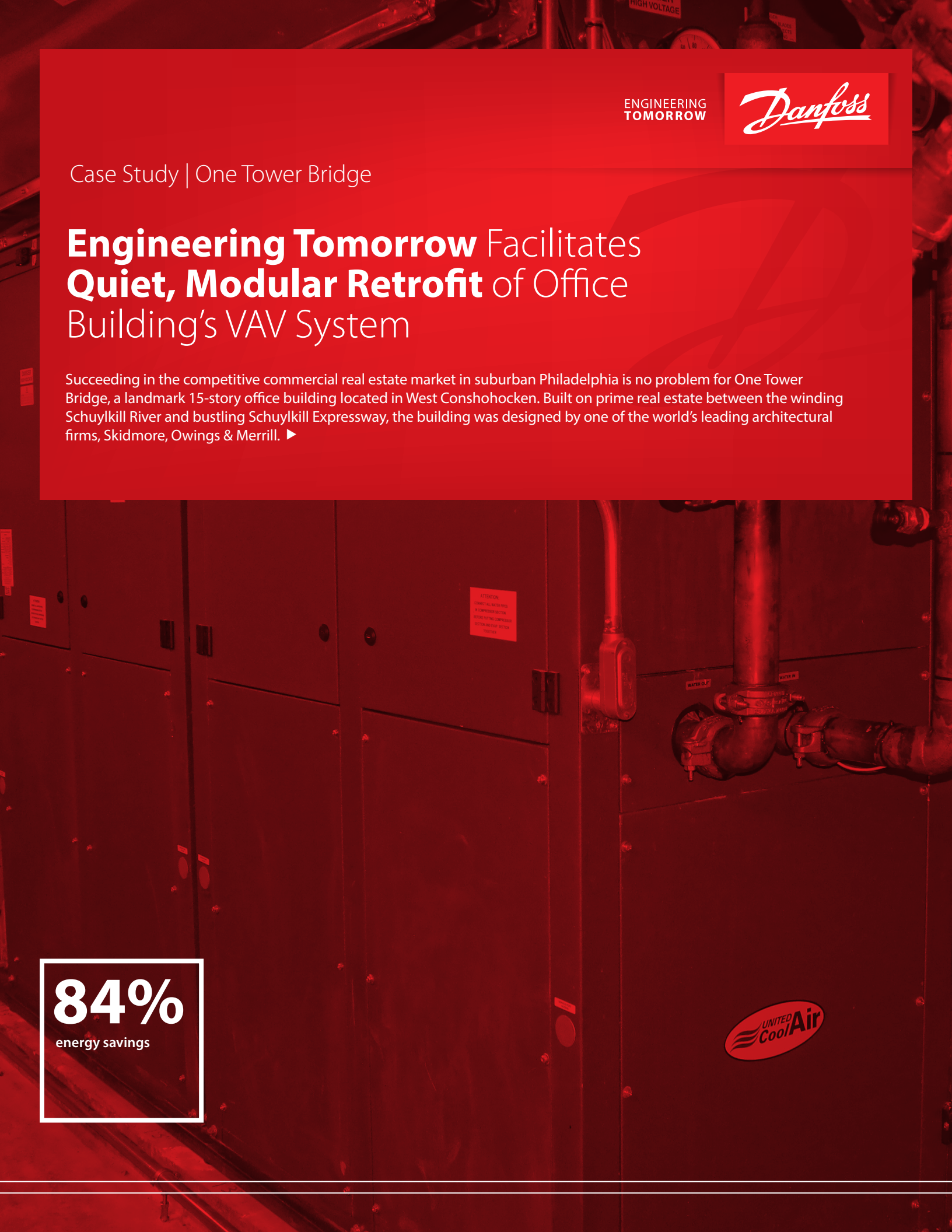
ENGINEERING
TOMORROW

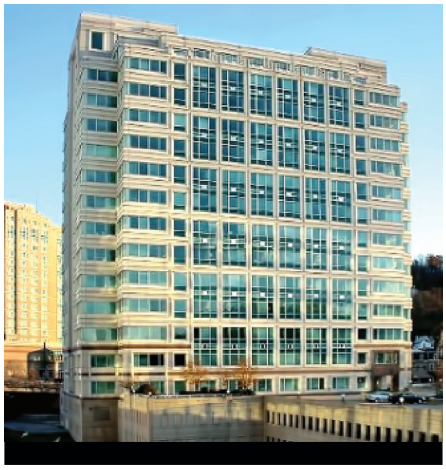
Case Study | One Tower Bridge

Engineering Tomorrow Facilitates **Quiet, Modular Retrofit** of Office Building's VAV System

Succeeding in the competitive commercial real estate market in suburban Philadelphia is no problem for One Tower Bridge, a landmark 15-story office building located in West Conshohocken. Built on prime real estate between the winding Schuylkill River and bustling Schuylkill Expressway, the building was designed by one of the world's leading architectural firms, Skidmore, Owings & Merrill. ▶



84%
energy savings



"Each advance in technology significantly increased our fan and compressor energy savings. The mechanically-modulated capacity scrolls provide some savings due to improved unloading capacity. But VariCool EZ-Fit units provide even more savings by ramping speed down to match capacity demands more closely."

John Sargent, building engineer, One Tower Bridge

But to keep its competitive edge, it was clear the owners had to replace the nearly 30-year-old HVAC units supplying the facility's floor-by-floor variable-air-volume (VAV) system. The problem was that retrofitting with conventional packaged equipment or chillers would require removing windows, walls, and ceilings, compromising the elegant architecture. Instead, self-contained modular units employing Danfoss variable speed scroll compressors were able to fit through doorways easily, assemble quickly and operate quietly.

"We faced replacing fifteen 45-ton packaged HVAC units originally bought from Blazer Industries in 1988," said John Sargent, building engineer for One Tower Bridge. "Transporting new, complete units to each floor was impossible. While the freight elevators are large, they certainly cannot transport a complete air-handling system. Removing windows or wall was also impossible. So, we were searching for a modular replacement unit that could fit our space restrictions and meet our particular performance requirements."

Considering self-contained HVAC for VAV

The One Tower Bridge building offers 270,000 square feet of office space for tenants ranging from investment banking to healthcare firms.

To meet their comfort needs, the facility employs floor-by-floor, self-contained HVAC units for a VAV system.

With a VAV system, each unit supplies conditioned air to terminal units, small metal boxes located in the supply air duct just before the outlet diffuser. The terminal units in One Tower Bridge use pressure-independent sensors that control a damper which regulates maximum and minimum volumes of conditioned air supplied to the space. For comfort, the settings in each self-contained unit and each terminal can be adjusted to meet specific needs of tenants and the building owner.

That's important to tenants in One Tower Bridge, because—contrary to the popular television series—it's not always sunny in Philadelphia. In fact, Philadelphia experiences wide swings in temperature and humidity. The result is many hours when an HVAC system must adjust to changing indoor and outdoor environments, functioning in "partial load" conditions that challenge systems primarily designed for maximum efficiency on the hottest days at "full load" conditions.

Another variable: Like many buildings, One Tower Bridge is exposed to significant amounts of sunlight on two sides of the structure, creating an imbalance in solar heat gain between the south and north sides.

To meet these challenges, the building originally used self-contained, water-cooled HVAC units developed by Blazer Industries for VAV using reciprocal compressors. But now, 30 years later, the original units were difficult to maintain due to unavailable parts and costly R-22 replacement refrigerant. Moreover, it was clear that technology of the 1980s couldn't meet 2020's efficiency and performance expectations.

Mechanically-modulated capacity scroll compressor capacity and noise were too much

In 2015, One Tower Bridge replaced a couple of the original units with a self-contained design using mechanically-modulated capacity scroll compressors. One new unit was installed on floor five, another on floor nine. Currently in operation, each unit contains two mechanically-modulated capacity and two conventional scroll compressors.

To handle varying loads, the units are configured to operate in two stages. Staging is split down the middle—the first stage runs two mechanically-modulated capacity scrolls, one on each of the left and right sections; the second stage runs a conventional fixed-speed compressor located in each section.

However, this solution proved less than ideal. To begin with, units were oversized. Only 60-ton units were available from the manufacturer instead of the required 45 tons. Consequently, during stage two, compressors were going off on alarm due to overcooling. As a workaround for the overcapacity, hot gas bypass was added to the stage two compressor circuit, which was costly and reduced efficiency.

Another issue was noise. During stage one operation, the mechanically-modulated capacity scroll compressors emitted a disruptive sound that couldn't be blocked by acoustic blankets.

Variable speed compressors adjust to the challenges

Fortunately, Sargent learned about a more advanced solution that could better handle the capacity, efficiency, and noise challenges. ▶

"In 2016, I became aware of a manufacturer offering modular units—United CoolAir located in nearby York, Pennsylvania. When John Sargent and I toured their plant, we immediately saw their new VariCool EZ-Fit® self-contained modular unit was a better solution," said Robert Miller of Coward Environmental Systems, the manufacturer representative providing One Tower Bridge's mechanical systems.

United CoolAir was able to eliminate the first problem: oversizing. That's because the VariCool EZ-Fit product line ranges from 12 to 90 tons, so a 45-ton selection was available.

Second, the technology is engineered specifically for floor-by-floor VAV retrofit projects. The system is designed in three distinct sections that easily mate to form a system module. Single modules are comprised of a fan, an evaporator coil, and a condensing section. For this application, one module supplies the north side, and another module the south side of the building.

The sections were completely assembled during manufacturing, charged with R-410A refrigerant, run tested, and then separated for shipment.

Third, the design's customizability made it possible to build a far better solution. For this application, key components included electronically commutated motor (ECM) fans and Danfoss inverter scroll compressors VZH with CDS 303 variable frequency drives.

In November 2017, two VariCool EZ-Fit modules were installed—one for each side of the third floor. Each module employs one 25-ton Danfoss variable speed compressor VZH on one circuit and a conventional single speed scroll compressor on the other three circuits, each cycling sequentially as more capacity is needed.

By adding a second variable speed compressor, the design enables a 4:1 turndown ratio for optimum capacity control.

For many applications, this staging configuration provides balanced air temperatures. However, given the differences between the north and south sides of One Tower Bridge, the air supplied to the outlet terminals benefited from further tweaking.

In November 2017, VariCool EZ-Fit modules using a slightly different configuration were installed on the first floor. Each of these modules employs one 25-ton variable speed scroll compressor VZH on the first and third circuits and a fixed speed 20-ton scroll compressor on the second and fourth circuits.

Stage one cooling activates the two variable speed compressors, stage two cooling runs the regular scroll compressor, then stage three cooling runs all four compressors.

By adding a second variable speed compressor, the design enables a 4:1 turndown ratio for optimum capacity control. As a result, the unit efficiently handles mild weather requiring as little as 25 percent cooling capacity—but can ramp up to 100 percent capacity on the hottest days.

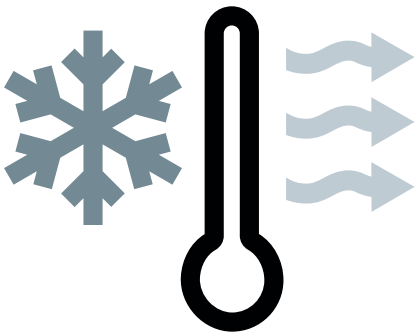
This is accomplished by using three cooling stages with variable speed compressors VZH in conjunction with variable frequency drive fan speed control that meets ASHRAE 90.1 requirements.

Inside advanced compressor capacity control

To optimize discharge air temperatures, the VariCool EZ-Fit's variable capacity control and high turndown ratio employs advanced Danfoss inverter scroll compressors VZH.

Compressors act as the heart of any mechanical HVAC system. They change the low-pressure/low-temperature refrigerant vapor into a high-pressure/high-temperature refrigerant gas that can expand in the evaporator section to absorb heat.

But there are significant differences in how compressors function. "Mechanically-modulated capacity scroll compressors use step-control or other methods," explained Miller. "So they struggle with cycling, ▶



From April 2018 through April 2019, a VariCool EZ-FIT® AHU using Danfoss variable speed scroll compressors provided practically the same cooling capacity of two other AHUs cooling different floors of the One Tower Bridge building.

voltage, and temperature fluctuations. In contrast, Danfoss VZH compressors use a VFD to condition the current to ramp speed smoothly to match the load more precisely."

In Danfoss variable speed compressors VZH, the VFD powers a permanent magnet motor that offers efficiency, size, and torque advantages over standard induction motors.

"Danfoss also uses the CDS 303 VFD (also known as an "inverter") for VZH compressor motors," said Miller. "The drive enables fast acceleration from a standstill with soft start ramp to managing minimum speed limits. The result is optimum efficiency across the entire operating range. Plus, speed reduction aids dehumidification by pulling more moisture out of the air as it contacts the cold coils for a longer period of time."

Another bonus: When VZH compressors are operating at their slowest, they also run quieter than mechanically-modulated capacity scroll compressors and fixed-speed compressors that frequently cycle on and off. Quieter operation allows tenants to occupy more floor space because noise levels are less intrusive.

Tweaking comfort for each floor

To make sure the modules met Sargent's and Miller's expectations, United CoolAir worked closely with Danfoss experts.

"Danfoss came to our factory to ensure compressors, controls, expansion valves, and other components were properly integrated," said Brad Dunn, United CoolAir's national sales manager.

To determine optimum compressor configuration, Danfoss provided full functional testing, including variable speed ramping and vibration/resonance analysis.

"Danfoss also helped us tweak the design to apply VZH compressors on two circuits instead of one to optimize balancing both sides of the building," Dunn added. "As a result, we were able to build the most efficient and flexible solution on the market with capacity, size, and sound advantages that competitors can't match."

After the 2016 installation on the thirteenth floor, One Tower Bridge purchased additional dual variable speed compressor units for the seventh and eleventh floors. As before, the units were disassembled in three sections, each fitting on the freight elevator. Each replacement was executed over a single weekend. Prior to installation, the existing units were disassembled and removed from the building. BAS connections were made over ModBus TCP over IP, which also supports a tablet interface.

Now with four VariCool EZ-Fit units up and running, One Tower Bridge is a "laboratory" containing the older units with reciprocating compressors, two units with mechanically-modulated capacity scrolls, and the four United CoolAir units with Danfoss inverter scroll compressors VZH.

"Each advance in technology significantly increased our fan and compressor energy savings," said Sargent. "The mechanically-modulated capacity scrolls provide some savings due to improved unloading capacity. But VariCool EZ-Fit units provide even more savings by ramping speed down to match capacity demands more closely."

Sargent has numbers to prove it.

The older units use 25 amps per phase. The mechanically-modulated capacity scroll units use 8 to 11 amps per phase. United CoolAir's VariCool EZ-Fit units use 5 to 7 amps per phase.

Monitored electricity usage from April 2018 through April 2019 was:

- 22,127 kW for VariCool EZ-Fit units with Danfoss inverter scroll compressors VZH
- 34,330 kW for units with mechanically-modulated capacity scroll compressors
- 38,292 kW for the older units with reciprocating compressors

Sargent is also taking advantage of the Danfoss variable speed compressor intelligence by further tweaking the controls to enable stage two cooling using all four compressors.

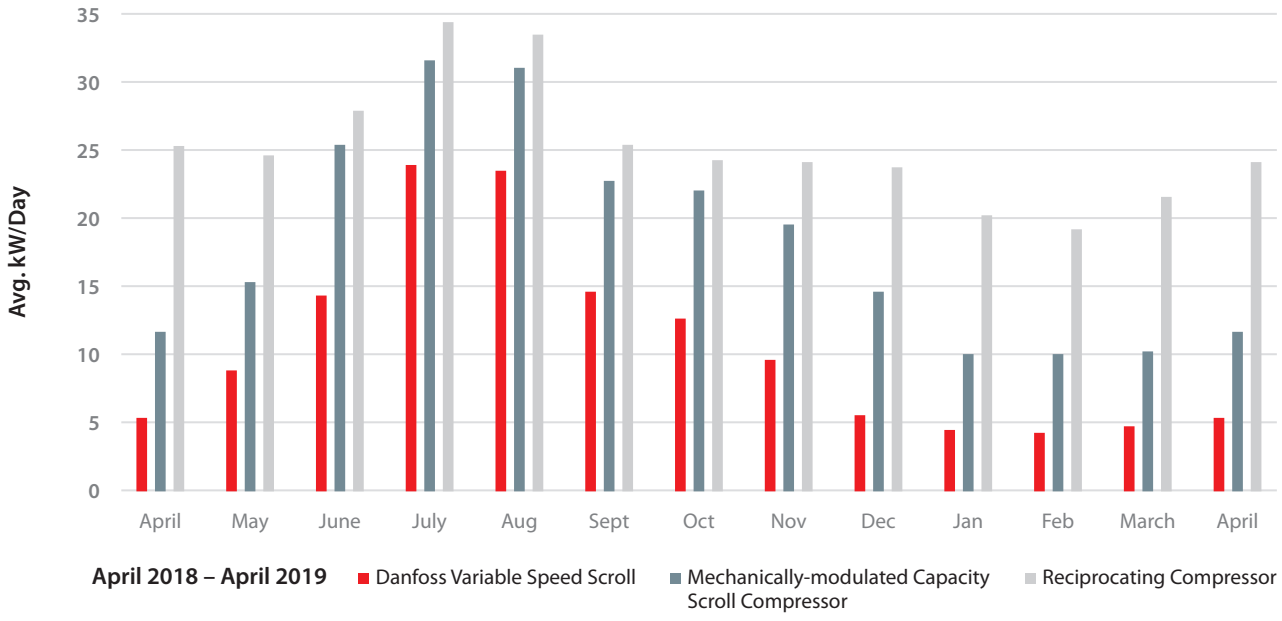
"My idea is to fine-tune capacity by getting all four compressors running, then use the VZH compressors to further adjust between different parts of the floor. The goal is to get nearly perfect capacity and discharge temperature control that delights our tenants."

The building owners were also delighted to learn that the VFD drives qualified for a rebate from their electric utility. The VFDs also reduce maintenance by avoiding huge amperage surges to decrease wear on motor windings and extend motor life. ▶

Advanced self-contained modules make a perfect fit for VAV

The new VariCool EZ-Fit self-contained modular systems from United CoolAir turned in outstanding efficiency and capacity control through the extreme weather variations of 2018. The bottom line: 84 percent energy savings compared to the older units and nearly 46 percent energy savings compared to the capacity modulated scroll systems.

"The VariCool EZ-Fit design with dual VZH compressor is ideal for our building," said Sargent. "This retrofit hits our temperature and humidity setpoints precisely. They reduce electricity consumption and noise, which our tenants value. VariCool EZ-Fit modular systems with Danfoss inverter scroll compressor VZH technology feels right at home in Philadelphia." ■



From April 2018-April 2019, up to 50% difference in kW/day resulted between floor-by-floor self-contained air-conditioning systems using Danfoss inverter scrolls VZH, mechanically-modulated capacity scrolls, and reciprocating compressors.

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