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2006 ASHRAE Technology Awards

Underfloor for Technology Firm

By **Dennis P. Sczomak, P.E.,** Member ASHRAE, and **Thom Barry, P.E.,** Member ASHRAE

Compuware World Headquarters is the anchor building in a seven-block development plan for the revitalization of downtown Detroit. It is a new \$350 million, 16-story, 1,140,000 ft^2 (106 000 m^2) building that includes office space for 4,000 employees, an 8,000 ft^2 (743 m^2) data center, a 16-story central atrium with a 14-story waterfall, 60,000 ft^2 (5574 m^2) of retail space, a 38,000 ft^2 (3530 m^2) fitness center, a modern day-care facility with 18 classrooms, an expansive, full service cafeteria and associated kitchen, and an attached, 12-story parking deck.

The design team's challenge was to provide a mechanical system that could easily accommodate future space renovations to suit the changing needs of a dynamic technology company. The resultant mechanical systems are flexible, reliable, and energy efficient, and provide a high level of indoor environmental quality.

Compuware's headquarters has a system that combines a variable volume, low-temperature primary air supply system with underfloor air-distribution.

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Air-Distribution System

The key component to the energy efficiency and flexibility of the building's mechanical system is the air-distribution system for the office areas, which combines a variable volume, low-temperature (46°F [8°C]) primary air supply system with an underfloor air-distribution system. Based on the energy model, this system provides $127,000 per year in energy savings when compared to a conventional variable volume, overhead air-distribution system with 55°F (13°C) supply air.

Low-temperature primary supply air is generated by large, variable volume air-handling units located in the mechanical penthouse. This low-temperature primary supply air is ducted down through shafts and is connected to the inlets of six vertical fan/mixing units (VFMU) on each office story. Each VFMU is located in a separate mechanical closet, and includes a primary air inlet, filtered recirculated air inlets, downflow supply fan with variable frequency drive, and sound attenuators. The VFMU mix the low-temperature primary supply air with recirculated air from the ceiling plenum, and discharges 62°F to 65°F (17°C to 18°C) air into the underfloor supply plenum, maintaining a low positive pressure (0.05 in. w.g. [12.5 Pa]) below the raised floor.

The energy efficiency of the air-distribution systems is primarily due to two main factors. First, the large airside temperature differential of the low-temperature primary air system results in lower primary airflows and less fan energy than a conventional 55°F (13 °C) system. Second, air distribution through the open underfloor plenum avoids the need for low-pressure secondary ductwork, and its associated pressure losses.

The overall airside temperature differential for the primary air-distribution system is approximately 33°F (0.56°C), (46°F [8°C] supply air temperature and approximately 79°F (26°C) stratified return air temperature). Compared to a conventional overhead supply air system having the typical 20°F (–7°C) airside temperature difference (55°F [13°C]) supply air and 75°F ([24°C] return air), the low-temperature primary air system requires 40% less airflow and much less fan horsepower compared to the conventional system. These fan energy savings are offset partially by reduced chiller efficiency when operating at the colder chilled water temperatures required by the 46°F (8°C) primary air, and by decreased duration of full cooling by the airside economizer.

With the underfloor air system, the VFMU discharge directly into the underfloor plenum. The low pressure and low velocities in the underfloor plenum (little underfloor distribution ductwork was used), combined with variable frequency drives on the vertical fan/mixing units, which respond to variations in airflow through the raised floor diffusers, results in reduced fan energy use.

About the Authors

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In addition to the energy-efficient air-distribution system, other energy-saving features of the mechanical systems include:

- Occupancy sensor control for HVAC systems in conference rooms and private offices, using the occupancy sensors already being provided to control the lighting, provides \$15,700 per year in estimated energy cost savings;
- Economizer coils in the air conditioners that serve the data center provide winter free-cooling in the data center, resulting in an estimated \$17,800 in energy savings each winter; and
- A comprehensive building management system integrates direct digital controls for HVAC systems with lighting control, power monitoring, fire alarm, security and elevator systems.

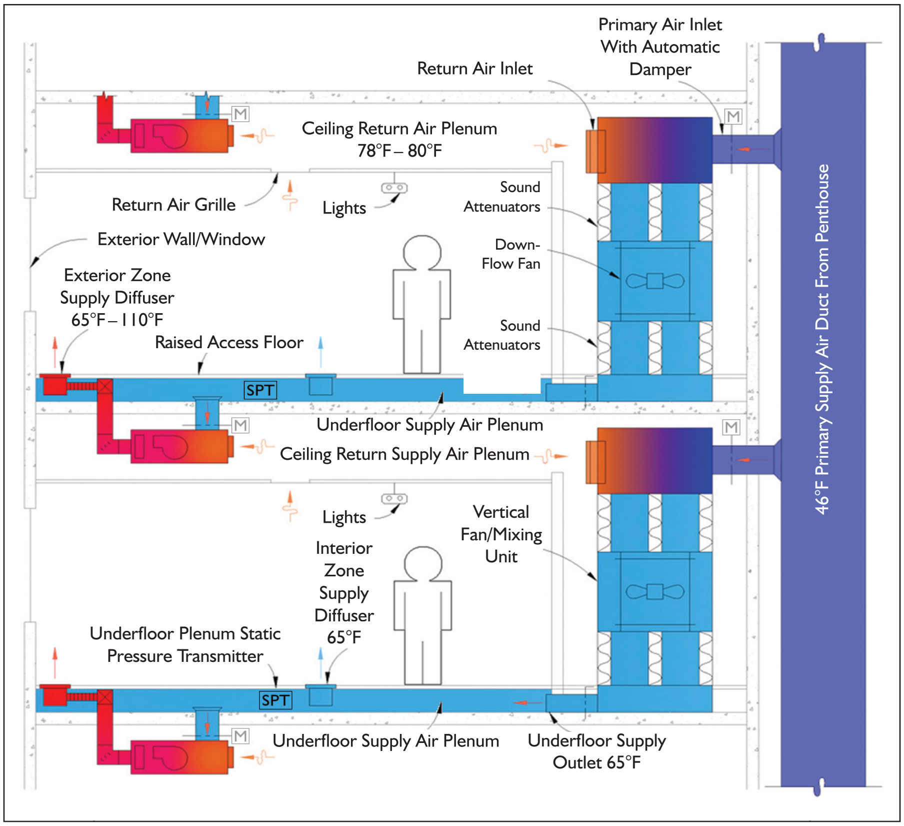

Figure 1: Compuware's air-distribution system.

IAQ and Thermal Environment

The air-distribution systems are designed to meet the guidelines in the Ventilation Rate Procedure of ANSI/ASHRAE Standard 62-1999, *Ventilation for Acceptable Indoor Air Quality*. The design team used airflow measuring stations in the outside air duct of each primary air-handling unit to maintain outside airflow at no less than the minimum required by the standard, throughout the range of operation of the variable volume air system.

With the long hours of moderate outside air temperatures in Michigan, outside air rates far exceed Standard 62-1999 requirements throughout much of the year. This is because the airside economizer cycle brings in outside air in excess of the standard's minimum setting, up to 100% outside air, except during extreme outside conditions.

Each office area cubicle includes an individual supply air diffuser located in the raised floor, the face of which can be manually twisted to increase or decrease airflow. This individual occupant control increases actual and perceived comfort for occupants.

Heating along outside walls of the typical office spaces in the Compuware Headquarters is provided by supply air diffusers located in the raised floor. Using floor diffusers for heating allows the supply air temperature in heating mode to be as high as 110°F (43°C), effectively warming interior surfaces of the outside walls and reducing radiant temperature asymmetry for occupants located near the outside wall. This is an improvement compared to typical overhead, all-air heating systems, which are challenged by either inadequate heating due to the buoyancy of the heated air (resulting in cold wall surfaces near the floor), or due to perceived draftiness if the overhead air temperature is limited to reduce buoyancy problems.

Perimeter System

Providing an effective perimeter heating and cooling system is a common, significant challenge for underfloor air-distribution systems. Series-type fan-powered boxes with electric heating coils were placed in the ceiling plenum of the story below the floor that they served. Supply air from the underfloor plenum of the floor being served was ducted down through the subfloor to the inlet of these fan-powered boxes. The fan-powered boxes also had inlets for return air from the ceiling plenum where they were located.

Discharge air from the fan-powered boxes was ducted to individual raised floor supply air diffusers located along the exterior wall. The fan-powered boxes were provided with electronically commutated motors (ECM) to allow reduced airflow and reduced fan energy use except at the limited times of peak cooling.

The underfloor supply air/return air mixture at each fan-powered box was modulated based on heating/cooling demand from the room temperature sensor, as was the speed of the fan-powered box's ECM and the output from the box's electric heating coil. Energy savings are achieved through the use of variable airflow using the ECMs, and also by the ability to recover energy from stratified return air in the ceiling plenum when perimeter heating is required.

This solution reduced construction cost because it allowed large capacity fan-powered boxes to be placed in the ceiling below, as compared to a much higher quantity of lesser capacity boxes that would have been required had they been placed within the underfloor plenum.

Operation & Maintenance

Redundancy was built into the air-distribution systems such that upon failure of any one of the primary air-handling units, the remaining units can compensate (at reduced total capacity) through common connections via the common underfloor plenum on each floor. Similarly, if one of the vertical fan/mixing units on each floor were to fail, the remaining units could compensate. A spare chiller was provided, allowing full cooling capacity to be provided even in the event of chiller failure.

The underfloor air-distribution system allows Compuware to quickly and easily modify office space layouts by moving the 24 in. × 24 in. (0.6 m × 0.6 m) floor tile in which the diffuser is located.

A commissioning process for the project verified that systems, as installed, were functioning in accordance with design intent, thus reducing ongoing troubleshooting and maintenance requirements.

Cost Savings

The low-temperature primary air system reduced the airflow capacity and cost of the primary air-handling units and duct mains, and the underfloor air system reduced the distribution ductwork on each office floor. Compuware already had committed to installing a raised access floor for accessibility of power and communications cabling, so the net added cost for this project's air-distribution system was only \$52,500 compared to a conventional overhead system, based on a comparative cost estimate by the mechanical contractor. With the annual energy cost savings of \$127,000, the payback for this system was only five months.

The total added cost for all of the energy conservation measures, including the air-distribution system, occupancy sensor control for HVAC systems in conference rooms and private offices (using existing occupancy sensors to control the lighting in these rooms), and economizer coils for the data center air conditioners was \$99,500. With their combined annual energy cost savings of \$160,500, the combined payback for these measures was only seven months.

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