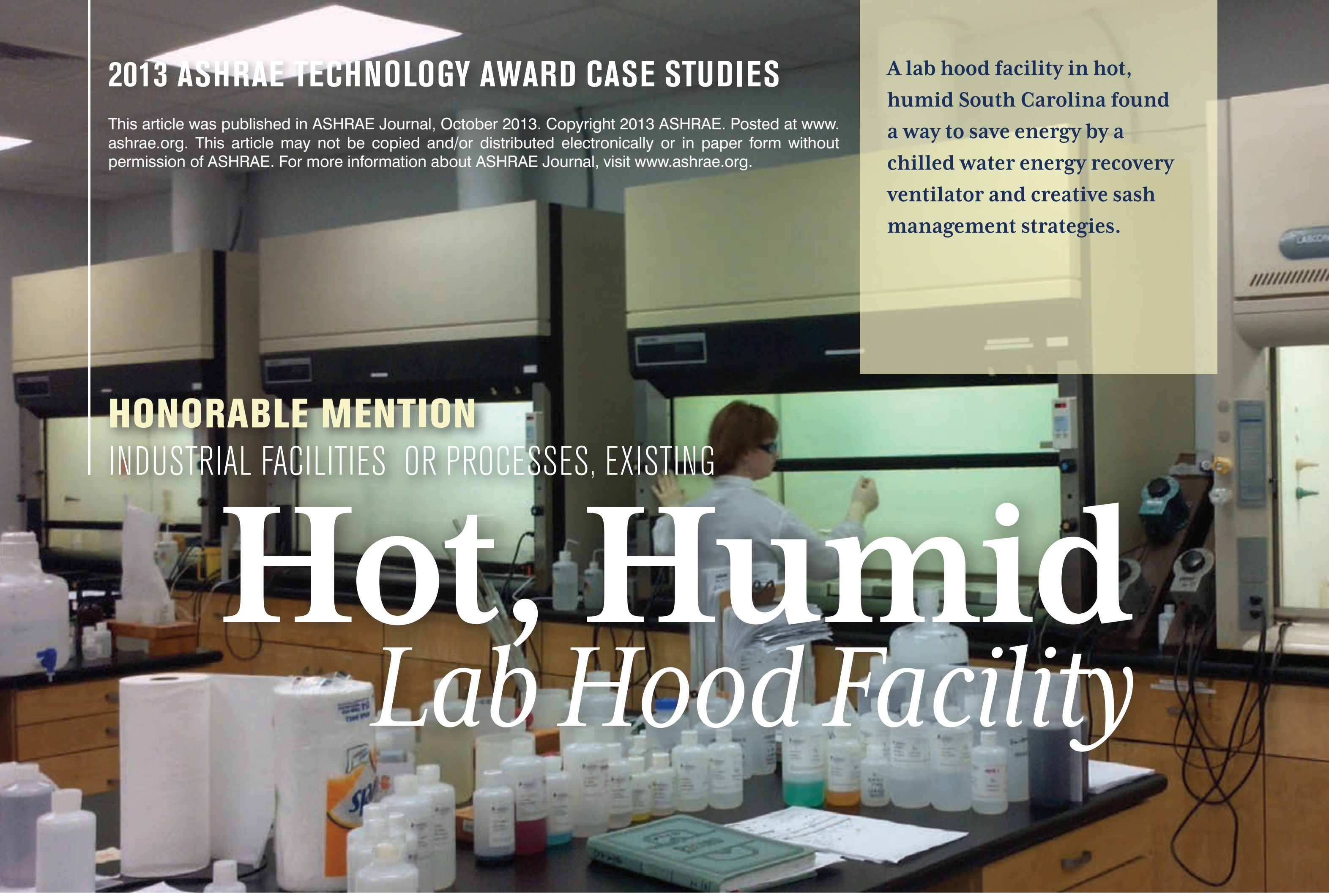

2013 ASHRAE TECHNOLOGY AWARD CASE STUDIES

A lab hood facility in hot, humid South Carolina found a way to save energy by a chilled water energy recovery ventilator and creative sash management strategies.

HONORABLE MENTION

INDUSTRIAL FACILITIES OR PROCESSES, EXISTING

Hot, Humid *Lab Hood Facility*

BY ROB TURNER, P.E., MEMBER ASHRAE

BUILDING AT A GLANCE

High Purity Standards

Laboratory

Location: North Charleston, S.C.

Owner: Connie Hayes

Principal Use: Chemical Lab Hood Facility

Employees/Occupants: 40

Gross Square Footage: 18,000

Conditioned Space Square Footage: 14,180

Substantial Completion/Occupancy: April 2011

Occupancy: 100%

Lab hood facilities are one of the most wasteful types of buildings constructed because tremendous quantities of fresh air are needed to make up the lab hood exhaust air. In South Carolina, air conditioning hot, humid outside air can be expensive. Also, it must be dry and cool in the lab, but it's difficult to recover the energy in chemical lab exhaust air because the toxic fumes and vapors can destroy the wheel substrate in an energy recovery ventilator (ERV) or cross contaminate the incoming fresh air and harm occupants.

In addition, ERVs connected to lab hood exhaust are not allowed by code (for direct communication with the lab hood exhaust). So how do we build these systems and save energy while maintaining quality and safety?

ABOUT THE AUTHOR
Rob Turner, P.E., is a mechanical engineer at Charleston Engineering in Charleston, S.C. He is a member of ASHRAE's Charleston chapter.

ABOVE Variable speed exhaust fan.

LEFT High Purity Standards produces chemical spectrometric standards used by other chemistry labs around the globe to measure and verify their chemicals.

High Purity Standards (HPS) uses chemical science labs to produce chemical spectrometric standards. These certified standards are used by other chemistry labs around the globe to measure and verify their chemicals. It is a bit like manufacturing high precision scale weights that are used as standards of weight measurement.

In addition to standards, HPS prepares custom chemical blends and difficult to prepare special mixtures. Many lab hoods and technical machines such as spectrometers are required for this high precision business.

The company moved to a new larger 18,000 ft^2 (1700 m^2) building (14,180 ft^2 [1300 m^2] of temperature-controlled space) in April 2011. Previously, HPS was housed in a smaller set of buildings that had minimally effective mechanical systems. These buildings totaled about 9,000 ft^2 (836 m^2) (approximately 8,000 ft^2 [743 m^2] of temperature-controlled space).

The new building has multiple organic and inorganic labs, a shipping department, and an administration area. Today, the company employs more than 40 chemists, sales associates, and shipping specialists.

The basic description of the new HVAC system in the labs is a variable volume hood exhaust system with a variable volume makeup air system. The makeup air air-handling unit has an ERV (not like the one discussed earlier) and a chilled water cooling coil with modulating gas heat. The exhaust and makeup air for each lab hood and each space are controlled with venturi-style control valves.

These control valves are actuated by the sash-height sensor at each lab hood. The entire HVAC system is controlled by a direct digital controls system. The pressure control design consists of a balanced building with various positive and negative spaces. The labs achieve the proper minimum turnover rates via a variable general exhaust valve. Sash management strategies in the labs are used to save energy and cost.

Energy Efficiency

The previous business location consisted of multiple basic metal buildings with minimum code-required insulation. There were R-19 insulation batts on the lay-in ceiling grids (which is not allowed by code today), R-15 in the walls, and a number of flaws in the envelope.

The mechanical systems used at the previous location were split system heat pumps with local thermostats. All of the lab hoods had a dedicated constant speed exhaust fan with a switch on the hood. There was no machine for makeup air. It was just drawn into the building through the doors, cracks, and flaws in the envelope. As a result, multiple stand-alone dehumidifiers had to be used in the critical areas where high humidity would affect quality.

The new building was an existing metal building with concrete walls. It had R-11 continuous insulation at the roof. It was brought up to code by adding R-19 in the attic (achieving R-30 total), and rigid insulation at the exterior walls to provide a total of R-19. There were a number of cracks and flaws in the envelope that were meticulously patched and sealed. The walls between the conditioned space and the unconditioned shipping

High Purity Standards mechanical room.

warehouse were fully insulated up to the deck. The attic was designed as a sealed attic.

The hood exhaust as well as the general/room exhaust was split into two exhaust systems based on chemical compatibility. This required one system to be made out of fiberglass ductwork, and one to be metal duct. Both exhaust systems are variable speed. Since each exhaust system is variable speed, the roof discharge duct sizes had to be sized such that they would be small enough to allow the discharge velocity to never fall below the code-required minimum. Having said that, consideration was given to sound issues with the high fan speeds. Each fan was wrapped with sound insulation from the fan discharge up to the roof as seen in the photo above.

This true variable speed system saves substantial power compared to constant speed fans. Details will be explained in the Innovation section about the sash management plan that further saves energy.

With the exhaust system being variable speed, the makeup air system is variable speed as well. The makeup air system is a custom chilled water AHU with an ERV wheel. As will be detailed in the Cost Effectiveness section, there were a lot of cost issues and value engineering efforts. Chilled water cooling for the variable speed makeup AHU system was nonnegotiable.

I believe that a DX unit cannot hold temperature and humidity as well as a chilled water unit for a complex variable speed AHU system. This ERV system is different from the traditional ERV system (see detail in Innovation section). The hot fresh air would follow a U-turn route through the custom AHU.

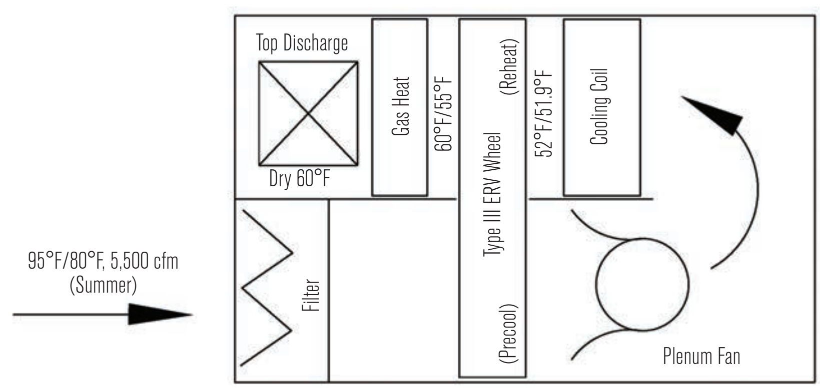

FIGURE 1 Makeup air unit.

Instead of using the hood exhaust air (which is not allowed due to the chemical vapors that are present), it basically provides free reheat for the dehumidification process. The hot fresh air would enter the AHU and be cooled by the right side of the ERV wheel. Then the air would do a U-turn and go through the cooling coil. At that point the cold air would be reheated by the left side of the ERV wheel. It would discharge at a very dry 60°F (16°C).

At 60°F (16°C), there is enough capacity to cool the labs, but it will not require too much final electric reheat at the venturi control valves. Therefore, most of the reheat is free. In the winter, a modulating gas-fired heat exchanger in the AHU will heat the air up to 60°F (16°C) as necessary.

For the areas that do not have lab hoods, the air conditioning is provided by split system heat pumps. These provide efficient cooling and very efficient heating. The entire building is balanced so that there is little infiltration. Control of infiltration limits unintended air-conditioning costs.

As will be detailed in the Innovation section, only one chilled water pump and one three-way valve was designed in lieu of a constant speed circulator pump and a variable speed pump. This saves initial cost and energy. The control system will set back temperatures automatically in the unoccupied mode.

Based on the available data in *Table 1* for months where occupancy was 100%, the total increase in square footage was more than 75%, while the energy usage only increased by 28%. In addition, the new building housed additional computers,

Table 1 Comparison of energy use in old and new HPS facility.

MONTH	OLD FACILITY (MWH)	NEW FACILITY APRIL 2011 (MWH)
MAY	28.9	20.8*
JUNE	29.0	46.3
JULY	32.7	44.1
AUGUST	31.2	--.-
SEPTEMBER	27.3	38.7
OCTOBER	20.7	29.4
NOVEMBER	19.0	21.7
DECEMBER	24.0	24.8
JANUARY	23.7	24.9
FEBRUARY	20.5	22.3
MARCH	18.8*	24.7
APRIL	13.1*	24.6

* Indicates time during transition from moving to new building (occupancy was less than 100%).

Note: Gas heating is used at the new facility at the ERV fresh air unit. Average winter monthly gas bill was about $250.

machines, and other new high-tech heat-producing equipment. The overall building humidity was much lower and more consistent.

IAQ and Thermal Comfort

In the previous building, none of the split systems had any fresh air ducted to them. The lab hoods brought in enormous quantities of hot, humid, infiltration air through the cracks of the building. There were significant humidity issues that had to be locally controlled with standalone dehumidifiers. When a large number of lab hoods were being used, the temperature could swing wildly. Some areas had the beginnings of mold formation.

The new building provided a significant improvement. The most difficult part of the design was designing the air control valves at the hoods and at the makeup air supplies. A generic calculation sheet was used to calculate the air valve flow minimums and maximums, as well as the room pressure relationship. After factory set up of these values, the venturi air valves could properly react to the particular open sash height(s). Recall that the higher the sash is opened, the more exhaust and makeup air is required. This equipment and design is critical to comfort and performance in the labs.

With the new systems in the new building, the code-required fresh air was designed at every split system AHU per ASHRAE Standard 62.1-2004. In addition, there was a controlled makeup air system (fresh air) that was designed to produce a 51.9°F (11°C) wet-bulb leaving air temperature at the cooling coil on a design day. This produced makeup air around 44% RH in the humid summers of Charleston. Indoor design conditions were targeted with ASHRAE Standard 55.

Innovation

The first innovative design detail is the "sash management" design. This principle was implemented for energy savings and budget concerns (which will be covered in the Cost Effectiveness Section). "Sash Management" can have multiple meanings, and typically refers to the practice of closing the hood sash when not using the hood. This will save energy.

But in the case of this project, it goes further. The concept of diversity was applied to the design of the lab hood systems. The facility has 14 lab hoods. If all of these hoods were to be used at the same time, the makeup air unit would need to be more than 10,000 cfm (4700 L/s), and around 100 tons (352 kW).

For reasons of first cost, operating cost, and sustainable operation, the system was designed such that no more than seven hoods could be used simultaneously at full open sash. This was a rule required for the lab technicians that reduced the makeup air unit to half the cfm and half the tonnage capacity (smaller chiller required). The owner was agreeable with this because each hood has particular uses that are relatively easy to schedule at mostly separate times. In addition, the exhaust system was downsized.

A variable speed chilled water system is usually designed with a constant speed circulator pump, which maintains a constant flow through the chiller, and a variable speed building pump that supplies cold water from the chiller loop to the coils that demand it. Since there was only one cooling coil to serve, the system could be designed with one pump. Basically, a large circulator pump was used with a three-way valve at the single cooling coil for the building. The AHU, the pump, and the chiller are all directly adjacent to each other. The pump cuts on and off with the chiller. With one pump, there is less energy used than the two-pump solution described earlier. This design is only effective if there is only one coil for the system to serve.

The design of the custom ERV makeup air unit was innovative. Since caustic and acidic exhaust could not be used in the ERV, a unique application of the ERV wheel was selected. This ERV wheel will both pre-cool the hot incoming fresh air, and reheat the very cold discharge air off the cooling coil.

Reheating the air to 60°F (16°C) will provide plenty of cooling in the lab environment because high airflow rates were required due to high room turnover rate requirements. But the real advantage is that less of the final electric reheat at the air control valves will be required (*Figure 1*, Page 43).

Operation and Maintenance

The operation and maintenance was greatly improved with the new designs. All of the following items are improvements over what was existing. Each new split system heat pump is either located in a mechanical room, hung overhead in the warehouse, or located on a fully accessible mezzanine. The units in the old building were mostly hung above the insulation above the ceiling. The custom AHU and chilled water piping system is located in a dedicated mechanical room with double door access and plenty of room. All of the piping components (buffer tank, expansion tank, pump, pot feeder, etc.) are neatly lined up against the wall for easy access.

The air-cooled chiller is on a pad directly outside. The DDC system allows centralized manipulation, scheduling, and automatic control. The chilled water makeup AHU is a very simple machine. This simplicity was considered as another reason not to go with a much more complicated DX system. Maintenance will be relatively easy as a result. Finally, a cooling tower was considered (with a water-cooled chiller), but ruled out due to cost and maintenance. The air-cooled chiller will be significantly easier for maintenance operations.

Cost Effectiveness

The budget for the job (not including the new property) was $1,000,000. I was able to convince the owner and architect that the HVAC budget would need to be at least 50% of the total budget ($500,000). Even so, I was doubtful that we could buy a good HVAC system for this sized lab building for that budget.

The first design included a 125 ton (440 kW) chiller, chilled water blower coils throughout, the larger makeup air ERV, and a full DDC system for all spaces. There was no sash management with this design. There was a full primary-secondary pumping system. There was a gas-fired boiler with piping system to the reheat coils as well. When the first budget numbers came back, the numbers landed at just under $900,000. The owner was shocked.

We deleted the chilled water blower coils and replaced them with heat pumps. We also deleted the boiler and used heat pump heating, some electric heat, and a gas fired heater at the makeup AHU. Then we cut the size of the chiller down to 50 tons (175 kW) by implementing my sash management concept. A DX makeup air system was looked at, but rejected because of its complexity and because of the superior temperature and humidity control of chilled water systems with variable airflow. The air control valves were evaluated for value engineering as well. The design called for venturi-style air control valves modulated by the lab hood sash-position sensor.

Other less expensive air control equipment needed to measure airflow to control it. This has inherent inaccuracies. This situation is not advisable if you want prolonged comfort and precision, therefore, the venturi-style equipment was deemed as mandatory and not a value engineering option. Some of the existing heat pumps were reused and/or relocated.

Finally, the control system was cut down to only control the chilled water and lab systems. With quite a bit of negotiation with contractors and vendors, the final price was brought down to just barely below $500,000.

Environmental Impact

By reducing the size of the chiller by more than one-half, a lot of electricity was saved (more than 50 tons [175 kW] of cooling). In addition, the sash management promotes efficient scheduling of the use of the lab hoods. This, in turn, greatly reduces the exhaust needs. The variable speed motors on the exhaust fans (5 and 2 hp [4 kW and 1.5 kW]) and the makeup AHU (10 hp [7 kW]) have saved significant energy through the year.

Since the piping system, chiller, and makeup AHU were in very close proximity, and used only one pump, there is a very small amount of energy loss. The ERV provides free precooling and free reheating approximately equal to 10 tons (352 kW).

All of the new heat pump heating provides HSPFs in the 8.0 range. The lab hood system is very advanced with alarms and safety features that protect the chemists and other building occupants. Finally, the improved envelope, the pressure balanced building, and the lack of infiltration saves energy and promotes a healthier environment for the employees.

Conclusion

The plant has been running efficiently and without major problems. The power costs continue to be lower than expected. Since construction, the plant has been expanded to include new labs with similar technologies. By using techniques similar to the ones detailed here, it is clear that it is possible for a chemical lab hood facility to operate more efficiently without sacrificing safety or comfort. These goals can be accomplished even in the hot and humid South. ■