Better Plants
U.S. DEPARTMENT OF ENERGY

Industrial Fan Systems
Virtual INPLT Training & Assessment

Session 2

U.S. DEPARTMENT OF ENERGY

Fan Virtual INPLT Facilitator

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Acknowledgments

- William (Bill) Hunter, PE, Airclean Systems, Seattle WA
- Eddie Radd, CFW Fans, Cape Town, SA
- William (Bill) W.T. Corey, Corey Consultancy, Surrey England
- US Department of Energy , Advanced Manufacturing Office
- Oak Ridge National Laboratory
- United Nations Industrial Development Organization
- Air Movement and Control Association, AMCA International
- Many industrial clients – both in the US and internationally

Agenda – Session 2

- Welcome and Introductions
- Safety and Housekeeping
- Agenda for Fan System Virtual INPLT (8 weeks)
- Today's Content:

  Industrial Fan Systems Fundamentals
  - Fan and system curves
  - Fan types

  MEASUR Tool
  - Demonstration
- Kahoot Quiz Game
- Q&A

Better Buildings is an initiative of the U.S. Department of Energy

Safety and Housekeeping

- Safety Moment
  - Make sure that belt guards are in place and firmly attached before removing the lockout/tagout and starting the fan
- You are welcome to ask questions at any time during the webinar
- When you are not asking a question, please MUTE your mic and this will provide the best sound quality for all participants
- We will be recording all these webinars and by staying on-line and attending the meeting you are giving your consent to be recorded
  - A link to the recorded webinars will be provided, afterwards

Fan system Virtual INPLT Agenda

- Week 1 – Industrial Fan Systems Fundamentals and Introduction to MEASUR
- **Week 2 – Fan and system curves, Fan types**
- Week 3 – Fan affinity laws, Fan system controls
- Week 4 – Creating a fan performance measurement plan & selecting measurement planes
- Week 5 – Pressure considerations, Sizing ducts and estimating losses, Optimization techniques
- Week 6 – Psychrometrics and air density for fan systems, System effect in fan systems
- Week 7 – Fan system optimization strategies, Fan system evaluation with MEASUR
- Week 8 – Industrial Fan System VINPLT Wrap-up Presentations

Learning objectives session 2

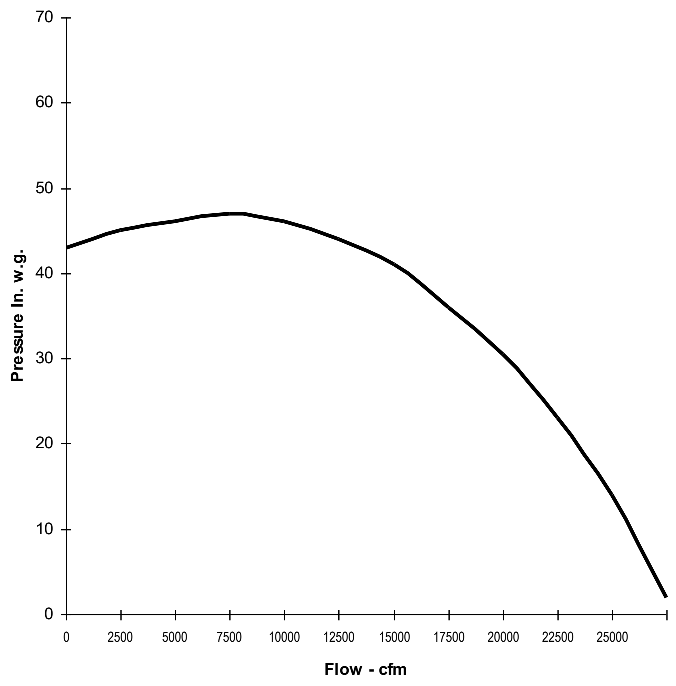
Class participants will:

1. Explain the general approach for developing a fan curve
2. Explain the interaction between the fan curve and the system curve
3. Understand the steps required to develop a system curve
4. Use pressure and flow data to develop a system curve

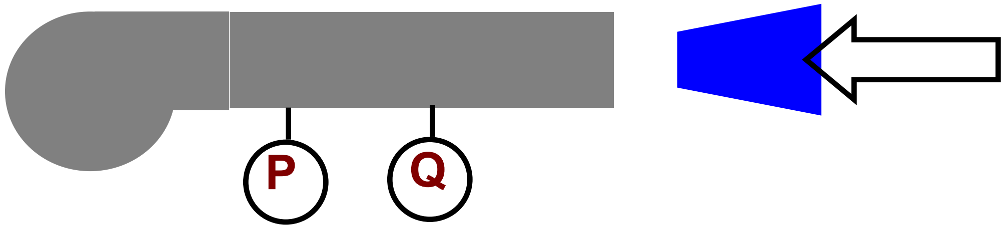
Fan and System Curves

Fan Curve Definition

"A graphical representation of how much flow a fan can develop over the range of fan static pressure that the fan can produce."

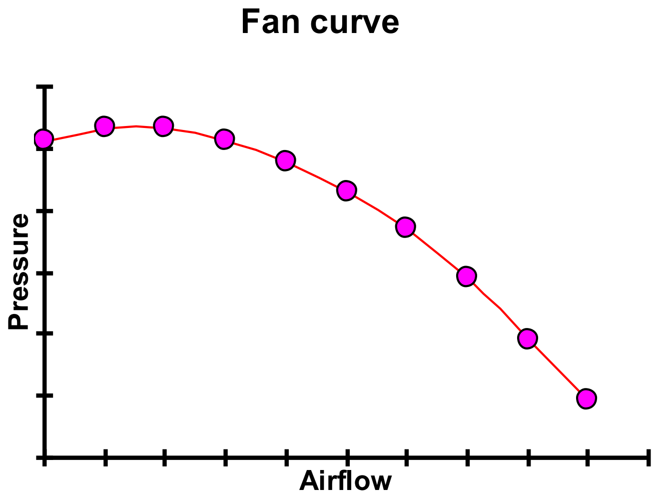


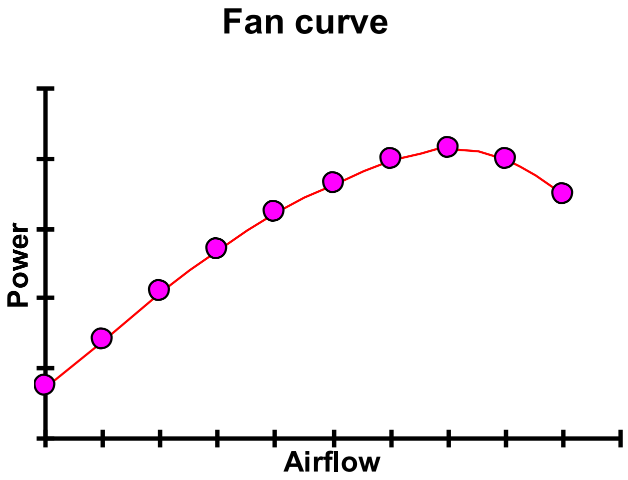
Fan Curve Development



1. Measure: flow, pressure, and power
2. Plot Data
3. Choke off Flow

Repeat Steps 1-3 until shut-off point is reached.



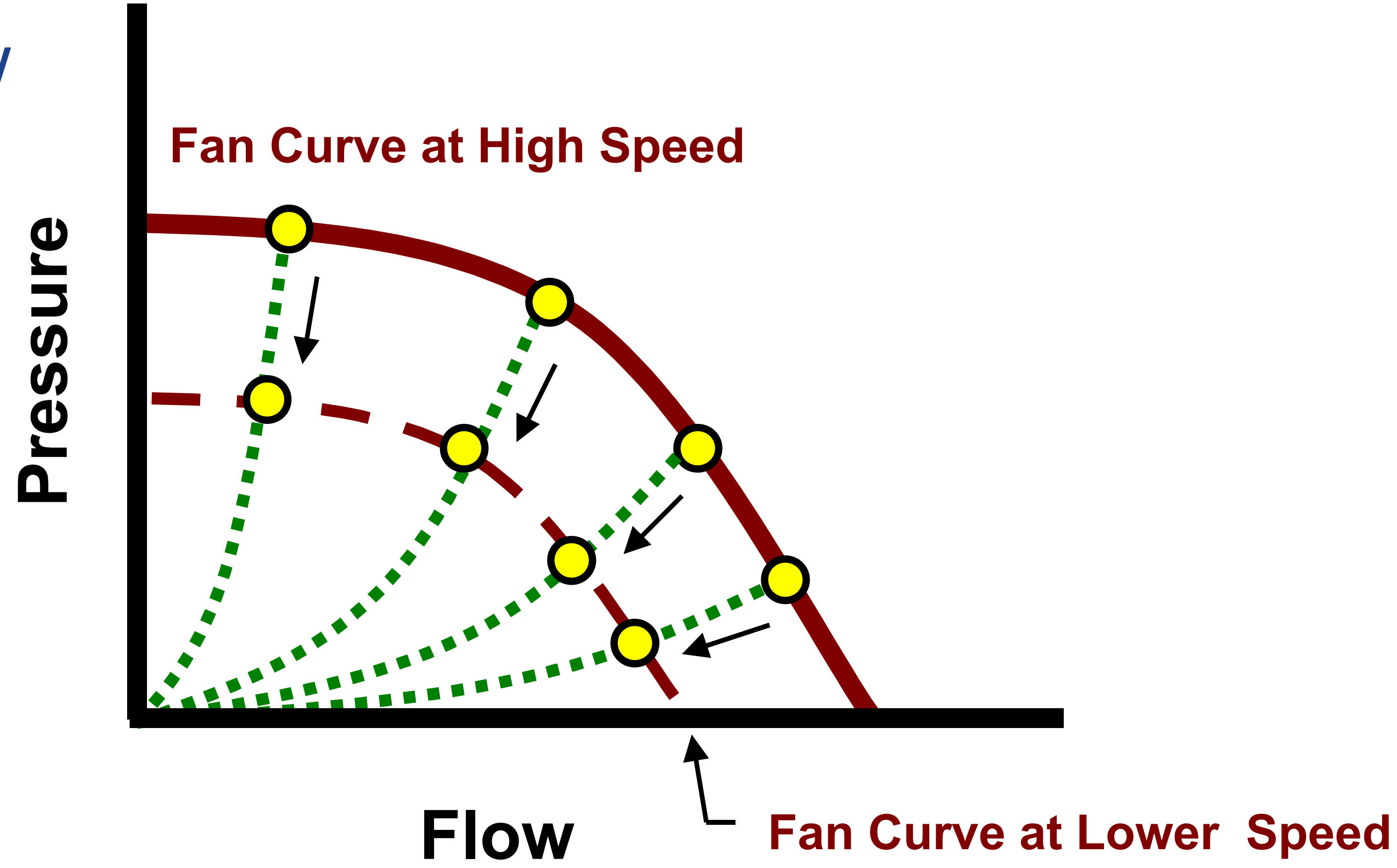


Centrifugal fan operation

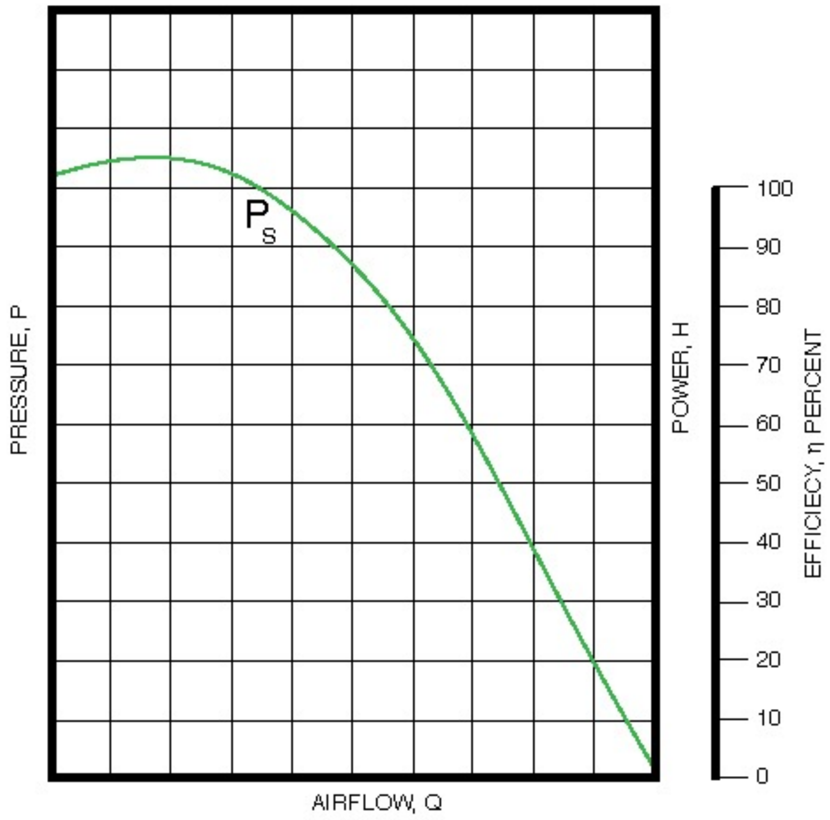
- Fan imparts centrifugal force on the air
- Uses same principle as twirling a can of water
  - Fan spins
  - Air is hurled outward and held again fan housing
  - Air reaches fan outlet and flies outward, creating airflow

Fan Speed and the Fan Curve

- Fan speeds up: more flow and pressure
- Fan slows down: less flow and pressure



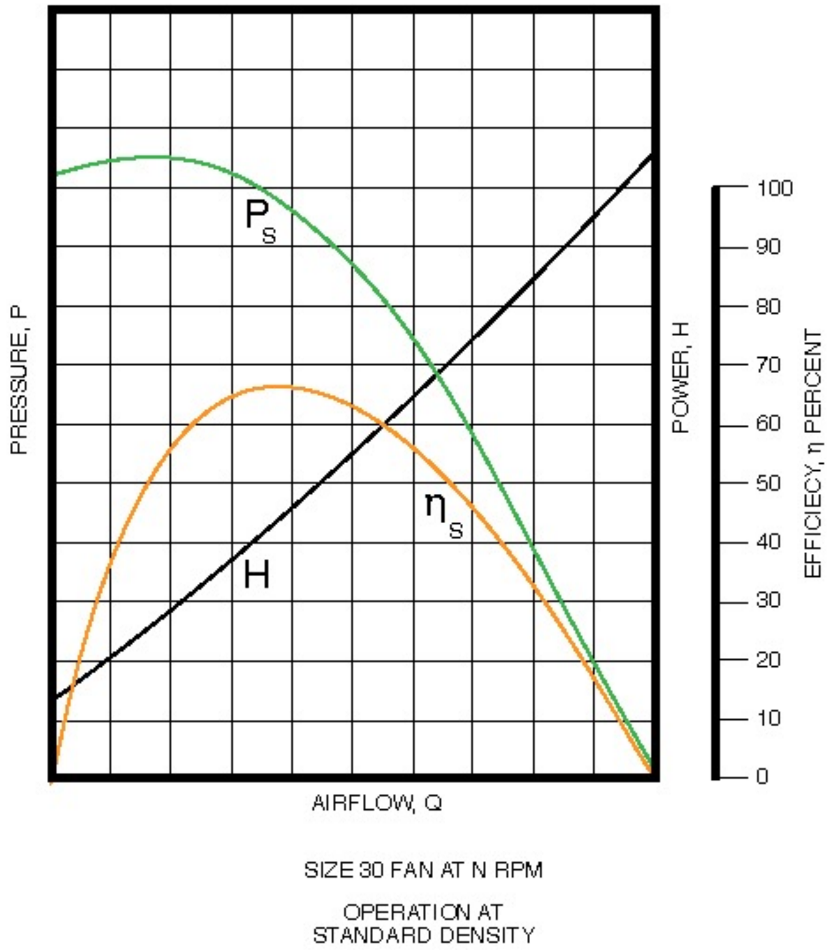
Fan Performance Curve with Efficiency



SIZE 30 FAN AT N RPM

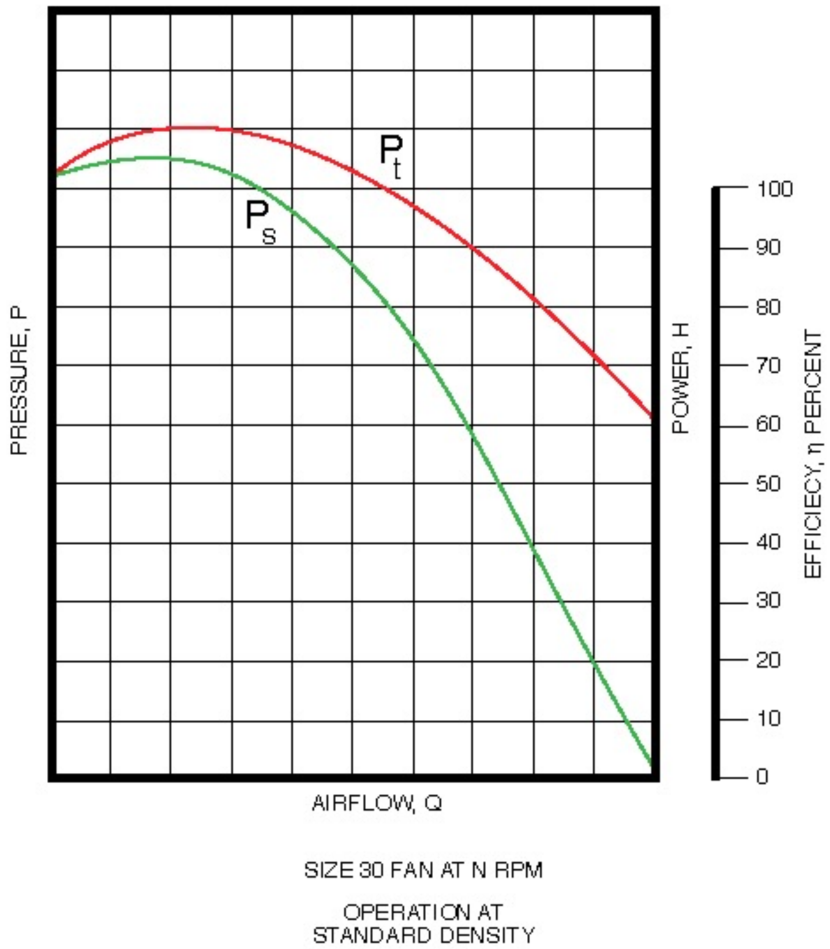
OPERATION AT
STANDARD DENSITY

Fan Performance Curve with Efficiency

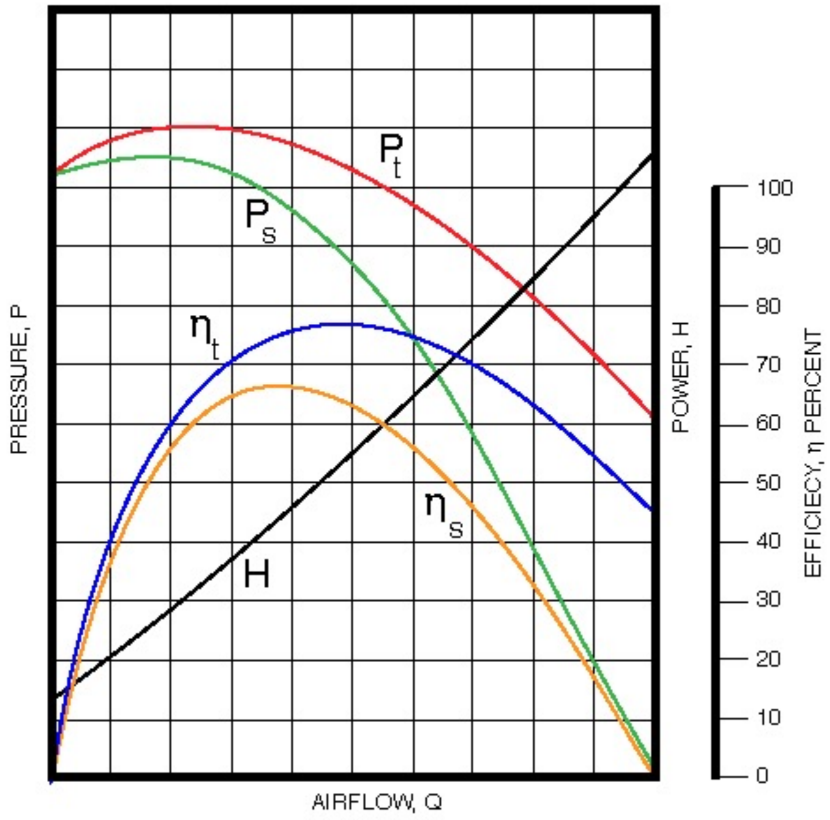


Fan Performance Curve with Efficiency

$P_s + P_v = P_t$



Fan Performance Curve with Efficiency



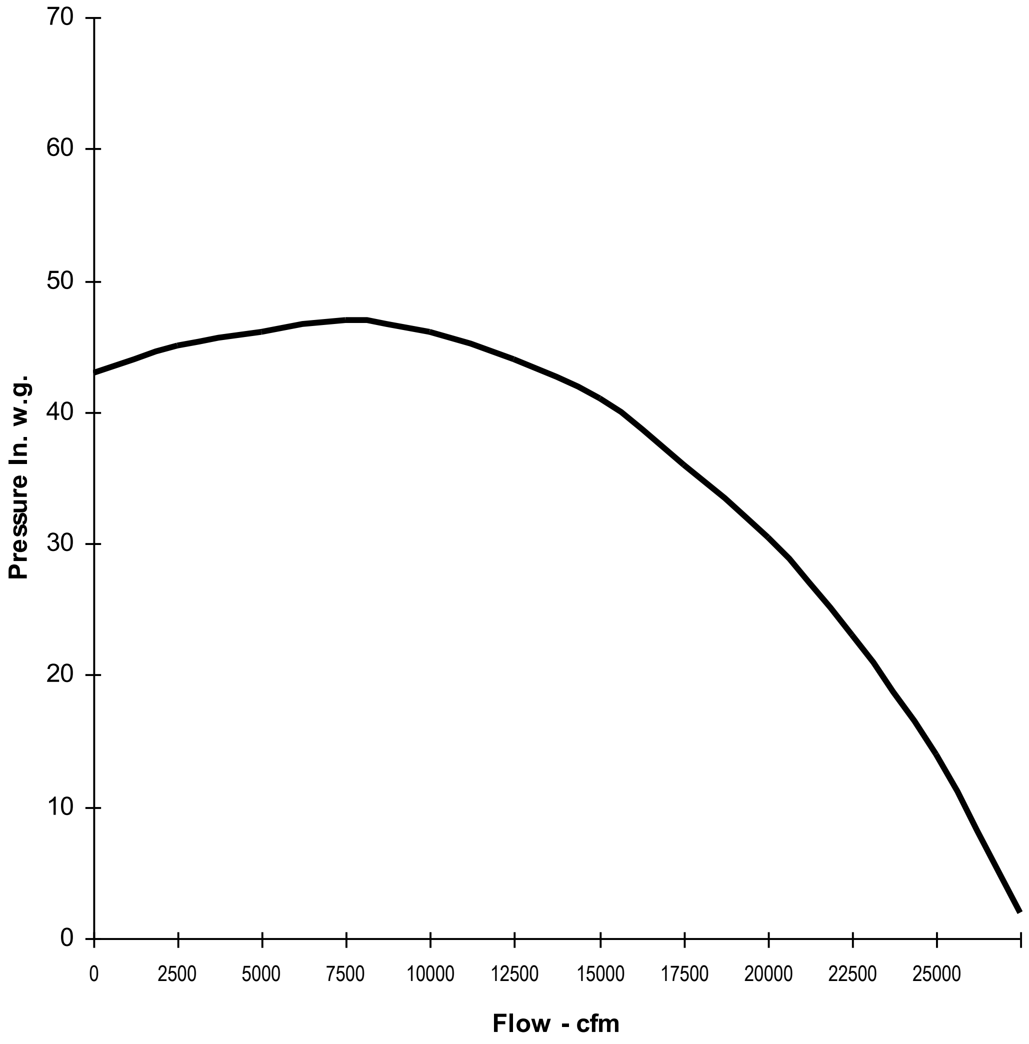
SIZE 30 FAN AT N RPM

OPERATION AT
STANDARD DENSITY

Fan Laws – More on this next week

- Also known as affinity laws
- Equations that relate fan speed to flow and pressure.
- Used to predict fan performance at different:
  - Fan speeds
  - Air densities (such as cold winter air or hot boiler gasses)
  - Size
  - Etc.
  - Etc.
  - Etc.

Combustion Air Fan - OSB



System Curve Definition

"A graphical representation of how much pressure is required to drive a certain amount of flow through the system."

What's a fan system?

- Everything attached to the fan, including:
  - Fume hoods
  - Ductwork
  - Volume control dampers
  - Filters
  - Heat exchangers
  - Driers

Fan System Component Types

Types of devices that cause pressure drops in fan systems

- Static – devices that don't change, like ductwork
- Changeable – devices that can be set in a certain position, like dampers, or gradually get dirty, like filters
- Dynamic – devices that change in response to a control signal

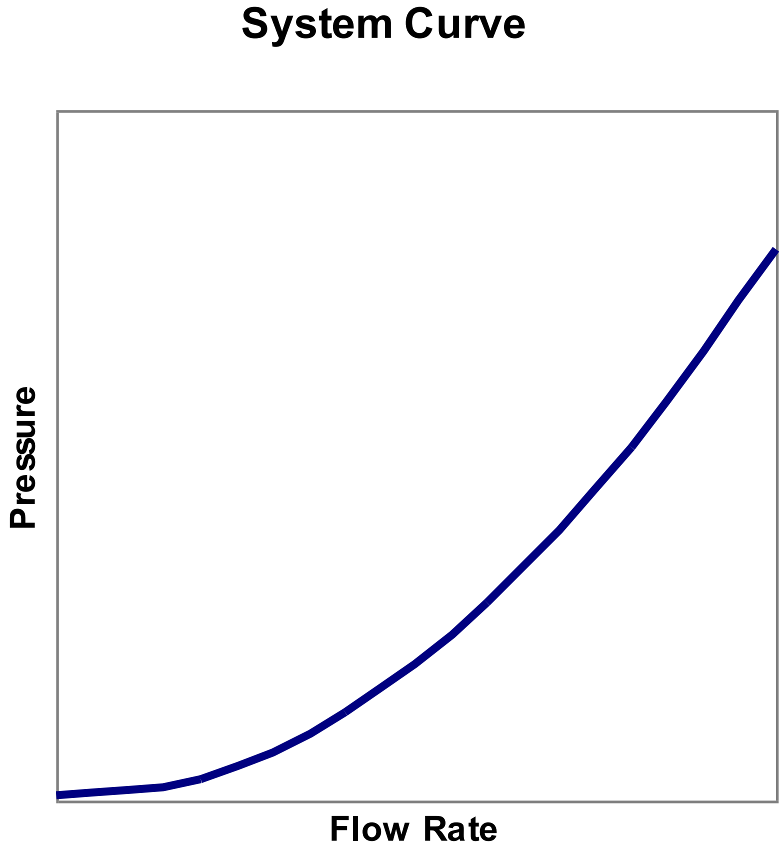
Static System Curve – Math Tricks

The curve is a parabola:

$$\Delta P \propto \Delta(Q)^2$$

or

$$Y = A \times X^2$$



What this means:

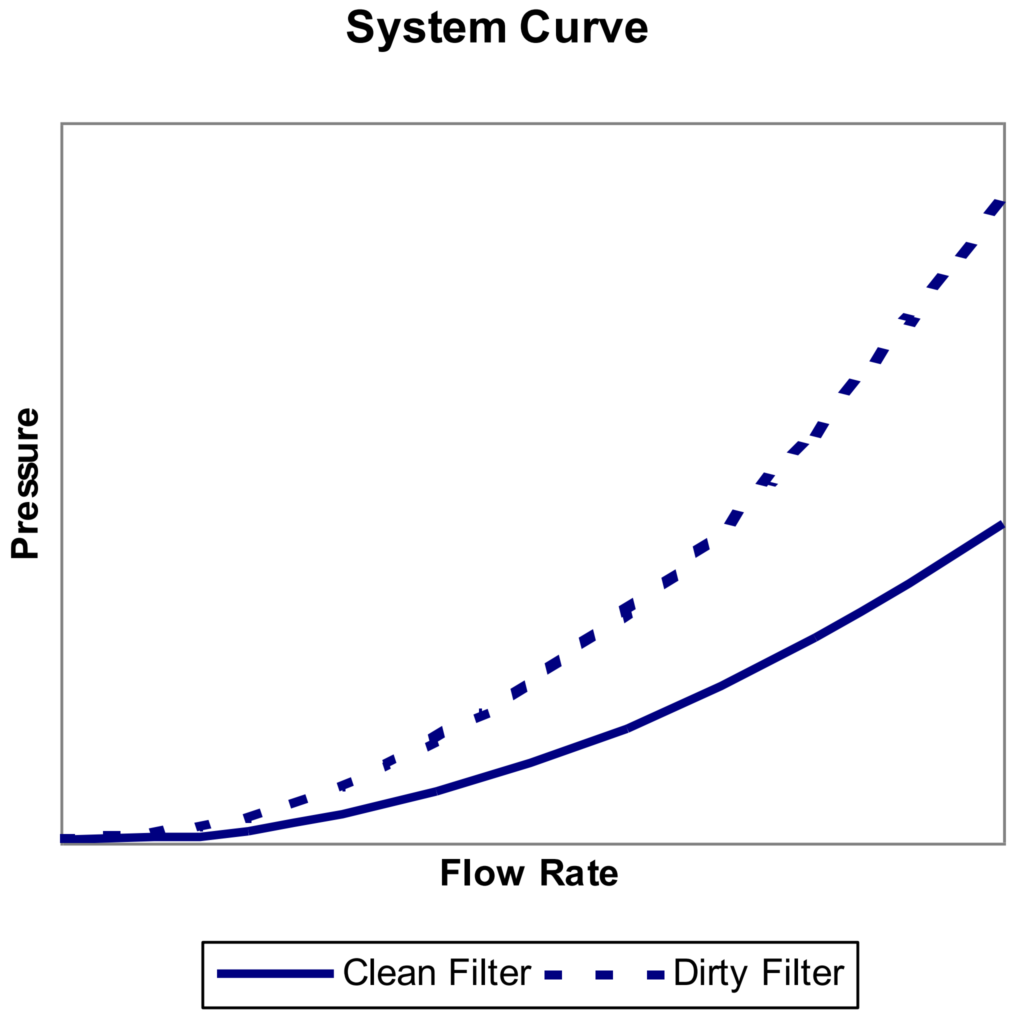
If we can measure the system pressure drop and flow rate at one point of operation, then we can calculate the pressure drop associated with other flow rates.

Changeable and Dynamic Devices

Airflow changes with time

Examples:

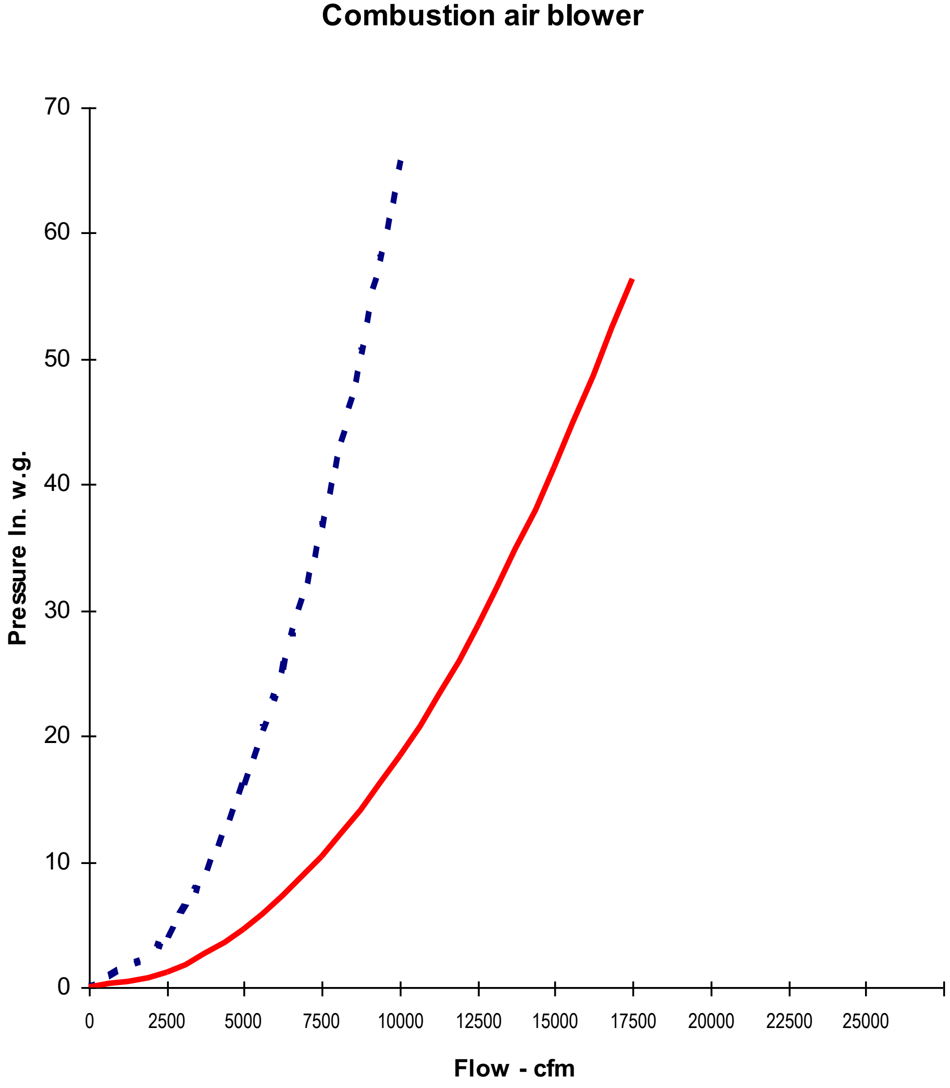
- Dampers are partially closed or opened to trim or increase flow
- Filters gradually accumulate dirt



Combustion Air Fan OSB plant

- Dashed line:
  - Damper partially closed, pressure drop across orifice plate

- Solid line:
  - Damper open, orifice plate removed



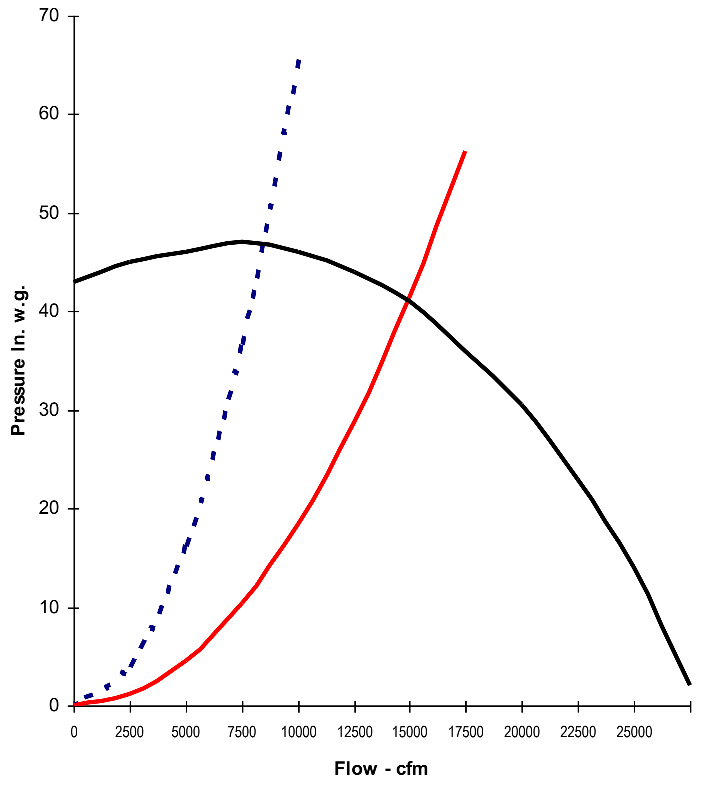
Fan and System Curve Interaction

- The fan operates on the fan curve
- The system operates on the system curve
- Therefore, the operating point is…

The intersection of the fan curve and the system curve

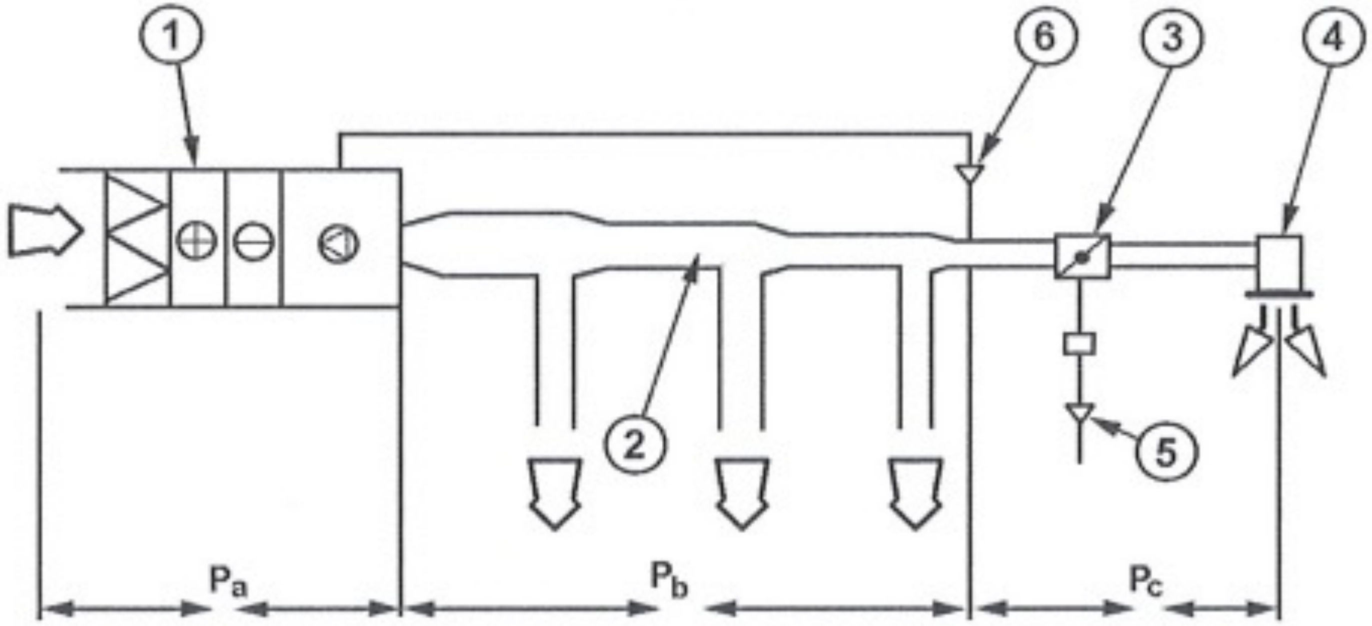
Combustion Air Fan - OSB

Fan Curve and System Curve Interaction



- Point P:
  - Process requirements (8,080 cfm and 12 in. w.g.)
- Point 1:
  - Flow and pressure with open damper (16,000 cfm, 42 in. w.g. – assumes the motor doesn't overload)
- Point 2:
  - Flow and pressure with damper closed (8,080 cfm, 43 in. w.g.)

Variable Air Volume (VAV) Systems

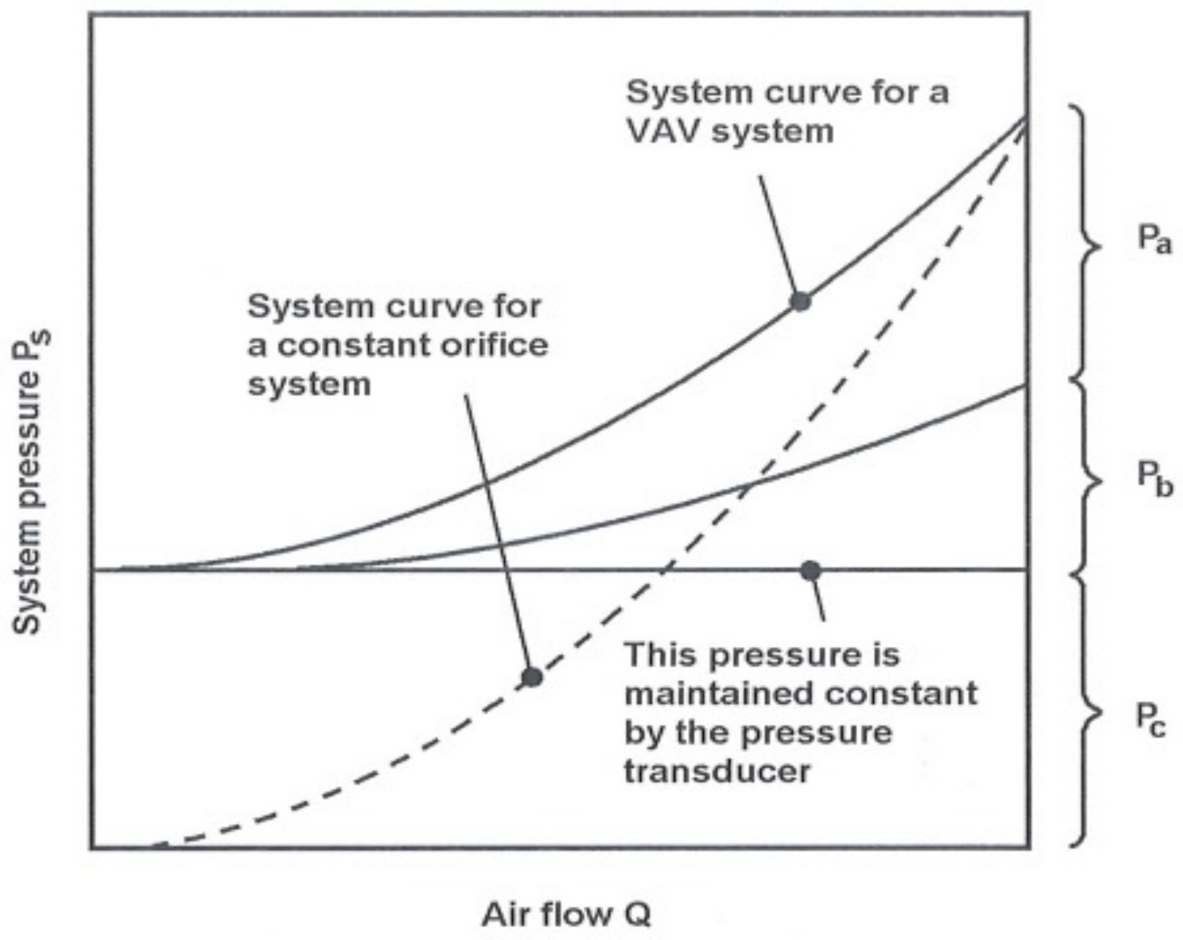


1 Central unit
2 Ducting
3 Flow variators
4 Supply air terminals
5 Room thermostat
6 Pressure transducer

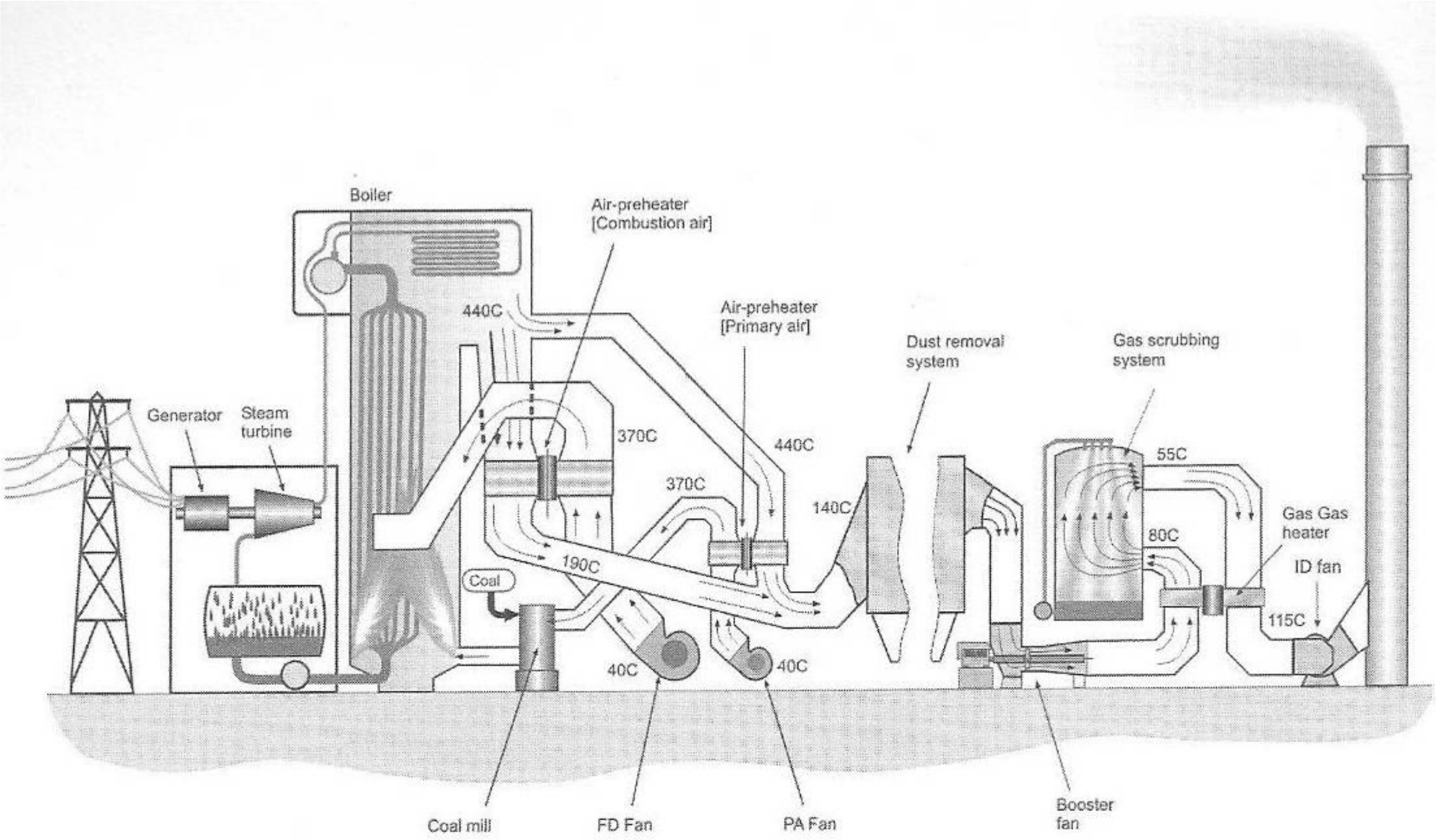
VAV System Typical Characteristic Curve

Note: newer digital VAV systems have a very tiny differential pressure requirement across the VAV

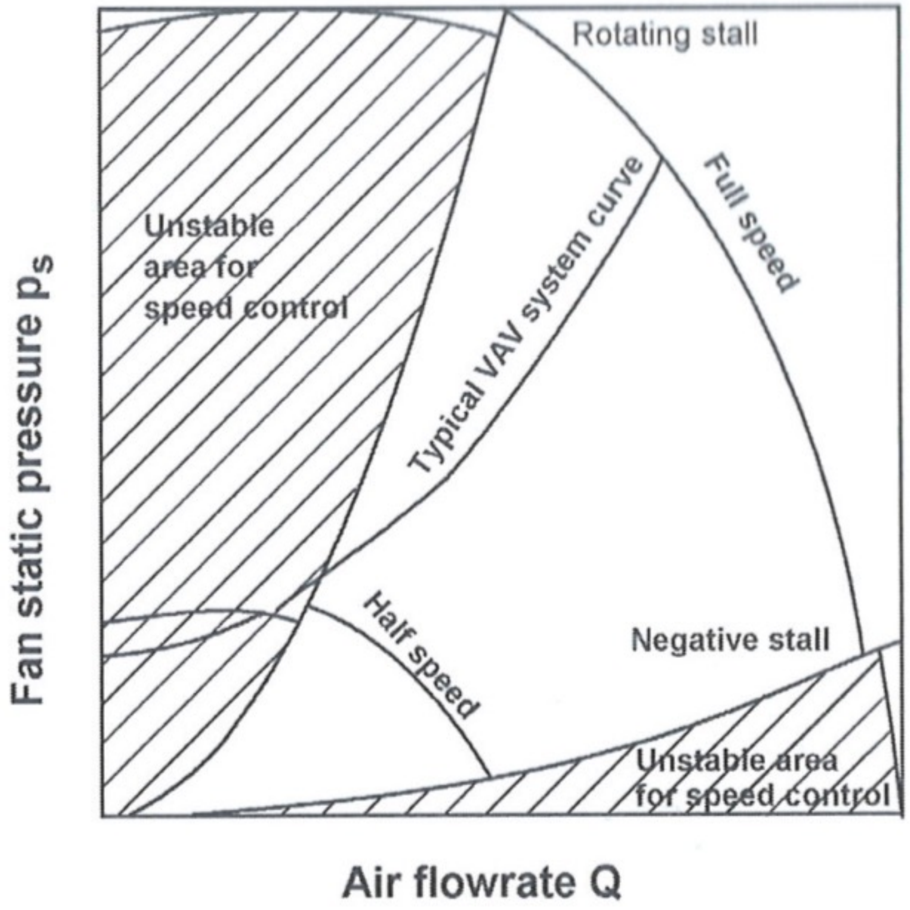
Sometimes process systems have a fixed pressure requirement.



Power Boiler – ID Fan has a fixed pressure component



VAV System Characteristic Curve and Fan Stall Regions for Backward Bladed Fans



System curve with constant pressure and baghouse

$$Y = A \times X^2 + B \times X + C$$

This mathematical model of the system curve incorporates all the elements typically found in industrial fan systems:

- C - the constant term represents the fixed pressure component
- $B \times X$ - the linear term represents the loss across air cleaning devices such as a baghouse or a cooling coil
- $A \times X^2$ - the square term represents the losses across ductwork

With a bit of cleverness when conducting a fan performance test, the constants can be calculated.

Survey Question

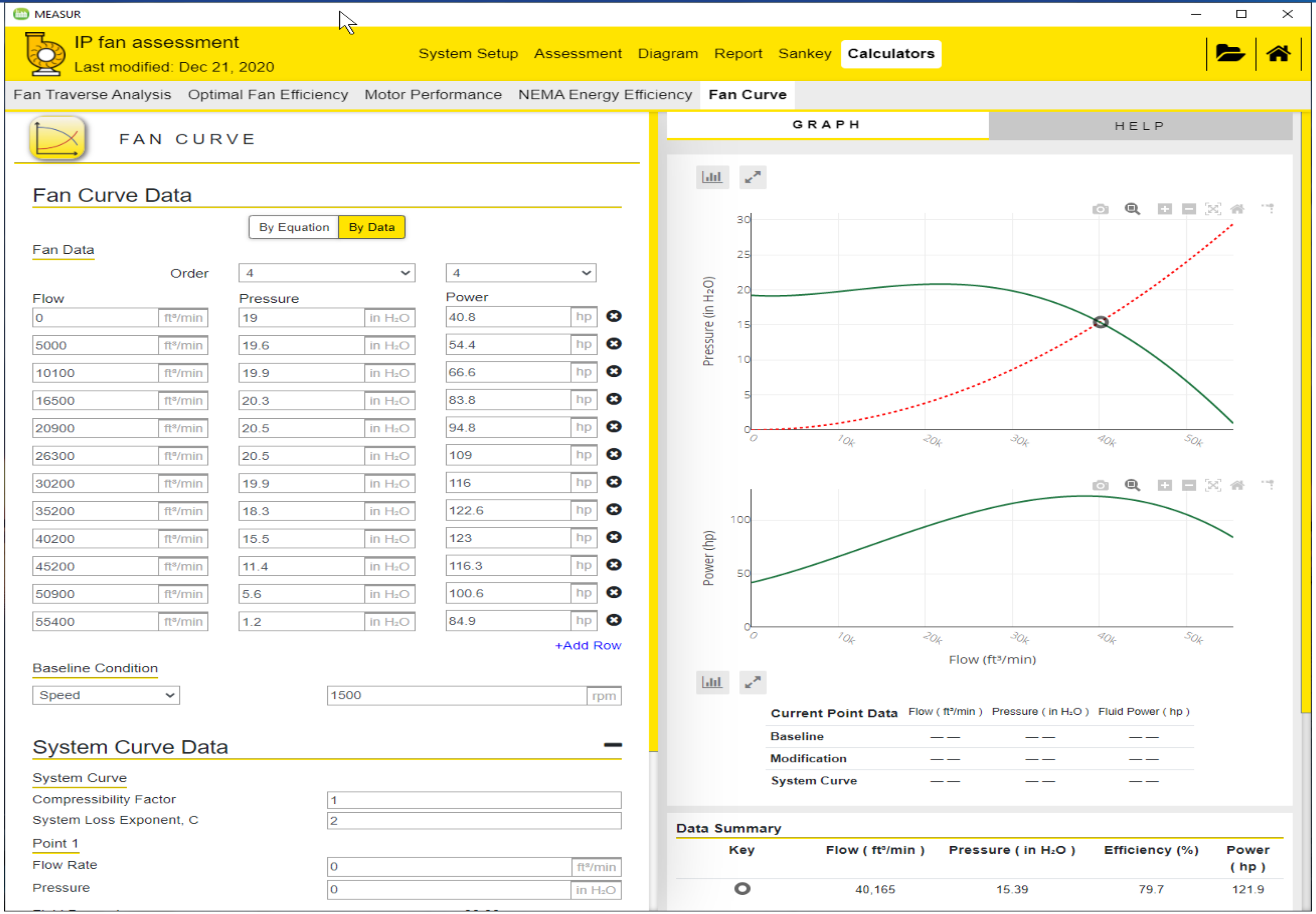
Survey Question

Can you think of any processes with a fixed pressure component?

Write your answer in the chat "to all"

No worries if someone else has already posted what you were planning to post, just post it anyway please.

MEASUR – Fan and System Curve Inputs



Fan Types

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Impeller Type Efficiency Worksheet

Application	Fan Type
1. Fabrication shop requiring 5,000 cfm ventilation air.	________
2. Process exhaust fan moving dust-laden air at 20,000 cfm, at 10 in. w.g. static pressure.	________
3. High-velocity fan used to chop paper trimmings and transport them to a central location.	________
4. 24,000 btu/hr. air conditioning unit required to deliver 800 cfm at 1.5 in. w.g. static pressure.	________
5. Industrial process requiring 50,000 cfm of clean air at 11 in. w.g. static pressure.	________
6. Tunnel ventilation application requiring 90,000 cfm at 3.5 in. w.g. static pressure.	________

Airfoil – Forward curved – Propeller

Backward-inclined – Vane Axial - Radial

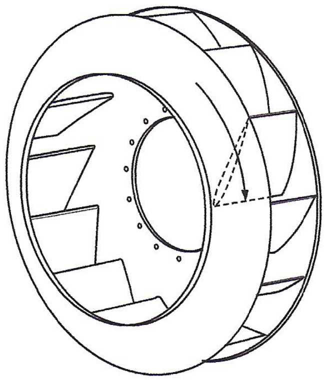
Airfoil

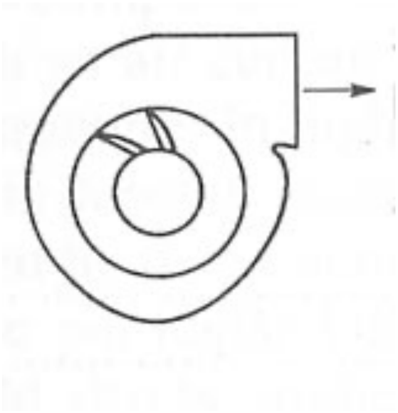
Advantages

- Non-overloading
- Highest efficiency

Disadvantages

- High tip speed
- Hollow blades may fill wit





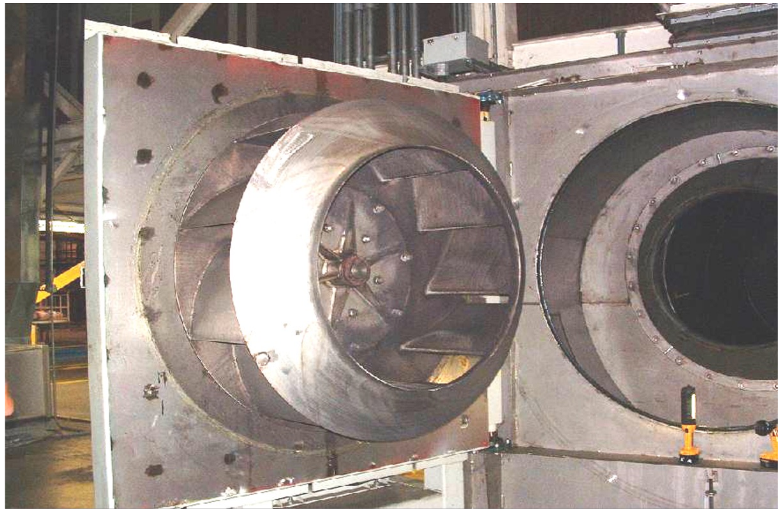
Applications

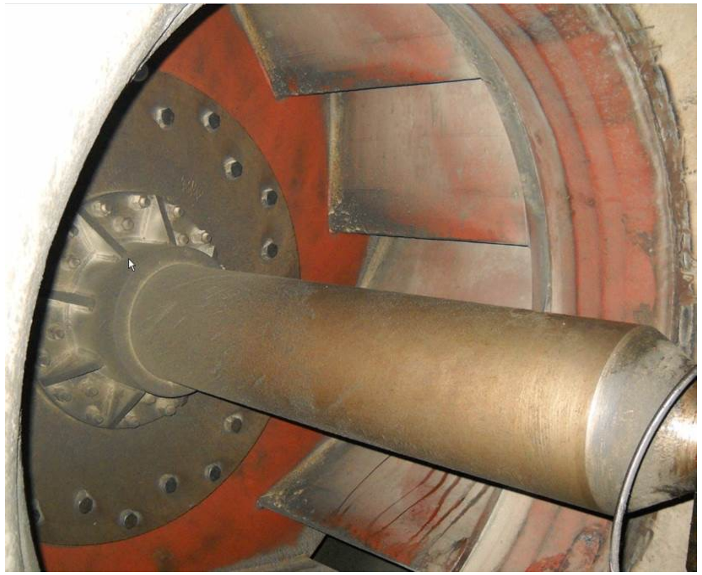
- High-velocity ventilation and supply systems

Optimization Tips

- Can be used in dirty settings if protected
- Requires careful setup

Airfoil

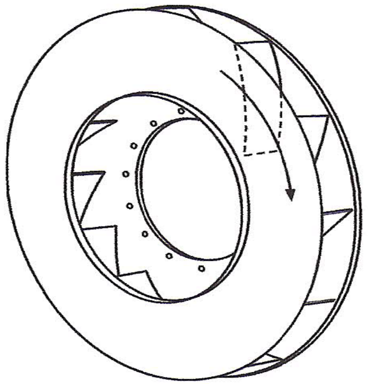


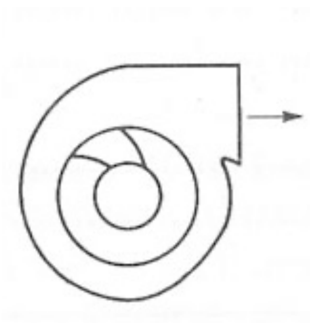


Backward-Curved

Advantages

- Good efficiency
- Can have non-stalling pressure/flow curve





Disadvantages

- High tip speed
- Underside of blades can fill with dust

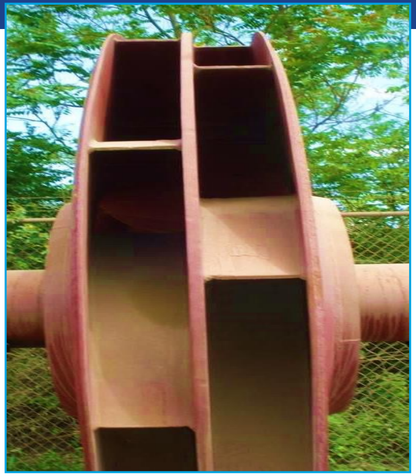
Applications

- High-velocity ventilation and supply systems

Optimization Tips

- Can handle some dirt

Backward-Curved



DIDW

SISW

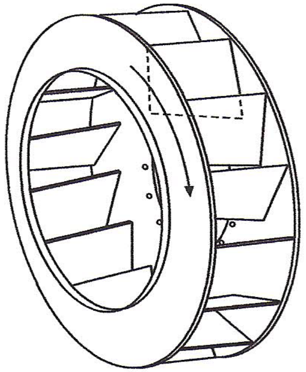
Backward-Inclined

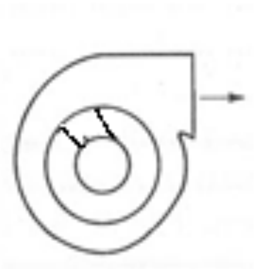
Advantages

- Fairly good efficiency

Disadvantages

- Can stall at low flows
- Blades weaker than backward-curved blade





Applications

- High-velocity ventilation and supply systems
- Can be used in dirty settings if protected

Optimization Tips

- Can handle some dirt

Backward-Inclined (flat blade)

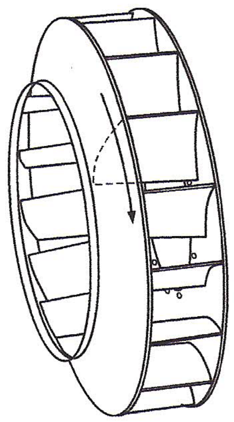
Radial Tipped

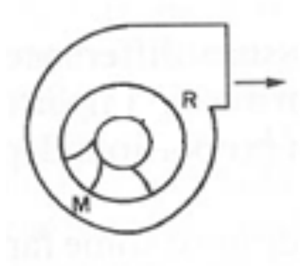
Advantages

- Strong Impeller
- Efficiency better than straight radial

Disadvantages

- Rising power characteristic
- Noisy
- Low efficiency





Applications

- Induced draught, high dust loadings

Optimization Tips

- Consider upgrading to BC or BI fan

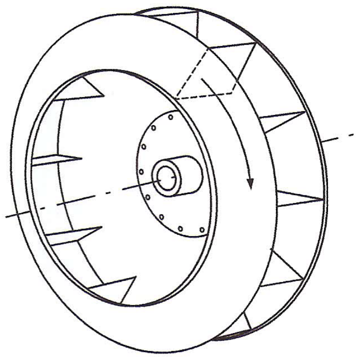
Radial Shrouded

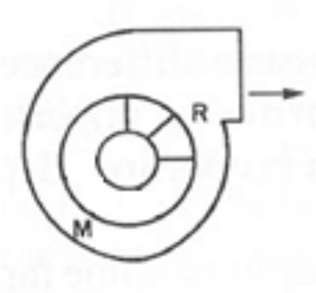
Advantages

- Very strong Impeller
- Simple construction

Disadvantages

- Rising power characteristic
- Noisy
- Low efficiency





Applications

- Induced draught, high dust loadings

Optimization Tips

- Consider upgrading to radial tipped

Radial Shrouded

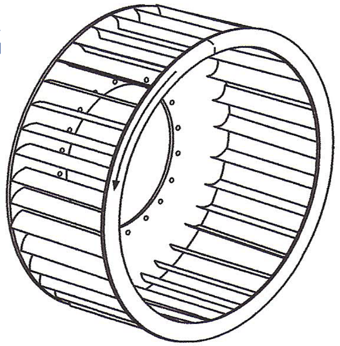
Forward-Curved

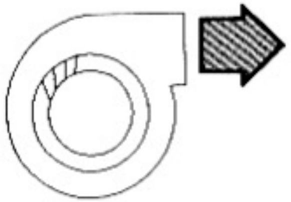
Advantages

- Low tip peripheral speeds
- Quiet
- Compact

Disadvantages

- Severely rising power characteristic
- Weak impeller





Applications

- Ventilation

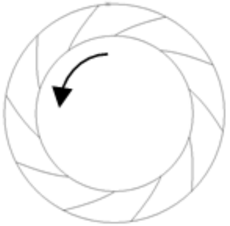
Optimization Tips

- Use for small HVAC applications only

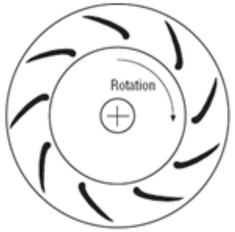
Forward Curved

Centrifugal Fan Types Summary

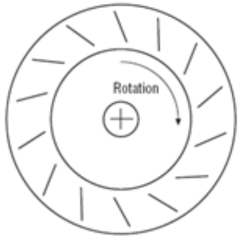
– Backward Curved (BCC)



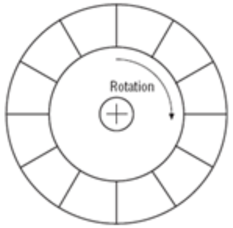
– Backward Aerofoil (BAC)



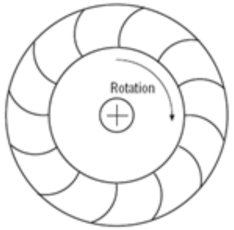
– Backward Inclined (BIC)



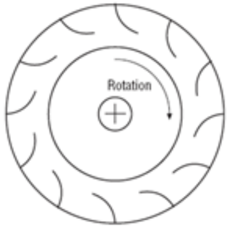
Radial Bladed (RBC)



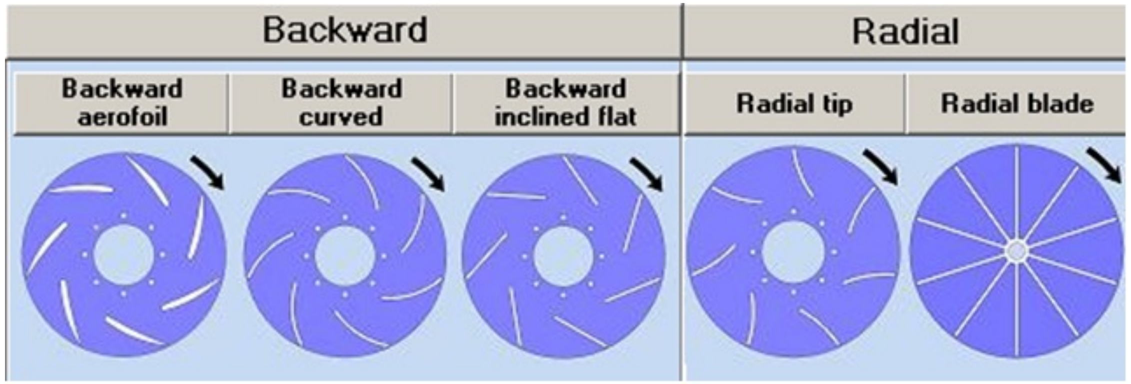
Forward Curved(FCC)



Radial Tipped (RT)



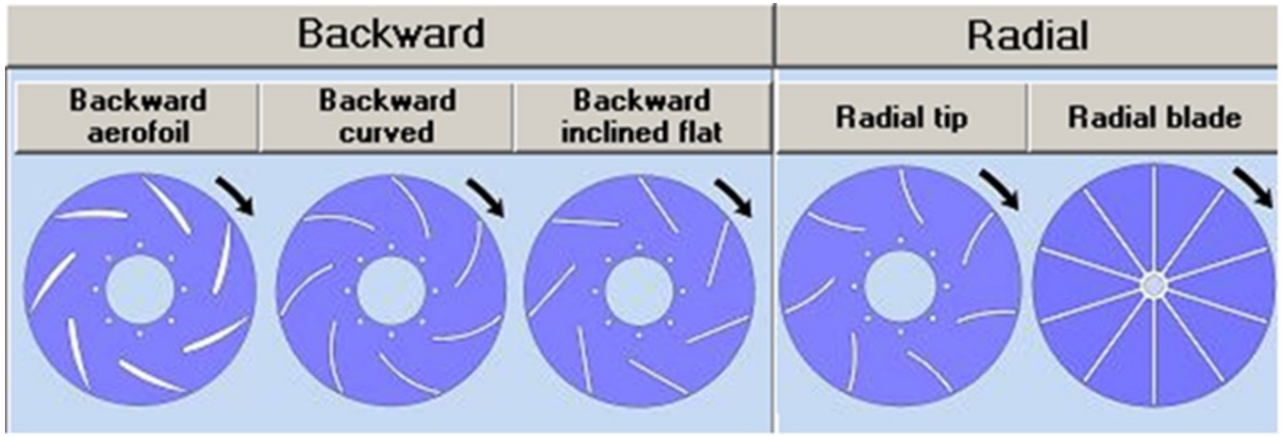
Decreasing impeller efficiency



Increasing dust loading

Centrifugal Impeller application

Decreasing impeller efficiency



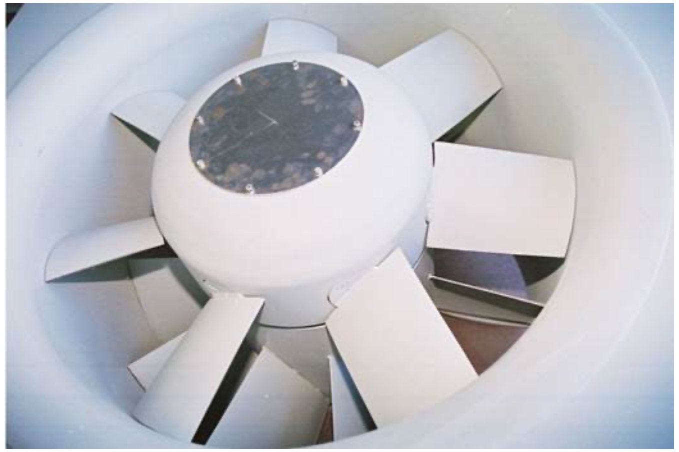
Increasing dust loading

Axial Fan Types - Summary

Propeller

Vane
Axial

(Includes guide vanes)



Tube
Axial
(no guide vanes)

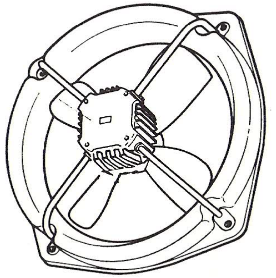
Propeller Fan

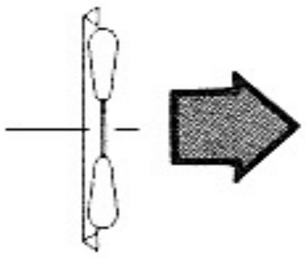
Advantages

- Lower first cost

Disadvantages

- Low efficiency
- Very low pressure





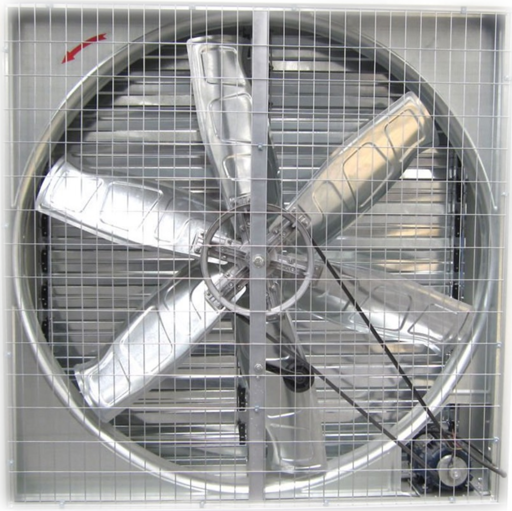
Applications

- Non-ducted

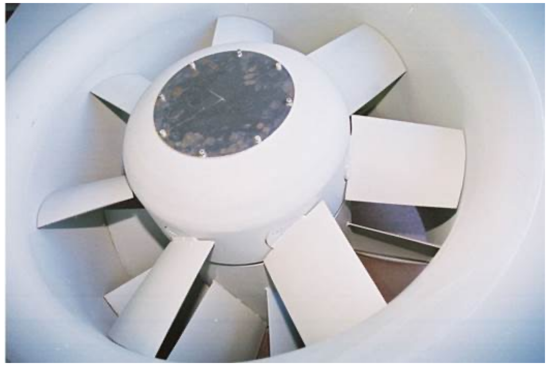
Optimization Tips

- Use for shop ventilation

Propeller Fans



Vane Axial Fan

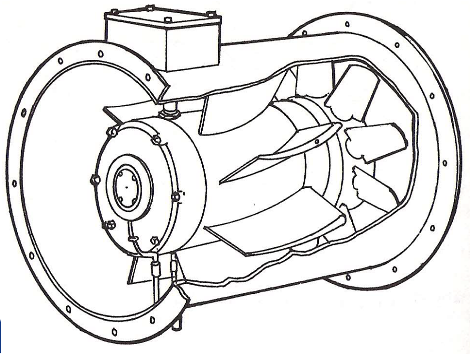


Advantages

- Straight-through flow
- Negligible swirl, higher pressure than propeller & tube axial

Disadvantages

- High tip speed
- High sound level
- Low pressure developm



Applications

- Low pressure
- Ducted

Optimization Tips

- Use diffusers at inlet and outlet

Polling questions 1 through 6

Polling Question

Application

Fan Type

1) Fabrication shop requiring 5,000 cfm ventilation air. __________
2) Process exhaust fan moving dust-laden air at 20,000 cfm, at 10 in. w.g. static pressure. __________
3) High-velocity fan used to chop paper trimmings and transport them to a central location. __________
4) 24,000 btu/hr. air conditioning unit required to deliver 800 cfm at 1.5 in. w.g. static pressure. __________
5) Industrial process requiring 50,000 cfm of clean air at 11 in. w.g. static pressure. __________
6) Tunnel ventilation application requiring 90,000 cfm at 3.5 in. w.g. static pressure. __________

a) Airfoil b) Forward curved c) Propeller

d) Backward-inclined e) Vane Axial f) Radial

Impeller Type Efficiency Worksheet

Application	**Fan Type**
A. Fabrication shop requiring 5,000 cfm ventilation air.	____P______
B. Process exhaust fan moving dust-laden air at 20,000 cfm, at 10 in. w.g. static pressure.	____BI______
C. High-velocity fan used to chop paper trimmings and transport them to a central location.	____R______
D. 24,000 btu/hr. air conditioning unit required to deliver 800 cfm at 1.5 in. w.g. static pressure.	____FC______
E. Industrial process requiring 50,000 cfm of clean air at 11 in. w.g. static pressure.	____AF______
F. Tunnel ventilation application requiring 90,000 cfm at 3.5 in. w.g. static pressure.	____VA______

Airfoil – Forward curved – Propeller

Backward-inclined – Vane Axial - Radial

Fans Choices in MEASUR

	In MEASUR	Not in MEASUR
Centrifugal Fans	• Airfoil • Backward-Inclined • Backward Curved • Radial	• Forward-Curved • In-Line (Tubular centrifugal)
Axial Fans	• Van Axial	• Propeller • Tube Axial

Key Points / Action Items

1. *The fan curve and system curve together can be used as a "road map" for navigating through a fan upgrade project, or for diagnosing system flow and pressure issues*

2. *Beware of selecting fans with their operating point too close to the surge point*

3. *Using the correct type of fan for the application is the first step towards a reliable and efficient system*

Homework #2

- Find the fan curves for the top 5 fans from past week's list.

- For the top 10 fans from last week's list, determine what type of blade shape they have.

- Find a fan curve (and power curve if possible) for the fan associated with the top project candidate and enter the fan curve data in MEASUR

Thank You all for attending today's webinar.

See you all on next Thursday –

If you have specific questions, please stay online and we will try and answer them.

Alternately, you can email questions to me at ron@productiveenergy.com

U.S. DEPARTMENT OF ENERGY

Fan curves, power curves and efficiency curves