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Mixed-Flow Exhaust Systems Cut Vibration and Noise

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Laboratory workstation fume exhaust systems based on mixed-flow impellers with direct drive motors provide silent, vibration-free operation needed for high measurement accuracy at the Univ. of Oregon's research laboratories.

Designing a world-class research facility requires careful planning, right down to the exhaust systems. The Integrative Science Complex (ISC) at the Univ. of Oregon, Eugene, is a unique approach to scientific research and technology problem solving, by bringing together scientists and researchers with different specialties and disciplines. Because of the nature of the research equipment at ISC, even the choice of a laboratory workstation exhaust system was critical to the success of the facility.

The direct drive fans that power the mixed-flow laboratory fume exhaust system at University of Oregon's ISC facility were located on the roof of an adjoining building to minimize noise and vibration.

Although the facility was being designed to demanding noise and vibration specifications, ISC laboratory workstations still required venting to the atmosphere, and in such a way that introduced minimal noise and vibration to the new facility or to surrounding buildings. The scanning electron microscopes (SEMs) used in the Univ. of Oregon's materials science and nanotechnology research efforts, for example, rely on an extremely stable foundation for accurate imaging of microscopic structures and could not tolerate excessive vibration from a workstation exhaust system and still maintain measurement accuracy. In addition, the proximity of the ISC facility to high-use spaces, including other departments and outdoor areas, meant the system had to be quiet.

As planning associate at the Univ. of Oregon, Fred Tepfer is the project planner in charge of the design of the two-building ISC facility. Part of his responsibility was the choice of laboratory ventilation systems. Since the university's most recent science building was built, around 1990, a great deal had changed in fume hood exhaust technology. Tepfer came to rely on the experience of Dave Knighton, mechanical engineer on the ISC design project. Knighton had been involved previously on several construction projects there, and had experience with several different types of fume exhaust systems, including mixed-flow impeller exhaust fan systems.

The first of the two buildings to be constructed for the new facility represented a particular challenge for an exhaust system, because the building would be located underground between two existing research buildings. In fact, scientists in these other two buildings had voiced concerns that excessive noise and vibration from the new facility could disrupt their operations. Because the new building would be below grade, the exhaust plume would have to reach that much higher to clear the boundary layers of the other buildings.

The below-grade architecture was necessary for maintaining a noise- and vibration-free environment for using sensitive scientific instruments. Knighton explains, "The only available location was the adjacent Dept. of Neuroscience building. Originally, we were

going to locate the exhaust fans directly on the roof of that building, adjacent to a penthouse."

The design team reviewed conventional belt-driven centrifugal exhaust fan installations, but excessive noise ruled out that option. Ultimately, the operational requirements were decided by the six SEMs and sensitive photolithography equipment for forming the fine-featured masks of semiconductor devices. Even the smallest amount of vibration can ruin the delicately patterned semiconductor masks.

Mixed-flow impeller technology

Direct drive mixed-flow impeller systems operate on a unique principle of diluting contaminated exhaust air with unconditioned, outside ambient air via a bypass mixing plenum and bypass dampers. The diluted process air is accelerated through an optimized discharge nozzle/windband where nearly twice as much additional fresh air is entrained into the exhaust plume before leaving the fan assembly. Additional fresh air is entrained into the exhaust plume after it leaves the fan assembly through natural aspiration. The combination of added mass and high discharge velocity minimizes the risk of contaminated exhaust being re-entrained into building fresh air intakes, doors, windows, or other openings.

As an example, a mixed-flow fan moving 80,000 cfm of combined building and bypass air at an exit velocity of 6300 ft/min can send an exhaust air jet plume up to 120 ft high in a 10 mph crosswind. This extremely high velocity exceeds ANSI Z.9.5 Standards by more than twice the minimum recommendation of 3000 FPM. Because up to 170% of free outside air is induced into the exhaust airstream, a substantially greater airflow is possible for a given amount of exhaust providing excellent dilution capabilities and greater effective stack heights over conventional centrifugal fans without additional horsepower.

A typical reduction of $.44 per CFM at $.10/kWh provides an approximate two year R.O.I. Energy consumption for mixed flow fans is about 25% lower than conventional centrifugal fans. Mixed-flow systems are designed to operate continuously and direct drive motor bearings can reasonably be expected to last 100,000 hours. The system's mixed flow wheel make it ideally suited for constant volume or variable air volume (VAV) applications, along with built-in redundancy, and design flexibility. VAV capabilities are achieved via the bypass mixing plenum or by using variable frequency drives to provide optimum energy savings.

Installation worries

The main 44-in-dia stainless-steel exhaust duct for the new ISC facility runs up a spare shaft for the elevator. Because of the size and capacity of the fans on the roof, there was concern that their vibration might be transmitted through the concrete in the Neuroscience building to the laboratories on the third floor. But those initial concerns appear to be unfounded. "You can stand up there next to the fans and put your hand on them and there's no vibration," says Knighton. "Even if they were sitting right on the steel structure, they probably would have been fine."

Along with the low vibration levels, concerns about noise from the fans were also unfounded. As installed, the 44-in-dia stainless-steel duct runs from the roof down through the elevator shaft to the basement ceiling, then turning and running adjacent to the building's main entryway stairs (which run from the ground level to the basement).

Knighton admits that he had more than a few sleepless nights until the startup of the exhaust fans. "As you come down the stairs you can touch the stainless-steel duct—it's that close," he explains. "But all you can hear is a faint airflow noise with up to 17,000 cfm being exhausted through the duct when we tested both fans operating at close to their peak capacity, a high rate that would never be used in the building." He credits the use of mixed-flow impeller technology. "It has to be directly attributable to these mixed-flow fans. It is remarkable when you consider that we avoided the use of sound attenuators at the fans or in the duct." By avoiding the use of the sound attenuators, the facility realizes greater efficiency from the exhaust system with resulting lower energy usage than systems employing sound suppression.

Two low profile mixed-flow impeller systems (Tri-Stack systems from Strobic Air Corp., Harleysville, Pa.,) were installed with service for multiple laboratories. The success of the installation has brought an unexpected dividend, says Tepfer: "One thing that is interesting about the facility is that it's attracting interest on the part of the equipment manufacturers; they all want to get their instruments into this space, so they're approaching us with pretty attractive deals for upgrades and new toys."

—Paul Livingstone