A Safety/Design Response

Laboratory fume hood exhaust. A case study.

The System of Choice
Strobic Air Corporation

Strobic Tri-Stack™ systems remove exhaust fumes from Gavin Laboratory Complex, University of Notre Dame

... reduced the number of fans from 41 to 16 while maintaining nearly 300,000 cfm of ventilation

Acoustical architectural screen was placed around exhaust systems to minimize transmission sound.

In summer 1998, the University of Notre Dame (UND), Notre Dame, IN, conducted a major renovation project on its Galvin Laboratory Complex. A chief concern consisted of upgrading the building's laboratory fume hood exhaust system. The building is a 30-year old structure containing three floors and 138,000 square feet of space. Two additions have been made over the years placing strain on its ventilation system. In fact, no major ventilation renovation had been done over the past 30 years, other than minor repairs and alterations.

The original structure and the extensions housed 60 laboratories, 78 laboratory work stations with fume hoods, and a few biological safety cabinets. Exhaust stacks that were six inches above the roof line were mounted on the roofs of the second and third levels. The building was used for animal, biological, and aquatic research; it also housed classrooms and offices. Centrifugal fans had been used to exhaust the work stations, either individually or with manifolds connecting two or three work stations into a common exhaust. There were 27 individual fans on the three story portion of the facility and 14 on the two story section.

The main chemicals used at the laboratory work stations are solvents, bases, aromatics, carbonyl compounds, even short life radioisotopes. Because it is used so intensively, the structure is a 100% fresh air building. The intake air vents are located on the first floor level.

The problem: fume hood exhaust re-entrainment

A third extension was being planned and an architectural/engineering firm from Minneapolis was called, Ellerbe Becket. The firm performed a computer simulation of the building's laboratory fume hood exhaust system and found that serious re-entrainment was taking place. That is, exhaust from the roof was reaching the ground level of the building; and thus being drawn into the air inlet vent. Though the re-entrainment was not detectable by sight or smell, it was decided that a complete overhaul of the exhaust system was justified.

Daniel Dickenson, P.E. is project manager for Ellerbe Becket and was responsible for the work completed at the UND site. Dickenson notes that "The initial and greatest concern was about the effect this facility had on itself. Also of concern was what effect this facility might be having on other buildings adjacent to it. The former was known to be a problem."

A properly designed exhaust system

An effective exhaust system transports laboratory fume hood vapors into manifolded ductwork on the building's roof. Exhaust stacks are given sufficient height to insure that gases are evenly dispersed into the atmosphere. ASHRAE recommends a stack height of 2.5 times the building's height. If the exhaust stack is not high enough, exhaust will re- enter the building via the outdoor intake air vent. Facilities management must ensure that exhaust gases do not become a health hazard by threatening air quality in the following ways:

- enter the air intake vent;
- accumulate on the roof top at dangerous levels;
- re-enter the building through doors or windows;
- present a danger to personnel on the roof top.

Pressure balancing is an important feature in the design of a building's ventilating system. The pressure of the laboratories should be lower relative to the rest of the building. Air should flow from offices to the laboratory, to the work station fume hood and not vice versa.

Design basis

In order to design a proper exhaust system for the Galvin Complex, a design basis is defined. A scenario analysis is done and the worst case design is selected. In this case, the system is sized for venting fumes from a spill where the largest vessel in the facility is turned over and the fluid with the fastest evaporating rate is spilled. The size of the exhaust system is designed such that the full flow of the evaporating liquid is vented and so concentration levels in the air are not a threat to people.

A second stipulation on the design basis is the use of a variable air volume (VAV) system. VAV

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Inline silencers were placed between the fan and exhaust stack to minimize airborne sound.

systems are complex. They require intensive control and monitoring systems. The control system is constantly checking temperature, pressure and humidity of the laboratory air. In contrast to constant air volume systems, VAV systems regulate the increase or decrease of the fresh air intake that is necessary to maintain the system at its setpoint. This has great value in that excess air is not air-conditioned needlessly; only the necessary amount of air required is air-conditioned. VAV systems normally have a short payback time.

The third stipulation is aesthetics. Systems like this normally require huge stacks. The building is easily visible from the main road on the UND campus. Tall exhaust stacks are not desirable with regard to aesthetics. Moreover, the building is next to the football field. Large industrial stacks do not really project the scholarly environment that the alumni, visitors, and especially the television cameras, have come to expect.

And last, the stacks must not be noisy. The mechanical sound of the fans must not be heard within the building, nor from the sidewalk below. Needless to say, the fans must not be heard in adjacent buildings nor across campus.

Exhaust acoustics is not a problem to be overlooked. It is part of the building's aesthetics. Dickenson highlights the fact that "Acoustical analysis early-on, prior to installation, can minimize the acoustical impact on the surrounding areas. This was particularly true at UND where the campus is primarily pedestrian . . ."

For this reason, Ellerbe Becket retained an architectural acoustics firm, Kvernstoen, Kehl and Associates, also of Minneapolis, to manage this aspect of the job. Steve Kvernstoen, a principal at the firm, describes how they approached the problem: "...We identified what the noise levels were currently on the site, because it seemed important to know what we were up against. If it was going to be a very quiet space, then a small amount of noise would probably be perceived as quite intrusive. And yet, if it was a space where there was a lot more traffic, or something else already making noise on the site, then our noise might very much blend into what was already there."

The solution

In an attempt to satisfy the above criteria, UND decided to install a Tri-Stack laboratory fume hood exhaust system by Strobic Air Corp. This system is unique for two reasons: first, it uses a specially designed fan blade that gives exhaust gases extra propulsion and lift; second, the exhaust stack has a nozzle-like shape that enhances the exit velocity of the gas.

The system is also an excellent choice for operating in conjunction with a VAV air-conditioning system. This is because of unique air inlet vents located within the exhaust stack itself. While the laboratory is operating under VAV conditions, the inlet vents in the stack are supplying makeup air to the fan blades thus keeping constant flow to the fans.

Furthermore, the high velocity exhaust jet (up to 350 feet into the atmosphere) ensures dilution and eliminates the need for a tall, unsightly vent stack. First, dilution air is taken from the roof top via the nozzle inlet vents and mixed with the exhaust gas. And second, the high velocity jet is so powerful that the plume is propelled to elevations equivalent to a traditional exhaust stack height. This system is typically 60% shorter than conventional systems.

The new exhaust system offers a variety of other benefits:

- 25% less energy consumption relative to conventional centrifugal fan systems;
- effective noise abatement;
- virtually maintenance-free operation;
- footprint reduction of 50%.

Much attention was given to noise attenuation. Dickenson states "Steve Kvernstoen suggested the inclusion of acoustical attenuation, in as much as possible, at each fan (the source). In addition, an acoustical screen wall/louver was also recommended. Attenuating silencers were incorporated at the (stack) outside air inlets as well as at the fan discharge."

The results

The new exhaust system has been in place for nearly a year. To date, the laboratories have had no problems with re-entrainment nor with fan noise. Previously, the building employed 41 fans for ventilation, while the new system has reduced the number to 16 and provides nearly 300,000 cfm of ventilation.

Mark Hummel, P.E., UND's maintenance manager, says "That's the benefit: rather than building a 30 or 40 foot chimney and discharging high to get dilution into the atmosphere, you can discharge at a velocity that ejects the plume to an equivalent height." Ron Erichsen, UND project manager, adds "We're in the process of converting the entire building to a VAV system. When we get all diversification on the VAV system, we should be able to save approximately 30% of the energy in heating and air-conditioning consumption."

Hummel also commented on the speed at which the VAV/laboratory work station exhaust system was installed. He said, "As far as down time to the laboratory usability, never was any laboratory down more than four days; we did this in a fully occupied building."

Dickenson believes that the investment in a complete acoustical analysis was well worth the effort. He points out that, "The result has been that most people have not noticed any change in the noise level. UND seems happy with the fans, as well as their acoustical performance."

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