The Fundamentals of Airflow

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- 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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Q & A

To submit questions:

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- Click "Send".

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Senior Sales Manager – AMCA Member Company

- BS in Civil Engineering from University of Minnesota Twin cities
- Has served the HVAC industry as an engineer and sales leader, focused on energy efficiency, reliability and quality.
- Served on several AMCA committees.

The Fundamentals of Airflow

Purpose and Learning Objectives

The purpose of this presentation is to provide industry professionals with an overview of the basic concepts and relationships between airflow and pressure, and how these concepts are affected by various outside factors in regard to fans.

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

1. Describe the basic components of airflow, how to measure them, and how they relate to each other.
2. Explain how to read fan curves, and what this knowledge helps to avoid.
3. Apply the Affinity laws for troubleshooting and solving problems.

Agenda

Section 1: Why the Fundamentals

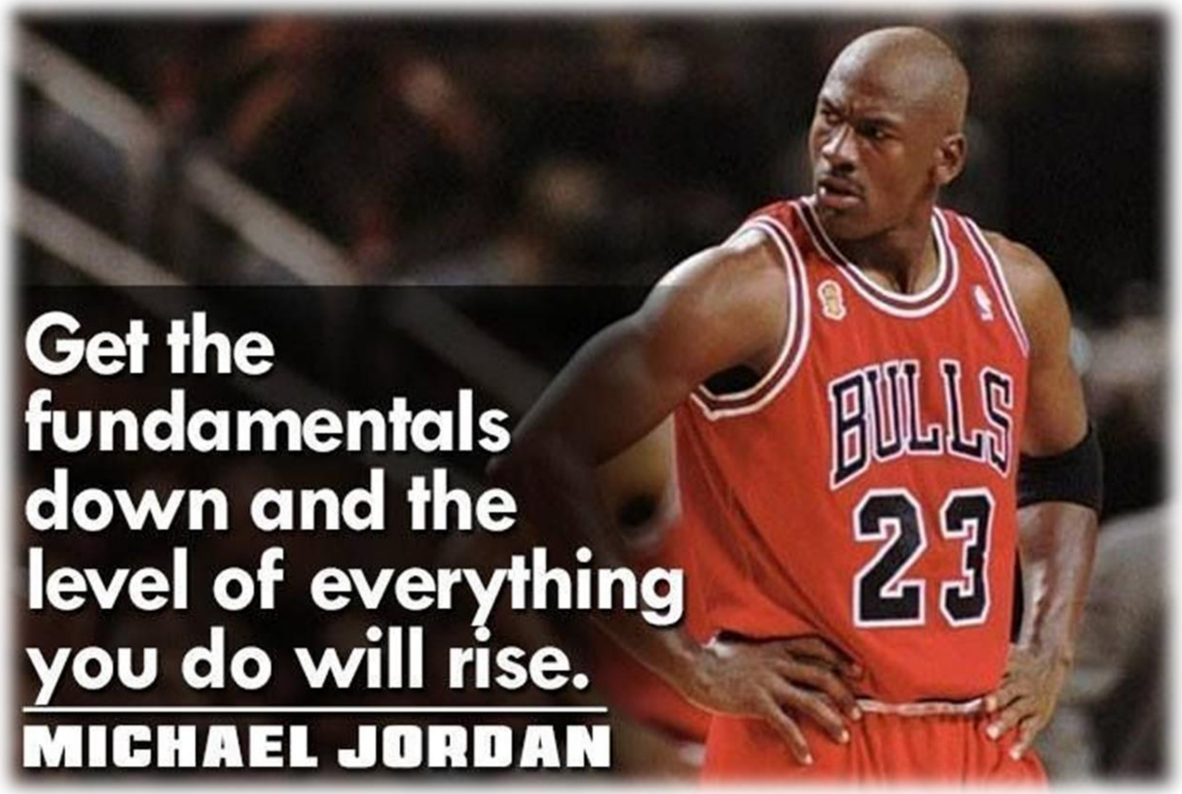
Section 2: Components of Airflow

Section 3: Power and Efficiency

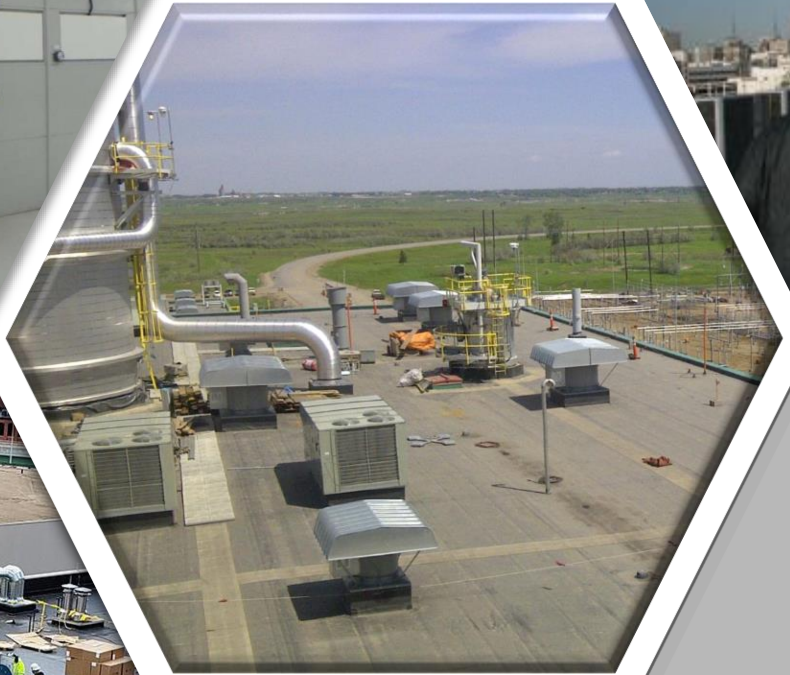
Section 4: Fan Curves

Section 5: The Affinity Laws

Section 1: Why the Fundamentals



Section 1: Building Your Foundation



Section 1: Heart of a system

Section 2: Components of Airflow

Key Terms and How to Measure them

- Air Density
- Volume
- Pressure

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Section 2: Air Density

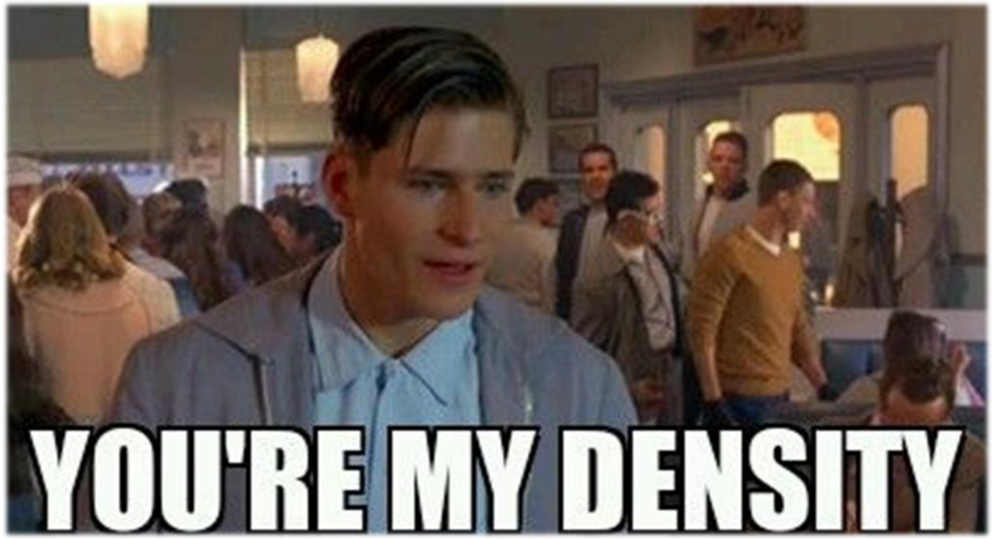
Standard air density = 0.075 lb./ft3

Air temperature of 70ºF (21ºC)

Altitude at 0 ft. elevation (sea level)

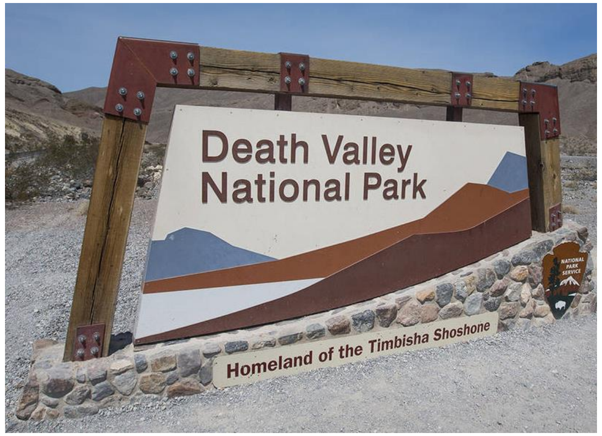
Barometric pressure of 29.92” Hg (101 kPA)

Specific volume of 13.33 ft3/lb.

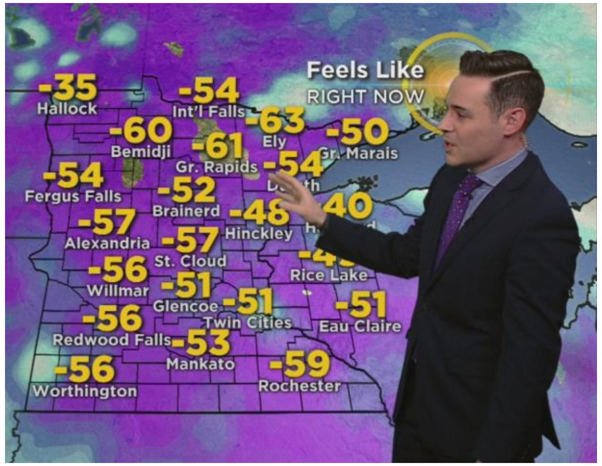


Section 2: Air Density – Temperature Effect

At temperatures above 70ºF, air density is less (lighter air)



At temperatures below 70ºF, air density is greater (heavier air)



Section 2: Air Density – Altitude

At altitudes above sea level, air density is less (lighter air)

At altitudes below sea level, air density is greater (heavier air)

Section 2: Air Density - Humidity

The addition of Water Vapor reduces the density of air (lighter air).

The dryer the air the more dense it will be (heavier air).

Section 2: Volume

A Requirement to get a job done

Common unit of measure : Cubic Feet per Minute (CFM)

ACFM	SCFM
Actual Cubic Feet Per Minute	Standard Cubic Feet Per Minute
• Represents the actual conditions of the job, not corrected to standard density conditions • Represents the volume of gas flowing anywhere in the system independent of air density	• Volume that gas would occupy if at standard density • Selecting a fan when SCFM is specified requires us to calculate the ACFM

Section 2: Volume (V)

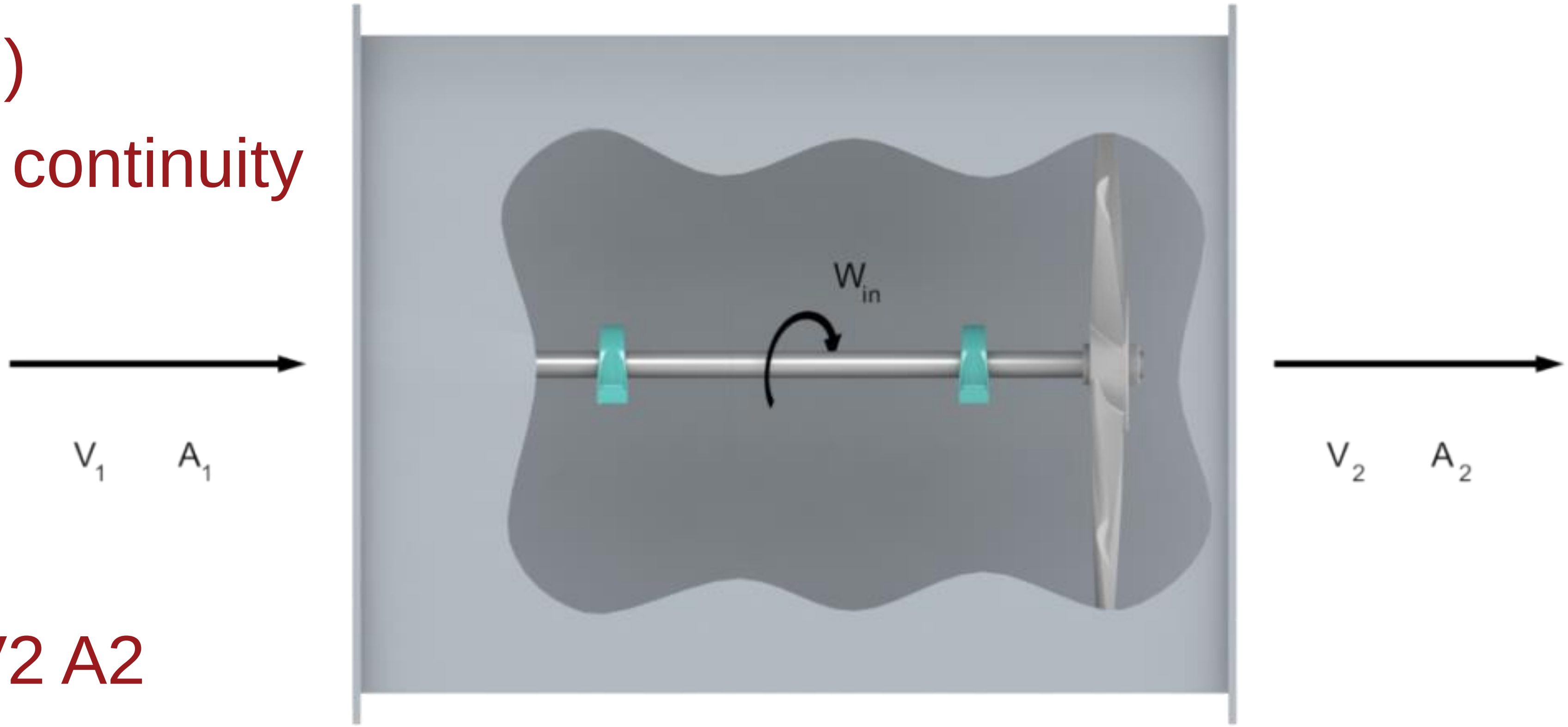
Fan Airflow (CFM)

CFM is based on continuity

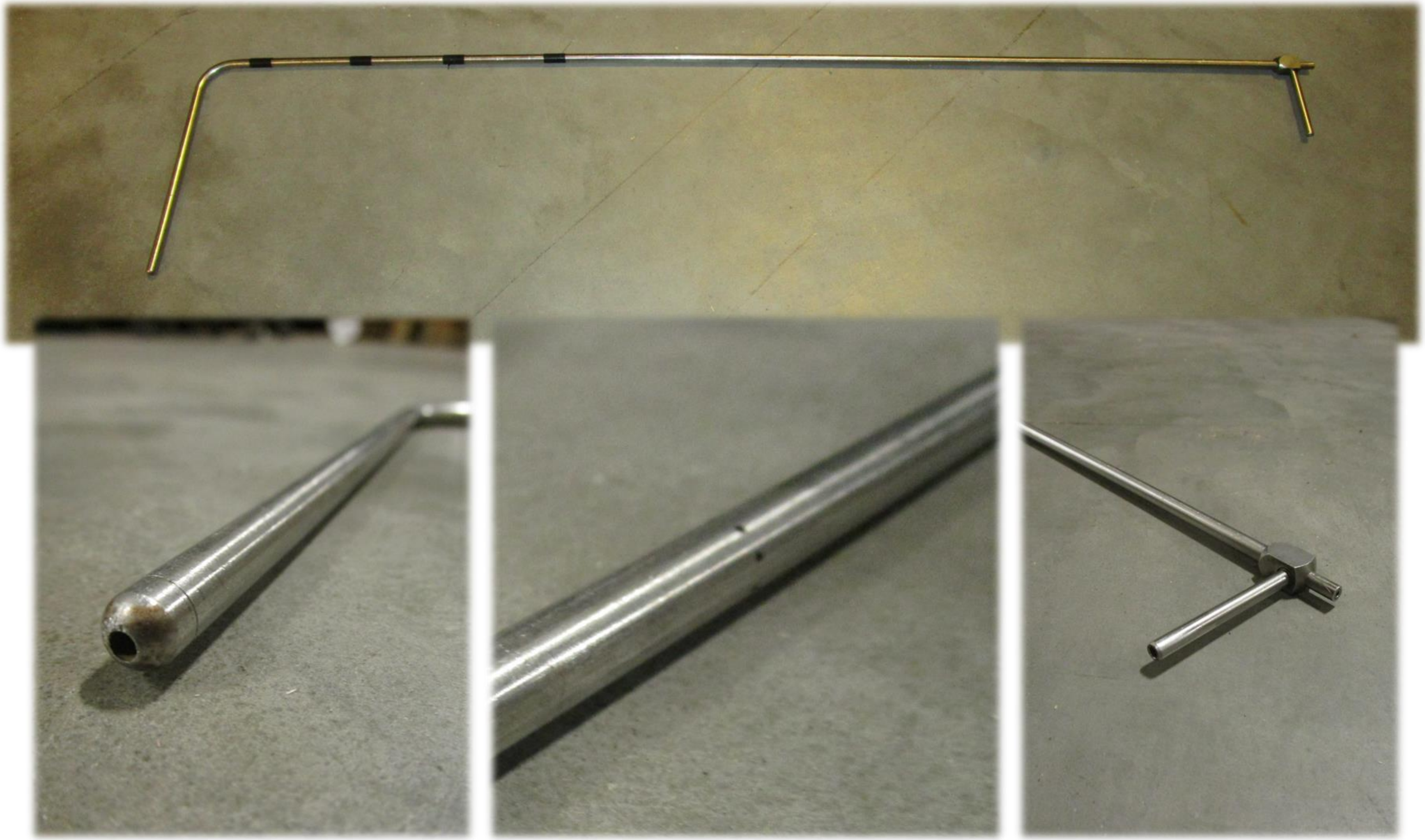
V = Volume

A = Area

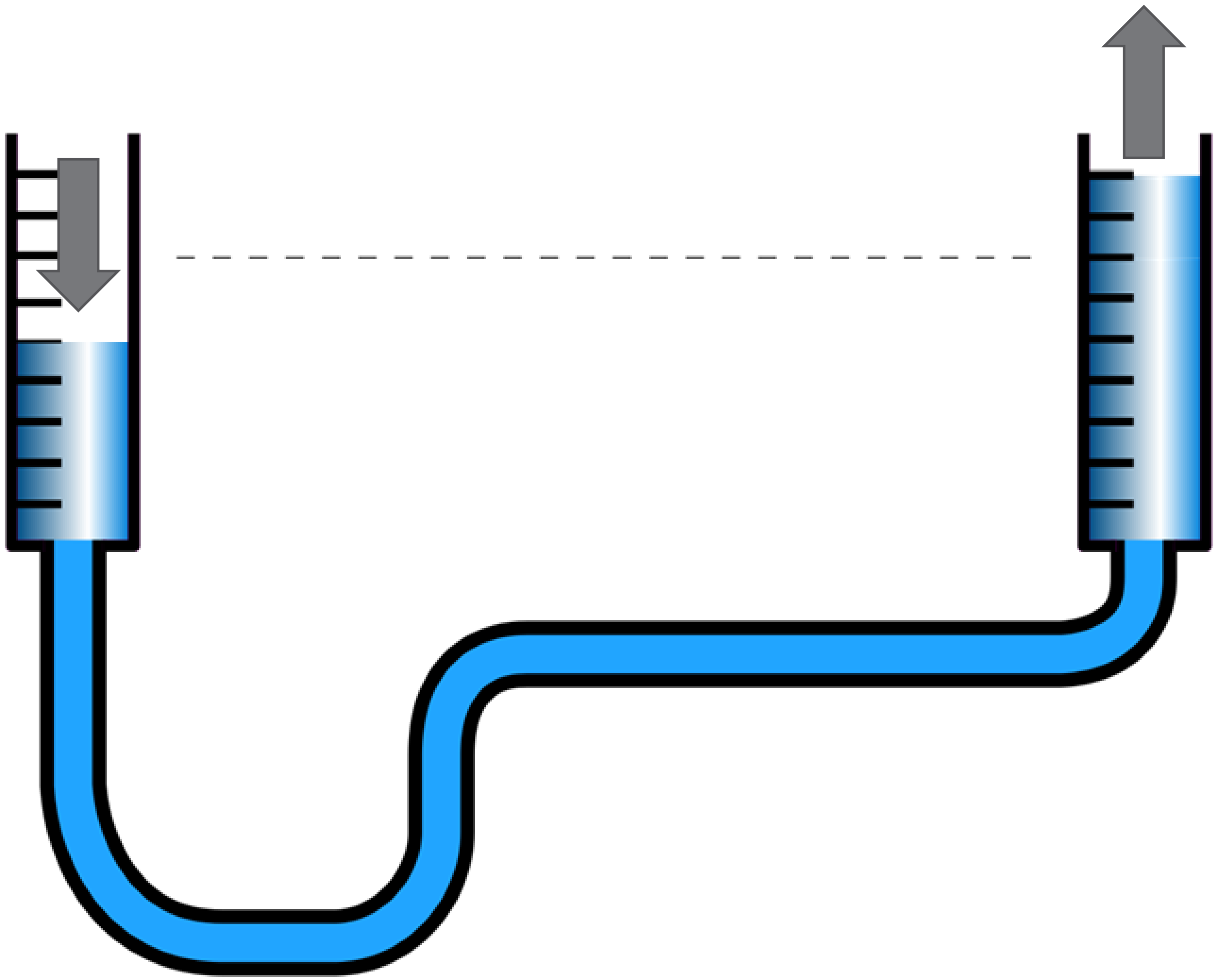
CFM = V1 A1 = V2 A2



Section 2: Measurement

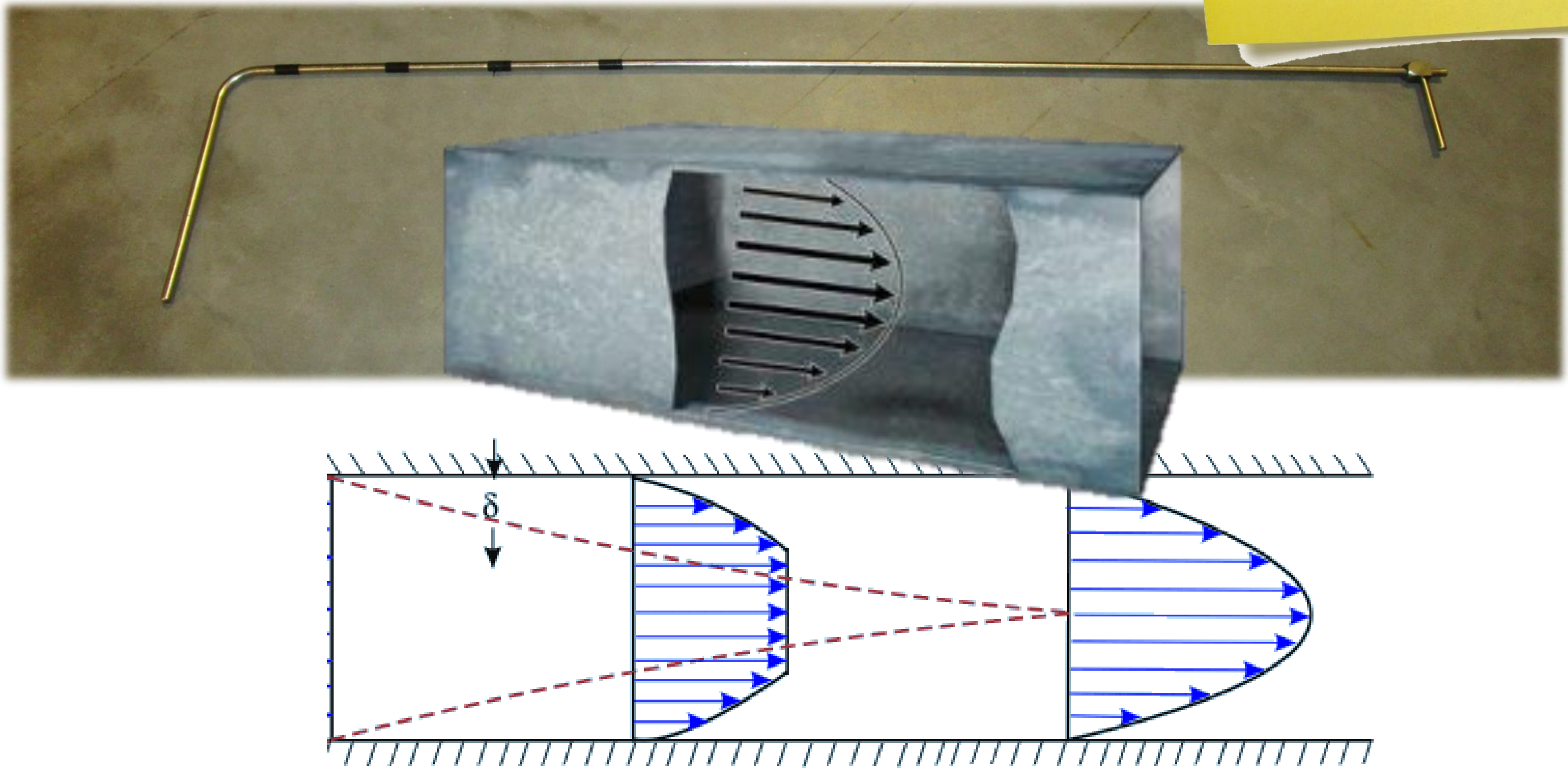


Section 2: Similar to a water level



Section 2: Volume (V)

CFM = Velocity (V) * Area (A)



Section 2: Modern Measurement

Section 2: Pressure

System

Negative vs. Positive Pressure

Static Pressure

Velocity Pressure

Total Pressure

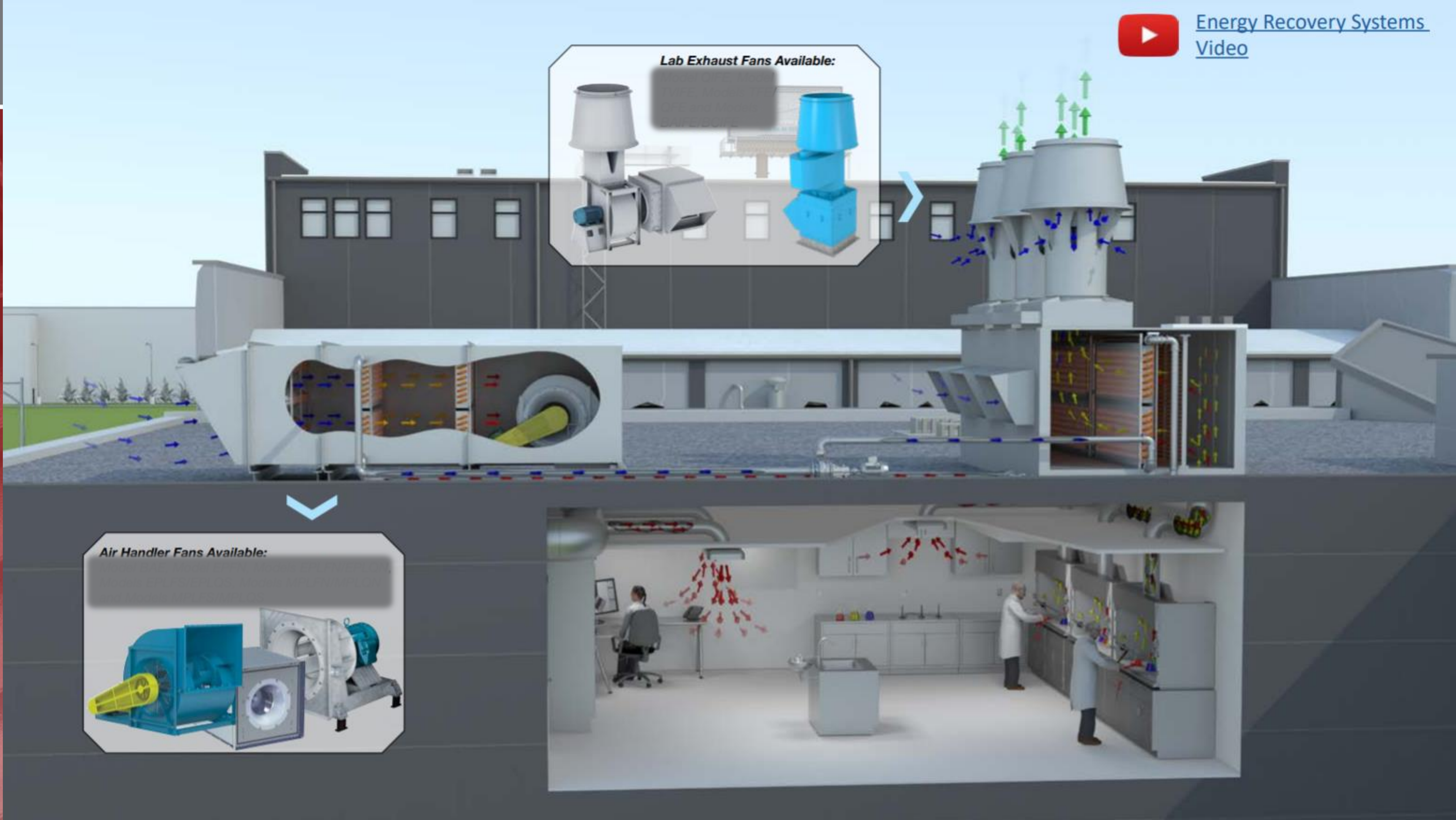
Fan Total Pressure

Fan Static Pressure

Section 2: System


Non-Acute Care
HEPA Filter (installed by customer)
HEPA Filter (installed by customer)

Energy Recovery Systems Video

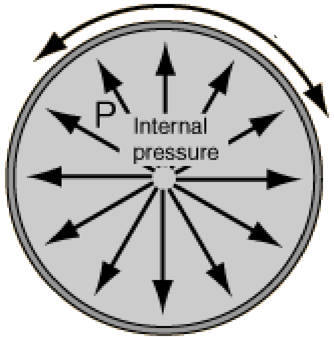


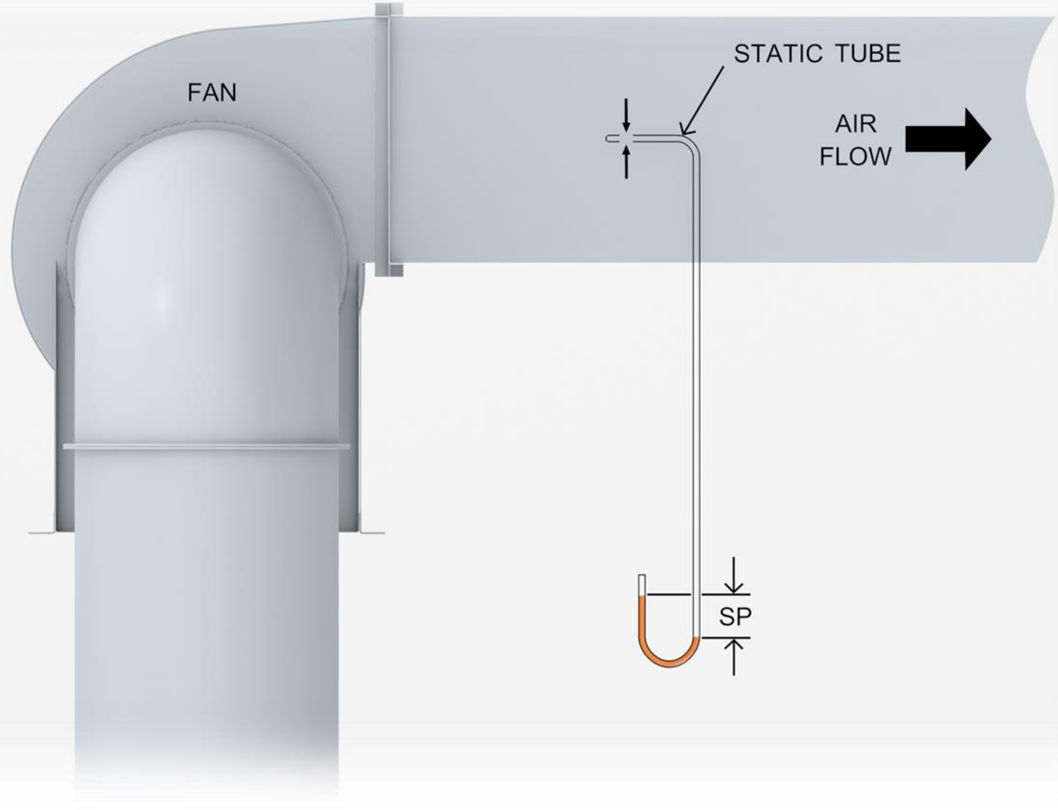
Section 2: Static Pressure (SP)

Definition:

The pressure exerted by air on a surface at rest

Commonly used to specify fan performance





Section 2: Velocity Pressure (V

Definition:

The Kinetic energy per unit volume

Equation

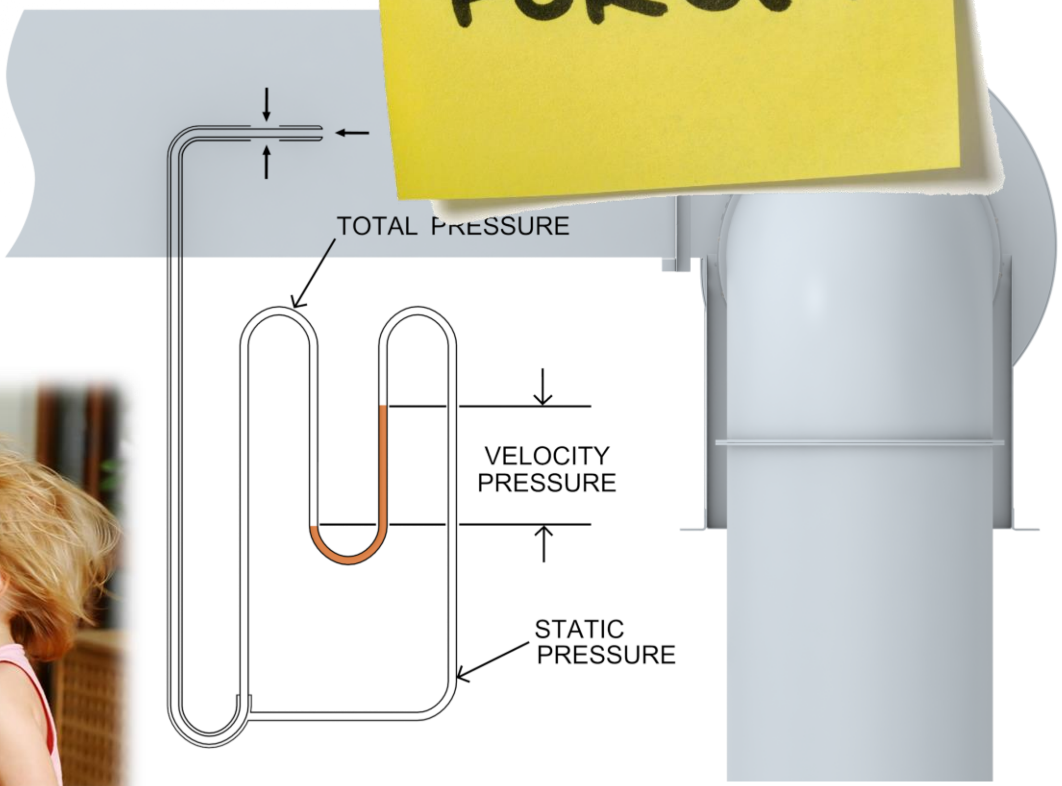
$$VP = \rho \, (V / 1098)^2$$

ρ = Density in lb./ft^3

V = Velocity in FPM

At standard air:

$$VP = (V / 4009)^2$$



Airflow (CFM) = V * Area (ft^2)

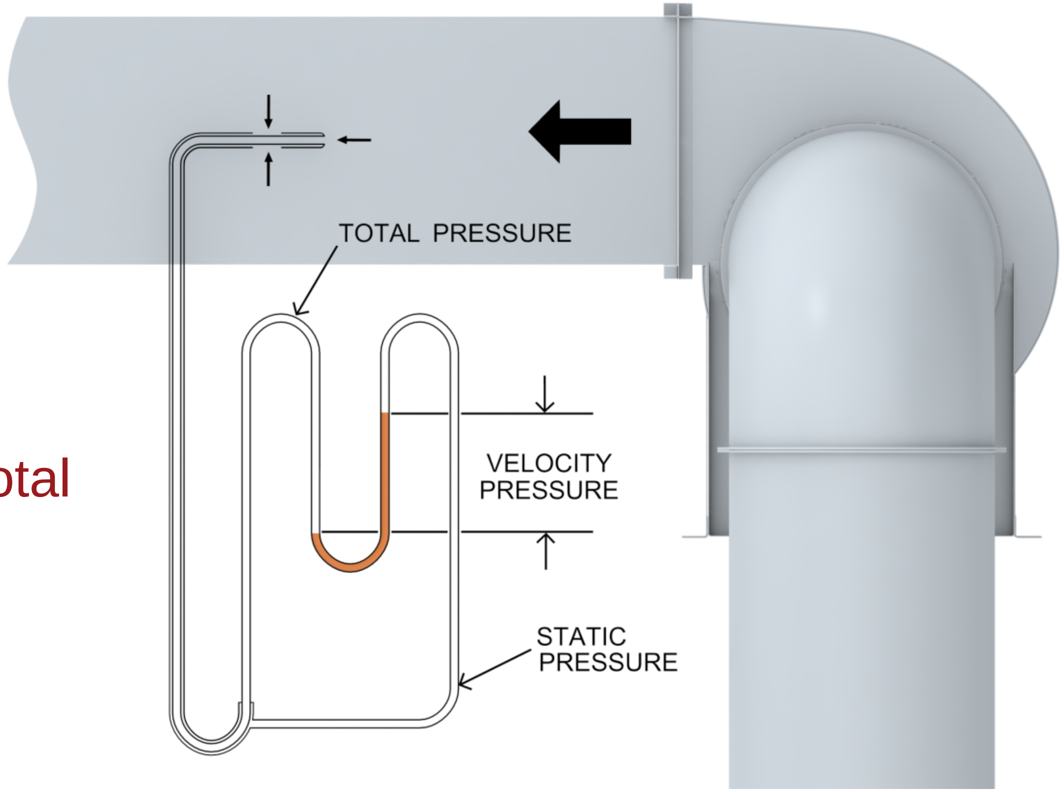
Section 2: Total Pressure (TP)

Total Pressure Definition:

The Measure of the total energy of the airstream

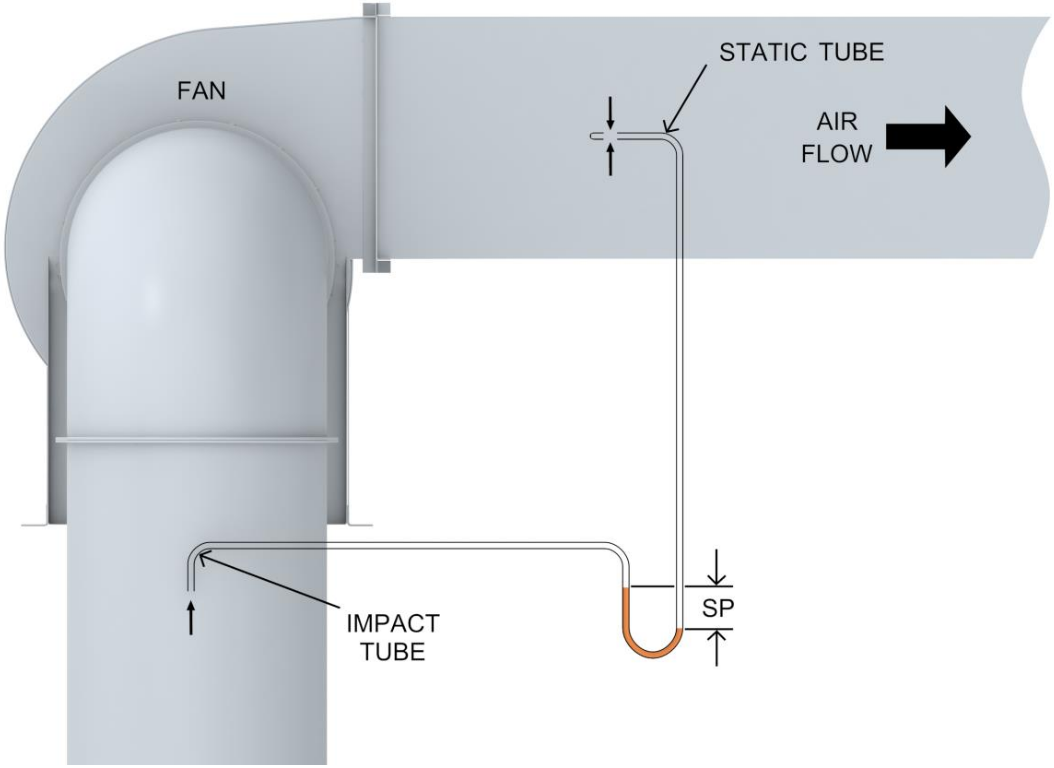
Equation

Static Pressure (SP) + Velocity Pressure (VP) = Total Pressure (TP)



Section 2: Fan Static Pressure (FSP)

This is important because this is used for ratings.



Equation

FSP = SP at outlet – TP at inlet

Section 2: Fan Total Pressure (FTP)

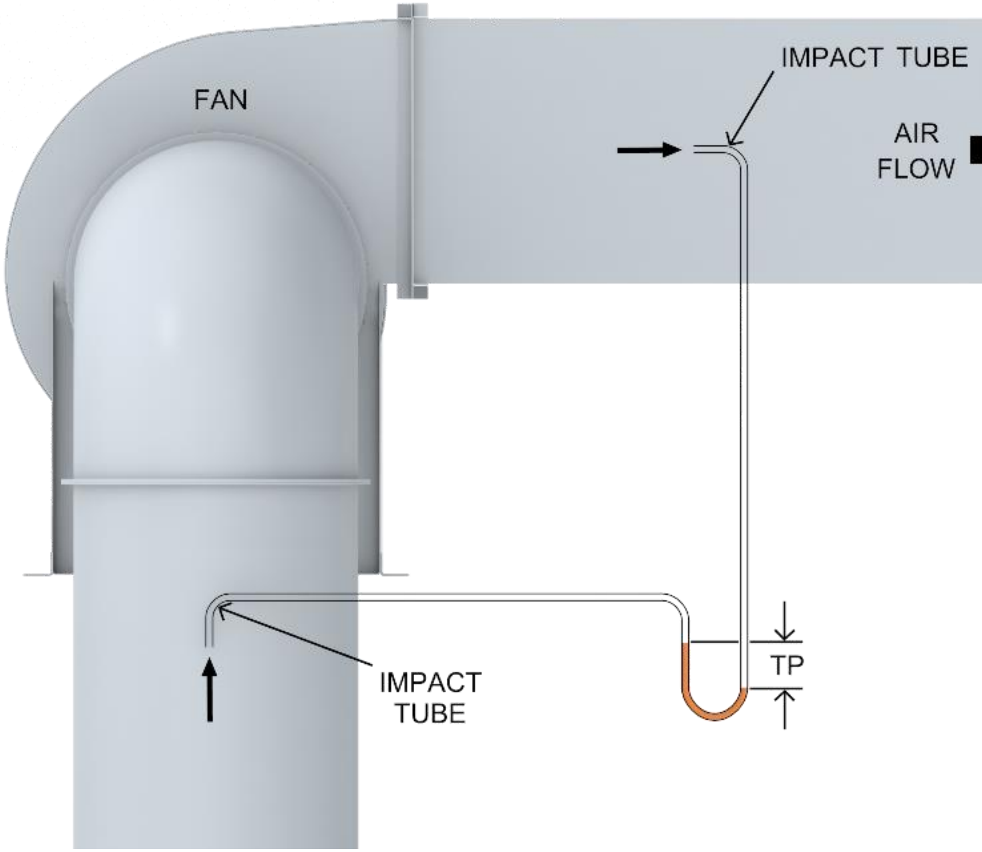
Fan Total Pressure Definition:

Total mechanical energy added to the air by the fan

Equation

Fan Total Pressure =

Total Pressure Outlet – Total Pressure Inlet



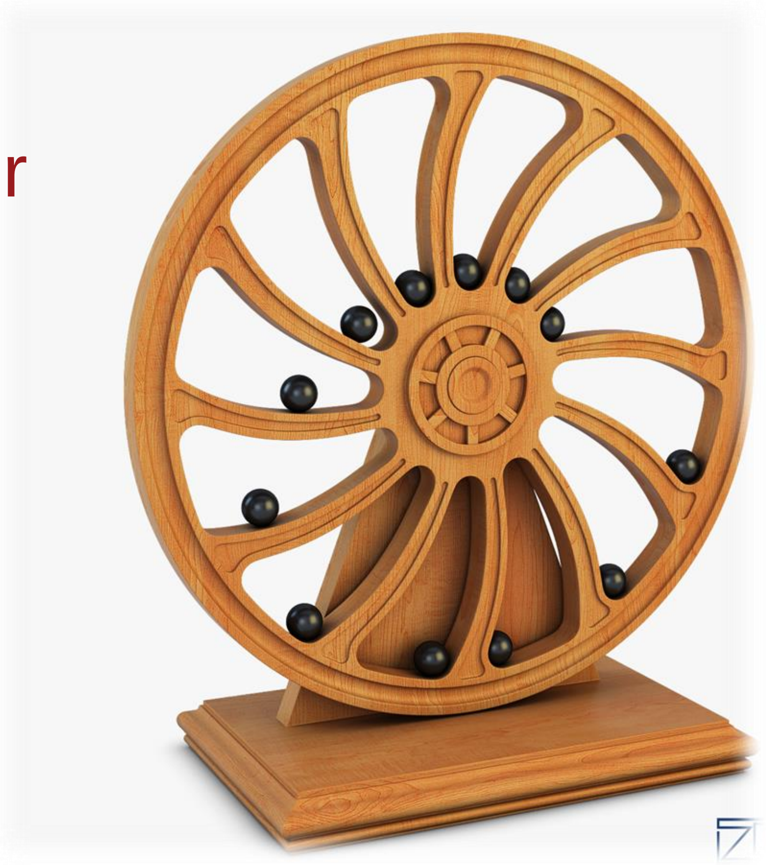
Section 3: Power and Efficiency

Key Terms:

- Air Horsepower
- Brake Horsepower
- Static Efficiency
- Total Efficiency

3

Section 3: Air Horsepower



Definition:

Assuming 100% efficiency, the horsepower required to move a given volume of air against given pressure (IP units)

Equations:

Static AHP = (CFM x SP) / 6343

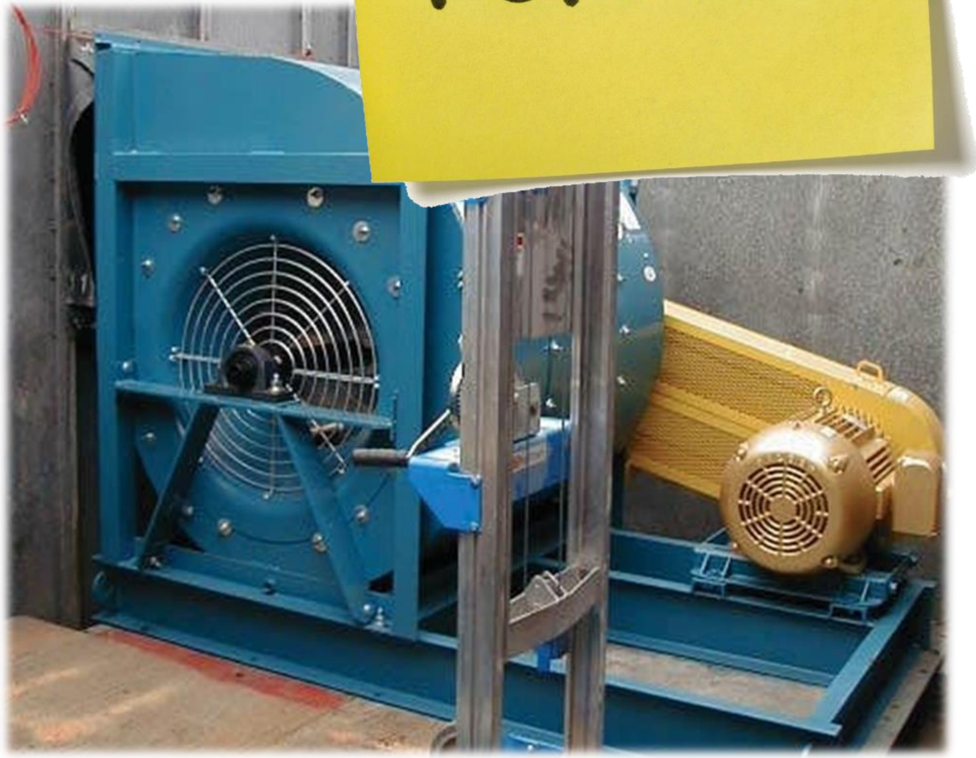
Total AHP = (CFM x TP) / 6343

Section 3: Brake Horsepower

Definition:

The actual horsepower a fan requires determined by testing.

BHP > AHP because a fan is not 100% efficient



Section 3: Static Efficiency

Definition:

Ratio of fan power output to the fan power input

Uses SP, which does not include kinetic energy

Equation

$$SE = AHP_{SP} / BHP$$

$$SE = (CFM \times SP) / (6343 \times BHP)$$

Section 3: Total Efficiency

Definition:

Ratio of total fan power output to the fan power input. Also referred to as Mechanical Efficiency.

Uses TP, which includes kinetic energy

Equation

$$TE = AHP_{TP} / BHP$$

$$TE = (CFM \times TP) / (6343 \times BHP)$$

Section 3: How Energy Flows through a Fan

Energy Equation

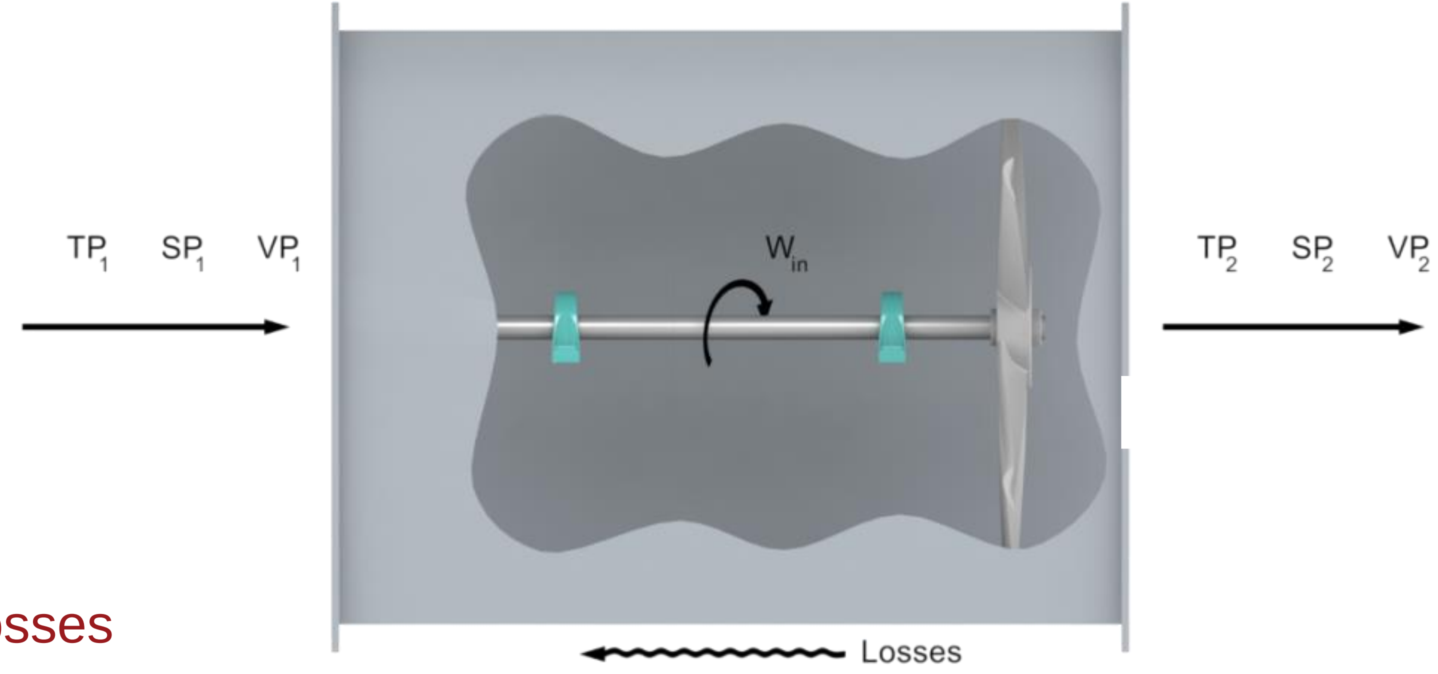
TP1 + Win = TP2 + Losses

and since TP = SP + VP

VP1 + SP1 + Win = VP2 + SP2 + Losses

Win is shaft power transferred to the air

Losses are due to fan inefficiencies and flow losses



Section 4: Fan Curves

Introduction to Curves

System Curve

Fan Performance Curve

BHP Curve

Static Efficiency Curve

Fan Operating Point

Total Efficiency Curve

Fans in Parallel and Series

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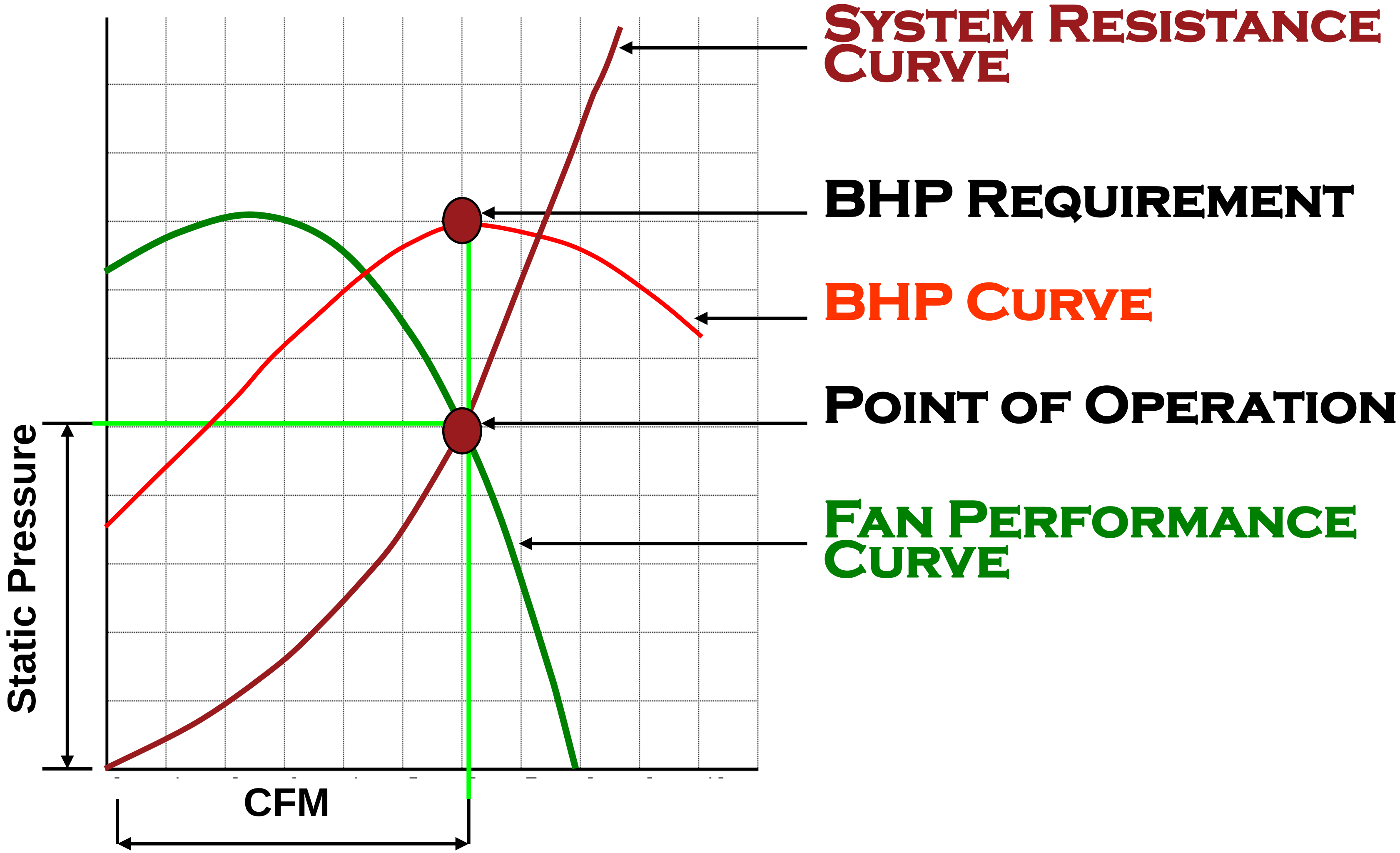
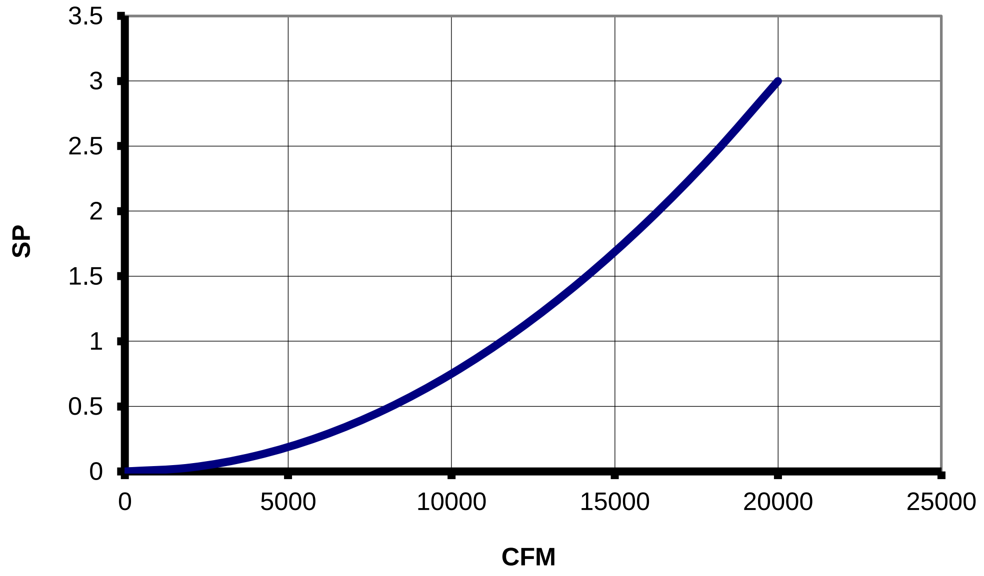
Section 4: Introduction to Curves



Section 4: System Curve



Pressure Loss = (V^X) where X = 2 for turbulent flow

Pressure Loss ~ SP ~ V^2 ~ Q^2

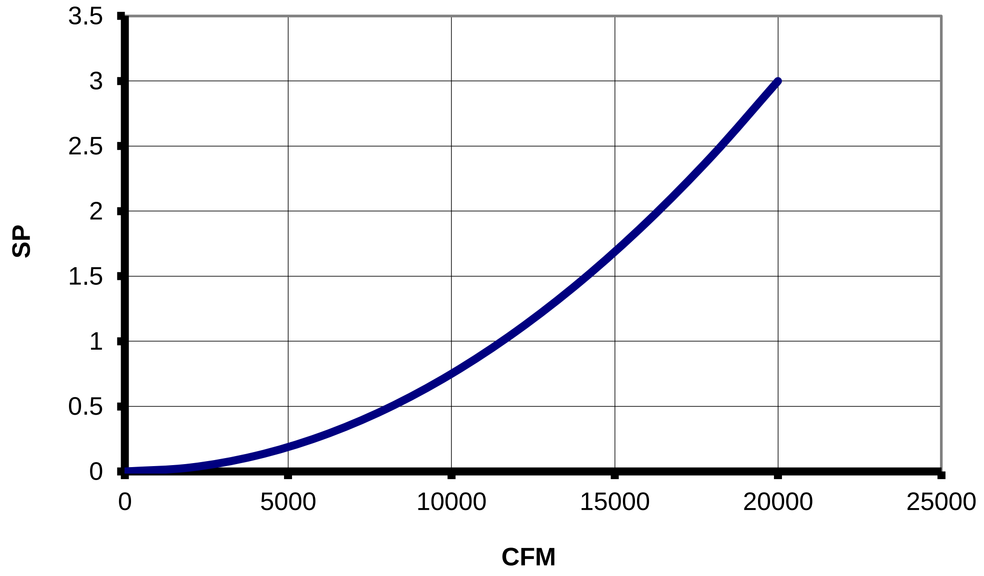
K = A Constant set by the system

$SP_{Loss} = kQ^2$ System curve

$$K = \frac{SP}{Q^2}$$

Section 2: System

Section 4: System Curve



Pressure Loss = (V^X) where X = 2 for turbulent flow

Pressure Loss ~ SP ~ V^2 ~ Q^2

K = A Constant set by the system

$$K = \frac{SP}{Q^2}$$

$SP_{Loss} = kQ^2$ System curve

Section 4: System Curve

$$K = \frac{SP}{Q^2}$$

$$K = \frac{9''}{60{,}000^2}$$

$$.0000000025 = \frac{9''}{60{,}000^2}$$

$$.0000000025 = \frac{X}{40{,}000^2}$$

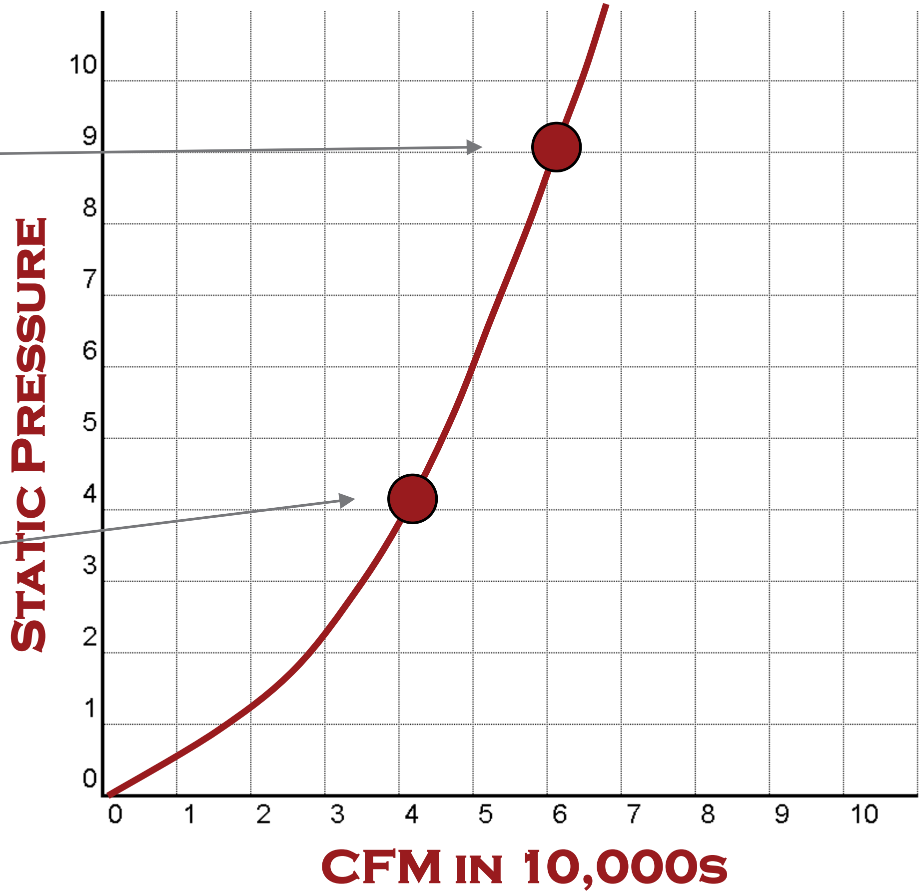
$$.0000000025 = \frac{4''}{40{,}000^2}$$

Point 2:

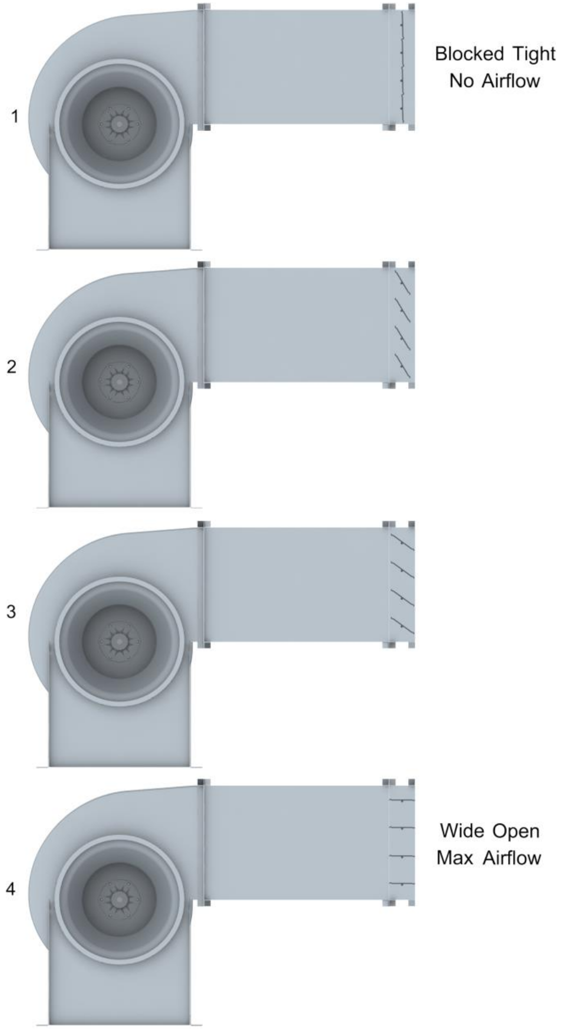
- 60,000 CFM
- 9 in. wg. SP

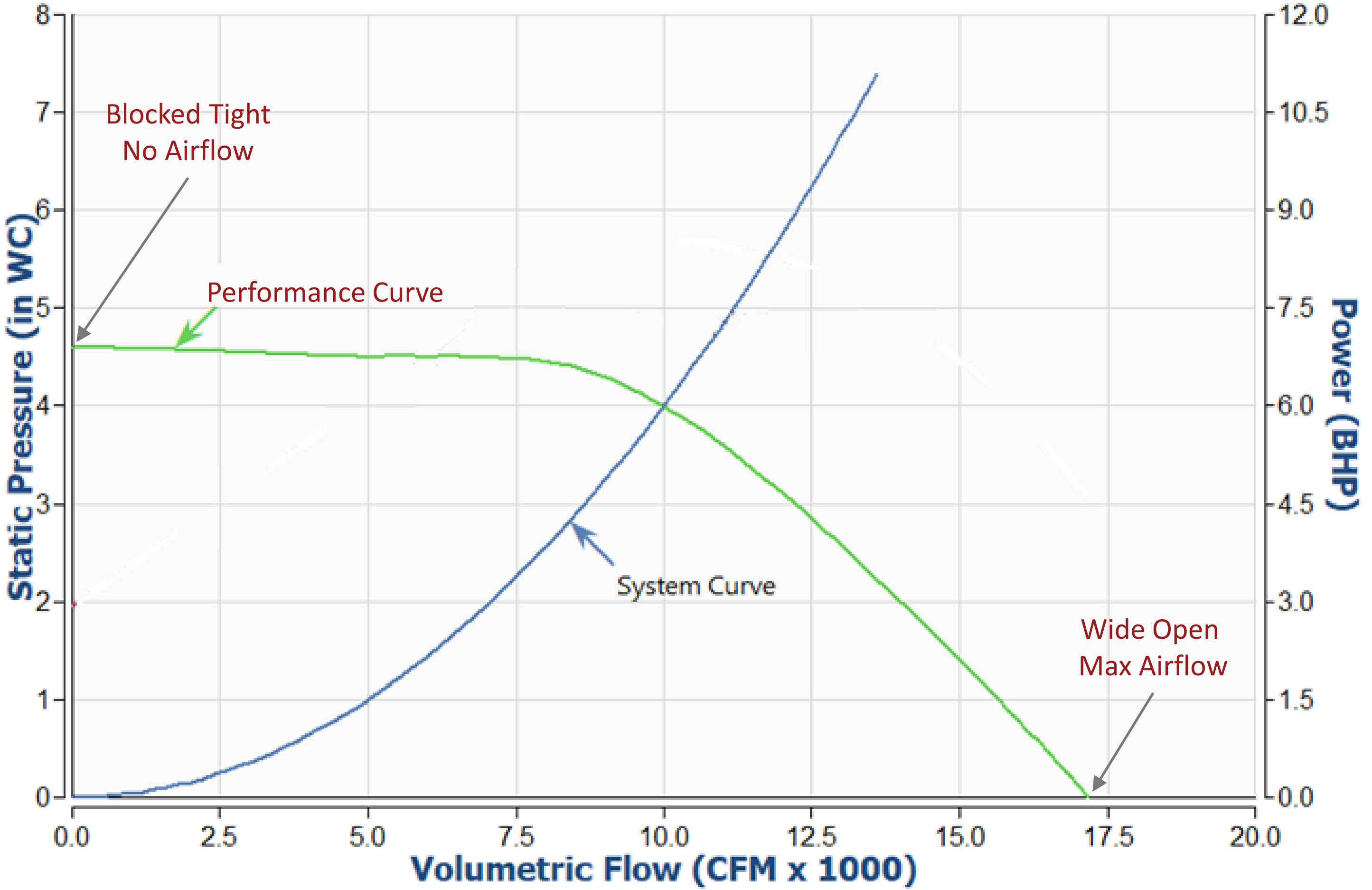
Point 1:

- 40,000 CFM
- 4 in. wg. SP

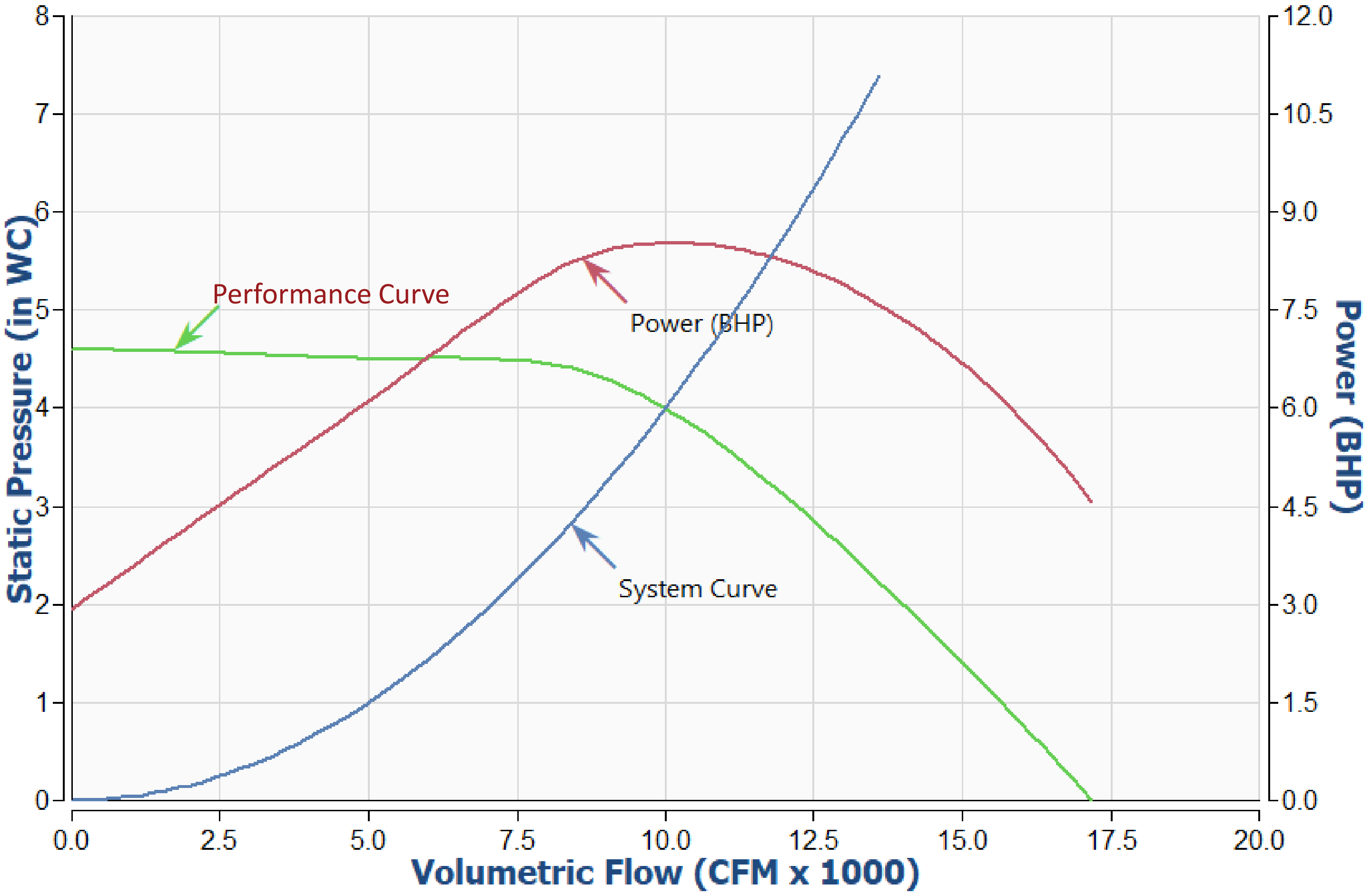


Section 4: Performance Curve (SP)

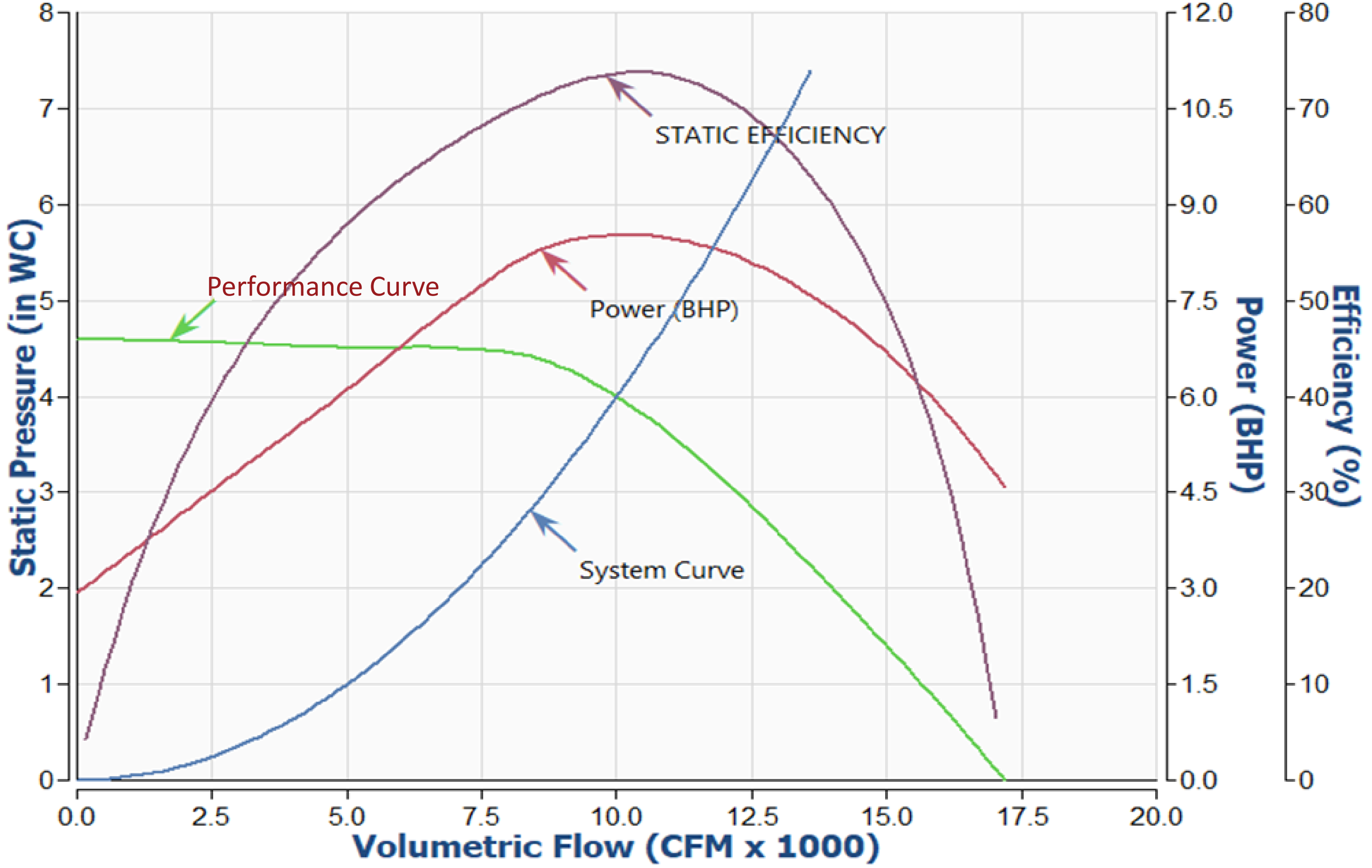




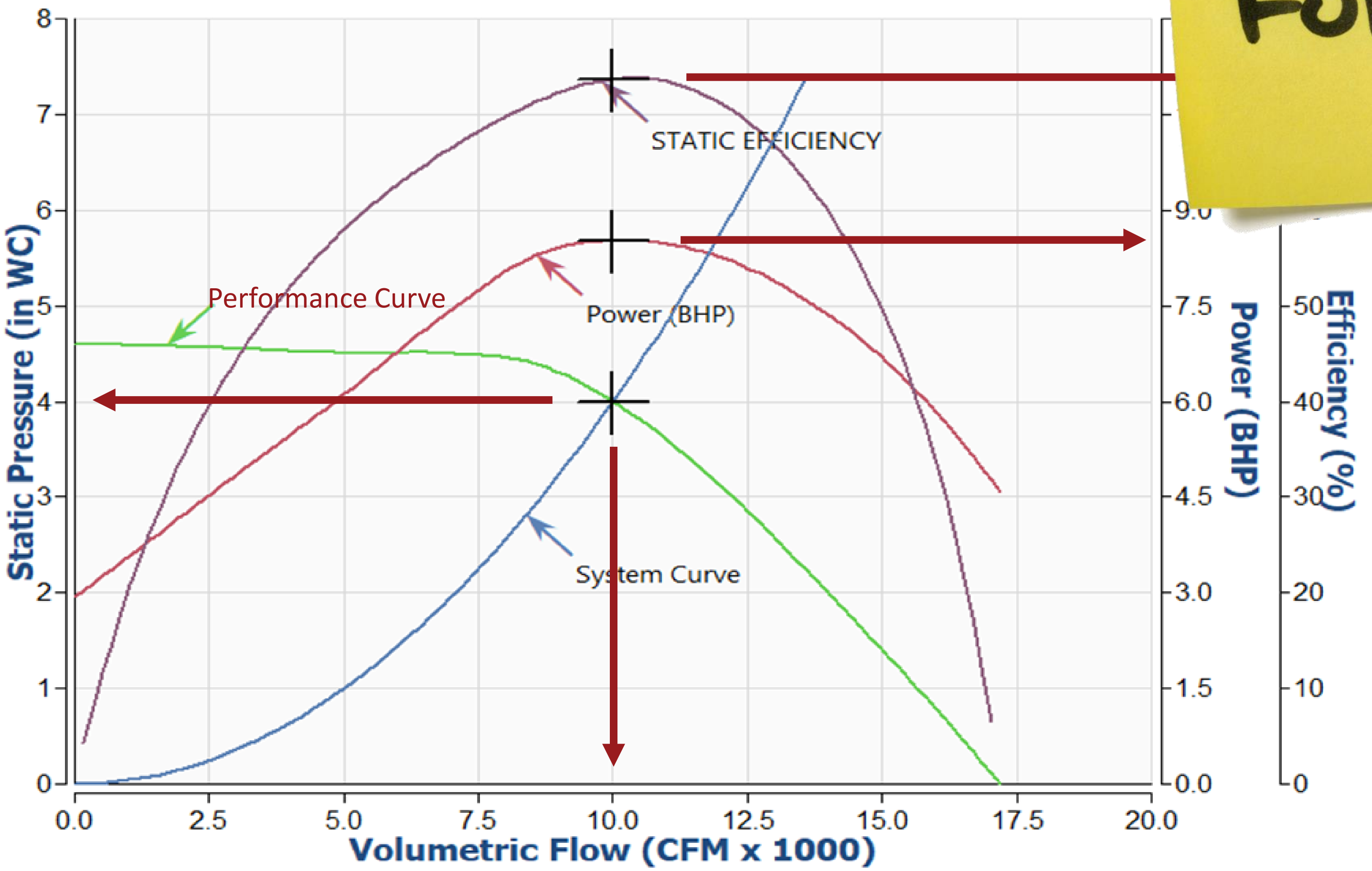
Section 4: BHP Curve



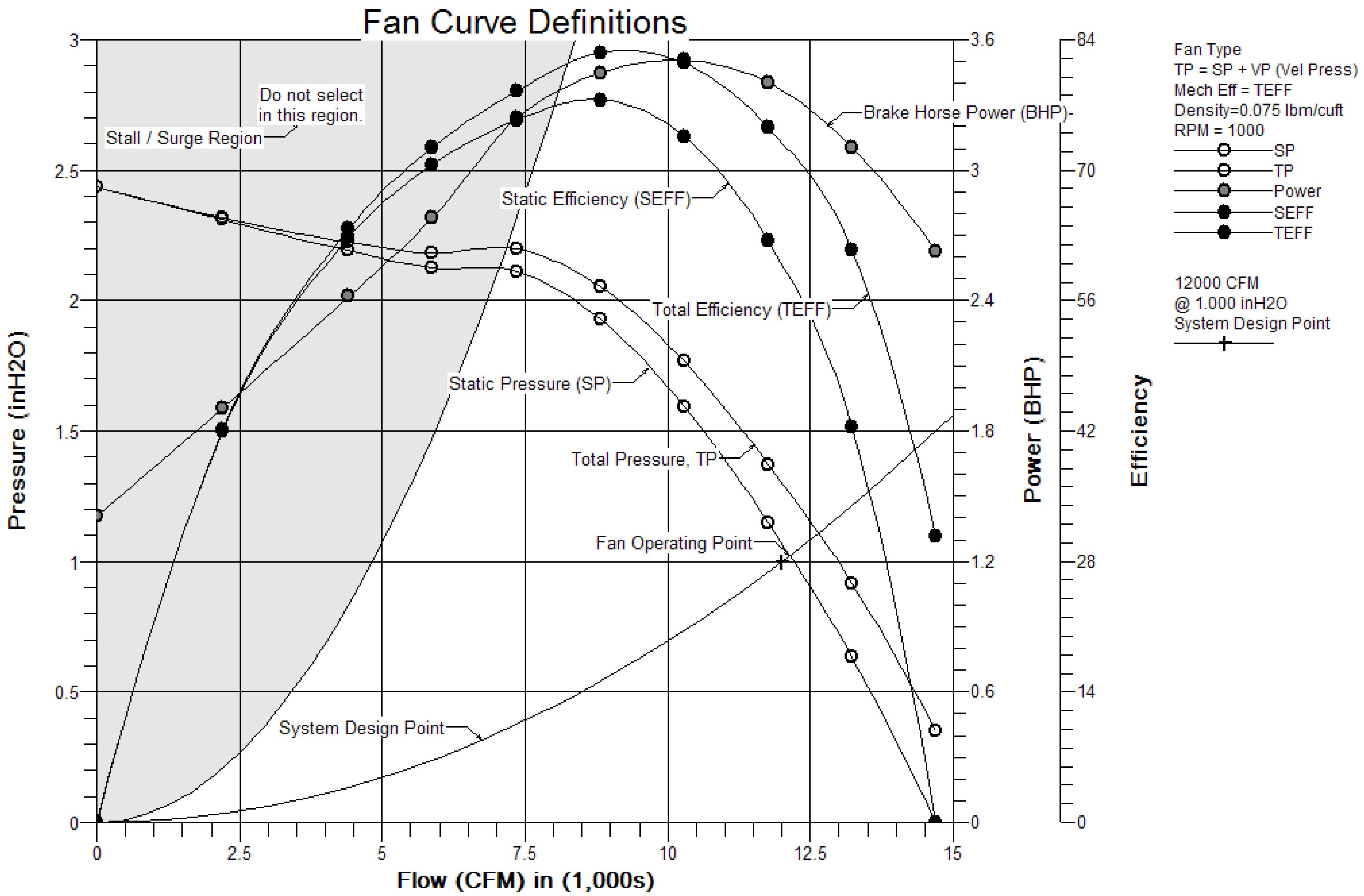
Section 4: Static Efficiency Curve



Section 4: Fan Operating Point



Section 4: Fan Curves

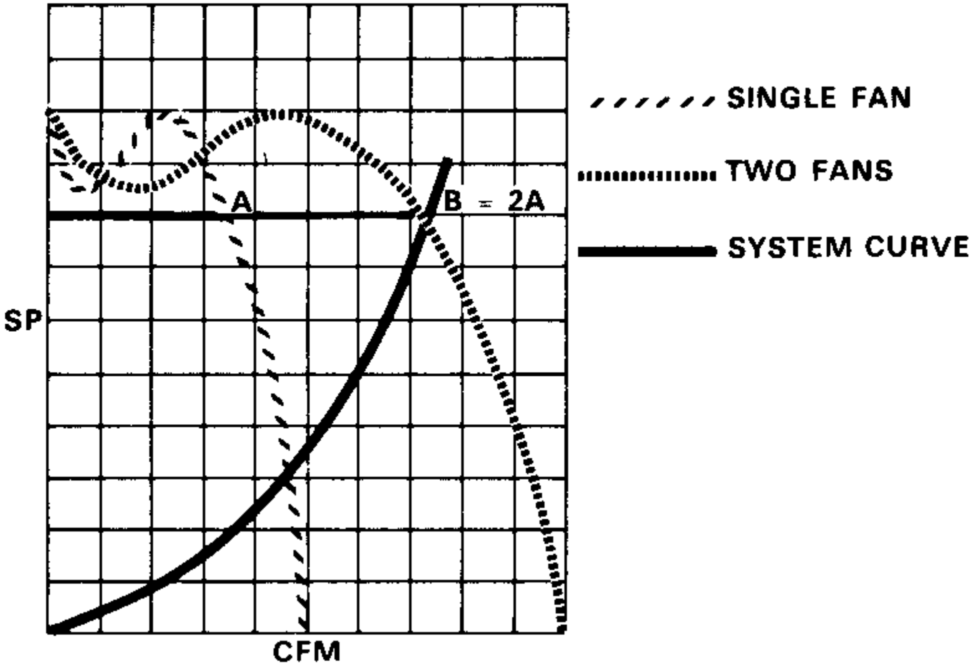


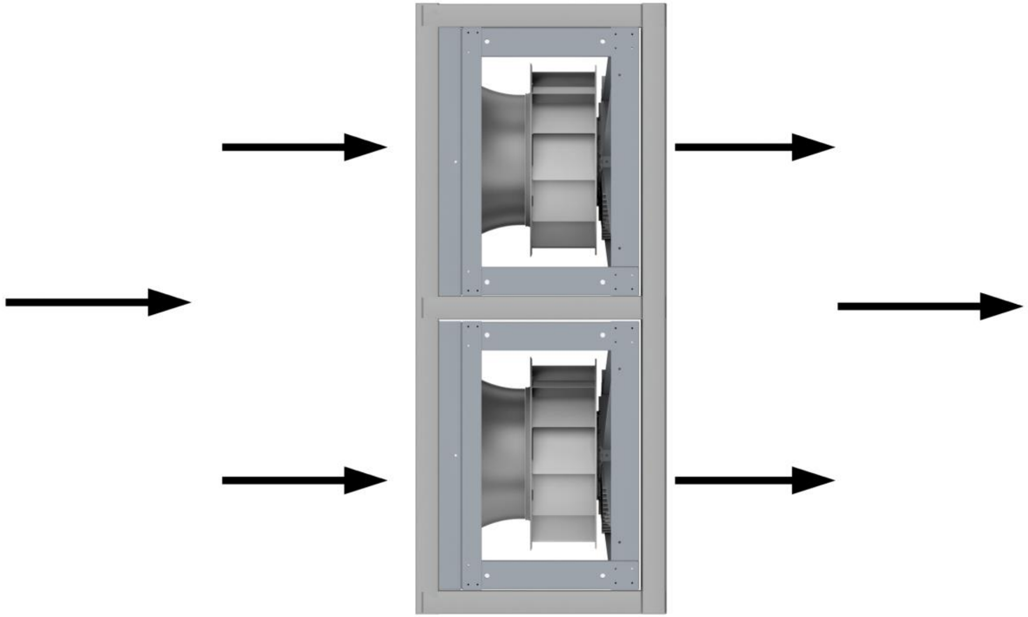
Section 4: Fans in Parallel

SP2 = SP1

CFM2 = 2 CFM1

BHP2 = 2 BHP1



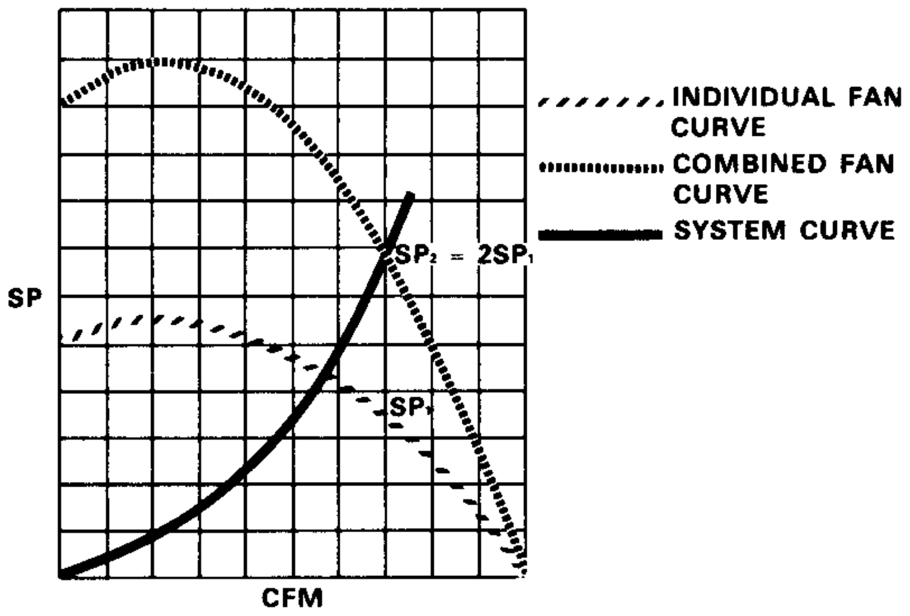


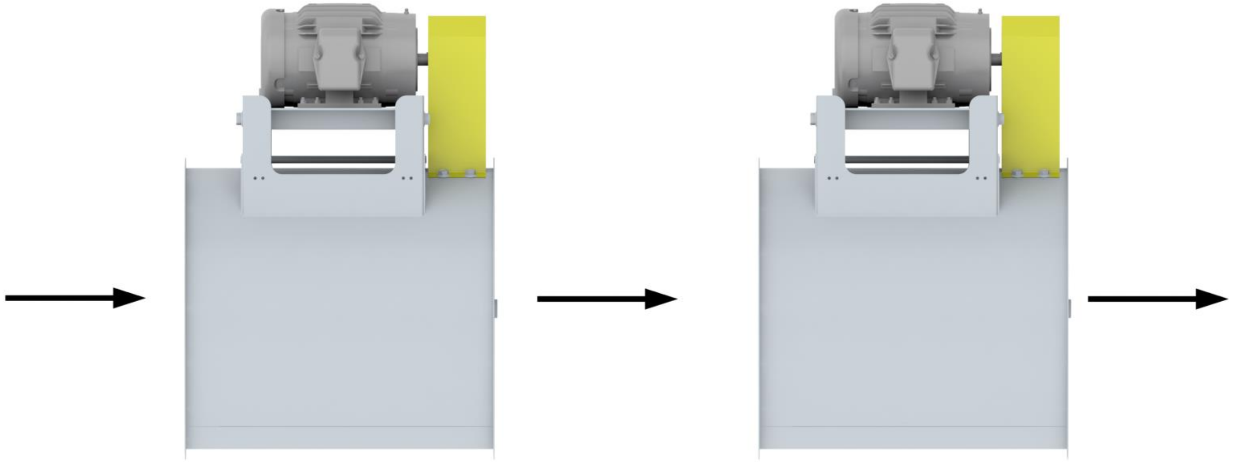
Section 4: Fans in Series

SP2 = 2 SP1

CFM2 = CFM1

BHP2 = 2 BHP1



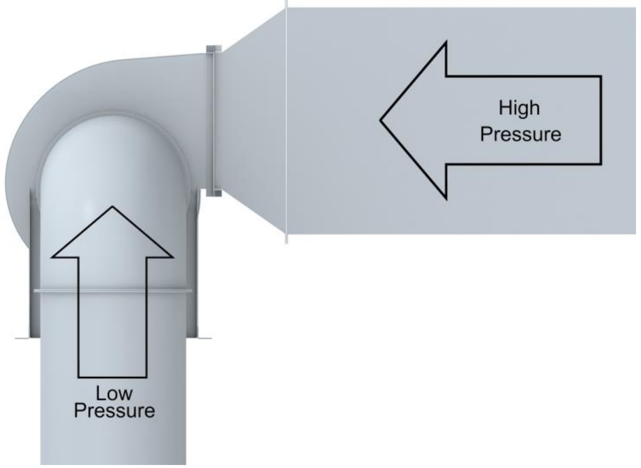


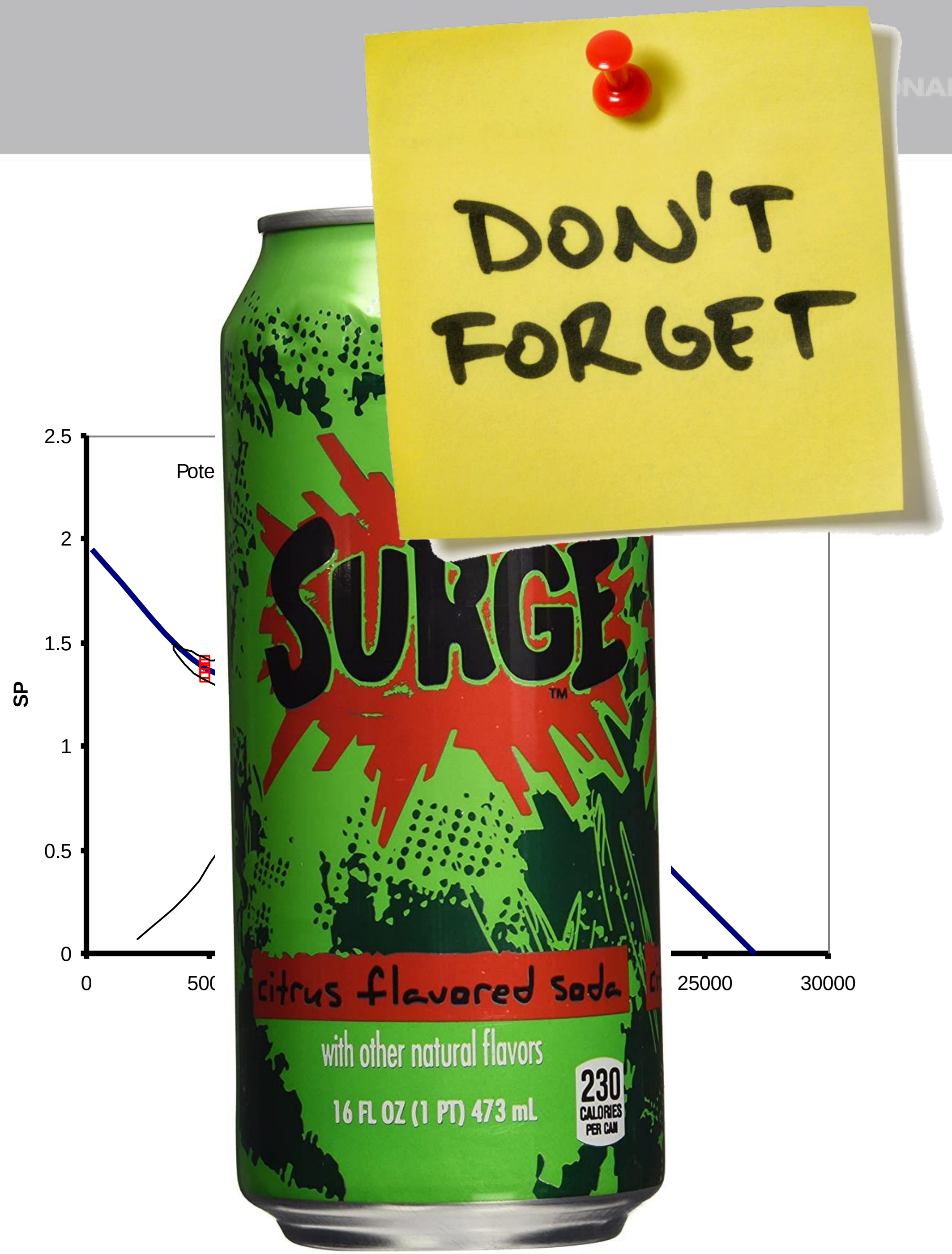
Section 4: Surge

Interaction with system

Fan operation is very unstable

Pulsating flow at inlet and discharge





Section 4: Surge

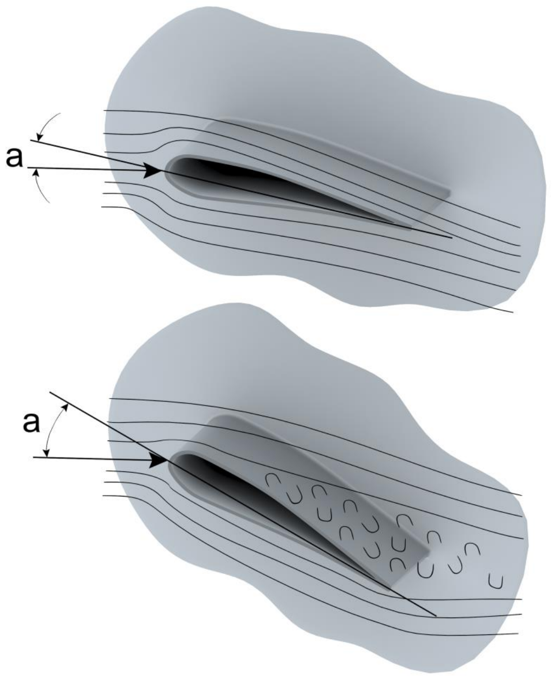
Section 4: Surge

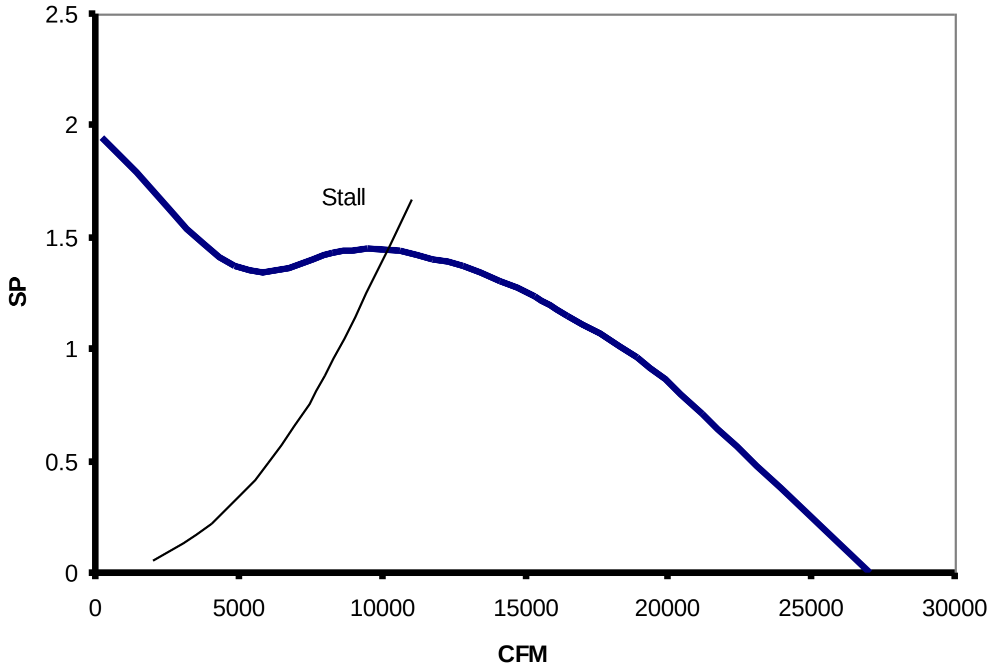
Section 4: Stall

Aerodynamic effect

Fan unstable operation

Less severe than surge





Section 4: Stall

Section 4: Stall

Section 5: The Affinity Laws (Fan Laws)

Dynamic Similitude

Law 1: RPM Change

Law 2: Diameter Change

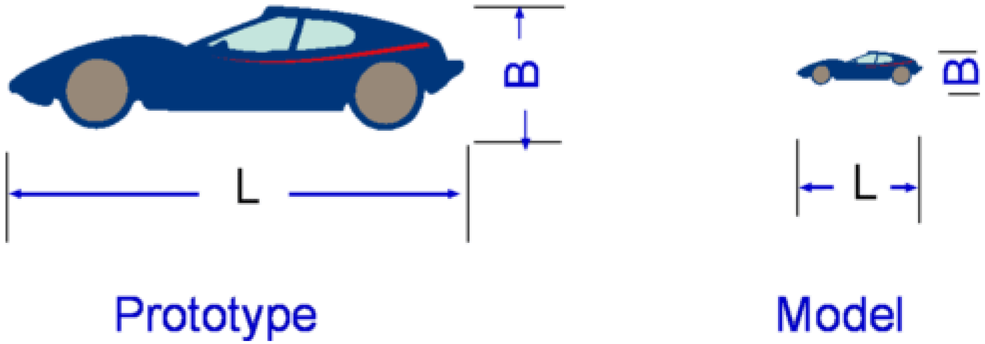
Law 3: Diameter & RPM Change

Law 4: Density Effects

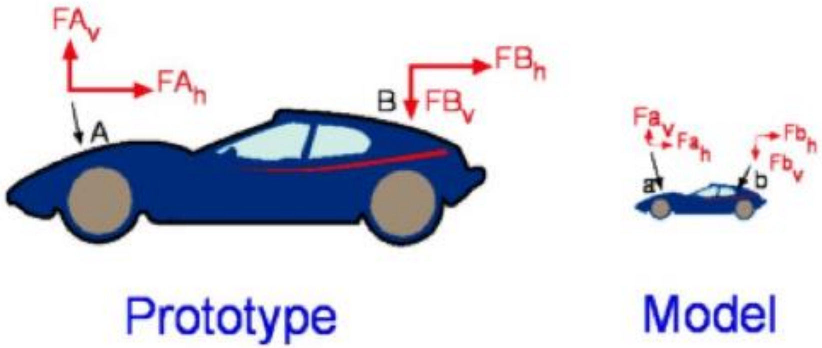
5

Section 5: Dynamic Similitude

Definition: The compared systems are geometrically similar and the forces acting in each system act in the same ratio to the forces of the other system.



Scaled Dimensions



Scaled Forces

<u>The Affinity Laws or only applicable in dynamically similar systems.</u>

Section 5: Law #1 – RPM Char

10000 CFM at 4” Static Pressure | RPM = 1500 R

We Need 12000 CFM

$$\frac{CFM_1}{CFM_2} = \frac{RPM_1}{RPM_2}$$

$$\frac{10000\ CFM}{12000\ CFM} = \frac{1500\ RPM}{1800\ RPM}$$

20%

$$\frac{SP_1}{SP_2} = \left[\frac{RPM_1}{RPM_2}\right]^2$$

$$\frac{4"}{5.76"} = \left(\frac{1500\ RPM}{1800\ RPM}\right)^2$$

44%

$$\frac{BHP_1}{BHP_2} = \left[\frac{RPM_1}{RPM_2}\right]^3$$

$$\frac{4.5\ BHP}{7.76\ BHP} = \left(\frac{1500\ RPM}{1800\ RPM}\right)^3$$

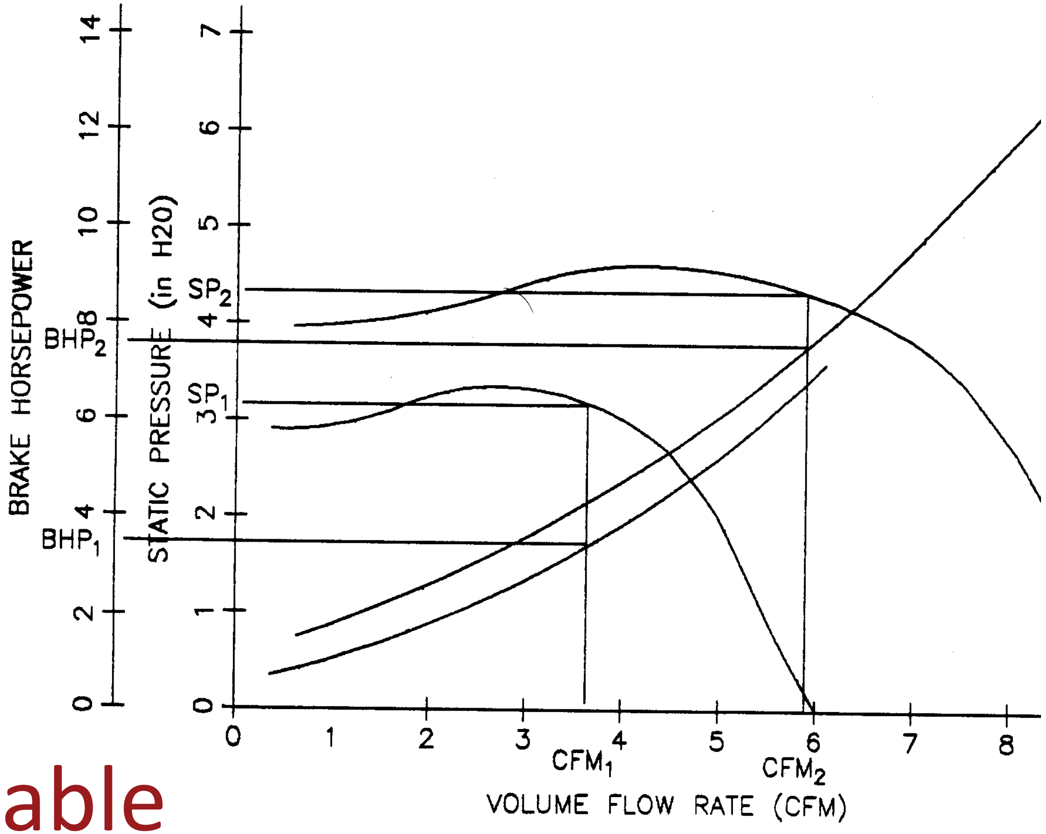
72%

Section 5: Law #2 – Diameter Change

$$\frac{CFM_1}{CFM_2} = \left[\frac{D_1}{D_2}\right]^3 \qquad \frac{3646\ CFM}{5789X\ CFM} = \left(\frac{10.5}{12.2}\right)^3$$

$$\frac{SP_1}{SP_2} = \left[\frac{D_1}{D_2}\right]^2 \qquad \frac{3.08''}{4.1X9''} = \left(\frac{10.5}{12.2}\right)^2$$

$$\frac{BHP_1}{BHP_2} = \left[\frac{D_1}{D_2}\right]^5 \qquad \frac{3.41\ BHP}{7.37X\ BHP} = \left(\frac{10.5}{12.2}\right)^5$$



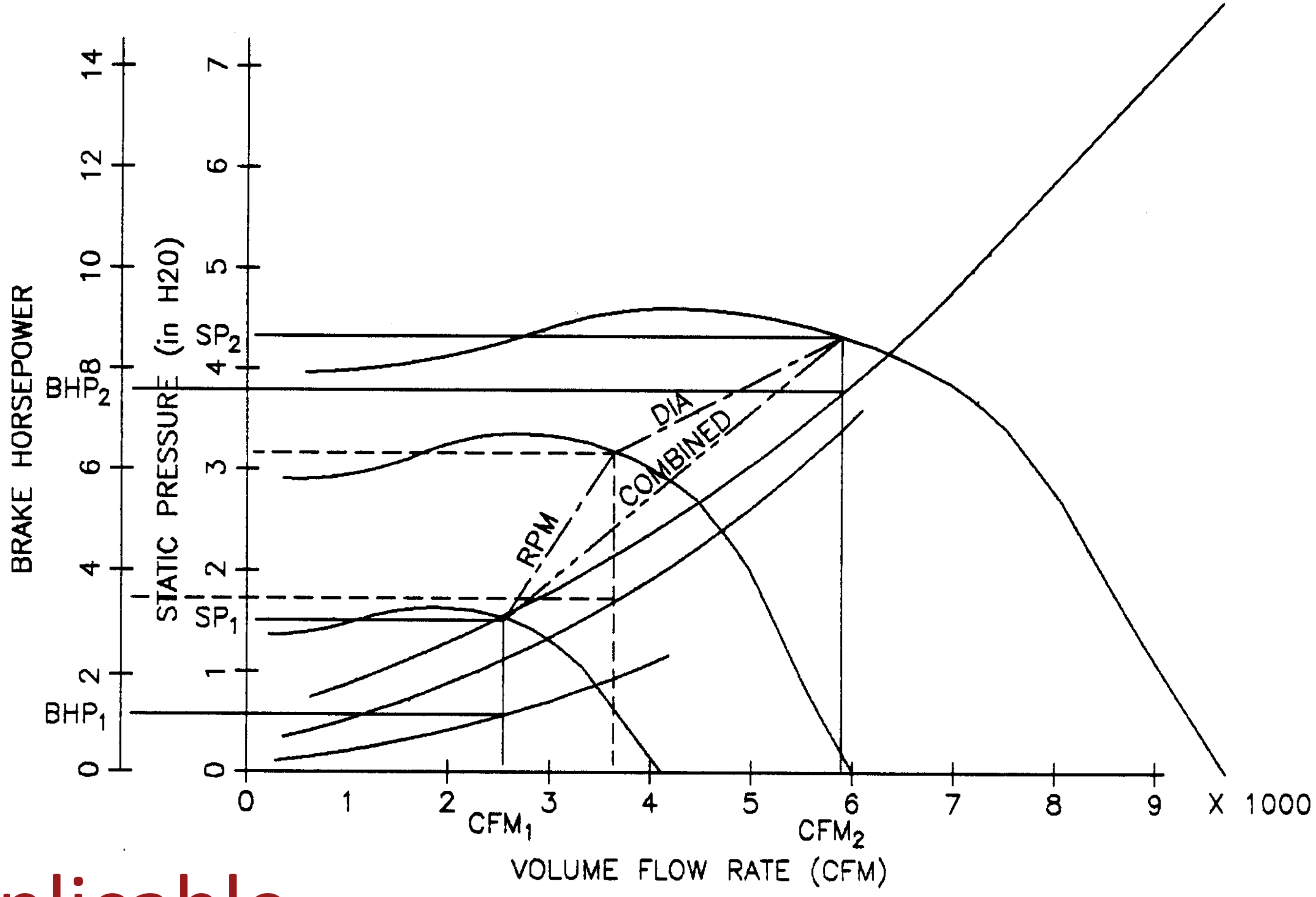
Rarely Applicable

Section 5: Law #3 – RPM & Diameter Change

$$\frac{CFM_1}{CFM_2} = \left[\frac{RPM_1}{RPM_2}\right]\left[\frac{D_1}{D_2}\right]^3$$

$$\frac{SP_1}{SP_2} = \left[\frac{RPM_1}{RPM_2}\right]^2\left[\frac{D_1}{D_2}\right]^2$$

$$\frac{BHP_1}{BHP_2} = \left[\frac{RPM_1}{RPM_2}\right]^3\left[\frac{D_1}{D_2}\right]^5$$



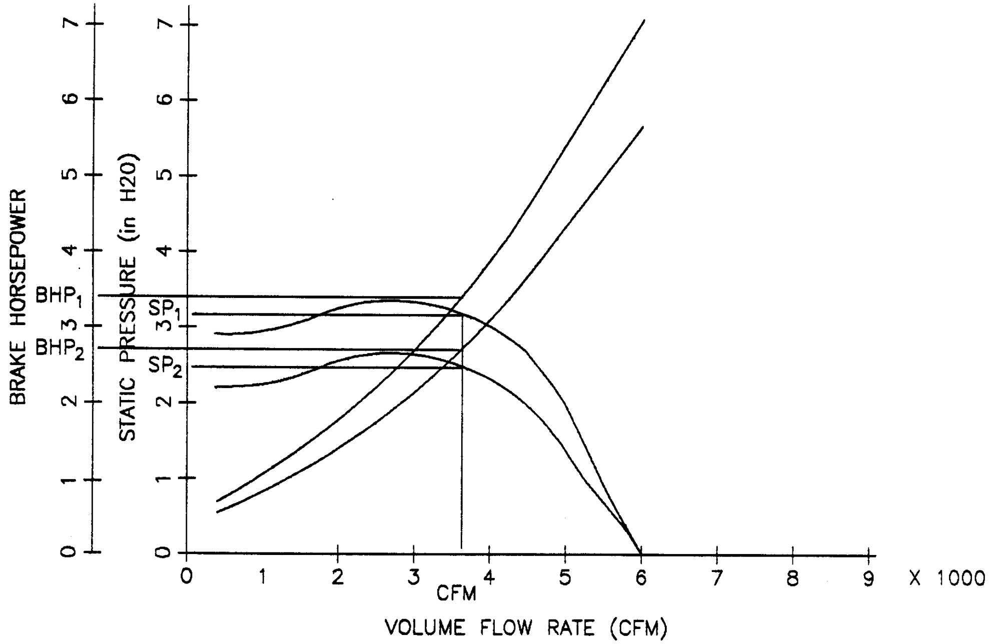
Rarely Applicable

Section 5: Law #4 – Density Ef

Fan volume will not change as density changes:

$$CFM_1 = CFM_2$$

SPP and BHP will vary in direct proportion to density change:



$$\frac{\rho_1}{\rho_2} = \frac{SP_1}{SP_2} = \frac{BHP_1}{BHP_2}$$

$$\frac{.075\, lb/ft^3}{.060\, lb/ft^3} = \frac{3.08"}{2.46"} = \frac{3.41\, BHP}{2.73\, BHP}$$

In Conclusion: 3 Take-aways

1. Every system and every fan is different. Now we can better design, plan for, measure, and troubleshoot these systems.

2. Perceived small changes can cause big unintended effects.

3. You don’t need to memorize the fundamentals to be successful in the HVAC industry, but the more you know, the more valuable you can be to your customers.

Resources

- **AMCA International**: *www.amca.org*
- **AMCA Presentations**: *www.amca.org/educate/#videos*

  > ASET-US 2018 – *“Fan Sizing and Selection: Basics and Fine Points”* by Mike Wolf

  > ASET-US 2018 – “*Tips and Tricks for Troubleshooting Fans”* by Ron Wroblewski
- **AMCA Publication**: *www.amca.org/store* (available for purchase)

  > 201-02 (R2011) – Fans and Systems

Thank you for your time!

To receive PDH credit for today's program, you must complete the online evaluation, which will be sent via email following this webinar.

If you viewed the webinar as a group and only one person registered for the webinar link, please email Lisa Cherney (lcherney@amca.org) for a group sign-in sheet today. Completed sheets must be returned to Lisa by tomorrow, May 7.

PDH credits and participation certificates will be issued electronically within 30 days, once all attendance records are checked and online evaluations are received.

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Questions?

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NEXT PROGRAM

Join us for our next AMCA *insite* Pop-Up Webinar:

- Thursday, May 14
- 12:00 – 1:00pm CDT
- ***TOPIC: 2018 International Building Code Overview (Life Safety Damper Section 717)***
- Presenter: James Carlin, Product Manager - Dampers, AMCA Member Company

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

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MAY 14, 2020

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