Eero Saarinen, the architect who designed the St. Louis Gateway Arch, designed Deere & Company's headquarters in the 1960s. This complex of three buildings marks the first architectural use of Cor-ten steel.

Deere: Running Efficient

By Bruce Davis, Life Member ASHRAE

When John Deere invented his famous steel plow in his blacksmith shop in 1837, he also forged the beginnings of Deere & Company, which has grown to become a world leader in providing advanced products and services for agriculture, forestry, construction, lawn and turf care, landscaping, and irrigation. Deere & Company corporate headquarters, located in Moline, Ill., is one of the most celebrated headquarters buildings in the world.

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Designed by Eero Saarinen, the center's clean practical lines and earth tones have won accolades from architects since its opening in 1964. The headquarters site includes 533,639 ft^2 (49 577 m^2) (gross area) including a seven-story East Office corporate headquarters building, a three-story West Office with atrium, a main entrance display building, and 350-seat auditorium.

The buildings—designed of glass and weathered Cor-ten steel—reflect the industrial nature of Deere's business and the rugged design of John Deere products. When first occupied in 1964, the construction materials, methods, equipment, and furnishings installed were the best available. However, in 1964 there was no green building concept or LEED rating. After 45 years, improved equipments, materials, design methods, and controls became available to improve building energy efficiency. The question arose: "Can a 45-year-old building made of steel and glass be retrofit to establish a LEED Gold certification?"

The concept of dual fans, and a building energy simulation predicted that savings resulting from retrofit of the East Office HVAC system could justify renovation of the office building. This project was carried out during 2009 and 2010 with the aim of attaining LEED-EB Gold certification for the Deere Headquarters site. And results so far are seen in *Figure 1*, which shows site energy intensity by month.

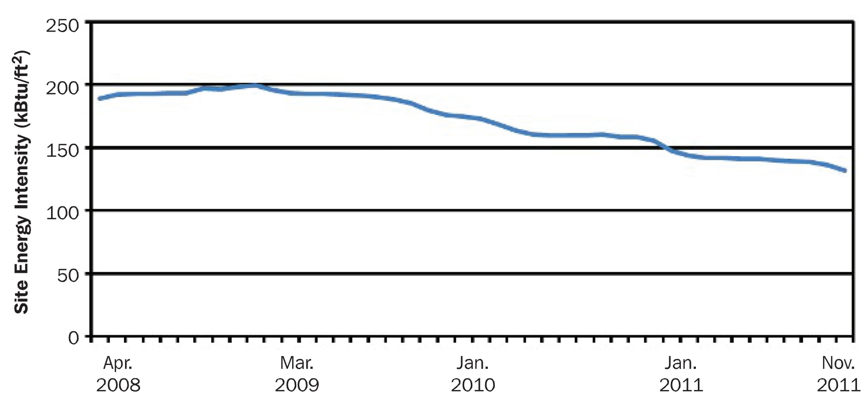

Figure 1: Results of site energy intensity by month.

Project Description

The East Office Building is the main office of Deere & Company World headquarters. A project begun in 2008 was designed for modernization and energy conservation purposes to revise the East Office Building HVAC penthouse air-handling system from a single fan constant volume mixed air system to a dual fans system (separate hot and cold deck fans). Above-ceiling mixing boxes were retrofitted from constant volume to dual duct variable air volume (VAV). In addition, single-pane glass on the original two buildings (East Office and Display building) was replaced with thermal glass.

Included in the project were two new roof hatches for moving materials into the HVAC penthouse; two new 150 hp (112 kW) return air fans with filters and discharge ductwork to supply the hot deck; 10 new variable speed drives for motor energy savings (total 1,000 hp [746 kW]); removal of old preheat coils and install of two new airflow measuring outdoor air dampers, install of a return air CO_2 sensor; install of 757 DDC retrofit kits to change DD-CV pneumatic-mechanical air boxes to DD-VAV with DDC airflow rings; and install of one penthouse and six floors of low-voltage wiring, DDC, and programming.

The following equipment room (partial) plan describes the HVAC penthouse system revisions that were installed in the East side. (The penthouse system has two sides—East and West—and matching elements were installed in the West side.) *Figures 2a* and *2b* show the installation of a new return air supply fan ducted to the hot deck and the split of existing supply fans to the cold deck, thus providing dual fans for the system.

Energy Efficiency Benefits

The work has transformed the DFDD-VAV system into a very efficient HVAC system. Previously, outside air and return air were constantly mixed and controlled to a mixed air temperature of 56°F (13°C) (±1). After retrofit, return air routed to heating coils increases the heating coil inlet temperature by 15°F to 20°F (–9°C to –7°C). Routing outside air directly to the cooling coils reduces air temperature to the cooling coils and permits 100% outside air cooling when available. Mixing of hot and cold air now occurs only when needed at the VAV boxes above the ceiling.

Indoor Air Quality Benefits

Outside air ventilation control is improved with return air CO_2 sensors and new outside airflow measuring and control dampers. Cold air ceiling VAV box dampers are controlled to a minimum required flow to maintain indoor air quality. Sound masking systems were installed to maintain consistent NC 35–38 sound levels in the offices despite the reduced HVAC airflows.

Innovation

A process of discovery led to the application. The following statement in a

Building at a Glance

Deere & Company East Office

Location: Moline, Ill.

Owner: Deere & Company

Principal Use: Offices and Meeting Space

Gross Square Footage: 533,639

Substantial Completion/Occupancy: 1964 to present, Retrofit completed March 2011

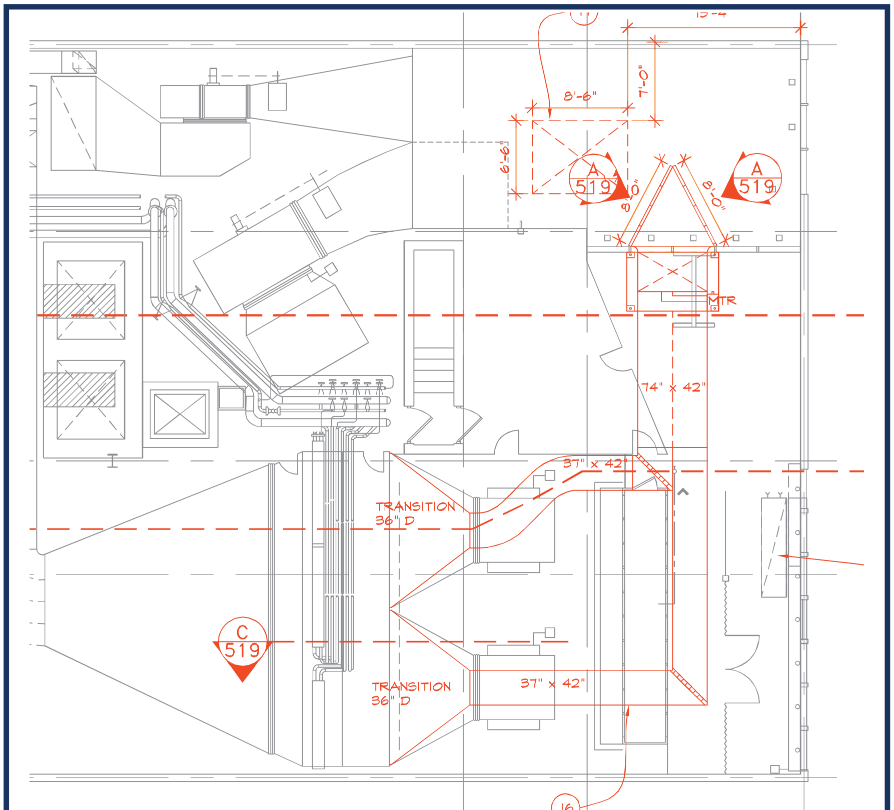

Figure 2a: Penthouse equipment room plan.

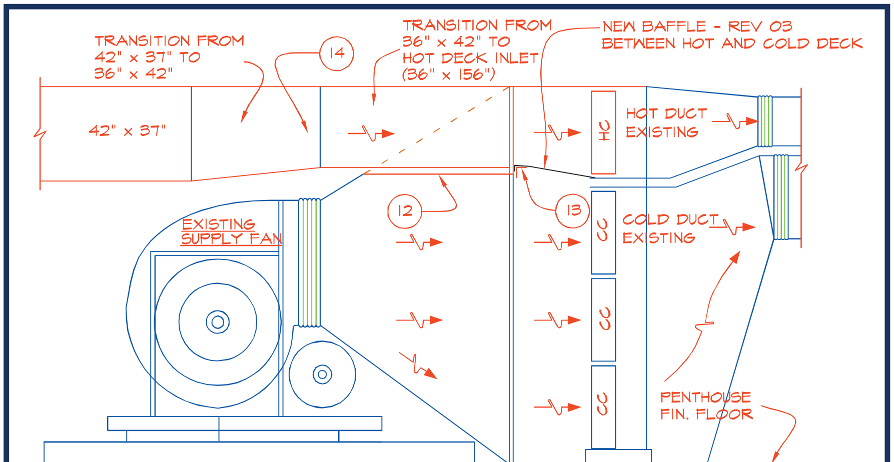

Figure 2b: Supply fan and coils selection.

2004 ASHRAE Journal article[1] led to investigating the DFDD concept.

"The dual fan dual duct (DFDD) system (at Topham Elementary School) uses *half as much heat per unit area* [emphasis is the author's] as any other system (in the Langley, BC, Canada, school district). Additionally, *records show the system has fewer problems and costs less to maintain*. Suitable for any climate, this inexpensive form of DFDD offers significant benefits not just for schools, but for most buildings where a central system can recirculate air to multiple spaces."

At Deere, it was necessary to ascertain how the dual fan concept might be implemented.

Space was found in the return air section for a new return air fan, and new return duct installation was found to be

Total Energy	Actual Energy (10^6 Btu/yr)			Actual Comparison Ratios		
Actual Energy	2008 (Before)	2009 (Partial)	2010 (75%)	2008/2008	2009/2008	2010/2008
Total Electric	51,771	45,747	44,857	100%	88%	87%
Total Gas	53,347	46,526	36,168	100%	87%	68%
Total Energy	105,118	92,273	81,025	100%	88%	77%

	Actual Energy Costs			Actual Comparison Ratios		
Actual Cost	2008 (Before)	2009 (Partial)	2010 (75%)	2008/2008	2009/2008	2010/2008
Total Electric	$710,168	$625,042	$626,432	100%	88%	88%
Total Gas	$461,511	$405,891	$220,057	100%	88%	48%
Total Energy	$1,171,680	$1,030,933	$846,488	100%	88%	72%

Total Energy	ECB–Predicted Energy (10^6 Btu/yr)			Actual to ECB Comparison Ratios		
Predicted Energy	ECB Before	ECB After	Ratio	Actual 2008	Actual 2010	Ratio
Total Electric	63,076	40,205	0.64	51,771	44,857	0.87
Total Gas	60,619	27,220	0.45	53,347	36,168	0.68
Total Energy	123,695	67,424	0.55	105,118	81,025	0.77

	ECB–Predicted Energy Costs			Actual to ECB Comparison Ratios		
ECB Cost	Before	After	Ratio	Actual 2008	Actual 2010	Ratio
Total Electric	$924,050	$588,995	0.64	$710,168	$626,432	0.88
Total Gas	$303,096	$136,098	0.45	$461,511	$220,057	0.48
Total Energy	$1,227,146	$725,093	0.59	$1,171,680	846,488	0.72

Table 1: Comparison of actual (site) energy use to predicted (ECB).

feasible. A building energy simulation was performed to prove the economic benefits. Each office building floor area was represented by at least 10 zones. The simulation included the main HVAC system covering 198,000 ft^2 (18 395 m^2) over six building floors and eight other HVAC systems, all fans, pumps, boilers, chillers, heat exchangers, and controls covering 379,000 ft^2 (35 201 ft^2) in office space plus support areas for a total 533,639 ft^2 (49 577 m^2) (gross area) on the gas and electric energy meters.

Operation & Maintenance Benefits

Existing pneumatic thermostats were replaced with wireless DDCs and air box controls were replaced for more accurate, reliable and flexible temperature control. VAV airflow valves control hot and cold flows at mixing box inlets. The mechanical constant volume pressure independent regulator in each air mixing box was removed to reduce supply duct pressure 1 in. w.g. (249 Pa). The existing mixing boxes continue in use as air-distribution boxes. New DDC airflow controls with flow measuring rings provide the following advantages over the previous pneumatics:

- Reduction of energy costs;
- Flexible thermostat placement;
- More stable control of room temperature;
- Real-time data gathering;
- Feedback to networked system;
- Remote airflow limit adjustment;
- Remote access for problem resolution;
- Ability to remotely override and test airflow boxes; and
- Reduction in maintenance time required.

Elimination of pneumatic devices above the ceiling will reduce maintenance and decrease energy use. DDC provided the means for improved remote control, increased reliability, and eliminated use of aged pneumatics. DDC provides the means for modern real-time control and the flexibility to adapt to future changes in building use. The economic benefit of DDC is great, and functionality is greater than a mechanical control system. DDC enables access and adjustment from any networked PC, automated collection and reporting of data, reduced problem analysis time, and reduction of operator time due to expanded span of control.

Cost Effectiveness

Capital funds were requested for the project to retrofit the HVAC system serving 198,000 ft^2 (18 395 m^2) on six floors. The project upgraded the system from a single fan dual duct, constant volume to a dual fan dual duct, variable volume system. This transformed the mechanical HVAC system into one of the most efficient that can be achieved.

Savings from the proposed revisions to the HVAC systems were analyzed with the use of a comprehensive building energy analysis computer program. Originally, considering only HVAC revisions, analysis predicted 35% yearly savings and qualified the project for approval.

In the retrofit project now completed, the glass on the older two of the three buildings was replaced. (Original glass U-factor = 0.93, new glass U-factor = 0.29.) Predicted annual energy savings rose to 41% but return on investment was reduced due to significant increased cost. The local utility awarded the project a $1,112,000 energy savings rebate incentive.

An energy cost budget (ECB) was produced. *Table 1* is a comparison of actual energy use vs. predicted energy use. For

2010 a total energy use of 72% of 2008 was recorded vs. the 59% predicted by the energy cost budget. But the difference for 2010 was due to the timing of the 12-month long floor-by-floor retrofit project that began about April 2009 and was fully completed in April 2010. The energy reduction data for 2010 includes about eight out of 12 months of expected benefits.

LEED commissioning was completed in March 2011 and yielded additional benefits. For example, supply duct static pressure dropped from 4 in. to 2 in. w.g. (996 Pa to 498 Pa). The system was monitored for a six-month LEED performance period from April to September 2011. Energy reduction trends predict that energy use will approach 59% of previous as predicted by the ECB. Commissioning created significant overall energy savings of 14.62% on a kBtu/ft^2 basis, and an increase in the ENERGY STAR building score from 54 to 66 (extrapolated using December 2011 data). Annual utility cost savings of $54,200 yielded a simple payback of 2.2 years for the commissioning effort.

Environmental Impact

The project returns significant energy savings. Analysis predicts a 55% reduction of heating gas, a 36% reduction of electric kilowatt-hours, and a total cost reduction to 59% of previous. Greenhouse gas release will be reduced by 5,540 tons for electric reduction and 3,219 tons for natural gas reduction in carbon equivalent per year.

Indoor air quality will be improved. CO_2 sensors have been added to the return air plenums for demand control monitoring of the ventilation systems. Outdoor airflow measuring was installed to measure ventilation airflows. One hundred percent economizer cooling control is now programmed. DD-VAV mixing box cooling valves are controlled to a minimum open as required ensuring better indoor air quality. An occupied/unoccupied control procedure has been implemented.

Conclusion

Several benefits were obtained by the project. Certainly significant energy savings are returned by the HVAC system revisions. Wireless thermostats blend easily with landscape furniture and avoid wiring costs. Sound masking systems installed present near optimum space noise characteristics despite reduced airflows in the HVAC system. ENERGY STAR rating is up from 28 to 66 and still rising! Simulation and actual site energy predict the revised system will attain a rating of 65 or better to enable LEED Gold certification. The total improvements befit the environmental expectations of the world headquarters campus of Deere & Company.

References

1. Warden, D. 2004. "Dual fan, dual duct goes to school." *ASHRAE Journal* 46(5). ■