HVAC Retrofit
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2005 ASHRAE Technology Award

Heating Plant Retrofit For Canadian College

By Gilles Desmarais, Eng., Member ASHRAE, and **Marie-Judith Jean-Louis, Eng.**

Collège Jean-de-Brébeuf in Montreal was in desperate need of a retrofit. The heating plant's aged equipment was unable to meet the school's heating demand effectively. Some equipment was unreliable and inefficient. In addition, rapidly rising fuel prices were increasing the cost of operating the plant. The school's administrative director needed a solution to increase the plant's energy efficiency to reduce its annual operating cost and minimize the impact of the rapidly increasing fuel cost.

The Outdated Heating Plant

The college's heating plant was composed of three 45-year-old hot water boilers (150 bhp [1500 kW] each), one 10-year-old steam boiler (70 bhp [700 kW]) and one 65-year-old steam boiler (150 bhp [1500 kW]).

A hot water heating circuit was used to compensate the heat losses at the perimeter of the building and to preheat the fresh air intake. The temperature of the water varied according to use. Some heating equipment, such as convectors, required hot water. Others, such as radiators, required temperate water. The steam was used to produce domestic hot water by means of steam-to-water heat exchangers, as well as for kitchen equipment, the school's ice rink heating system and humidification.

The college typically consumed more than 32 million ft^3 (906 000 m^3) of natural gas every year. Studies showed that the heating plant could not efficiently go beyond 71%. One of the causes of the plant's low performance was that the hot water boiler, which had a two-stage burner (low fire and high fire), was not appropriate during mild seasons. It cycled frequently, penalizing the overall efficiency of the heating plant and increasing energy costs. In addition, no backup existed for the production of steam.

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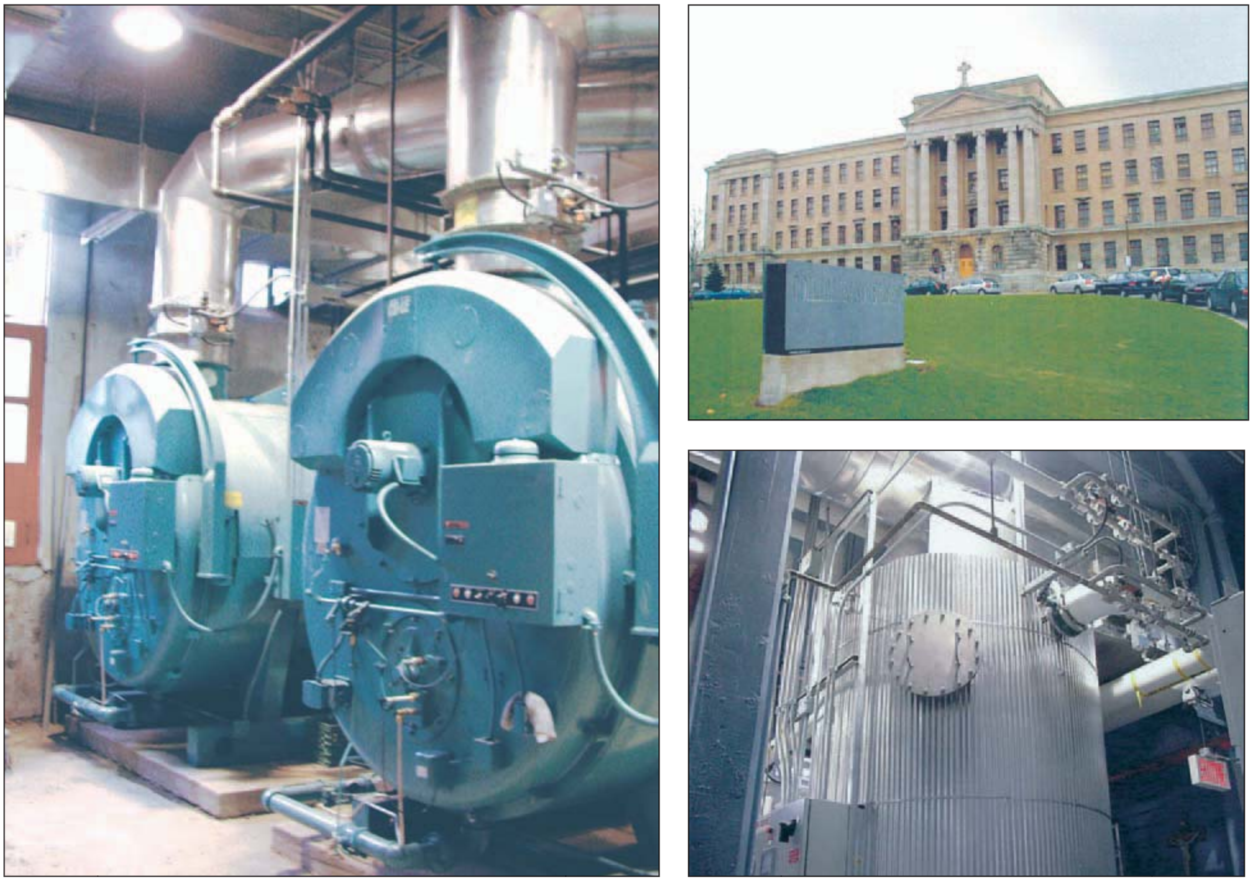

Figure 1 (left): New energy-efficient boilers; (top right) Collège Jean-de-Brébeuf; (bottom right) condensing stack economizer.

The Retrofitted Heating Plant

The solution to increase the school's energy efficiency was to retrofit the heating plant by replacing the outdated equipment. Then, heat recovery was added to further maximize its efficiency. As such, a condensing stack economizer and a heat exchanger, and an automated centralized control system were installed in the plant. The main heating equipment also was replaced by two 250 bhp (2500 kW) hot water boilers and a 70 bhp (700 kW) steam boiler.

Condensing Stack Economizer

A condensing stack economizer essentially is an open heat exchanger in the form of a large vertical cylinder with a reservoir. The top portion of the equipment, called the transfer zone, is filled with stainless steel modules used for the direct heat transfer process. As cold water is sprayed from the top of the equipment onto the modules, hot combustion gases are injected from below. The modules decelerate the water's descent and disperse the flow, thereby increasing the contact surface area between the water and the hot gases.

The highly efficient equipment increases the plant's energy efficiency significantly by recovering most of the residual energy from combustion gases. The direct contact between the cold water and the combustion gases results in the distinct improvement of heat transfer. Maximum energy is extracted from the hot combustion gases (275°F to 350°F [135°C to 177°C]) before they are released into the atmosphere. In this case, heat recovery is such that the exit temperature of the combustion gases is only 10°F (5.5°C) higher than the temperature of the returning water at the inlet of the recovery unit. The installed condensing stack economizer operates on an average energy efficiency of 92%, thus significantly reducing energy costs.

The condensing stack economizer stores 3,500 gallons (13 250 L) of water that is heated during the heat transfer process to preheat the low temperature hydronic heating circuit, the sanitary water (through the use of a heat exchanger), and the fresh air supply for the boiler room and locker room. The condensing stack economizer also is equipped with control elements that allow for modulation. The instantaneous efficiency of the system increases as the return water temperature decreases. As such, when the return water temperature is close to 85°F (29°C), the instantaneous efficiency is 95%.

Direct contact also eliminates the problem of heat transfer surface fouling, which is typical in conventional heat exchangers. As a result, efficiency remains high during the life of the

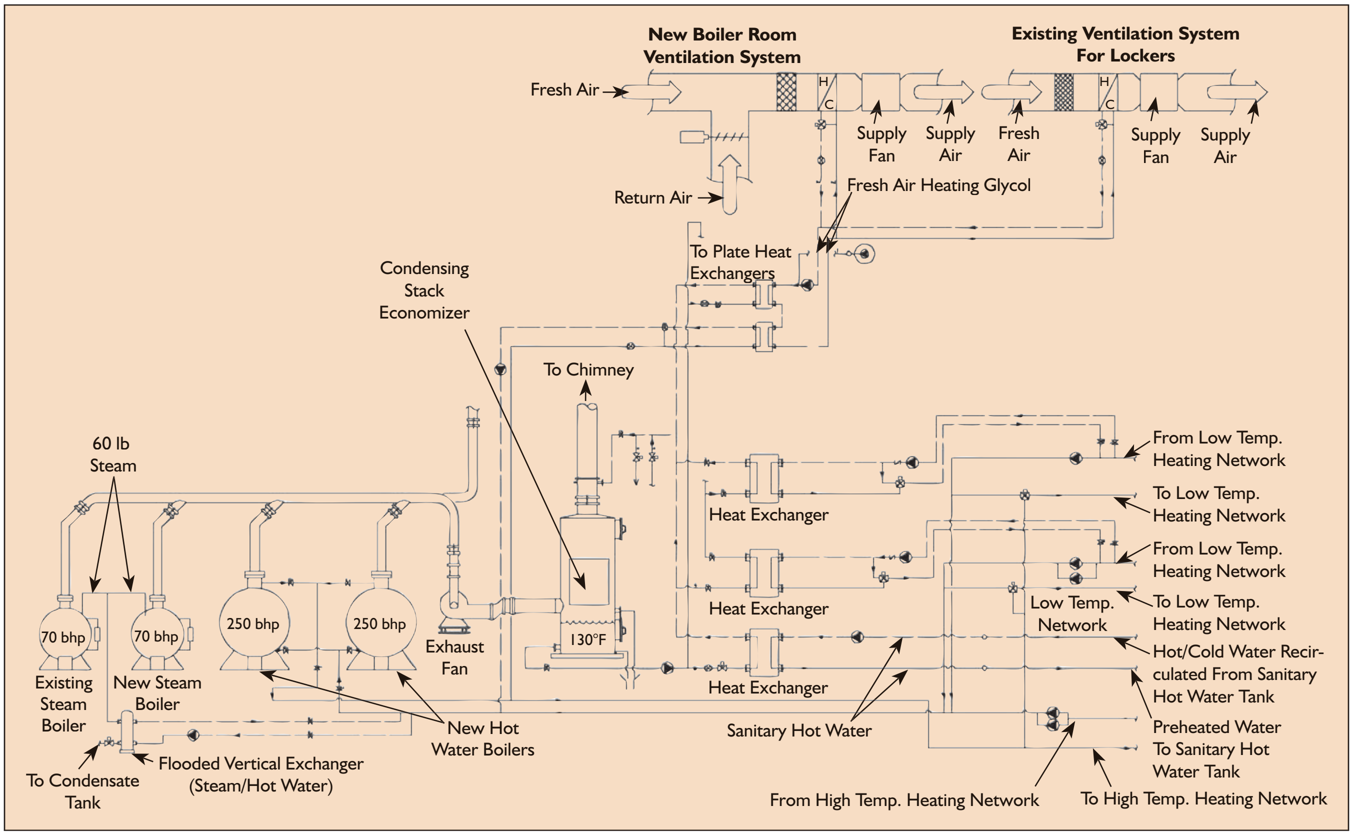

Figure 2: Hydronic flow diagram.

appliance. Furthermore, since these units are low-pressure appliances, they do not require constant monitoring on the part of the plant operator.

Flooded Steam-to-Water Vertical Heat Exchanger

A flooded steam-to-water heat exchanger also was installed in the heating plant to increase its overall energy efficiency. This heat exchanger enables a low capacity boiler to operate during off-peak periods. It uses a new, efficient technology to optimize the net output energy produced from steam, which is a different approach than conventional shell-and-tube heat exchangers. By modulating the condensate, the flooded vertical heat exchanger varies the exchange surface. This process optimizes the net output energy produced from the steam. Furthermore, the energy input of the flooded vertical heat exchanger is 85% of the conventional heat exchanger for the same net energy produced. This is due to the decrease of the condensate temperature and of the production of flash steam. The exchanger has the advantage of having a stable temperature setpoint by modulating the condensate.

Four-Pass Fire-tube Boilers

The important factors in the selection of the boilers were their life expectancy and energy efficiency. Fire-tube boilers

Outdoor Temp.	Supply Water Temp.	Return Water Temp.	Instantaneous Efficiency
40°F	90°F	84.5°F	95.0%
20°F	102°F	96.0°F	93.0%
0°F	114°F	106.5°F	91.5%
–20°F	127°F	118.0°F	90.0%

Table 1: Instantaneous efficiency vs. outdoor temperature.

Figure 3: The historic chapel has been converted into a library that houses more than 200,000 books. This retrofit has been done using low temperature fluid for heating equipment that will maximize the recovery of flue gases at the new heating plant.

are known to last 40 to 50 years, and can be very efficient based on the number of passes inside the boiler. As such, four-pass fire-tube boilers that preheat their combustion air were installed during the retrofit. The steam boilers have an efficiency of 82% and the hot water boilers have an efficiency of 84%. Their high performance also is characterized by modulating burners that have a turndown ratio of eight to one, minimizing the on/off cycles. The boilers also are designed to reduce the emission of NO_X gas to a maximum of 40 ppm.

The Costs

The renovation of the heating plant at the college generates savings on energy consumption and plant maintenance. The total cost of the heating plant renovations was CDN $1.3 million. The new installation generates annual energy savings of CDN $85,000, annual maintenance savings of CDN $15,000, for a total annual cost savings of CDN $100,000. The simple return for this investment is 13 years, which is less than half of the life expectancy for this type of equipment.

The Benefits

Through its retrofitted heating plant, which includes a new condensing stack economizer and a flooded vertical exchanger, the college has one of the most economical composite heating plants in Canada. Not only is the renovated heating plant highly efficient (up to 95%), it is also very flexible and requires minimal maintenance. The careful analysis of the plant operation resulted in a retrofit solution that saves energy, money and reduces pollution.

The newly renovated plant consumes less than 25 million ft^3 (708 000 m^3) of natural gas annually, which represents a reduction of 7 million ft^3 (198 000 m^3) of fuel consumption per year. The new plant is energy-efficient, environment-friendly and costs less to maintain.

By reducing the energy consumption of the plant, the emission of carbon dioxide, known to be a major contributor to global warming, was significantly reduced and greenhouse gas emissions are down by 368 tons (333 Mg).

This transformation also has greatly reduced the maintenance costs and number of boilers used simultaneously. The use of natural gas and condensing systems simplifies maintenance, and the cleanliness of natural gas combustion products completely eliminates transfer surface fouling. Therefore, only routine inspections are required. The new installation increases the reliability of the heating plant and reduces downtime periods.