Renovation of Wausau West High School, Wisconsin, United States of America

US1

1 Photos

Figure 1: Wausau West High School

2 Project summary

Project Scope: The project's main thrust was to change the strategy used in design and operation of the HVAC system in the High School. The project included replacement of the existing ventilation system, installation of a direct/indirect evaporative heating and cooling system while introducing 100% outside air. Other energy efficiency improvements made in the school included changing of green house operation from propane to natural gas, changing kitchen equipment to natural gas, conversion of booster heater from electricity to natural gas and changing of the domestic hot water system from steam to a direct fired system (See section 1.6.3). Upgrading of lighting throughout the building is also part of this total upgrade; however was not completed at this time.

Project objectives: This school building caused complaints regarding indoor air quality and energy inefficiency. The Local Public Health Department had received complaints and had investigated. The complaints included hot and cold rooms, poor ventilation and poor IAQ. The project objective was to improve the IAQ, comfort, and overall energy efficiency of the building.

Stage of construction: HVAC improvements have been made and validated. Other energy improvements are still in progress.

3 Site

Central Wisconsin, United States, is in a climate where winter temperatures will drop to as low as –34°C and the temperature during the day will average 0°C. The temperatures during the spring and autumn will vary between –5°C to 26°C. The summer temperatures can range from 15°C to 35°C.
Latitude: 45° N., longitude: 90° W. Altitude: 364.2 M (1195') Heating Degree Days – 8354°(F)

4 Building description /typology

4.1 Typology / Age

Typology/Age	Pre 1910	1910–30	1930–50	1950–70	1970–
The multi-storey school				●	

4.2 General information

Year of construction: 1968
Year(s) of renovation: 1998-2000 Phase I
Total floor area (m^2): 25548
Number of pupils: 1850
Number of classrooms: 65
Typical classroom
Size (m^2): 65
Number of pupils: 25
Hours of operation: Majority of the building is operated 12 hours a day 7 days a week

4.3 Architectural drawings

None Available at this time

5 Previous heating, ventilation, cooling and lighting systems

The existing heating system before the retrofit started consisted of three 9 million BTU (3 x 2640 kW) steam boilers. The cooling system used a 7.68 million BTU (2250 kW) Chiller. The ventilation system was designed to meet ASHREA Standard 62-19xx prior to 62-1989, which was about 39.3 cm^3/min. of outside air per student. The current standard is at least 118 cm^3/min. of outside air per pupil and the recommended standard is at least 157cm^3/min. of outside air per student. The lighting system consists of the use of T-12 lights with magnetic ballasts, incandescent lights and mercury vapour lamps.

6 Retrofit energy saving features

6.1 Energy saving concept

The relative strength of the regenerative double-duct system is that it was derived to address the fundamental flaws in conventional HVAC strategies. First, the system was specifically developed to be a fundamentally efficient ventilation scheme, something no conventional strategy for schools does. This permitted us to use 100% outside air efficiently, which, of course, is how we gain such high air quality conditions.

Second, the scheme was specifically conceived to close several major thermodynamic holes in conventional HVAC strategies. The configuration permits recycling of previously expended energy resources, like lighting and equipment gains, and the sensible and latent heat given off (or not given off) by people which are typically exhausted through free cooling cycles or removed with refrigeration. It uses an alternative cooling process, modified to be a full-range energy avoidance process, to reduce the system's dependence on mechanical refrigeration. It also uses another process to amplify the recoverability of cooling energy and eliminate terminal reheat energy, which dramatically reduces the need for refrigeration in temperate and moderately warm weather conditions. This permits us to avoid the use of refrigeration through most of the annual hours when temperatures are below 29°C (85°F). This feature does not eliminate the need for refrigeration in hot and humid weather, but it does sharply reduce both the amount of cooling required and the number of hours of operation. Finally, the scheme closes the loop on latent energy, permitting us to employ waste heat for humidity control and provide cooling when outside conditions are warm and dry. This same process provides an active air cleaning process which, unlike filters, which are only effective against particulates and hold them in suspension in the air stream, removes many gaseous contaminants as well as particulates and permanently removes these contaminants from the air stream and the system.

For all it achieves, the system is remarkably simple in configuration. This is achieved by use of multi-function processes, which permit us to literally eliminate entire systems. Thermal performance is enhanced, not only by the use of energy recovery as the basis of the system, but by the synergism we create between the processes. This strategy makes them work together to enhance the energy avoidance capabilities of the system, reserving the expenditure of new energy resources for the relatively few hours annually when conditions of extreme cold or extreme heat and humidity occur. In between, it is basically operating on fan energy. At Wausau West, it was found that it was basically operating without supplemental heat down to –4°C (25°F) and without the need for refrigeration up into the 26.6°C (+80°F).

Finally, because, through process synergism, it eliminated the need for terminal reheat (there are actually three different ways to do this), it enhanced the energy conservation benefits of other energy conservation measures, like lighting modifications. With other system approaches, in order to meet minimum ventilation requirements in the spaces, these loads offset terminal reheat energy loads. When they are reduced in conventional strategies, these loads are shifted to whatever is meeting the reheat needs, or summer humidity control is lost.

Another interesting feature of this system is our use of local lighting controls, not only to turn off lights when the space is vacant, but also to manage the use of ventilation. During hours of scheduled occupancy, the system is permitted to run, but vacant spaces are not ventilated except when their temperatures rise above or drop below certain temperature limits. This reduces the cost of maintaining ventilation rates in these spaces.

Still another feature is the flexibility of the scheme. With ordinary HVAC systems, meeting ventilation requirements of disparate spaces can be costly in energy when using a large system. Because of this, the typical school uses multiple air handling systems. This increases the number of systems, which increases the cost of installation, maintenance, modification, and the overall complexity of the facility. Because we can use 100% outside air efficiently, it dramatically reduces the number of systems required, the number of systems to be maintained, and the overall complexity of the systems as a whole. It also makes the system far more flexible as far as its ability to serve multiple spaces of disparate function is concerned.

The costs of construction are different, as well. The air handling system is more expensive, but these costs are offset by reductions in costs brought about by the ability to significantly downsize, or actually eliminate chillers and boilers, and the piping, pumping, and insulation systems associated with them. An interesting comparison, which stands out clearly at Wausau West High School.

6.2 Building

Though the building had minimal insulation on the exterior walls no effort was made to add or improve the outside insulation.

6.3 Heating

The heating system was converted from steam to hot water boilers. This meant the replacement of three 9 million BTU (3 x 2640 kW boilers with new hot water system of seven 2 million BTU (7 x 586 kW) boilers. The domestic hot water was changed from steam to direct fired. The dishwasher hot water booster was changed from electricity to gas. Ten pieces of kitchen equipment were changed from electricity to natural gas. The greenhouse was changed from propane to natural gas.

6.4 Ventilation:

The ventilation system is a hybrid natural and mechanical system; indirect/direct regenerative using 100% outside air; Pre-heating of ventilation air – preheated with exhaust air. Horsepower of motors before retrofit was 600 h.p. (2250 kW); after retrofit it was 300 h.p. (224 kW).
The fuel and electricity was reduced with installation of the new ventilation equipment. The number of air handlers was reduced by seven (7); the size of equipment was reduced as well; multi-use equipment was installed, converted from steam to hot water, which also used heat recovery equipment. Chiller requirements were reduced. The old chiller was 640 tons (2250 kW) and was replaced with 20 tons (70kW) for the office area, 30 tons (105 kW) for the music and auditorium and a 50 tons (176 kW) ice bank unit for the main building.

Comfort cooling: Yes – See above
Dehumidification: Yes – See above
Pre-heating of ventilation air: – See above
Heat recovery: – See above
Controls: – See above

6.5 Lighting

Replacement of lighting systems with current energy efficient technology – T-12 lamps replaced with T-8's

6.6 Other environmental design elements

None

7 Resulting Energy Savings

Heating and other related natural gas requirements:
Baseline figure (1997): 222,411 Therms (6,518,870 kWh)
Actual Usage (March 2000 – February 2001): 171,338 Therms (5,021,917 kWh)
Savings: 51,073 Therms or 53 x 10^{11} Joules (1,496,953 kWh)

Cooling and Ventilation:
Baseline Figure (1997): 2.634 Million Kwh;
Actual Usage (March 2000 – February 2001): 2.239 Million Kwh
Savings: 385,184 Kwh or 13.85 x 10^{11} Joules

These energy savings have been validated and are less than originally estimated.
Lighting savings: 945,000 Kwh/yr

8 User evaluation

Indoor air quality: Tests accomplished by the Wisconsin Division of Public Health Indoor Air Program found that between 1998 and 1999 and partial operation of the new HVAC system the indoor air quality improved significantly. Carbon dioxide concentrations were reduced from over 1000ppm to 400, 850ppm when occupied. Humidity ranges were between 30–60%.
Quality of daylight / artificial light: Currently under construction.
Sound quality: Reduction in noise levels due to reduction in ventilation requirements.
General feeling: The reaction of the staff and students indicated that the IAQ had improved significantly with the retrofit of the HVAC system.
Technical functionality: The system is working as designed.
Architectural quality: Not a consideration.

9 Renovation costs

The renovation cost to upgrade the lighting was 193,000 euros ($174,000) and the mechanical system was approximately 4.24 million euros ($3.8 million). The payback period for these improvements based on energy and maintenance savings will between 10 and 15 years.

10 Experiences/Lessons learned

10.1 Energy use

See the other sections.

10.2 Impact on indoor climate

Thermal: Temperature control has significantly improved
IAQ: Improvement in the Carbon Dioxide level.

10.3 Economics

The project is being paid back through the energy savings that occur during the next 10–13 years. Thus the project had minimal financial impact on the school system.

10.4 Practical experiences of interest for a broader audience

The use of the dual-duct system at Wausau West High School demonstrates to both the design engineers and to the general public, energy efficiency is not always based on new technology or high tech devices. Existing equipment and strategies configured to maximize their capabilities can achieve the desired result and more without introducing devices and equipment in which additional education for personnel is needed.

10.5 Resulting design guidance

New techology is not always the answer to a problem. Existing technology may provided the needed result without additional cost.

11 General data
NA

11.1 Address of project
Wausau West High School, Wausau, Wisconsin, USA

11.2 Project dates
Project initiation: 1996
Design completed: 1998
Renovation construction completed: Phase I – 1999; Phase II – 2001
Monitoring and evaluation completed: Phase I – 2001; Phase II – 2002

11.3 Date of this report/revision no.
June 2003/revision #3.

12 Acknowledgements

Builder: Wausau Public Schools
Architect: None Involved
Engineer: Mark Lentz, Mark Lentz and Associates
National, international support programmes: Rebuild America/Wisconsin
Energy Initiative – Contact: Terry Pease
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13 References

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