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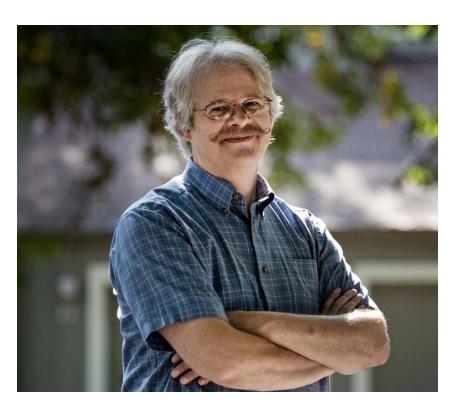
Today's Presenters William Howarth

- AMCA Consultant; President- Ventilation
 & Fan Consulting Service International
- Independent Consultant since 2017
- 30-yrs Fan Engineering & Sales at Illinois Blower and Hartzell Fan
- Instructor at North Carolina Industrial Ventilation Conference
- Member US delegation for ISO Technical Committee 117 Fans
- ASHRAE Member
 WHowarth@vfcsintl.com
 Mobile +1 (847) 454-5420



Today's Presenters

Ronald Wroblewski, PE



Industrial Fan Systems Optimization, Consulting, and Training since 1998

- Developed online FEI training for AMCA
- Lead Trainer US DOE Industrial Fan Systems Optimization since 2004
- Lead Trainer UNIDO Industrial Fan Systems Optimization since 2008
- 39 years experience designing, troubleshooting, and optimizing fan systems
- Assessed fans at hundreds of industrial and commercial facilities
- Identified fan efficiency projects savings of over \$11 Million/yr.

Ronald Wroblewski, PE, Productive Energy Solutions, LLC Madison, Wisconsin

Landline (608) 232-1861 Mobile (for SMS) 1-608-770-4195

Pressures in a Ventilation and Fan System

Purpose and Learning Objectives

At the end of this course, you will be able to:

- List two safety hazards of fans.
- Explain fan's role in an air system.
- Identify pressure types in an air system.
- Identify sources of pressure losses in a system.
- Calculate airflow velocities.
- Calculate velocity pressures.

Fan Safety

- Fans contain moving parts and can be dangerous.
 - Install guards.
 - Know the "Hidden Dangers"
 - Suction and Pressure
 - Windmilling
 - Temperature
 - Noise and Environment
 - Stroboscopic Effect
 - Special Purpose Fans and Systems
 - Have a "lock out" procedure.
- AMCA Publication 410-96, "Recommended Safety Practices For Users and Installers of Industrial and Commercial Fans" is an excellent resource.

AMCA Publication 410 RECOMMENDED SAFETY PRACTICES

for Users and Installers of Industrial and Commercial Fans

AIR MOVEMENT AND CONTROL ASSOCIATION INTERNATIONAL, INC.



30 West University Drive
Artington Heights, L. 60004-1893 U.S.A.

Tel: (847) 394-0150 • http://www.amca.org
Fax: (847) 253-0308 • info@amca.org









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Wall Exhauster Propeils







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i. This publication has been prepared by the AP Movement OMistin of the AP Movement and Control Association International, inc. (AACA International). The information contained in this publication has been derived from many sources. The suggestion made necessary should be general in their mainting and cannot be applied librarily to all security subtactors or conditions.

The safe installation and operation of fans is the responsibility of the system designer, installer, maintainer, and user.

From the Initial system design through the life of the equipment, safety should be a formed consideration. Some areas with require some special attention include system design, layout and construction, fan performance specification, thundeline and installation design, storage production, start-up and commissioning procedures, consider, maintenance, and repair. Specific safety requirements are manifested by federal, safes, and local costes. Procurement Safety Practices at Users and Installation of Industrial and Commissionia Safety Practices in MacCantinemation for assistance. System designers, installate, maintaines, and users should consult and properly comply with all application could content and properly comply with all application could content and guidelines.

- iii. The safety recommendators contained herein are intended to assist dissignms, installars, maintainer, or other users of air moving devices in the safe operationand used the device mentioned. These recommendators do not represent the only methods, procedures, or devices appropriate for the sibastions discussed. Caution should be used stall times when working in or around moving parts.
- Nr. AMCA International doctains any and at warranties, oppressed or impled, regarding the products sold by the menufacturer with which this bookle has been provided. Further, AMCA International recommends that competent personnel be consisted in deciding what is the preferred or recommended selfey proordure in a particular instroom where the guidelines contained in this boddet are unclear or in any way homorphis.
- x. AMCA International has ofered the Information within this booket to assist in the saist question, melineramous, and use of the products sold by members of AMCA international, in so doing, AMCA international does not assess any logid dates of the doings nor manufacturer to instruct on seam about, their product, AMCA international operatory decidents habitly through play of damage entities of the operation or use of the product or the galaxies contributed having.
- vi. These recommended safety practices were adopted by the AMCA international membership on April 28, 1996.

dential and consumer firm.

1.2 Marious faith factors are important when assessing potential for injury, some Sectors include: diameter of impoter (wheat, rotat, propalar), relational inertia, voltage, and current.

- 1.3 This guide is intended to assist in the safe installation of air moving equipment and to wern operating and maintenance personnel of the commonly recognized hazards associated with this equipment.
- 1.4 Handling and institution should steepy be performed only by experienced and trained personnel who are areas of the hazards associated with notating explament. Pallar to comply with these practices may result in death or serbous bodily liquid, in addition to decidently the manufactural institution in structions, one should be bloom to ensure compliance with specific series yearly requirements manufacted by feature, sites, and loos dooks, blooky safety advantants and practice published by AMCA Informational and by other recognized apendic and associations should be consulted and federed when experiences.

2. Personnel Safety Accessories

2.1 General

Protective divisions are incorporated as standard constitution on some types of finals but on many fam, head devices are offered as optional accessories. This is done because the need for the devices and the design required will frequently depend upon the type of system. And locatton, and operating procedures being employed. Proper protective sinkly devices; company safety standards; specific safety requirements mandated by federal, state, and locat codes; and industry safety standards and practicion published by AMCC International and by other recognized agencies and associations should be determined by the user who should specify and obtain the appropriate devices from the firm manufacturer or others, and should not allow operation of the equipment without them. Exemples of available devices include the following:

2.2 Fan Guards

2.2.1 All fams have moving parts which require guarding in the same vary as other moving machinery. Fans located less than seven (7) feat above the floor require special consideration. Specific safety requirements should comply with mandated federal, state, and local codes; and industries safety statements and practices published by AMCA International and

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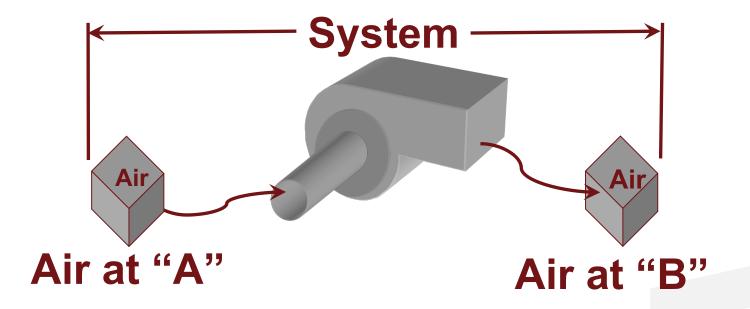
Question: What moves Air?

Differential pressure moves air.



Fan's Role in Air System

• The purpose of a fan is to supply an air system with energy (in the form of a pressure differential) necessary to maintain airflow through the resistance of the system.

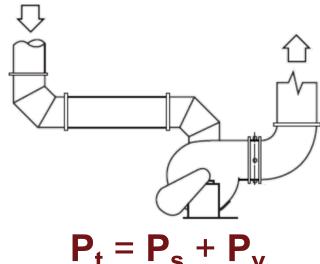


Different Fan Systems

- HVAC heating, ventilating and air conditioning
 - Indoor environmental air comfort
- General Ventilation
 - High Flow Low Pressure Systems
 - Dilution Air Systems
- LEV System (Local Exhaust Ventilation)
 - Combination of hoods, ducts, cleaning devices, fan, and stack to control contaminant or exposure.
- Replacement Air System
 - Every CFM exhausted will be replaced.
- Process system
 - Dryer, Oven System, Boiler, Cooling System

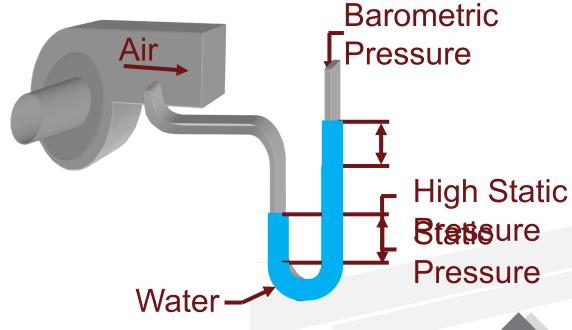
Pressures in a System

- Static Pressure, P_s (SP)
 - The portion of air pressure that exists by virtue of the state of the air.
 - measured perpendicular to flow
 - Static Pressure may be positive or negative
- Total Pressure, P_t (TP)
 - The air pressure state and motion of the air.
 - Algebraic sum of P_s and $P_v \rightarrow P_t = P_v + P_s$
 - measured parallel to flow
 - If air is at rest the total pressure will equal the static pressure
- Velocity Pressure, P_v (VP)
 - "Dynamic pressure" resulting from the motion of the air
- The pressures are changing throughout the system.



Static Pressure, Ps

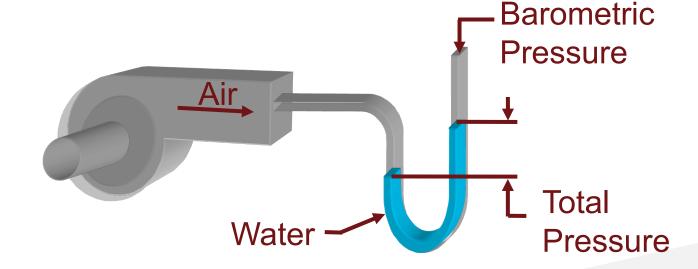
- "Potential pressure" in all directions
- Measured perpendicular to direction of flow
- Overcomes resistance in flow due to:
 - Dynamic losses:
 - Hood and duct entries
 - Fittings (e.g., dampers, elbows, etc.)
 - Air cleaners
 - Duct friction



Total Pressure P_t

- Measured parallel and in the direction of flow
- Sum of static pressure P_s and velocity pressure P_v

$$P_t = P_s + P_v$$



Velocity Pressure, P_v

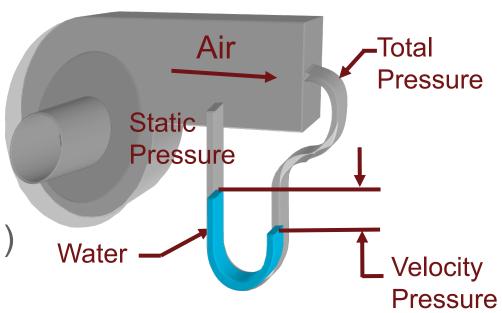
- Measured indirectly (the difference between P_t and P_s) in existing system
- "Dynamic pressure"
- $P_V = (V / 1097)^2 \cdot \rho (I-P)$
- $P_v = 0.5 V^2 \cdot \rho (S-I)$
- Where:

 P_v = velocity pressure, inch wg (Pa S-I)

V = velocity, fpm (m/s S-I)

 ρ = density, lbm/ft³ (kg/m³ S-I)

1097 = I-P Units Constant



Flow Rate (Q) Equation

Calculate velocity of the air (in duct).

Q=Flow (volume/time)

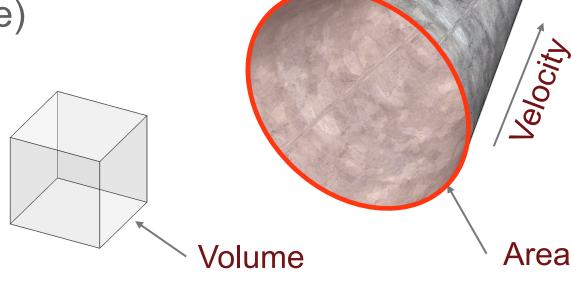
- $f^{3}/m (I-P)$
- m^3/s (S-I)

V=Velocity

- f/m (I-P)
- m/s (S-I)

A=Area

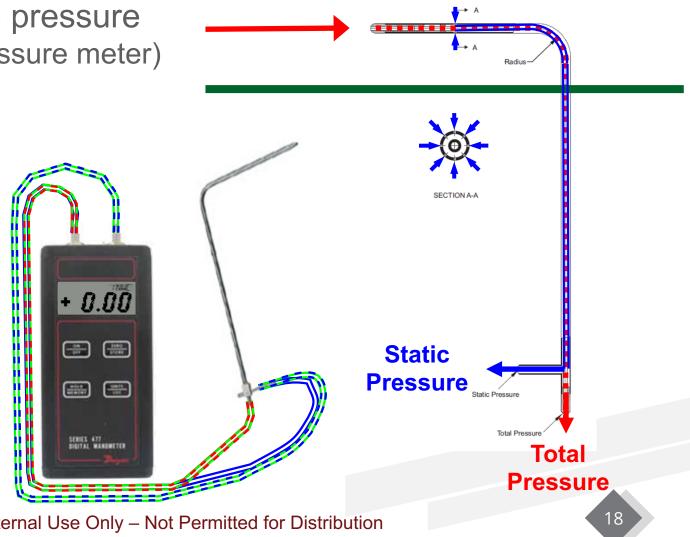
- $f^2 (I-P)$
- m² (S-I)



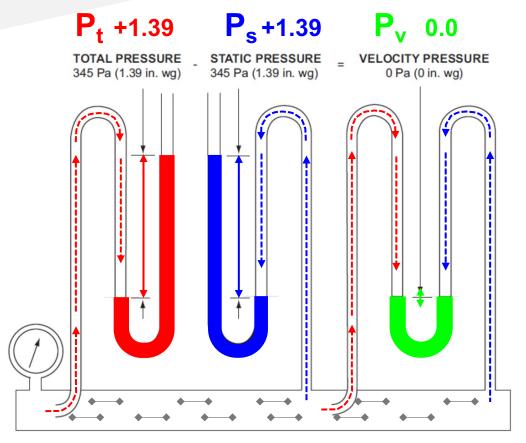
$$Q = V \cdot A$$
 $V = \frac{Q}{A}$ $A = \frac{Q}{V}$

Measuring Pressures with Pitot-Static Tube

- Pitot tube is used to measure pressure
 - Used with a manometer (pressure meter) connected by flexible tubing.
 - Measured in the duct
 - Typical measurements:
 - Pascals (Pa)
 - Inches water (in. H₂O)
 - Millimeters water (mm H₂O)
 - Total Pressure
 - In the direction of airflow
 - Static Pressure
 - Velocity Pressure



Pressure in a Non-moving Airstream



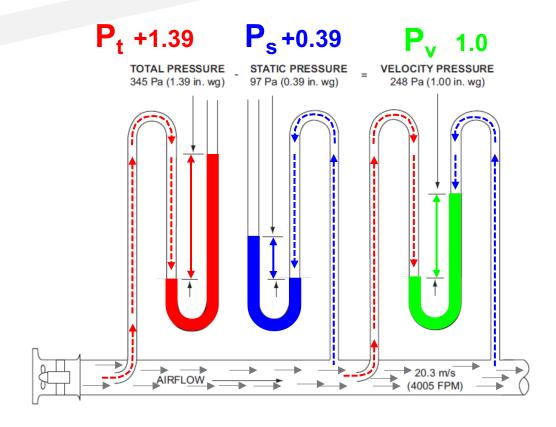
$$P_s + P_v = P_t$$

1.39 + 0.0 = 1.39

Reference AMCA 200 Air Systems Figure 5A - Sealed System

The pressure in the seal length of duct is 345 Pa (1.39 in. wg) above atmospheric pressure. Since there is no airflow the velocity pressure is equal to zero. Total pressure equals static pressure.

Positive Pressure System



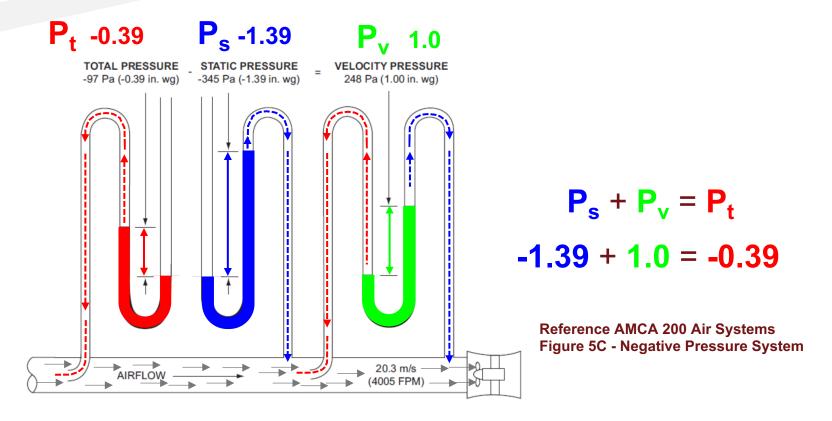
$$P_s + P_v = P_t$$

0.39 + 1.0 = 1.39

Reference AMCA 200 Air Systems Figure 5B - Positive Pressure System

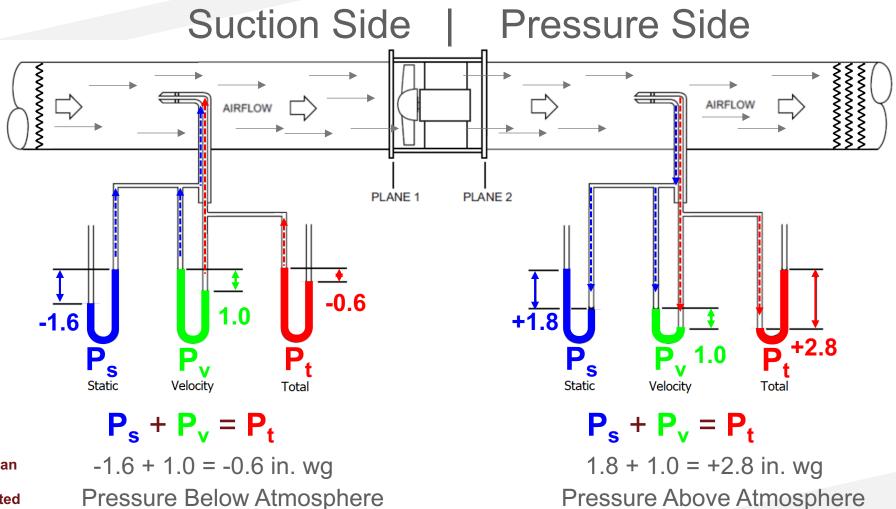
The duct open and a fan placed at one end blowing air through the duct, we find both static pressure and velocity pressure as illustrated by the water gauge. The total pressure is the sum of velocity pressure and static pressure.

Negative Pressure System



The fan is placed at the end of the duct and draws air through the duct. In this case, the static pressure is below atmospheric pressure.

Pressures for Airflow in a Duct



Reference Figure C.5 - Fan Static Pressure for Installation Type D: Ducted Inlet, Ducted Outlet

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Velocity Pressure and Velocity Calculation

Velocity Pressure Calculation

$$P_{v} = \left[\frac{V}{1097}\right]^{2} \cdot \rho \quad \left(in \, wg, f/m, \frac{lbm}{f^{3}}\right)$$

$$P_v = \frac{V^2 \cdot \rho}{2} \quad (Pa, m/s, kg/m^3)$$

Velocity Calculation

$$P_{v} = \left[\frac{V}{1097}\right]^{2} \cdot \rho \quad \left(in \, wg, f/m, \frac{lbm}{f^{3}}\right) \qquad V = \sqrt{\frac{P_{v}}{\rho}} \cdot 1097 \, (f/m, in \, wg, lbm/f^{3})$$

$$V = \sqrt{\frac{2 \cdot P_v}{\rho}} \qquad (m/s, Pa, kg/m^3)$$

$$P_{v} = Velocity Pressure (in.wg or Pa)$$

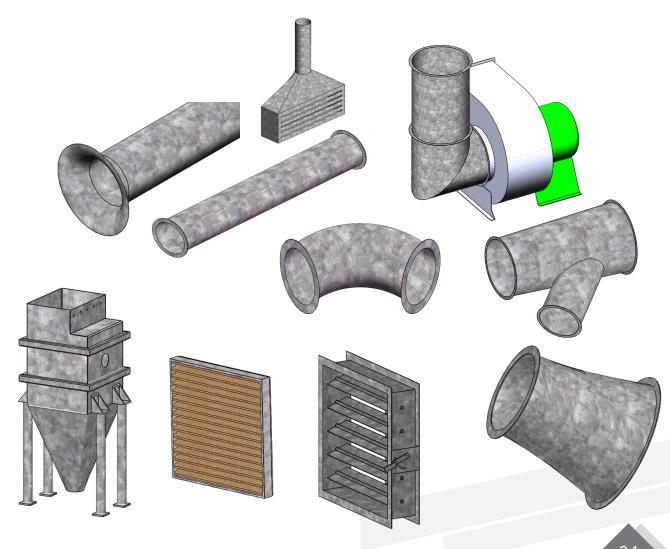
$$V = Velocity (f/m \ or \ m/s)$$

$$\rho = Gas\ Density\ (lbm/f^3\ or\ kg/m^3)$$

$$Q = V \cdot A$$
 $V = \frac{Q}{A}$ $A = \frac{Q}{V}$

Overview of System Losses

- Acceleration losses
- Friction losses
- Dynamic losses
- Component losses
 - Air Cleaning Devices
 - Dampers
 - Other
- System Effects
- Losses will be proportional to velocity pressure



Losses are a Fraction(s) of Velocity Pressure

- The losses will be fraction(s) of the velocity pressure.
- The fraction(s) will be dependent on how much turbulence through the element.
- All elements have a friction loss.
- Increase in velocity will have pressure loss.
- Decrease in velocity will sometimes have a pressure gain.
- The flow must be accelerated into the duct system.
 - This is an additional loss to the loss for the inefficiency of the element.

 $Duct\ Acceleration\ Loss = 1 \cdot P_{v(duct)}$



Simple hood (Bell Mouth Entry)

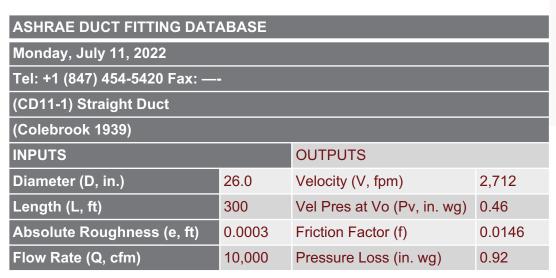
Hood Entry Loss Coefficient			
Plain Duct End	Flanged Duct End	45° Cone Entry	Bell Mouth Entry
	0		
F _h =0.93	F _h =0.56 Conical	45° 2X area F _h =0.15	F _h =0.04
Sharp-Edged Orifice		4	9
	EJ .		
F _h =1.78	F _h =0.64 Rectangular	45° 2X area F _h =0.25	See Compound Hood

Hood Entry Loss = $F_{\cdot}VP$

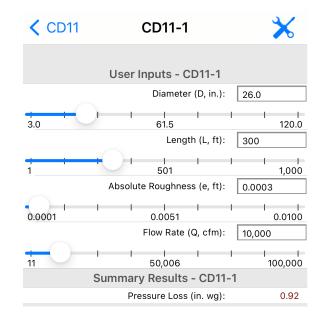
Compound Hood Entry Loss = $F_s \cdot VP + F_d \cdot VP$

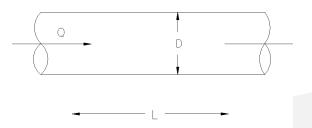
ASHRAE Duct Fitting Database App

 Application is available to calculate pressure losses for HVAC fittings.





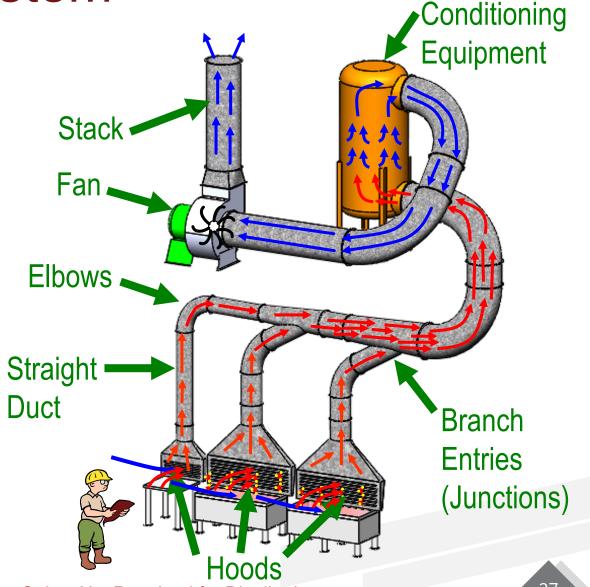




Pressure Losses the System

Where are the static pressure "losses" in this ventilation system?

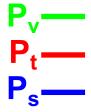
- Hood entry losses due to:
 - Dynamic losses (turbulence)
 - · Acceleration of the air and fumes into system
- Duct Friction
 - Duct losses (due to friction; measured centerline-to-centerline).
- Elbows
 - Dynamic losses (due to turning of the air stream)
- Branch Entries
 - · Dynamic loss due to joining two airstreams together
- Pollution Control Equipment
- Fan
 - · Adds energy to the system in the form of pressure
 - System Static Pressure (SSP)
- Discharge Duct (Stack)
- Dampers and other control devices (not shown)
- Duct expansions and contractions (not shown)



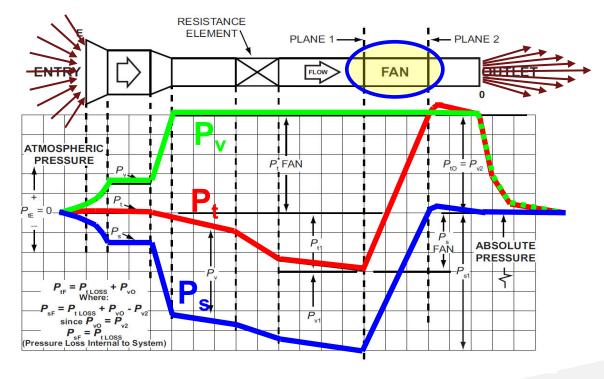
Pressures Through System

- The fan starts building pressure at the fan.
- Static pressure starts to increase
- The most negative point in the fan system will be the inlet of the fan.
- · Velocity starts increasing
- Total pressure = static + velocity pressure.

$$P_t = P_s + P_v$$



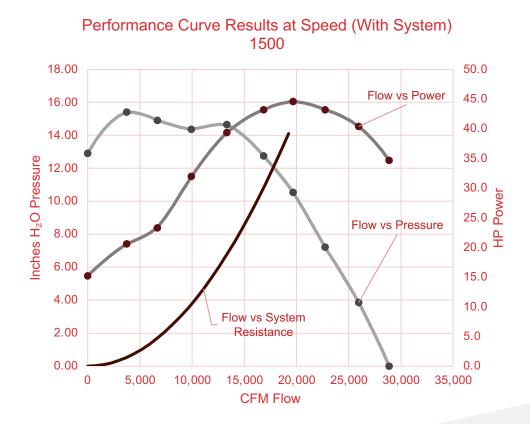
- Note the density and temperature at the fan inlet.
- The pressure on the fan outlet will be highest and be dissipated through the outlet side elements to the outlet of the fan system and discharge.



$$Fan_{SP} = SP_{out} - SP_{in} - VP_{in}$$
 @ ___CFM at ___Density and ___Temp.

Fan & System Point of Operation

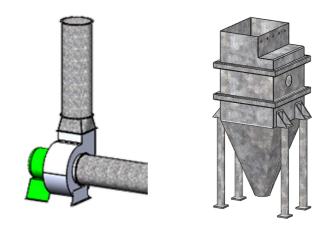
- Fan System Calculation
 - The flow and pressures for the entire system are calculated.
 - The pressure required to produce the flow will be cumulative up to the inlet of the fan plus the pressure requirement on the discharge side of the fan.
 - The flow from each inlet will combine in the duct system into the inlet of the fan.
- A fan provides the pressure to move the air through the system and the flow rate will reach a point of equilibrium (point of operation) when the pressure provided by the fan equals the pressure losses in the system at that flow rate.



$$Fan_{SP} = SP_{out} - SP_{in} - VP_{in} @ __CFM at __Density and __Temp.$$

Pressures in a Ventilation and Fan System Summary

- Fans have obvious and hidden hazards.
- The fan provides the differential pressure energy to the system to create airflow.
- Pressures in an air system are:
 - P_s Static Pressure
 - P_t Total Pressure ($P_t = P_s + P_v$)
 - P_v Velocity Pressure (Δ P_s and P_t)
 - Pressures changing throughout system.
- Pressure Losses for all system elements should be considered.
 - Hoods, Ducts, Elbows, Junctions, Conditioning Equipment, Transitions, Discharges
 - Losses are fraction(s) of velocity pressure.
- Velocity through system can be calculated.
- Velocity pressure can be calculated.



Element Loss = $F_{element} \cdot P_{v_{element}}$

$$Q = V \cdot A$$
 $V = \frac{Q}{A}$ $A = \frac{Q}{V}$

$$P_v = \left[\frac{V}{1097}\right]^2 \cdot \rho \quad \left(in \, wg, f/m, \frac{lbm}{f^3}\right)$$

$$P_v = \frac{V^2 \cdot \rho}{2} \qquad (Pa, m/s, kg/m^3)$$

AMCA Technical Seminar Introduction to Fans and Systems Topics

Date	Topics
Week 1	Fan and System Curves Pressure Considerations in Fan Systems Live introduction to online on-demand Simplified affinity laws Motors
Week2	Centrifugal & Axial Fan types Losses in Elbows and Ducts Fan-System Controls

Date	Topics
Week 3	Power and Efficiency of Fans System Effect Power and Efficiency of Fans Advanced Affinity Laws
Week 4	Fan Selection Certified Ratings Wrap up Review Final Questions

Resources

- AMCA International: www.amca.org
- ANSI/AMCA Standards: www.amca.org/store (available for purchase)
 - ➤ 210-16: Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating (ASHRAE 51-16)
- AMCA Publications: www.amca.org/store
 - > 200-02 (R2011) Air Systems
 - > 201-02 (R2011) Fans and Systems
 - > 410-02 (R2009) Recommended Safety Practices

Questions?

Contact Information

- William Howarth whowarth@vfcsintl.com

- Ron Wroblewski ron@productiveenergy.com



To receive PDH credit, you must complete the post-course evaluation

