methods for dehumidification are being discussed and taught to HVAC designers, the concepts for providing positive pressurization are less well understood. Pressurization must be looked at in each pressure zone at the exterior of the building as well as from a whole building perspective to ensure the success of the building.

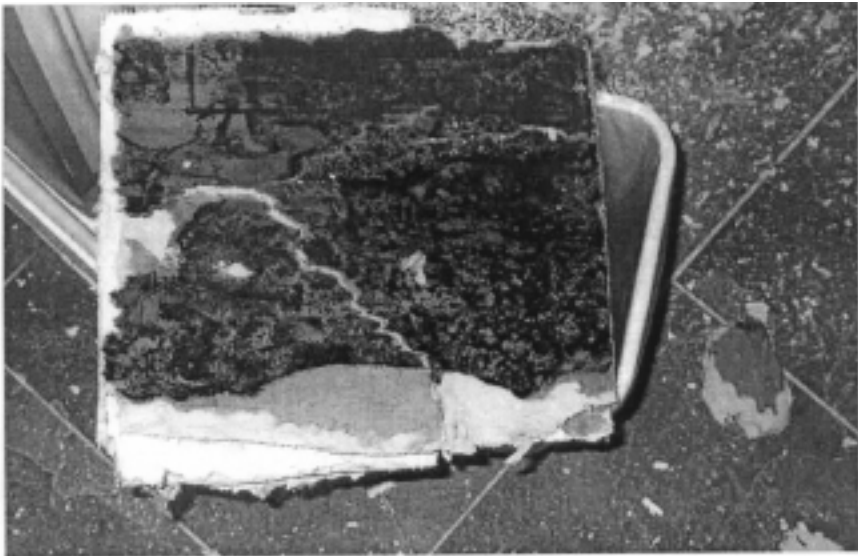


Figure 6. Mold Growth Caused by Infiltration in a Hotel Room

References

- American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE). 1997. *Handbook of Fundamentals*.
- Florida Solar Energy Center (FSEC). 1996. Uncontrolled Air Flow in Non-Residential Buildings.
- Harriman, Lew. 2000. *Dehumidification Handbook*, Munters
- Stanke, Dennis. 2000. *Engineer's Newsletter*. Volume 29, No. 24. Trane Company.
-

ABOUT THE AUTHOR

David MacPhaul is a senior HVAC engineer at CH2M HILL with more than 15 years experience in building investigations, indoor air quality consulting, and expert testimony for failed buildings. He is also a co-inventor of a patented HVAC control system for economical moisture control in small systems. David is currently commissioning HVAC systems for institutional, educational, and commercial buildings to assist owners with identifying problems before they can occur.