Fan and System Curves with Fan Energy Index (FEI), Part 1 of 2

Ron Wroblewski, PE, president, Productive Energy Solutions, and William (Bill) Howarth, president, Ventilation & Fan Consulting Service International LLC

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Today's Presenters

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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.

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Fan and System Curves with Fan Energy Index

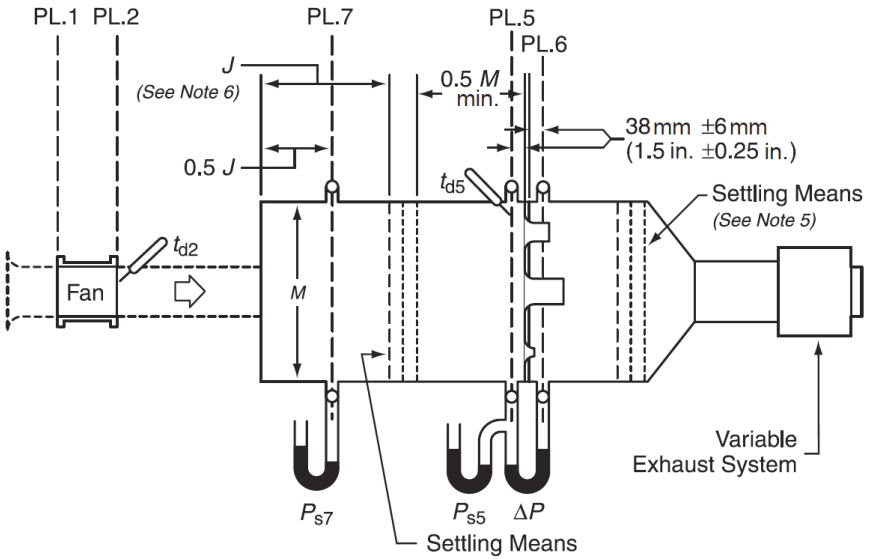
Purpose and Learning Objectives

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

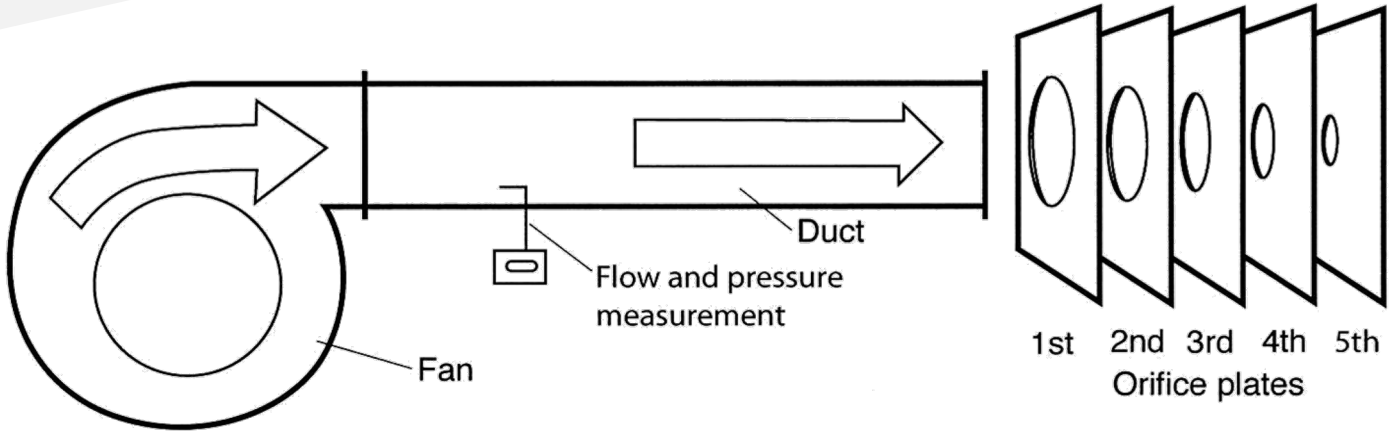
- Explain how a fan flow curve is developed by fan manufacturers
- Explain how the fan power curve is developed by fan manufacturers
- Explain how the system curve is developed
- List 5 typical fan system elements affecting the system curve
- Explain the significance of the duty point
- List two benefits of using the Fan Energy Index rating

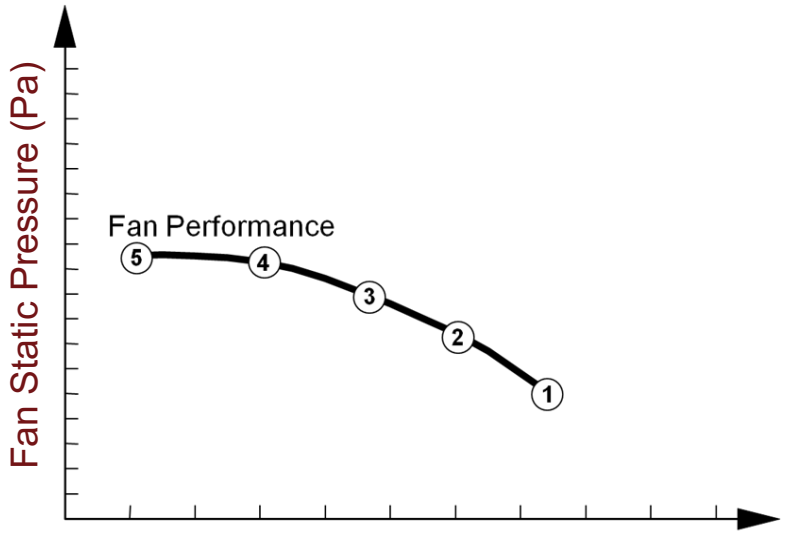
Fan Testing

- Laboratory testing under ideal conditions AMCA 210
  - Ideal Measurement Stations
  - Straight ducting
  - Flow conditioning devices

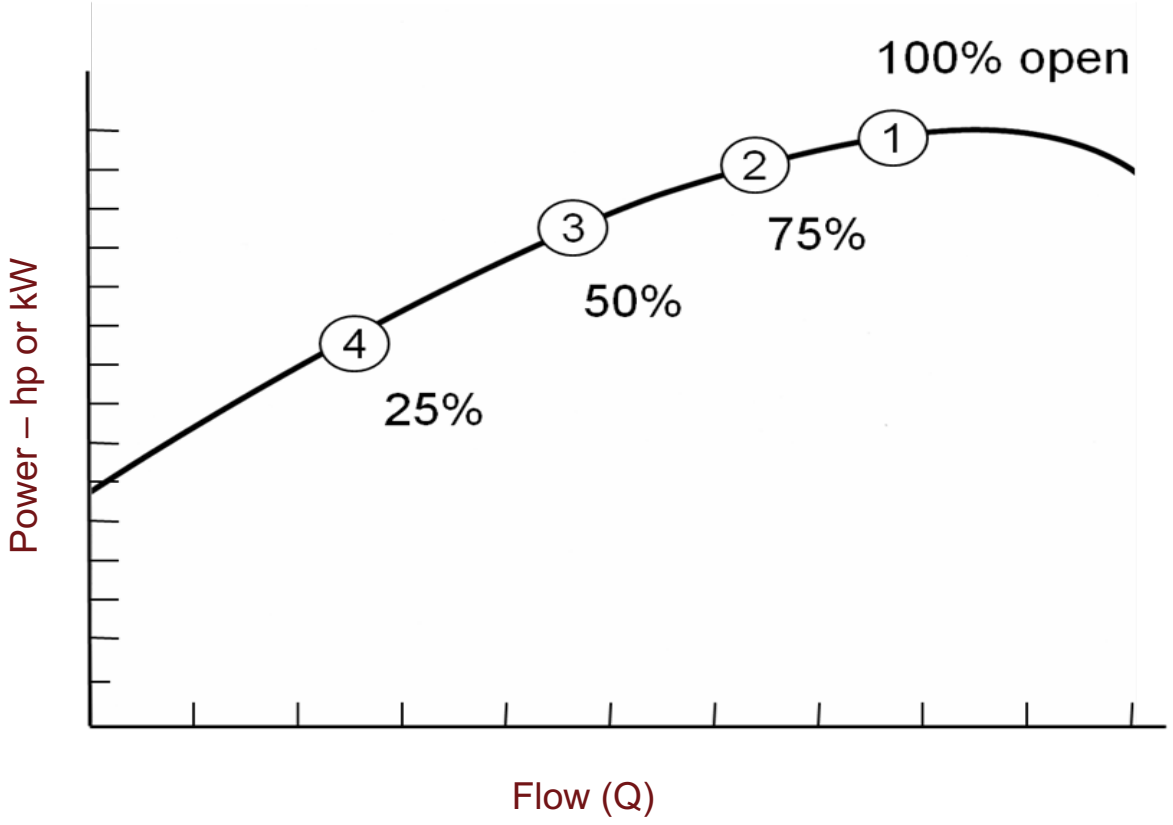


Fan Curve



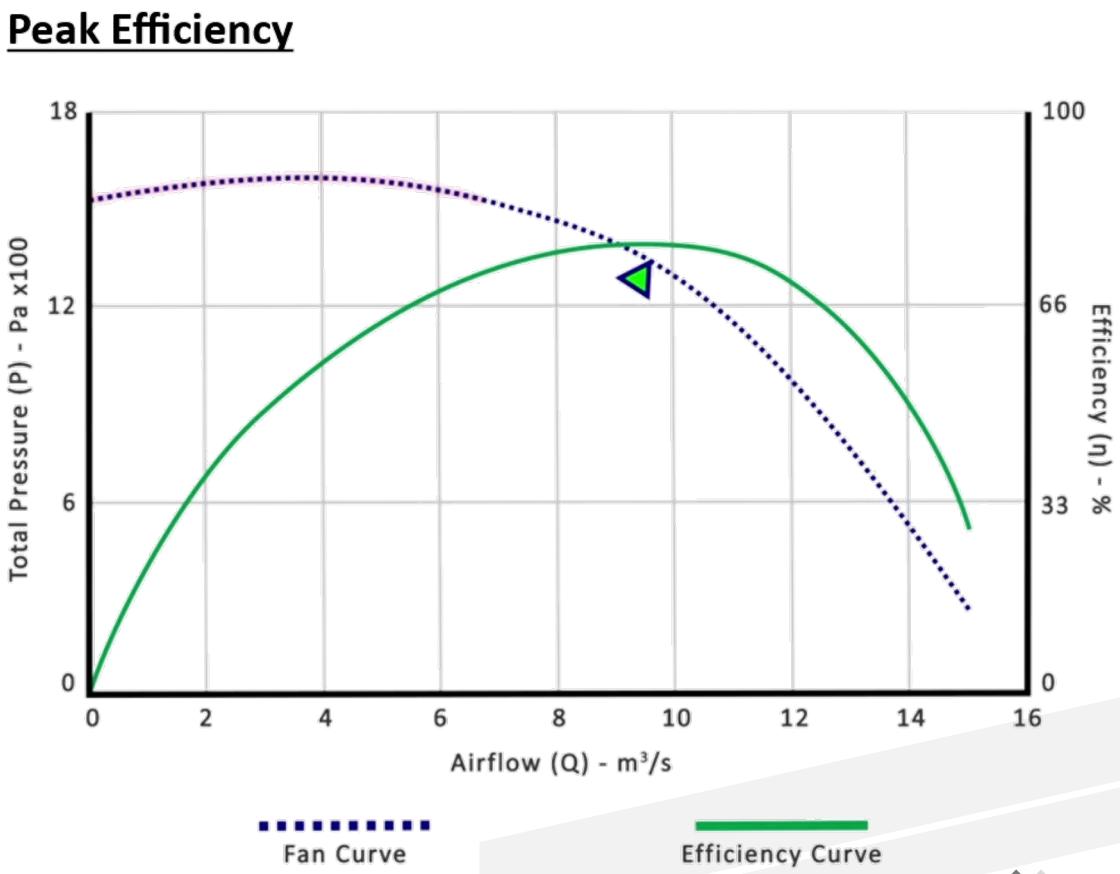


Fan Power Curve



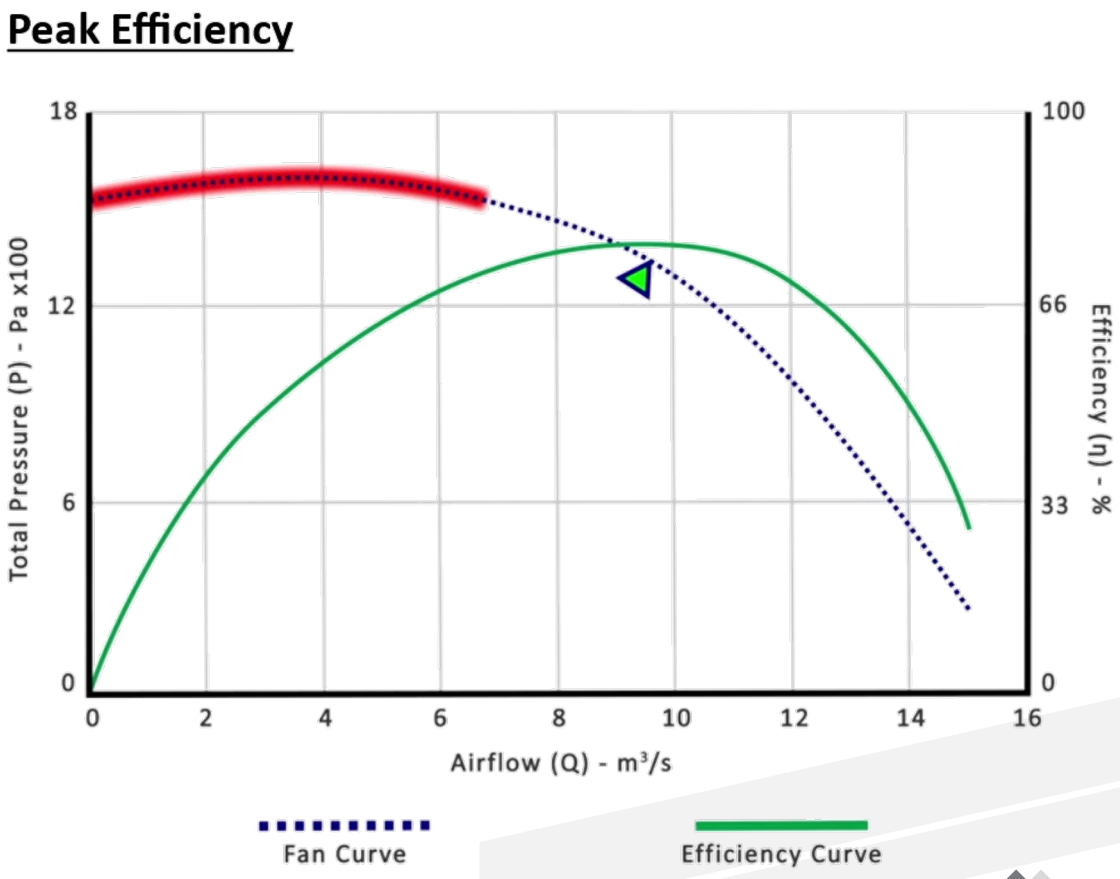
Fan Curve and Efficiency Curve

- The fan curve is a graphical representation of the operational characteristics of the fan
- Think of it as a “road map” to understanding fan performance
- The efficiency curve starts at 0 at no flow, rises to a maximum, then falls at maximum flow
- The green triangle represents the best efficiency point



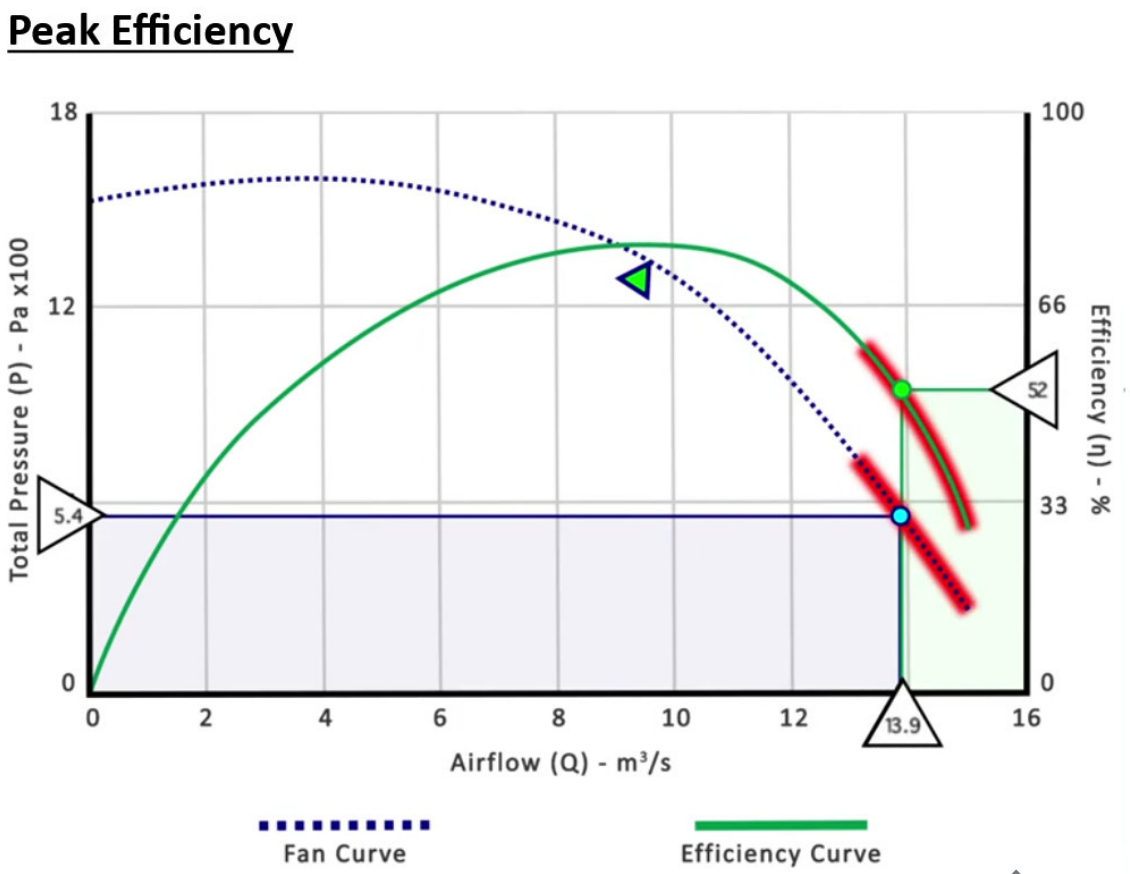
Warning – Surge zone

- The fan should never be selected to operate to the left of the peak in the fan curve
- In this part of the curve, the fan will experience extreme vibration that might cause a structural failure.
- Operating a fan in surge can cause property damage and severe injury or loss of life or limb

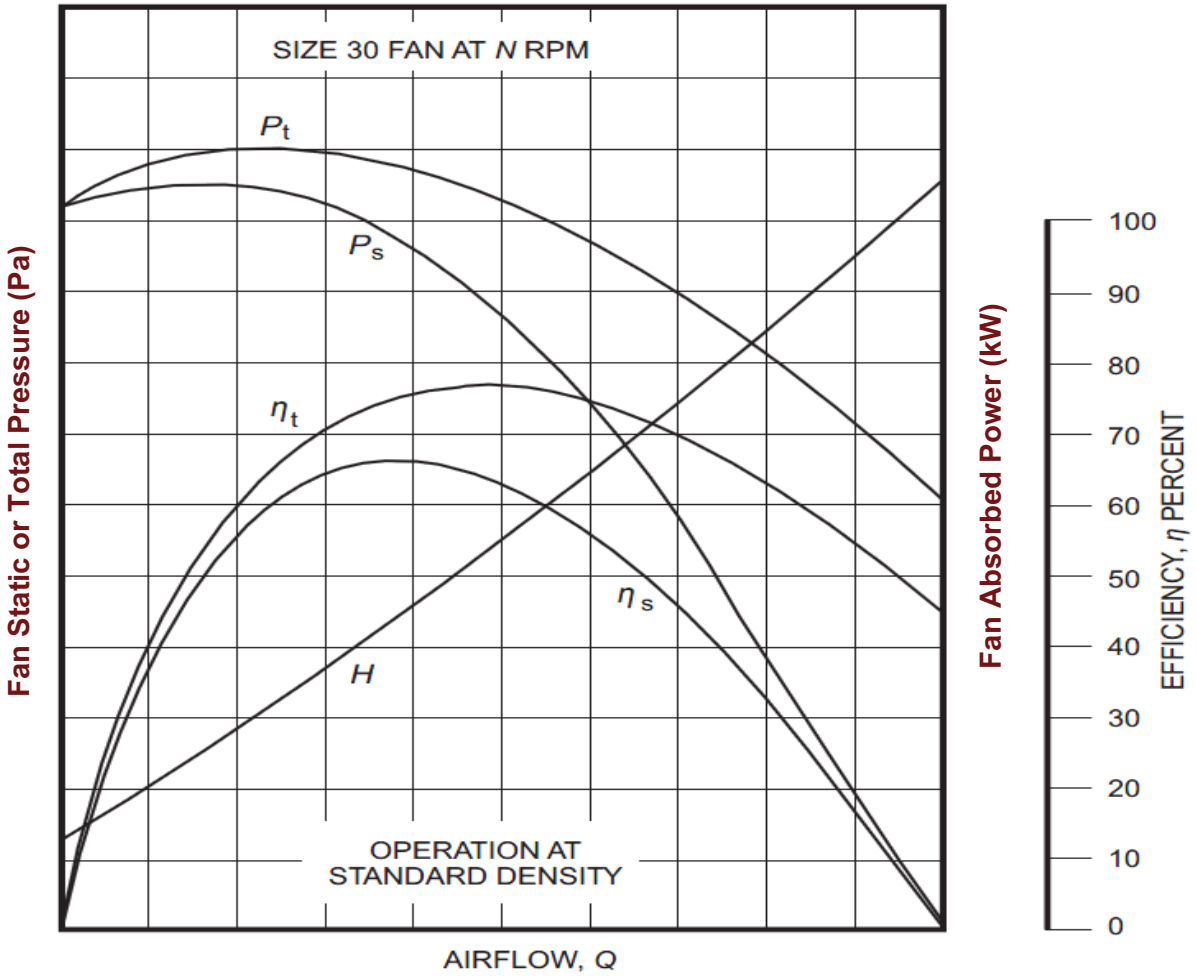


Stall zone

- At high flow rates the fan will be noisy and inefficient.
- There may be air-generated noise and rumbling, but not as damaging as the surge

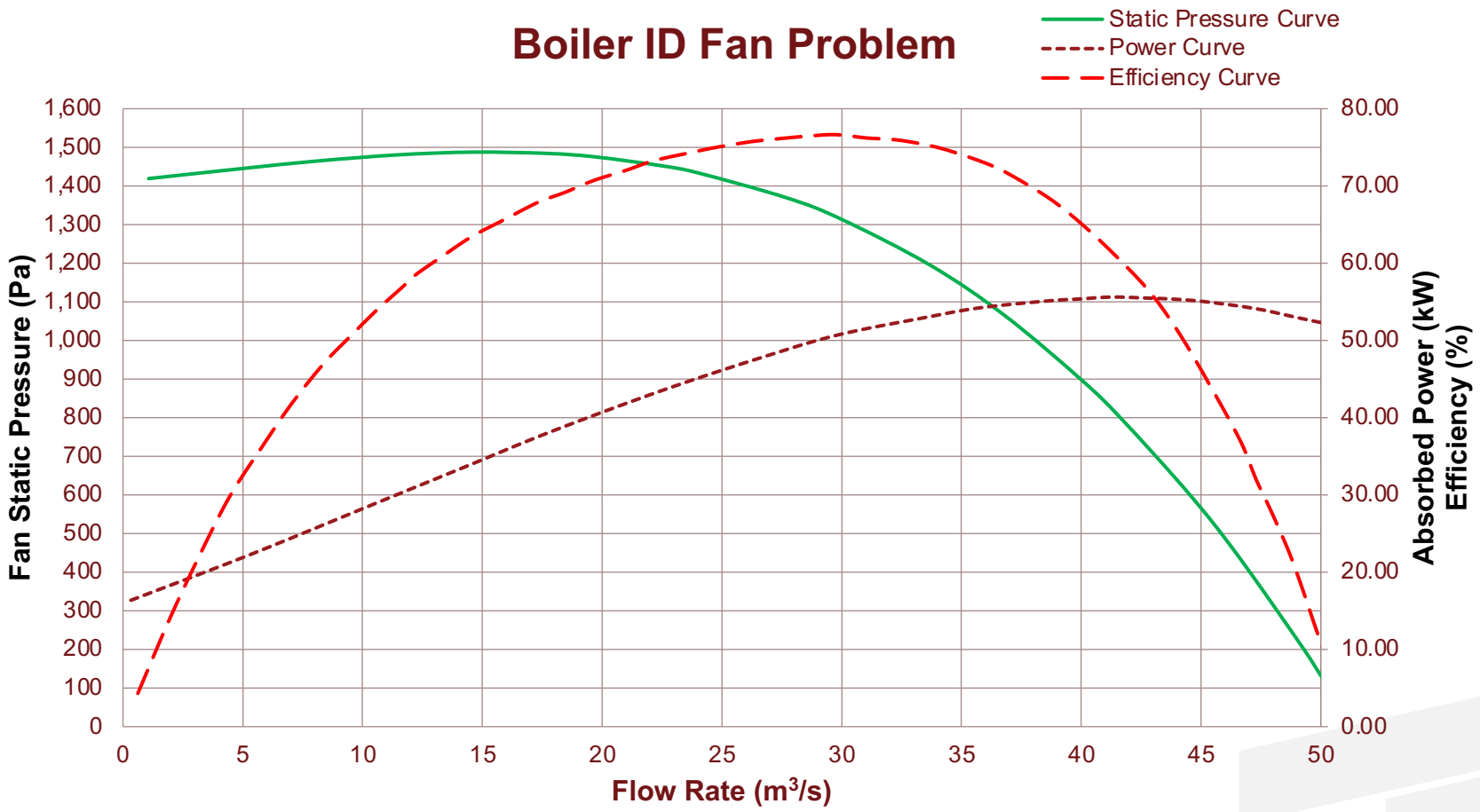


Fan Performance Curve with Efficiency



$$P_t = P_s + P_v$$

Boiler ID Fan – Characteristic, Power and Efficiency



Factors Influencing the Fan Curve

- Type of fan (blade shape)
- Diameter of the impeller
- Width of the impeller
- Rotational speed
- Density of the fluid

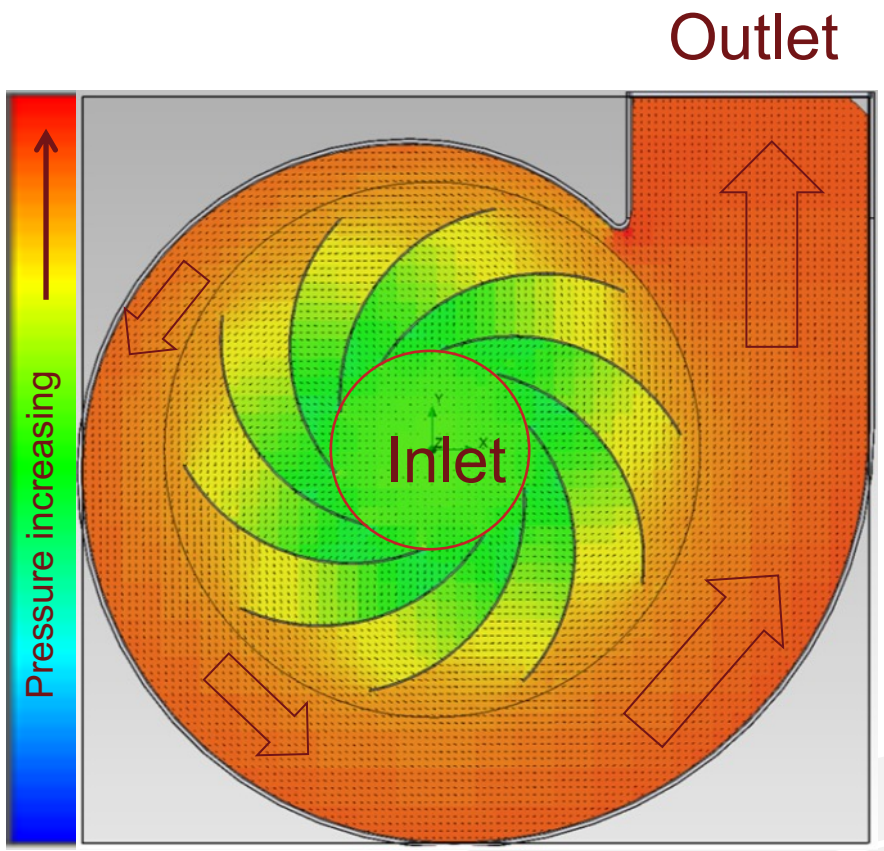
Physics of Centrifugal Fans

Centrifugal effect is largest contributor to pressure

As the fan spins, the housing:

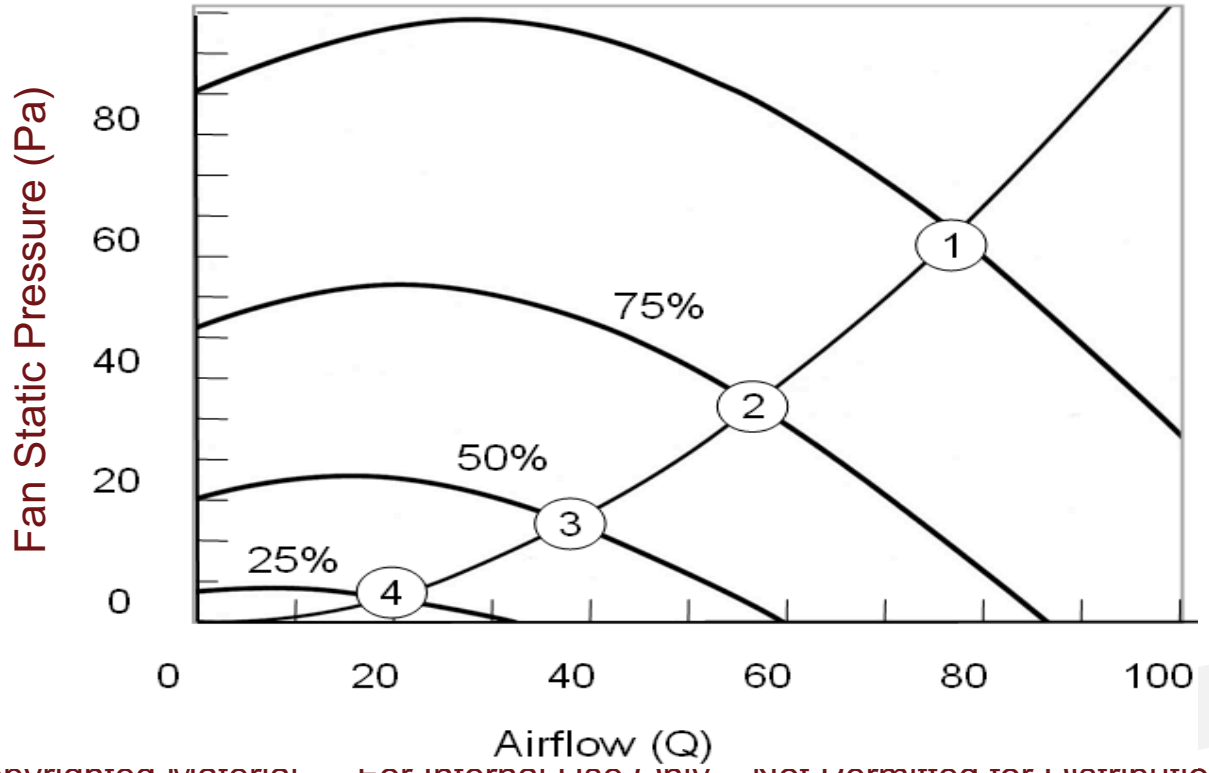
1. Collects air
2. Slows it down to recapture pressure
3. Provides direction to air leaving fan

Changing the rotational speed changes the ability of fan to do work



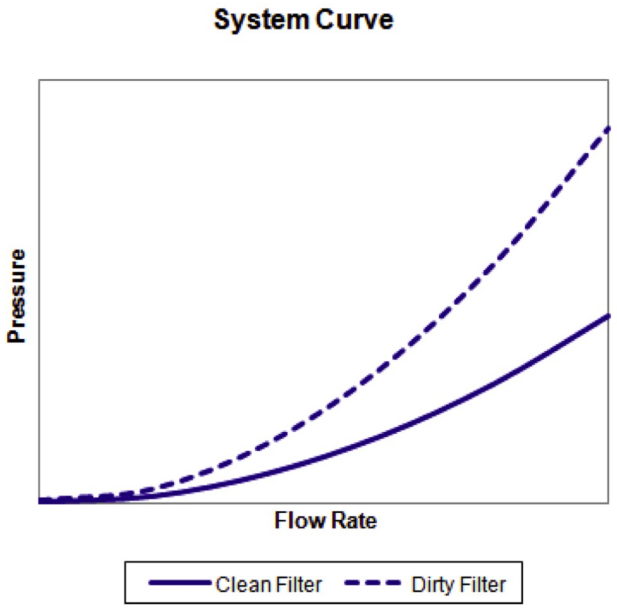
Fan Speed and the Fan Curve

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



System Curve

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



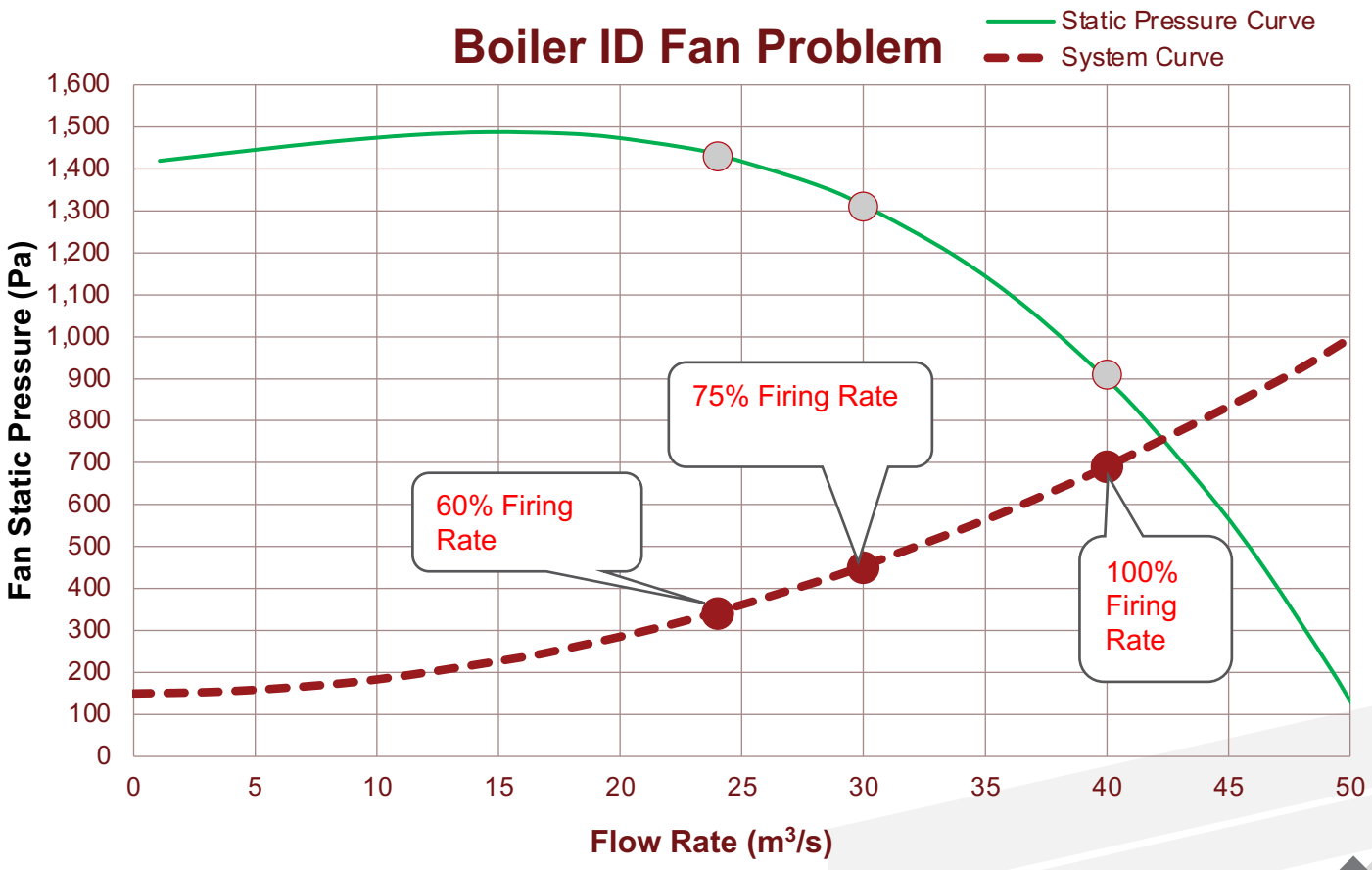
What Is A Fan System?

Everything attached to the fan, including:

- Fume hoods
- Ductwork
- Volume control dampers
- Filters
- Heat exchangers
- Driers

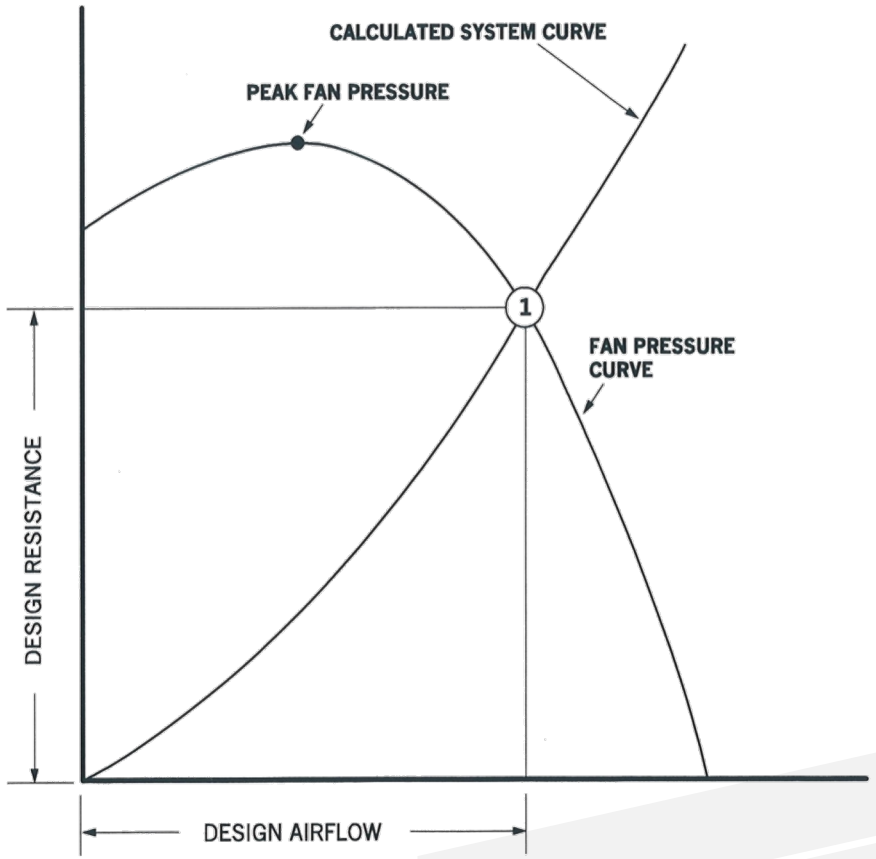
Advanced System Curve Modelling

- If the system contains laminar flow elements like filters or cooling coils, a linear term can be added in the form of B*x
- If there is a constant pressure requirement such as in a boiler ID fan, then there is an offset added
- $Y = A*x^2 + B*x + C$
- The exponent of 1.9 can also be used



Fan and System Curve Interaction

- Fan operates on fan curve
- System operates on system curve
- The **duty point** (1) is the intersection of the fan curve and the system curve - also known as the operating point, or point of rating

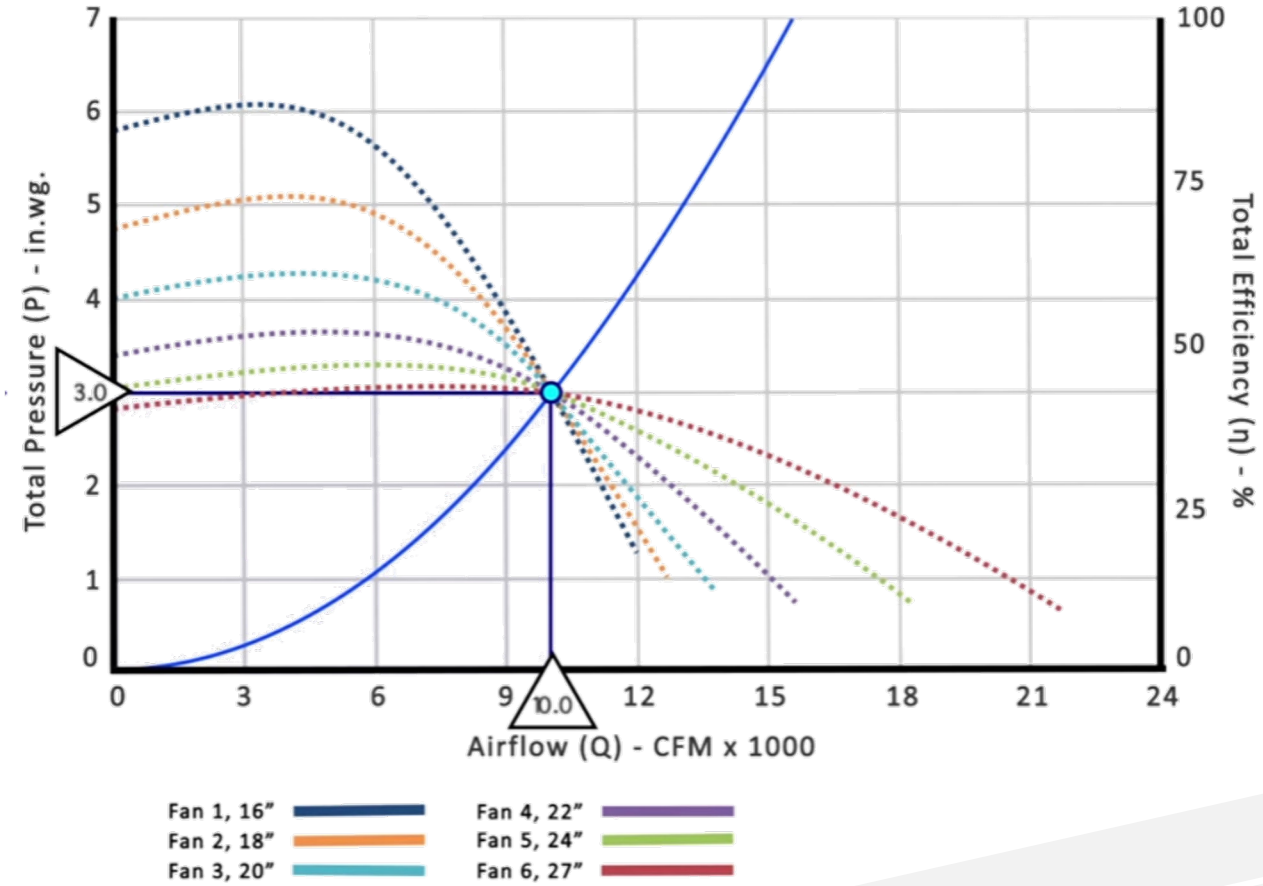


Different size fans serving the same duty point

Fan Curve

The smaller fans have a steeper fan curve

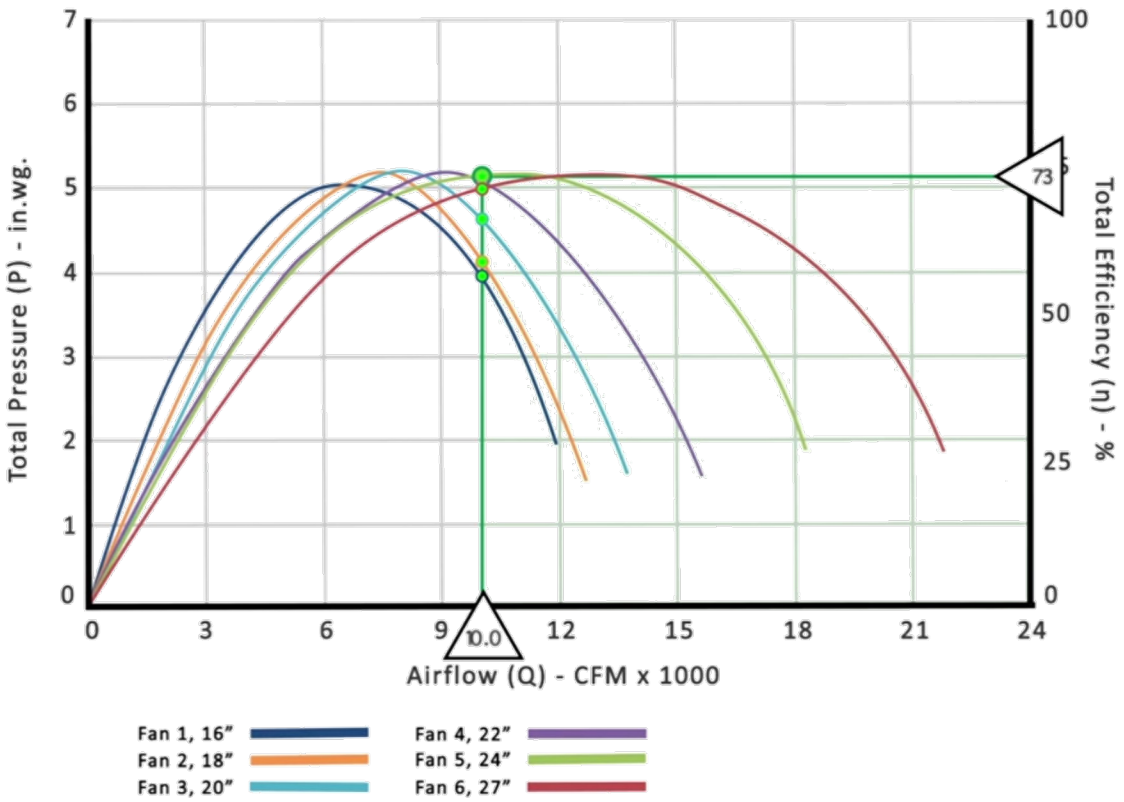
Each fan produces 10,000 cfm @ 3 in. w.g.



Different size fans serving the same duty point

Efficiency curves

Each size fan achieves its peak efficiency at a different flow rate

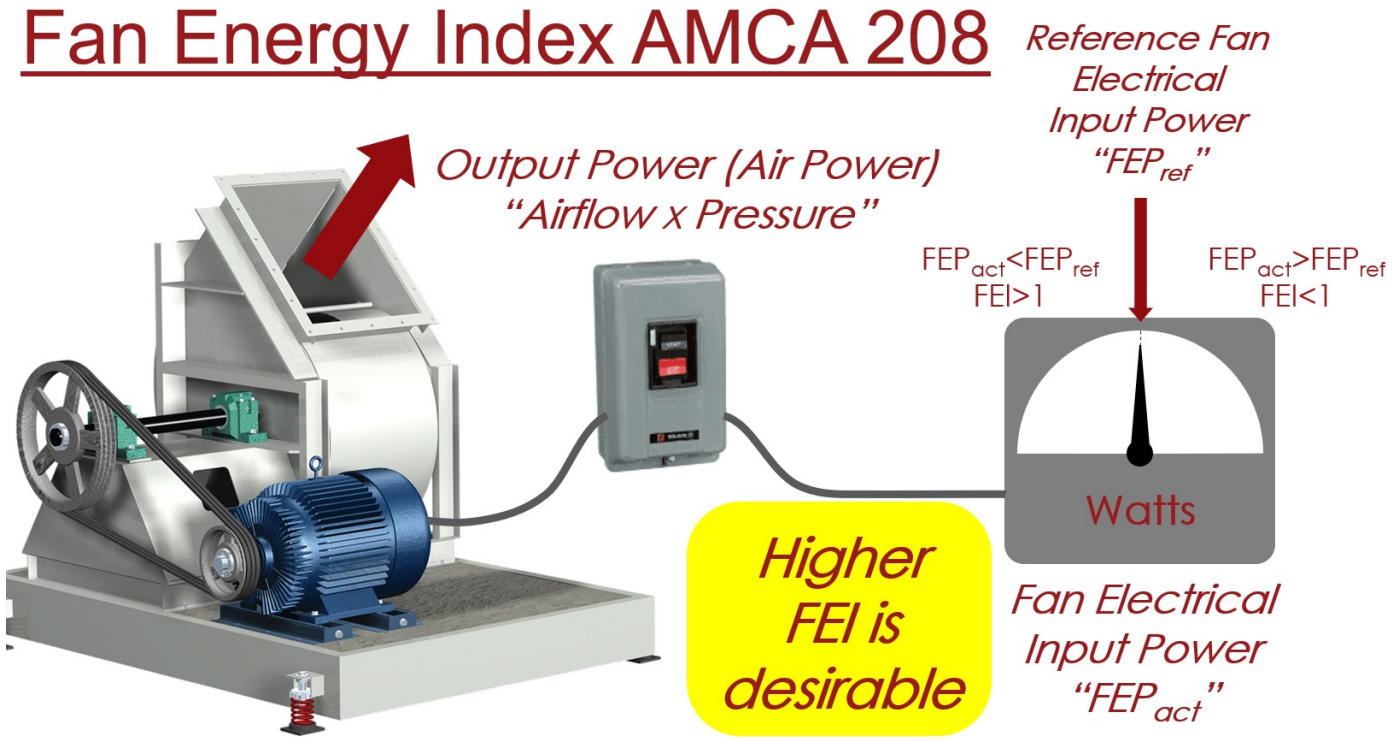


Efficient Fan Selection

- Each fan selection will have a specific efficiency.
- Similar fans from different manufacturers will have different efficiencies.
- “Pressure Reserve” is extra pressure capacity that helps avoid operating in surge condition.
- Too large of a fan may operate in a surge condition.
- In general, for a given operating point smaller fans running faster will be less efficient.
- Fan Energy Index **(FEI)** is a new fan metric comparing the installed fan to a reference fan.

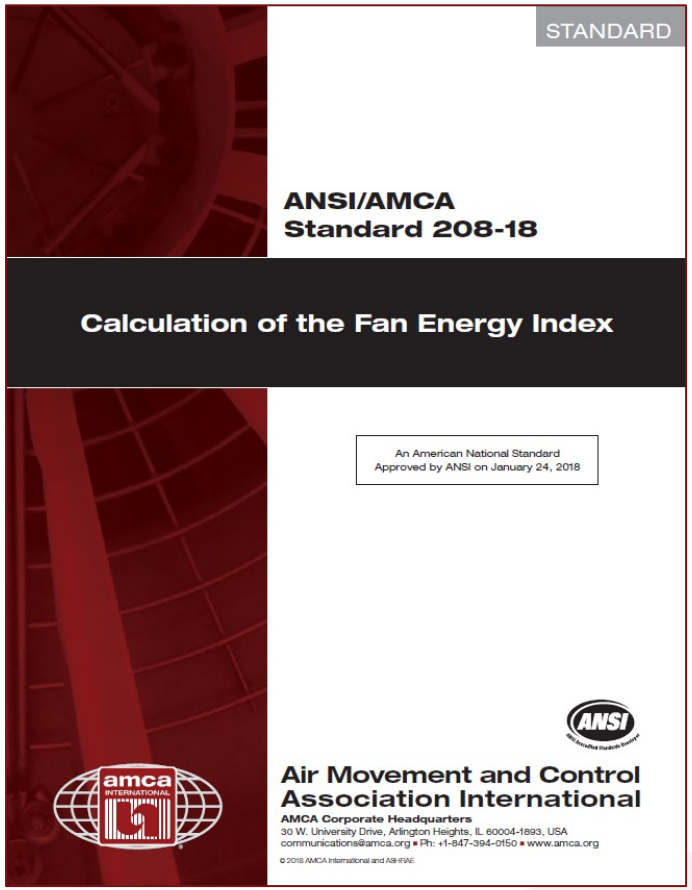
Efficient Fan Selection (continued)

- FEI rating: 1.2 – 1.3 typical for engineering best practices
- Minimum FEI rating of 1.00 requirements are being adopted in building codes.
- Green Energy Buildings Minimum FEI rating 1.10
- Department of Energy and California State in rulemaking process.



FEI – Fan Energy Index – AMCA 208

- Introduction to FEI
- Benefits of FEI
  - Reflects energy consumption
  - Establishes compliant range of operation
  - Provides comparison tool for fan selection


STANDARD

ANSI/AMCA
Standard 208-18

Calculation of the Fan Energy Index

An American National Standard
Approved by ANSI on January 24, 2018

Air Movement and Control
Association International

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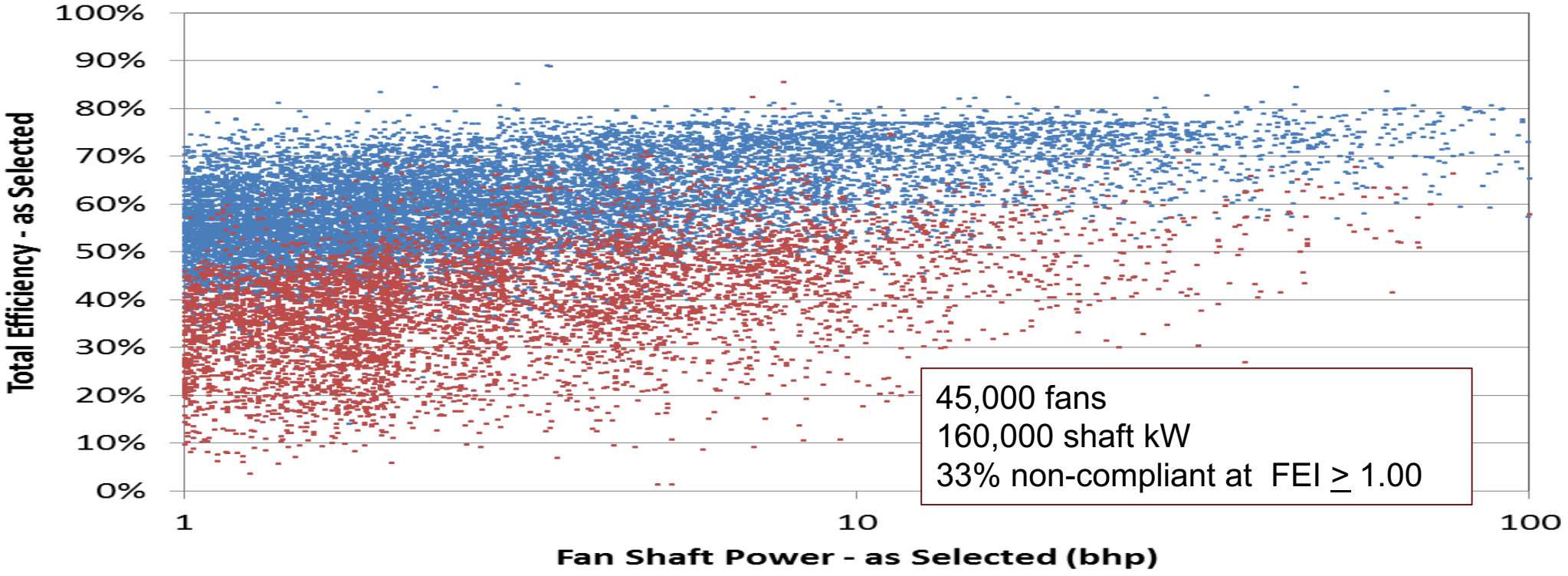
Fan Energy Index Primer

- FEI is an OPERATING POINT METRIC
  - Fan efficiency is highly dependent on where the fan is operating on the fan curve
  - Fans typically selected to provide airflow at a designated duty point
  - Turns out, help is needed for selecting fans

Engineers Selections at Duty Point

One Company's entire 2012 fan sales
Selections Compliant FEI ≥ 1.00 (Blue)
and Noncompliant FEI < 1.00 (Red)



FEI – Fan Energy Index

$$FEI = \frac{Reference\ Fan\ Electrical\ Input\ Power}{Actual\ Fan\ Electrical\ Input\ Power}$$

$$FEI = \frac{FEP_{ref}}{FEP_{actual}}$$

- FEP_{ref} and FEP_{actual} calculated at the same duty point
- FEI is a relative measure of power required for a given duty point – relative to the *Reference Fan*

Reference Fan

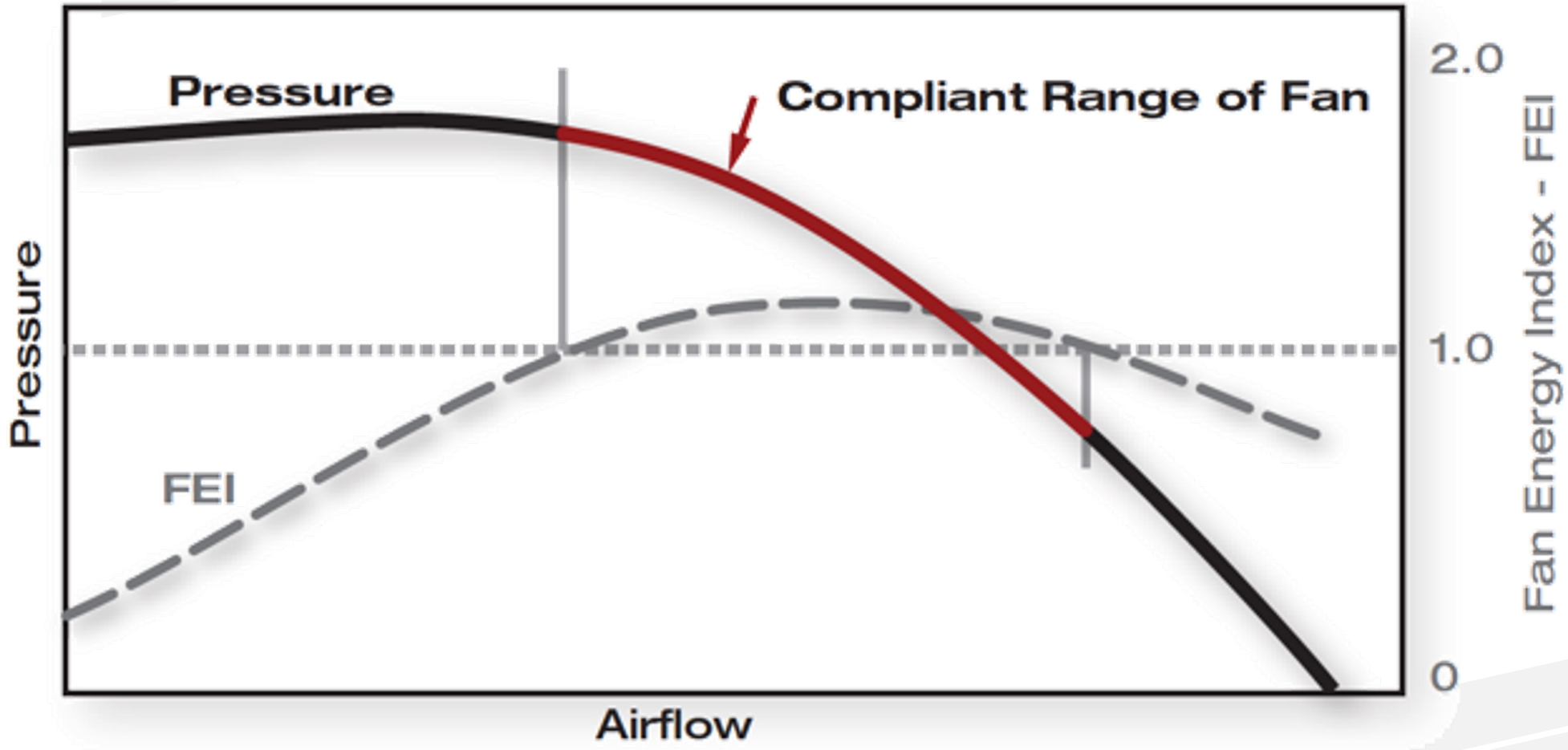
- The efficiency coefficients ensure required ducted fan efficiency is higher than for a non-ducted fan.
- The reference fan is a conceptual fan based on:
  - Produces required airflow and pressure at specified shaft input power
  - Motor efficiency based on 4-pole, 60-Hz, IE3 motor
  - V-belt transmission
  - No speed control

Higher FEI is Desirable

- Higher FEI reflects higher efficiency
- FEI helps engineers improve fan sizing and selection
- Enables comparisons of:
  - Different fan types
  - Different fan sizes
  - Different motor and drive combinations

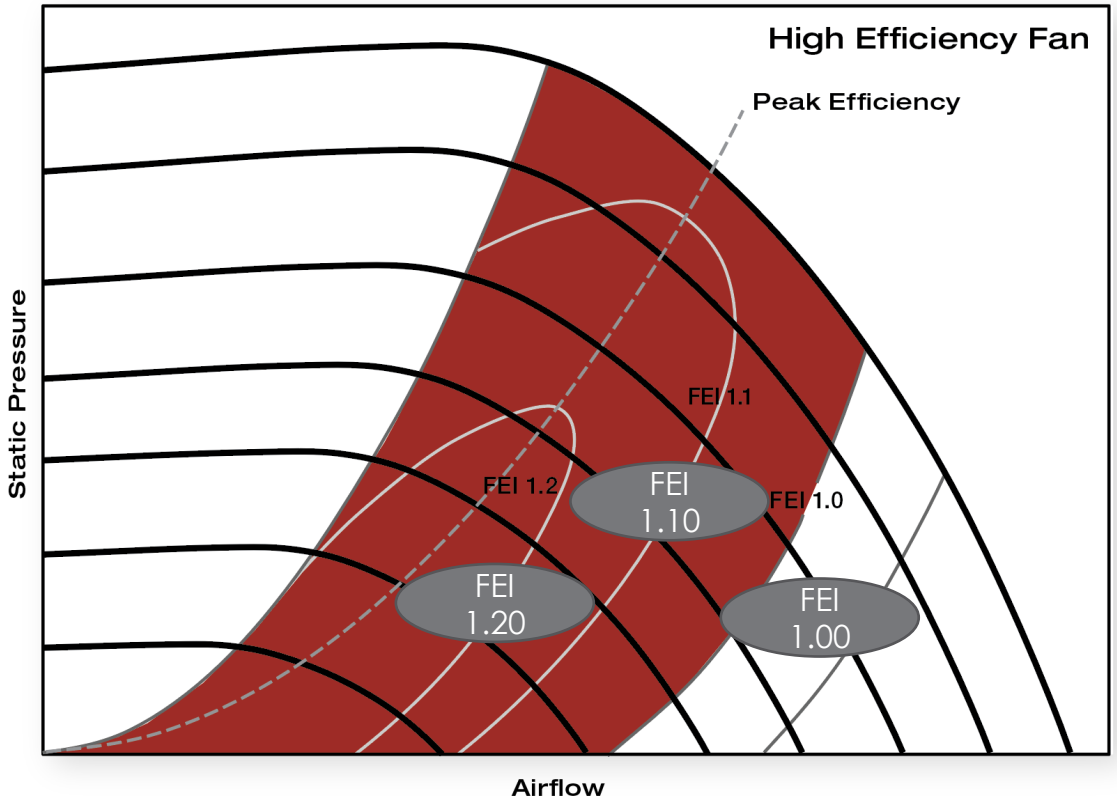
Compliant Range (FEI ≥ 1.00)

For a fan at a single fan speed

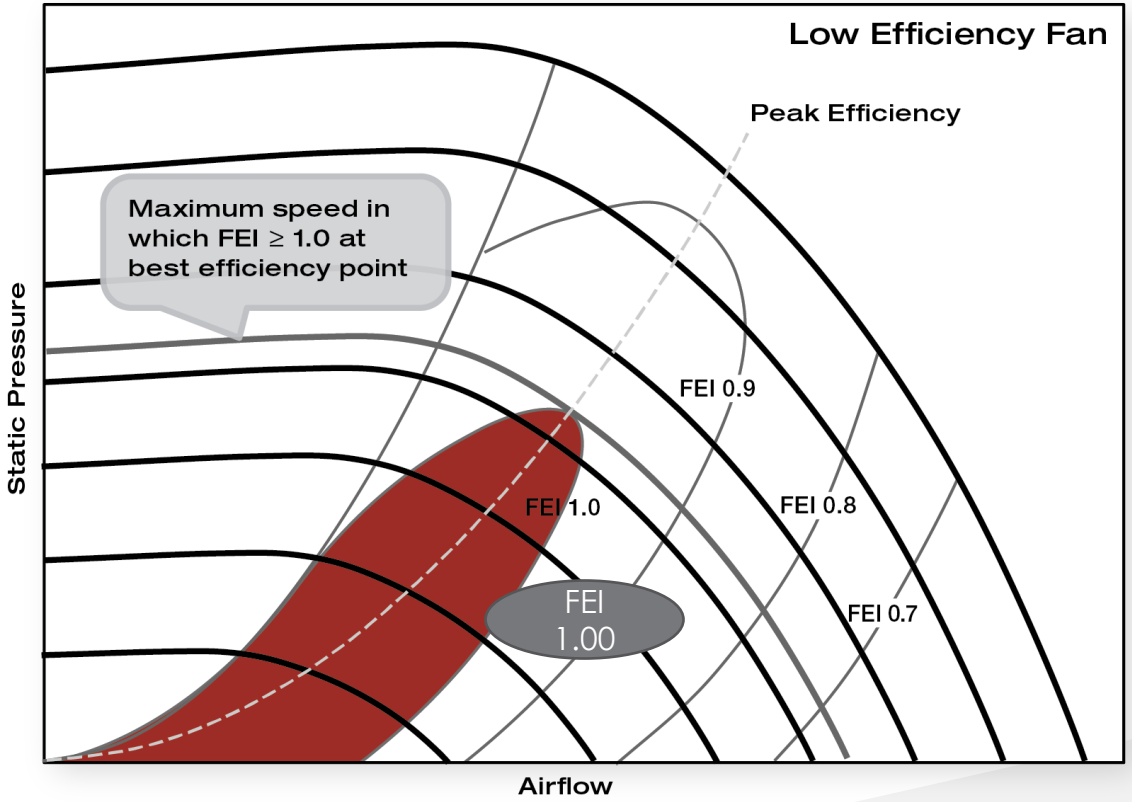


Compliant Range (FEI ≥ 1.00)

For a fan at multiple speeds



EFFICIENT FAN



INEFFICIENT FAN

The Contractor's Selection

- Any fan can hit any point
  - Too small fan running fast is inefficient and may be noisy
  - Too large fan may be operating in surge and no capacity for additional pressure
- Size for the flow and pressure using FEI will help comparison
- Size for efficiency and other factors

FEI Distinguishes Static and Total Pressure Reference Fan (From AMCA 208)

For fans with a ducted outlet:

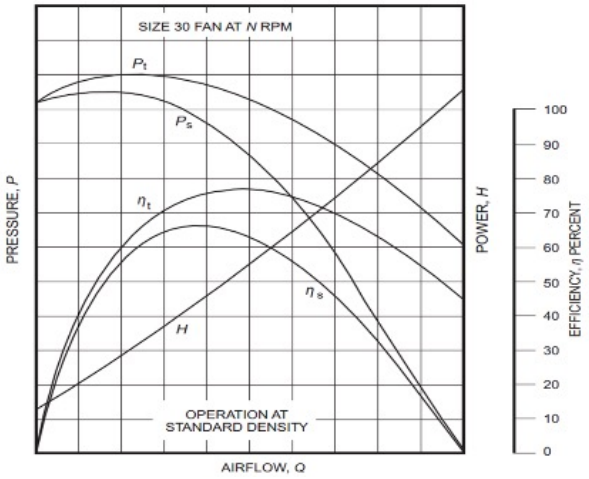
$$H_{i,\,ref} = \frac{(Q+250) \times (P_t+0.40)}{\eta_{t,ref}\,(66\%)}\ \text{IP}$$

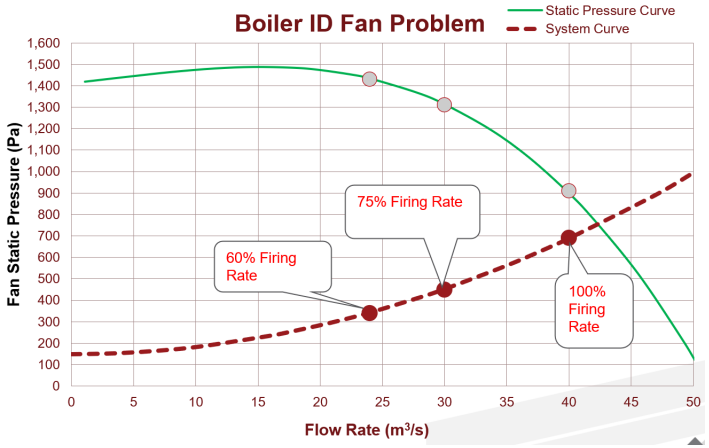
For fans with a non-ducted outlet:

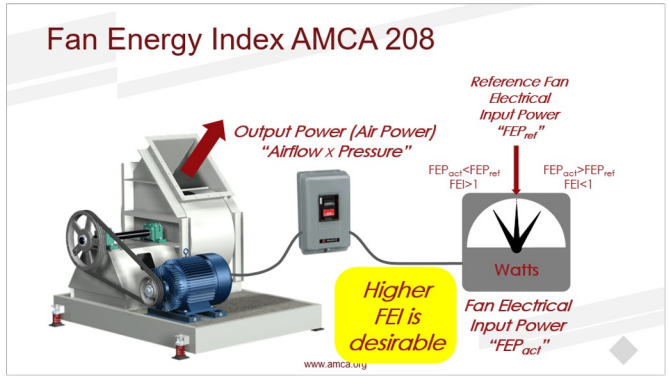
$$H_{i,ref} = \frac{(Q+250) \times (P_s+0.40)}{\eta_{s,ref}\,(60\%)}\ \text{IP}$$

Fan and System Curves with Fan Energy Index Summary

- Fans testing is under ideal conditions
- Pressure curve
- Power curve
- System curve $y = Ax^2 + Bx + C$
- Fan Energy Index
  - Based on duty point
  - Wire to air metric
  - Code requires minimum FEI rating of 1.0
  - Best Practices FEI rating possibly 1.2 – 1.3







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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)
  - ANSI/AMCA Standard 210-16: Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating (ASHRAE 51-16)
  - ANSI/AMCA Standard 207-17 – Fan System Efficiency and Fan System Input Power Calculation
  - ANSI/AMCA Standard 208, Calculation of the Fan Energy Index
- **AMCA Publications**: *www.amca.org/store*
  - 200-02 (R2011) – Air Systems
  - 201-02 (R2011) – Fans and Systems

Questions?

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- William Howarth whowarth@vfcsintl.com

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