Design constraints at Montreal's Mount Royal, McGill University's McIntyre Pavilion, a cutting-edge medical research and teaching facility, led to innovative electromechanical systems that significantly reduced the energy consumption of the building.

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Cutting-Edge *Renovation*

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BUILDING AT A GLANCE

McGill University
McIntyre Pavilion

Location: 3655 Promenade Sir William Osler, Montreal

Owner: McGill University

Principal Use: Research and teaching facility

Includes: Laboratories, library, classrooms

Employees/Occupants: 1,200 students, 400 researchers

Gross Square Footage: 320,000 ft^2 (30 000 m^2)

Conditioned Space: 290,000 ft^2 (27 000 m^2)

Substantial Completion/Occupancy: December 2011

Occupancy: 100%

Nestled on the southern slope of Montreal's Mount Royal, McGill University's McIntyre Pavilion is a cutting-edge medical research and teaching facility. The installation features world-renowned research laboratories in fields including oncology, pharmacology, biochemistry and infectious diseases. Built 50 years ago, this 16-story, 30 000 m^2 (320,000 ft^2) building was in need of major renovations (about $25 million).

In addition to replacing the McIntyre Pavilion's electromechanical infrastructure, the designer's mandate included upgrading building facilities to meet current bio-safety standards. *Figure 1* details the extent of the work completed.

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ABOVE Renovation of the laboratories before occupation.

LEFT Renovation of the chilled water pumps.

Medical research facilities are extreme energy consumers for a number of reasons, including the significant amount of fresh air required to replace exhaust air expelled by lab fume hoods, their high-density lighting, as well as frequent use of specialized electronic equipment and cold rooms for research activities. This enormous energy use drives up the demand for air conditioning and, despite Quebec's harsh winters, such facilities experience year-round internal cooling loads.

In the case of the McIntyre Pavilion upgrade, the new air-handling units had to supply 100% fresh air. Therefore, the overall outside airflow had to be increased by 150%, requiring an additional capacity of 56 634 L/s (120,000 cfm). These changes, coupled with the replacement of the building's core systems, provided several interesting opportunities to improve the building's overall energy efficiency.

Energy-Efficiency Concepts

Heat Recovery and Low-Temperature Water Loops

Due to the increase in outside air supply, the new design had to include a great deal of extra heating capacity. An interesting option involved recovering the heat generated by interior air conditioning to help heat peripheral areas and incoming fresh air. Water supply systems must be kept at low temperatures 43°C (110°F) to fully benefit from energy recovery potential. However, the McIntyre Pavilion used a high-temperature system 79°C (175°F) supplied by a steam/water exchanger connected to the steam system serving the entire McGill Campus. Therefore, to process the sizeable quantity of outside air admitted by the units, high-temperature heating coils had to be installed.

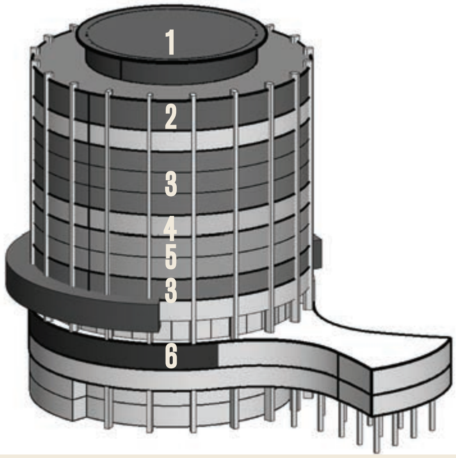
The designers chose coils with a large temperature differential (ΔT = 36°C [65°F]), which meant that return water could be used as a low-temperature system to supply the new heating system coils. Return water from the terminal coils is then preheated by excess heat from two new 530 kW (150 ton) recovery chillers before being heated via steam/water exchanger to resupply the fresh air coils. The new high/low temperature system retains the university's existing steam system while benefiting from available regenerative energy. The two new screw chillers were selected to provide maximum recovery performance and produce water heated to 51°C (124°F) in winter. They also support the two existing 2,920 kW (830 ton) chillers in cooling interior heat gains and outside air during the warmer summer months.

To recover energy from the exhaust air, a total of 13 glycol-based recovery coils were installed in the various exhaust vents and a network of pipes connects them to the preheating coils for the fresh air supply systems. The designers opted for eight-row coils to achieve maximum heat transfer and a recovery efficiency of 45%. This measure provided a recovery capacity of 3,640 kW, which is substantially more efficient given the sizeable increase in outside air supply.

The creation of a low-temperature heating system based on an existing high-temperature system made for an innovative design. This design made it possible to satisfy the enormous heating load caused by the increase in fresh air intake and recover energy from the internal building heat gains.

Outside Air Modulation

Using a system to measure air quality in the labs, coupled with the installation of variable frequency drives on the five new air-handling units, the amount of outside air intake during periods of reduced activity was diminished. Furthermore, the addition of sophisticated air



1 – Fully renovated 840 m² (9042 ft²) mechanical room. Replacement of ventilation system. Installation of high-speed exhaust fan system on roof.

2 – 1880 m² (20,236 ft²) electromechanical room, 80% renovated. Addition and replacement of pumps. Addition of two chillers and one cooling tower. Replacement of air-handling units. Renovation of engine control center.

3 – Replacement of laboratory fume hoods, variable air volume boxes and terminal heating coils.

4 – Redevelopment of ventilation occupying 30% of the floor.

5 – Complete redevelopment of floors: ventilation, plumbing, laboratory fumes, fire protection, and alarm system.

6 – Complete redevelopment of electrical distribution center.

FIGURE 1 Scope of work to the McIntyre Pavilion at McGill University.

valves and detectors in the new laboratory fume hoods makes it possible to vary the exhaust airflow from the hoods based on how they are being used. The laboratory ventilation rate can be reduced from nine air changes per hour (ach) to six during periods of reduced activity, and to 5 ach overnight. The outside air modulation enables a reduction in the energy required for heating, cooling and humidification and also reduces the power demand on the ventilators.

Pumps

By opting for heating coils that permit large temperature variations (ΔT = 36°C [65°F]), the amount of water and the required pumping drive force were reduced considerably. Also, the chilled water pumps are equipped with variable frequency drives to modulate motor speed and water flow depending on the actual load, which generates further energy savings.

Lighting

The fully renovated labs were supplied with natural light detection lighting. This technology makes it possible to minimize energy consumption despite the high-density lighting required by the university (1.2 W/ft²).

Design Constraints and Innovation

Energy Simulations

The design team developed models for the building and its electromechanical systems using DOE2.1e simulation software to precisely map out the energy savings and feasibility of the proposed solutions. An analysis of

TABLE 1 Consumption (kWh Equivalent)

SOURCE	PRIOR TO RENOVATION	AFTER RENOVATION	
		STANDARD DESIGN	HIGH-PERFORMANCE DESIGN
LIGHTING	3,660,398	3,660,398	3,207,325
EQUIPMENT	1,300,302	1,300,302	1,300,302
PROCESSES AND LOSSES	4,322,930	4,322,930	4,322,930
HEATING	10,734,620	23,292,762	7,677,407
HUMIDIFICATION	1,824,423	2,797,156	2,101,677
COOLING	935,578	1,227,039	1,270,747
HEAT REJECTION	264,045	934,360	654,982
PUMPS	437,087	1,461,805	1,215,568
VENTILATORS	2,717,580	3,302,390	2,308,026
DOMESTIC HOT WATER	671,200	655,662	655,662
TOTAL	28,868,163	42,954,803	24,714,626

the various simulation options allowed the team to select the optimal course of action. Through an integrated design approach and energy simulations developed by the design team, high-performance electromechanical systems were installed. Energy simulations are a powerful tool for the design team to measure energy recovery potential and point out major energy consumption elements that can be reduced through an innovating design.

Indoor Air Quality and Thermal Comfort

Indoor air quality was a serious concern in the lab ventilation system design. Not only do many contaminants need to be sufficiently diluted, but laboratory pressure must always be negative for the lab to be certified. To provide users with high air quality (in accordance with the ASHRAE Standards 55-2004 and 62.1-2004), high efficiency filters (MERV 14) were installed on each air treatment system. As mentioned earlier, air quality measurement systems installed in the labs ensure sufficient fresh air intake whenever the use of contaminants increases. In addition, the new air valves installed on the laboratory fume hoods ensure that the exhaust flow is always at a safe level for users and the system is equipped with an alarm.

Building temperatures are precisely maintained at comfortable levels by way of the 284 new terminal reheating coils installed alongside the new low-temperature heating system.

Fume Hood Exhaust Systems

Initially, every lab fume hood was equipped with its own individual ventilator and shaft. The 80 ventilators were located inside the building, which is no longer permitted by current standards. Since the new design required a substantial redevelopment of the ventilation systems, the designers opted to merge all the fume

TABLE 2 Energy bills for 2012.

	ELECTRICITY (KWH)	ELECTRICITY COSTS ($)	STEAM (1,000 LBS)	STEAM COSTS ($)	TOTAL ENERGY (KWH-EQ)	TOTAL ENERGY COSTS ($)
JAN.	926,846	57,064	5,982	149,550	2,680,050	216,614
FEB.	830,888	51,314	5,145	128,625	2,338,785	179,939
MAR.	885,497	55,561	4,558	113,950	2,221,356	169,511
APR.	805,603	58,821	2,892	72,300	1,653,191	131,121
MAY	823,965	60,671	1,803	45,075	1,352,388	105,746
JUNE	913,288	69,440	1,435	35,875	1,333,858	105,315
JULY	1,025,925	77,270	1,467	36,675	1,455,873	113,951
AUG.	986,685	71,638	1,478	36,950	1,419,857	108,588
SEPT.	824,996	62,640	1,535	38,375	1,274,874	101,015
OCT.	824,751	59,437	2,392	59,800	1,525,799	119,237
NOV.	833,302	53,521	3,320	83,000	1,806,328	136,521
DEC.	910,505	56,470	5,403	135,075	2,494,016	191,545
TOTAL	10,592,251	733,854	37,410	935,250	21,556,374	1,669,104

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hood shafts into four new high-speed exhaust fans with a capacity to move air at 15 m/s (2,950 fpm) at all times. The air speed ensures sufficient throw distance to prevent contamination of neighboring buildings. The use of this technology was critical in meeting constraints imposed by the building's specific location, given that a number of residential towers are located near the McIntyre Pavilion on the slopes of Mount Royal.

Complexity

One of the project's greatest challenges involved modifying the electromechanical systems of working laboratories without disrupting academic activities or scientific experiments, which often run on a 24-hour-a-day schedule. Another challenge lay in meeting the multiple needs and specific requirements of the various departments being served, which required stringent management of entry data to identify needs throughout the design process.

The logistics deployed to coordinate the necessary electromechanical services when moving laboratory equipment represented a significant challenge as well.

The confinement and contamination protection measures were of vital importance to user health, given the negative and positive pressure control to be maintained at all times between the work and occupied areas.

Last, executing these works in an existing occupied space required the design team to wield a detailed understanding of the building components and functions, to the smallest minutiae. This labor-intensive process involved scrutinizing and dissecting more than 480 electrical and 560 mechanical plans, as well as construction plans dating back to 1965 and many renovation plans and work details for expansions and upgrades carried out over the decades.

Control System

Since the building's HVAC systems were equipped with a pneumatic control system, the designers encouraged McGill University to take advantage of the opportunity to centralize the building controls. A central control system to regulate all HVAC systems was installed, ensuring the optimal operation of equipment while providing a snapshot of all operations and guaranteeing user comfort. The new digital regulation system, which has more than 5,000 control points and is BACnet® protocol compatible, makes it possible to view system statuses at all times and facilitates the diagnosis of problems and system maintenance.

Cooling Tower Water Treatment

The water treatment system for the cooling tower operates magnetically, which is better for the health of operators, who no longer have to wear protective gear to perform maintenance work, as the system does not use chemicals and is not harmful to their health.

Results

Energy Simulations

Table 1 (Page 62) compares the building's initial energy consumption with that of the simulated renovated building (with and without energy recovery measures). The significance of the energy-efficiency measures introduced and the impact they can have on energy consumption, primarily in terms of heating, are clear. Despite a major increase in fresh air supply 56 634 L/s (120,000 cfm), overall consumption could be reduced by 14% throughout the existing building and 43% in the upgraded space, with no additional energy-saving measures employed.

Taken as a whole, the performance of all these new innovative systems is meant to generate recurring energy savings of 18,000,000 kWh-equivalent (64,800 GJ), compared to a standard electromechanical system without energy recovery components.

Energy Bills

Table 2 (Page 63) presents energy bills for 2012. Ultimately, thanks to this energy-saving design, McGill University is achieving a better savings than expected with a 21,000,000 kWh equivalent savings in energy consumption. This better performance translates into energy savings of more than $816,000 a year. The cost of installing effective energy-recovery systems will be recovered in less than three years.

Environmental Impact

In addition to reducing energy consumption and operating costs, the exceptional performance of the new systems, based on energy recovery principles, reduces the environmental impact of the project. Compared to standard designs without energy-efficiency measures, the custom-designed high-performance systems reduce greenhouse gas emissions by 4,670 tons a year. Also, the installation of motion detectors on taps and toilets throughout the building has reduced potable water consumption significantly. Furthermore, the water treatment system for the cooling tower is magnetic and requires no use of chemical products.

Conclusion

Design constraints for this project have led to innovative electromechanical systems that significantly reduced the energy consumption of the building. Energy simulations have proven to be an essential part of the design and remain the best tool to figure out where energy consumption goes and how it can be reduced. These simulations showed that energy recovery for exhausted air, and heat recovery on cooling loads, were the priority energy-efficiency measures to implement, especially for this kind of building.

The McGill University McIntyre Pavilion renovation project was successful because of its energy and financial savings and because students and researchers enjoy a safe and comfortable workplace. Furthermore, all deadlines and budgets were strictly met, thanks to a flexible accelerated work schedule adopted by the project manager. The designers are convinced that the success of the McIntyre Pavilion renovation will serve as a model for similar projects in the future, which stand to become more and more widespread given the amount of aging institutional infrastructure that was built according to outdated standards. ■