BEST PRACTICES 2010

UC Irvine Exhaust Stack Discharge Velocity Reduction

Careful analysis and wind tunnel testing identified opportunities for energy reduction by reducing exhaust air velocities at four campus labs. Retrofits incorporating variable frequency drives, exhaust stack extensions, and tuned control strategies resulted in significant cost and energy savings.

Award Category

HVAC Design and Retrofit

Green Features

Reduced velocities established through wind tunnel studies

Exhaust stack extensions

Variable frequency drives

Dynamic exhaust duct static pressure reset

Annual Energy and Cost Savings

2141 mWh

$225,000

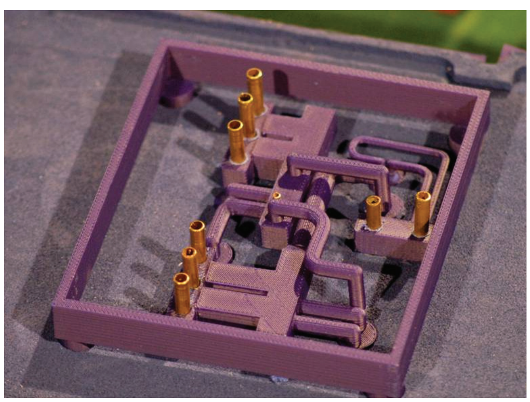
Cost

$800,000

Completion Date

Winter 2010

Laboratory buildings are highly energy intensive, and may have five to ten times the energy intensity of typical office buildings. At UC Irvine, lab buildings consume approximately two-thirds of all campus energy consumption. With energy bond financing from the UC Office of the President, and incentive payments from the UC/CSU/IOU Energy Partnership, campus staff and design consultants collaborated to identify strategies for HVAC energy savings in campus laboratories, focusing on the reduction of exhaust system energy use. The project was led by the UCI energy team, with staff from Facilities Management and EH&S, as part of a "Smart Laboratory Concept" to incorporate multiple retrofit strategies aimed at providing efficiencies of 40-50 percent below ASHRAE and Title 24 standards.



Detail of wind tunnel model used to evaluate exhaust plumes and velocity requirements. Photo: Ambient Air Technologies.

Exhaust ventilation is a major contributor to the energy intensity of laboratory buildings — a single fume hood running continuously can use more energy than several typical homes. However, advanced operational strategies can greatly reduce exhaust fan energy use. Laboratory exhaust systems are commonly designed to maintain high exhaust velocities of up to 3500 fpm (close to 40 mph) to ensure that contaminants are well dispersed, and do not re-enter the lab air supply, or impact other buildings, pedestrians, and/or facility staff. When the airflow volume from exhaust hoods is not sufficient to maintain standard exit plume velocities, exhaust systems induce additional "plenum bypass" air — additional outside air brought into the airstream. However, excessive use of bypass air is an indication of wasteful operation.

By reducing the minimum airflow below 3000 fpm, it's possible to greatly reduce exhaust fan energy use. The fundamentals of fan dynamics also provide opportunity — because fan energy is a function of air velocity cubed, a 50 percent velocity reduction theoretically could yield an eight-fold energy savings.

Wind tunnel testing is an effective method to identify opportunities for exhaust velocity reductions, while maintaining safe operation.

The project team first collected information from a number of campus labs, identifying the chemical inventories for each lab, and making physical observations of damper positions to identify buildings using the greatest amount of plenum bypass. Buildings that operated frequently with plenum bypass were considered the best candidates for more thorough analysis. The team finally identified four priority buildings for retrofit: Croul Hall, Natural Sciences II, Sprague Hall, and Hewitt Hall.

The team then contracted with Ambient Air Technologies to conduct wind tunnel studies that would establish detailed retrofit options for each building. Chet Wisner, president of the firm, explains in project presentations that wind tunnel testing is the most reliable method for modeling wind flow around buildings, and for evaluating the dilution of contaminants in exhaust plumes. The tests were conducted using 1:200 scale models of

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Project Team

Wind Tunnel Testing: Ambient Air Technologies

Mechanical Engineering: P2S Engineering

More Information

http://www.slideshare.net/cabbamonto/exhaust-stack-discharge-velocity-reduction

http://www.slideshare.net/cabbamonto/labs21-esdvr-2009-final-wisner

http://www.labs21century.gov/pdf/bp_modeling_508.pdf

large sections of the campus. The tests took into account the locations of other campus buildings, including air intake locations as well as trees and terrain, and used a combination of smoke visualization and tracer gas analysis.

These tests provided the minimum exhaust velocities required for safe operation, and identified which buildings would require stack extensions. Since changes to exhaust systems concern the health and safety of all campus populations, UCI's EH&S staff was involved throughout the project.

With the wind tunnel results in hand, the team selected the most cost-effective retrofit combinations of variable frequency drives (VFDs), static pressure reset, and/or exhaust stack extensions. Since the taller stainless steel exhaust pipes would be visible from ground level and from adjacent buildings, they required approval by the design review team (DRT). Matt Gudorf, UCI's Campus Energy Manager, explains that securing the DRT's approval was not difficult, as visible exhaust stacks and other types of rooftop equipment have become more common on campus. With the current interest in energy savings on UC campuses, design reviewers may be more prone to agree with the adage that form follows function.

Projects that do not require stack extensions and VFD retrofits are likely to be the most cost effective in terms of simple payback.

The selected options were finally incorporated into design documents prepared by the project mechanical engineer, P2S Engineering, and the retrofits were completed during the fall of 2009. The total project cost for the four buildings was $800,000, and will yield savings of $225,000 per year, resulting in a simple payback of just over 3.5 years. With incentives taken into account, the simple payback on the individual buildings varied, from 0.9 years at Sprague Hall, to 9.8 years at Hewitt Hall. Actual energy savings have been documented for rebate requirements, and are in line with predicted estimates.

Exhaust stack extensions installed at Croul Hall. Photo: UC Irvine.

LESSONS LEARNED

The project's success has led the campus to contract for wind tunnel analysis on the remaining 15 lab buildings on campus, and to implement similar retrofit strategies. Chet Wisner explains that UC Irvine's Natural Sciences I lab is expected to be the first operational implementation of a "wind-responsive" exhaust fan control system. In wind-responsive mode, rooftop sensors measure wind speed and direction, and indicate when exhaust ventilation speeds can be reduced, resulting in large energy savings.

Matt Gudorf notes that payback times can be reduced in buildings that already have VFDs installed, and/or do not require stack extensions. He notes that some exhaust stacks are more costly than others to retrofits, and that care must be taken when designing stack extensions to insure that the structural design solution is cost-efficient. He also notes that raising the stack heights by 4 to 8 feet can allow for greatly reduced exhaust velocities, but that extensions beyond that height generally do not provide greater efficiency.

Best Practices case studies are coordinated by the Green Building Research Center, at the University of California, Berkeley.

The Best Practices Competition showcases successful projects on UC and CSU campuses to assist campuses in achieving energy efficiency and sustainability goals. Funding for *Best Practices* is provided by the UC/CSU/IOU Energy Efficiency Partnership.