School HVAC

2005 ASHRAE Technology Award

Performing Arts & Aquatic Centers

By **Wayne Edward Kerbelis,** Associate Member ASHRAE

Energy conservation strategies such as underfloor air distribution, demand control ventilation, energy recovery units, an energy management system and direct digital controls were used for the additions of a performing arts center and natatorium to an existing high school in Allegan, Mich.

Building Description

Performing Arts Center. The 30,000 ft^2 (2787 m^2), 1,200 seat performing arts center was designed to handle dance, acting, concerts, and music festivals for the students. The center includes a 75 ft (23 m) high fly loft, rehearsal areas, scene shop, theater support areas and a lobby with a 35 ft (11 m) high curved exterior glass wall.

Aquatic Center. The 23,700 ft^2 (2200 m^2) natatorium was designed to offer a competitive swimming/diving pool and also a recreational pool that includes a "lazy river," a 10 ft (3 m) high water slide and adjustable water fountains that simulate sprinkler systems for children's play. A 30 ft (9 m) glass wall separates the competition pool from the recreation pool. The aquatic center also includes a lobby, offices, locker rooms, and showers.

Design Challenges

The HVAC systems had to be flexible to adapt to varying occupancy loads and to facilitate rapid changeover from drama to dance and from music to academic use.

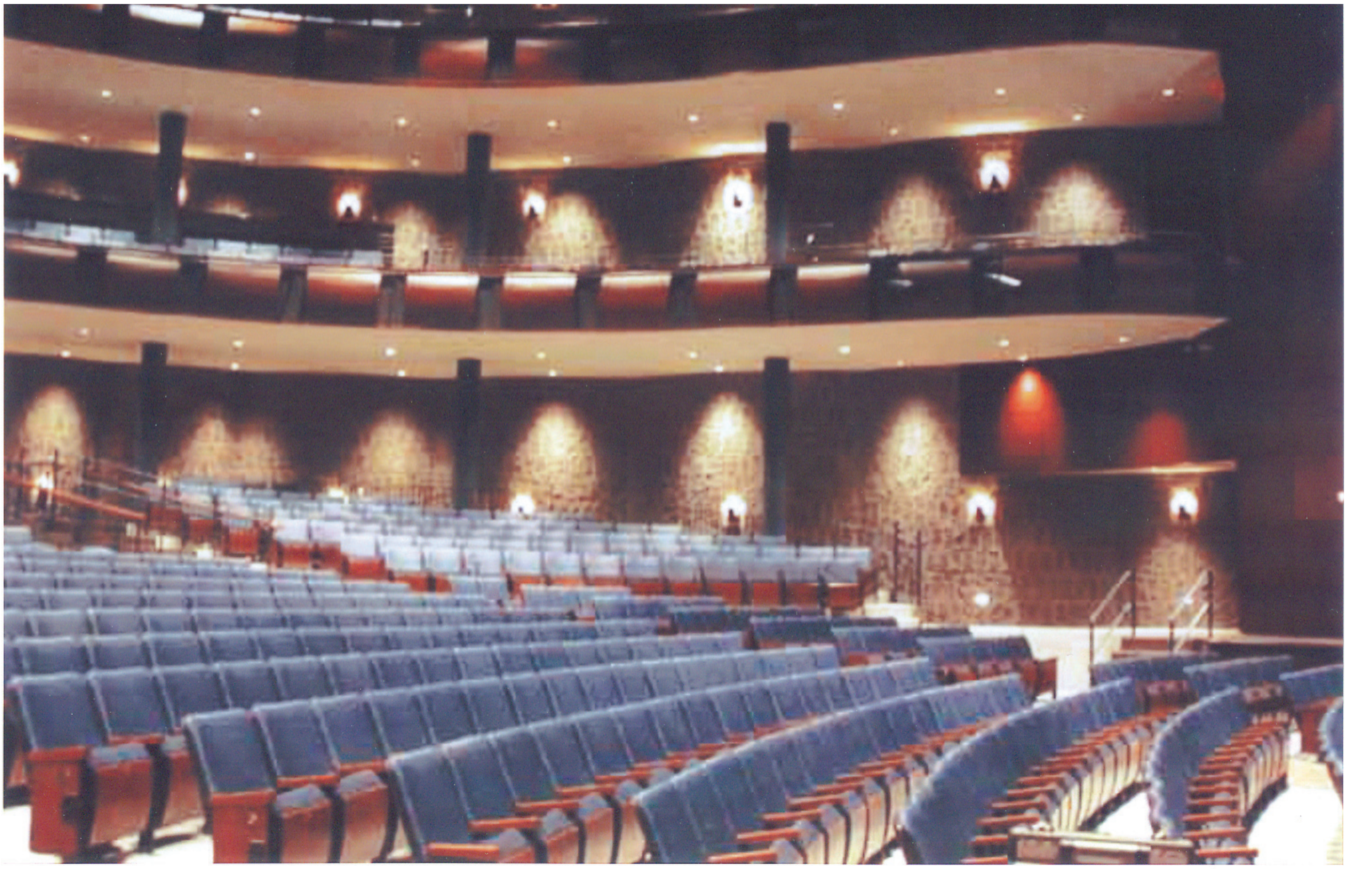
The aquatic facility, with its large expanse of glass on the exterior wall, required an HVAC system that maintains comfort for the occupants while preventing condensation and/or icing on exterior glass caused by severe Michigan winter temperatures.

Project Design Criteria

General Outdoor Temp.	
Summer	90°F (32°C) DB
Winter	–1°F (–18°C) DB
Performing Arts Center	
Cooling	75°F (24°C) DB
Heating	72°F (22°C) DB
RH	Reset gradually from 30% RH in winter to 55% RH in summer
Sound Design Levels	20 NC (Noise Criteria)

About the Author

Wayne Edward Kerbelis is the mechanical and electrical engineering manager of the project and is a senior associate at Peter Basso Associates in Troy, Mich.



The author won a 2005 ASHRAE Technology Award (2[nd] Place Institutional Buildings [New]) for the Allegan High School additions.

Aquatic Center	
Cooling	80°F (27°C) DB or 2°F (1°C) above pool temperature
Heating	80°F (27°C) DB or 2°F (1°C) above pool temperature
RH	50% RH

Innovation and Energy Conservation

Innovative and energy conservation technologies were incorporated into the design to meet the guidelines established by ANSI/ASHRAE/IESNA Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings*, as well as to address Allegan Public Schools' primary concern of controlling high operating costs for a specialized environment with superior indoor air quality.

Performing Arts Center. A single zone air-handling unit was provided for the theater, which supplies 68°F to 70°F (20°C to 21°C) air through an underfloor air-distribution system. The underfloor ventilation displacement system is quiet and provides ventilation air directly to the occupied zones at the theater seating areas on the main floor and the two balconies.

The supply and return air-distribution system was designed for equal friction, thereby eliminating the need for balance dampers. The result is equal air distribution and elimination of possible noise generated from air flowing through balance dampers. This system saves electrical fan energy compared to the conventional higher air velocity overhead distribution systems.

The ductwork for the theater includes sound attenuators on the supply and return air ducts, vibration spring hangers, and sound attenuating lagging on selective ductwork. Piping for the theater is supported by vibration spring hangers and includes sound attenuating lagging on selective piping located in sound critical locations to further reduce the possibility of noise generated from the HVAC system.

A single zone air-handling unit for the lobby supplies conditioned air via an overhead duct air-distribution system.

Carbon dioxide sensing demand control ventilation is installed on the air-handling units serving the theater and lobby areas. Outside air ventilation to the space increases or decreases based on occupancy in the space, which optimizes energy use to condition the outside air when these spaces have little or no occupancy. Carbon dioxide sensing demand control ventilation maintains proper ventilation rates in accordance with ASHRAE standards and local codes.

During unoccupied periods, the air-handling units serving the performing arts facility are de-energized by the direct digital control (DDC) system and are automatically cycled on/off to maintain temperature and humidity limits.

The stage area is served by a separate air-handling unit that supplies conditioned air through an overhead duct distribution system. The supply and return ductwork was sized based on low air velocities to eliminate or minimize air noise. This dedicated air-handling unit can operate during stage rehearsal and allows the larger theater and lobby air-handling units to be shut down when unoccupied.

Aquatic Center. Roof-mounted energy recovery air-handling units serve the locker and toilet areas. These air-to-air plate and frame energy recovery units provide 100% fresh air to the locker and toilet rooms and will recover up to 60% of the waste heat contained in the exhaust air. The recovered heat is used to temper the incoming outside air required to ventilate the space.

Roof-mounted energy recovery dehumidification units serve the competition swimming/diving pool and recreation pool areas. These units consist of air-to-air plate and frame heat exchangers, hot water heating coil and direct expansion coil with hot gas reclaim coil used for dehumidification.

Outside air ventilation introduced to the space is preheated with waste heat recovered through the air-to-air plate and frame heat exchanger. During the dehumidification cycle, the direct expansion coil cools air to remove moisture, and the hot gas reclaim coil uses the rejected condenser heat to temper the supply air to the space.

The pool units are equipped with heat exchanger bypass and return air dampers to use outside air for pool area temperature and humidity control when outside temperature and humidity conditions permit.

The energy recovery dehumidification units provide ventilation through the overhead fabric ductwork, which was custom designed to withstand the corrosive environment around the pools. Three filters protect the fabric distribution system.

Perforations in the fabric create a continuous air curtain, to prevent any particulates from resting on the ductwork. Engineered vents located at varying radial positions on both sides of the fabric ductwork control supply air volume and throw. These low velocity airstreams wash the 30 ft (9 m) high exterior glass wall in the recreational pool and remove chloramines in the recreational and competition pools.

The design incorporates an architectural bench system at the base of the exterior glass wall with an integrated reverse return hot water finned tube radiation system to offset thermal losses.

The heating plant consists of two separate variable flow hot water heating systems for the performing arts and aquatic center. These systems incorporate a primary piping loop configuration with variable flow primary hot water heating circulating pumps using variable-speed drives. The perimeter heating loop is reset or disengaged based on outside air temperature and the variable flow pumps operate based on system demand.

Fully modulating gas-fired flexible water tube boilers with low NO_x burners match the load of the building. The burners produce 40% less nitrous oxide and up to 75% less carbon monoxide than conventional burners.

An air-handling unit with a variable frequency drive provides the required combustion air for the boilers to minimize energy use and provide tempered filtered air to the boiler room. A 30% ethylene glycol/70% water mixture was used in the heating system for the aquatic center to prevent any freezing of coils and piping due to high outside air requirements during winter.

Indoor Air Quality and Occupancy Comfort Conditions

The air-distribution systems are designed to meet the guidelines set forth in ANSI/ASHRAE Standard 62 -2001, *Ventilation for Acceptable Indoor Air Quality*.

The underfloor supply air system in the theater provides filtered conditioned air directly to the breathing zone of the occupants, which results in a high level of indoor air quality. The toxins from the occupants' respiration and the offgassing of chemicals from the building materials are carried away from occupants in the thermal currents and relieved outside based on feedback from carbon dioxide sensing.

Humidification levels throughout the performing arts center are reset based upon outside air temperature, enabling compliance with the design intent without the necessity for special or expensive construction of the building envelope. The design provides ample supply air changes to the different spaces to allow for moisture control, the removal of chloramines generated by the pools chemical treatment and odors from toilet/locker rooms.

The engineering team used a reverse return perimeter hot water heating system integrated into the architectural bench seating located in the theater lobby and recreation pool. This offsets heat losses through the multistory exterior glass based on ANSI/ASHRAE Standard 55-2004, *Thermal Environmental Conditions for Human Occupancy*.

Cost Effectiveness

A value engineering and energy analysis was performed. The result was a cost-effective design with major annual energy and operational cost savings. The mechanical systems designed were installed within the construction budget.

The theater chiller system size was reduced as a result of diversities attributable to the demand control ventilation system. The theater air-handling unit fan horsepower was reduced and supply ductwork was eliminated as a result of the underfloor ventilation displacement system, which provided a low velocity, low static distribution system.

The installation cost of the fabric ductwork was 30% less than the installation of chemical resistant fiberglass and 20% less than field-applied coated galvanized ductwork. The installation of the lightweight fabric ductwork requires less structural support than conventionally ducted systems and allowed the fabric duct system to be hung directly to the wood ceiling system of the natatorium.

The HVAC system was able to achieve an estimated energy savings of $43,000 per year in electricity and natural gas costs. The simple payback based on the additional investment cost of approximately $130,000 compared to conventional systems was approximately three years.⬢