DDC and Ice Thermal Storage Systems Provide Comfort and Energy Efficiency

Category II: Institutional Buildings
(New and Existing)

First Place
New Building

Facility
Whitehall Elementary School
Norristown, Pennsylvania

Entrant
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Energy efficiency was the primary goal in the development of both the mechanical and electrical systems for the Norristown Area School District's Whitehall Elementary School. This new facility is the first school in the Commonwealth of Pennsylvania to utilize ice thermal storage as the primary cooling medium. By applying innovative technology, the result is not only a building in which energy savings exceed those anticipated but which contributes to the children's education by providing a comfortable atmosphere for learning.

Energy efficiency

The energy saving systems utilized have reduced the building's annual electricity consumption by approximately 22,000 kWh (79 200 MJ), close to 30%, in comparison to Paul V. Fly Elementary School, a similar building in the district. Paul V. Fly has 71,000 ft² (6596 m²) as compared to Whitehall's 70,000 ft² (6503 m²). The two schools have roughly the same thermal load characteristics. However, Whitehall has more computers and more lighting fixtures.

One factor in reducing energy consumption at Whitehall is the use of energy efficient lighting. Lighting sources include fluorescent, metal halide and high pressure sodium. Classroom lighting uses parabolic fluorescent fixtures that are wired for two lighting levels, providing daylight hours savings of approximately 50%.

The primary contribution to the energy efficiency of this facility is the inclusion of a DDC energy management system and an innovative 720 ton-hour (9.1 GJ) partial thermal ice storage system that uses low temperature air and a series fan-powered VAV box for each space.

System design

The thermal storage system, using ice made during off-peak hours (8 pm to 10 am), supplies the majority of the school's daytime air-conditioning needs. The chiller required to satisfy these needs is approximately one-half the size of one that would be needed to cool the building conventionally.

The building load analysis indicates that 144 tons (507 kW) is needed to cool the facility conventionally. For thermal storage, the 80 ton (282 kW) chiller selected produces a full load of ice in only 10 hours, instead of the 14 available off-peak hours. This provides a safety factor because the building is frequently occupied until 10 pm.

The chiller, operating during off-peak hours, cools an ethylene glycol and water solution to 20 °F (−7 °C), which is circulated within coils in four water-filled storage tanks to make ice. From 10 am to 5 pm, the chiller runs, mixing 20 °F (−7 °C) brine from the tanks with return water to supply 36 °F (2 °C) brine to the HVAC units. The chiller is off-line from 5 pm to 8 pm, when the DDC system directs it to again make ice.

The system is designed to bypass the chiller and operate on an economizer cycle. When cooling is required and the outdoor temperature is 45 °F (7 °C) and below and the humidity is within the designated range, the system can operate at 100% outside air as directed by the enthalpy controller.

The thermal storage equipment supplies air at 44 °F (7 °C). This is about 10 °F (6 °C) colder than conventional cooling system supply air temperature.

Several factors led to the decision to use low temperature air. First, it would reduce the size of the distribution equipment, chilled water piping, pumps and ductwork. These smaller components would not only lower the cost of construction and energy consumption but would more easily fit in the limited amount of space available above the ceilings. Second, because of its reduced

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humidity, low temperature air would provide for a more comfortable environment for the children.

The next design consideration was the terminal equipment that would distribute the air to the classrooms. Traditional classroom unit ventilators were considered but rejected for two primary reasons.

First, the tops of these units frequently become depositories for books and other materials, and this affects air distribution. Second, their use would have disallowed using low temperature air and taking advantage of the benefits it can provide. Therefore, an overhead air distribution system was chosen.

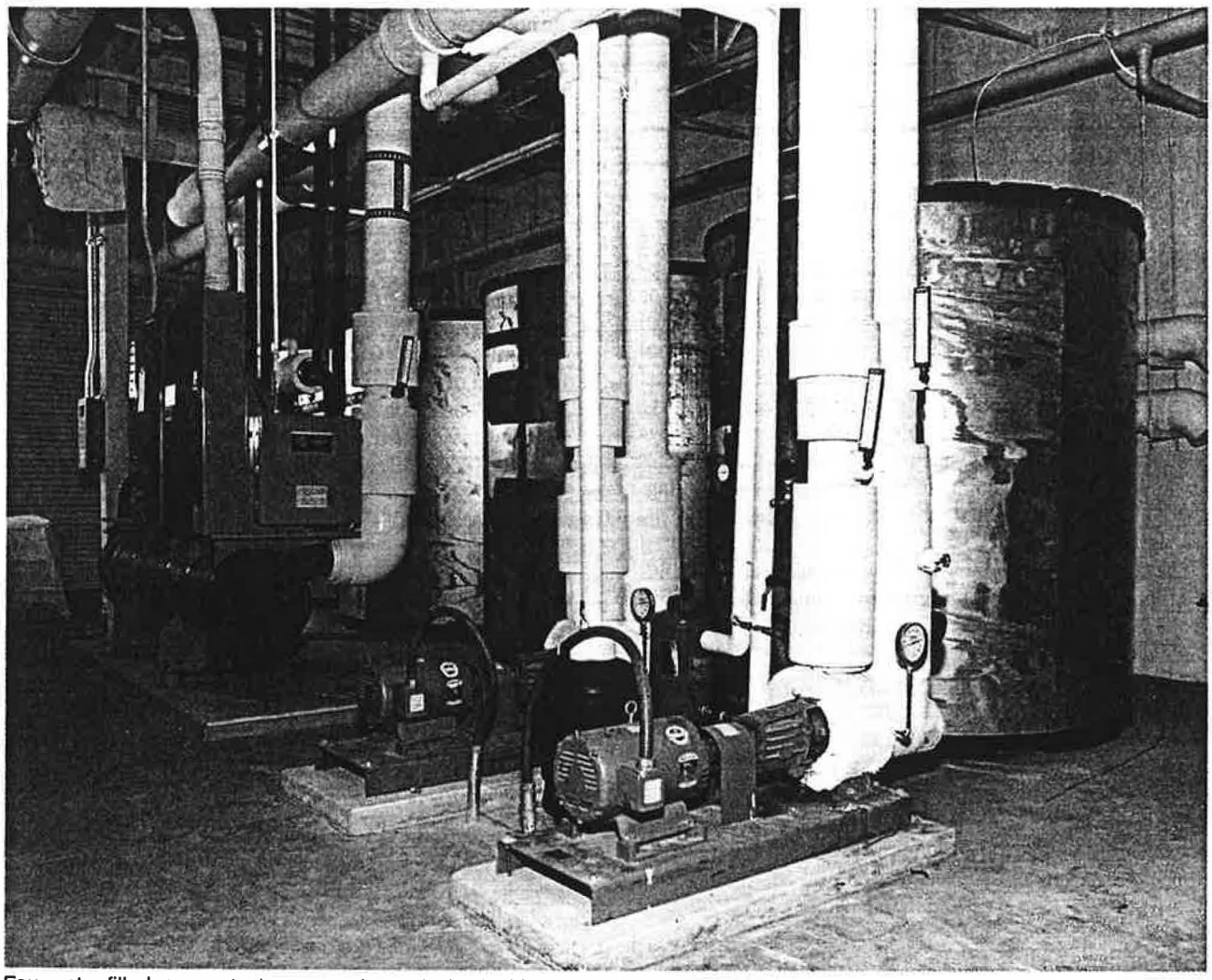
A constant volume system requires reheat coils to effectively control the temperature in each room and the use of low temperature air would require larger than normal reheat coils, consuming additional energy. For this reason, a system using seven VAV air handling units, supplying air to 37 series fan-powered VAV boxes, without reheat coils, was selected.

A typical classroom can require up to 1,100 cfm (519 L/s) of air. Each series fan-powered VAV box is supplied with 450 cfm (212 L/s) of 44°F (7°C) primary air. This is mixed with 640 cfm (307 L/s) of 76°F (24°C) room air to supply approximately 57°F (14°C) air to the space. Depending on the room load, the VAV box air quantity can vary from a minimum of 500 cfm (236 L/s) to 1,100 cfm (519 L/s).

Because this system uses low temperature air, the system components (air handling equipment, ductwork, chilled water piping, fans, circulating pumps, etc.) could be downsized approximately 33% as compared to a conventional air-conditioning system. The smaller equipment consumes less energy than traditional air delivery systems, contributing to the reduction in the school's total demand and utility costs.

The downsized equipment also contributed to an HVAC system that costs less than a conventional system. This system was installed at a cost of $12.44 per ft² ($1.16/m²) as compared to approximately $15.00 per ft² ($1.39/m²) for a conventional system. Therefore, the ice storage system installation reduced construction costs by $192,000 and resulted in an immediate payback.

It was estimated that a thermal storage system would reduce electrical energy costs by approximately 15% to 20% over a conventional system. However, for the first year Whitehall was used, its electrical costs were $65,416 while those for Paul V. Fly school were $88,660, or 35% higher. These savings are even more signifi-



Four water-filled storage tanks are used to make ice in this thermal storage system.

cant than they might appear because Whitehall is used approximately 16 hours per day as compared to 10 hours for Paul V. Fly.

DDC system

Even though thermal storage is more complex than conventional air conditioning, the school district has found that this system has been easy to operate and maintain primarily because of the DDC system.

The DDC system supervises 208 points in 12 zones throughout the building. This system allows the school district to monitor and control temperatures in all spaces, equipment operations and setpoints.

This control system is especially useful for a school where the evening use of the building is irregular and DDC can be used to program the systems to accommodate the individual needs of the user group. Whitehall is the only school in the district with this feature, so it is assigned most frequently to groups requesting the use of a facility for after-school-hours activities.

Indoor air quality

Because indoor air quality has become a major concern in public buildings, it was important to address ventilation as well as thermal comfort. This was especially important because new construction building materials emit chemicals that can cause discomfort and health concerns.

Although the Pennsylvania Department of Education's minimum outdoor air requirement is only 7.5 cfm (3.5 L/s) per person, the system was designed to provide 15 cfm (7 L/s) per person. A higher quantity of outdoor air is supplied to overcome the use of variable air volume distribution and to conform to *ASHRAE Standard 62-1989.*

The typical Whitehall classroom, which contains 30 students, requires 1,100 cfm (519 L/s) of conditioned air, of which 450 cfm (212 L/s) is outdoor air. After one year of use, there have been no occupant complaints of poor indoor air quality even though the building is new, is totally carpeted and contains building products and equipment manufactured from man-made materials.

One of the advantages of the low temperature air distributed by this system—a reduced relative humidity level—has permitted the school district to raise the summer thermostat settings from 76°F (24°C) to 78°F (25°C) while maintaining a comfortable environment in a building filled with active children.

To benefit more fully from Whitehall's thermal storage system, the district has designated the building as the facility to be used for summer school classes. As school districts continue to seek ways to contain costs, more boards of education are beginning to consider the possibility of a 12-month school year. For any school district that chooses to conduct year-round classes, an ice storage system similar to the one at Whitehall should be even more cost effective than this one has proven to be. ■