EQUIPMENT EARNS HIGH GRADES

A new Minnesota high school combines the use of energy recovery, quiet fans, round ductwork, and efficient boilers and chillers without sacrificing first cost. End result? Students breathe easier and the administration enjoys the cost-savings.

BY JOHN C. BRADY, P.E.

Students and teachers in Red Wing, MN, began the 1995-96 school year in a new high school that uses the latest in efficient, quiet hvac technology to provide optimal indoor air quality.

The air quality requirements mandated by ASHRAE Standard 62-89, Ventilation For Acceptable Air Quality, have reversed the impact of the post oil embargo reduction in outside air ventilation to occupied spaces of the late 1 970s.

When energy was the primary concern, ventilation rates of 5 cfm per person were required by code. The subsequent tightening of building envelopes, coupled with this ventilation reduction, have spawned a rash of litigation relating to Sick Building Syndrome and Building-Related Illnesses.

The design of Red Wing High School exceeds the goals of energy efficiency from the 1 970s, while retaining the ventilation requirements of the ASHRAE standard. Advances in new hvac technology, along with an integrated approach to design problems, have provided the school with hvac systems that operate with efficiency and provide exceptional comfort, air quality, and acoustics.

The 267,000-sq-ft school, located in Red Wing on the west bank of the Mississippi River, accommodates 1,400 students. Our firm, Armstrong, Torseth, Skold and Rydeen Architects and Engineers in the Twin Cities, worked with the local equipment suppliers to implement a design incorporating products that provide energy efficiency, acoustics, and IAQ, some of which were not yet introduced to the market at the time of design.

THE IAQ AND ENERGY CHALLENGE

The initial design called for a standard variable-volume reheat system.

It became clear that the increased energy consumption required to comply with ASHRAE 62-89 would create an unanticipated burden on the school's operating budget. Of particular concern was the high percentage of outdoor air required for multiple-space ventilation in a variable volume system.

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On the air side, numerous innovations were made to ensure good IAQ without excessive energy consumption.

Historically, the measurement and control of outdoor airflow has been achieved only through a combination of airflow-measuring stations and outdoor air damper control.

The new Trane Company "TRAQ" damper integrates these functions to measure and control outdoor airflow into one device. At the time of design, this product was still in development and testing. The company now offers the dampers as a standard component of their air handler's mixing box module in place of a standard damper.

The product, which requires a 0- to 10-vdc signal, has demonstrated accuracy's within 5% for a velocity range of 100 to 2,500 ft/mm. The device works in the same manner as a variable-volume box located in the outdoor air intake.

Although attaining the required ventilation rate in a constant-volume system is a relatively simple proposition, performing the same function in a multiple-space, variable-volume system is a significant challenge overlooked by many design professionals.

The result can be to over-ventilate certain zones, wasting energy. While this is certain to occur in a multiple-space vav design, other zones often are simultaneously under-ventilated.

Some design engineers have suggested returning to constant-volume systems, or providing dedicated outdoor air units for constant ventilation air supply to each space, in addition to the variable-volume distribution system.

While these solutions accommodate this design problem, neither the construction budget, operating budget, nor the limited structural clearances in the high school could accommodate them.

Red Wing High School combines heating and cooling with IAO to accommodate 1,400 students.

62-89 CALCULATIONS

Other engineers have started using Equation 6.1 in ASHRAE 62-89 to address the concern of over- or under-ventilation in multiple-space vav systems. Use of Equation 6.1 essentially allows a credit for unused ventilation air in the over-ventilated spaces. This allows reduction of the outdoor air being introduced at the air-handling unit.

Trane Company 'Modular Climate Changer" air handlers with integral "Traq" dampers to meter outdoor ventilation air.

Round ductwork provided substantial noise reduction and first-cast savings compared to rectangular duct.

While this is helpful in selecting reduced-capacity coils, implementation into building operation was a greater challenge.

Nevertheless, with a known outdoor air requirement for each space, and information of the total circulated air at each space tracked by the automation system, it is possible to perform a real-time analysis of the outdoor air requirements at each air-handling unit.

The control algorithm was incorporated into the specification and termed "Ventilation Reset Control." The temperature control contractor was required to perform the following:

Outdoor air ventilation volume reset — Provide a minimum outdoor ventilation volume reset control based upon ASHRAE Standard 62-89, Equation 6.1.

Equation 6.1:

$$Y = X/[1 + X-Z]$$

Where:

$Y = V_{ot}/V_{st}$ = Corrected fraction of outdoor air in system supply.

$X = V_{on}/V_{st}$ = Uncorrected fraction of outdoor air in system supply.

$Z = V_{oc}/V_{sc}$ = Fraction of outdoor air in critical space.

(The critical space is that space with the greatest required fraction of outdoor air in the supply to this space.

V_{ot} = Corrected total outdoor airflow rate.

V_{st} = Total supply flow rate, i.e., the sum of all supply for all branches of the system.

V_{on} = Sum of outdoor airflow rates for all branches on the system.

V_{oc} = Outdoor airflow rate required in critical space.

V_{sc} = Supply flow rate in critical space.

Occupancy sensors are provided to control lighting. An occupied signal also adds the outdoor air requirement of that particular space to the calculation of Equation 6.1, for establishing the minimum outdoor airflow at the air-handling unit.

When unoccupied, the outdoor air~ component of each particular space is dropped from this equation.

Where economizer functions call for cooling with ambient air, the economizer control functions override the minimum outdoor air damper position defined by Equation 6.1.

A few years ago in the era of pneumatic controls, this was unthinkable. With the advent of high-speed networks, powerful PCs, and ddc controls, this algorithm now can be readily implemented.

The ultimate design solution for the school was to use Equation 6.1 to calcu-

The new 267,000-sq-ft Red Wing High School benefits from six energy recovery units, quiet fans, round ductwork, and efficient boilers and chillers while retaining the ASHRAE ventilation requirements and saving more than $400,000 in first costs.

late the critical zone ventilation requirements on a real-time basis, and position the TRAQ dampers to respond to this need.

This eliminated unnecessary heating and cooling of excessive outdoor air to satisfy a single critical zone. Furthermore, it eliminated heating and cooling of outdoor air for a particular zone if it was unoccupied.

ENERGY RECOVERY

Equally important to the air quality and energy efficiency of the school's design is the use of six 25,000-cfm energy-recovery units (manufactured by SEMCO).

The energy-recovery units incorporate "Exclu-Sieve" 3-Angstrom molecular sieve enthalpy wheels that transfer sensible heat and perform selective adsorption of water molecules for latent energy recovery.

This selective adsorption transfers water molecules, which are 2.8 Angstroms in diameter, but not the larger molecules of carbon dioxide, ammonia, formaldehyde, etc.

Adsorption is accomplished by a combination of the vapor pressure differential between the wheel surface and the airstream; the uniform pore size of the desiccant media; and the affinity of polar molecules in the airstream with the cations in the desiccant coating of the wheel.

The wheel, introduced in 1987, consists of crystalline alumina-silicates precisely covering an aluminum substrate wheel. By introducing potassium cations into the crystalline structure, the uniform pores of the molecular sieve adsorb polar molecules.

The effectiveness of the enthalpy wheels used at Red Wing High School is in excess of 80%. This means that on a design heating day, -20^{0}F outdoor air is preheated to 52^{0}F by the energy recovery unit.

On a design cooling day, outdoor air at 92^{0}F drybulb / 75^{0}F wetbulb is reduced to 79^{0}F drybulb / 65^{0}F wet-bulb. This preconditioning of the outdoor air is performed on 150,000 cfm during periods of full occupancy.

Pre-conditioning the outdoor air during the cooling season reduced the chiller plant requirements by 440 tons. Preconditioning during the heating season reduced boiler plant requirements by 400 boiler hp. The resultant cost avoidance of the boiler and chiller downsizing exceeded $500,000.

An added benefit of the energy-recovery units is the elimination of heating coils in the air-handling units. On a -20^{0}F design day, 52^{0}F outdoor air enters the air handlers.

Even if the variable-volume system has turned down to a volume equal to the outdoor air volume, the 2^{0}F pickup across the fan and duct pickup will deliver 55^{0}F to the reheat coils, which is common practice.

Elimination of the heating coils provided an additional $100,000 cost avoidance for the high school. A significant reduction in chilled water and heating water system piping costs also was achieved.

ACOUSTICAL, IAQ CHALLENGES

Air quality engineering practice encourages elimination of internal duct insulation due to increased potential for dust accumulation and microbial growth.

A smooth, cleanable internal duct surface is widely accepted as a design standard. This approach, while logical from an air-quality perspective, presented a significant challenge in meeting the acoustical requirements of the school.

This was compounded by the close proximity of mechanical equipment rooms to acoustically critical spaces such as the media center, band, choir, orchestra, concert hall, and theater spaces.

To attain the desired NC levels, the mechanical system design involved careful attention to the details of source noise and distribution design. The design included in-line axial flow fans integral to the air-handling units, which reduce source noise by at least 20 db in the first two octave bands, compared to conventional centrifugal fans.

The design also included perforated double-wall discharge plenums in several key air-handling units. The entire air distribution system consists of round ductwork, providing a 25-db reduction in duct breakout noise in the lower octive bands compared to rectangular ductwork, and eliminated attenuators.

DUCTWORK COORDINATION

The use of round ductwork offered accoustical advantages, but its large size in limited clearances challenged the design team to coordinate the work of different trades.

Distribution ductwork originating in one of two centrally located fan rooms traversed the sprawling complex in a carefully planned manner.

While it was a challenge to coordinate round ductwork design, this labor paid off. Jim Wiggin of General Sheet metal, the ventilation contractor on the project, estimated the round ductwork saved $70,000 over a conventional rectangular duct design.

This complex design process was simplified by using an integrated approach to the design and CADD drafting functions for the project.

The Trace to AutoCAD Duct Design Program (T2A) by Trane integrates the design and drafting functions into one step. The program uses static regain methodology for duct design and provides simplified acoustical analysis and material take-off information.

Most importantly, the program automated the CADD drafting requirements.

FURTHER ENERGY CONSIDERATIONS

If the two centralized fan rooms designed for IAQ air distribution are a pair of lungs, then the central energy plant constitutes the heart of the system.

The system consisted of 400-ton and 200-ton three-stage centrifugal chillers at 0.56 and 0.59 kW per ton respectively, and two 85%-efficient 300-boiler hp boilers.

Chilled-water distribution is accomplished with a primary-secondary pumping scheme. Both the heating water and chilled water distribution systems incorporated variable-speed packages for maximum energy savings in water distribution.

Condenser water pumps and cooling tower fans also incorporate variable-speed drives, and are controlled to maintain constant head pressure at the chiller.

REBATES

The considerations of energy efficiency did not go unnoticed by the local gas and electric utility, Northern States Power.

The school qualified for numerous rebates from Northern States Power under its customer incentive programs.

Tom Bredesen, of The Trane Company, and John Brady, of Armstrong, Torseth, Skold, and Rydeen Architects and Engineers, on the job at the Red Wing High School.

Electric utility rebates included:	
Variable-speed drives	$80,150
Energy-efficient chillers	24,200
Energy-efficient motors	7,932
Business energy grant (energy-recovery units)	93,000
Energy-efficient lighting	8,716
Gas utility rebates included:	
Energy-efficient boilers	$30,000
Energy-recovery units	20,000

Total rebates
$263,998

While the nearly $1 per sq ft rebates reduced the first cost, the school will see a reduction in demand and energy charges in excess of $120,000 annually, which represents more than 30% in operating savings over the life of the building.

The Red Wing High School mechanical project costs were comparable to a conventional hvac system design even before the significant rebates.

The success with air quality, acoustics, and energy efficiency encountered with this project confirm my strong belief that optimum performance can be attained without sacrificing first cost, when an integrated approach to total building design is implemented. **ES**

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