Natatoriums:

What Can Go Wrong—and Did

'Value engineering,' lack of preventive maintenance, and Mother Nature undermine otherwise state-of-the-art Florida health club

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Three years after the completion of a new state-of-the-art health club on the central east coast of Florida, all of the major mechanical equipment has been—or soon will need to be—replaced. What's more, the owner's energy bills and maintenance costs are excessive. This article discusses what can go wrong with a natatorium, even one designed to the highest standards and with the best technology available.

Remnants of piping and support brackets where solar hot-water panels were destroyed by Hurricane Francis in September 2004. The panels damaged the roof deck and one of the condenser coils as they were blown across the roof.

HVAC AS DESIGNED

Ventilation and pressure relationships were the chief concerns of the project's HVAC designers. To keep humidity from the 75-ft, 10-lane pool out of other spaces, natatorium fresh-air and exhaust-airflow rates were calculated to maintain a pressure slightly positive with respect to the outdoors, but significantly negative with respect to the adjacent exercise spaces. The next-highest-pressure space is the locker/shower rooms, which were designed to be at a pressure slightly higher than that of the natatorium, but significantly lower than that of the exercise areas for reasons of humidity and odor control. The remainder of the 21,000-sq-ft, two-level building, which includes a weight room, aerobics studio, cardio mezzanine, children's room, and offices, was designed to a pressure of 0.12 in. wg to keep out humidity from the outdoors, showers, and pool, as well as chlorine and locker-room odors.

In the pool area, a 79-F space temperature is maintained year-round. The humidity set point is 60 percent, which is met to within ±5 percent by a rooftop dehumidification unit. The unit conditions a mixture of 10,000-cfm return air and 2,000-cfm fresh air and can provide 250-MBH pool-water heating via four coaxial heat exchangers. A 1,200-cfm exhaust fan allows a slight positive space pressure, while two natural-gas water heaters provide 400-MBH pool and 250-MBH spa heating. A 500-MBH natural-gas boiler supplemented with solar panels provides hot water for showers and lavatories.

Ventilation for the remainder of the building is provided by a 100-percent-outside-air unit, which feeds the mixed-air sections of five rooftop package units and one split system. The outside-air

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intakes on the package units are blocked off—all 4,000 cfm of fresh air enters the system fully conditioned via the 100-percent-outside-air unit. This arrangement ensures adequate ventilation and humidity control under all load/occupancy conditions year-round. Air is exhausted via restroom fans.

HVAC AS BUILT

The design called for a simple HVAC control system to interface with the pool unit, the fresh-air unit, the package units, and the exhaust fans. Communicating thermostat-humidistat modules were to be networked with on-board controls in the rooftop dehumidification and 100-percent-outside-air units, as well as a simple graphical interface programmed to coordinate and schedule equipment operation. Unfortunately, this $22,000 (a little more than $1 per square foot) control system was "value-engineered" out of the project. The pool unit and fresh-air unit are controlled by on-board sensors, while the package units are controlled by programmable wall thermostats.

Without a user-friendly control panel, unit set points are held at constant/default values, equipment status is difficult to monitor, and operation of the package units and exhaust fans is uncoordinated. And without integrated controls, operation is less than optimal: Heating and cooling occurs simultaneously, exhaust and outdoor airflows are out of sync with scheduled temperature-set-point changes, and pressurization faults exist for as long as several days while exhaust-fan or fresh-air-damper failure goes undetected. Occasionally, a power surge or outage will reset the pool-water set point to the default value of 80 F, which is below the pool-boiler set point of 84 F. This means "free" pool heating from the rooftop unit is being discarded, with costly boiler pool heating making up the difference.

Not surprising is that energy costs total about $80,000 a year, for a rather high Energy Use Index of $3.88 per

Natatorium Design Parameters

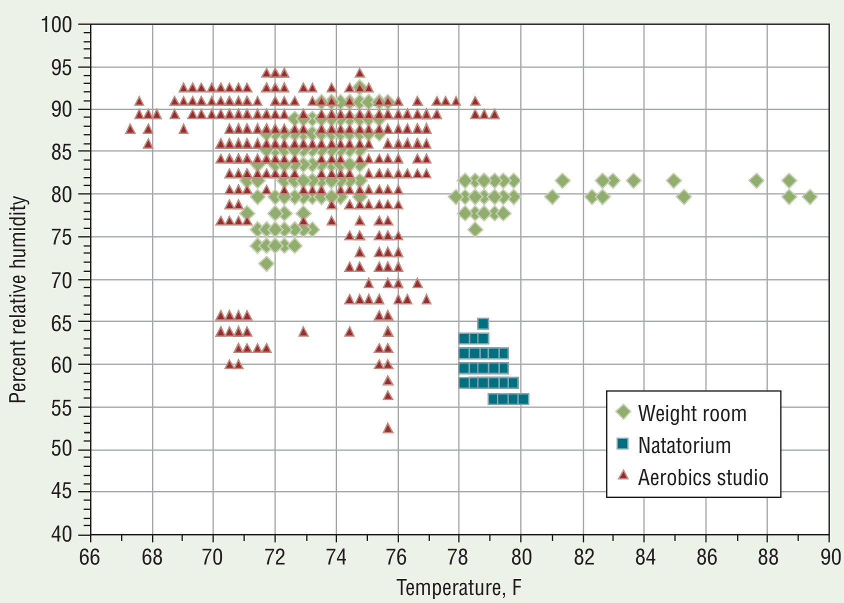
Indoor heated pools involve high evaporation rates and extreme humidity-control issues that must be addressed during the first steps of a building's architectural and mechanical design to ensure acceptable comfort, to protect structural integrity, and to provide the owner with reasonable equipment, energy, and maintenance costs. If humidity is not actively controlled, pool water will evaporate, and space dew point will rise high enough for condensation to occur on walls and other interior surfaces.

Natatorium design parameters begin with control of pool evaporation rate. For the Florida health club discussed in the accompanying article, pool evaporation rate was determined to be 300 gal. per day—based on a water temperature of 84 F and space conditions of 80 F and 60-percent relative humidity (dew point 64.9 F)—using the following equation:

$$\text{Evap-rate}\left[\text{pounds per day}\right] = 2.4 \times \text{area}\left(p_{water} - p_{air\text{-}saturated}\right)F_{activity}$$

For evaporation at a rate of approximately 13 gal. per hour, dehumidification capacity of 9.6 tons is needed. This means airflow rates will exceed 2 cfm per square foot. With the pool-area cooling load's large latent-heat fraction, reheating must be accomplished downstream of the cooling coil, if comfort is to be achieved. This will increase energy requirements. Some of the energy can be recovered by using it to heat the pool water, which is continuously cooled by evaporation.

Water in active pools evaporates at rates 40- to 70-percent greater than water in inactive ones. To keep evaporation rates down, the velocity of air flowing over a pool surface should be minimized. Relative humidity below 60 percent increases evaporation and reduces the comfort of swimmers exiting a pool, while relative humidity above 60 percent enables mold and mildew growth, as well as finish and structural damage. All interior surfaces should be non-porous. Insulation levels must be sufficient to ensure that surface temperatures do not dip below the dew point during winter.

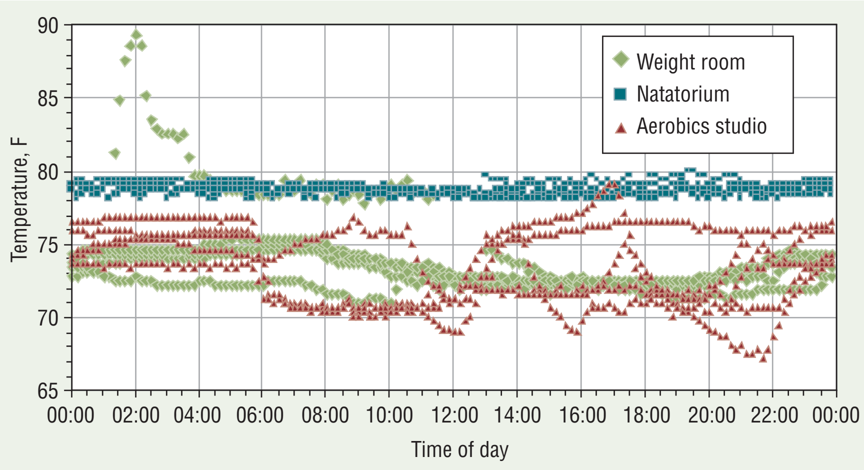


Air-handling-unit inlet conditions.

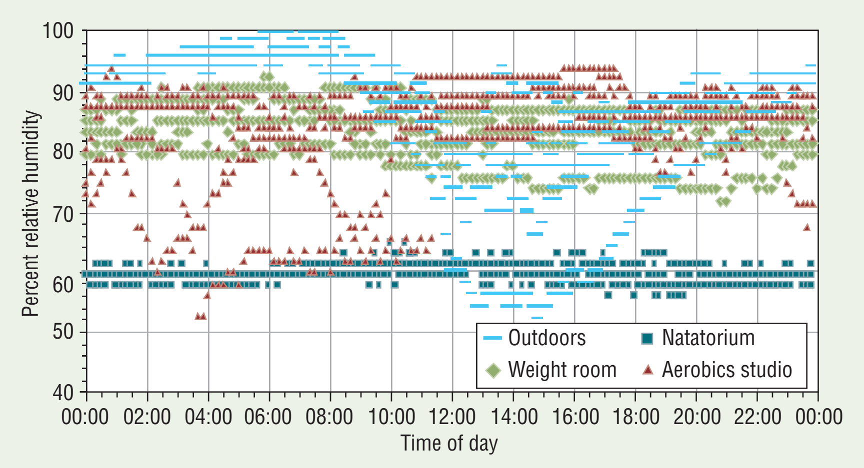
square foot per year. Utilities are the owner's third-largest facility expense (after wages and mortgage), accounting for about 8 percent of the annual budget. Of this total, about $1 per square foot per year is for water heating. Air-conditioning energy costs are estimated to be more than $44,000 a year.

Compare the health club's energy bill with that of the 2005 ASHRAE Technology Award-winning aquatic center at Allegan (Mich.) High School. The 23,700-sq-ft facility employs energy-conservation strategies such as underfloor air distribution, demand-controlled ventilation, energy-recovery units, an energy-management system, and direct digital controls to achieve energy costs of only $43,000 ($1.81 per square foot) per year. The payback for the $130,000 investment in energy-saving features is approximately three years.

Water/sewer charges for the health club are a reasonable $14,000 per year, which equates to approximately $5 per member per year. This relative efficiency is attributed to the specification of water-saving 2.5-gpm showerheads, 0.5-gpm faucets, 1.6-gpf toilets, and 1.0-gpf urinals.



Air-handling-unit inlet temperature vs. time of day.



Air-handling-unit inlet humidity vs. time of day.

CURRENT STATE

In addition to the missing control system, the health club's excessive energy costs are the result of the poor condition of its HVAC equipment. The condenser coils are located on the roof, in the direct path of salty breezes from the Atlantic Ocean, which is just 200 yards away. Knowing that condenser coils typically will last only four to seven years in such an environment if left untreated, the HVAC designers specified that all units receive a protective coating. Apparently, that coating never was applied. As a result, the flaking and corroded coils will need to be replaced soon. Until then, they will continue to cause inefficiency and drive energy costs upward.

In September 2004, hurricane winds caught loose package-unit access panels. One panel was folded open; another was sent tumbling across the roof, gashing the roof membrane and crashing into a satellite dish and condenser coils. Wind-driven rain flooded the open air-conditioning units, causing ductwork to collapse into the building.

In May 2004, an informal on-site survey was conducted to gauge the condition of the facility. There had been exhaust- and air-handling-unit-(AHU-) fan failures in the restrooms, which affected pressure relationships. At the time of the survey, the natatorium exhaust fan had been awaiting replacement for several days. With the broken exhaust fan, space pressure was higher in the pool area than in the adjacent weight room and aerobics studio. A rusted damper in the outside-air unit resulted in insufficient ventilation airflow and negative pressure. Trend data showed that while the natatorium conditions were well-maintained at the desired set point (79 F, 60-percent relative humidity), a significant quantity of humid pool air was being drawn into the adjacent air-handling returns because of the pressure imbalance. Because of the transfer of pool air, trend logs showed weight-room and aerobics-studio AHU-inlet conditions to be much more humid than the general space conditions (actual space conditions in those areas were within the comfort range). While no mold growth was observed, there were signs of condensation and wet gypsum board.

Also failing prematurely were the water softener, which resulted in numerous steam-room and sauna heating-element replacements; the pool and spa boilers; and six pool-pump motors (230-v single-phase pump motors were replaced with proper 208-v units).

LESSONS LEARNED

The design engineers made use of the best-available HVAC strategies and equipment, creating a state-of-the-art system capable of providing optimal comfort and operating efficiency for many years. Unfortunately, the desired control system and coil-corrosion protection were not installed—lower-cost equipment was substituted. Other than filter changes and lubrication, a scheduled preventive-maintenance program does not appear to have been implemented—maintenance is performed mostly on an as-needed basis. Just three-and-a-half years after occupancy, much of the original HVAC equipment still is operating, albeit nowhere near its full potential. Even though the facility is quite comfortable in terms of temperature, humidity, and ventilation, energy and maintenance costs are exorbitant. This is an example of why even the best design and equipment specifications need to be verified and commissioned and why quality operation and maintenance are so important to achieving intended performance and desired results.

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A History of Pool Problems

Prior to constructing its current state-of-the-art home, the health club leased approximately 14,000 sq ft of space in a strip mall, where it added a semiconditioned natatorium. The HVAC system consisted of typical unitary direct-expansion equipment—several small package units and split systems. This standard retail-store equipment could not cope with the unusual humidity load of a heated indoor pool and the high fresh-air needs of densely occupied exercise rooms. Additionally, the space above the suspended ceiling was open to the outdoors via continuous soffit vents, while the restroom exhaust fans produced a negative building pressure. Dew-point temperatures above the ceiling far exceeded the 72-F space temperature for much of the year. The result was sagging and moldy ceiling tiles continually in need of replacement and recessed light fixtures that would fill with water and drip from condensed humidity.

A local service company mitigated these problems by installing a large exhaust fan above the suspended-ceiling space, ostensibly to "ventilate" the space and remove humidity to the outdoors. The fan distorted the building-pressure relationships so that conditioned air was drawn upward through the suspended ceiling and light fixtures, partially conditioning the space above the ceiling. This had three effects:

- The dew point above the ceiling was reduced because of conditioned air from the space below mixing with outside air from the soffit vents.
- The flow of outdoor air into the building increased greatly because of the negative-pressure condition caused by the fan. However, the additional air-conditioning load increased electricity use significantly.
- Space temperatures tended to rise to 76 to 80 F (because of excessive cooling load) and, thus, were well above the dew-point temperature most of the time.

Currently, the space is occupied by another health club, which continues to struggle with comfort and humidity concerns.

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