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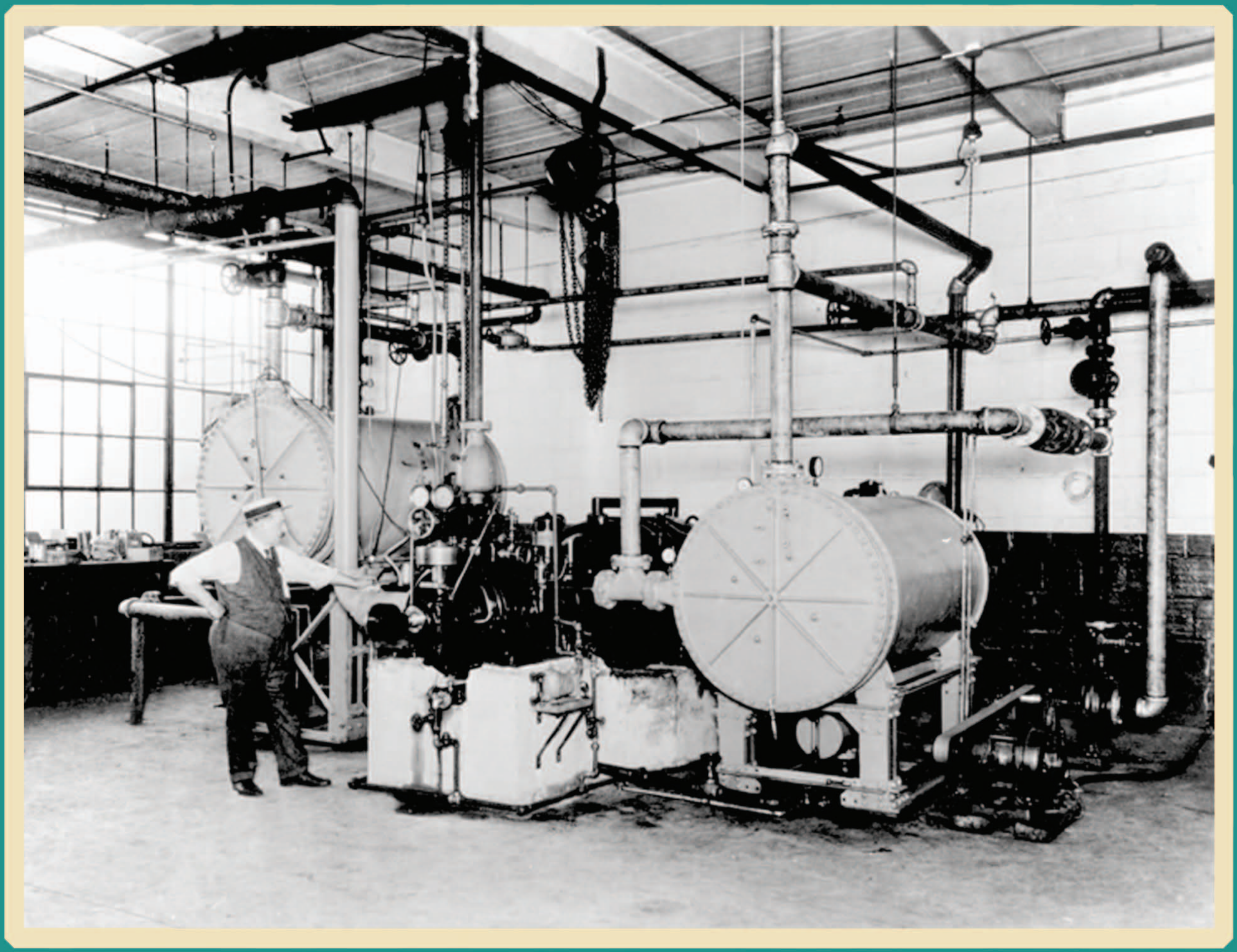

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2005 ASHRAE Technology Award

Providing Care for Medical Office Building

By Jeff Blaevoet, P.E., Member ASHRAE

Thermally powered VAV diffusers historically have been used in retrofits to provide additional zoning for existing systems. The Kaiser Geary Medical Office Building in San Francisco is the first significant new building in the United States to use thermally powered VAV diffusers as the basis of design. An improved direct digital control (DDC) approach for reheat control was developed, and a prototype tested at the factory before construction commenced.

This project demonstrates why medical office buildings particularly can benefit from this HVAC system type. Other building types where fully enclosed offices are needed, such as attorney offices, are also well suited for this system given.

As the number of reheat coils is greatly reduced, heating hot water distribution is also a fraction of a VAV/reheat box system, which has cost benefits and reduced liability of water leaks above the ceiling. Ductwork distribution is greatly simplified, and the extent of powered controls also is much less.

Where operable windows are provided, a possibility exists of a window being left open, which would affect the thermostat of a VAV box, causing discomfort for the occupants in the other rooms served by that box. With self-contained thermally powered VAV diffusers, the master DDC zone controllers are much fewer, reducing the chances of this happening. If it did, the VAV diffusers would compensate. For these reasons, as well as the improved comfort and energy efficiency afforded, thermally powered VAV diffusers also have a much broader application potential.

Project Overview

The Kaiser Geary Medical Office Building is a high-rise building constructed in 2000. The $60 million building is eight stories with an atrium and five additional floors of underground parking. Each floor has an area of 32,800 ft^2 (3047 m^2) and the building has a total floor area of 261,600 ft^2 (24 303 m^2) The facility contains a cafeteria, a large data/telecom room, doctor's offices, nurse's stations, a full pharmacy, exam rooms, waiting areas, a cancer center, neurology, orthopedics, otolaryngology, urology, dermatology, podiatry, ultrasound, radiography and other imaging services. This outpatient facility also houses procedure rooms for performing minor and noninvasive medical procedures. The project program was for 150 provider offices and all the necessary support spaces.

The project site is located in a mild weather climate with summer conditions (0.1%) of 84°F (29°C) DB and 66°F

About the Author

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Kaiser Geary Medical Office Building uses thermally powered VAV diffusers.

Doctors and nurses offices are located along the building perimeter and architectural interior light shelves provide indirect natural light for the perimeter spaces.

(19°C) WB and winter conditions (0.2%) of 41°F (5°C) DB. The climate has 3,080 heating degree-days.

Architecturally, the building has a rectangular floor plate with the long sides facing north and south for solar control. The floor plate is divided into two halves, east and west, by a three-story atrium.

The envelope is comprised of cement plaster, metal frame walls with R-19 batt insulation and concrete deck roof with built-up rigid insulation. A layer of R-19 rigid insulation board provides thermal isolation between the first floor and the parking garage level. The glazing is a clear single-pane float glass with 88% visible light transmittance.

Doctors and nurses offices are located along the building perimeter and architectural interior light shelves provide indirect natural light for the perimeter spaces. A solar shade-cloth provides solar protection and prevents glare on interior work surfaces. The facility has an overall window-to-wall ratio of 45%, but is 27% below California's energy code.

Mechanical System Overview

Chilled water is provided to rooftop air handlers from the facility's central plant located on the first level of the parking area. Two 0.48 kW/ton (0.14 kW/kW) 220-ton (774 kW) water-cooled screw chillers piped in a primary/secondary-pumping scheme are provided for chilled water distribution throughout the building. A 50-ton (176 kW) water-cooled reciprocating chiller provides chilled water to serve the building's 24-hour loads. Two induced draft cross-flow cooling towers serve the water-cooled chillers.

On the roof are four screened roof-mounted variable-air-volume (VAV) air-handling units. Since the building is split into east and west halves, one air handler serves the perimeter of the east and another serves the interior, while the other two air handlers serve the west perimeter and west interior, respectively, to optimize supply air temperature and minimize wasteful reheat. Chilled water fan coil units serve the data rooms and medical equipment room loads. Run and standby secondary chilled water pumps with variable frequency drives and two-way valves keep pumping costs low. Fiberglass cooling towers are used to resist the aggressive ocean fog climate. Two boilers provide heat to the building, one sized at 1.6 million Btu/h (469 000 kW) output and the other sized at 4 million Btu/h (1.2 million kW) output.

A 15,000 gallon (56 780) water storage tank is provided along with diesel and electric fire pumps, combination stand pipes and full sprinkler systems. High-rise stair pressurization, vestibule ventilation, and atrium exhaust systems on emergency power are included. Double containment fuel oil storage with duplex pumps in the garage feed the roof-mounted emergency generator and day tank. Domestic water booster pumps, gas-fired domestic water heaters, medical and control air compressors, and medical vacuum pumps round out this highly serviced building.

Individual Exam Room and Doctor's Office Zoning

Medical office buildings contain many individual doctor's offices, exam rooms and special procedure rooms, with dressed and undressed patients. As medical office buildings usually are provided with reheat on interior as well as exterior zones, there is a significant cost associated with heating hot water distribution, VAV box hook-ups and controls. Conventional VAV boxes with reheat typically are zoned at no less than three to five or more rooms per thermostat. If each room could have its own temperature controls, the comfort of patients and staff would be enhanced, but how can that be done given limited construction budgets?

During the schematic design phase, Kaiser expressed interest in considering VAV diffusers as they had used some in a small project which had handheld remote controls. The on-board contractor conducted a cost study that showed that wired or remote-controlled VAV diffusers were more than the budget. However, thermally powered VAV diffusers could be provided for the same cost as a conventional VAV reheat system. This is because the number of reheat coils is greatly reduced, and they often are able to be located close together around each shaft, which reduces the amount of heating hot water piping dramatically. Also, the duct distribution is greatly simplified, reducing the amount of ductwork that needs to be installed.

What Are Thermally Powered VAV Diffusers?

Thermally powered diffusers have a built-in thermostat and VAV dampers. The thermostat/actuator is a small brass cylinder containing petroleum-based wax that responds to room temperature by expanding and contracting, which in turn modulates a damper actuator in the diffuser that regulates air volume. Usually, the damper movement results in a constant discharge velocity, which improves part load air distribution by maintaining throw and avoiding cold air dumping that can occur at low discharge velocities. Room air is induced by the supply air and routed over the self-contained thermostat to sense room temperature for control. No external connections (other than sheet metal duct) are required for operation. Thermally powered diffusers have been reliably in service for more than 25 years.

Thermally Powered Diffusers With DDC Control

DDC-controlled diffusers are available that require power and control wiring to operate, but the cost of such systems is usually prohibitive, and the objective was to provide accurate control of each room for the same cost as a conventional system with VAV boxes and reheat. However, in using affordable thermally powered diffusers, supply air temperature control must be resolved. Simultaneous heating and cooling from a single temperature source is not possible, so each group of diffusers must have the same type of load—either heating or cooling. In a large new building, this is most practically accomplished by means of hot water reheat coils for each exposure and interior space. Individual air-handling units per exposure and interior space would be better, but they are usually difficult to integrate into the building economically. In the case of this project, Kaiser has a policy of providing separate air-handling systems for interior and perimeter areas, which provided a good zoning basis for optimum supply air temperature control.

DDC Master Zone Reheat Control

The main challenge to date has been how to control the reheat coils. Previous designs have the thermostat in a room with a fixed diffuser, but then energy is wasted reheating that zone at full volume and, worse, supply air temperature can be raised more than other zones would like. Other designs have the thermostat in a room with a thermally powered diffuser. Although this can work in theory by having the room thermostat working within a wide heating/cooling VAV diffuser dead-band, instability is a danger, particularly if the initial setup is not maintained.

A conventional DDC VAV reheat sequence is preferred, and this was accomplished by providing an electrically operated, DDC controlled master zone VAV diffuser. Full volume reheat is avoided and damper position feedback is provided to control the reheat coil. Other benefits such as central monitoring, optimized supply air temperature reset and morning warm-up scheduling are also provided. Working with a major control company who has a national purchase agreement with Kaiser, and a thermally powered VAV diffuser manufacturer, factory mockups were prepared and tested.

Static Pressure Control

The other critical issue for thermally powered diffusers is static pressure control. Unlike regular VAV boxes, they must operate in a static pressure range of 0.15 to 0.25 in. w.g. (37 Pa to 62 Pa). If the duct pressure at the neck of the diffuser is below that range, less than the rated cfm will be delivered. Above 0.25 in. w.g. (62 Pa), the diffuser will be noisy. In a large system, there may be multiple static pressure control dampers downstream of the reheat coils. Avoiding VAV boxes, and designing low pressure, low velocity ductwork also has a beneficial effect on fan energy use. The four air-handling units serving the building, have a combined power to airflow ratio of 0.58 W/cfm (1.23 W per L/s), which is 53% less than the ratio of 1.25 W/cfm (2.65 W per L/s) for VAV systems allowed by California's energy code.

Implementation and Commissioning

Following the successful mockup and testing of the master zone DDC with the control and diffuser manufacturers, construction, test and balancing, and commissioning proceeded smoothly. Balancing VAV diffusers is accomplished by unhooking the tension spring that connects the thermostat/actuator and the blades (so the blades are full open constant volume) setting the static pressure controls to the correct range, and adjusting the duct-mounted balancing dampers for design cfm at the diffuser.

Operating Experience

Feedback from facilities staff at the medical office building is that the system had few startup problems and has performed very well since coming into operation. The main problem was the failure to reconnect some of the actuator mechanisms after initial balancing had occurred. In the four years of building operation, no malfunctions of the VAV diffusers have occurred and the system has been easy to maintain. Most importantly, complaints from building occupants have been significantly lower than other similar facilities without individual room control. Service calls were quickly resolved by adjusting the diffuser setpoint.

Energy Performance and Environmental Impact

The project design minimizes building energy consumption, which was projected to be 27% below California's energy code, thereby reducing the environmental impact of electricity generation. The DOE-2 energy model showed that the building design resulted in a savings of 1,859,430 kWh/year over a standard building designed to comply with California's energy code. Approximately 1.33 lbs (0.6 kg) of CO_2 are produced for each kWh of electricity generated. The 1,859,430 kWh reduction in energy use corresponds to the elimination of more than 2,473,040 lbs/year (1.1 million kg/year) of the greenhouse gas CO_2.

Conclusion

The use of thermally powered VAV diffusers should be applied to new construction as well as retrofit HVAC systems (which has been the main market for the product to date). As they typically are used for retrofitting problem systems, and they cannot solve inherent problems with existing systems, only provide additional zoning—they perhaps have not been fully appreciated.

This approach offers improved comfort through individual room temperature control, better air distribution at part load, simplified duct distribution, and greatly scaled back reheat piping with reduced leakage, and associated mold growth potential above ceilings. They enhance use with operable windows, have simple, robust controls, lower energy use, and offer easy commissioning and maintenance.

These benefits have not been well publicized, and few new buildings using this technology have been designed to date. Thermally powered VAV diffusers appear to be greatly underestimated, and should be much more widely used in new construction.

The 261,600 sq.ft. Kaiser Medical Office Building was built in 2000, in San Francisco, CA. The $60 million facility is eight stories with an atrium. Each floor has an area of 32,800 sq.ft.

Mechanical Design Impact

- Reheat coils significantly reduced
- Hot water distribution a fraction of a VAV reheat box system
- Ductwork distribution greatly simplified
- Powered controls much less
- DDC controllers much fewer

System Overview

- Two 220-ton (774kW) water-cooled screw chillers piped in a primary/secondary-pumping scheme
- One 50-ton (176 kW) water-cooled reciprocating chiller
- Two induced draft cross-flow cooling towers
- Four screened roof-mounted VAV AHU
- Two boilers 1.6 and 4 M Btu/h (469 and 1200 MW)
- and 1203 Therma-Fuser™ VAV Diffusers

Owner & Occupant Benefit

- Less cost
- Better control
- Improved comfort
- Reheat coils significantly reduced
- No Maintenance (after four years)
- Significantly lower complaints compared to other similar facilities
- Significantly better energy utilization, i.e., 27% below California energy code, $185,943 estimated annual savings.
- Substantial drop in greenhouse gas CO2, 2,473,040 lbs/year

Each Acutherm Therma-Fuser™ VAV Diffuser is an individual zone of VAV control that includes the thermostat, modulating damper, and diffuser in a single package. The VAV diffuser opens and closes to meter air flow into the occupied space in response to the room temperature set point. The dampers are modulated by thermal actuator thermostats.

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