



Exhaust Stack Discharge Volume Reduction

ESDVR – Potential Energy Savings

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Scott Arnold

Content Manager, AMCA International

Webinar Moderator

- Joined AMCA in 2017
- Leads development and publication of technical articles, white papers and educational materials.
- Editor-in-chief of the award-winning *AMCA inmotion* magazine.



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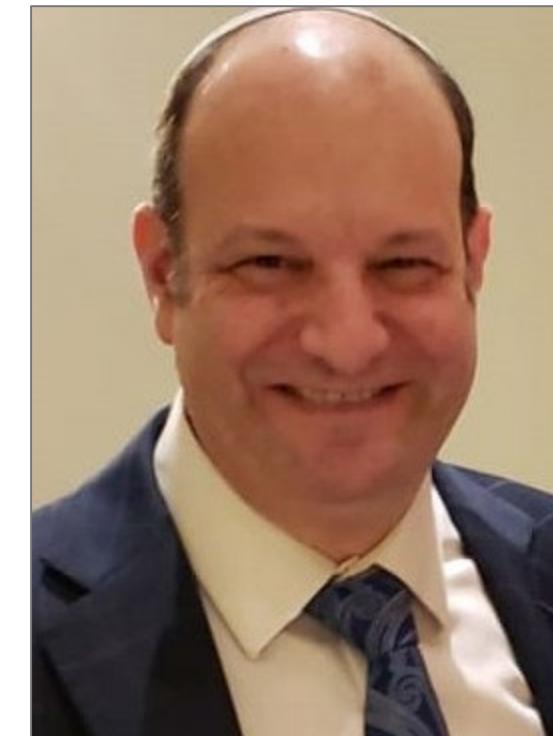
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Doug Ross

Business Development Manager, AMCA Member Company

- Automation & Control Engineer from Auckland Technical Institute in New Zealand; moved to Canada in 2000
- Working in the Air Movement industry since 2005
- Focus on laboratory exhaust system design, especially in critical environment applications



Exhaust Stack Discharge Volume Reduction

Purpose and Learning Objectives

The purpose of this presentation is to inform industry professionals about the factors involved in designing a laboratory exhaust system. The presentation will outline the selection of the exhaust fans enhancing the highest potential turndown and the different laboratory control options that will affect the energy consumption of the laboratory.

At the end of this presentation you will be able to:

1. Select a suitable fan construction, based on project criteria and operation.
2. Explain how to select a fan with maximum turndown.
3. Determine which laboratory control will deliver the lowest energy consumption.
4. Describe examples of a laboratory exhaust system and the related energy consumption.

Exhaust Stack Discharge Volume Reduction

- Topics covered in this presentation:
 - Exhaust Fan Selection
 - Minimize Energy Consumption
 - Maintain Critical Design Parameters
 - Laboratory Exhaust Fan Control Systems

Exhaust Stack Discharge Volume Reduction

Laboratory Exhaust

System Fundamental
Design Considerations



Exhaust Stack Discharge Volume Reduction

Obtaining answers to the following items will assist in the selection, design and specification of the required lab exhaust system:

- Materials of construction
- Fan / blower type
- Exhaust orientation with respect to other campus buildings & HVAC intakes
- Acoustic considerations
- Economics including operating, maintenance and replacement costs
- Constant or variable volume exhaust
- Utilizing “system” design approach
- General or specialized fume hoods
- Chemical and /or biological exhausts
- Excessive concentrations
- Heat recovery or HEPA filters
- Architectural considerations
- VFDs on exhaust fans

Materials of Construction

Fiberglass Reinforced Polymer (FRP) provides:

- Ability to manufacture complex shapes
- Corrosion resistance capabilities similar to 304 and 316 Stainless Steel
- Strong while being less weight than comparable materials
- Spark and Static resistant meet AMCA 99 – 041 – 86 Spark A
- Low thermal conductivity greatly reducing sweating.
- Cost competitive to 316 and 304 Stainless Steel
- Life expectancy of over 25 years providing excellent return on investment



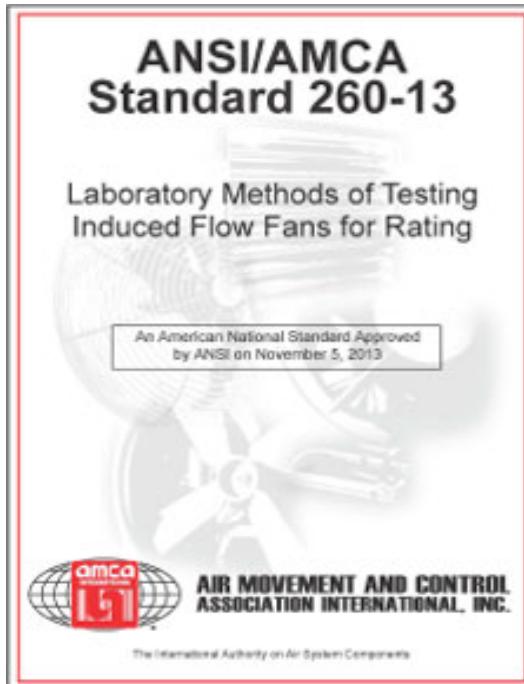
Selecting Induced Flow (or High Plume Dilution) Fans

Performance



Selecting Induced Flow (or High Plume Dilution) Fans

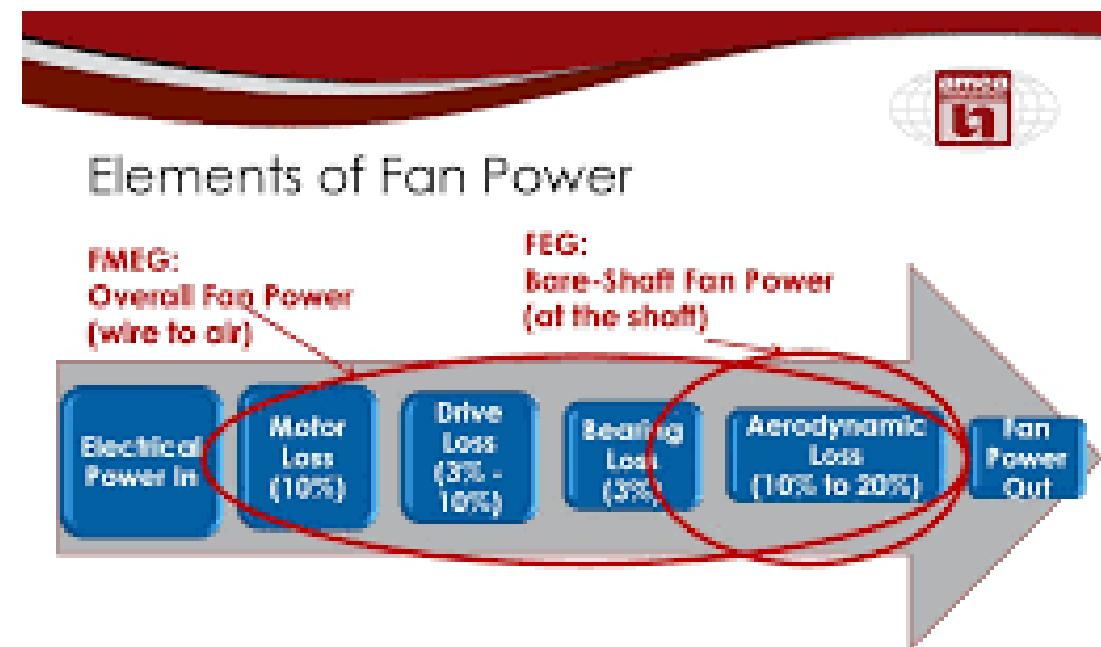
Performance



Selecting Induced Flow (or High Plume Dilution) Fans

Performance – Fan Efficiency Index

The fan energy index (FEI) is defined as a ratio of the electrical input power of a reference fan to the electrical input power of the actual fan for which the FEI is calculated, both calculated at the same duty point, i , which is characterized by a value of airflow (Q_i) and pressure ($P_{t,i}$ or P_s,i). FEI can be calculated for each point on a fan curve.

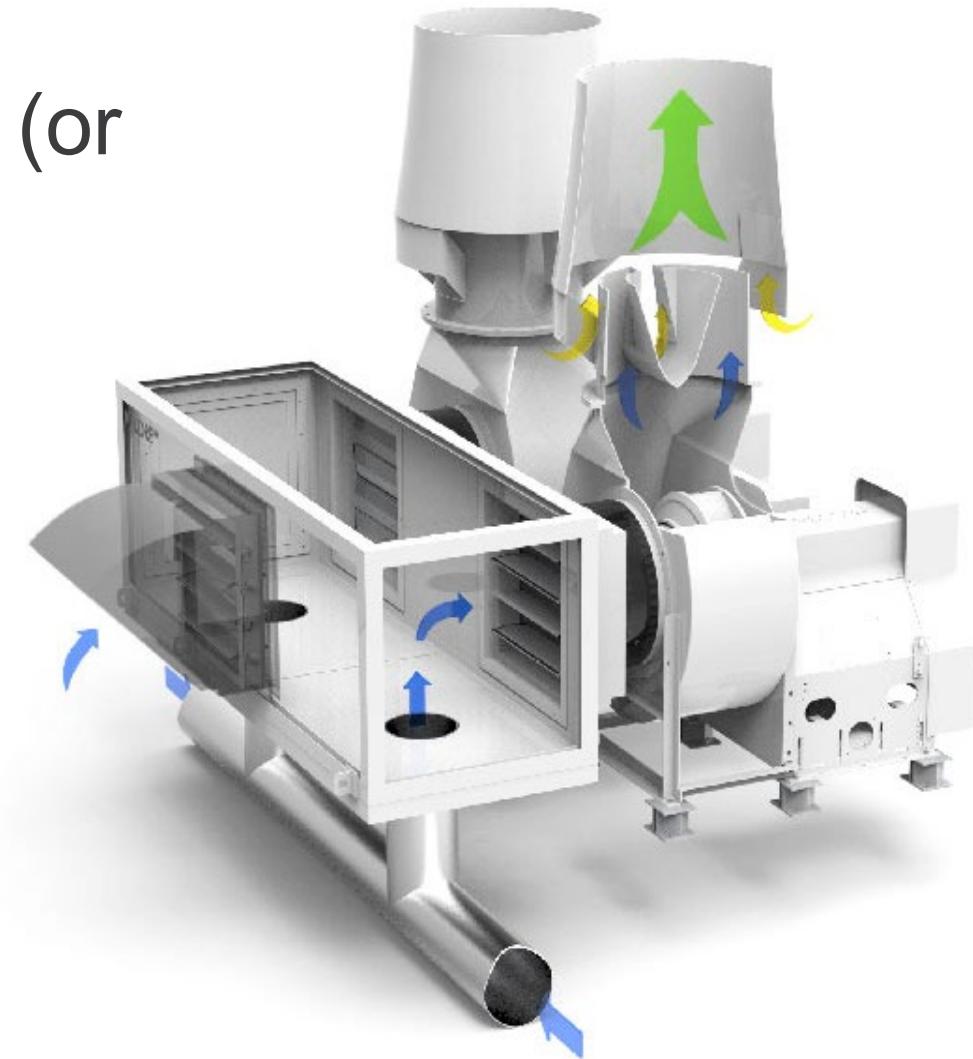


Selecting Induced Flow (or High Plume Dilution) Fans

AMCA Definition - Induced Flow (or High Plume Dilution) Fans

5.1 Induced flow fan

An inducted flow fan is a housed fan whose outlet airflow is greater than its inlet airflow due to induced airflow. Those induced flow fans under the scope of this standard will include a nozzle and wind-band. All of the flow entering the inlet will exit through the nozzle. The flow exiting the wind-band will include the nozzle flow plus the induced flow.

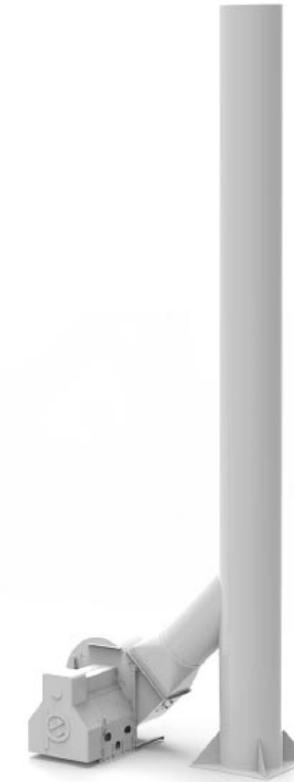


Selecting Induced Flow (or High Plume Dilution) Fans

Fan / Blower Selection



\$ 1 x



\$ 1.5 x – 2 x

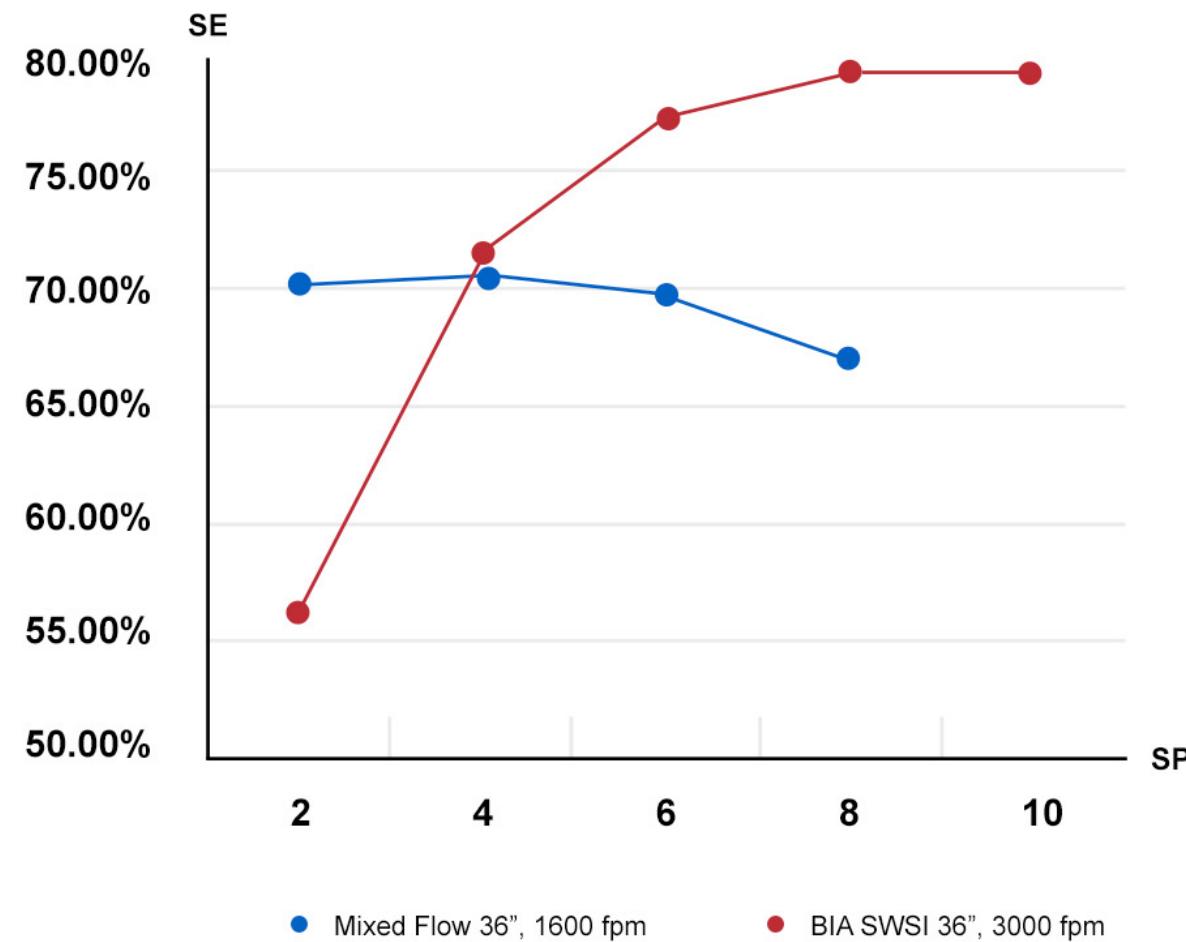
Selecting Induced Flow (or High Plume Dilution) Fans

Fan / Blower Selection



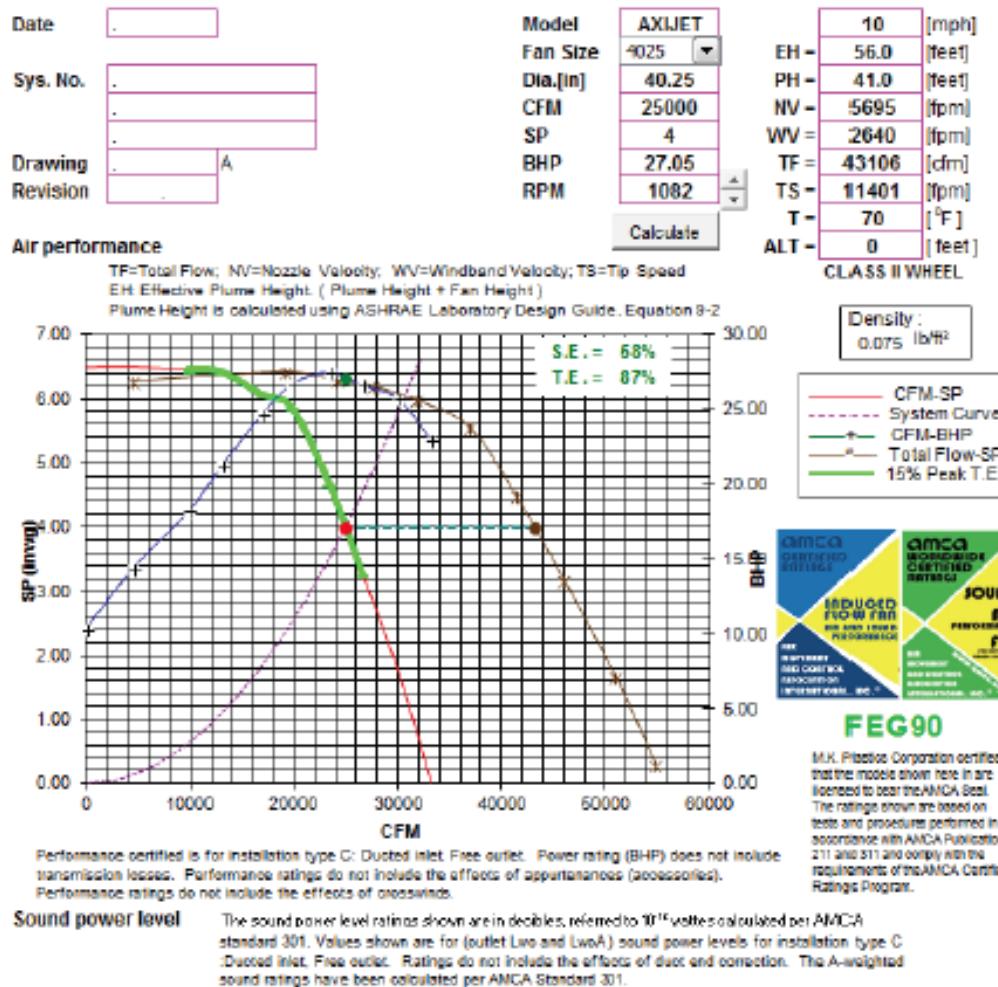
Selecting Induced Flow (or High Plume Dilution) Fans

Fan / Blower Selection



Selecting Induced Flow (or High Plume Dilution) Fans

Fan / Blower Selection



Exhaust Stack Discharge Volume Reduction (ESDVR)

Exhaust Orientation – Dispersion / Fume Re-Entrainment

24.2

2013 ASHRAE Handbook—Fundamentals

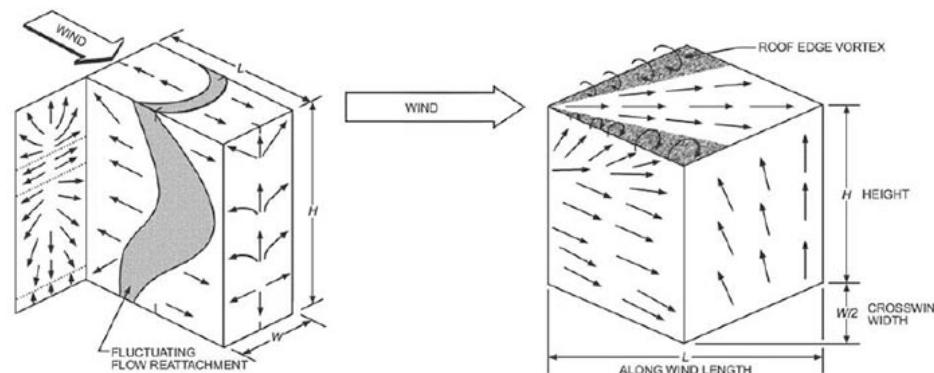


Fig. 2 Surface Flow Patterns for Normal and Oblique Winds
(Wilson 1979)

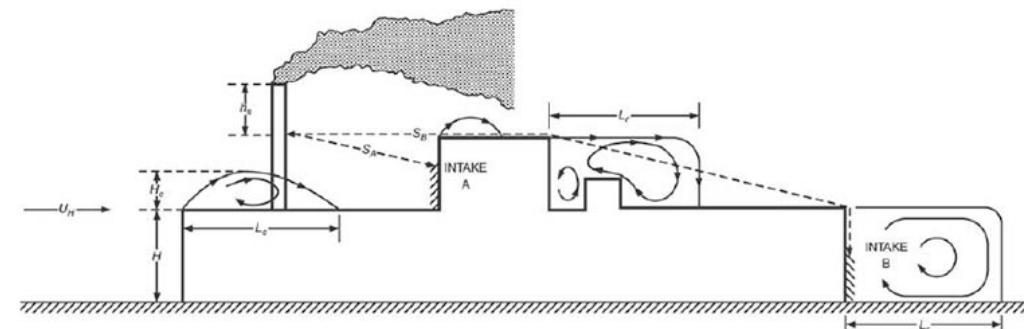


Fig. 3 Flow Recirculation Regions and Exhaust-to-Intake Stretched-String Distances (S_A , S_B)

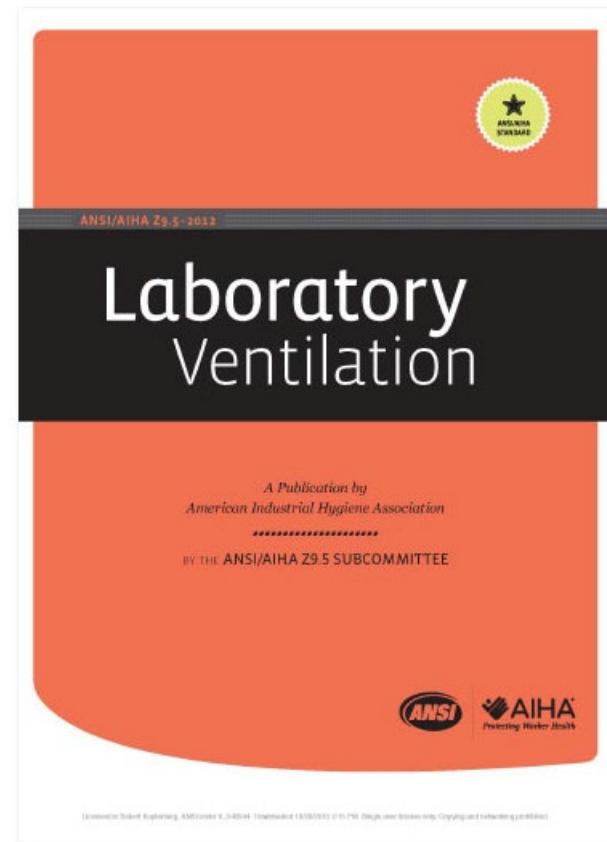
Exhaust Orientation – Dispersion / Fume Re-Entrainment



- What isn't included in the TAB?
- What does the wind dispersion model rely on?

Exhaust Orientation – Dispersion / Fume Re-Entrainment

Fundamental system design concepts



ANSI Z 9.5

Exhaust Orientation – Dispersion / Fume Re-Entrainment

Fundamental system design concepts

Wind modeling



Image provided courtesy of CPP

Exhaust Orientation – Dispersion / Fume Re-Entrainment

Fundamental system design concepts
Dilute and disperse exhaust effluent



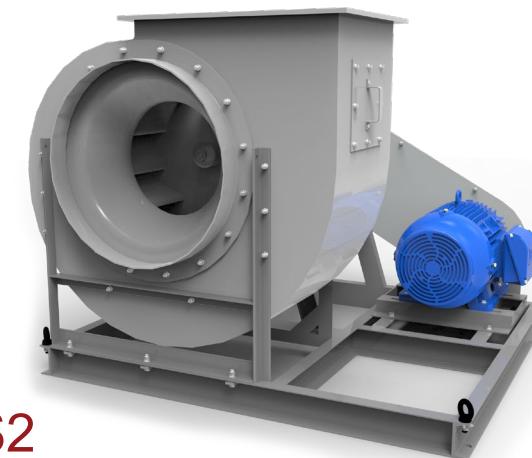
Economics – Operating, Maintenance & Replacement Costs



Economics – Operating, Maintenance & Replacement Costs



Steel Fan – Purchase Price \$1



FRP Fan – Purchase Price \$2



Stainless Steel Fan – Purchase Price \$4

Economics – Operating, Maintenance & Replacement Costs

Typical Building Installation	Initial Purchase Price	Cost to Replace after 15 years assuming 2% inflation/Yr.	Cost of equipment for the building life of 30 years
Galvanized Metal Fan	\$1000	\$1,320	\$2,320
FRP Fan	\$2000	\$0	\$2,000

Exhaust Stack Discharge Volume Reduction (ESDVR)

Fan / Blower – Selection Criteria

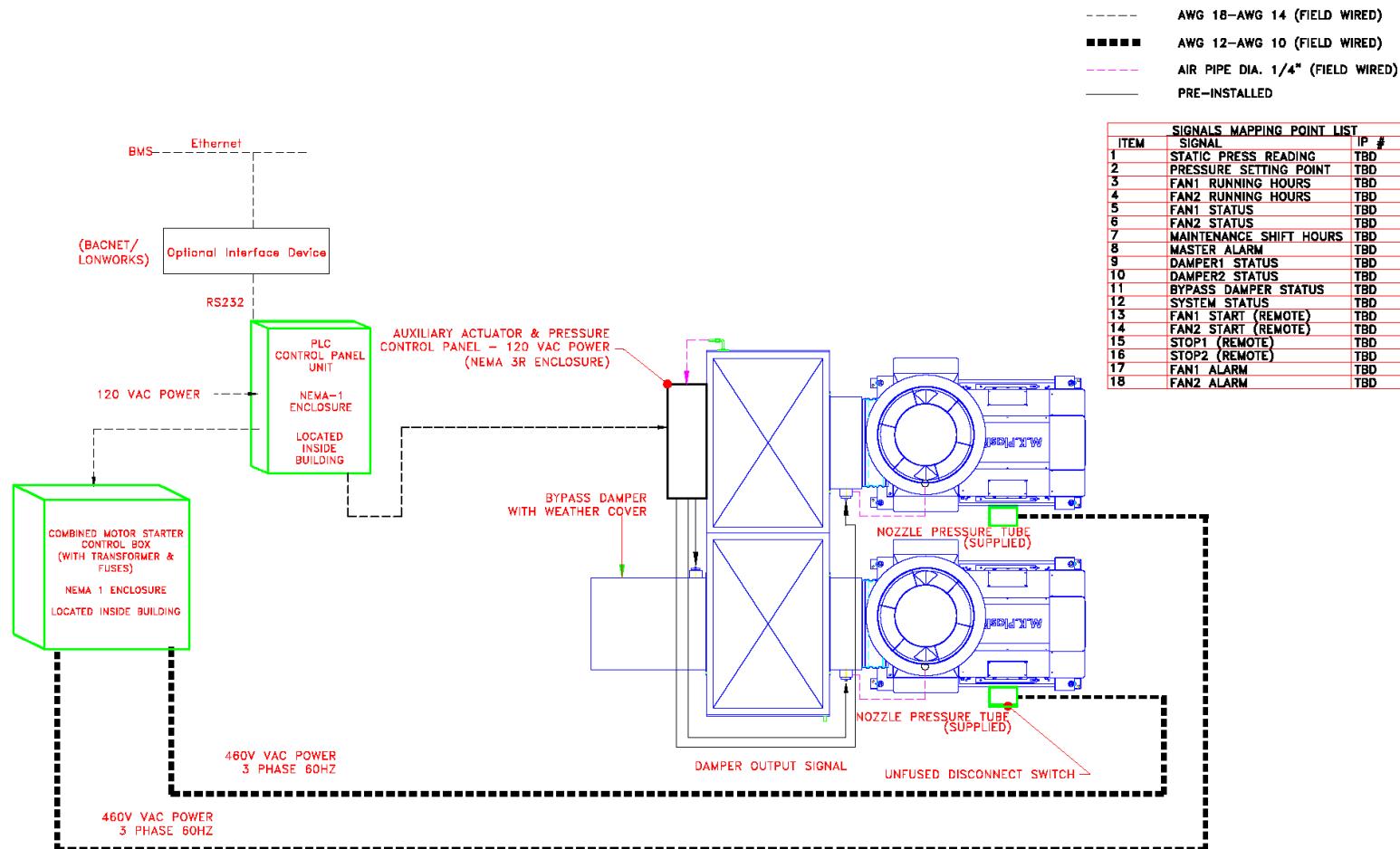
Discharge nozzle (primary effluent) velocity is critical for:

- Exhaust dispersion development
- Accommodating safe VAV fan turndown range with VFD control
- Satisfying appropriate design considerations (i.e. ANSI Z 9.5)



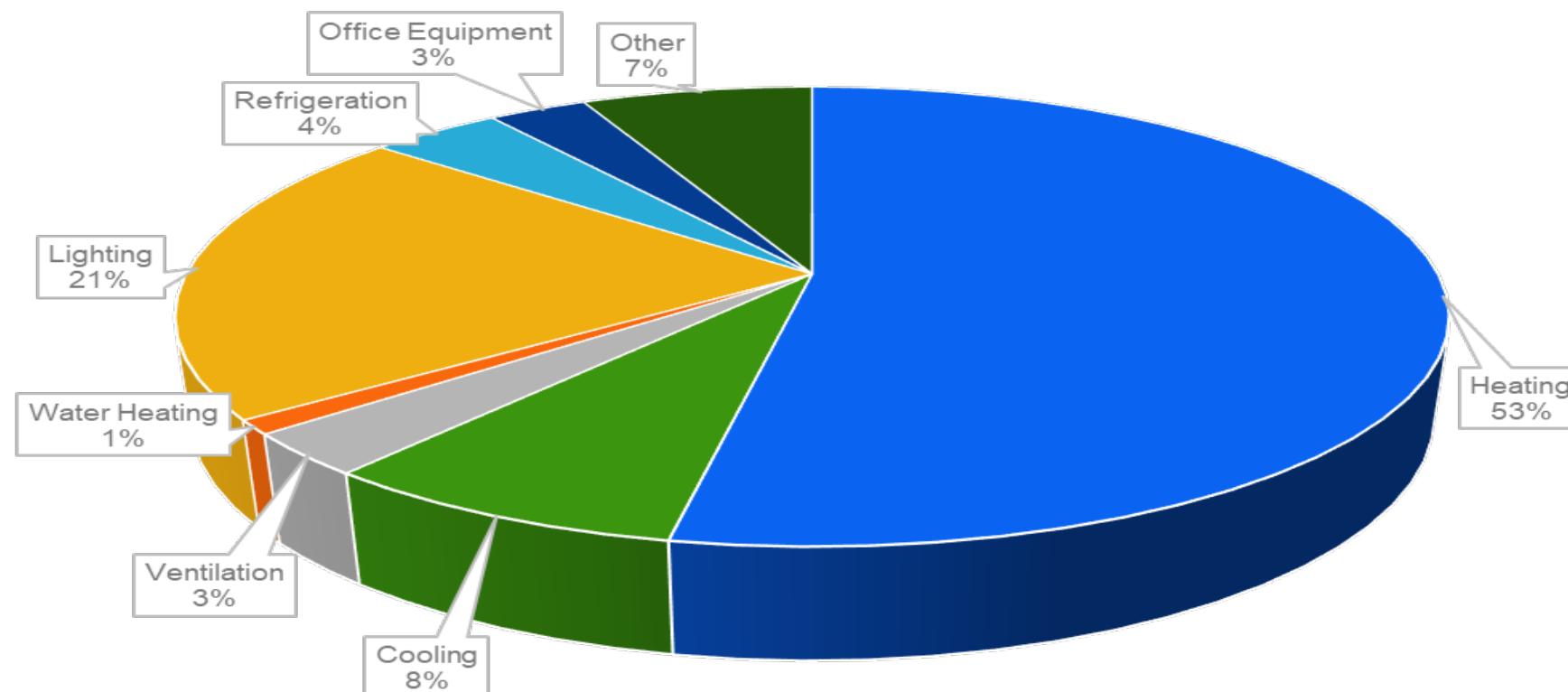
Exhaust Stack Discharge Volume Reduction (ESDVR)

Controls - Utilizing “System” Design approach



Exhaust Stack Discharge Volume Reduction (ESDVR)

Energy Consumption in Laboratories



■ Heating ■ Cooling ■ Ventilation ■ Water Heating ■ Lighting ■ Refrigeration ■ Office Equipment ■ Other

64%

Reference article by Brian Spangler in Laboratory Equipment Magazine

Designing Controls for Laboratory Exhaust Fans

Ventilation standards and design criteria

- **ANSI/AMCA Standards**
 - 210 – Laboratory Methods of Testing fans
 - 260 – Induced Flow Fan Testing
 - 300 – Fan Sound Testing
- **ANSI / AIHA Ventilation Standard**
 - ANSI Z9.5 - 2012
- **ASHRAE**
 - ASHRAE 90.1- 2016 Building Energy Codes
 - ASHRAE 110 - 2016
- **NFPA**
 - NFPA 45 Standard on Fire Protection for Laboratories
- **Leadership in Energy and Environmental Design (LEED)**
 - USGBC (U.S. Green Building Council)Leadership in Energy and Environmental Design

Designing Controls for Laboratory Exhaust Fans

What is a VAV laboratory exhaust system?

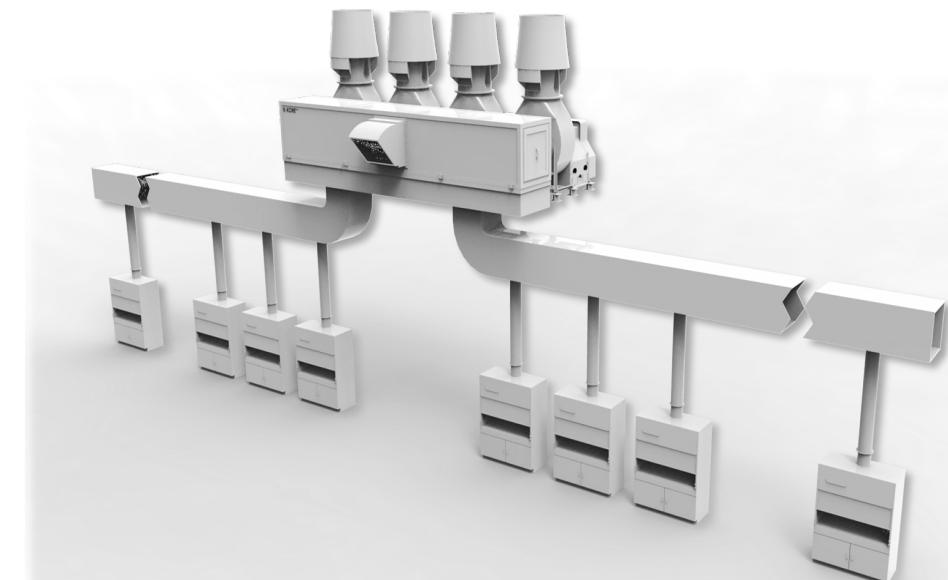


An exhaust system in which the total exhaust CFM varies depending on a number of conditions.

Designing Controls for Laboratory Exhaust Fans

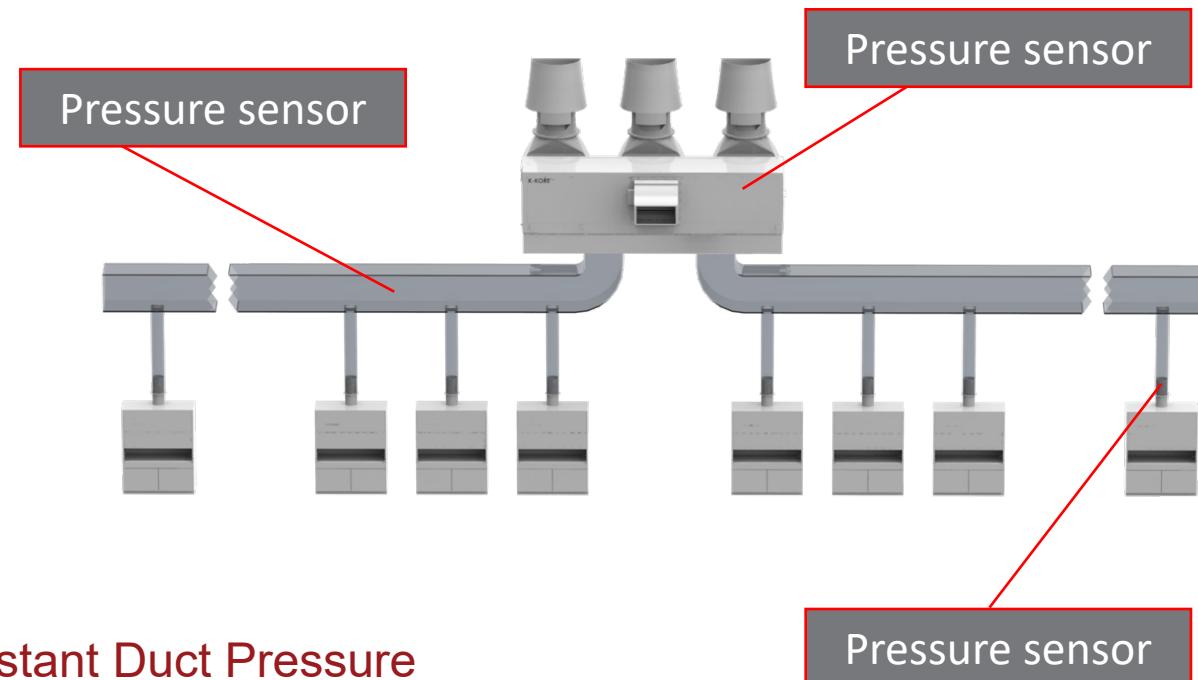
Typical VAV System Considerations

- Temperature
- Humidity
- Occupant comfort
- Air change rates (air changes per hour, ACH)
- Redundancy and emergency backup requirements
- Modes of operation: normal, emergency, setback
- Equipment and space criteria monitoring and alarms
- Room airflow direction and speed
- Pressure relationship between spaces
- Filtration: supply and exhaust
- Hood HVAC requirements
- Fire and life safety requirements
- Energy efficiency
- Energy/utility metering



Designing Controls for Laboratory Exhaust Fans

Different Control Points for Exhaust Fans



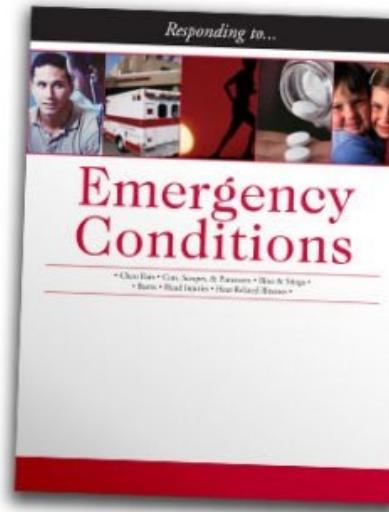
Constant Duct Pressure

Variable Duct Pressure

Dynamic Duct Pressure

Designing Controls for Laboratory Exhaust Fans

External Feedback or Secondary input may include:



Designing Controls for Laboratory Exhaust Fans

1. Constant Volume Lab Operation

- a. Constant (speed) volume with bypass damper

2. Variable Air Volume Lab Operation

- a. Multiple fans staging to meet variable flow demands
- b. *VFD controlled without a bypass damper
- c. VFD controlled with bypass damper
- d. VFD controlled with bypass and External Feedback

3. Demand Based Static Pressure Lab Operation

- a. Multiple fans staging to meet variable flow demands
- b. VFD controlled with bypass damper
- c. VFD controlled with bypass and External Feedback

Designing Controls for Laboratory Exhaust Fans

Practical Example of Laboratory Control through various scenarios



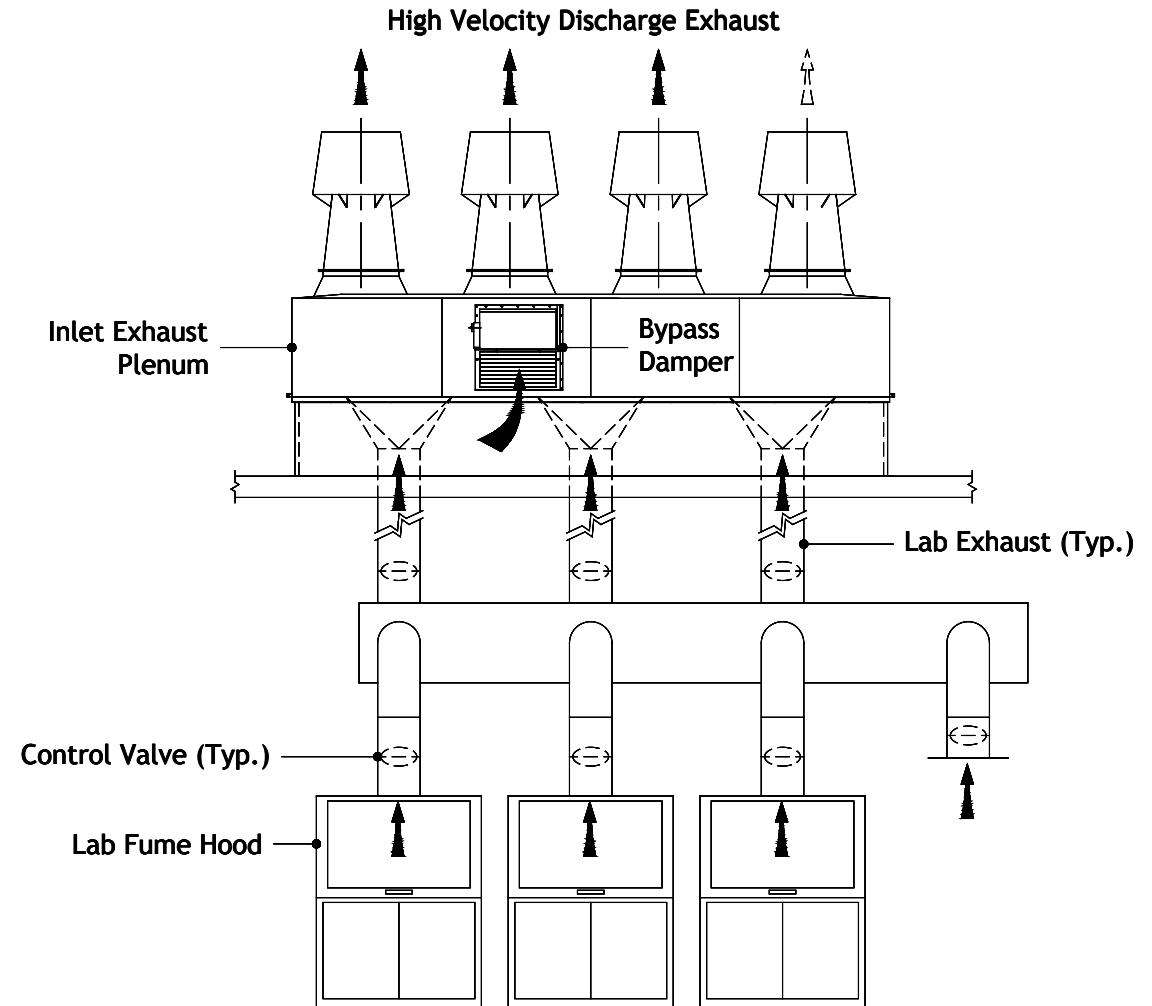
**Keep in mind – Steps to help reduce
Energy Costs - Objective:**

- N + 1 System with minimal use of by-pass damper

Designing Controls for Laboratory Exhaust Fans

Scenario #1: N+1 Configuration, VAV Exhaust, Constant Duct Pressure Control Point

1. Control Point:
 - Constant Duct Pressure
2. System:
 - N+1
 - 3 fans total; 2 running + 1 standby
3. Operating Conditions:
 - Nozzle Velocity to be 3000 FPM or greater
 - Maximum Exhaust flow is 99,488 (2 x 49,744) CFM
 - 4.5" TSP



Designing Controls for Laboratory Exhaust Fans

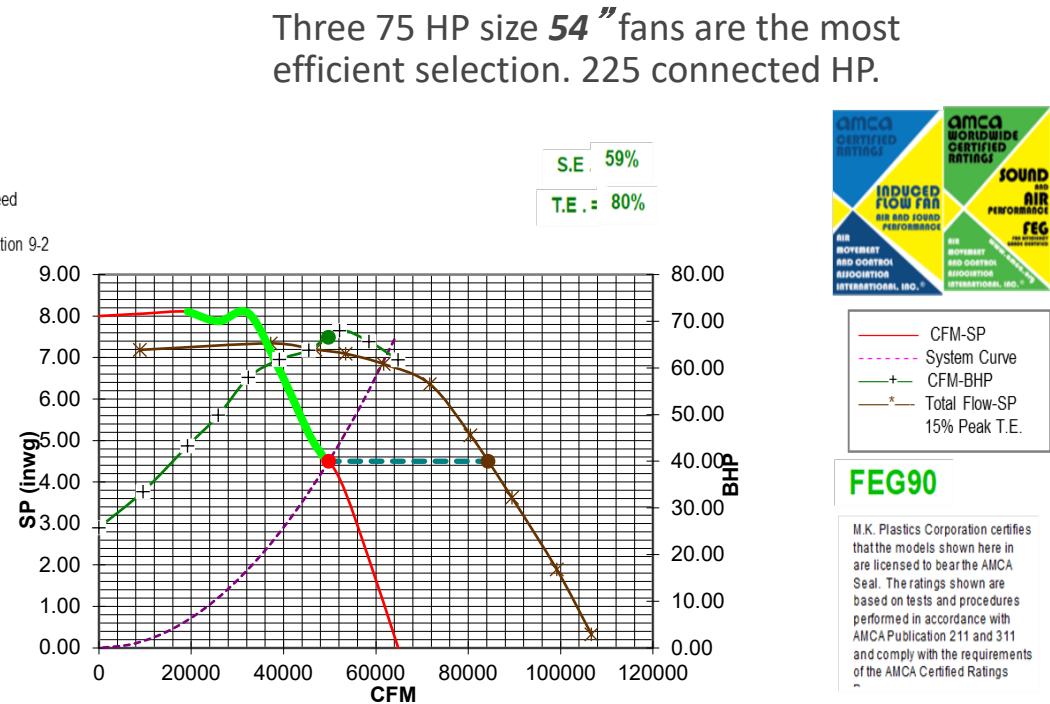
Scenario #1: N+1 Configuration, VAV Exhaust, Constant Duct Pressure Control Point

Using an N + 1 Design

Air performance

TF=Total Flow; NV=Nozzle Velocity; WV=Windband Velocity; TS=Tip Speed
 EH: Effective Plume Height. (Plume Height + Fan Height)
 Plume Height is calculated using ASHRAE Laboratory Design Guide, Equation 9-2

Model	AXI-JET	10	[mph]
	5425		
Fan Size		EH =	79.5 [feet]
Dia.[in]	54.25	PH =	59.5 [feet]
CFM	49744	NV =	6241 [fpm]
SP	4.5	WV =	2842 [fpm]
BHP	66.51	TF =	84267 [cfm]
RPM	859	TS =	12200 [fpm]
		T =	70 [°F]
		ALT =	0 [feet]
		CLASS II WHEEL	



CFM-SP
System Curve
CFM-BHP
Total Flow-SP
15% Peak T.E.

FEG90

M.K. Plastics Corporation certifies that the models shown here in are licensed to bear the AMCA Seal. The ratings shown are based on tests and procedures performed in accordance with AMCA Publication 211 and 311 and comply with the requirements of the AMCA Certified Ratings.

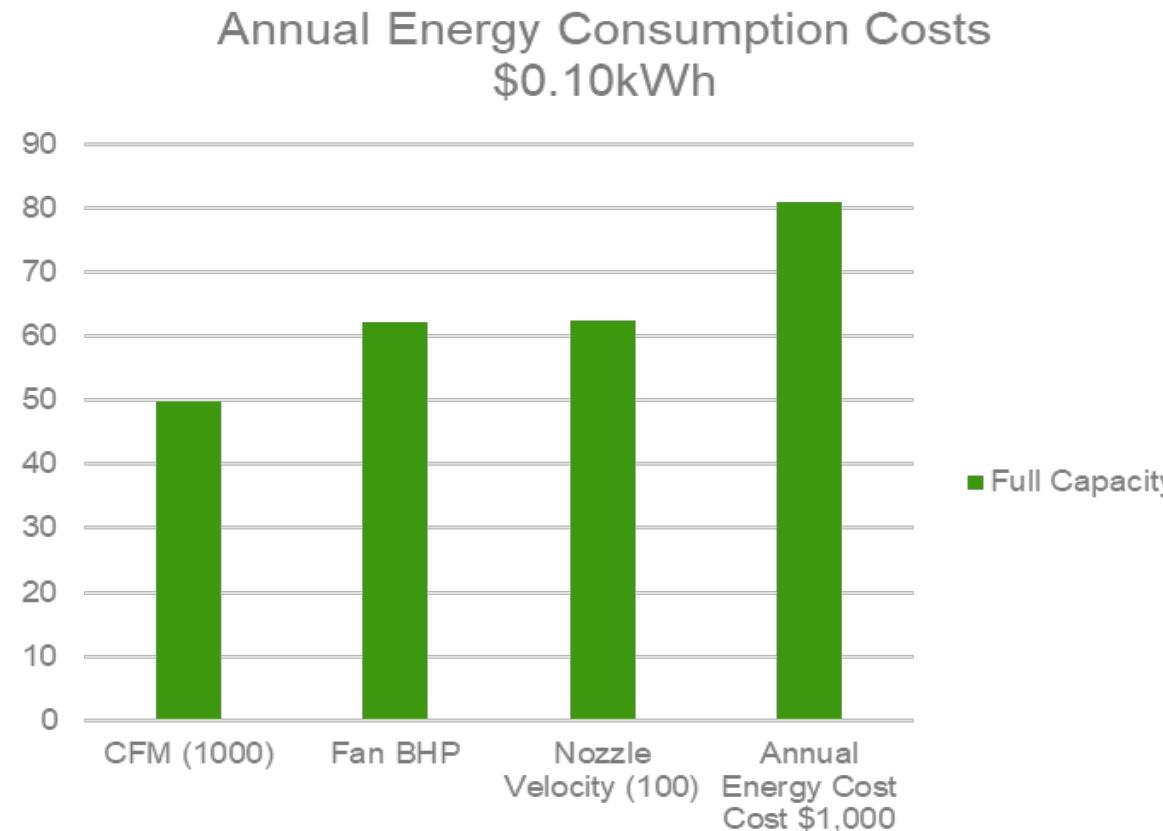
Designing Controls for Laboratory Exhaust Fans

Scenario #1: N+1 Configuration, VAV Exhaust, Constant Duct Pressure Control Point

Fan Size	Full Capacity 99,488 CFM 4.5" TSP							
	CFM/Fan	Fan BHP	System BHP	Motor HP	Nozzle Velocity	Exhaust Momentum	System bypass CFM	Annual Energy Cost \$0.10Kw
MK 5425	49,744	62.10	124.20	75	6241	310,452,304	0	\$80,942

Designing Controls for Laboratory Exhaust Fans

Scenario #1: N+1 Configuration, VAV Exhaust, Constant Duct Pressure Control Point



Designing Controls for Laboratory Exhaust Fans

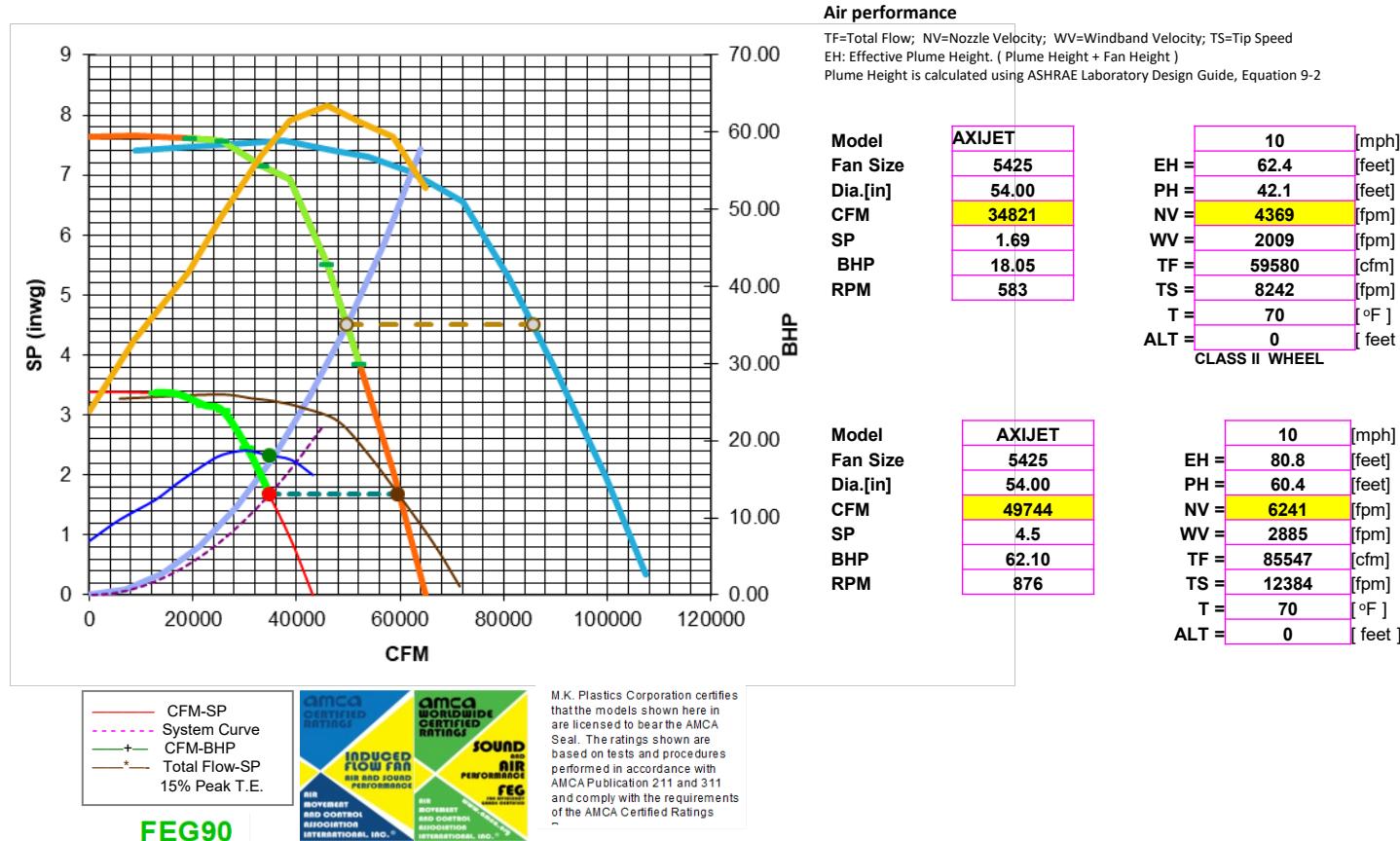
Scenario #2: N+1 Configuration, VAV Exhaust, Constant Duct Pressure with Turn Down



- Now, let's add Control to the system
- Providing the ability to turn down to a minimum flow of 69,642 CFM(2 x 34,821 CFM).
- Still maintaining nozzle velocity of 3000 fpm or greater.
- With not using additional air via By-pass damper.

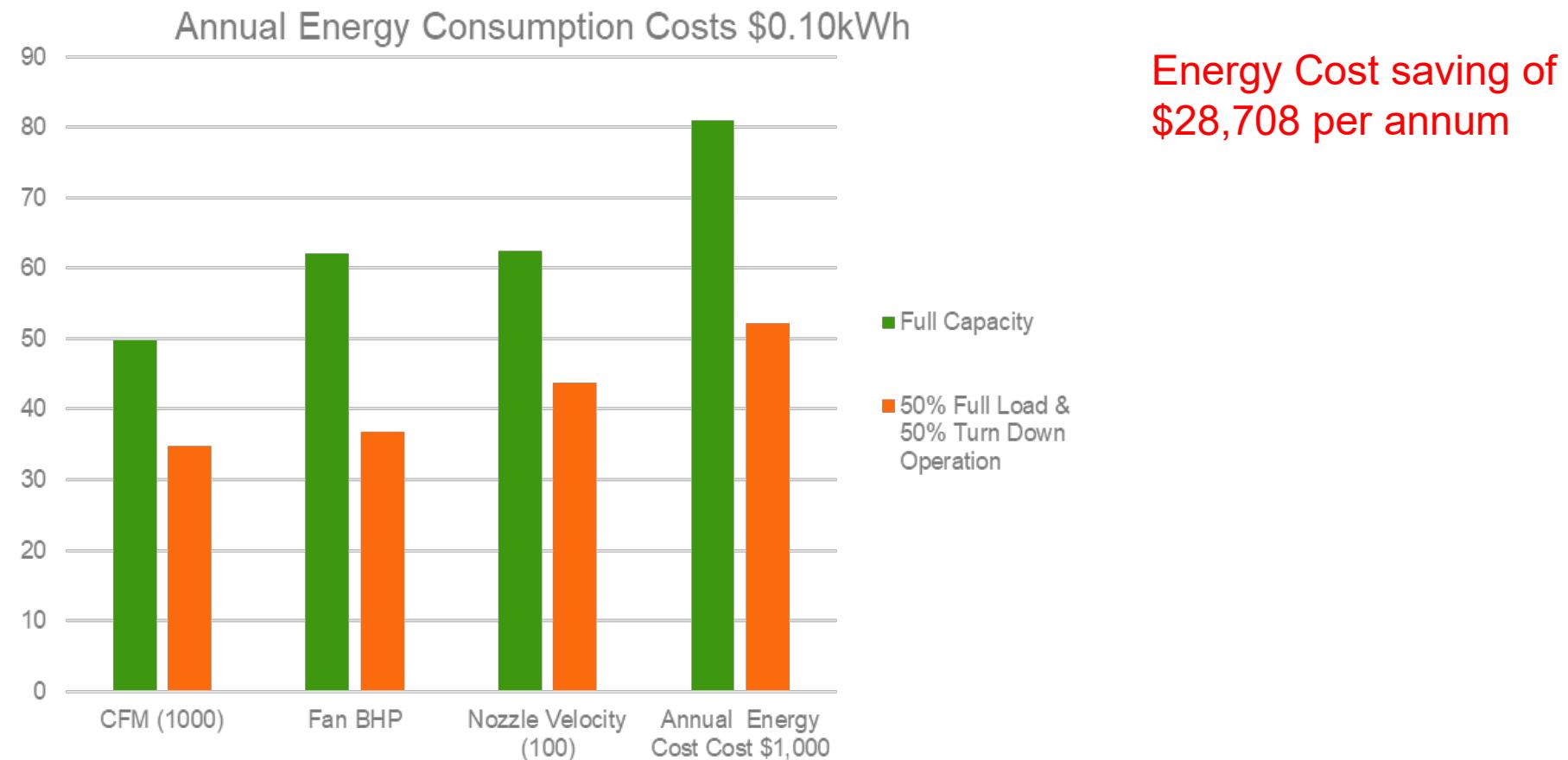
Designing Controls for Laboratory Exhaust Fans

Scenario #2: N+1 Configuration, VAV Exhaust, Constant Duct Pressure with Turn Down



Designing Controls for Laboratory Exhaust Fans

Scenario #2: N+1 Configuration, VAV Exhaust, Constant Duct Pressure with Turn Down



Designing Controls for Laboratory Exhaust Fans

Can we can reduce Energy Costs Further ?



- Better system design:
- Apply time associated distribution to the exhaust flow turndown range.

Designing Controls for Laboratory Exhaust Fans

Scenario #3: N+1 Configuration, VAV Exhaust, Variable Duct Pressure, Time dependent operation

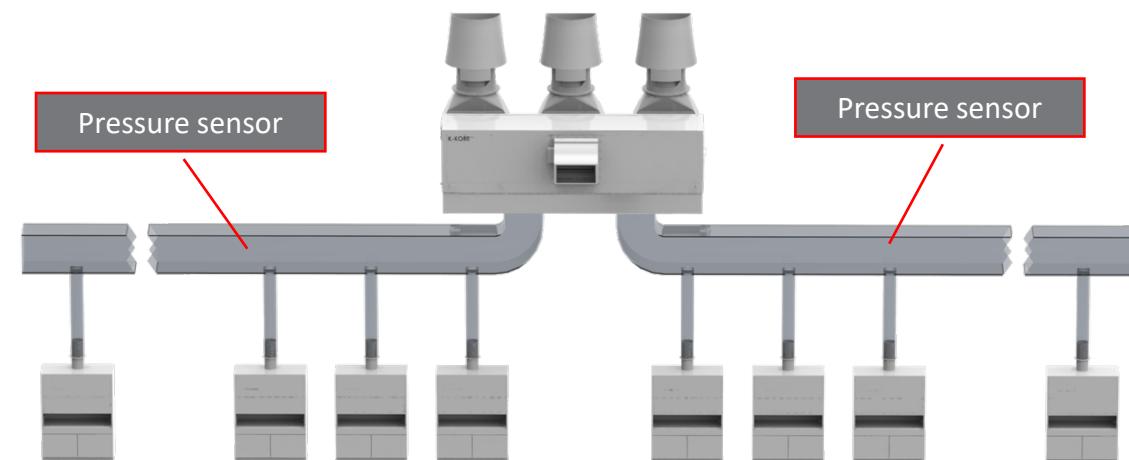
Multiple Fans: VFD and Bypass Damper

- Number of fans running can vary based on operating requirements
- Proper fan selection for complete range of operating conditions
- System static pressure maintenance (system curve changes)
- **VFDs must be run at the same speeds for all operating fans**
- **Bypass damper opened on demand**
- **Isolation damper between fan and plenum is operated correctly to minimize system pressure drop**
- Track fan operating hours to ensure even wear on fans due to equal operating time
- Discharge velocity maintenance
- Dilution rate maintenance
- Plume height maintenance

Designing Controls for Laboratory Exhaust Fans

Scenario #3: N+1 Configuration, VAV Exhaust, Variable Duct Pressure, Time dependent operation

- Allowing for a time distribution model to be utilized
- 99,488 CFM for 5% of the time
- 69,642 CFM for 65% of the time
- 49,744 CFM for 30% of the time



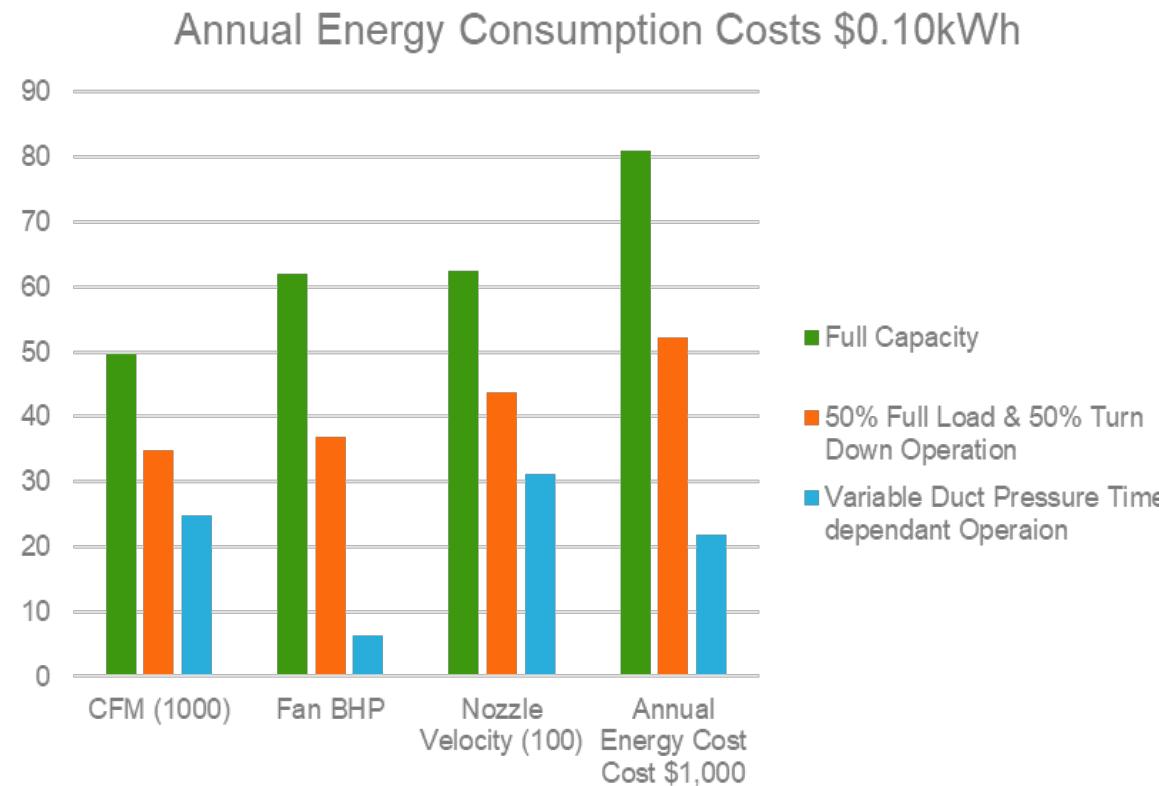
Designing Controls for Laboratory Exhaust Fans

Scenario #3: N+1 Configuration, VAV Exhaust, Variable Duct Pressure, Time dependent operation

Fan Size	Full Capacity 5% of operational demand 99,488 CFM (47,244/Fan) @ 4.5" SP						
	CFM/Fan	Fan BHP	System BHP	Motor HP	Nozzle Velocity	Exhaust Momentum	System bypass CFM
MK 5425	49,744	66.51	133.02	75	6241	310,452,304	0
Fan Size	Day time Mode 65% of operational demand 69,642 CFM (34,821 / Fan) @ 4.5" SP						
	CFM/Fan	Fan BHP	System BHP	Motor HP	Nozzle Velocity	Exhaust Momentum	System bypass CFM
MK 5425	34,821	18.05	36.10	75	4369	152,132,949	0
Fan Size	Night Mode 30% of operational demand 49,744 CFM (24,872/Fan) @ 4.5" SP						
	CFM/Fan	Fan BHP	System BHP	Motor HP	Nozzle Velocity	Exhaust Momentum	System bypass CFM
MK 5425	24,872	6.21	12.42	75	3121	77,625,512	0

Designing Controls for Laboratory Exhaust Fans

Scenario #3: N+1 Configuration, VAV Exhaust, Variable Duct Pressure, Time dependent operation



Further Energy Cost saving of
\$30,466 per annum

Designing Controls for Laboratory Exhaust Fans

Reduce Initial Cost and maintain Energy Savings



- Alternative system design:
- N-1 System
- Dynamic Pressure Control

Designing Controls for Laboratory Exhaust Fans

Scenario # 4: N-1 Configuration, VAV Exhaust, Dynamic Duct Pressure, Demand dependent operation, External Feedback



Same time distribution and turn down volume conditions as in previous scenario.

All 3 fans operating with the capability to ramp up any 2 fans to full flow on demand.

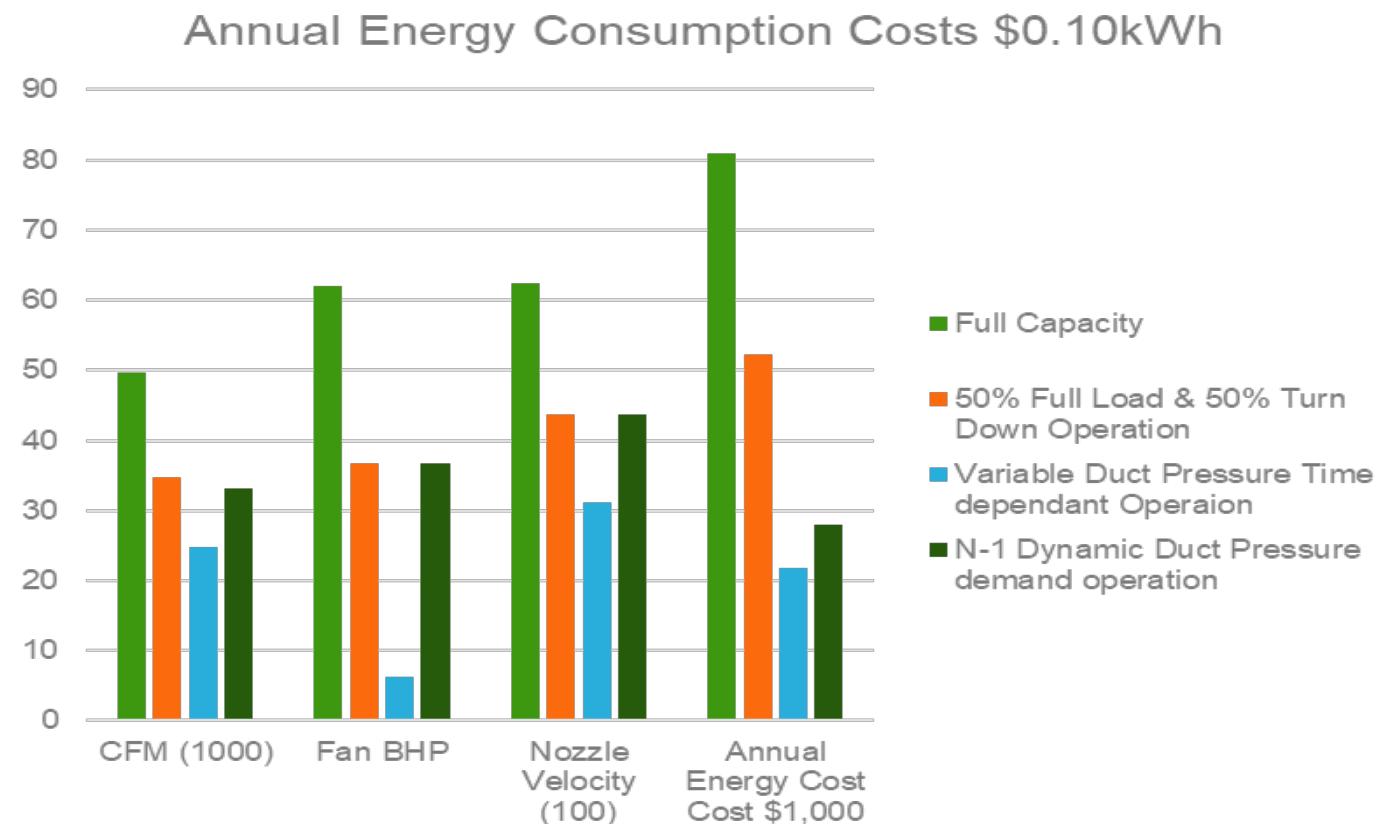
Designing Controls for Laboratory Exhaust Fans

Scenario # 4: N-1 Configuration, VAV Exhaust, Dynamic Duct Pressure, Demand dependent operation, External Feedback

Fan Size	Full Capacity 5% of operational demand 99,488 CFM (47,244/Fan) @ 4.5" SP							
	No. of Fans Operating	CFM/Fan	Fan BHP	System BHP	Motor HP	Nozzle Velocity	Exhaust Momentum	System bypass CFM
MK 4900	3	33,163	37.19	111.57	75	5102	169,197,626	0
Fan Size	Day time Mode 65% of operational demand 69,642 CFM (34,821 / Fan) @ 4.5" SP							
	No. of Fans Operating	CFM/Fan	Fan BHP	System BHP	Motor HP	Nozzle Velocity	Exhaust Momentum	System bypass CFM
MK 4900	3	23214	12.81	38.43	75	3571	82,892,194	0
Fan Size	Night Mode 30% of operational demand 49,744 CFM (24,872/Fan) @ 4.5" SP							
	No. of Fans Operating	CFM/Fan	Fan BHP	System BHP	Motor HP	Nozzle Velocity	Exhaust Momentum	System bypass CFM
MK 4900	2	24872	15.67	31.34	75	3826	95,160,272	0

Designing Controls for Laboratory Exhaust Fans

Scenario # 4: N-1 Configuration, VAV Exhaust, Dynamic Duct Pressure, Demand dependent operation, External Feedback



Total project Cost
saving of \$15,113

Designing Controls for Laboratory Exhaust Fans

Total system approach to designing economically viable and sustainable exhaust systems for critical environment applications.

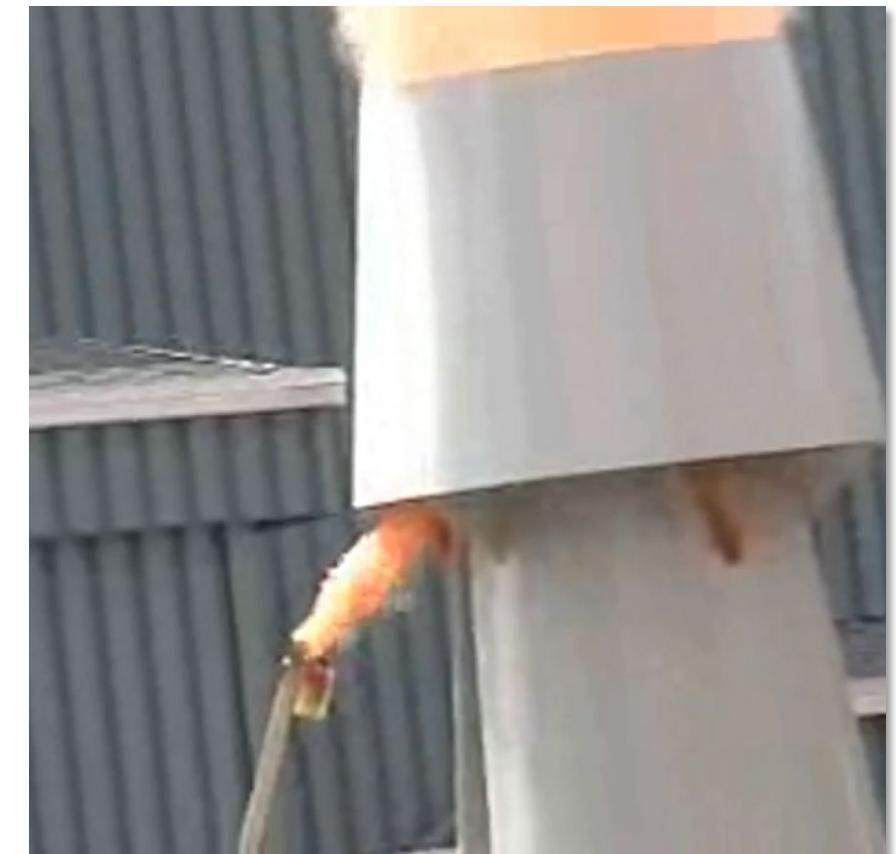
Control Point of Exhaust fans	Redundancy Configuration	Comments	Annual Energy Cost \$0.10Kwh
Constant Duct Pressure	N+1	No consideration for minimum CFM requirement	\$80,942
Constant Duct Pressure With Turn down	N+1	Minimum CFM included turn down is factored in	\$52,234
Variable Duct Pressure With Time Dependent Operation	N+1	Day/Night operation is considered with turn down factored in	\$21,768
Dynamic Duct Pressure With Demand Dependent Operation	N-1	Ability to select fan operation based on demand conditions. Ability to reduce fan size and therefore footprint	\$28,015

- Total Energy Cost saving achievable with N+1 system
\$59,174 per annum
- Total Energy Cost Saving achievable with N-1 system
\$52,927 per annum
plus initial cost savings \$15,113

Total System Approach for Laboratory Exhaust Fans

Total system approach to designing economically viable and sustainable exhaust systems for critical environment applications.

- When selecting your High Plume Dilution Fan ensure your Nozzle velocity is sufficient to allow substantial turn down.
- Look at various scenarios as to which system will provide most effective design. It maybe more smaller fans and/or how you control them.



Resources

- **AMCA International:** www.amca.org
- **ANSI/AMCA Standards** (Available for purchase): www.amca.org/store
 - > **260-20:** Laboratory Methods of Testing Induced Flow Fans for Rating
 - > **300-14:** Reverberant Room Method for Sound Testing of Fans
- **ANSI/AMCA Standard 210-16/ASHRAE Standard 51-16** (Available for purchase): www.amca.org/store
 - > Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating

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Questions?

NEXT PROGRAM

Join us for our next AMCA *insite*[™] Webinar:

- Wednesday, September 30
- 1:00-2:00pm CDT
- ***TOPIC: Environmental Noise Due to Fans and Equipment***
- Presenter: John Sofra, Market Manager, AMCA Member Company

>> For additional webinar dates go to: www.amca.org/webinar