

Mixed-Flow Exhaust Technology A New Approach for Energy Savings and Pollution Abatement



Paul A. Tetley

This article discusses the use of mixed-flow impeller technology for exhausting laboratory fume hoods at pharmaceutical research facilities and for handling the exhaust from manufacturing processes at pharmaceutical manufacturing facilities. Mixed-flow impeller technology can **eliminate air pollution, prevent exhaust reentrainment into the facility (or adjacent buildings), and eliminate odors in the neighborhood.** It may substantially reduce heating and cooling costs when used in facilities that require 100% conditioned makeup air.

Pharmaceutical manufacturers and research organizations face many challenges in terms of increasingly restrictive regulations and tougher competitive markets. This article discusses two concerns that have a direct effect on performance and profitability: energy consumption and pollution abatement. Nearly all pharmaceutical companies are justifiably concerned about these factors because they are burdened with extraordinarily high costs for energy and environmental compliance.

Mixed-flow impeller technology for roof exhaust systems is a relatively new technology that addresses both these concerns and has been gaining popularity in the pharmaceutical industry. Mixed-flow impeller technology is particularly advantageous for pharmaceutical organizations for two reasons: First, it offers a highly efficient approach to handling laboratory workstation fume-hood and manufacturing-process exhaust. Second, for facilities that require 100% conditioned makeup air for processing or laboratory workstation environments, mixed-

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TKG CONSULTING ENGINEERS INC.

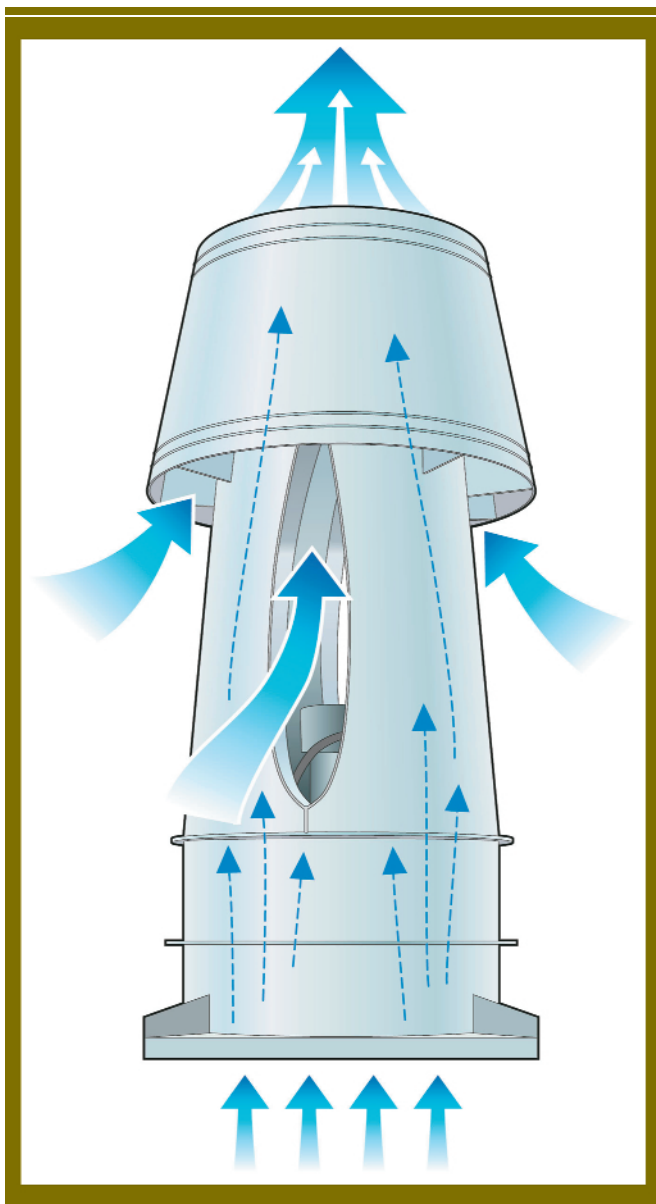


Figure 1: A typical mixed-flow impeller exhaust system that dilutes outside air with plenum exhaust air at high discharge velocities.

flow exhaust systems can extract warm air or chilled air from ambient air before its discharge into the exhaust stream. This capability can result in significant annual savings in heating fuel and electricity costs.

Everything old is new again

Mixed-flow impeller technology incorporates a unique fan-blade design configured for optimum performance in nearly all combinations of low pressure–high flow, high pressure–low flow, and other operating combinations for meeting various performance criteria. The technology originated in the late nineteenth century as a combination of axial-, radial-, and centrifugal-flow technologies that had existed for many years. When it was originally developed it provided ~70% total efficiency (TE) performance, which was remarkable for that time. Independent testing at Strobic Air (Harleysville, PA) determined that its

performance now is $\geq 80\%$ TE. Interest in this technology was revived a few decades ago, and during the past 10 years the technology has been refined to such a degree that most of the problems associated with centrifugal-type fans, which are commonly used for laboratory workstation fume-hood and process-exhaust applications, have been eliminated. Modern mixed-flow impeller systems accomplish the same purpose but do so much more efficiently—in part because of their high aerodynamic stability—and with substantial savings in operating and installation costs, according to independent testing conducted by Strobic Air.

The solution for pollution abatement

Mixed-flow exhaust systems combine ambient (i.e., outside) air with exhaust discharge and send a nearly vertical jet plume of exhaust gases <350 ft above the building roofline (see Figure 1). The exhaust gas–air mixture contains as much as 170% free outside air, effectively diluting the exhaust plume into the atmosphere and eliminating potential pollution problems as defined by appropriate regulatory codes and industry standards. The powerful vertical plume also eliminates reentrainment possibilities, which, in turn, prevents indoor air quality (IAQ) problems in the workplace that may have otherwise been caused by roof exhaust. IAQ has received much scrutiny during the past few years, mainly because of public awareness of pollution issues but also because of media coverage of well-known, multi-million-dollar lawsuits concerning employee health and IAQ.

Maintaining a good-neighbor policy

The serious problem of roof exhaust reentrainment can take many forms. In the pharmaceutical industry, exhaust gases from research or processing activities can be toxic, noxious, odoriferous, or a combination of these qualities. Their effects cover a broad spectrum from mildly annoying but not harmful to seriously unhealthy in certain conditions. Even if exhaust reentrainment does not become a health concern, generating odoriferous emissions still can create problems in the neighborhood. A facility that produces them—regardless of the emission's degree of toxicity—will most likely be confronted either by neighbors or a regulatory agency.

The conventional solution to these problems has been the use of centrifugal roof exhaust fans that usually include a single belt-driven motor and a dedicated tall exhaust stack (typically ~25 ft tall). However, as antipollution laws become more stringent, even the sight of a tall stack imparts negative connotations in a community. In addition, tall exhaust stacks usually require expensive mounting hardware (e.g., elbows, flex connectors, spring vibration isolators, guy wires, roof curbs, etc.) and often still do not totally prevent reentrainment of exhaust fumes back into the building or adjacent facilities. The belt-driven centrifugal fans associated with these systems generally require periodic maintenance; thus, they are often housed on the roof in a separate penthouse. The penthouse protects workers from the elements during maintenance operations; however, these workers might also be subject to exposure from toxic or noxious fumes because the fans' discharge is always under positive pressure.

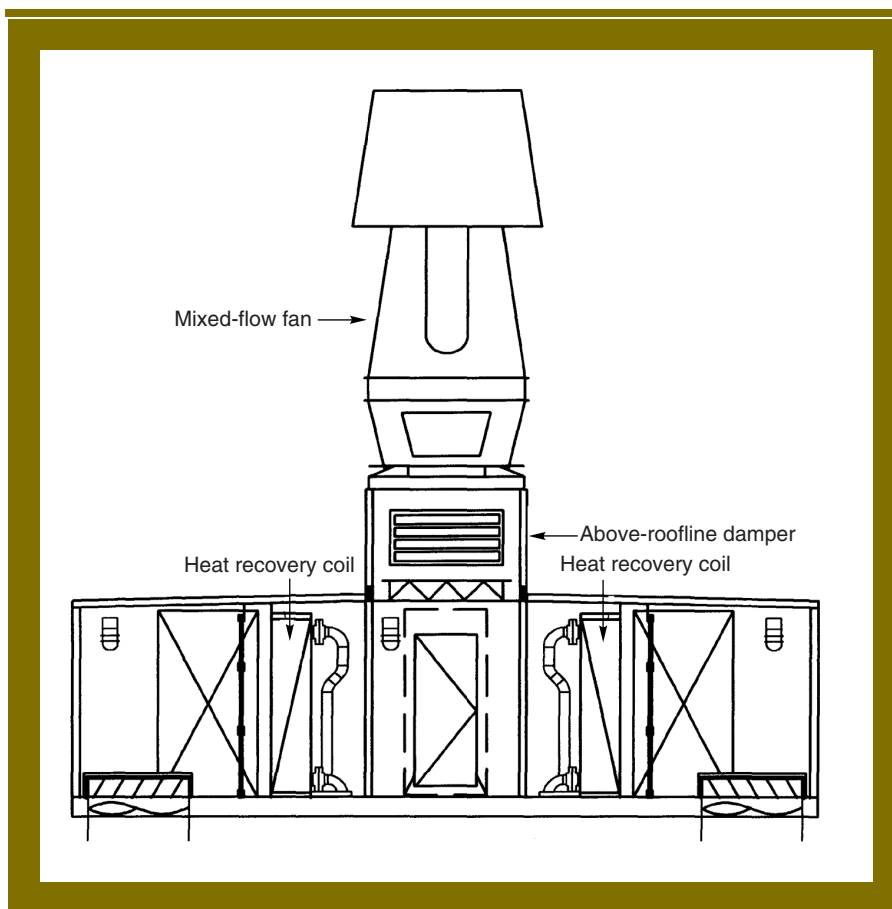


Figure 2: A typical roof-mounted mixed-flow fan-heat-exchanger system for laboratories that require 100% conditioned makeup air.

Installation and maintenance

Roof exhaust systems that incorporate mixed-flow impeller technology have low-profile designs (typically ~15 ft high) and do not require structural reinforcements on the roof. Because they are substantially shorter (and constructed modularly), installation time and costs are reduced. In fact, in many retrofit applications almost no downtime is associated with their installation.

In normal conditions, mixed-flow impeller systems are designed to operate continuously for years with minimal maintenance. Direct-drive motors have bearing lifetimes of L50 200,000 h. The nonstall, nonoverloading characteristics of the blade design permit variable-frequency drives to be used for added variable-air-volume (VAV) savings, built-in redundancy, and design flexibility.

Mixed-flow impellers operate at lower noise levels than do centrifugal fans of equal capacity, particularly in the low-octave bands, which could be advantageous in some locations. When noise is still a problem, however, accessories such as low-profile acoustical silencer nozzles can be used.

Mixed-flow impeller fans commonly consume ~25% less energy than do conventional centrifugal fans, and they offer faster payback periods as well. The typical energy reduction is \$0.44/cfm at \$0.10/kw-h, providing an approximate two-year return on investment. These numbers do not include the en-

ergy savings the system can provide for conditioned makeup air facilities.

Heat recovery efficiency

Energy costs during the past few years have been on a roller coaster. Although they are more moderate today than they were last year, there is no guarantee that wild price fluctuations won't happen in the future as the result of the extremely unstable geopolitical climate among many energy-producing nations. Because many firms in the pharmaceutical industry have experienced the energy squeeze first hand, they are seeking innovative ways to reduce their costs. To that end, mixed-flow impeller technology has proved to be beneficial for organizations at which 100% makeup air is required either in the laboratory environment or the processing area.

Pharmaceutical organizations are burdened with perhaps the most expensive energy costs in the country, mainly because most require conditioned 100% makeup air for workstation or processing environments. This makeup air must be filtered, heated, cooled, humidified, or dehumidified (or some combination thereof) depending upon requirements (see Figure 2). These organizations must provide comfortable and safe environ-

ments for their scientists, technicians, and other workers, and that requires efficient—and expensive—heating and cooling of makeup air for the workplace environment. In addition, workstation fume hoods usually require sophisticated controls and energy-consuming hood management equipment for proper operation. When fume-hood exhaust systems are added on the roof—and they must operate whenever a workstation is being used—energy costs can mount quickly.

Mixed-flow impeller technology is a solution to these problems. By adding accessory heat-recovery modules consisting of glycol- and water-filled coils (see Figure 3) that extract heat from workstation fume-hood exhaust before it is discharged above the roofline, substantial energy savings may be realized. The warm air from the heat exchanger is transferred to the supply-side handler to preheat the conditioned air entering the building (see Figure 4), thus reducing the amount of natural gas or fuel oil needed to heat makeup air. This process works the same way for chilled air.

Energy savings per temperature increase

Mixed-flow impeller exhaust systems with heat-exchanger coils save ~3% of energy costs for each 1 °F rise in recovered heat. Similar but not quite as dramatic savings are realized for cooling applications. The systems are most practical when outside air temperatures are typically below 40 °F or above 80 °F be-

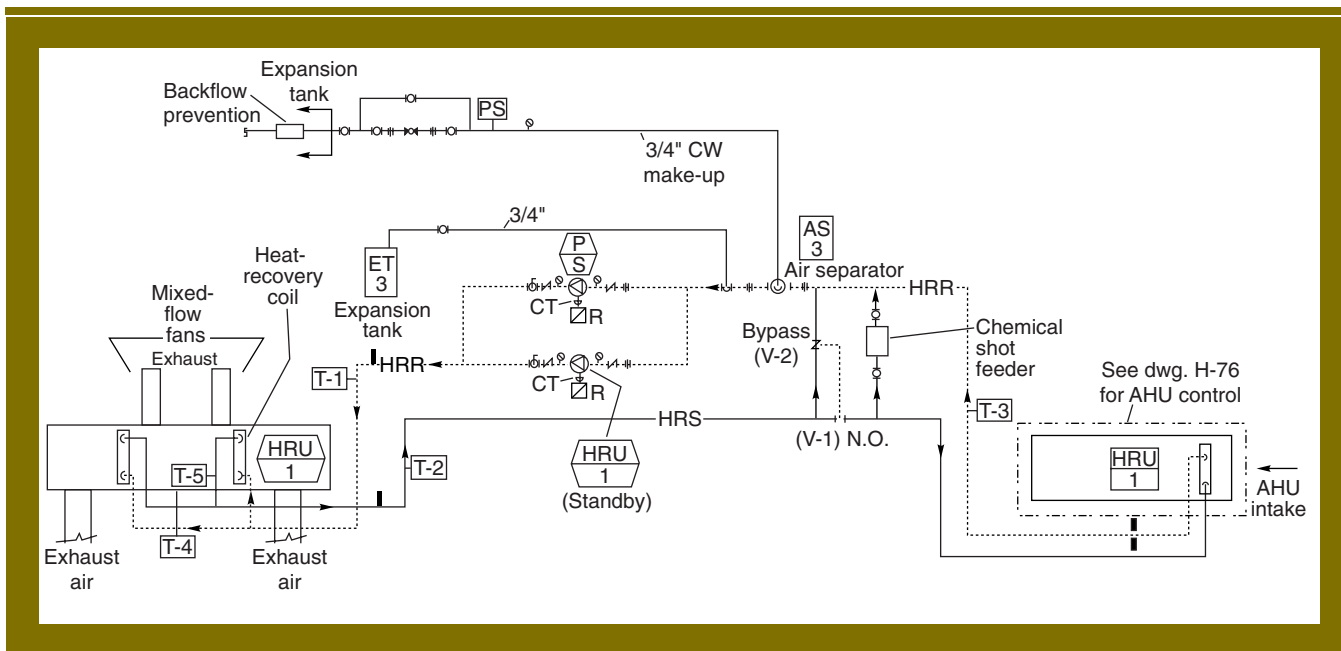


Figure 3: A runaround-coil heat-recovery flow system configured at a pharmaceutical research facility.

cause there must be a large-enough difference between outside and inside air to make it cost effective. For cooling, if the outside air temperature is 90 °F and the chilled indoor air is sent through the heat-recovery coils, then the drop in makeup air temperature is typically 4–5 °F.

Building aesthetics

When designing or retrofitting a new roof exhaust system, stack height should also be considered in terms of performance (reentrainment prevention), aesthetics, and code–standards compliance. Ideally a company should seek the lowest profile possible that not only eliminates negative pollution-generating smoke-stack perceptions, but also helps it conform to applicable architectural–aesthetic ordinances (see Figure 5). Elimination of tall, unsightly stacks that are either prohibited by code or otherwise undesirable is an added benefit. In some areas of the country, for example, no stacks are allowed on the roof under any conditions.

Application

The Torrey Pines area of San Diego, California, is one place where building-height restrictions place severe limitations on exhausting laboratory workstation fume hoods. A height restriction of 30 ft, which applies to structures mounted above the roofline, prohibits the use of tall exhaust stacks on a roof. For two new pharmaceutical research facilities—Pfizer Pharmaceutical’s Global Research and Development Facility (La Jolla Laboratories) and neighboring Syrrx Pharmaceuticals, tall, roof-mounted exhaust stacks for laboratory workstation fume-hood exhausts were not an option.

Both new facilities (Syrrx has 84,000 ft² and Pfizer has >220,000 ft² in two buildings) required conditioned makeup air in occupied work spaces. These companies had to confront the problem of exhausting nearly 400 laboratory workstations

without consuming valuable floor space, yet conform to the building code that requires a 30-ft height limitation. The solution required unique thinking. Instead of thinking “outside the box” to develop it, the engineers and designers for these projects literally thought “inside the box.” In other words, they installed mixed-flow technology exhaust systems inside of the buildings, an approach that presented some interesting engineering challenges.

The laboratory-workstation exhaust systems at Pfizer and Syrrx are installed in specially designed fan rooms inside the buildings that require less than half the space of centrifugal fans. What’s more, the exhaust stacks are not visible from the property line because they extend ~10 in. above the roofline, and decorative parapets around the roof perimeters obscure them from view.

In the case of Pfizer Pharmaceuticals, the mechanical, electrical, and plumbing systems contractor (TKG Consulting Engineers Inc., San Diego, CA) had used mixed-flow impeller laboratory workstation fume exhaust systems before, but Pfizer’s was the first project where the fans were placed inside the buildings with slight modifications. The decision was mainly made on the basis of available space and ability to locate the mixed-flow impeller fans in a confined area within each building (at Pfizer) that maximized the use of valuable research and administrative space while permitting compliance with building-code height restrictions.

Use of acoustical silencers. The problem of noise generation must be considered when a company plans to install laboratory workstation fume-hood exhaust systems inside a building and close to work areas. This problem can be solved by incorporating fiber glass–reinforced plastic in-line acoustical silencer nozzles on each exhaust fan. In addition, the areas in which the fans are located can be insulated with fiber glass on the walls and ceilings. In the Pfizer project, the walls that were

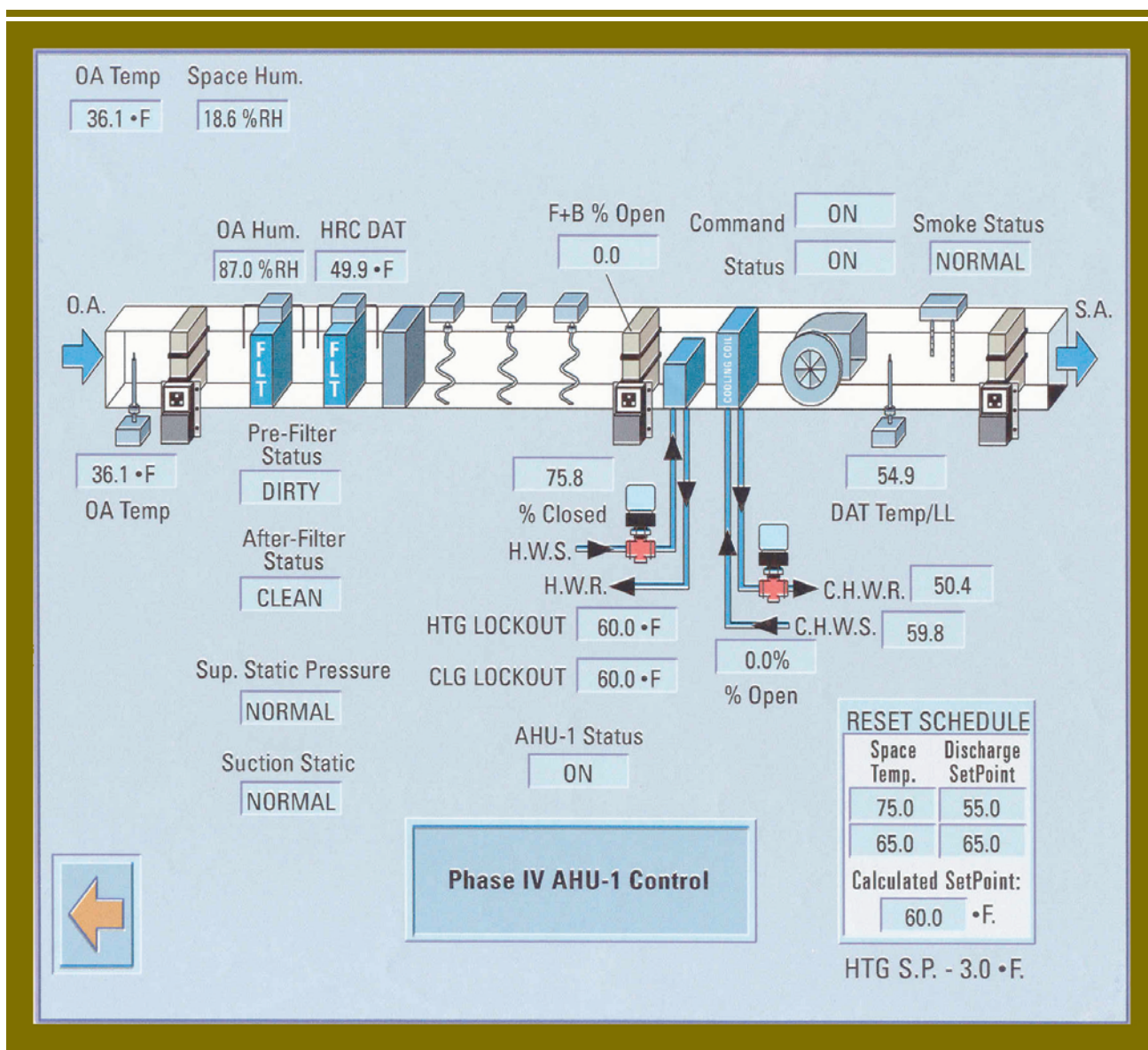


Figure 4: A video printout of the system status of a heat recovery-mixed-flow impeller system.

closest to the people in offices or workstations (two locations within the building) were provided with heavier sound insulation material than in other places where the fans were located more remotely. As a result, noise was not a factor.

Within both new Pfizer facilities, which are used for biological and chemical research, all the laboratory workstations incorporate 6- and 8-ft-wide fume hoods. Each of the building's 36 individual mixed-flow impeller fans are configured for VAV operation for enhanced efficiency and energy savings for the workstation fume-hood exhaust. Twelve mixed-flow impeller fans use 20-hp motors that provide 17,000 cfm at 3.0-in. SP, and 24 use 15-hp motors that provide 12,500 cfm at 3.0-in. SP. All the fume hoods are connected to the mixed-flow impeller fans by means of ductwork and common plenums. The Pfizer fans are also nearly maintenance free, with the exception of greasable bearings.

Meeting pollution-control standards and codes

Hundreds of pollution-control standards must be met when considering dedicated roof exhaust systems. In addition to Occupational Safety and Health Act and Environmental Protection Agency requirements, ventilation standards have been established by organizations such as the American National Standards Institute (ANSI)/American International Hospital Association (AIHA); American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE); and National Fire Prevention Association (NFPA). Underwriters' Laboratory standards also must be met. All these entities are concerned with air quality both outdoors and indoors. During the past few decades, mixed-flow impeller technology has proved its value with regard to conformance to virtually all appropriate pollution-control codes and standards as evidenced by independent testing per these organizations' standards.



NEUROGEN CORPORATION

Figure 5: Two mixed-flow impeller systems mounted on top of a heat-recovery system.

Conclusion

Mixed-flow impeller technology exhaust systems represent a sensible and economic approach to eliminating reentrainment, preventing pollution and neighborhood odor, conforming to aesthetic ordinances and standards, and cutting energy costs. In addition to fuel savings for heating and cooling in 100%

conditioned makeup air facilities, mixed-flow impeller technology offers the advantages of lower energy consumption compared with comparable centrifugal-type exhaust fans as well as reduced maintenance requirements. This technology likely will be used to retrofit existing facilities as well as meet the needs of a growing number of new pharmaceutical research and manufacturing facilities. **PT**

FYI

Call for Papers

The World Batch Forum (WBF) has issued a call for papers for presentation at its North American Conference, to be held 13–16 April 2003 in Woodcliff Lake, New Jersey.

The deadline for submitting abstracts for proposed papers is 27 September 2002. Any subject related to batch manufacturing will be considered, but WBF encourages topics such as services and products supporting 21 *CFR* Part 11, applying S88 in manual operations, batch scheduling, and project execution processes. Accepted presenters will be notified by 4 November 2002. PowerPoint presentations and final papers must be submitted by 14 March 2003.

To request paper and presenter guidelines, contact Dennis Brandl, WBF North American program committee chairman, at tel. 919.852.5322 or dnbrandl@bellsouth.net, or contact DeAnn Fedyski at WBF headquarters at tel. 480.893.8803 or deann@wbff.org.