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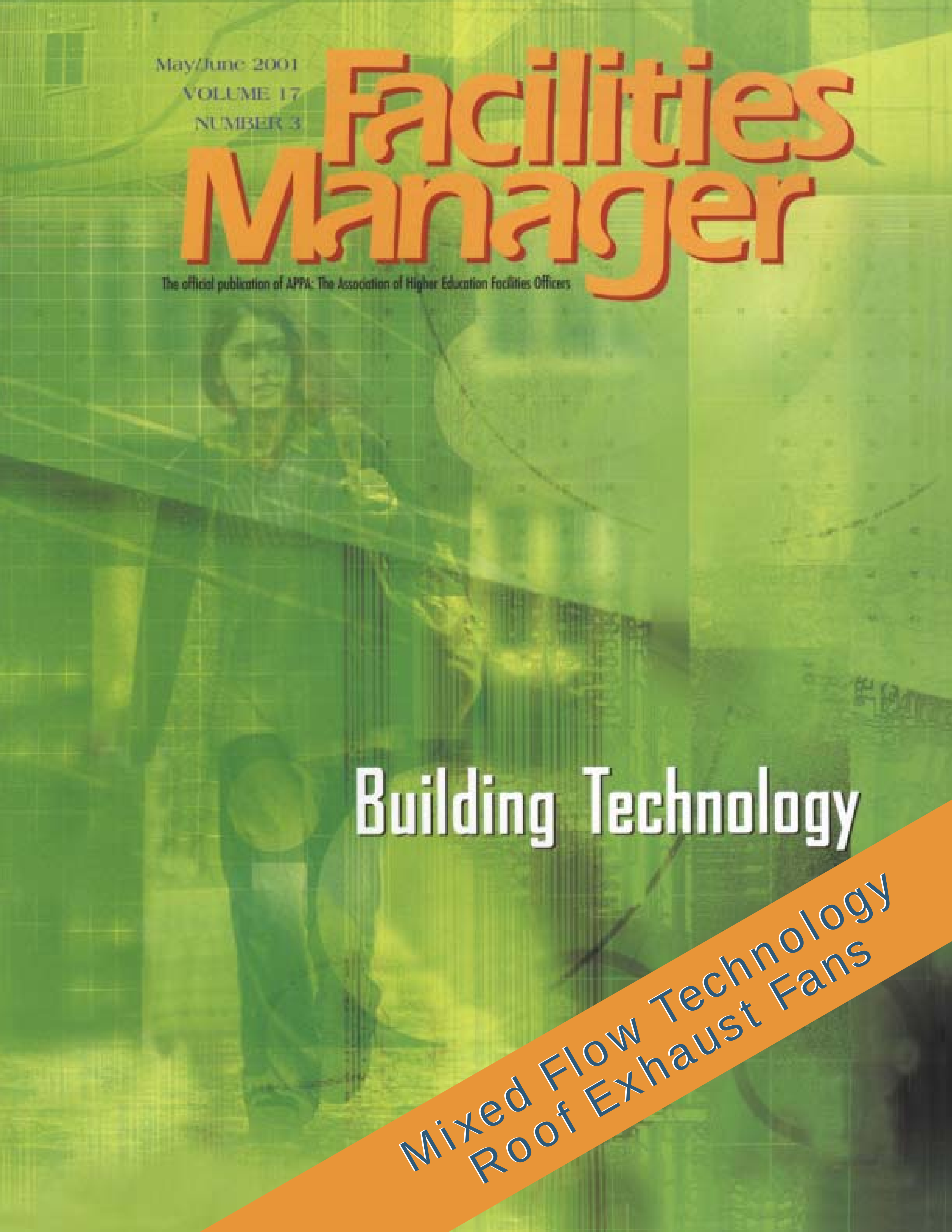


Building Technology

Mixed Flow Technology
Roof Exhaust Fans

THE BENEFITS OF MIXED FLOW TECHNOLOGY

ROOF EXHAUST FANS

By Paul A. Tetley

Many educational institutions use sophisticated laboratories for teaching and research. Operating laboratory workstations presents problems to facilities managers that typically include issues of indoor air quality (IAQ), pollution abatement, HVAC equipment/system acquisition and operating costs, odor prevention, roofline aesthetics, and other "good neighbor" considerations. Each of these issues is important, of course, more or less prioritized by the severity of the problems they create at a particular campus.

There is a practical and cost-effective way to deal with these issues—that is, through use of mixed flow impeller exhaust fans, a century-old technology that has undergone many evolutionary refinements during the past few decades. This article will discuss the problems associated with laboratory workstation exhaust faced by most colleges and universities. It will explain how selection of a proper fume hood exhaust system can prevent or eliminate these problems and help provide a clean, healthy, safe, and quiet environment for students and instructors, maintenance staff, technicians, and neighbors.

IAQ and legal implications

The subject of indoor air quality in the laboratory has received widespread publicity over the past few years. There are many reasons for this—perhaps partly because of greater public awareness of pollution issues, and perhaps because of widespread news media coverage of multi-million dollar lawsuits involving workplace pollution issues. No doubt litigation against a well-known university hospital with regard to IAQ and employee health problems helped focus public attention on this issue.

These lawsuits resulted from claims that dangerous laboratory workstation fume hood exhaust either remained in the laboratory work area, and/or roof exhaust gases from the workstation were being re-entrained into this area. In some of these cases building owners, consulting engineers, contractors, and even architects were named as defendants in lawsuits associat-

Paul Tetley is vice president and general manager of Strobic Air Corp., a subsidiary of Met-Pro Corp., Harleysville, Pennsylvania. He can be reached at ptetley@strobicair. com.

ed with employee illness allegedly caused by harmful IAQ. Many of these cases have been in the courts for more than a decade, some of them not yet resolved.

Exhaust re-entrainment can be caused by improper or inefficient roof exhaust fans, poor exhaust stack and/or ventilation air intake design and/or location, weather and wind conditions, and other factors. While roof exhaust re-entrainment can be a serious problem, all of its negative implications may not be widely known. In fact, not only can the health of building workers be affected by exhaust re-entering the building through windows, vents, air intakes, and door openings (among other possibilities), but the legal consequences can be troublesome and expensive to say the least.

Roof exhaust re-entrainment takes on many forms. It can be harmless and unperceptible; but more likely it can be toxic, noxious, or odoriferous. Its influence on people covers a full spectrum from innocuous to mildly annoying (but not harmful) to seriously unhealthy. However, if exhaust re-entrainment is not a health concern at a laboratory facility, generating odoriferous emissions can also create problems on the campus. When they are produced—regardless of toxicity—university management will ultimately be confronted, either by neighbors or a regulatory body.

IAQ is only one side of the equation with regard to laboratory workstation roof exhaust systems. There are two distinct terms used to discern differences between roof exhaust that is being “re-entrained” into the facility and workstation exhaust that is not removed from the building in the first place (containment). Probable causes of “containment” include building ventilation/ductwork design/configuration, and exhaust equipment/accessories at the laboratory workstation, or some combination. IAQ problems—and lawsuits that might be associated with them—have been caused by both containment and re-entrainment issues.

Mixed flow impeller technology for roof exhaust

For many pollution abatement problems—including prevention of re-entrainment, and odor control—there are two popular exhaust technologies. These include conventional centrifugal roof fans, usually with a belt drive motor and dedicated single exhaust stack, and newer mixed flow impeller exhaust systems mentioned previously.

While many educational institutions have been using conventional centrifugal exhaust fans for their laboratory workstation fume hood exhaust, more and more are switching to mixed flow impeller technology for retrofit as well as new construction. There are many reasons for this. As anti-pollution laws have become more stringent, even the sight of a tall exhaust stack imparts negative connotations in the community Also, tall exhaust stacks usually require expensive mounting hardware (bases, guy wires, roof curbs, etc.), and often they still do not prevent re-entrainment of exhaust fumes back into the building or adjacent facilities. In addition, the belt driven centrifugal fans associated with these systems generally required periodic (and occasionally hazardous) maintenance, and are sometimes housed on the roof in a “penthouse,” another added expense. Penthouses are designed to protect workers from the elements during fan maintenance operations; however, these maintenance people can still be subjected to exposure from unhealthy exhaust fumes.

Development of mixed flow impeller technology

Mixed flow impeller technology originated in the late 19th century in France. It is actually a combination of axial, radial, and centrifugal flow technologies that existed for many years prior to that point. Mixed flow impeller technology capitalizes on the outstanding performance characteristics offered by each of these fan types by combining them into a unique fan blade design that provides constant acceleration ratios through blade passageways of volume, or the pressure to the volume curve. What makes the technology unique is that both sides of the blade are performing equal work for maximum efficiency. As a result, the performance curve is perfectly stable with no stall or unstall sections.

When this technology was developed it provided approximately 70 percent peak efficiency performance which was remarkable for the time; today it is more like 80 percent+. Mixed flow technology was originally designed for low pressure, high flow applications; with today's advances in blade aerodynamics, it provides optimum performance in virtually all combinations of low pressure/high flow, high pressure/low flow, etc.

About 20 years ago, interest was revived in this technology. Over the past decade it has been refined to such a high degree that most of the problems associated with centrifugal type fans have been eliminated, with mixed flow impeller technology fans accomplishing the same purpose, more efficiently, and much more economically.

Exhaust dilution and jet plumes

Mixed flow exhaust fans combine outside (ambient) air with exhaust discharge, sending a nearly vertical “jet plume” of exhaust gases up to 350' high above the building roof line. The exhaust gas/air mixture contains as much as 170 percent free outside air, effectively diluting the exhaust plume into the atmosphere, thus eliminating pollution problems (as defined by appropriate regulatory codes). The powerful vertical plume also eliminates re-entrainment possibilities, solving some—or all—of the IAQ problems that may have been caused by laboratory workstation fume hood exhaust.

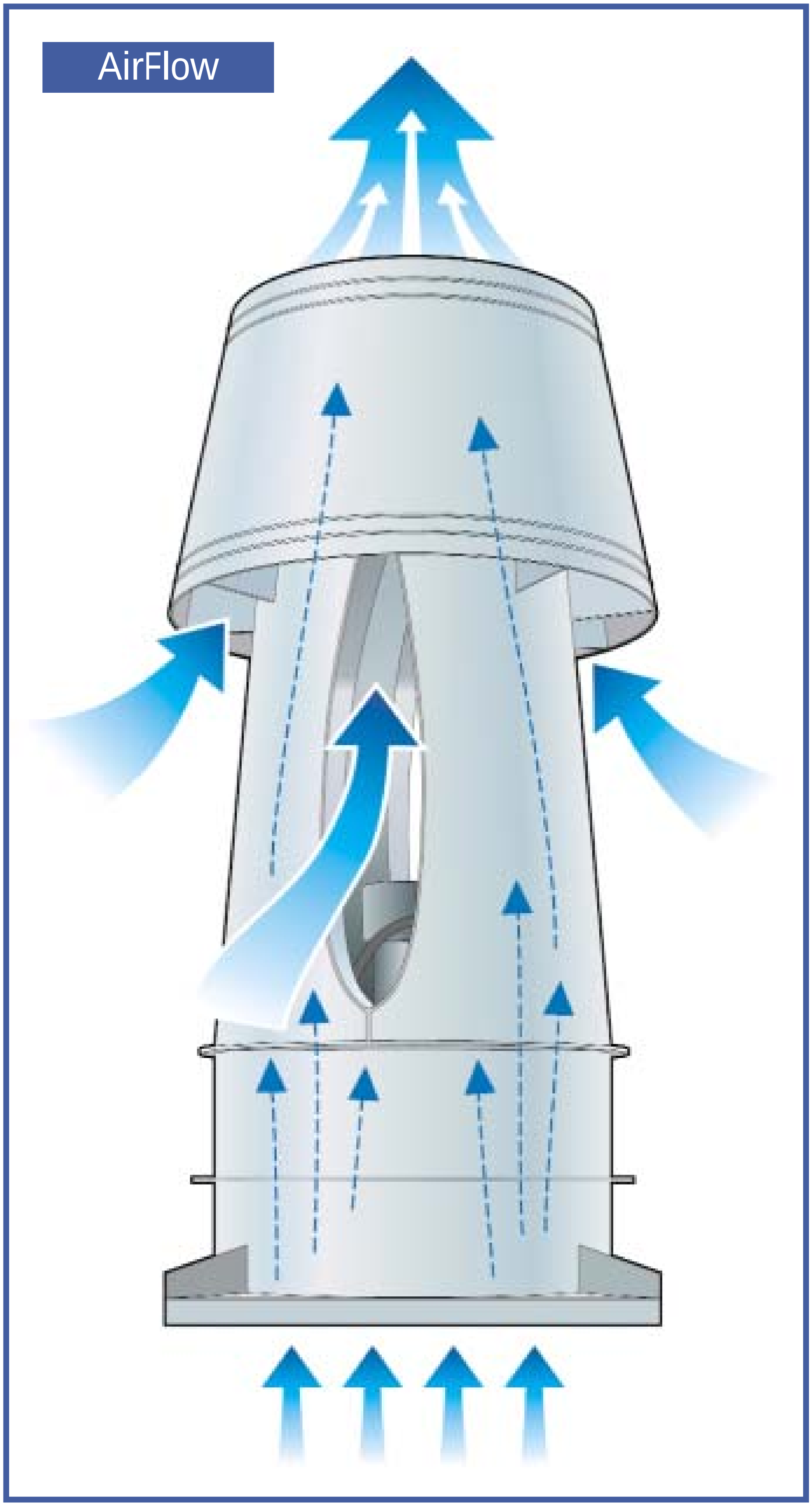
Addressing the containment issue

With regard to containment issues (sometimes “the other half” of the IAQ equation), various equipment within the building at the workstation is available to eliminate containment problems. This can include dedicated but simple air moving systems through complex, automated hood or ventilation systems designed to prevent workstation exhaust from remaining in place. In addition, there are many automated laboratory workstation fume hood controllers and other sophisticated instrumentation that prevent containment problems at the fume hood. These devices usually incorporate set point alarm systems to automatically close off the workstation if a pre-set value is exceeded. In this way exhaust containment is elimi-nated, and the quality of indoor air is not compromised.

Fan noise can also create problems

The subject of noise generation—while not directly associated with IAQ—has also become popular since many people are increasingly aware of unwanted noise. Centrifugal-type dedicated roof exhaust systems are generally noisier than mixed flow impeller-type systems (on a direct CFM comparison basis) because the mixed flow fans are typically in the mid-to-upper 80 percent efficiency range vs. the mid-to-upper 50 percent efficiency range for centrifugal fans (based on total efficiency [TE]). Since sound is a function of efficiency mixed flow technology is inherently quieter. In addition, noise generation caused by peripheral blade tip speeds also plays a role in performance sound levels, and mixed flow impellers rotate at substantially slower speeds than centrifugal fans for the same amount of work.

Most campus laboratory buildings contain two different noise sources—the supply fans that provide conditioned air (HVAC) and the workstation fume hood exhaust fans mounted on the roof. Each of these systems is usually independent; and each requires a separate set of standards and criteria with regard to noise generation and/or minimization.



Exhaust acoustics are considered part of a building's aesthetics. Acoustical analysis of exhaust and ventilation systems early on, prior to installation for new or retrofit construction, can minimize the acoustic impact on surrounding areas. Obviously facilities managers don't want the mechanical sound of exhaust fans to be heard within a building or at the property line; and, exhaust fan noise should not be detectable in adjacent buildings as well. To eliminate possible noise problems, many organizations, when building a new facility or refurbishing an existing one, look to independent noise study experts to help make determinations as to exhaust system operating noise levels, usually at the property line.

If mixed flow impeller type fans are employed, and noise is still an issue, there are also accessories available to reduce sound generated at the property line. These typically include acoustical screens and/or louvers, chevron screen walls, and acoustical silencer nozzles that use a combination of sound absorption material as well as special airflow patterns to achieve high attenuation values.

UND and re-entrainment prevention

Eliminating re-entrainment with quiet exhaust were two issues facing the University of Notre Dame (UND) in South Bend, Indiana. The university recently completed a major renovation project at its Galvin laboratory complex—a 30-year old, four-story building with 138,000 sq.ft. of space. One upgrade included the building's laboratory fume hood exhaust system. The need for additional fume hoods in the existing Galvin complex had taxed most of the original systems beyond their performance capabilities, yet eliminating re-entrainment possibilities with quiet exhaust fans were key objectives.

The re-entrainment issue was determined to be a serious problem at the original complex which housed 60 laboratories with 78 workstations and fume hoods along with some biological safety cabinets. A few additions had been made over the years and a fourth addition, the Hank Family Center for Environmental Sciences, was also planned. At the existing facility workstation, exhaust was reaching the ground level of the building and being drawn into the outside ventilation intakes.

To solve these problems, the university conducted a study which included evaluation of the existing building and its systems (building audit), a feasibility study for the renovation of the Galvin HVAC systems, and a computer simulation of the building's laboratory fume hood exhaust systems. Though re-entrainment was not detectable by sight or smell, the building audit and wind model provided compelling data to support a complete overhaul of its exhaust systems. At that point, standard centrifugal workstation fume hood exhaust fans were ruled out because they were not able to prevent re-entrainment. Consequently more powerful fans were evaluated which, while solving the re-entrainment issue, would likely create higher noise levels which were also objectionable.

Mixed flow impeller fans eliminated re-entrainment—quietly

After studies were completed, the university purchased mixed flow impeller workstation fume hood exhaust systems that eliminated re-entrainment possibilities. The system also reduced noise—with substantially lower noise levels in the lower octave bands—and cut energy consumption while providing enhanced performance.

Since acoustics were an important issue at UND, the university had acoustical analyses performed to potentially eliminate the mechanical sound of any exhaust fan that might be heard within the building and in its pedestrian and mall areas adjacent to the building.

Sound calculations were performed based on varying distances, both theoretical and practical, by an architectural acoustics firm. Noise characteristics were obtained directly from the fan manufacturer. Ambient noise levels from surrounding areas were analyzed. A decibel meter was positioned at various locations surrounding the Galvin facility to gather noise level information. From these studies—including a review of the fan manufacturer's noise abatement options—total sound values in decibels were determined. As this project evolved, more and better information, such as exact equipment location, building plans, surrounding buildings, wind patterns, and other considerations were also reviewed. While noise codes were not a factor since the university was its own neighbor, the amount of noise generated by the exhaust system is of critical importance on a campus site with proximity to a library and classrooms.

Lowering overall system costs

At the University of Quebec at Montreal (UQAM) the institution's facilities managers and design team evaluated many HVAC products while planning a new 400,000 sq. ft. laboratory building for its science campus. Teaching and research activities there include mathematics, computer sciences, physics, earth sciences, and environmental sciences. By any standards, this was a huge project. The ten-story building accommodates over 4,000 students, and incorporates over 150 individual laboratory workstations for research and education. The building also houses classrooms, teachers' offices, and a library.

One of the many HVAC considerations was managing the workstation fume hood exhaust for the 150 laboratories. As is typical with many university laboratories, a wide variety of chemicals and materials is used at the workstations; as a result some fume hood exhaust effluents are highly corrosive, and noxious.

"The issue of laboratory workstation exhaust was a major consideration in planning the entire HVAC system for the building," according to Andre Couture, an architect at the university. Couture's department was responsible for overseeing the design and development of the technical/mechanical systems of the entire building, and he served as the link between the architects, the engineering consultants, the future occupants, and UQAM's maintenance department.

Cutting energy costs drastically with mixed flow impeller technology

For laboratories that require 100 percent conditioned makeup air, mixed flow impeller systems are also being used in a new and unique manner; that is, adding heat to ventilation intake air to achieve substantial energy reductions.

Heating energy costs are expected to rise by 50 percent or more this year over last. Many universities with laboratory workstations are seeking relief from these high costs, particularly since laboratory facilities account for unusually high energy consumption.

Add 1° F for 3% energy savings

Laboratories that require conditioned 100 percent makeup air experience extraordinarily high costs for heating and cooling. With heat recovery coils as part of the mixed flow impeller system, for every 1° F you add, energy costs are reduced about 3 percent. A 10° F rise in intake air temperature translates into a 30 percent energy saving—quite impressive based on today's high fuel costs.

In addition to lowering costs, users help contribute to a cleaner environment since less fossil fuel is consumed. Systems of this type are practical when outside air temperatures are below 40° F or above 80° F That's because there must be a sufficiently large temperature difference between outside and inside air temperatures to make it effective. With regard to cooling air in warmer temperatures, if outside air at 90° F is brought back into the building and sent to the heat recovery system, the air temperature drop is typically 4°-5° F—also equating to a 3 percent drop in energy consumption for each 1° F drop in air temperature.

To sum up, in addition to the dramatic fuel savings for heating and cooling (in 100 percent conditioned makeup air facilities) other advantages offered by mixed flow technology fans include lower energy consumption over comparable centrifugal-type exhaust fans, virtual elimination of periodic maintenance, re-entrainment prevention, odor elimination, and quiet operation. Based on current trends this technology will likely be used by more college and university research facilities.