The Mountain Equipment Co-Op project is only one of three projects to win the Award of Engineering Excellence in 25 years .

Creating Synergies For Sustainable Design

By Frédéric Genest, Eng., Member ASHRAE; and **Roland Charneux, Eng.,** Fellow ASHRAE

Reduce, reuse, recycle and rethink. The four R's of sustainable design were the operative words in the design and construction of a 45,000 ft² (4180 m²) retail store in Montreal. The design team researched and incorporated many design features to maximize possible positive interactions between various building elements (synergies), while minimizing negative ones.

The goals of the team designing Mountain Equipment Co-Op's new two-story open-space commercial retail store were simple:

• To be the first commercial building in Quebec to obtain Canada's C-2000 integrated design certification;

• To be at least 50% more energy efficient than Canada's Model National Energy Code for Buildings 1997 (MNECB);*

• To incorporate features matching LEED®-NC 2.0 Gold level certification; and

• To be able to participate in the 2005 Green Building Challenge (GBC/SB05).**

This project also was intended to promote sustainable construction in the community, while being critical of the typical "big box" architecture used for large-surface, single-story commercial stores.

Looking for Synergies

To reach these aggressive goals, design features impacting building energy efficiency included:

* Roughly equal to 45% more efficient than ANSI/ASHRAE/IESNA Standard 90.1-1999.
** See www.greenbuilding.ca.

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ASHRAE Award of Engineering

Excellence

ASHRAE Technology Awards

- Optimized building envelope;
- Natural lighting coupled with energy-efficient fixtures;
- Geoexchange central plant using HFC heat pumps;
- Radiant concrete slab structure for heating and sensible cooling;
- Dedicated outside air system (DOAS); and
- Hybrid ventilation system.

Optimized Building Envelope and Glazing

Reducing heat gains and heat losses due to the building envelope is the first step in achieving high energy efficiency, especially for a location such as Montreal, which has harsh winters and humid summers (*2001 ASHRAE Handbook—Fundamentals'* 99% heating design value is –7°F [–21.7°C], while the 1% cooling design values are 83°F [28.3°C] dry bulb and 70°F [21.1°C] wet bulb).

For example, a standard curtain wall system gives a low overall building R-value, which is bad for energy efficiency. Glazing, though useful to allow sunlight for an improved indoor environment and natural lighting, is a two-edged sword. Winter solar heat gains are a benefit while summer gains are not, and a high glazed surface typically means a lowered global building R-value. Thus, a careful balance must be reached.

High Performance Envelope

With the help of energy simulations, the building's R-values were finally established at 35 ft^2·°F·h/Btu (6.2 m^2·°C/W) and 40 ft^2·°F·h/Btu (7 m^2·°C/W) for the walls and roofs, respectively. These were combined with high performance double-glazed low-e window units with a U-factor of 0.3 Btu/h·ft^2·°F (1.7 W/m^2·°C), with shading coefficient optimized according to exposures. Estimated operational savings with triple-glazed windows units did not offset their first costs significantly enough to be deemed acceptable. The overall building U-factor is approximately 0.08 Btu/h·ft^2·°F (0.45 W/m^2·°C).

Designing Second Floor Daylighting

Next, placement, orientation and shape of the building's glazing was carefully studied with the help of commercial lighting software that includes a natural lighting processor. The goal was to give about 30 footcandles (325 lx) of general daylight to the second floor during an overcast day, while minimizing glare during sunny days. The final solution includes a set of glazed continuous rows of different sizes located on the north and south exposures of the building, as well as within a roof monitor (*Figure 1*). Daylight sensors shut down parts of the artificial lighting when it is not required.

Estimates indicate enough natural lighting will exist to shut down the artificial lights for nearly half of the building's yearly operating hours. Nevertheless, an efficient artificial lighting system is installed with an average building power density of 1.3 W/ft^2 (14 W/m^2), lower than the MNECB requirements for retail buildings of 2.5 W/ft^2 (26.9 W/m^2) and Addendum *g* of ANSI/ASHRAE/IESNA Standard 90.1-2001, *Energy Standard for Buildings Except Low-Rise Residential Buildings,* of 1.5 W/ft^2 (16.1 W/m^2).

Geoexchange Central Plant

A measure of the impact of a building on its environment is the reduction of greenhouse gas emissions, especially CO_2. Since fossil fuels emit CO_2, they were dismissed from the start as a potential heating source. Instead, Quebec's hydroelectric potential would be relied on to supply the required energy in a greener way.

To achieve a high energy efficiency, the design team used a geoexchange system with liquid-to-liquid heat pumps as the heating and cooling energy source, based on the calculated loads of 600,000 Btu/h (175 kW) in heating and 25 tons (88 kW) in cooling, respectively, and simulated monthly energy demand and rejection profiles. The result was a geoexchange system composed of twelve 575-ft (175 m) deep wells linked to ten 10-ton nominal (35 kW) liquid-to-liquid HFC heat pumps (theoretical number based on load calculations). These heat pumps were special units built for the European market (operating at 50 Hz) and converted to the North American 60 Hz electrical line frequency.

Heating and Cooling With Radiant Slabs

Ventilation and air-conditioning fans are another of the greatest energy consumers in a typical building. To avoid this consumption, the building structure was designed with concrete

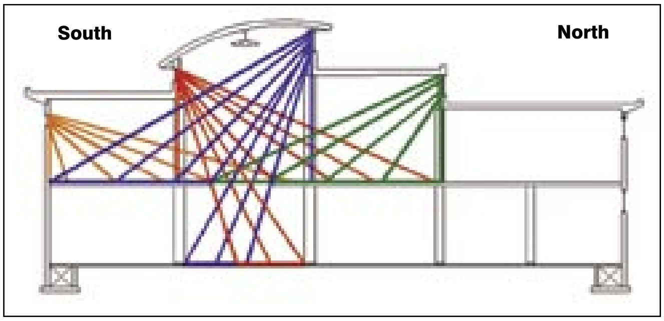


Figure 1: Natural lighting on the second floor.

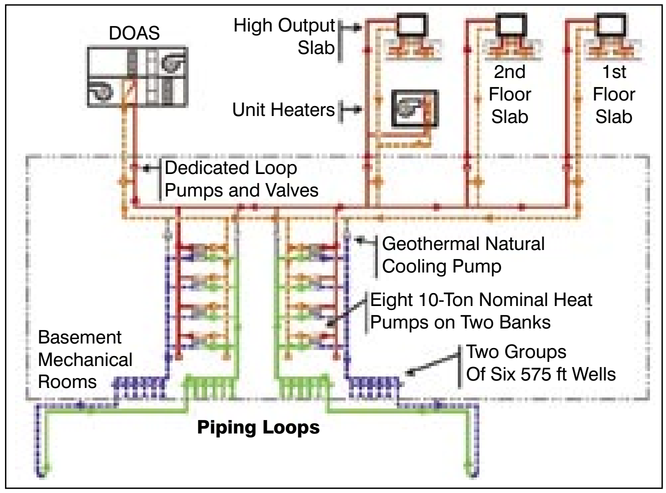


Figure 2: Schematic of the heating and cooling system.

floors in which PEX tubing was embedded, which turned them into radiant surfaces for heating and sensible cooling. Of course, for the slabs to act well as low-temperature radiant emitters, they must have a lot of exposed surface with minimal finish. That paralleled the initial intention of the design team to limit volatile organic compound (VOC) emissions inside the building and improve indoor air quality.

The slab water temperature ranges required in heating and cooling match well with the available ranges from the heat pumps. Also, pumps as energy-movers are more efficient than fans. Therefore, costs due to piping loop pressure losses were carefully balanced with first costs to obtain a reasonable payback.

Additionally, the radiant environment created allows a broader range of acceptable indoor temperature, as defined in ASHRAE Standard 55-1992, *Thermal Environmental Conditions for Human Occupancy.* In this case, it was calculated to be as low as 65°F (18.3°C) in winter and up to 80°F (26.7°C) in summer. This gives another opportunity to further reduce heat gains and losses through the building envelope and limit the capacity of installed systems.

Finally, the concrete slabs could be used as a thermal energy storage system, allowing installation of only eight of the 10 required heat pumps with room for two future units (*Figure 2*). Because of concrete slab's slow reaction time, the building automation system uses predictive logic based on weather forecasts automatically retrieved from the Internet to start loading the slabs in advance of very cold or very hot days.

Geothermal Natural Cooling

A synergy that later became apparent is natural cooling of the radiant slabs directly using the geoexchange system. Required supply water temperature to the slabs is 60°F to 65°F (15°C to 18°C), which is easily obtainable from the geoexchange system because the ground is about 50°F (10°C) all year. Therefore, the heat pumps were divided into two banks of four units. One bank was dedicated to supplying the slabs and the other was assigned to the DOAS. To take advantage of geothermal natural cooling whenever possible, a bypass path linking the slabs to the geoexchange with a dedicated pump was added and control logic was incorporated within the building automation system. This step further reduced energy consumption by delaying or avoiding using the heat pumps except when absolutely necessary.

Main Ventilation Mode: Hybrid Ventilation

From the start, the design team wanted natural ventilation to be the main building ventilation mode. Natural ventilation, the admission and circulation of outside air within a room or building to satisfy both ventilation and cooling needs without using mechanized means, uses the stack effect caused by warm air rising and exiting through openings located in upper parts of the building to draw the cooler outside air through lower ones. This allows greater amounts of outside air to be admitted than by using systems designed according to IAQ standards such as ANSI/ASHRAE Standard 62-2001, *Ventilation for Acceptable Indoor Air Quality,* and saves fan and compressor energy.

However, a true natural ventilation system was not possible because the store is close to a high-traffic boulevard and a highway.

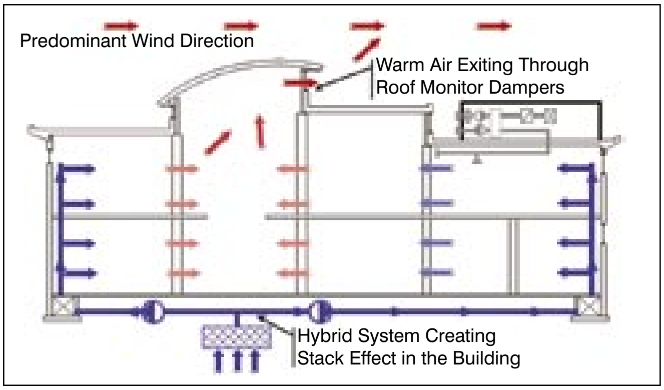
More Green Features

The building parking lot was reduced to allow the inclusion of a drought-resistant landscape designed to limit formation of heat islands.

Some of the broadleaf trees planted are located so they will provide shading to part of the building's glazed surfaces.

Also, a water recovery system was designed to collect storm water and use it to supply the toilets and landscape irrigation needs. The 10,000 gallon (45 000 L) storage tank was sized for two weeks of normal operation. Combined with water-conserving fixtures and drought-resistant plants, domestic water consumption and sewage transportation requirements are estimated to be reduced by 300,000 gallons (1.1 million L) per year.

Last, through education of the construction teams, more than 67% of construction waste (plastic, metal and wood) was sorted on-site and recycled or reused without impacting work progress.



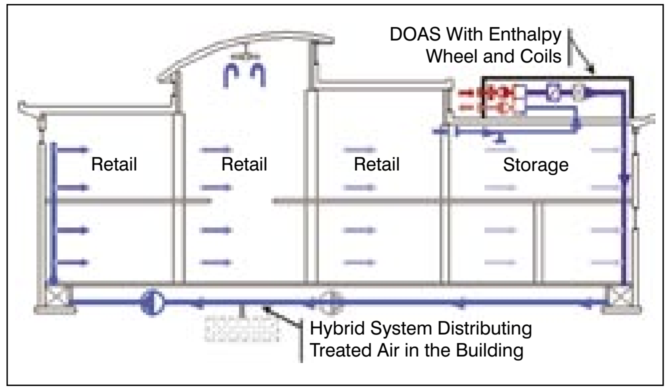


Figure 3 (left): Natural/hybrid ventilation is the primary mode of ventilation. Figure 4 (right): A DOAS system is the secondary mode.

Filtration and sound attenuation would have been needed to ensure a clean, quiet environment. Therefore, the design evolved into a large underground 4 ft by 4 ft (1.2 m by 1.2 m) tunnel system running along the building's perimeter, along with four 12,500 cfm (5900 L/s) low horsepower propeller fans (*Figure 3*).

The fans draw outside air from ground level, through filter banks, and blow it through the tunnel system, having just enough static pressure to overcome the restrictions due to the filters and to initiate the stack effect. From there, the air is transferred into the retail and storage spaces using vertical ventilation shafts on both floors, and exits through 16 dampers located in the uppermost clearstory. Opening and closing dampers helps modulate the amount of outside air circulating through the building.

Extended Hours of Natural Cooling

Due to the amount of outside air that can be supplied by the hybrid system and the extended range of indoor temperatures accepted by the client, the system is in use when the outdoor dry-bulb temperature is between 55°F (12.8°C) and 80°F (26.7°C), but only when the dew-point temperature is below 65°F (18.3°C); it is combined with natural cooling of the slabs when needed. The dew-point temperature limit is set to prevent condensation on the cool concrete floors.

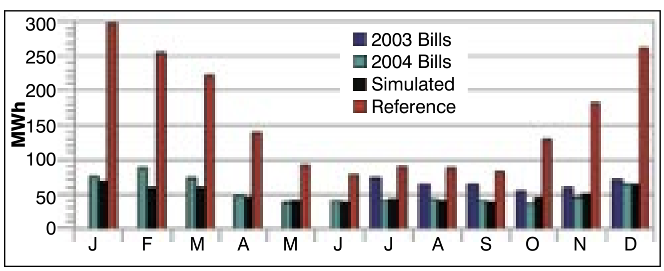


Figure 5: Monthly energy consumption for 2003–2004.

Based on typical weather profiles for the location, that range of temperatures annually gives about 1,500 hours of natural cooling during the 3,200 hours the store is open to the public. When outdoor conditions are outside of that temperature range, the DOAS is used. Switchover between the two ventilation systems is controlled by the building automation system.

Improved Indoor Air Quality

With a maximum capacity of 50,000 cfm (23 600 L/s), the hybrid system is able to supply up to 1.11 cfm/ft² (5.6 L/s per m²). This is about four times more than the minimum outdoor air requirements set by Standard 62-2001. The standard would require an average of approximately 0.25 cfm/ft² (1.3 L/s per m²), considering the different spaces (ground- and second-floor retail, storage and offices).

Secondary Ventilation Mode: DOAS

The use of radiant slabs for both heating and cooling dictated that a separate DOAS (*Figure 4*) be used to supply preheated outdoor air when heating was required, or to supply dehumidified air when outside conditions were too extreme for natural cooling through the hybrid ventilation system. Equipped with variable speed drives and a 75% efficient enthalpy heat recovery wheel, this roof-mounted system was designed to supply the required dehumidification during hot and humid summer days and preheating during the winter days, while maintaining acceptable CO_2 levels. The rest of the time, it is used to meet minimum sanitary exhaust needs.

To minimize metal ductwork, the DOAS sends the treated outside air directly into the tunnels of the hybrid ventilation system, and the latter is used in recirculation mode to distribute fresh air within the building.

Energy Efficiency…

Simulations were performed according to C-2000 rules and requirements. The simulations indicated a reduction in energy consumption of 68% compared to a MNECB reference building (or approximately 60% below the Standard 90.1-1999 reference building[†]). Based on these simulations, annual energy costs (*Table 1*) were estimated to be reduced by $105,000 CAN, or 69%. Also, reduced energy consumption prevents emission of the equivalent of 400 tons (363 metric tons) of CO_2 that would be produced each year by a thermal power plant.

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[†] Source: LEED Canada-NC 1.0 documentation.

2005 Technology Award Winners

The ASHRAE Technology Awards recognize outstanding achievements by members who have successfully applied innovative building design in the areas of occupant comfort, indoor air quality (IAQ) and energy conservation. Their designs incorporate ASHRAE standards for effective energy management and IAQ. Performance is proven through one year's actual, verifiable operating data.

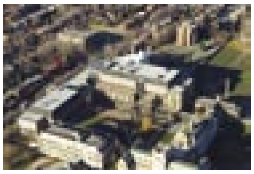
The following are descriptions of the other ASHRAE Technology Award winners and honorable mentions. Articles about these projects will be published in future issues of ASHRAE Journal.

<u>First Place Winners</u>

Jeffrey Paul Blaevoet
Category I: Commercial Buildings (New)
Big Rock Ranch, Lucas Films, Nicasio, Calif.

This project uses a geothermal heat exchanger with central chillers and chillier heat pumps. One result is that the design has greatly reduced the facility's need for propane as a source of heating.

Nicolas Lemire
Category II: Institutional Buildings (New)
Concordia University Science Complex, Montreal



To save energy, improve indoor air quality and meet the ventilation needs of laboratories, classrooms and offices, a dedicated and centralized system were combined into one centralized system. This and other strategies helped the building to be 50% more efficient than the Model National Energy Code of Canada for Buildings.

Gilles Desmarais
Category II: Institutional Buildings (Existing)
Collège Jean-de-Brèbeuf, Montreal

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The college's outdated heat plant was retrofitted with a direct-contact water heater, a flooded steam-to-water vertical heat exchanger, and fire-tube boilers as well as using heat recovery.

The result was an annual energy savings of $85,000 and an annual maintenance savings of $15,000.

<u>Second Place Winner</u>

Wayne E. Kerbelis
Category II: Institutional Buildings (New)
Allegan High School New Natatorium and Theater Additions, Allegan, Mich.

The performing arts center uses an underfloor ventilation displacement system to provide ventilation air directly to theater seating areas. The natatorium uses roof-mounted energy recovery dehumidification units for the pool areas. These strategies and more led to an estimated energy savings of $43,000 annually in electricity and natural gas costs.

<u>Honorable Mentions</u>

Steven T. Taylor and Jeffrey R. Stein
Category I: Commerical Buildings (New)
Electronic Arts II, Redwood City, Calif.

This building consumes 39.5% less energy than a standard California energy code compliant building. This was achieved using a variety of energy-saving features such as underfloor air distribution, high-efficiency chillers, high-efficiency cooling towers, high chilled water ΔT and more.

Antonio Costa
Category II: Institutional Buildings (New)
William B. Race Health Sciences Building —Santa Rosa Junior College, Santa Rosa, Calif.

Evaporative cooling and 100% outdoor air VAV systems are used to save energy and improve indoor air quality. The simple payback for the evaporative cooling systems, based on energy savings, is estimated to be 6.7 years.

Jeffrey Paul Blaevoet
Category III: Health Care Facilities (New)
Kaiser Geary Medical Office Building, San Francisco

This project uses thermally powered VAV diffusers and an improved DDC approach for reheat control. It is estimated that the design resulted in savings of 1.8 million kWh/year over a standard building designed to comply with California's energy code.

Jeffrey L. Ewens and Blake E. Ellis
Category V: Public Assembly (New)
SBC Center, San Antonio

The SBC Center is an 18,500 seat arena that uses dual VAV air-handling units with variable speed drive. Using a 45°F supply air temperature instead of the more traditional 55°F supply air temperature reduces airflow rates and reduces fan energy by 33% from a standard system.

Evans J. Lizardos
Category IV: Industrial Facilities or Processes (Existing)
Port Authority of New York and New Jersey, New York

Staffed shelter booths at the Holland and Lincoln tunnels were replaced by booths that had custom designed HVAC units that fit into the curved tops of the booths. Using 100% outside air supply and maintaining the booths under positive pressure to prevent CO infiltration provides for good indoor air quality.

Jeffery D. Celuch
Category IV: Industrial Facilities or Processes (New)
LaFarge Gypsum Drywall Plant, Silver Grove, Ky.

This application uses a cogeneration plant and other strategies that result in lower NO_x, SO_2, particulate matter, mercury, HCl and selected metals emissions. Estimates include an annual reduction of CO_2 emissions by almost 15,000 tons.

Synergies, From Page 19

	kWh	$Canada
Real (07/03 – 06/04)	762,286	$56,273
Real (01/04 – 12/04)	652,320	$47,447
Simulated (MEC)	615,900	$46,654
Reference (MNECB)	1,948,200	$151,644

Table 1: Annual energy consumption & costs.

…Through Building Commissioning

The store opened to the public in May 2003, and building energy demand and consumption monitoring began in July 2003. The building automation control computer has an Internet portal to allow remote monitoring of building performance. Monitoring revealed that the energy profile was as predicted by the simulations (*Figure 5*), but needed adjustments. Over time, peak demands and energy consumptions approached predictions as improvements were made and modifications to the control sequences were implemented. This demonstrates that the commissioning process in a real-life setting is an essential part of fine-tuning HVAC systems.

…With Good Payback

The HVAC systems designed and installed for this project are a far cry from the ones typically found in the "big box" architectural concept traditionally used for this type of building, and higher first costs were expected. Choosing standard off-the-shelf or prefabricated components whenever possible and minimizing redundant field work (such as exchanging ductwork installation by radiant tubing installation) helped diminish the higher costs associated with the mechanical systems selected. The added costs were evaluated at approximately $475,000 CAN, for a simple payback of about 4.75 years.

Conclusion

To achieve high energy efficiency and sustainable design and construction, it is important to use up-to-date and pertinent design tools and references, such as ASHRAE standards and guidelines. However, a dedicated integrated design team that works together to identify possible synergies, correctly evaluate their impact, and implement them is necessary.

Other elements for a successful design include creativity and an open mind—going beyond the usual design strategies and exploring new combinations or possibilities—and believing in the goals you've set. The Mountain Equipment Co-Op's Montreal store is evidence that these elements work.

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