The Heat Wheel: A New Lab Experiment

Laboratory ventilation is always a delicate proposition (and often a contentious topic). Heat wheel technology is a known quantity, but it is not often seen in lab applications. So how did it wind up in the design for a new $20 million facility at Indiana University? A long schedule and a close look at everything from contamination testing to project accounting paved the way.

BY JOHN SAUER, P.E.

Energy efficiency, lower costs, and assurances of safety were key factors in Indiana University's decision to use heat wheel technology in its new $20.8-million Professional and Medical Education Building in Gary, IN. The decision was intensely discussed and researched. Heat wheel technology generally is not used in laboratory buildings because of the fear of contaminating incoming ventilation air with lab exhaust air. The circumstances surrounding the facility made the choice of a heat wheel system appropriate once all factors were considered.

This new building will replace an older facility, which was no longer conducive to modern education techniques with inadequate systems and teaching facilities. Enrollment at the regional medical school was declining when the overall trend for the University was increasing. Planning for the new facility began in 2001, first phase construction will be completed in July 2004, and the entire project will be completed in July 2006.

The new building will consist of 126,250 square feet of medical education spaces, including exam rooms, X-ray rooms, operating rooms, gross anatomy laboratories, nursing areas, tissue culture rooms, procedure rooms, and dental teaching areas. Among other specialty areas are teaching laboratories, animal spaces, study areas, lecture classrooms, advanced technology classrooms, as well as general staff offices, student common areas, and lounges.

CHALLENGES

As is always the case with state universities in tough economic times, cost of new construction is debated and discussed

Added First Costs	
Heat wheel system:	$200,700
Added controls:	$5,000
Added electrical:	$3,000
Added penthouse space:	$104,300
Total added cost:	$313,000
Saved First Costs	
Chiller system:	$160,000
Heating system:	$73,000
Control system:	$162,000
Total saved costs:	$395,000
Net saved first costs:	$82,000 (Added building value)
Annual Costs	
Added fan energy:	$4,200
Added energy for constant volume:	$4,400
Total annual costs:	$8,600
Annual Savings	
Cooling energy:	$19,400
Heating energy:	$58,200
Total annual savings:	$77,600
Net saved annual costs:	$69,000 (Lower operating costs)

TABLE 1. The addition of a heat wheel to the Professional and Medical Education Building at Indiana University reduced first costs and, ultimately, annual energy costs.

throughout design. By nature, University buildings are designed to last at least 50 years, with engineering systems designed to be replaced only once during the life of the facility. The challenge with the Gary project was to design and build a facility that would endure over time but at a relatively low cost. In addition, University operating budgets were not keeping pace with the added needs for energy and maintenance costs.

The site also presented challenges. It had a high water table, thus preventing the use of a basement without significant added cost for special construction techniques. All construction needed to be above ground. Once it was determined that the new building would use the footprint of the existing building and a small adjacent parcel of land, the challenge of maintaining the business of teaching in the existing building throughout construction was added to the mix.

Finally, the campus has a central chilled water utility system that will connect to the new building. This requires expanding the distribution system and increasing the plant capacity to meet the new cooling load of the building. Heating requirements will be met within the new building by gas-fired hot water boilers.

PHASING STRATEGY

The much larger new building could not be accommodated by the existing building's footprint. Thus, an adjacent parcel had to be added to the project. A decision was made to build the facility in two phases over a four-year period. This would allow teaching to continue throughout the project and save costs by not having to provide temporary facilities or pay a premium for a condensed building schedule. The first phase would be built on the adjacent parcel while the existing facility remained open for teaching.

Once the first phase is completed this July, the existing facility will be demolished and classes will be moved into facilities in the finished section, which will contain most of the medical and professional education laboratories. The second phase will then start and embrace the old building's footprint. When both phases are completed, the building is designed to appear as one facility.

To make the phasing work, much of the systems infrastructure of the building, such as utility distribution and energy production, had to be completed in the first phase with provisions to be connected during the second phase without interrupting classes.

ENERGY RECOVERY

The issue of inadequate central system cooling capacity and operating cost was more challenging. The central cooling plant was already stretched to its maximum and the existing distribution system had little available capacity. Cooling requirements were estimated at approximately 560 tons for the new facility. Because most of the teaching facilities completed in phase one require once-through air systems, conditioning of the high amount of makeup air in summer and winter dictated larger equipment with a higher capital cost and increased operating expenses.

Energy recovery systems became the focus to solve the problem. Up to this time, the vast majority of energy recovery systems used for this building type throughout the nation were relatively inefficient. The conservative nature of engineers normally meant that energy systems were designed to accommodate the peak load as though the recovery system was not there. The inefficiency of most recovery systems, coupled with the small change in peak load savings, dictated the smart approach of full size production equipment.

Most heat recovery systems used in laboratory building are runaround systems. Coils are placed in the exhaust airstream leaving the building as well as in the incoming airstream feeding the AHUs. A combination water/glycol solution is pumped back and forth between the coils absorbing heat from the warmer airstream and depositing it in the colder airstream.

In Gary, heat will flow from the exhaust airstream to the inlet airstream in winter, preheating the incoming air. In summer, the opposite will happen, which will, in effect, precool the incoming airstream. This system has several advantages. First, the exhaust airstream and the inlet airstream can be as remote as needed to accommodate the floor plan layout and the requirement to separate the building exhaust air from the building intake air. Second, there is no chance of cross contamination from the airstreams and, thirdly, the cost of the equipment is relatively low and has an attractive payback.

The disadvantages include a relatively inefficient amount of energy recovery, which does not normally allow significant reduction of centralized production equipment. Runaround systems have only about a 55% sensible heat effectiveness. These systems exchange sensible heat, which is only one component of the total energy picture. Latent heat, especially in humid summer conditions, becomes the overriding driving factor for the sizing of central production cooling equipment and related systems.

The relative cost of cooling equipment to heating equipment is

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much higher and any significant reduction in the cooling load can pay handsome dividends. Other sensible heat recovery methods, such as heat pipes (50% sensible effectiveness) and plate heat exchangers (75% sensible effectiveness) fall into the same category of runaround systems with respect to savings and the minimal reduction in cooling equipment costs.

HEAT WHEEL DECISION

Project accounting at Indiana University dictates that when a building is connected to the central cooling plant on campus, the building budget will reimburse the central plant at a rate of $1,000 per ton of cooling demand. In this case that equates to $560,000, money that would be taken from the building budget thus reducing building value. This predicated the serious look at heat wheel technology, which has been around for many years.

A heat wheel is comprised of a desiccant-coated matrix. The wheel rotates slowly, typically about 20 revolutions per minute, between the building exhaust and supply airstreams. The desiccant medium transfers heat with a total energy effectiveness of 75% to 85% by absorbing and transferring vapor from one airstream to the other. Both sensible heat and latent heat are exchanged. Applying this technology to this building would mean a savings of 30% of the cooling demand (162 tons) and 40% of the heating (and humidification) demand (two million Btu). The savings are less than the efficiency listed above because the heat wheel would only be applied to the portion of the building containing labs. However, a first-cost savings could be realized along with a yearly savings in energy cost.

Applying the heat wheel technology also affords the chance to simplify laboratory air system control costs. Without using heat recovery or even with the use of a runaround system, economics has driven the use of VAV laboratory hood design. Minimizing the amount of makeup air to laboratories pays dividends in energy cost savings. Variable flow hoods only use the amount of air required at the time of use and minimize the flow while not in use. However, to accomplish this, the controls are complicated and expensive. By using a heat recovery system that is 80% effective for both sensible and latent heat, constant air volume can be considered. Simplifying the control system greatly reduces control costs without a significant energy cost penalty.

ECONOMICS

Before moving forward to investigate the risk and layout issues associated with heat wheel applications, we calculated the economics to justify the system. What we found justified its use (Table 1).

The addition of a heat wheel to the laboratory part of the building accomplished the goals of reducing the first costs and providing savings on annual energy costs. Added maintenance costs for the heat wheel were not estimated but will be more than offset by the savings in control cost maintenance associated with the control simplification.

ASSESSING RISK

The main obstacle to using heat wheel technology in laboratory applications is dealing with cross-contamination into the supply airstream. This is a very serious issue and much time and effort was invested in designing and testing systems in laboratory applications.

Although limited, this technology has been used for this application in the past with as much as 13 years of continuous operation. The Johns Hopkins Ross Research Building has eight 14-ft diameter 3-angstrom (Å) heat wheels installed, and flowing 450,000 cfm of air. Connected to the exhaust are 164 fume hoods, 154 biosafety cabinets, and general exhaust. This system has been in successful operation for 13 years. Testing over that time has confirmed the energy savings and safety of the system.

Our project team focused on a heat wheel system using the 3-Å molecular sieve, which prevents the transfer of larger molecules. All molecules larger than three angstrom pass by the wheel without being absorbed into the underlying desiccant medium. Water vapor at 2.8 Å passes through the sieve so that latent energy is recovered. With a heat recovery wheel and this selective adsorption feature, cross contamination has been virtually eliminated. The 3-Å sieve does not transfer bacteria and viruses because they are too large for the 3-Å pore. Viruses run in the 3,000-Å range and higher, while bacteria run in the 10- to 100-Å range.

Independent testing has been done by several organizations such as the University of Minnesota, Georgia Institute of Technology, and John Hopkins Institute. Testing was conducted in the laboratory as well as actual building applications, including new facilities and those with many years of service. Testing also was conducted with a wide variety of compounds and chemicals including ammonia, formaldehyde, hexane, carbon dioxide, o-xylene, isopropanol, propane, and sulfur hexaflouride. Potential sources for carryover include wheel carryover, purge ineffectiveness, seal leakage, and system short-circuiting. Spill scenarios were also considered in the testing.

Testing confirmed that contamination of exhaust air with supply air using a 3-Å wheel with a proper purge design is extremely low and is not a concern to health. In many cases, the chance of contamination is higher from outside-of-building recirculation of exhaust air or by plain ambient air pollution.

Other issues need to be considered such as certain research that cannot tolerate even a minute amount of carryover. This research should be conducted using dedicated isolation systems. Analysis of the chemicals used in the Medical Education Building along with the high volume of dilution air indicate that the carryover rate will be even less than those tested by independent organizations.

Testing has also concluded that the 3-Å sieve's performance has not significantly deteriorated over time. With only one moving part (the wheel) and one motor to drive the wheel, concern over a major failure is minimized. A spare motor can be kept as a replacement. Even in case of failure, systems have adequate capacity to keep the building well above freezing in the winter.

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BUILDING SYSTEM LAYOUT

The main mechanical room housing the energy and utility equipment was placed on the first floor of phase one construction in order to provide the infrastructure required for both phases, provide for easy equipment replacement, and to compensate for the high water table and the inability to have a basement. A utility corridor was established for the main utilities that would eventually feed phase two construction. The systems were designed so that no interruption would take place when both sections are connected.

To effectively apply the heat wheel technology, the supply and exhaust airstreams must pass in close proximity to one another. To accomplish this and still ensure the proper separation of exhaust air relief and supply air intake, we located the heat wheel in the penthouse along with the air-handling equipment. Laboratories were located on the upper floor of the first phase of the building where duct runs for the large exhaust and supply ducts could be kept to a minimum. This also minimized shaft space, maximizing building floor area efficiency.

Outside air was ducted from the penthouse and pulled through louvers at the second floor level on the prevailing upwind side of the building. Two constant volume exhaust fans with stacks located well above the penthouse roof exhausts the labs at a fast velocity to thrust it high above the building.

Solutions come in many forms. In this case, taking advantage of a long schedule let us utilize the existing building while we were construcing part of a new building. By designing the building to be built in phases, we accomplish the goal of uninterrupted teaching while staying within budget. The use of this rarely used technology for laboratory buildings enabled us to add value, while lowering operating costs. In the end, once the building is completed, Indiana University will have a medical education complex that will enable those who need to attend a local campus a chance to succeed in the field of medicine. ES

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