# Energy Saving Opportunities in Laboratory Exhaust Systems



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# Fume Exhaust Systems

## Matt Gaedtke

- Segment Manager – Lab and Fume Exhaust Systems
- Employed at Greenheck since 1994
- Member NE WI ASHRAE
- Mechanical Engineering – UW Madison
- Masters of Business – UW Oshkosh

# Learning Objectives

- Lab Exhaust Ventilation System Basics
- Review Solutions to Safely Reduce the Cost of Ventilating Lab Spaces

# The Main Objectives of a Laboratory Exhaust System

- Remove hazardous or noxious fumes from a laboratory
- Dilute the fumes as much as possible
- Expel them from the lab building so that the fumes do not contaminate the roof area
- Prevent re-entrainment into building make-up air systems

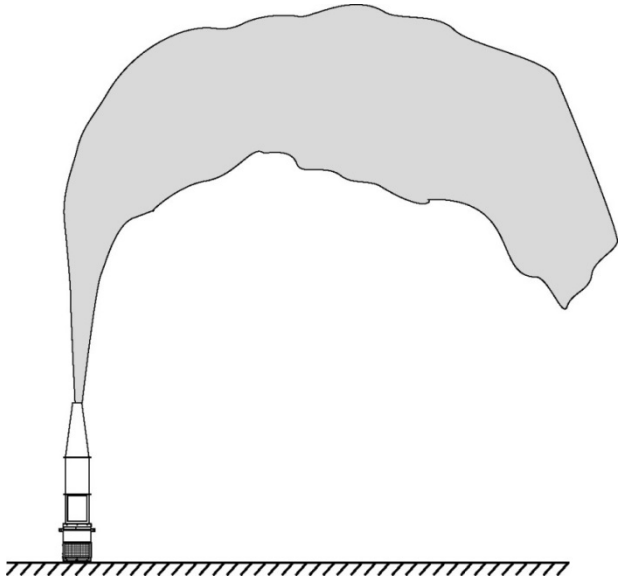
# ANSI Z9.5 and NFPA 45

- Minimum stack discharge velocity shall be 3000 FPM (15.2 m/sec)
- Stack height shall not be less than 10 ft (or 3 m) above roof line

# Maximizing Plume Rise

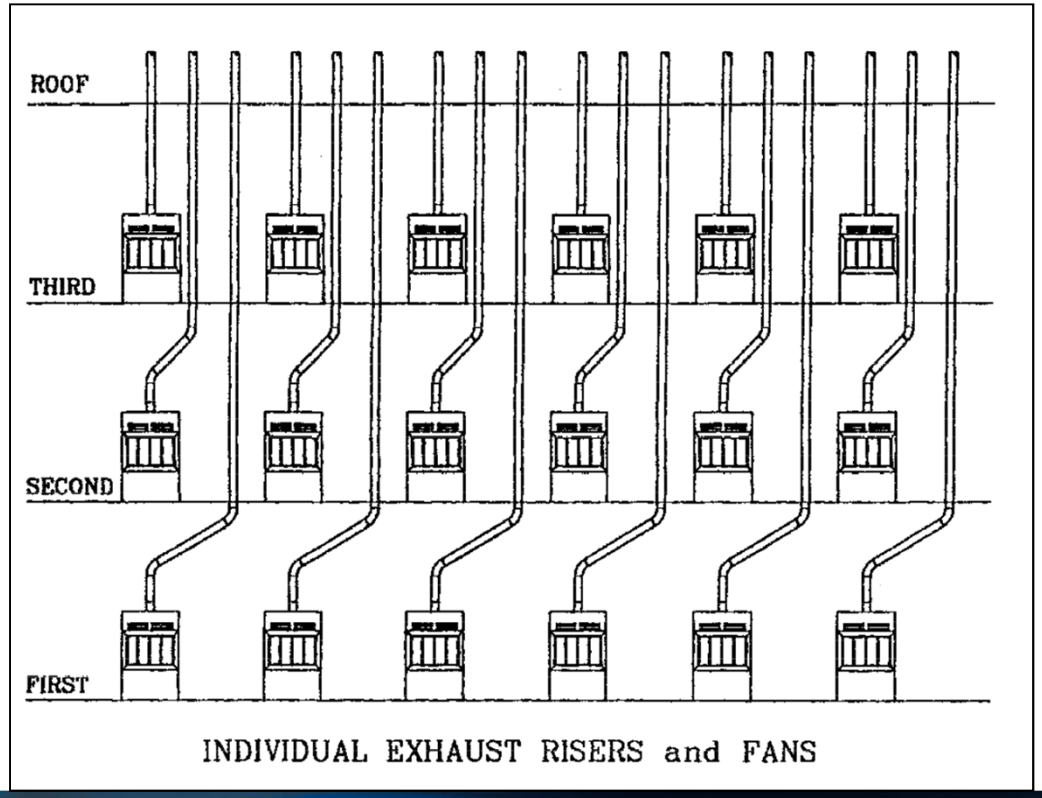
$$h_r = \frac{3Vd}{U}$$

where: $h_r$ = plume rise, feet
V = discharge velocity, fpm
d = nozzle diameter, feet
U = wind speed, ft/min



Plume Rise, $h_r$, equation (Briggs)

# Older Lab Designs




INDIVIDUAL EXHAUST RISERS and FANS



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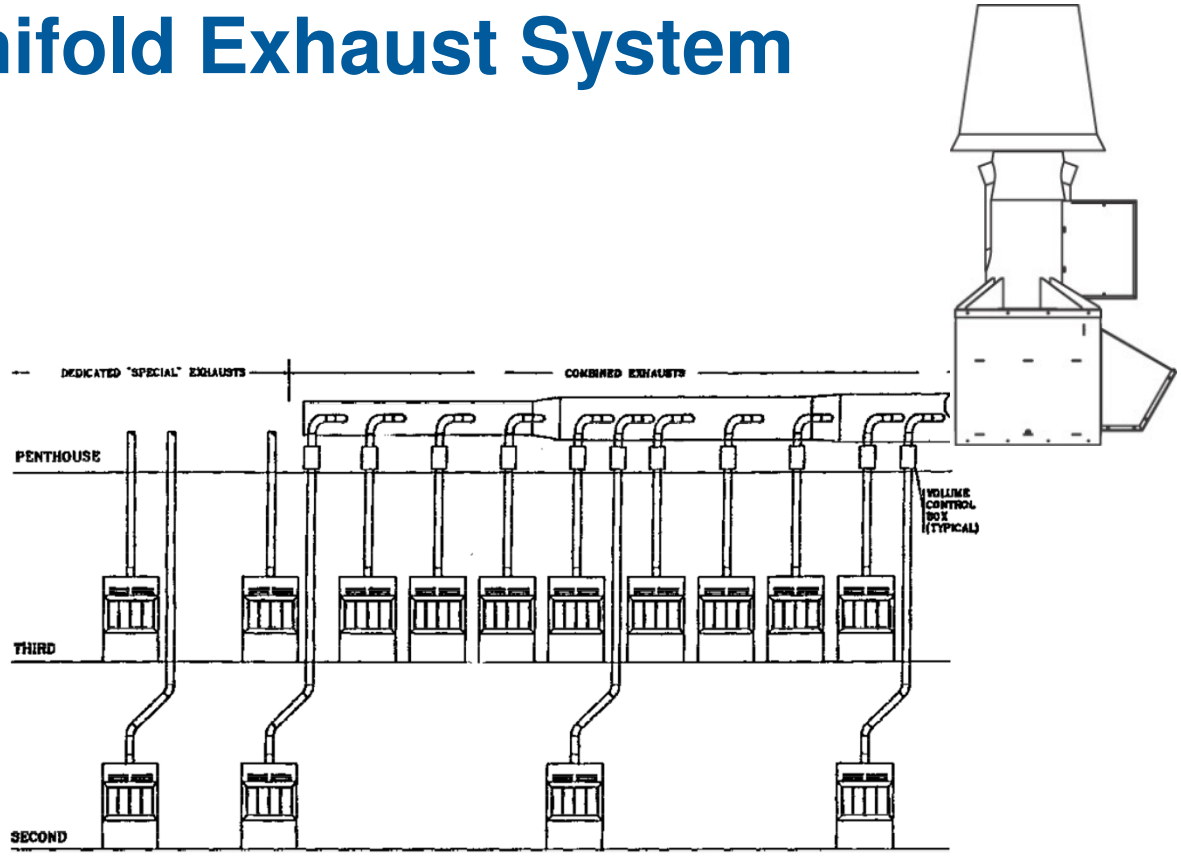
# Manifold Exhaust System

A manifolded exhaust system reduces the number of exhaust stacks and the stack height, improves the dilution, plume rise, and architectural aesthetics of the building as well as reducing neighbor attraction to the exhaust system



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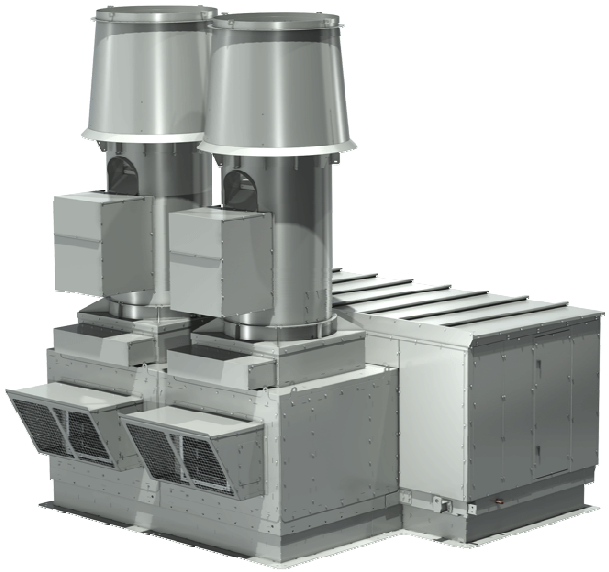
# Challenge – Labs Are Big Energy Users



- *Laboratories 100% ventilated.*
- *You cannot recirculate air in a laboratory (except in special cases).*
- *50% of the energy used in a laboratory is attributed to ventilation.*
- *Understanding solutions to reduce energy consumption will pay off!*



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# Utilizing “Pre-Engineered Fan Systems” to Reduce Energy Costs



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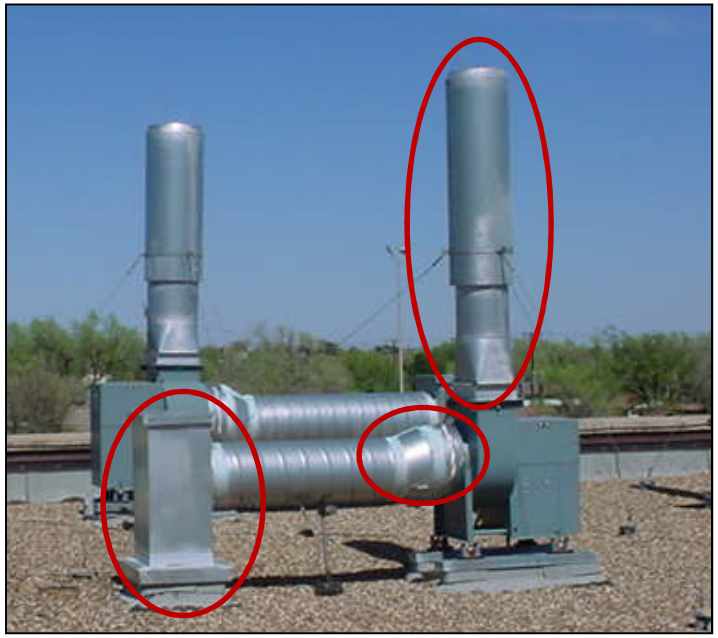
# Field Built Lab Systems



- Multiple locations for unaccounted performance loss in this system…

# Cost of 25% Increase in RPM

| | CFM | PS | RPM | Bhp | Motor | Sound | $ Annual |
|---|---|---|---|---|---|---|---|
| **Design** | 1000 | 1.5 | 1789 | 0.42 | 0.5 | 67 | $124 |
| **Measured** | 800 | 1.5 | 1789 | 0.42 | 0.5 | 67 | $124 |
| **Adjustment** | 1000 | 2.3 | 2133 | 0.66 | 0.75 | 72 | $166 |

- 25% increase in CFM
- 57% increase in Bhp
- 34% increase in $ Annual Operating Cost
- 5 dB increase in Outlet Sound



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# Pre-Engineered Lab Systems

- Nozzle losses included in fan data (*AMCA licensed!*)
- No unnecessary transitions
- Meet applicable velocities and unit heights
- Easy to install
- No guy wires to meet 125 mph windload

# Benefits of Variable Volume Laboratory Exhaust Systems



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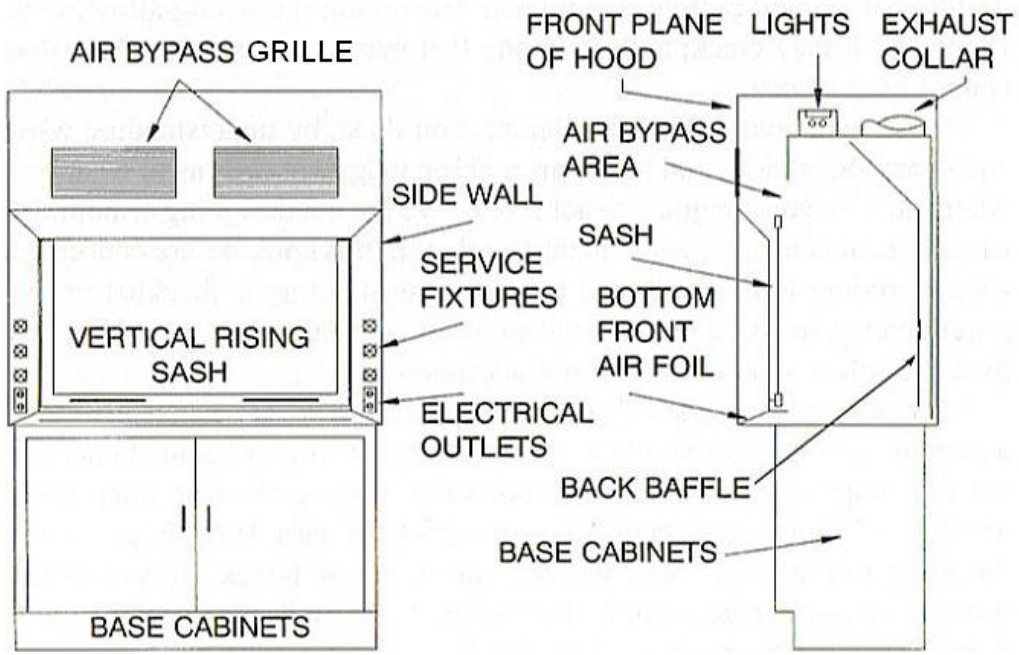
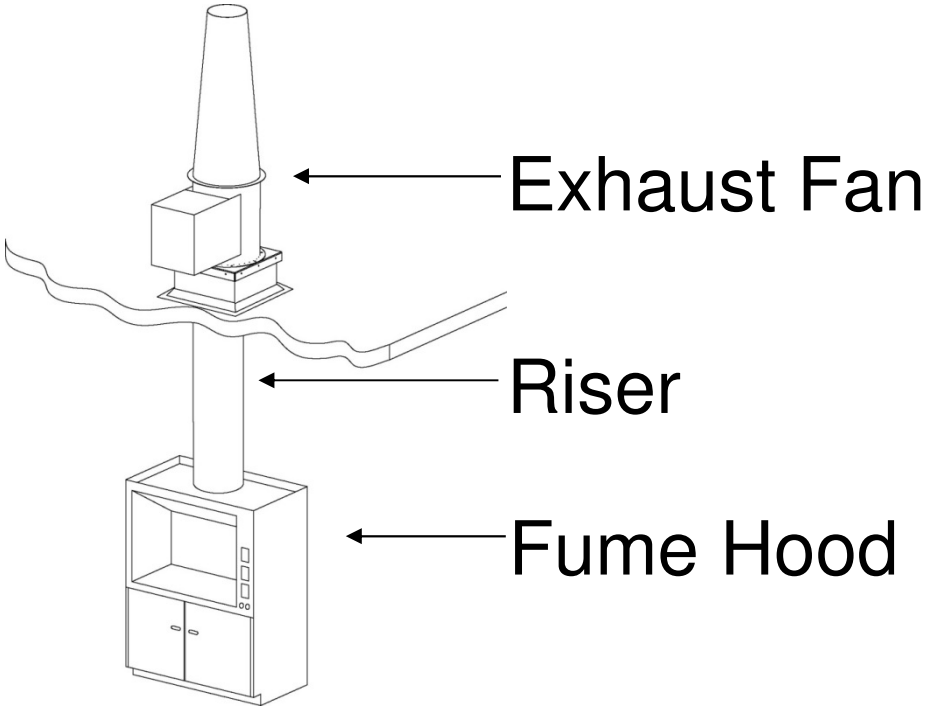
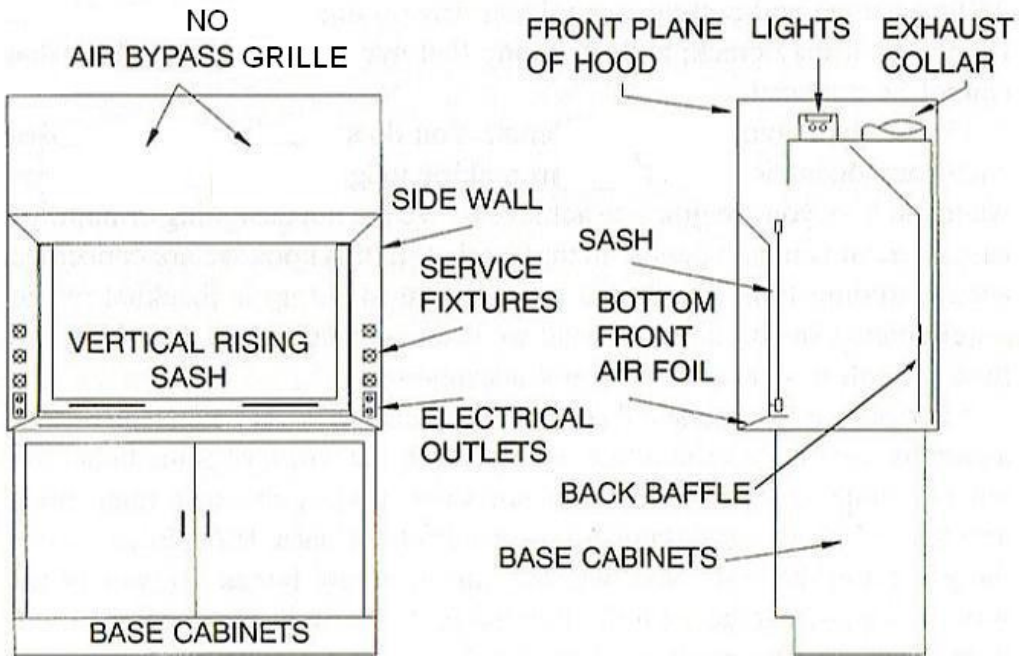
# Constant Volume Fume Hood



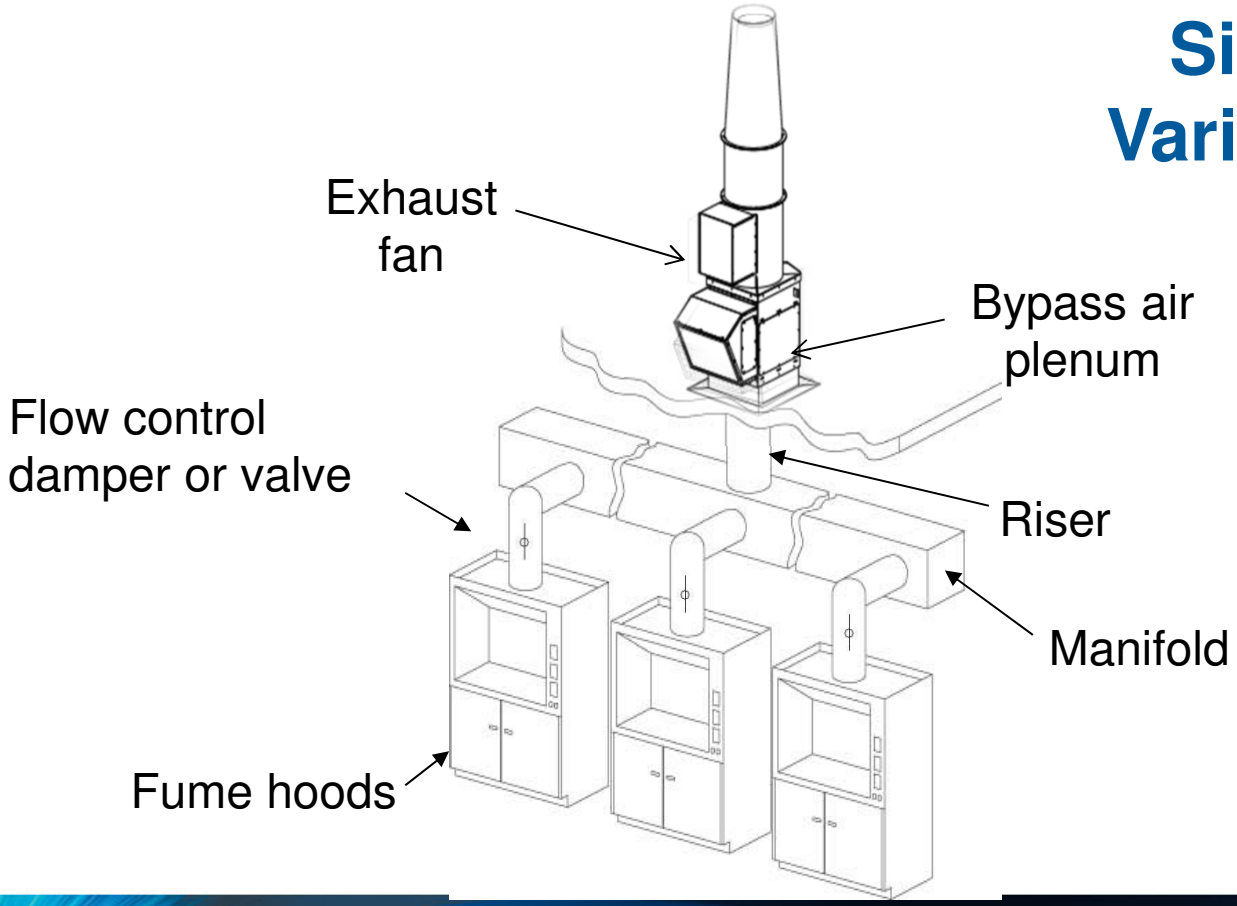
# Constant Volume Fume Hood



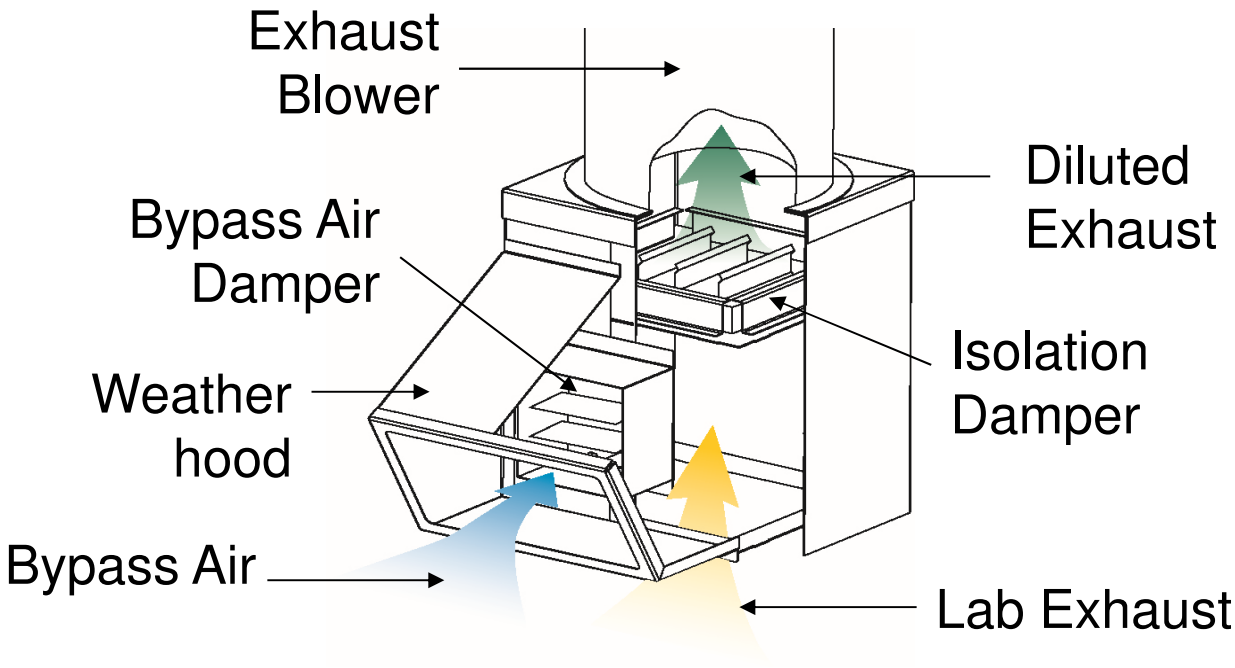
# Variable Volume Fume Hood



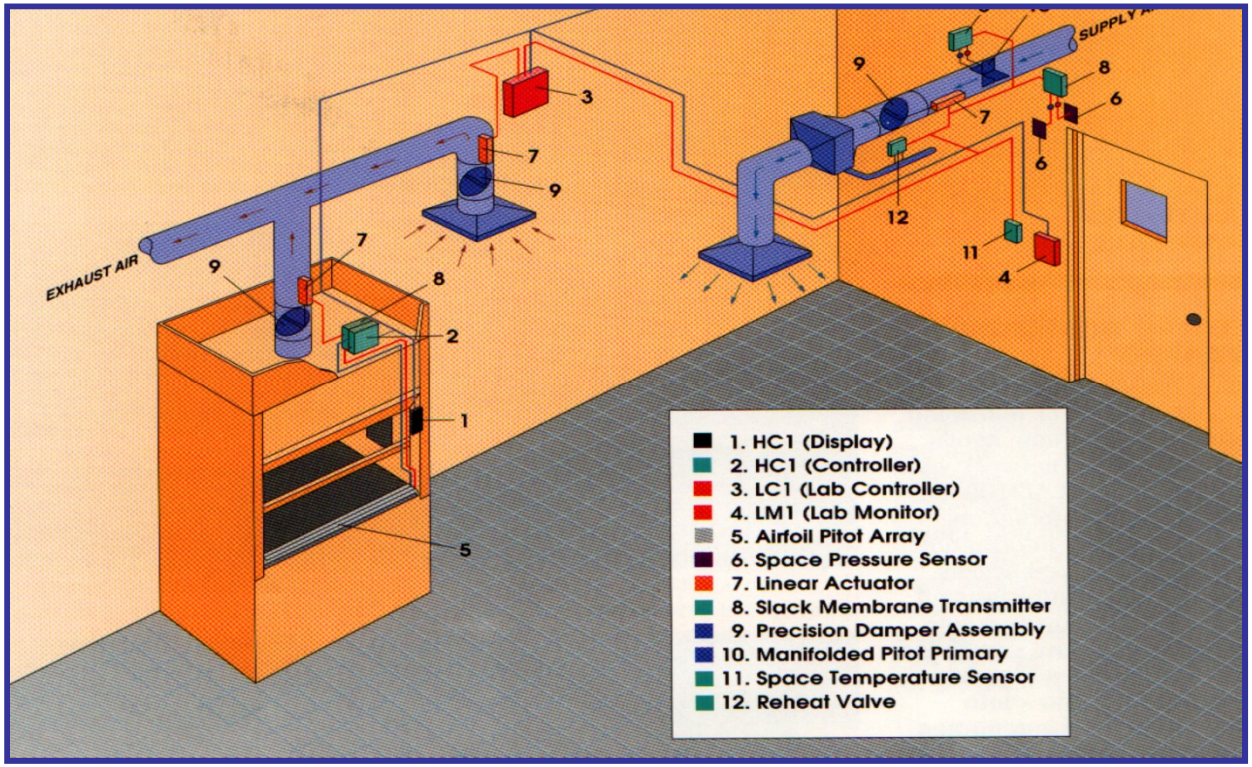
# Single Fan – Variable Volume



# How Bypass Air Plenums Work



# VAV Savings Summary




*Less Exhausted Air*
*Equals Less*
*Conditioned Intake Air*



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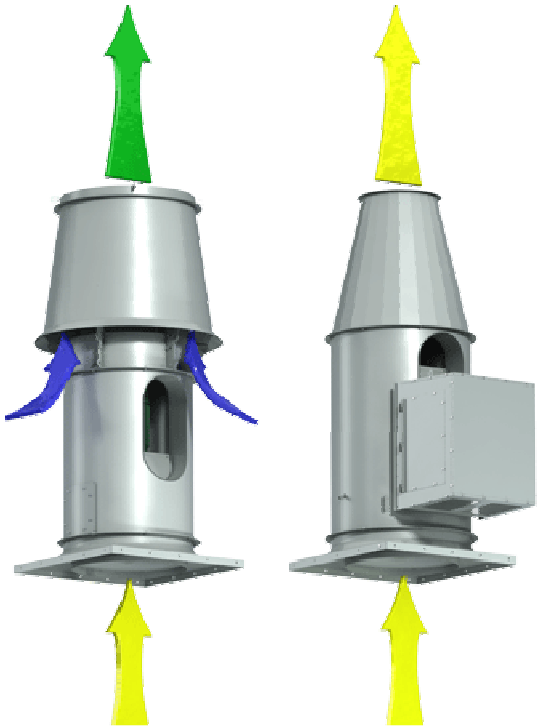
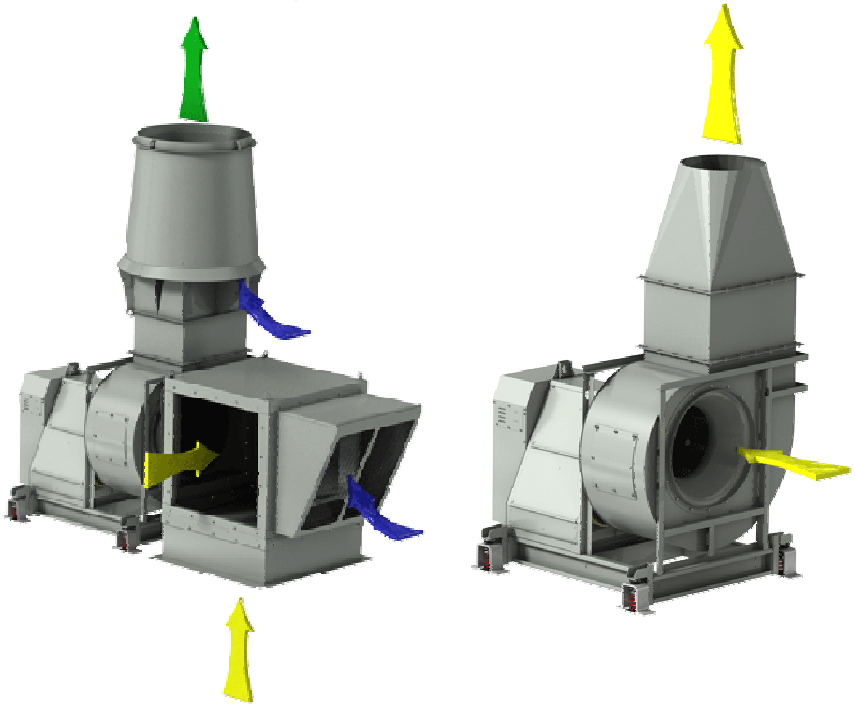
# High Efficiency Exhaust Fan Technology to Reduce Energy

# Fan Technology



Inline Fans



Centrifugal Fans

**Inline fans are excellent for tight space areas**

**Mixed flow inlines are capable of efficiencies in excess of 70%**



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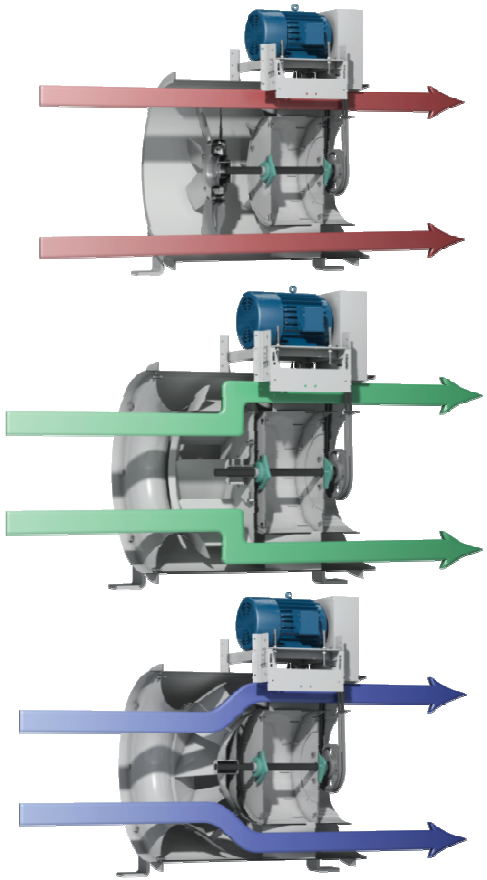
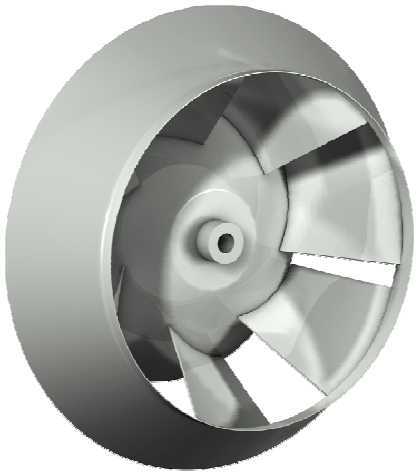
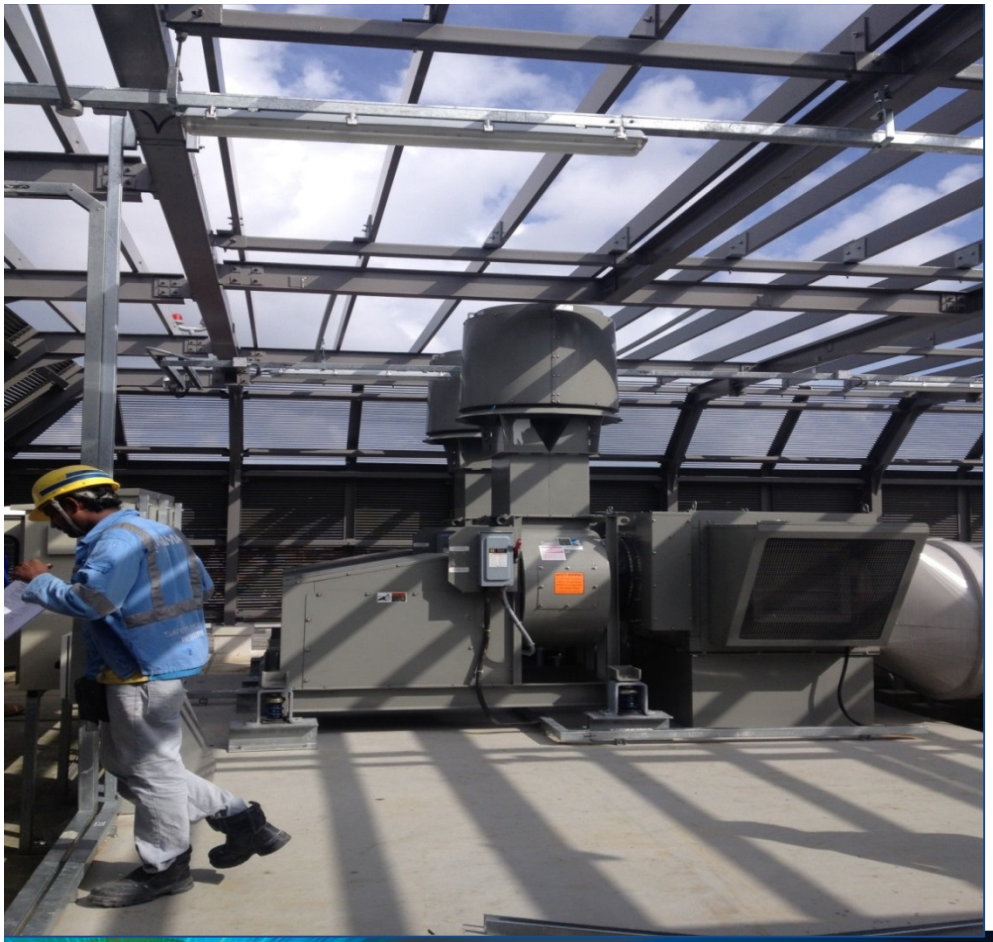


# What is “Mixed Flow”?

- A mixed flow wheel has a hybrid impeller with performance characteristics between an axial an centrifugal





**Centrifugal systems are easier to service, but tend to take up more roof space**

**Airfoil centrifugal fans are capable of efficiencies exceeding 80%**



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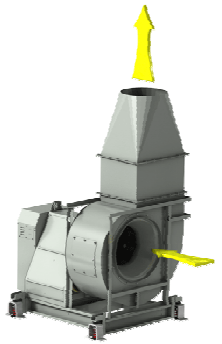
# Fan Performance Comparisons

30,000 CFM at 5” w.g. (Single Fan Only)

| Model | Size / Nozzle | BHP | Nozzle Velocity (fpm) | Effective Plume Rise (ft) | Outlet Sound | Relative Cost |
|---|---|---|---|---|---|---|
| Mixed Flow | 40 | 40 | 3119 | 44.6 | 85 | 1.10 |
| Centrifugal | 40 | 37 | 3831 | 48.4 | 85 | 1.00 |

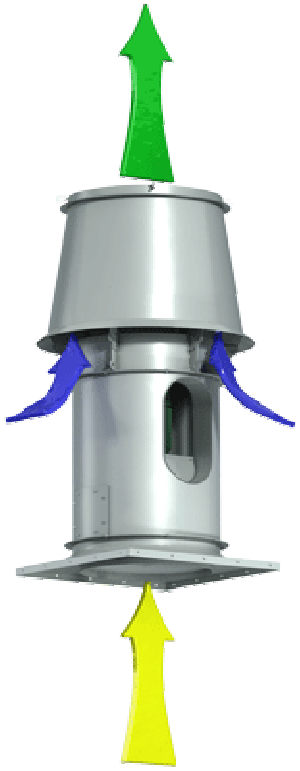
Mixed Flow Inline



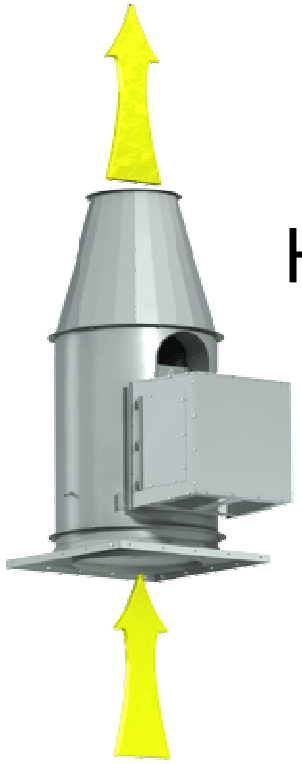
Airfoil Centrifugal

# Advanced Stack Technology to Reduce Energy

# Fan/Stack Technology

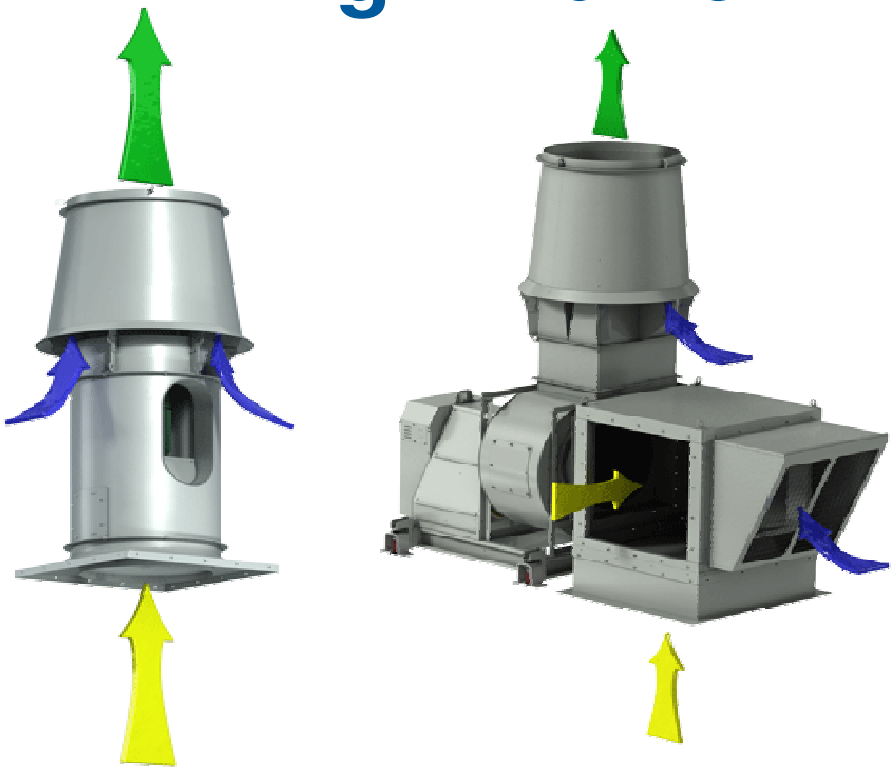


High Plume
Dilution



High Plume

# “High Plume Dilution” Stacks



- Dilution nozzles add entrainment air to dilute the exhaust effluent
- Energy levels can increase to attain necessary nozzle exhaust levels

# Impact of Outlet Velocity

Pressure drop through a nozzle is proportional to the square of the outlet velocity (outlet area if flow is held constant).

| Approximate Pressure Loss Through a Nozzle at Various Outlet Velocities | |
|---|---|
| **Outlet Velocity (FPM)** | **Static Pressure Loss (in wg)** |
| 2000 | 0.25 |
| 3000 | 0.56 |
| 4000 | 1.00 |
| 5000 | 1.56 |
| 6000 | 2.24 |

*Some high plume dilution nozzles exceed 5,000 ft/min*

# Impact of Outlet Velocity on BHP

- 30,000 cfm @ 3” wg
- Same fan with different outlet nozzles

47.7% reduction in BHP

| Power | Outlet Velocity |
|---|---|
| 42.86 | 7433 |
| 38.07 | 6424 |
| 33.09 | 5536 |
| 26.71 | 4487 |
| 22.4 | 3134 |

*High plume dilution nozzles may drive higher motor HP’s*

# Pop Quiz

*What is the annual cost to operate a 25 HP motor, 24x7x365 @ $.10/kw-hr?*

A) Between $7,500 - $12,000
B) Between $12,001 – $17,500
C) Between $17,501 – $22,500

# Pop Quiz

*What is the annual cost to operate a 25 HP motor, 24x7x365 @ $.10/kw-hr?*

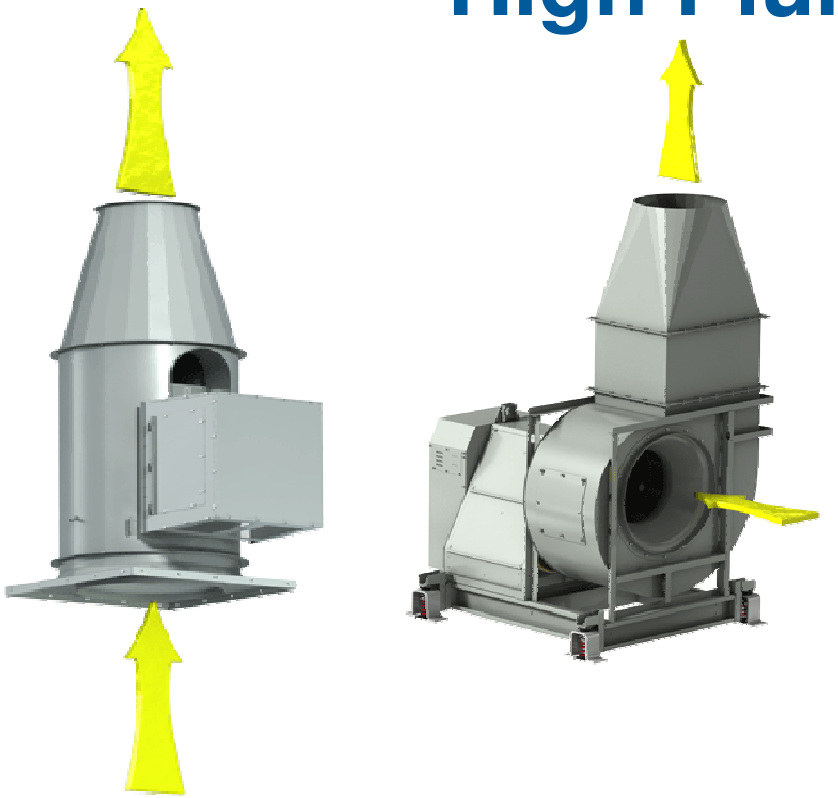
A) Between $7,500 - $12,000

B) Between $12,001 – $17,500

C) Between $17,501 – $22,500

*Just over $16k. By the way, a 50 HP costs over $30k to operate.*

# “High Plume” Stack



- High Plume Stacks attain plume heights without excessive pressure drop keeping HP low
- There is no measureable dilution with a high plume nozzle

# Nozzle Comparisons

30,000 CFM at 5” w.g. (single fan only)

| Model | Size / Nozzle | BHP | Nozzle Velocity (fpm) | Dilution (%) | Effective Plume Rise (ft) | Outlet Sound | Relative Cost |
|---|---|---|---|---|---|---|---|
| Dilution | 40-85-MV | 55.1 | 5882 | 196 | 50.4 | 91 | 1.00 |
| High Plume | 40-85 34 | 43.0 | 3807 | N/A | 54.0 | 88 | 0.90 |

Dilution Nozzle

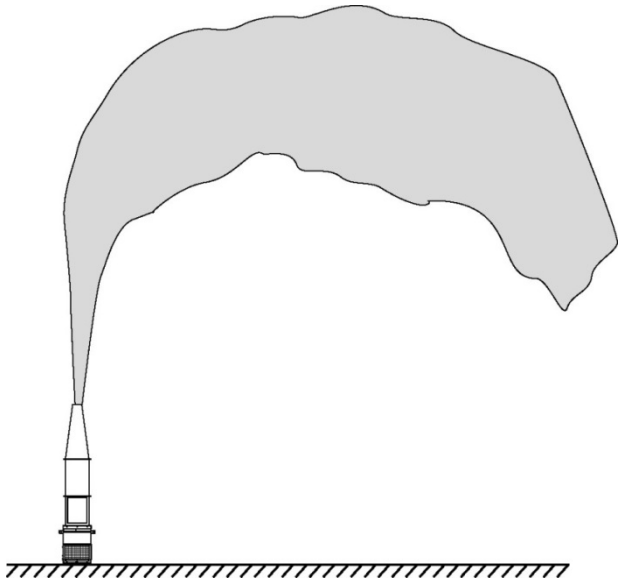
High Plume

*A 50 HP vs. 60 Hp is roughly $6,800 annual savings*

# Why Not Use VFD's in Laboratories?

Concerns

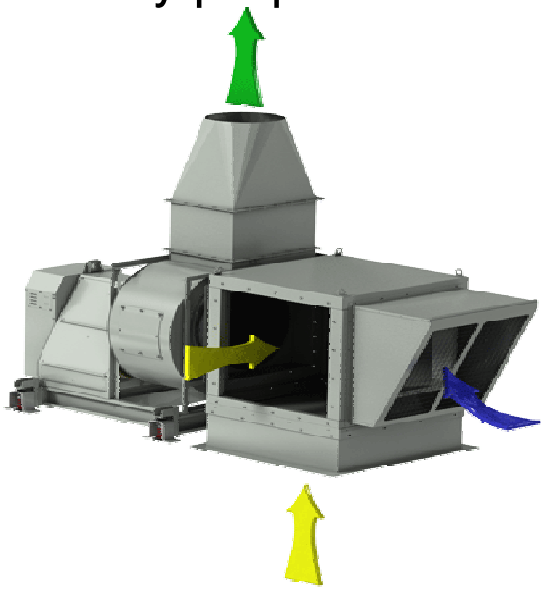
- Potential for loss of design exit velocity
- Potential for re-entrainment of lab of exhaust air into buildings
- Oversizing nozzle velocity costs money in increased horsepower



# Variable Geometry Nozzles

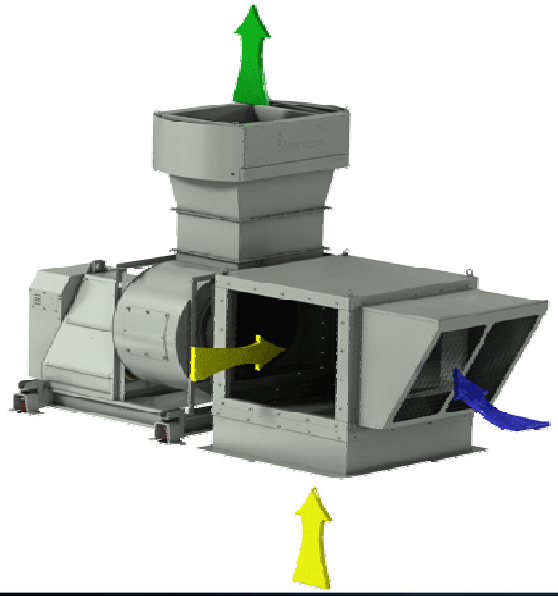
## Fixed Nozzle

(Outlet velocity proportional to flow)



## VGN

(Outlet velocity constant)



# How The Variable Geometry Nozzle Works


Occupied / Open Sash

- VFD max. speed
- 100% fully open nozzle
- Discharge velocity 3,000 FPM
- Bypass damper closed

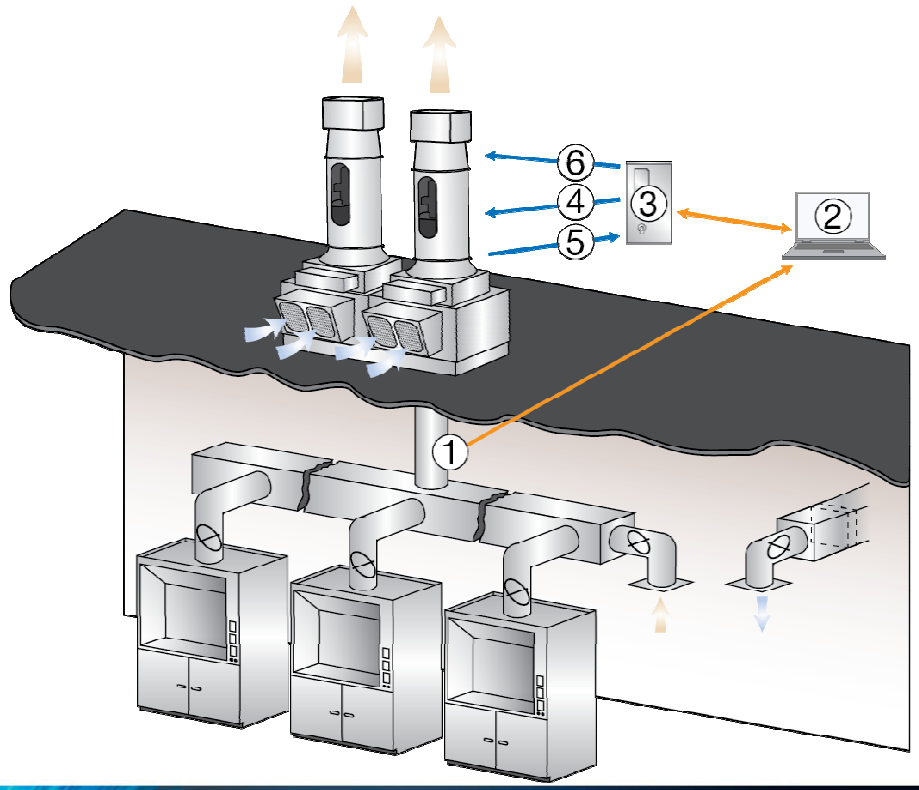

Occupied / Sash Closing

- VFD speed reduced
- Partially closed nozzle
- Discharge velocity 3,000 FPM
- Bypass damper closed


Unoccupied

- VFD min. speed
- Minimum nozzle position
- Discharge velocity 3,000 FPM
- Bypass damper may open

# Variable Geometry Nozzle System




1. Static pressure measurement
2. Building Management System
3. Variable frequency drive and fan controller
4. Signal to fan motor
5. Non-Invasive air flow measurement
6. Signal to Variable Geometry nozzle actuators



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# Nozzle Comparisons

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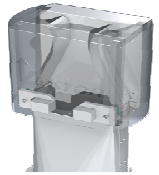
| High Plume | 40-85 34 | 43.0 | 3807 | N/A | 54.0 | 88 | 0.90 |
| VGN | 40-85 | 38.5<br>29.2 | 3400 | N/A | 51.5<br>47.0 | 87<br>82 | 1.13 |

*VGN requires additional electronics, flow station and controller*

Dilution Nozzle

High Plume



Variable Nozzle

# Benefits of Variable Geometry Nozzles

- Lower first cost of motors and electrical
- Reduced fan energy consumption
- Lower acoustics at unoccupied modes
- Maintain discharge velocity to meet ANSI Z9.5
- Real time system monitoring with BMS
- LEED credit opportunities

# Advanced Controls Technology (Staging) to Reduce Energy

# Fan Staging Controls on VAV Labs

Alternative means to reduce energy for variable airflow systems

- Uses a greater quantity of fans
- Uses smaller fans
- Uses bypass air dampers



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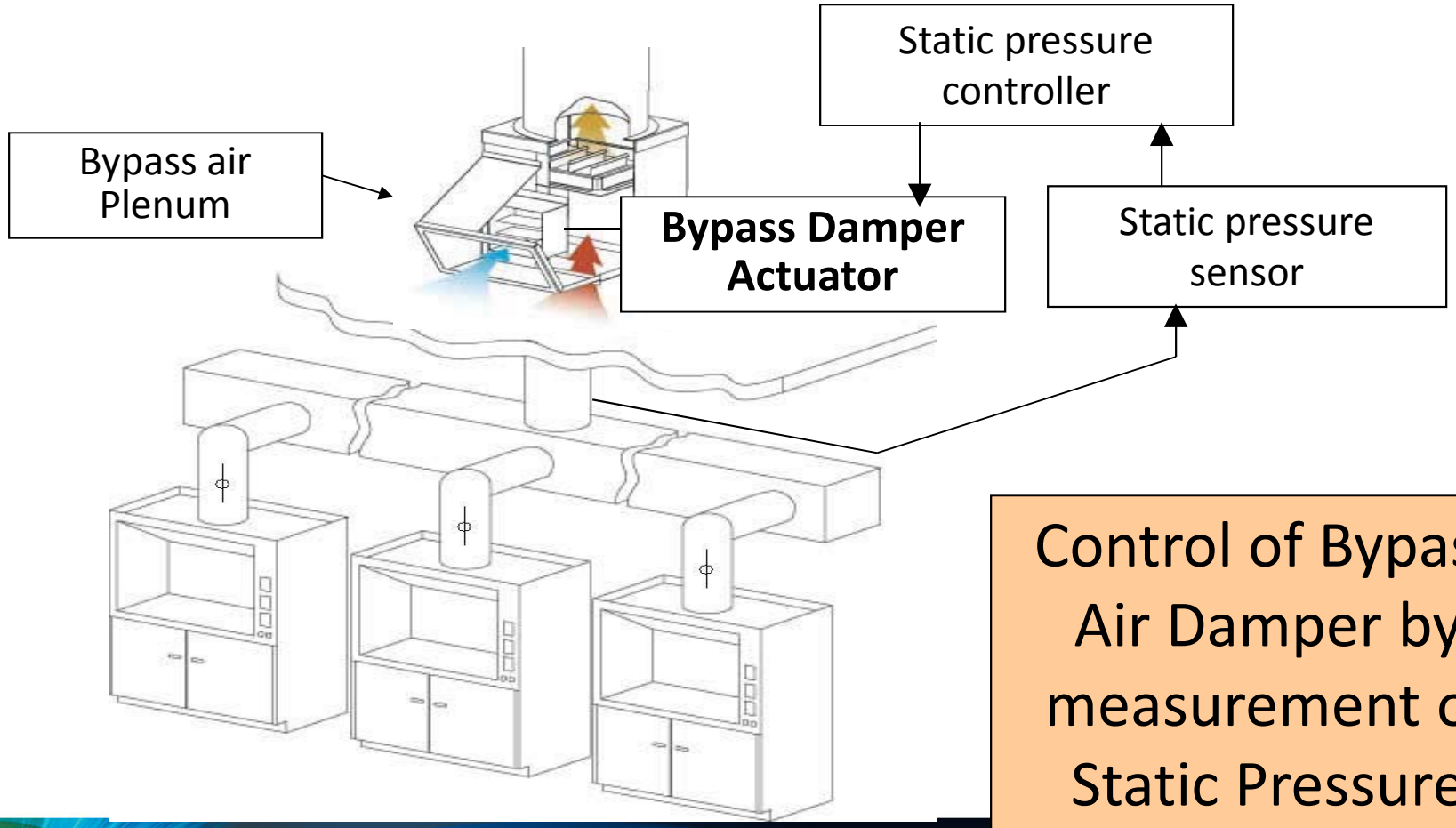


Control of Bypass Air Damper by measurement of Static Pressure



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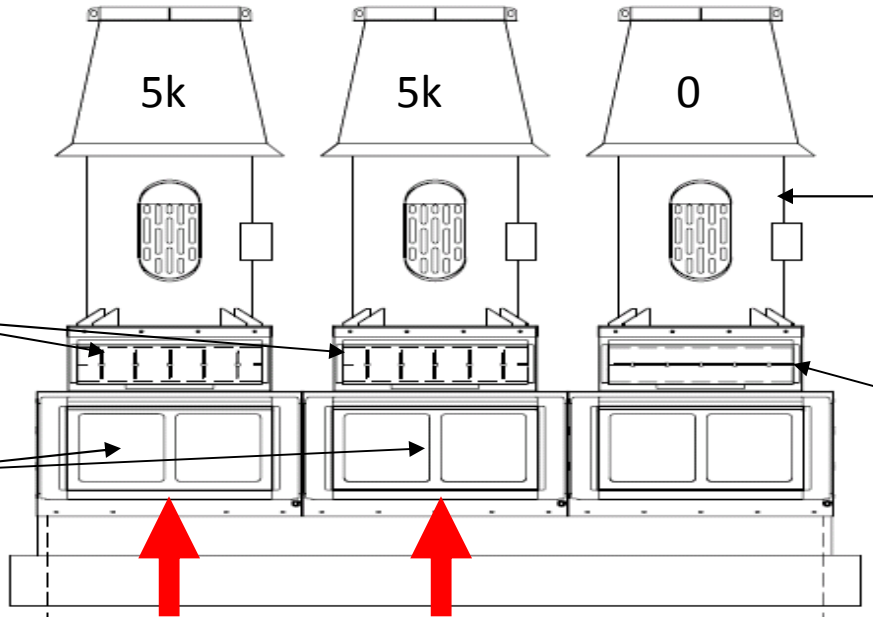
# Example: 5k – 10k CFM



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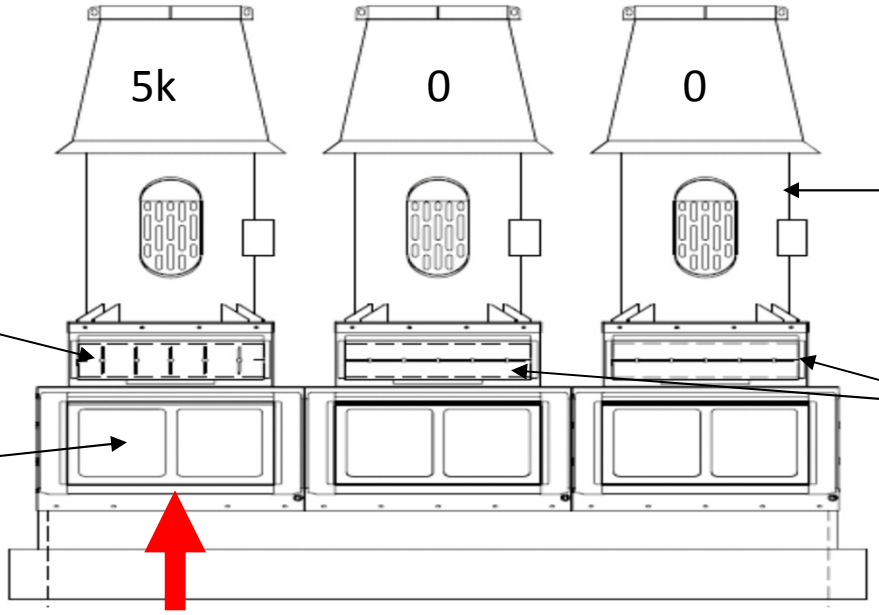
# Example:  Up to 5k CFM




Isolation Damper (Open)

Bypass Air Dampers

Standby Fan

Isolation Dampers (Closed)

Up to 5,000 CFM





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# Fan Staging Results

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Up to 10k 2 Fans | 12.5% (6 Hours) | | | | | | 25% (12 Hours Total) | |
| Up to 5k 1 Fan | | | | | | | | |
| | 12 a.m. | 3 | 6 | 9 | 12 p.m. | 3 | 6 | 9-12 |



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# Additional Advantages

- Maintains stack discharge flow and velocity
- Allows selection of fans to maximize efficiency
- Allow use of smaller fans with smaller motors
- Can be programmed to alternate the standby by fans
- Will help reduce sound levels during low usage periods



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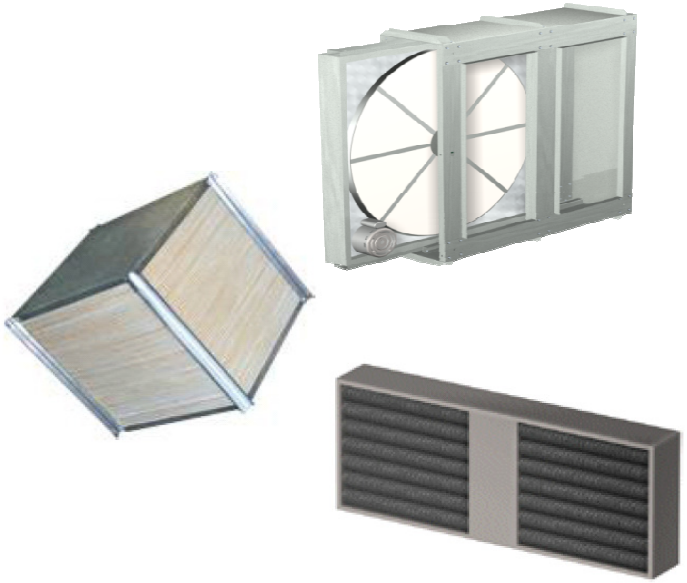
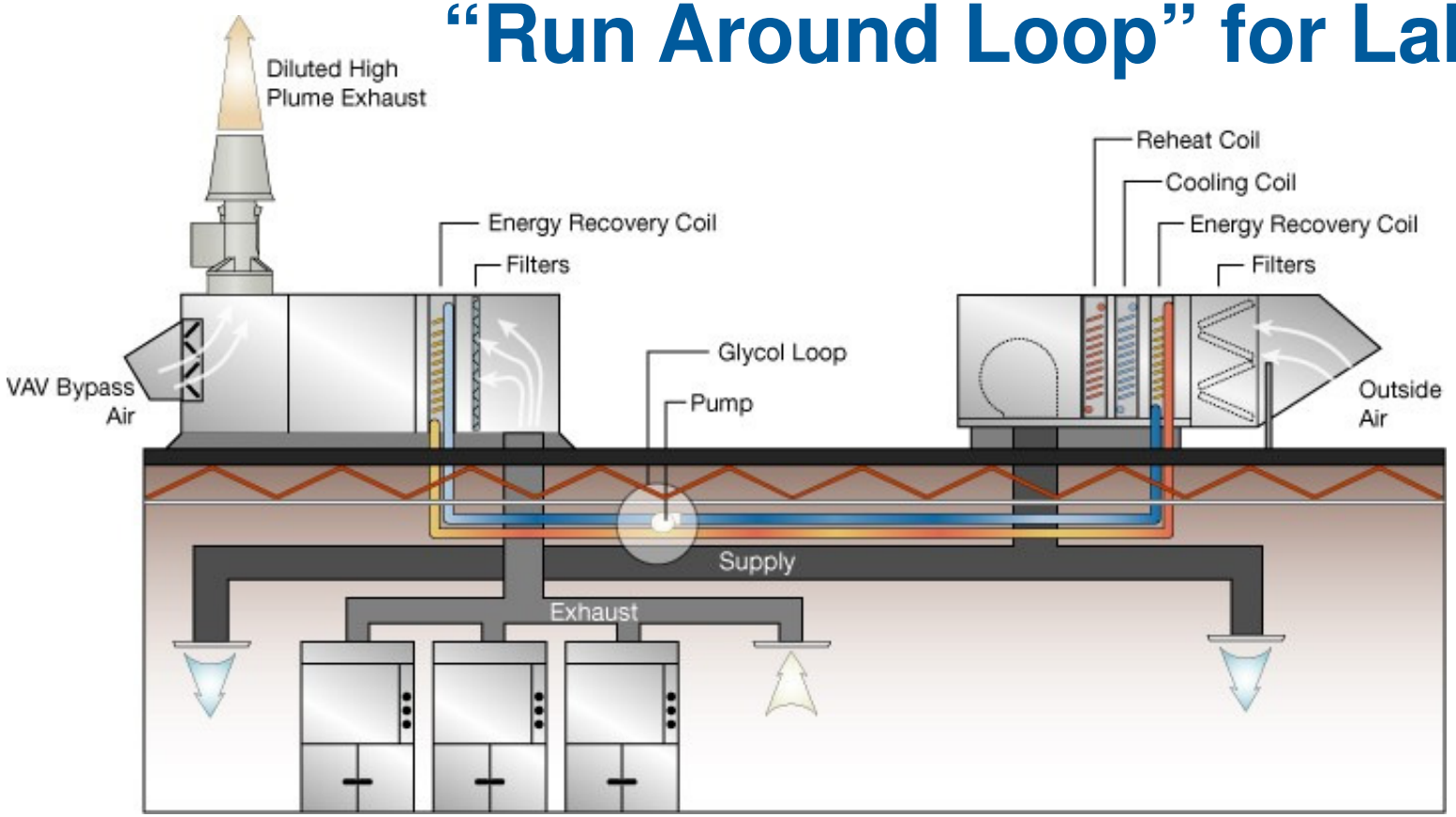
# Laboratory Exhaust Energy Recovery Systems

# Energy Recovery Types

- Wheels
- Plates
- Heat Pipes
- Run Around Coil Loops



# “Run Around Loop” for Labs

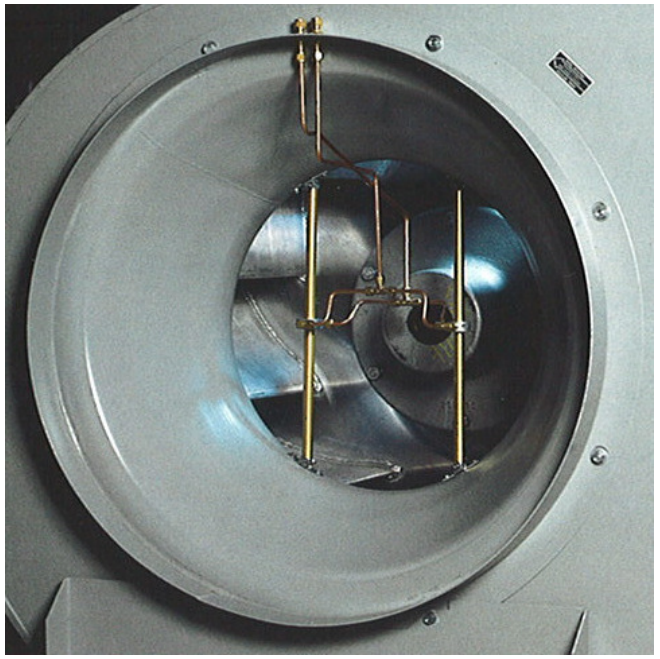


# Effectiveness Up to 45-55%

# Energy Saving Accessories and Metering

# Fan Inlet "Invasive" Mounted Probes

- Mounted into the smallest diameter of the fan inlet venturi
- Use 3/8-in. to ¾-in. tubing that is designed to measure total and static pressure components of airflow



# System Effect (in. wg) for Typical Invasive Probes

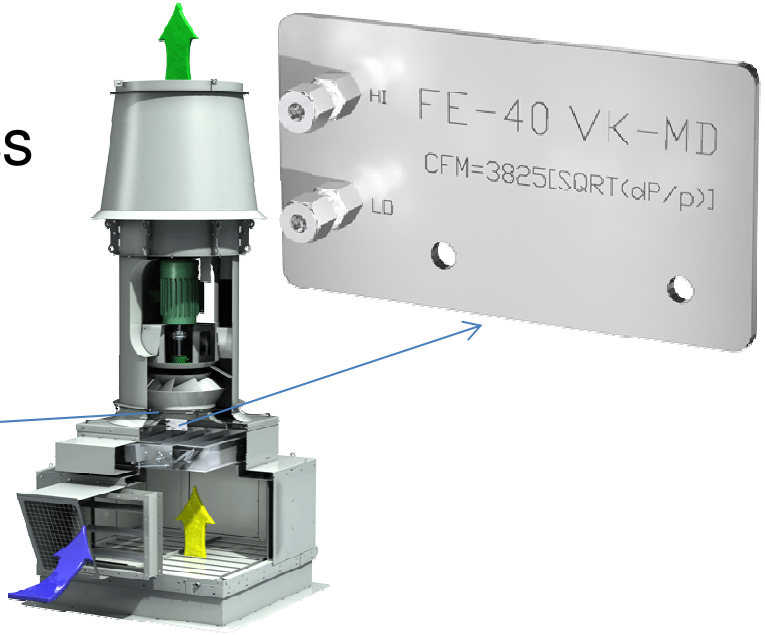
| SWSI Size | Max Class I | Max Class II | Max Class III |
|---|---|---|---|
| 20 | 1.2" | 2.0" | 3.2" |
| 36 | 0.8" | 1.3" | 2.1" |
| 73 | 0.4" | 0.7" | 1.1" |

Performance taken at 70% WOV and at max class RPM
All measured using AMCA accredited test chamber

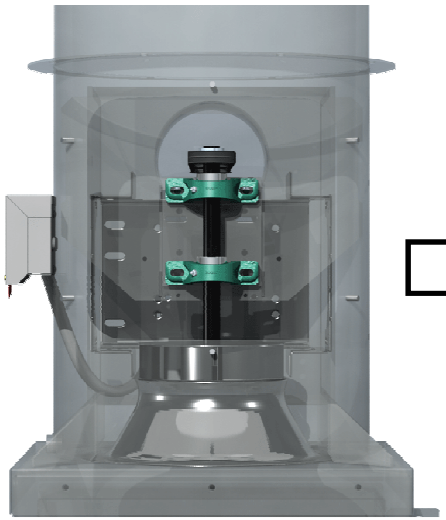
# Piezometer Rings

- High degree of accuracy ±3%
- Non-invasive
- Available with or without electronics





# Metering & Maintenance



Vibration
Current
Pressure
Bearing Temp
Airstream Temp
RPM


To BMS



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# To Conclude:

**Lab Ventilation is Life Safety**

**But we can reduce the cost to operate by:**

***Eliminating Excess Pressure***
***Utilizing Pre-Engineered Equipment***
***Looking at New Nozzle and Control Technology***
***Applying Energy Recovery Systems***
***Monitoring Your System to Continuously Optimize***

# Thank you for your time.

# Questions?


*The mission of Greenheck is to be the market leader in the development, manufacture and worldwide sale of quality air moving and control equipment with total commitment to customer service.*