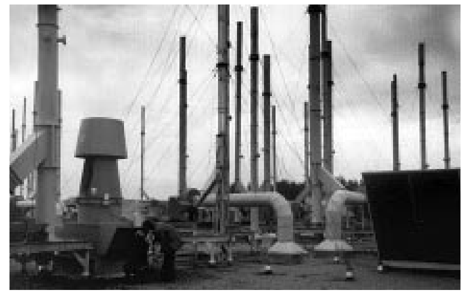
Strobic Air Corporation

Number 101

# TECHNICAL APPLICATIONS BULLETIN

## Effective stack height and re-entrainment: Tri-Stack vs. tall stacks

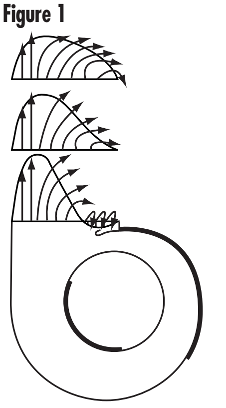


***Tri-stack ... or tall stacks?***

There's virtually no comparison between low profile Tri-Stack systems (typically about 15' high) vs. a combination 30'+ centrifugal fan/dedicated exhaust stack with regard to their exhaust efficiency (at the exit nozzles). For the sake of this discussion we'll concentrate solely on exhaust efficiencies without addressing the many other advantages that Tri-Stack offers over centrifugal fans such as lower profiles, reduced installation costs and time, less vibration, minimal maintenance, and many others.

One measurement of exhaust efficiency concerns crosswinds and their effects on re-entrainment possibilities. Centrifugal fans produce highly rotational discharge flows. This characteristic creates a non-uniform velocity profile at the fan discharge **(See Figures 1, 3).** High velocities concentrated to the outside of the centrifugal fan housing, and reversal of airflow towards the blastgate of the fan housing causes the discharge air stream to tumble, or rotate. This is wasted energy. Remember, the main goal of any fume hood exhaust system is to remove contaminated laboratory workstation exhaust away from the building, away from fresh air intakes, and away from neighbors' buildings as well. This requires all the energy of the exhaust emission plume to be directed vertically into the atmosphere for highest possible efficiency. Any rotation, or spinning, takes energy from the vertical air stream thus retarding velocity (plume rise).

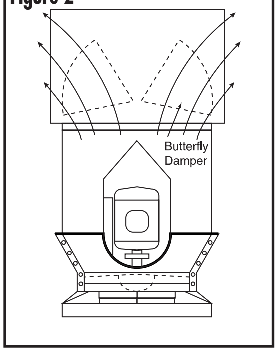
**Figure 1**



**Centrifugal fan showing rotational airflow at fan discharge**

Exhaust system attachments (or other appurtenances) such as weather caps, butterfly dampers, side hinged dampers, etc., obviously obstruct the discharge air stream. Thus, the exhaust air stream is deflected at varying side angles depending upon installed accessories. Rain caps prevent exhaust air from discharging vertically; butterfly dampers can divert the discharge air as much as 30° from vertical **(See Figure 2).** Any obstruction to the discharge air stream or rotation of the discharge air stream will degrade the predicted effective stack height performance of a roof exhaust system. ASHRAE Chapter 43 states "...stacks should be vertically directed and uncapped. Stack caps that deflect the exhaust jet have a detrimental effect on both the initial dilution of the exhaust jet and the exhaust plume rise."

**Figure 2**




Many fan manufacturers use the *Briggs Equation* (1984) to predict the plume rise of their fans (reference *ASHRAE Fundamentals 1997 Ch 15.13):*

Hr = Plume rise
Uh = Crosswind speed
D = Stack diameter
B = Capping factor (stack)
Ve = Exit velocity

$$Hr = 3.0\ Bd\ \left(\frac{V_e}{U_h}\right)$$

The "Stack Capping Factor" in the Briggs Equation is the provision for quantifying the effect of a deflected or rotating exhaust plume. The Stack Capping Factor, which is often overlooked by fan manufacturers, predicts plume rise for their product. Therefore, the designer must account—and perhaps compensate—for the direction and magnitude of the discharge air stream. This is essential when determining placement of exhaust fans with regard to the building's fresh air intakes.

ANSI Z9.5 urges designers to specify exhaust systems (and their location on the roof) so as to avoid re-entrainment into the building or adjacent buildings. The severity of the rotation or angle of deflection of the exhaust air stream determines the Capping Factor. Discharge exhaust air streams that rotate or are deflected have capping factors **less than 1.0.**

**Discharge airflow profile from centrifugal and axial fans**

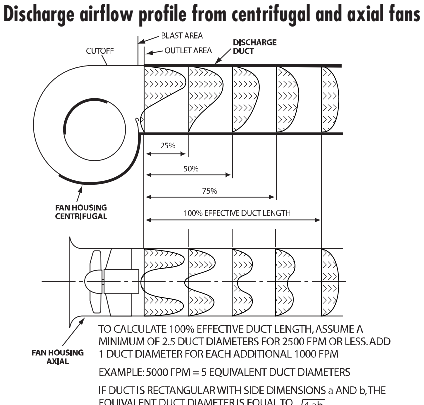



**Figure 3**

The Capping Factor for the Tri-Stack system is always 1.0. Tri-Stack fans are specifically designed to maximize the discharge momentum of laboratory exhaust without plume rotation or deflecting the exhaust plume. How do we accomplish this? By adding unconditioned, ambient outside air to the contaminated lab exhaust we maximize mass. Our unique mixed flow impeller technology aerodynamically and uniformly moves this large mass of diluted exhaust air through the downstream guide vanes. The job of the guide vanes is to remove the rotational component from the exhaust air as it leaves the impeller. Next, the exhaust air is accelerated through our patented nozzle windband. It is here that we combine maximum mass with maximum velocity to produce maximum momentum. All this energy is directed straight up into the air without rotation, deflection, or restriction providing superior plume efficiency.

Building systems, obstacles, accessories, and other appurtenances such as architectural screens (used to mask roof top centrifugal fans in many cases) can adversely effect exhaust dilution according to the ASHRAE handbook. Also, large buildings, structures, and terrain close to the emitting buildings can (and usually do) have adverse effects on dilution of stack exhaust. That's because the emitting building may be within the recirculation flow zone downwind of these obstacles. Air intakes located on nearby taller buildings can also be contaminated by exhaust from shorter buildings. This is especially true for centrifugal roof exhaust systems and virtually impossible for Tri-Stack systems that are properly located.

ASHRAE Chapter 43 *(Building Air Intake and Exhaust Design)*, in discussing stack design strategies says that, "the dilution a stack exhaust can provide is limited by the dispersion capability of the atmosphere. Before discharge, exhaust contamination should be reduced by filters, collectors, and

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scrubbers." The chapter also discusses combining exhaust flows from many collecting stations (manifolding) and states that they… "should always be used where safe and practical." It goes on to say that combined flow forms an exhaust plume that rises "a greater distance" above the emitting building. Additional air volume can be added to the exhaust near the exit with a makeup air unit to increase the initial dilution and exhaust plume rise. This added air volume does not need heating or cooling, which helps reduce energy consumption.

**Conclusion**

To achieve maximum potential plume rise the concept of how air leaves the exhaust fan must be clearly understood. Centrifugal fans – with non-uniform discharge velocity profiles – essentially cap the fans' discharge because of aerodynamic principles. Exhaust fans with butterfly, or side hinged dampers deflect the exhaust plume laterally, thus reducing overall vertical plume rise. Tri-Stack mixed flow exhaust fans with standard downstream guide vanes maintain a uniform, high velocity 100% vertically diverted exhaust stream to maximize plume rise.

# "A bargain at any price"

## *Or, you get what you pay for...*

**We've all heard these clichés before. If they weren't true they wouldn't be clichés.**

Okay, so Tri-Stack fans and systems cost more—initially—than ordinary centrifugal fans with belt drives and tall, dedicated stacks. It is true in most cases. However, the key word here is, "acquisition" cost, since in the long run Tri-Stacks are substantially less expensive than any other system with comparable performance. *We can prove it.*

Consider these "value added" advantages offered only by Tri-Stack fans and systems:

***Fast, convenient, straightforward installation***—Tri-Stack systems are composed of three individual modules, specially designed to speed and simplify installation while reducing installation costs. As a result, mounting Tri-Stack fans directly on the roof is fast, and there's no need for expensive construction equipment and helicopters that may require building evacuation. Typical installation can be accomplished in less than two hours, with minimal—*or no*—disruption of work schedules causing wasteful and expensive downtime. Tri-Stack systems are also easily retrofitted onto existing roofs with minimal effort.

***Substantially lower installation costs***—Because Tri-Stack fans are free-standing, they do not require complex and expensive mounting hardware such as roof curbs (with associated pitch pocket roof leaks), guy wires, flex connectors, or spring vibration isolators to install and maintain. Engineering costs are also reduced, as well as disruption of work schedules.

***Direct drive motors with seven year warranties***—*No other company in the industry offers such a liberal motor warranty.* That's seven years of worry-free performance for your system, with motors rated at $L_{10}$ at 100,000 hours.

***Virtually maintenance free operation***—Tri-Stack systems require no maintenance (other than occasionally greasing bearings on some systems). There's no need for time-consuming, maintenance-intensive, and sometimes dangerous belt adjustment and/or replacement. Unlike belt-driven centrifugal fans, advanced technology Tri-Stacks also eliminate the need for roof-mounted penthouses to protect workers from the elements (and possibly harmful fumes).

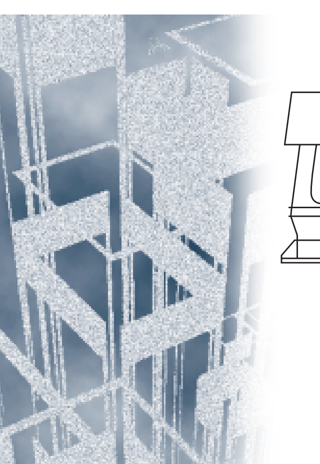
***Tri-Stack systems offer the lowest vibration performance characteristics of any other comparable system.*** This means there's no additional expense down the road for replacing fan components damaged by vibration, and no replacement concern for other system components such as ducting, mounting hardware, roof supports, etc., that might be damaged by vibration from centrifugal belt-driven systems.

***Reduced horsepower motors help reduce energy costs***—Tri Stack's exhaust nozzle design maximizes system performance to provide increased airflow and efficiency while lowering horse power requirements, thus further reducing energy consumption.

**Lower operating costs** also result from Tri-Stack's computer designed, advanced exhaust nozzle configurations that help lower resistance, increase flow and pressure, and increase stack outlet velocities to minimize bypass requirements.

**Further energy savings** result from Tri-Stack's unique fan wheels which help lower horse power requirements with subsequent energy reduction. Non-stall characteristics permit use of variable frequency drives, further enhancing efficiency and reducing energy consumption—*all without the need to exchange pulleys and/or adjust belts.*

**Unique heat recovery systems** available with Tri-Stack fans can help save thousands and even hundreds of thousands of dollars. Tri-Stack fans with heat recovery systems cut building heating costs approximately 3% for each 1°F of ambient heat recovered in closed-loop, 100% makeup air facilities.

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