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A Green Building On Campus

By Mark Rosenbaum, P.E. Member ASHRAE

Techniques such as occupant control, careful sizing of the HVAC equipment, and using a DDC system, have helped a campus building in Vermont to be environment friendly and save energy.

James L. and Evelena S. Oakes Hall at the Vermont Law School is a 23,500 ft^2 (2183 m^2) classroom building designed for the country's leading environmental law school. The building houses nine classrooms and a student lounge, including three 100-seat classrooms and three 25-seat classrooms. The building needed to be a superb teaching facility, and safe, healthy, durable, resource efficient, and adaptable to the future. Satisfying these goals benefits the users, the institution, society, and the health of the planet.

System Description

The design approach integrates the superinsulated building envelope, high-efficient HVAC systems, and non-toxic materials to create a healthy indoor environment while consuming much less energy and water. The principal energy load in a classroom building is ventilation air. The key element of the HVAC system is a central ventilation system with an enthalpy recovery wheel and variable-speed drives that send 100% outdoor air to a classroom when it is occupied, and no outdoor air when it is unoccupied (see *Figure 1*). This design strategy cuts annual thermal energy consumption by a factor of four.

The superinsulated envelope (which consists of stress-skin foam panels over a structural steel frame, triple glazed low-e windows with insulated sash and frames, and field-tested airtight construction detailing) eliminated the need for perimeter heating. Composting toilets serve the two upper levels of the building (lowest level was not possible due to ledge conditions), and, coupled with fixture removal from some adjacent buildings, have reduced the total campus water consumption by almost 50,000 gallons (189 000 L) annually.

Energy Efficiency Strategies

Expanded polystyrene foam core stress skin panels (R-24 wall, R-38 roof) enclose the structural steel frame. The insulation is continuous from sub-slab to ridge with no thermal bridges. Fiberglass windows with low-e triple glazing are used throughout. Airtightness was blower-door tested (6172 cfm50), and the thermal shell follows the exterior skin of the building. This strategy ensures that all mechanical/electrical/communications/fire protection services are completely within the conditioned envelope. The high-quality envelope eliminates the need for perimeter heating.

Only occupied rooms receive outdoor air. Ventilation in each space is initiated by the users with a push button switch, and is turned off by an occupancy sensor. Provision exists for either Auto-ON, Auto-OFF control or fully scheduled controlled via the DDC system. A central enthalpy wheel recovers about 80% of heat and moisture.

Full airside economizer cooling is available in this cold Vermont climate. Southwest corridors are not mechanically cooled. An exhaust fan and several automatically opened windows accomplish cooling in this less stringent occupancy. (Fan coil units can provide cooling if desired. This is a DDC modification decision.)

Premium efficiency motors, variable-frequency drives, and efficient blower wheels minimize electrical usage of the mechanical system, and having outdoor air quantity track building occupancy significantly reduces blower energy. The central air handler was built without a supply blower. Instead an external blower was used to take advantage of the need to make a 90-degree turn in airflow im-

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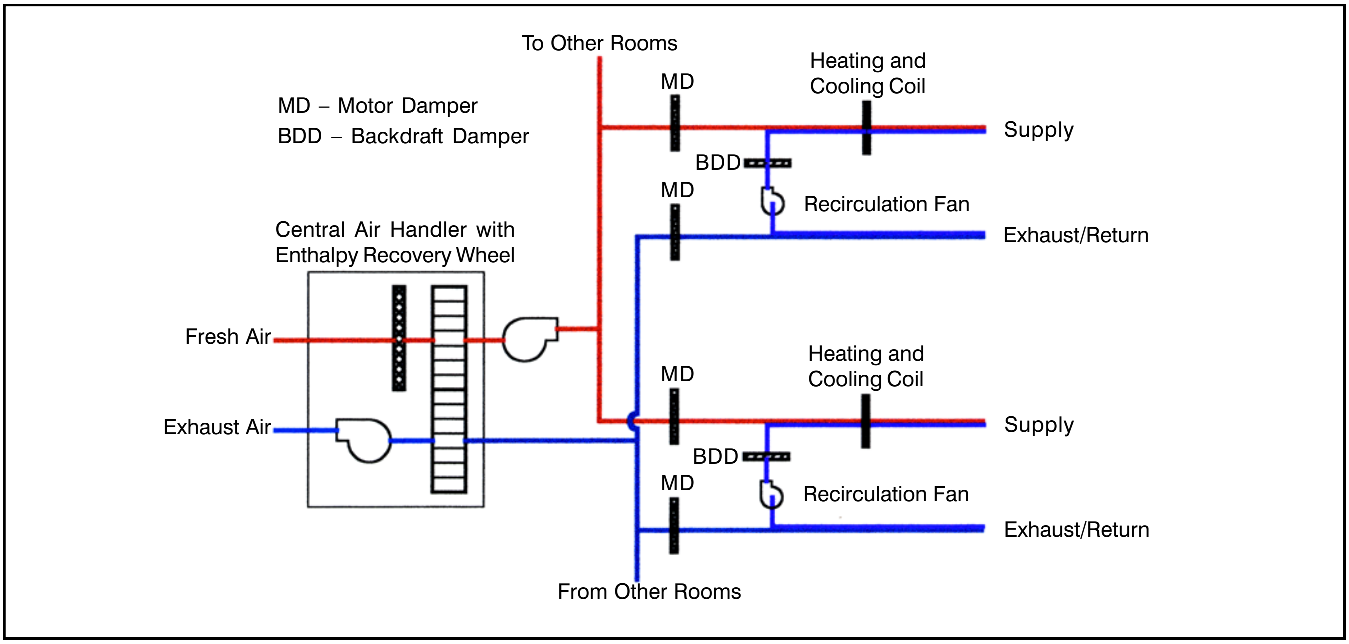

***Figure 1:** This HVAC schematic is typical of each large classroom at Oakes Hall.*

mediately after leaving the unit. This enabled a more optimized blower selection and reduced supply fan horsepower from 10 to 7.5 (7.5 to 5.6 kW).

Four modular, low-mass, sealed combustion oil-fired boilers replace a single aging boiler in an adjoining building and heat both buildings, yielding savings in the adjoining building while providing an efficient heating plant for Oakes Hall. A DDC system allows monitoring of performance and permits easy system adjustments.

Lighting is electronically ballasted T8 and CFL lighting with occupancy sensors. Classroom lighting is principally by three lamp fixtures (T8 with electronic ballasts) with switching that allows the use of one, two, or three lamps, so light levels can be tailored to need. Southwest side corridors have photosensors that turn lights off when daylighting is adequate.

Performance

The first year's energy consumption data indicate fuel oil consumption of approximately 2,200 gallons, or about 0.1 gallon/ft^2 (0.003 L/m^2), or about 13,000 Btu/ft^2/yr (41 kWh/m^2/yr). (Thermal data are approximate because two buildings now share the same four boilers. Previously the existing building used approximately 4,000 gallons (15 000 L) of oil annually. The two buildings together in the first year of operation consumed 5,831 gallons (22 000 L). Some savings are attributed to more efficient boilers heating the existing building.) Electrical consumption was approximately 115,000 kWh, or 4.9 kWh/ft^2/yr. Total energy consumption, converted to Btu, is below 30,000 Btu/ft^2/yr (95 kWh/m^2/yr). These figures are substantially below typical buildings of this type, especially in this climate. The campus library at the Law School, designed by the same architectural firm and built in the early 1990s, uses approximately five times as much fuel oil per square foot, and twice the electricity.

Indoor Environmental Quality Strategies

There is no onsite combustion or fuel storage except for a small, sealed combustion propane-fired fireplace in the lounge. This reduces chances for contamination from combustion products or fuel leaks. Biological contamination is prevented through envelope design—no thermal bridges, proper drainage and weather barriers, minimal carpet—and HVAC design, providing for adequate condensate collection from chilled water coils. The moisture recovered in the enthalpic recovery ventilation system stabilizes relative humidity, producing higher RH in the winter and lower RH in the summer. Ventilation air is filtered, 100% outdoor air ventilation for each occupied room. Recirculated air is not used. Outdoor air designed at 20 cfm (9.4 L/s) per occupant.

Great care was used in specifying low toxicity materials, adhesives and finishes. Most rooms have natural linoleum flooring, which is easily cleaned and does not harbor biological contaminants. The superior envelope and a zone per room strategy ensure thermal comfort. Operable windows contribute to occupant satisfaction. The classrooms have a comfortable visual environment due to modest daylighting, high CRI artificial lighting, light-colored surface finishes, and glare-free design.

Innovative Aspects

Occupants manually initiate ventilation air. The occupancy sensors that turn lights off approximately 10 minutes after a room is vacated also turn off outdoor air to that room. This strategy was devised to reduce the incidence of "false ons" caused by casual entry into a 100-seat classroom, and also to enable occupants to make their own decision as to whether mechanical ventilation is needed. For example, it is not unusual for two or three students to do homework in an unscheduled 100-seat classroom. They can decide to call for mechanical ventilation (by using a pushbutton labeled "Push for Ventilation" adjacent to the light switches), open windows in mild weather, or do nothing. The designers felt that if this strategy was found to work poorly, then the control of the ON function could be easily turned over to an Auto-ON function controlled by the occupancy sensor. Thus far, we feel the strategy is working well.

Occupants have the ability to alter the temperature setting in each classroom by up to ±3°F (±1.6°C). This change is permitted to remain for a timed period set in the DDC system (currently one hour). This allows some user fine-tuning of thermal comfort without allowing the building to go completely out of control.

Composting toilets serve the two upper levels and conventional low-flow flush toilets serve the lowest level. Some fixtures were removed from adjacent buildings in recognition that the new building added no additional population on campus. This strategy has reduced the combined water demand of the Old Classroom Building and Oakes Hall by almost 50,000 gallons (189 000 L) annually. The building used 5,100 gallons (19 300 L) of water during the first year of occupancy.

Sharing boilers with an adjoining building begins the distribution infrastructure of an eventual campus-wide central energy system, proposed as a wood-chip gasifier boiler plant but not implemented at this time.

The four large classrooms each have two space-conditioning coils, permitting a room to be divided into two smaller classrooms in the future. This feature is used during the cooling season to maintain dehumidification effectiveness at off-peak sensible loads. One coil has its supply water temperature raised while the other receives full chilled water. Eighty percent of dehumidification is retained at 50% sensible load. Coils are alternated to maintain even conditions across the room.

The air-cooled chiller plant was carefully sized to serve the projected occupancy of the building, which is such that all classrooms are never simultaneously occupied. The result is a 23 ton (81 kW) chiller to serve a 23,500 ft^2 (2183 m^2) building. The interior liquid side heat exchanger and piping to it was sized to accommodate a second identical chiller should the need arise (it hasn't).

A real effort was made to allow users control of their environment. This was facilitated by laying out the controls (temperature, ventilation, lighting) identically in each classroom, and by labeling these controls with permanent, easy-to-read labels. Each light switch (five in the largest classrooms) is labeled as to which lights it controls. A brief set of instructions on the temperature and ventilation controls is posted adjacent to the switches in each room.

Cost Effectiveness

The estimated net present value of the energy savings over 20 years is $275,000, calculated before the current oil price hike. The robust, durable envelope, durable mechanical components, and no perimeter heating system minimize operations and maintenance costs. The hard construction cost of the building was about $115/$ft^2$, very competitive with other buildings of similar occupancies. The innovative integrated systems approach used here considered the envelope design, glazing choices, lighting design, and mechanical system design together to create a comfortable, healthy, resource efficient building that pleases the users and satisfies the original goals while staying within the project budget.

Environmental Impact

Annual energy savings predicted by computer simulation over a code-conforming base building were 80,399 kWh and 10,054 gallons (38 000 L) of fuel oil, which is in line with energy consumed at the Law School Library building mentioned earlier. The avoided emissions are estimated to be:

CO_2 – 161 tons (146 Mg) annually
SO_2 – 0.63 tons (571 kg) annually
NO_x – 0.57 tons (517 kg) annually

In addition, the composting toilet system has reduced the campus water usage by almost 50,000 gallons (189 000 L) annually, and has significantly reduced the discharge of human waste (primary contaminants fecal coliform and nitrates) into the environment.

The designers feel that a significant environmental impact of Oakes Hall is in the education of building users and visitors to the environmental impacts of buildings and their means of mitigation. Information about the building is also hosted on the Vermont Law School web site (www.vermontlaw.edu).

Acknowledgments

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