Urban Outfitted

AS SEEN IN ES Engineered Systems

Chicago's Michael A. Bilandic Building has 21 stories, one for each year since the previous retrofit. Recently, an open-minded project team paired modular chillers and hydronic gas boilers with pumps and VFDs to conquer some upgrade challenges, bring the mechanical system into the 21st century, and knock 15% off the tower's measured energy use.

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The Michael A. Bilandic Building, located in the Chicago Loop, is a 21-story office tower serving state of Illinois facilities, including the Illinois Supreme Court. In 1989, the existing building structure was completely gutted and renovated. At that time, a new top (twenty-first) floor was added to house major mechanical equipment. Three gas-fired, two-stage absorption chiller-heaters (each machine with an output of 600 tons cooling and 7,200 MBtuh heating) were installed on the top floor. Dedicated dual-cell cooling towers with 20-hp high/low speed fans were installed on the roof above.

All three old gas-fired absorption chiller-heaters were replaced with equivalent capacity modular electric chillers and sets of duplex hydronic gas boilers. This has resulted in enhanced equipment reliability, easier maintenance, and 15% savings in overall energy use during the first year of operation.

EXISTING HYDRONIC SYSTEM

Four-pipe primary heating and cooling mains, with pumps mounted on the 21st floor in the vicinity of the chiller-heaters, serve multiple VAV AHUs and perimeter radiant ceiling coils located throughout the building. The hydronic return mains feed into four 30-hp primary heating pumps and four 40-hp chilled water pumps which pump into the respective chiller-heaters (the fourth pump provides manual standby duty).

Likewise, there were four condenser water pumps (each 100 hp, but now replaced with 40-hp pumps), taking in water from the cooling tower supply header, pumping cool water into the respective absorption chiller, and then returning the hot condenser water to a dedicated cooling tower.

HEATING–COOLING PLANT REPLACEMENT

Due to year-round use, one chiller-heater machine broke down only after about 16 years of useful life and became unserviceable. However, the building continued to sustain itself comfortably on the remaining two functional chiller-heater machines but without any emergency standby capacity. Needless to say, the facility management staff of the building found itself in a precarious and worrisome situation. Hence, they moved ahead with urgency to replace the old absorption chiller-heaters with new machines of like kind, one machine at a time. The state of Illinois Capital Development Board chose Melvin Cohen and Associates, Inc., the consulting engineering firm in Chicago to prepare design documents for bid and construction. Primera Engineers in Chicago was simultaneously assigned the task of providing commissioning expertise.

FIGURE 1. The VFD-driven triplex house booster pump set.

BIG CHALLENGES AHEAD

Absorption chiller-heaters are heavy, bulky machines weighing up to 40,000 lbs each. Installing new units on the 21st floor of the building would require disassembling (and reassembling) them into smaller pieces for rigging by helicopter, creation of a large opening in the existing roof, and procurement of special building permits to close downtown streets around the building on several occasions during the construction period. Furthermore, the new absorption machines were unavailable locally and would require shipping from Japan with a minimum of six months lead time.

FRESH NEW THINKING

Given the urgency of the task at hand, the above scenarios were daunting. Additionally, absorption chiller-heaters are not well known for thermal efficiency. Consequently, it became obvious that a new approach was needed. Why not try using modular electric chillers and modular gas boilers that could be transported through the building freight elevator? Very convenient, but how would the vast amount of new electric power needed to feed the top floor, and could all the required modular equipment fit within the available space vacated by the old absorption machines?

Further building surveys indicated that the existing 480-V electric switchboards in basement had available physical and electrical spare capacity sufficient to meet the new power needs. It was also determined that it was feasible to run new power risers from the basement switchgear room up to the 21st floor and that sufficient storage space was available to expand the existing chiller-heater room if necessary. This early hope seemed to be convertible into sure promise of better design and construction strategy, as it was generally acceptable to members of the project team.

FINAL DESIGN AND CONSTRUCTION

The three old gas absorption chiller-heaters were replaced (in three distinct contiguous phases), each with a bank assembly of eight modular electric chillers served from spare existing 800-amp bolted pressure switches in the existing switchgear in the basement. Power feeders were extended from each bolted pressure switch to the respective modular chiller bank on 21st floor. Duplex gas-fired boilers for the replacement heating accompanied each chiller bank assembly. All three equipment assemblies of modular chillers/duplex boilers were located in the same floor area previously occupied by the old gas absorption chiller-heaters. No additional space was required, and all equipment fit properly without undue congestion. Most equipment was purchased within North America.

Modular chiller data. Two 35 ton, R-410a scroll compressors (with independent refrigerant circuits) and stainless steel plate heat exchangers, 16.8 EER, 0.54 kW/ton NPLV; Physical size 28- x 49- x 69-in. x 2,200 lbs operating weight.

Modular boiler data. 2,640 MBtuh output, 88% efficiency, VFD forced draft burner, 1:3 turn down ratio; Physical size 39- x 41- x 85- in. x 2,400 lbs operating weight.

OTHER IMPROVEMENTS

- The existing cooling tower target nozzles were replaced with smaller orifice nozzles to properly help distribute the reduced condenser water flow required by the new chiller banks.
- The old DDC panels and sensors for the existing HVAC control system were replaced with a state-of-the-art system that utilizes the interoperable open BACnet® protocol.
- The triplex house booster pump system for domestic water was replaced with a new modern package system with VFD controls for each pump.
- All 12 primary hydronic pumps were replaced with new pumps due to age and to suit new system requirements.
- The cooling tower chemical feed system and fine sidestream filters at the heating and cooling hydronic mains were replaced with new equipment with pipe corrosion monitoring hardware.
- An existing 3,000-amp building lighting switchboard with old style circuit breakers (not removed during the 1980s renovation) was replaced

FIGURE 2. Duplex gas boiler set.

FIGURE 3. The modular chiller set, supplied by Tandem Chillers, Inc.

with a new switchboard containing modern switch and fuse construction for better reliability.

NEW HEATING–COOLING PLANT'S ENERGY SAVING FEATURES

- For the same amount of cooling produced, the new electric chillers use and reject one-third less thermal energy compared to the old absorption chillers. Hence the condenser flow was reduced sharply (old condenser pumps with 100-hp motors were replaced with new 40-hp pumps), and the cooling tower fans did not have to work quite as hard.
- A scroll modular electric chiller uses up to 25% less electrical energy at part load than at full load. Multiple chiller compressors at each chiller bank are automatically controlled in a lead-lag manner by a factory-furnished master control panel (one such panel at each bank) to help maximize chiller operating efficiency at part load.
- Unlike an absorption chiller that must receive condenser water at steady 85°F, the operating efficiency of a scroll modular chiller improves significantly at lower condenser water supply temperatures. Hence, cooling tower fan operation was programmed to reset condenser water supply temperature to within 8° differential from the prevailing outdoor wetbulb temperature.
- All six new modular boilers are automatically controlled for lead-lag operation so as to inject heat into the building heating water supply main as needed to maintain the supply main temperature. An inline pump and a three-way control valve at each modular boiler ensure minimum 140° boiler entering water temperature to prevent flue gas condensation hazard within the boiler. The new boilers provide 88% thermal efficiency at full load vs. 80% efficiency of old absorption chiller heaters.
- Each cooling and heating bank assembly (containing a set of eight modular chillers and two modular boilers) is fitted with energy meters to monitor its operating efficiency: kW/ton for cooling bank and thermal efficiency for the heating bank. These parameters are displayed at the building automation front-end computer system. A degrading performance over time would alert for critical maintenance needs such as a heat exchanger cleaning and gas combustion tune-up. Back-flush valves have been added at each condenser (plate heat exchanger) location.
- A year-to-year comparison of electric and gas utility bills before and after project construction illustrates that the gas consumption was reduced by 29% and the electricity consumption for the whole building went up by only 1%. Keep in mind the old chiller-heater equipment operated mostly using natural gas. While the total of annual heating and cooling degree days (weather impact) was nearly the same, the gross energy consumption on Btuh basis went down by nearly 15% during the first year. These energy savings are remarkable.

MERITORIOUS OUTCOME

- Starting with the design work in early 2007, the project construction was completed by mid 2009. All the while the building remained in full normal operation.
- The construction work was completed smoothly and on time, with no significant glitches.
- The construction costs were about 25% below original CDB budget and included payments for correcting several previously undiscovered conditions.
- It has been found that the building can be kept comfortable with just one bank of boilers and no more than two banks of chillers. Hence, there is significant standby equipment capacity.
- The new replacement plant is not only easy to maintain but will continue to realize substantial energy savings in the years to come.

OLD LESSONS RELEARNED

- Difficult challenges often carry hidden opportunities for a better tomorrow, provided we are resourceful enough to look for them.
- When a project is handled by a dedicated team of professionals representing the using agency, project administration, engineering and construction, the rewards can be quite satisfying.
- Compared to the electric driven cooling systems, the absorption cooling systems are inherently inefficient, and their role is limited to when and where the heat energy is cheaply available.

CREDITS

Melvin Cohen and Associates, Inc. thankfully acknowledges the exper-

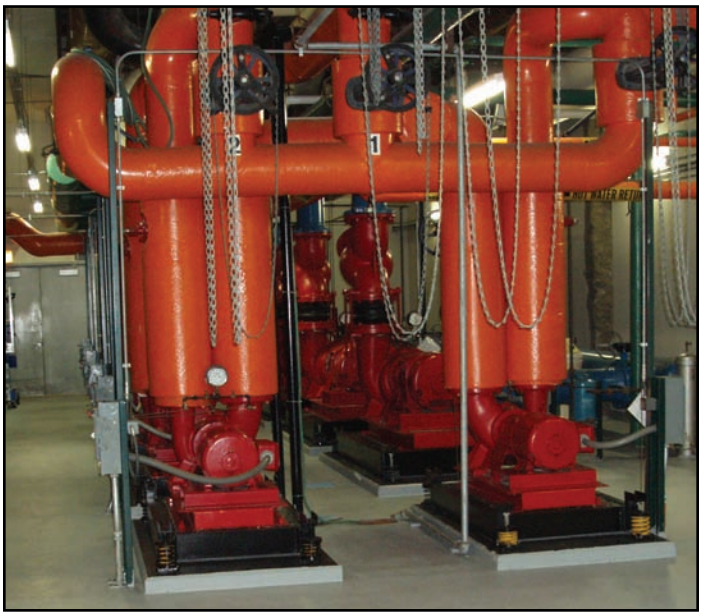

FIGURE 4. Heating-cooling system pumps.

FIGURE 5. The last of the old chiller-heater before demolition.

tise provided by the following project team members: from the state of Illinois, Jerry Adams, regional manager, Central Management Services,; Mohammed Haq, project manager, Capital Development Board; Donald Barnes, energy manager, Central Management Services; and John Teubert, assistant chief stationary engineer, Central Management Services. Contractors Pat Liston and Larry McMahon of Anchor Mechanical and Robert Fimbianti, Linear Electric. As well as Stanley Lawrence, project manager, Control Engineering Corp. and Andrew Sebescak, Commissioning Services, Primera Engineers. **ES**

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