Martin County Courthouse - The Untold Story

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> ***Editor's Note**: Florida's Martin County won the lawsuit it brought against the contractor of its new courthouse complex, which required renovations that cost well over twice the original construction price. The county was awarded $11.5 million, plus back interest and legal fees. The $26 million spent by the county for renovations was to correct a severe mold problem, construction defects, and employee health complaints. The lawsuit focused on contractual disputes rather than on negligence.*

This perspective on a widely publicized building failure presents a mechanical engineer's forensic assessment of the two buildings involved, the extensive moisture problems, and subsequent evacuation and reconstruction of the facilities. The design of the heating, ventilation, and air conditioning (HVAC) systems was so fatally flawed that the buildings were destined to fail.

Review of the multiple problems with the HVAC systems reveals that the buildings were under negative pressure when air conditioning equipment was operating. These conditions favored mold and mildew growth inside the wall cavities and the interior of the buildings. Two topics not addressed here are the building shell problems and the odor complaints presumably caused by the sewage-treatment plant directly adjacent to the site, on the prevailing upwind side.

Background

A thorough examination of the numerous problems and resulting failure of the Martin County Courthouse Complex offers invaluable insight into best building practices and yields lessons that are particularly important for buildings in hot, humid climates. Interrelations among many problems went ignored or unrecognized due to the overwhelming impact of shortcomings of the HVAC systems.

Much of the published analysis of this failure has dealt with the microbiological problems, investigative techniques employed, and construction problems. This article explores a different perspective involving two elements:

- The building complex's problems were caused by inherent design flaws.
- Early involvement of qualified engineering professionals and building science specialists could have avoided most of these problems. This early involvement

could have substantially reduced or eliminated the cost of litigation and reconstruction.

In 1993, attorneys representing the installing HVAC contractors and their insurers contacted the Bailey Engineering Corporation, based in Palm Beach Gardens, Florida. Initial investigation of the building and plans showed severe shortcomings in the HVAC system design and its ability to control indoor relative humidity. Deeper investigation of plans and site conditions revealed latent defects that had gone undiscovered and ignored for years. The resulting high relative humidity throughout the facility was recognized within the first months of building occupancy. This lack of moisture control ultimately led to extensive microbiological amplification and building failure.

The two separate buildings on the Martin County Courthouse site both failed, but each for different reasons. The Courthouse Building (Courthouse) had courtrooms and judges' chambers on the top two floors and had general offices, recordkeeping, a law library, and a jury assembly room on the first floor. This building connected to the Constitutional Office Building (Office Building) through a walkway located on the second floor. The Office Building, a four-story office tower, had offices for Martin County as well as the state's attorney on the first three floors. The fourth floor of the facility, which was never built out, air conditioned, or occupied, exhibited very few of the problems observed elsewhere in the building.

Each building was served by a chilled water HVAC system, each with its own separate air cooled chiller. Within each building, a primary loop supplied chilled water to a secondary loop serving fan coil units in the ceiling spaces. Air was distributed by single-zone fan coil units that fed small independent zones or small sections of offices with ducted supply and ceiling plenum returns. The HVAC system designs lacked any of the basic design recommendations for humid climates found in the 1985 *ASHRAE Handbook of Fundamentals*, Chapter 21, one of the standard references available at the time this design was executed.

Improperly Preconditioned Outdoor Air

In the Courthouse, outdoor air was not preconditioned or filtered. The importance of the failure to precondition the air in Martin County's humid climate must not be underestimated. This air could carry approximately 390 pounds of water per hour into the building in the summer. Constant-volume supply fans on the roof supplied this air to fan coil units throughout the building. Maximum occupancy (900 people) in the Courthouse could add 163 more pounds of moisture per hour to the building.

In the Office Building, the outdoor air was inadequately preconditioned to 71°F dry bulb at 86% relative humidity, and then injected above the ceiling plenum. This subjected drywall and ceiling materials to unacceptably prolonged high relative humidity. This

preconditioned ventilation air carried 125 pounds of water per hour into the Office Building. Not surprisingly, mold and mildew were amplified in many of these ceiling areas. In addition, the occupant load could contribute 42 more pounds of water per hour. None of these figures includes any factor for moisture gain through the envelope due to water vapor transport caused by the high vapor pressure differential from outside to inside.

Fan Coil Unit Design Considerations

The fan coils that were specified for the Office Building were incapable of adequate dehumidification performance. The fan coils serving much of the Office Building were selected with sensible heat ratios of 0.88 and higher, which means that the dehumidifying potential of the coils was thus limited by design to less than 12% of total capacity. To put this in perspective, consumers can buy window units directly off the shelf of local appliance stores with 20% to 30% dehumidifying potential, or two to three times the dehumidifying potential of the fan coil units specified for the Office Building.

The fan coil unit specifications listed an external static pressure for the equipment that far exceeded the actual operating external static pressure. Consequently, the fan coil units supplied to the site delivered up to 60% more airflow than intended. This problem was caught at initial test and balance. The final resolution by the engineer was to leave some of the fan coil units "overaired" by up to 25%. This excess airflow undermined the already limited dehumidifying capabilities of the fan coils, assuring that the coils could not maintain acceptable relative humidity. The 25% "overaired" condition violated the fundamental tenets of system design.

Separate load calculations done by Bailey Engineering Corporation and an engineer hired by Martin County both found some of the fan coil units to be oversized by initial design. This oversizing of some units exacerbated the many other factors that contributed to inadequate dehumidification performance. Further review of HVAC design calculations showed that no allowance was made for moisture load due to water vapor diffusion through the building shell. In humid climates, the water vapor pressure differential between the outside and the inside is more than twice that of a humidified building in a northern climate.

Outdoor Air Distribution

The outdoor air supply blower and duct system in the Courthouse supplied unconditioned outdoor air to fan coil units in the courtrooms and the judges' chambers. Motorized dampers in the outdoor air ductwork that supplied the courtrooms were designed to modulate the outdoor air intake. These courtroom dampers were driven by an "indoor air

quality sensor" that modulated the outdoor air for the courtrooms based on occupancy. The courtrooms were designed and built for occupancies ranging from 50 to 100. Rarely did the courtroom have more than 20 occupants. This situation left the single-stage equipment serving the courtrooms severely oversized, but led to worse problems in the judges' chambers.

As these modulating dampers to the courtrooms closed down, the unconditioned, unfiltered outdoor air was forced to seek another path. This path was the outdoor air ductwork supplying the fan coil units that served the judges' chambers. Since there was no variable volume control on the supply fan to vary the overall flow rate of outdoor air being supplied to the system, large quantities of unconditioned outdoor air were forced into the judges' chambers as the courtroom dampers closed. The fan coil units serving the judges' chambers were incapable of removing the moisture that accompanied this humid outdoor air. Evidence to support this hypothesis was extensive. At one point in the investigation, the superintendent for the general contractor indicated that the complaints "radiated out of the judges' chambers."

Two-Position Chilled Water Valves

The majority of the chilled water valves in the system were two-position, two-way valves. Each fan coil unit's chilled water coil was controlled by such a valve, which shuts off water flow to the coil as the temperature in the space is satisfied. Four primary results are associated with this method of control.

- Humid outdoor ventilation air introduced into the space is not conditioned, which causes widely fluctuating and elevated relative humidity in the occupiable space.
- Moisture left on the coil re-evaporates back to the space during the coil off-cycle.
- Any moisture gain, either from people or from moisture diffusion through the building envelope, raises the relative humidity, since no moisture is being removed.
- Units are unable to operate at partial capacity under part-load conditions.

Water Loop Design

The secondary loop that supplied chilled water to the fan coil units was a constant-volume pumping system. Each fan coil unit's chilled water valve shut off flow when that room's temperature was satisfied. With the valve closed, the chilled water that had been flowing through that fan coil was then forced to other units in the system. This setup

resulted in substantial excess flow of chilled water through the fan coil units still calling for cooling. The higher flow of chilled water could actually be a benefit, by boosting latent removal capacities for coils. But since the system was controlled by temperature only, the sensible loads for these other spaces were satisfied more quickly. This setup resulted in even shorter cooling cycle times. The reduced moisture removal during these shorter cycles resulted in even higher average indoor relative humidity.

Another significant defect was the secondary loop piping configuration in the Office Building. The design drawings show the return side of the secondary loop connected to the primary loop upstream of the supply tap. As a result, warm return water tempered the primary chilled water before entering the secondary loop, elevating chilled water temperatures going to the fan coils. As the heat load on the building climbed, the temperature of the secondary chilled water loop also increased. These higher supply water temperatures further undermined the dehumidification performance of the fan coil units.

Thermostat Placement

Thermostat placement was not specified on the original drawings. A revised set of drawings was later issued to indicate thermostat placement, in response to the contractor's request for information. On this revised set of drawings, the thermostat placement was poor or missing in at least eight instances. In one instance, the thermostat for a unit that served an exterior space was located in an interior space. As a result, this thermostat was unable to properly respond to changing external heat loads in the space. In two other cases, the ceiling grille from one air handling unit blew on the thermostat that controlled another zone, which led to loss of temperature control in these spaces.

Uncontrolled Airflow in Interstitial Spaces

Many of the walls in the Courthouse and all the walls in the Office Building that subdivided office spaces went to the underside of the slab. This setup prevented the interstitial spaces from communicating freely with each other, which led to several isolated zones of negative pressure differentials. These same interstitial spaces were used intentionally for circulation of return air, and were depressurized by system-induced pressure relationships in many areas.

Ventilation and Outdoor Air

Many spaces were underventilated by design, particularly in the Office Building. The Office Building outdoor air intake system distributed the outdoor air by blowing it into sections of the ceiling plenum. However, 97% of the walls went to the underside of the slab, and no provision was made for transfer of outdoor air from one area of the ceiling plenum to another. Fire walls and office demising walls blocked the outdoor air from getting to the fan coil units in many areas. As a result, most areas did not have proper ventilation. This compartmentation resulted in overpressurization of some plenum areas and caused exterior walls in several areas to be under negative pressure. The compartmentation that resulted from the design approach caused lobby areas of the Office Building as well as the main entrance of the Courthouse to be under a substantial negative pressure. In a fruitless attempt to overcome the negative pressure at the Courthouse, an air curtain was installed over the entrance door.

Use of the ceiling plenum as an outdoor air distribution system is a flawed design concept that exhibits extremely reduced ventilation effectiveness even under optimal conditions. Resulting problems include uncontrolled airflows, poor management of zone-to-zone pressure relationships, and loss of control of overall building pressurization.

Planning for Outdoor Air

Of the 67 fan coil units and air handlers listed on the plans, 64 showed no outdoor air intake listed on the schedules. Of the remaining three, one was the 100% outdoor air pretreatment system for the Office Building. Even by inference from data provided on the engineering drawings, including the specified entering and leaving air conditions on the equipment schedules, only seven fan coils were intended to have some quantity of outdoor air. Even though most units were not specified for mixed air conditions, outdoor air intake blowers and ductwork were provided. In the courthouse, this outdoor air was ducted directly to the units. In the Office Building, this outdoor air was dumped into the ceiling plenums.

High Humidity in Ceiling

An initial walk-through of the courthouse facility revealed that the ceiling grid throughout several areas was rusted. The pattern of the water marks on the ceiling tiles traced the position of the chilled water lines above. These stains were caused by profuse sweating of the chilled water lines due to the high humidity in the plenum space.

Misplaced Vapor Retarders

In both buildings, vinyl wall coverings were used on the interior of exterior walls as well as on interior walls. The fact that vinyl wall coverings act as a misplaced vapor retarder in humid climates is now widely recognized. But references that date back several years, to the time when this building was constructed, outline the problems with vinyl wall coverings.

Fatal Design Flaw

The designs of the HVAC systems were so fatally flawed that the buildings were destined to fail. Without proper modifications to the engineering design, this failure was inevitable, no matter what actions were taken by the maintenance and operating personnel.

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