Office Building Saves Costs With Free Cooling and Peak Shaving Systems

Category I: Commercial Buildings
(New and Existing)

Second Place
New Building

Facility
American Family Insurance National Headquarters Facility
Madison, Wisconsin

Entrant
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Madison, Wisconsin

The American Family Insurance National Headquarters Facility was completed in 1992 and provides an 840,000 ft^2 (78 039 m^2) work environment for up to 2,000 employees. The complex consists of a five-story office building, a large data processing center and support facilities. The support facilities include a food preparation center, cafeteria, auditorium, mail processing area, training rooms, central utility plant and two parking structures.

The complex incorporates several unique systems: a free cooling system, variable volume chilled water pumping, and a mini-supervisor control and data acquisition (MSCADA) system.

The free cooling system incorporates a 600 ton (2112 kW) counterflow cooling tower and heat exchanger to take advantage of Wisconsin's low ambient temperatures during much of the year. The system acts as a waterside economizer providing chilled water without chiller operation when outside air temperatures permit.

In addition, the system provides 24-hour cooling and dehumidification for a large data center complex and other sensitive areas. This permits some of the air handling systems to be shutdown during unoccupied periods, saving fan energy throughout the year.

Constant volume chilled water pumping is provided for each primary chiller pumping circuit, and variable volume pumping is provided for the secondary chilled water circuit. Variable frequency drives for the secondary chilled water pumps match pumping energy to actual demand.

The MSCADA system uses emergency power generators to reduce electric demand and secure lower energy rates from the local utility. Three diesel-powered 1,250 kW electrical generators were installed to provide emergency back-up power to the data processing center.

To provide a dual benefit, the generators are synchronized with the utility's electric grid. During the local utility's peak periods, the generators assume a portion of the facility electric demand. The utility charges lower interruptible rates in exchange for the owner's agreement to reduce facility demand to 2,600 kW within 15 minutes after being notified by the utility. In addition to reducing electric costs, this operating strategy provides routine testing of the generators with real connected loads.

Energy efficiency

The free cooling system and chillers operate with a common cooling tower. A lifecycle cost analysis was performed to determine the optimum tower size. Results from the analysis indicated the tower should be sized to provide full-load cooling when the outside wet bulb temperature is below 25°F (−4°C).

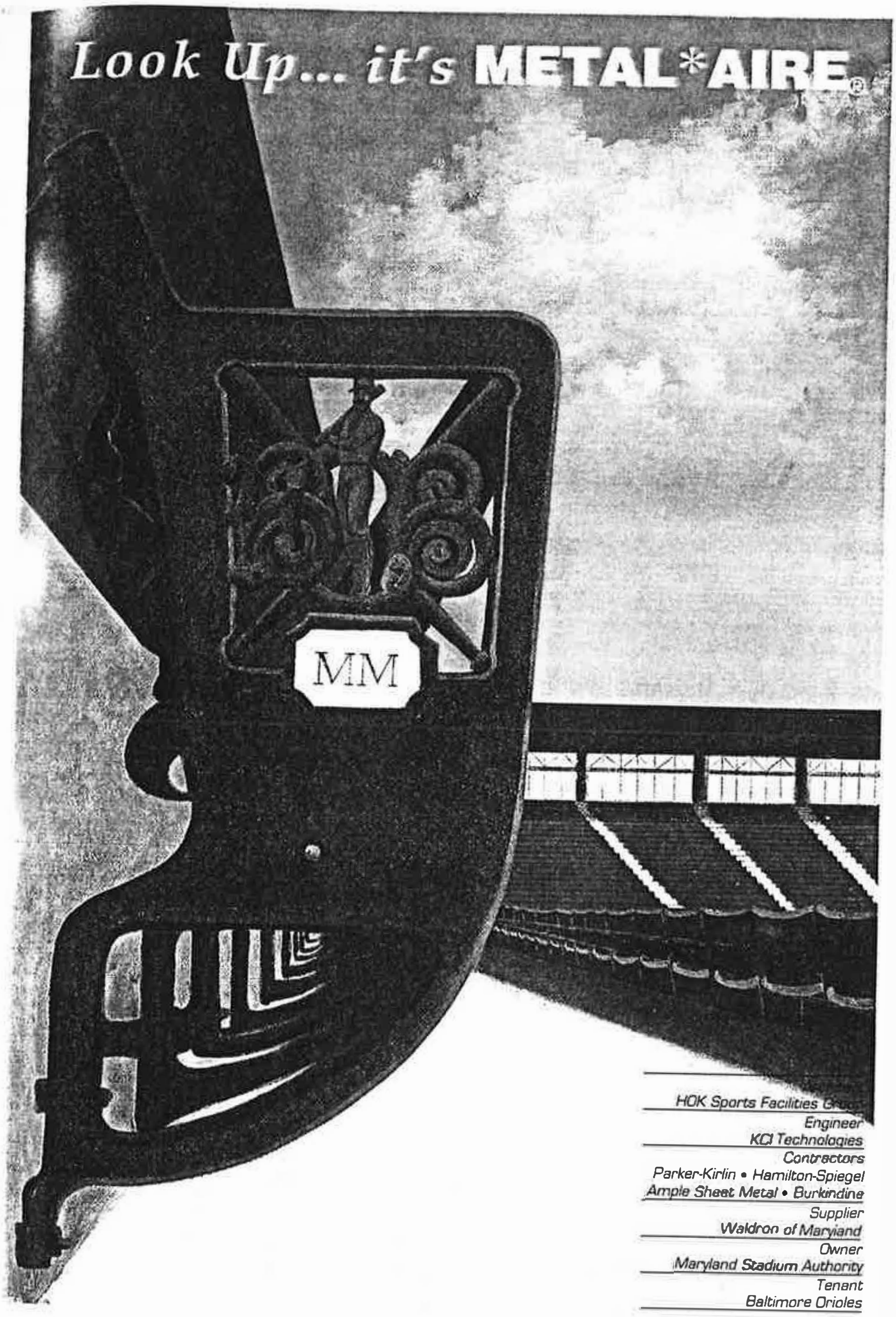
Free cooling can be provided for approximately 3,600 hours each year and the system can deliver an estimated 1 million ton-hours (3.52 million kWh) of cooling. During the 1992-93 heating season of November through March, the free cooling system reduced energy consumption by an estimated 650,000 kWh (2.3 GJ). Furthermore, electric demand was reduced by as much as 210 kW or 4.5%.

The heat exchanger is piped in series with the data center chilled water supply circuit. This allows some beneficial free cooling from the cooling tower for outside air temperatures up to 50°F (10°C). A mixing valve on the chiller condenser water supply allows the chillers to operate with 65°F (18°C) condenser water while the water in the sump remains at 42°F (6°C).

Lighting of the office spaces was done with ceiling mounted indirect light fixtures located over the workstations. The fixture spacing was designed to maintain a uniform 40 fc (400 lux) light level on the workstation surface while allowing the light level in circulation spaces to drop slightly.

About the author

Gene C. Nelson is a lead project engineer with Affiliated Engineers Inc., Madison, Wisconsin. He received his BS in mechanical engineering from the University of Wisconsin. His experience includes new systems design and renovation as well as HVAC retrofits for commercial, industrial, healthcare and R&D facilities.



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Studies were performed to compare the savings that could be achieved by installing occupancy sensors and daylighting control of the fixtures along the perimeter walls. The results indicated that automatic dimming of fixtures within 15 ft (4.6 m) of the glassed walls in response to ambient light would save more energy than would occupancy sensors. Accordingly, light fixtures with electronic ballast and automatic dimming of perimeter lighting in response to ambient light conditions were installed.

Other on-site tests had indicated that electronic ballasts drew 25% less power per fixture than the standard ballasts. Ambient outdoor light caused the perimeter lights on the north and south sides of the building to reduce their power consumption by an additional 65%.

Taken together, these measures reduced the lighting load from a standard 2.0 to 1.2 W/ft^2 (22 to 13 W/m^2). During the cooling season, the reduced lighting load will also reduce chiller demand and operating cost.

Indoor air quality

The owner's high priority to indoor air quality guided the design team to select certain HVAC design features over other design options, including some architectural features competing for a portion of the fixed construction budget. Selected design options included:

- Outdoor air ventilation rate based on *ASHRAE Standard 62-1989* (20 cfm per person);

- Installation of 65% efficient rigid cartridge type filters with 25% prefilters and space for future carbon filters;

- Installation of linear slot diffusers for good part-load performance at high (1.0 to 1.3 cfm/ft^2) (18.3 to 23.8 m^3/hr/m^2) and low (0.5 to 0.7 cfm/ft^2) (9.1 to 12.8 m^3/hr/m^2) flow conditions;

- Use of variable air volume terminals with reheat setup for 50% minimum flow to ensure comfort at low load conditions;

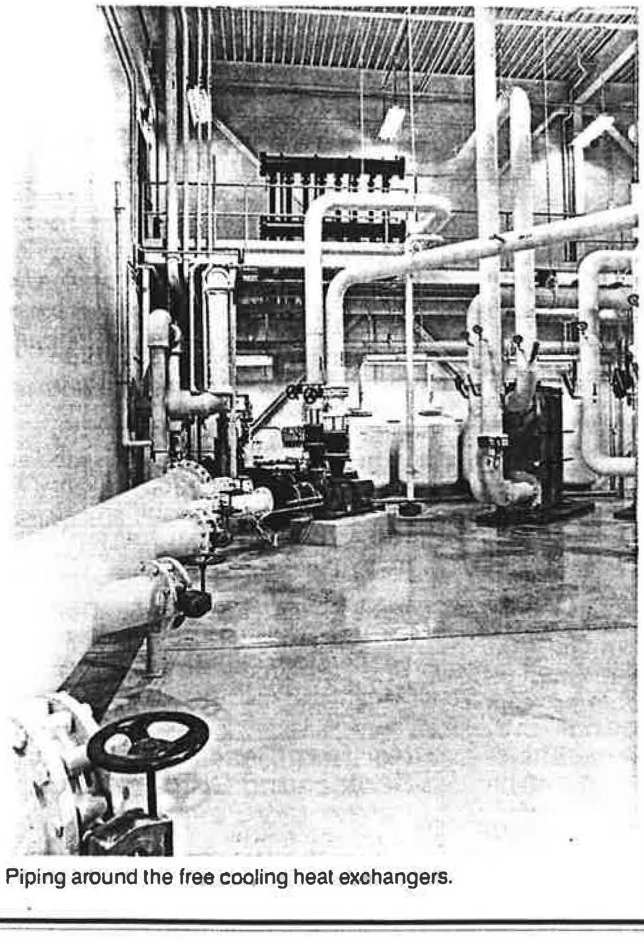
- To reduce potential dust, fibers and microorganism growth, internal duct-liners were not used, except in exhaust ducts and transfer ducts;

- The internal insulation of terminal boxes was surfaced with aluminum foil to avoid erosion and contamination;

- Relative humidity during the winter is specified at 30% in general work areas and 50% in mail, printing and data processing areas; and

- Filters were mounted at return duct intakes in ceiling plenums to catch potential dust and fibers from exposed structural steel spray-on coating.

The low rate (0.2%) of IAQ-related employee complaints during 1992 suggests the design goals were achieved. Indoor carbon dioxide levels were measured at 300 to 400 ppm during 1992 and were verified by an independent testing laboratory as part of the facility commissioning process.



Piping around the free cooling heat exchangers.

Innovative design features

To achieve the required high level of cooling and electrical system reliability, the data center cooling system was designed as an independent system with cross-ties to the office building cooling system, with at least one point per subsystem for redundancy. This provides a redundant piping system to the data center.

The chiller, cooling tower and pumps associated with the data center are on standby emergency power. One cooling tower cell and the pumps for one office building chiller are also available for standby use in the event that one data center chiller or tower is down.

Cross-ties between the systems can maintain 100% capacity to the data center at all times, even during emergency power situations. For secondary chilled water for the data center, dual secondary pumps are sized for 100% of the present load. Cross-ties to the office system provide backup capacity.

The MSCADA system is a computer interface controller that collects information from each electrical unit substation, each standby generator, and from the two utility service entrance switches. The controller provides an interface for the operator to log electrical trends, provide control of unit substation main breakers, and perform load shedding of unit substations.

The MSCADA system is used to initiate the generator peak shaving operation. Upon receipt of a phone call from the utility, the operator can reconfigure the electrical distribution system to a single utility input, start the generators, synchronize them with one another, and synchronize them to the utility grid. All of this is performed from menu-driven keyboard commands.

Once the generators are synchronized to the grid, the controller regulates the speed of the generators to limit facility demand, on the utility grid, to a maximum of 2,600 kW during the prescribed time duration.

Technology Awards

Upon receipt of a second phone call from the utility, the operator disconnects the generators from the utility bus and puts them into a cool down mode. This operation is also performed with menu-driven keyboard commands.

In addition to the peak shaving benefit, if the utility has an outage, the MSCADA system will automatically terminate the load shedding, reconfigure the utility source distribution system, and re-connect the generators, maintaining the required loads.

Operations and maintenance

The free cooling system requires no additional maintenance over the mechanical cooling system for the data center. Winter operation of the free cooling system allows for scheduled maintenance of chillers before the summer cooling season begins.

To ensure reliable, optimum winter operation in a cold climate, a freeze resistant counterflow cooling tower with ceramic fill and indoor sump were used. The system was designed to use a centrifugal chiller or a second indoor sump as back-up whenever the heat exchanger or indoor sump required servicing during winter months.

The facility needed an emergency back-up power system, which is being creatively used by the owner for savings in electrical energy costs. No additional maintenance of these generators is needed to fulfill this function. The generators are exercised weekly, running them under full load. The power generated during these exercise runs is captured and used by the facility rather than being applied to a resistor bank and wasted.

Summary

The free cooling system saves the owner an estimated $21,080 each year in electrical power costs. The payback for this component of the mechanical system is 5.5 years.

The peak shaving system yields an instant payback because it required no additional hardware, yet it produces significant savings on the monthly electric bill. The lower rates reduce energy charges by $4 per kW and 1.4 cents per kWh. When operating costs such as diesel fuel are compared to higher electric charges, annual savings produced by the peak shaving system are projected at $150,000.

The 15,000 energy efficient electronic ballasts in the main office building save an estimated $69,600 in annual energy costs. Of these, 4,000 dimming ballasts located at the perimeter save an additional $18,480, for a combined savings of $88,080 over the originally proposed core-and-coil type. Reduction in air-conditioning heat load is estimated at 80 tons (282 kW). ■