Humidity Control Systems for Civil Buildings in Hot Summer and Cold Winter Zone in China

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Abstract: In the hot summer and cold winter zone, moisture-laden outside air poses real problems for proper ventilation, air-conditioner sizing, and strategies to overcome the reduced dehumidification capacity of more energy-efficient air-conditioning (AC) systems. Based on our research, this paper further provides the rate and characteristics of moisture resources in civil buildings. Although the ventilation rate is limited with the minimum ventilation rate in the sanitation ventilation mode of the air conditioning period, dehumidifying period and heating period, the ventilation rate is unrestricted in thermal comfort ventilation mode. It is suggested that the operating conditions of the forced ventilation system should be determined on both outdoor air temperature and outdoor air relative humidity (RH). Therefore, the ventilation system should satisfy these requirements during prolonged periods of high ambient humidity. After a detailed presentation of the technical issues, this paper gives specific recommendations for providing adequate ventilation, moisture control and dehumidifying for buildings in hot-humid climates, and takes both the indoor environmental quality (IEQ) and the building energy efficiency into account. Supplying conditioned ventilation air to the buildings appears to be a promising approach to solve the heath problems associated with excessive indoor RH by installation of a separately controlled unit to dry and cool outdoor air.

Key words: hot summer and cold winter zone; civil buildings; humidity control; air-conditioning system; ventilation mode

1 INTRODUCTION

The Yangtze River basin, its special geographic location causes typical climate characteristics, is named hot summer and cold winter zone. According to the statistic data [1], there are 15-25 days air temperature exceeds 35°C in summer, the daily maximum air temperature is beyond 41°C. Moreover, it is characteristic of humid climate, e.g. annual mean RH is above 77%-80% in Chongqing, Wuhan, and other main cities in this region [2]. People often feel stifling hot in the hottest season. There are 2-2.5 months which daily mean air temperature is lower than 5°C in winter, as well as short sunshine duration, people often complain of the wet and cold weather in heating season.

ASHRAE Standard 62, “Ventilation for Acceptable Indoor Air Quality,” recommends that the RH is not exceed 60 percent at any load condition. For the civil buildings in such climate, high air humidity not only brings limits to ventilation system, but destroy human thermal comfort and badly influence the indoor sanitation conditions. Therefore, humidity control and dehumidifying in buildings is especially important for IEQ control.

2 ANALYSYS OF MOISTURE PROBLEMS

2.1 What Causes Moisture and Air Quality Problems in Civil Buildings?

Moisture can come into buildings from many channels. For example, excessive moisture will produce when ventilating with outdoor air during spring and summer can cause lots of condensation, especially in basements; by evaporation from showers, washing dishes and clothes, cooking, aquariums, standing water, people, pets and plants;

from earth floor basements or crawlspaces, especially in buildings.

Because the effect of humid climate on weather parameters, duration for thermal comfort ventilation is limited [3], so discussion in this paper mainly adopts ventilation system for indoor sanitation conditions all year around. We assume, the most of the typical internally generated moisture (humidity) sources in buildings can be controlled by properly implemented ventilation systems. Then, the outdoor air is the key source to lead to higher indoor humidity.

2.2 Moisture Problems can Lead to Air Quality Problems

For our health and comfort, our house should have an exchange of air between the indoors and outdoors. Without the air exchange, moisture can accumulate, mold can become a problem and we can experience poor indoor air quality. Mold growing can release mold spores, toxins from mold and moldy odors. [4][5] Mold can cause: unsightly stains; damaged paints, wood, drywall, ceiling tiles and fabrics; damage to personal items; allergies; and illness.

Certain kinds of molds like an extremely wet environment. Other kinds of molds may be growing even if no water can be seen. Dampness inside the material can be enough to allow them to grow. To avoid most mold problems, we must keep materials and indoor air dry**.** If mold is present, clean affected area as soon as possible and identify the source of moisture that allowed the mold to grow in that location.

3 CONFIGURATION OF VENTILATION SYSTEM

3.1 Building Ventilation Types

Based on different purpose, building ventilation can be divided into following types: [2] one is thermal comfort ventilation, which refers to ventilation for improving on human thermal comfort when outdoor air temperature is lower than indoor air temperature. The second is sanitation ventilation, which refers to mechanical ventilation for improving on indoor air quality by removing toxic materials with outdoor fresh air in place of indoor air, when the air conditioning, dehumidifying or heating equipment is running with windows closed. The third is balanced ventilation systems, in which exhaust fan runs in conjunction with fresh air intake to the furnace circulating air system. Still another is heat recovery ventilation, combustion appliances with matched intakes and exhausts run smoothly. In some houses that employ combustion devices, gas, oil or wood furnaces, water heaters, fireplaces, etc, a fresh air supply may be required to match the flows of exhaust-only ventilation systems.

All ventilation systems above related should be balanced, i.e., air in = air out, with intakes sized to allow easy entry of enough air to supply all exhaust devices. Now, building construction often aims at minimizing leaks in the shell for airflow control (including moisture) and energy related reasons. Usually, a proper ventilation system should provide constant minimum ventilation values, and the minimum ventilation rate must be delivered to each room effectively.

3.2 Ventilation Modes Options

In hot summer and cold winter region, humid climate causes long dehumidifying period, ventilation adds more moisture to indoor air, so ventilation system dehumidifying energy consumption occupies majority in the annual ventilation energy consumption. Taking Chongqing for example, when indoor design conditions are dry-bulb temperature 28°C, RH 70%, ventilation air energy consumption in dehumidifying period is about three times of that in AC period [3]. Therefore, ventilation air dehumidifying is more important than cooling in air treatment system for buildings. In order to dry moist outdoor air more efficiently, we think that cooling design conditions cannot be used to determine the energy efficiency of ventilation air treatment system in which operates during most of the cooling season just for dehumidifying independently.

Ventilation combined with air circulation includes balanced ventilation systems and heat recovery ventilation. If we have a forced air system, operate the fan continuously or intermittently. Combined with opening windows or using an exhaust fan, this will result in improved air quality through the whole house, while its drawback is that most fans have a high energy consumption.

A heat recovery ventilator (HRV) also exhausts moisture and odors. An HRV is a self-contained ventilation system that provides balanced air intake and exhaust. Like a central exhaust fan, it can be connected to several rooms by ducting.

3.3 Constant-volume or Variable- volume System

Many HVAC designers prefer a low-cost constant-air-volume (CAV) solution, believing that it also simplifies ventilation and inherently provides sufficient dehumidification. Dennis Stanke, Trane staff engineer and member of ASHRAE SSPC 62.1, uses psychrometric analyses to demonstrate the difficulty of providing proper dehumidification, particularly at part load, when dry-bulb temperature determines system capacity. Therefore, we should put more attention on the latent capacity of a ventilation system and its effectiveness.

Variable-air-volume (VAV) systems provide effective, indirect dehumidification over a very wide range of indoor load conditions. As long as any zone needs cooling, the VAV air handler supplies dry (low-dew-point) air to all terminal units. The dry supply airflow, modulated to control the sensible indoor load directly, removes the latent indoor load indirectly by absorbing space-generated moisture and removing it with the return air.

4 DEHUMIDIFIERS AND HOW THEY WORK

4.1 Heat Pump Dehumidifiers

Dehumidifiers use a heat pump (similar to an air conditioner's heat pump) or chemical adsorbents to remove moisture from the air without cooling the air. A heat pump dehumidifier uses a fan to draw indoor air over a heat exchange coil. The coil is almost freezing. The water in the air condenses on the coil and is drained. A second heat exchange coil reheats the air, which the dehumidifier exhausts into the room. A heat pump dehumidifier dumps heat lost from the compressor and fan motors into the air. It returns to the indoor air the heat generated by the dehumidifier turning water vapour to liquid.

4.2 Chemical Adsorbent Dehumidifiers

This type of dehumidifier is designed for hot, humid climates. Chemical adsorbent dehumidifiers absorb moisture from the air with a "desiccant" -- a drying agent such as silica gel. The desiccant is on a heat exchange wheel. A separate air loop dries the wheel and exhausts the hot, damp air outdoors through special ducting. A chemical adsorbent dehumidifier uses more energy than a heat pump dehumidifier. It is only cost-effective when it uses natural gas for heat exchange.

4.3 Dehumidifying Ventilators

This type of dehumidifier has a sensor-controller and exhaust fan. We set the sensor-controller to run when humidity reaches a set level. A dehumidifying ventilator is particularly effective if the humidity source is in our basement. Dehumidifying ventilators don't recover heat but they use less electricity than heat pump dehumidifiers. They are not effective in hot, muggy weather, as they bring more outside air into the house. They can be effective in cold weather.

4.4 Placing Dehumidifier

If we have forced-air heating and central cooling and the fan moves the air continuously, it doesn't really matter where we place the dehumidifier. It will remove roughly the same amount of moisture from the house .

Placing a dehumidifier in a room may not be a good idea. The unit may be too noisy and we have to empty the condensate tub every day. In the muggy days of summer, set the controls to remove more moisture. Lower the setting to remove less moisture in spring, fall and on clear, dry summer days.

5 SEPARATELY CONTROLLED AC UNIT IN HOT SUMMER AND COLD WINTER ZONE

If properly designed and controlled, the HVAC system can significantly reduce the moisture content of indoor air. Ironically, the most widely used means of ventilation—the single-zone, CAV system is also the most problematic when it comes to dehumidification. Designers typically size cooling coils based on the peak sensible load, that is, when it is hottest outdoors. In many climates, especially in Hot Summer and Cold Winter Zone, the latent load on the cooling coil—and often the total load (sensible plus latent)—peaks when outdoor dew point, not dry bulb, is highest.

The operating conditions of building ventilation system should be determined on both outdoor air temperature and humidity. Ventilation rate is limited with the minimum ventilation rate in sanitation ventilation mode of AC period, dehumidifying period and heating period. However, in thermal comfort ventilation mode, ventilation rate is unrestricted. Building ventilation system should satisfy these requirements during prolonged period of high ambient humidity.

Therefore two separate AC units are needed, one is for indoor human, equipment, lighting and building envelope, the other for sanitation ventilation. Ambient air treated by ventilation unit is introduce into living area at a dew-point temperature sufficient to undertake the entire latent load, while the recirculation unit operates with sensible heat ratio (SHR) of 1.0 to meet any remaining sensible load. At the same time, the conditioned ventilation air rate should overcome the exfiltration air rate, so that the conditioned room is pressurized. As a result, reduction of interior humidity is achieved.

6 CONCLUSIONS

In many air-handler arrangements, we know coils selected for the highest sensible load may not provide sufficient cooling capacity when the highest latent load occurs. More importantly, however, coils controlled to maintain the dry-bulb temperature in the space often operate without adequate latent capacity at part-load conditions.

Considering the annually humid weather characteristic of main cities in Hot Summer and Cold Winter Zone, indoor RH exceeds comfort limits in buildings when conventional AC equipment is thermostatically controlled to provide comfort. In order to achieve comfortable IEQ, after building large moisture source in toilet or kitchen first controlled at the source, moist ambient air identified as the major source of high humidity must be properly conditioned. Supplying conditioned ventilation air to the buildings appears to be a promising approach to solve the heath problems associated with excessive indoor RH. The proposed solution is the installation of a separately controlled unit to dry and cool outdoor air based upon demand of an indoor humidistat.

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