AIR CONDITIONING FANS

June 2020

An **Air Conditioning Clinic** brought to you by

TRANE

“Trane” is a Registered Provider with The American Institute of Architects Continuing Education System. Credit earned on completion of this program will be reported to CES Records for AIA members. Certificates of Completion are available on request.

This program is registered with the AIA/CES for continuing professional education. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the AIA of any material of construction or any method or manner of handling, using, distributing, or dealing in any material or product.

INSTRUCTOR

- Michael Johnson
  - Trane Madison, WI
  - Systems Account Manager
- May 12, 2021

Air Conditioning Fans
Agenda

INTRODUCTION

fan array

forward curved centrifugal fan

LEARNING OBJECTIVES

- Recognize different types of fans used in HVAC systems
- Summarize the different types of fan capacity control available in the marketplace
- Identify the differences between static and velocity pressure
- Recognize where surge occurs on a fan map and realize the implications of selecting a fan at or near this threshold

period 1

FAN PERFORMANCE

IN THIS PERIOD

- Types of fan pressure
- Fan pressure measurement
- Fan performance curves
- Selecting a fan using performance curves

FAN PRESSURE

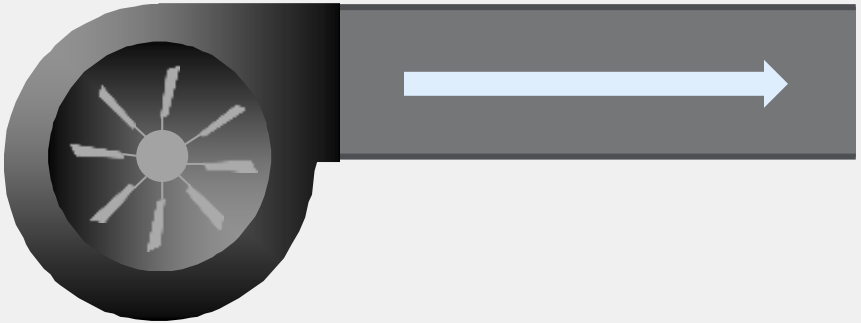
static pressure

The portion of the air pressure that exists by virtue of the degree of compression only.

FAN PRESSURE

velocity pressure

The portion of the air pressure that exists by virtue of the rate of motion only.

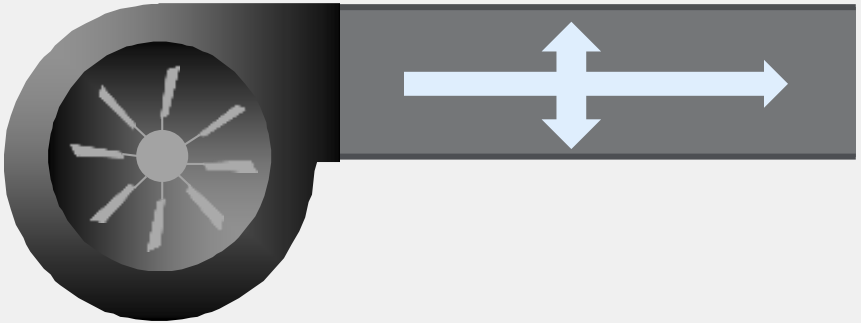


FAN PRESSURE

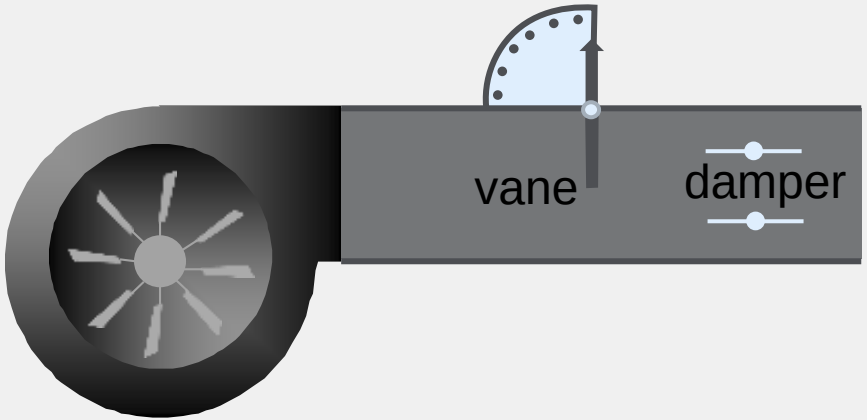
total pressure

The algebraic sum of the velocity pressure and the static pressure at a point.

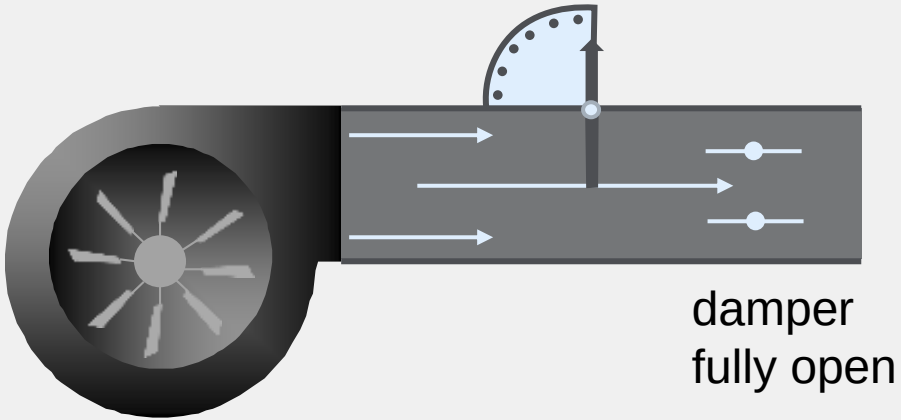
$$P_t = P_v + P_s$$



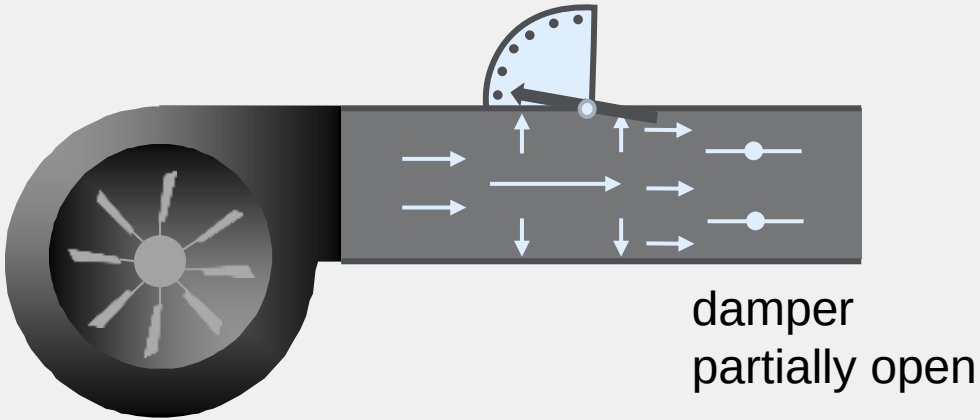
VELOCITY VS. STATIC PRESSURE



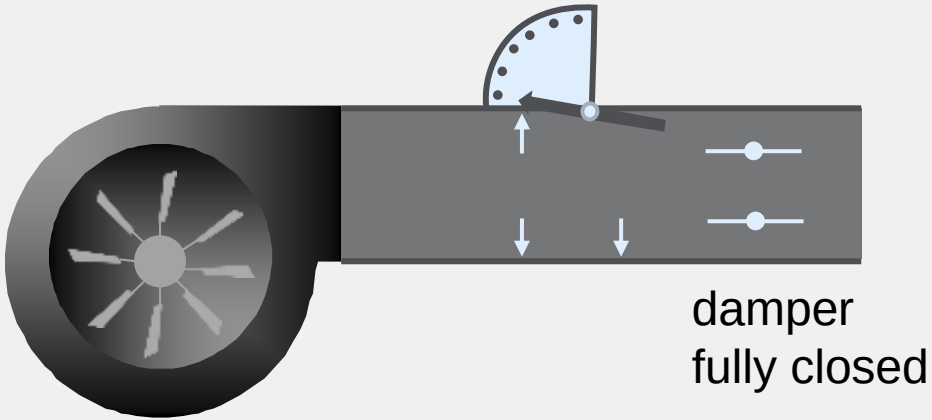
VELOCITY VS. STATIC PRESSURE



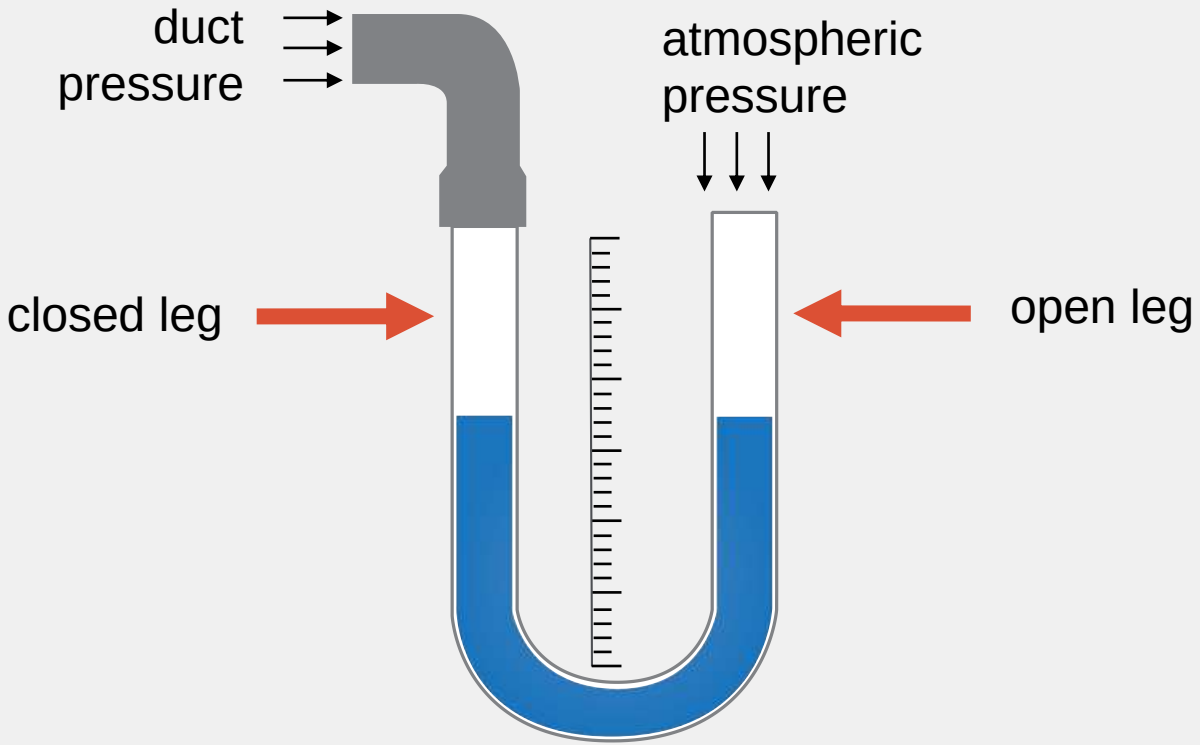
VELOCITY VS. STATIC PRESSURE



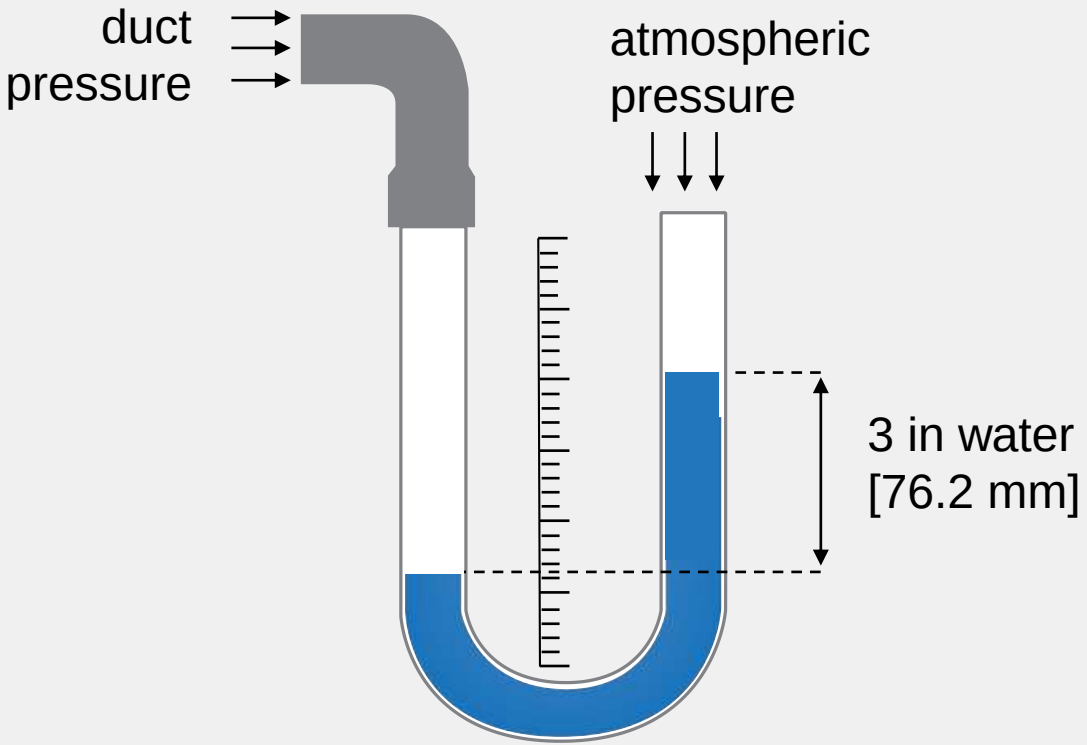
VELOCITY VS. STATIC PRESSURE



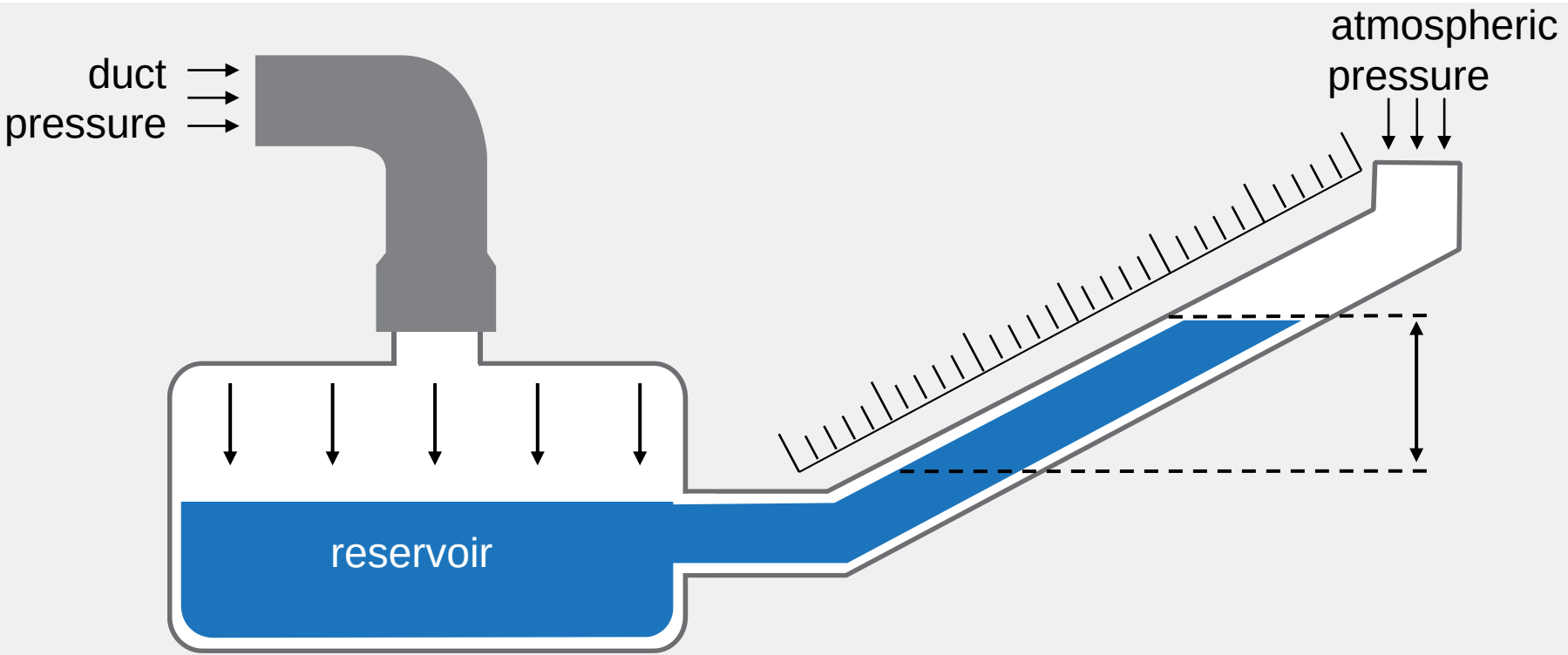
MEASURING PRESSURE



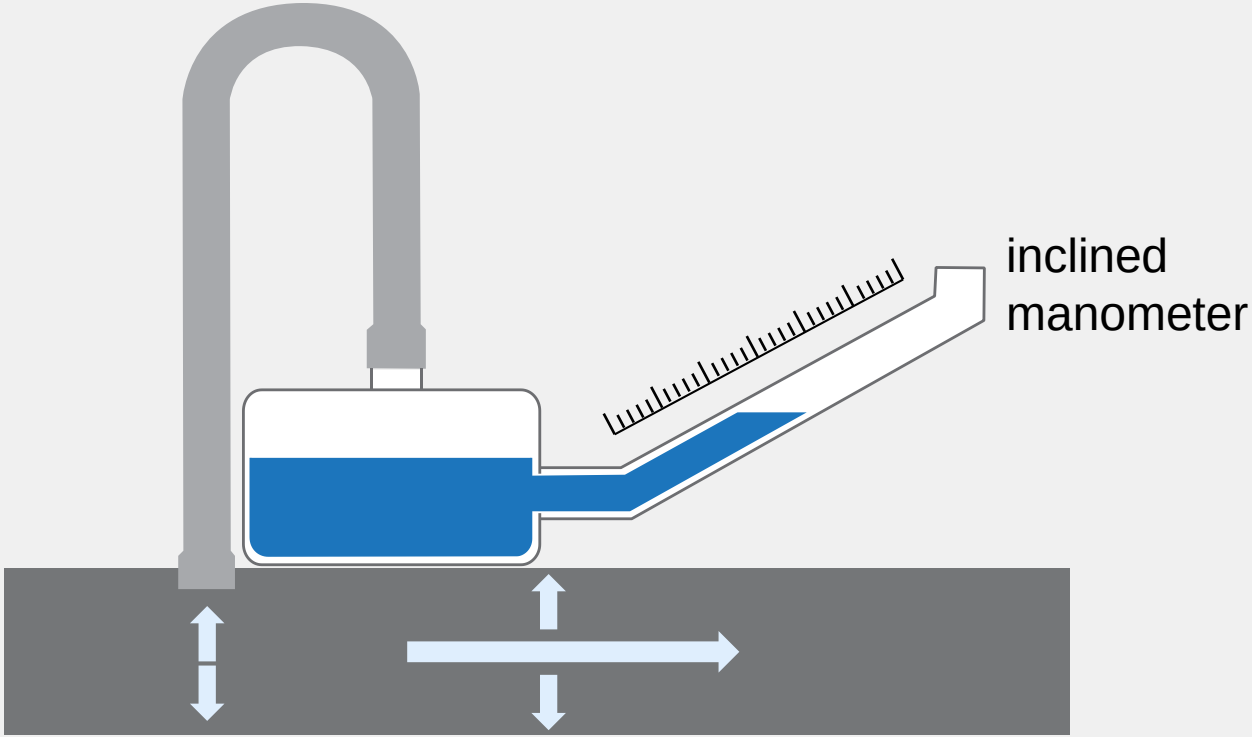
MEASURING PRESSURE



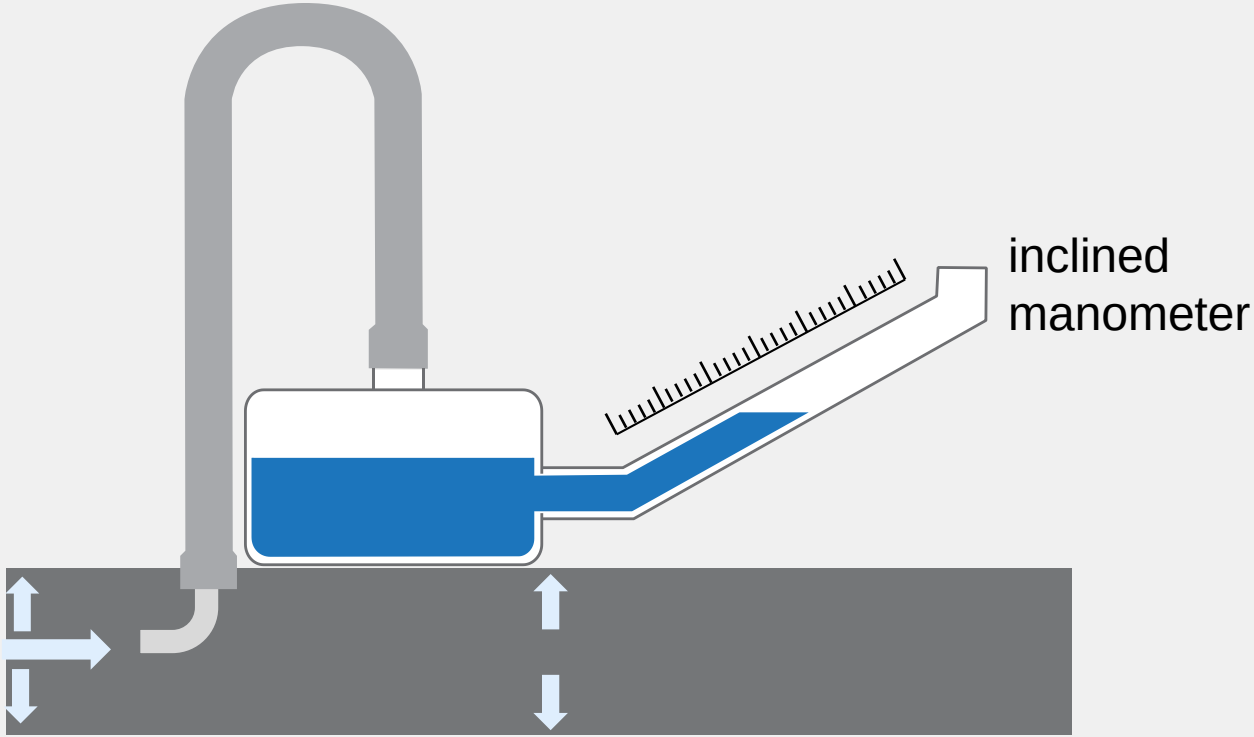
INCLINED MANOMETER



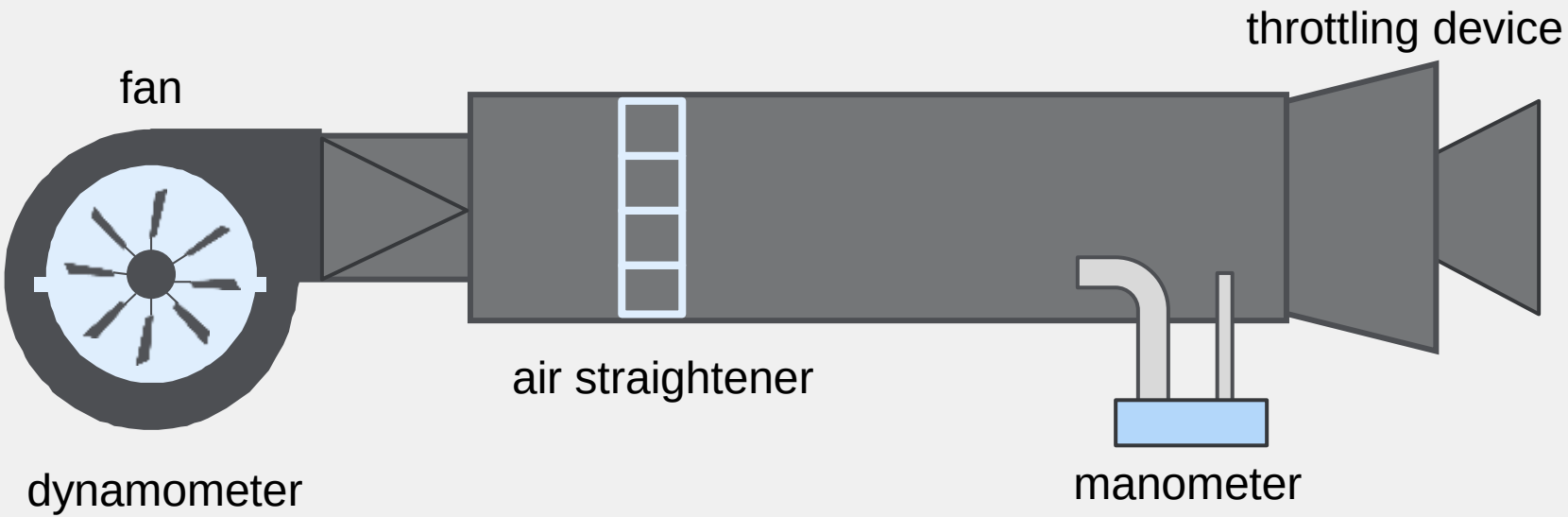
MEASURING STATIC PRESSURE



MEASURING TOTAL PRESSURE



FAN PERFORMANCE TEST



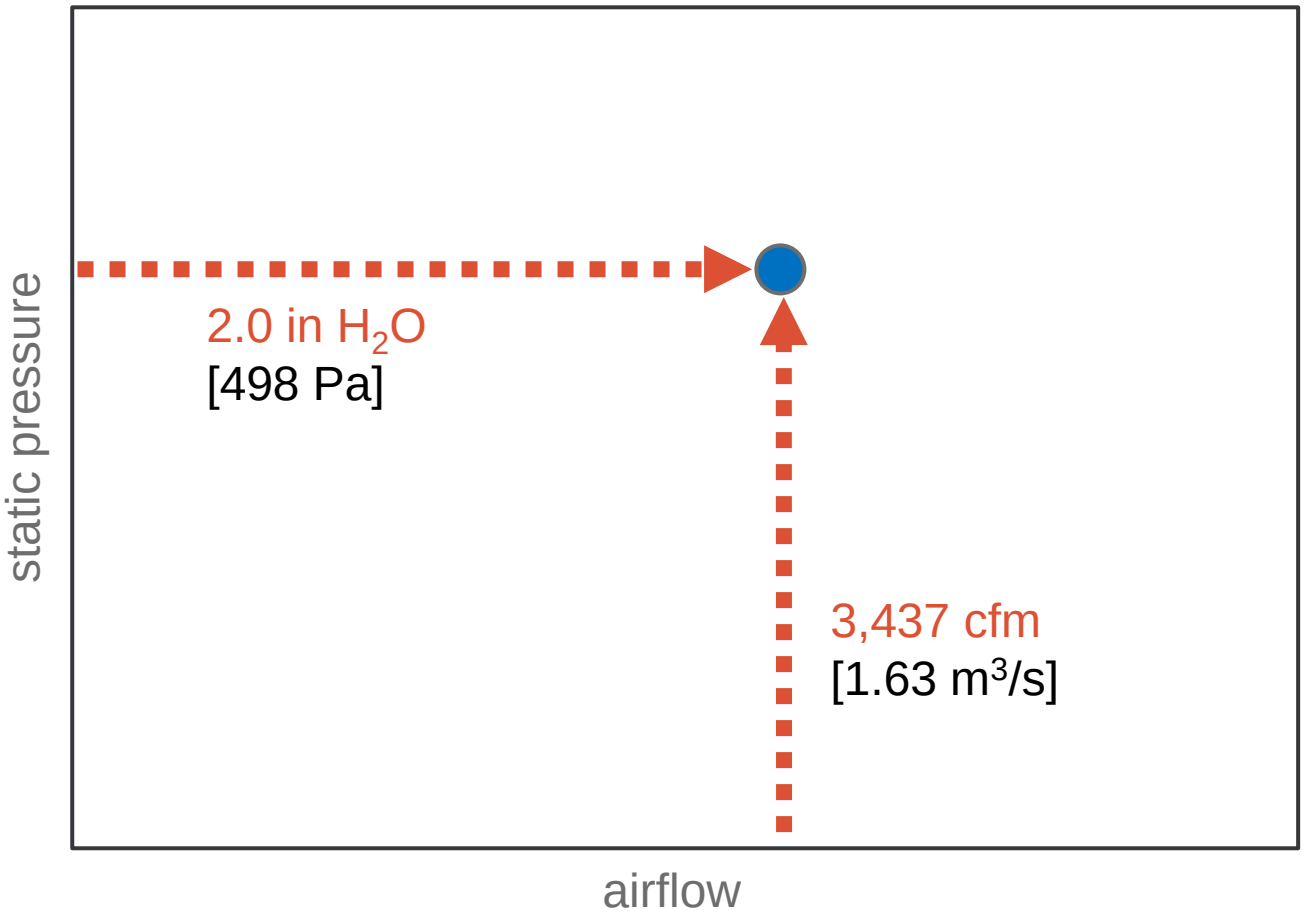
DETERMINING FAN AIRFLOW

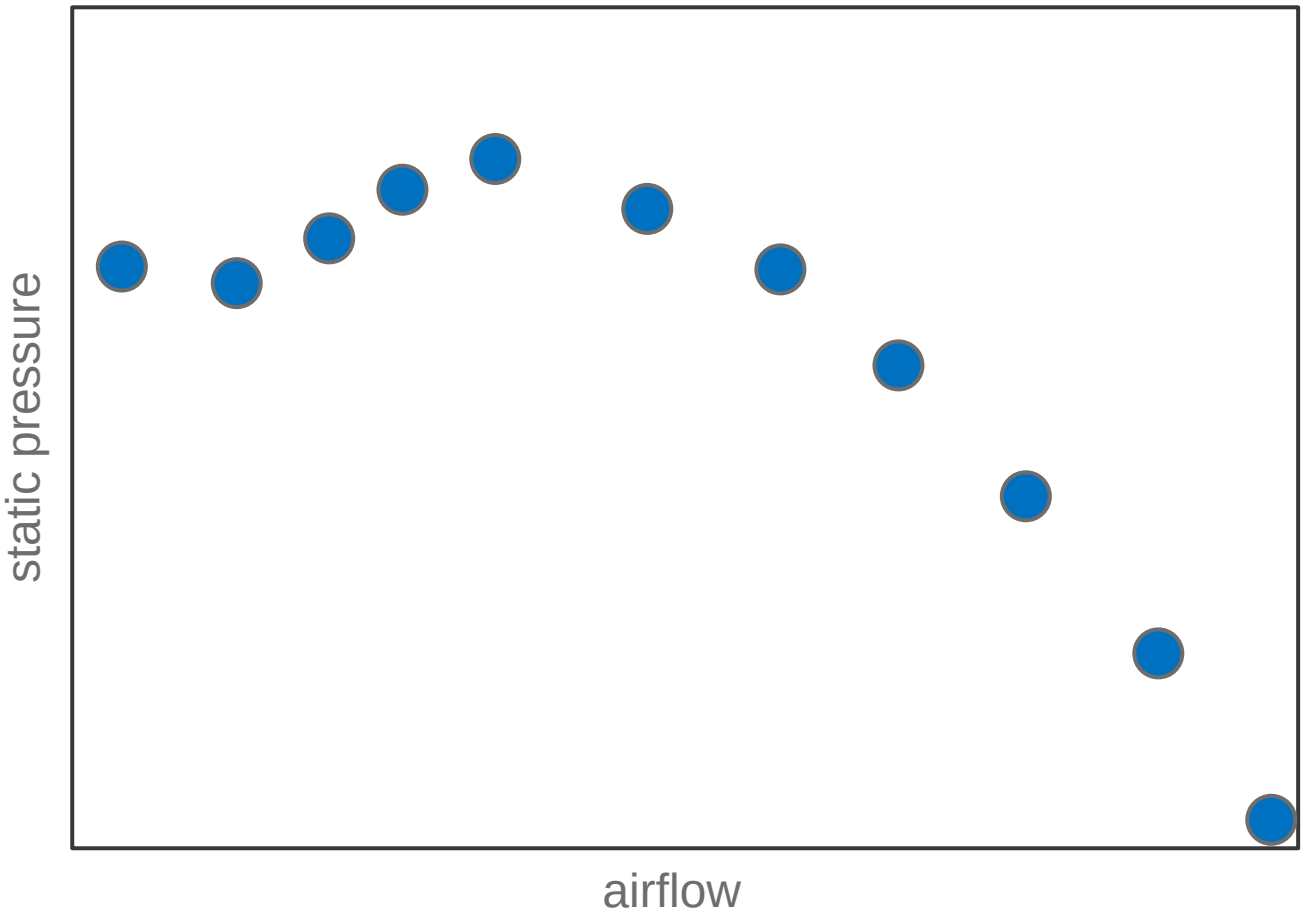
Velocity Pressure (P_v) = P_t – P_s

Velocity (V) = Constant $\times \sqrt{\frac{P_v}{\rho}}$

Airflow = Velocity $\times$ Fan Outlet Area

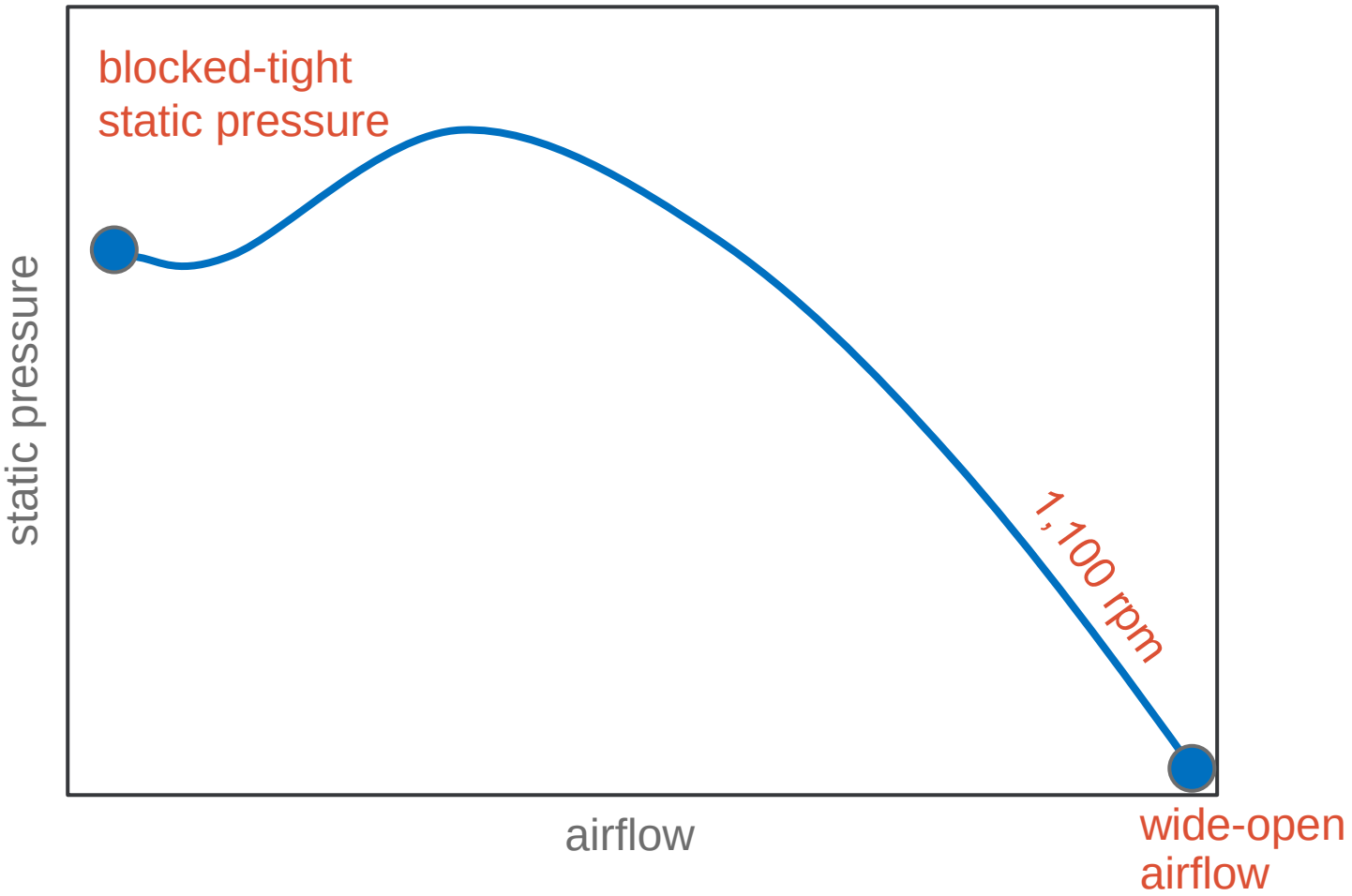
FAN CURVES



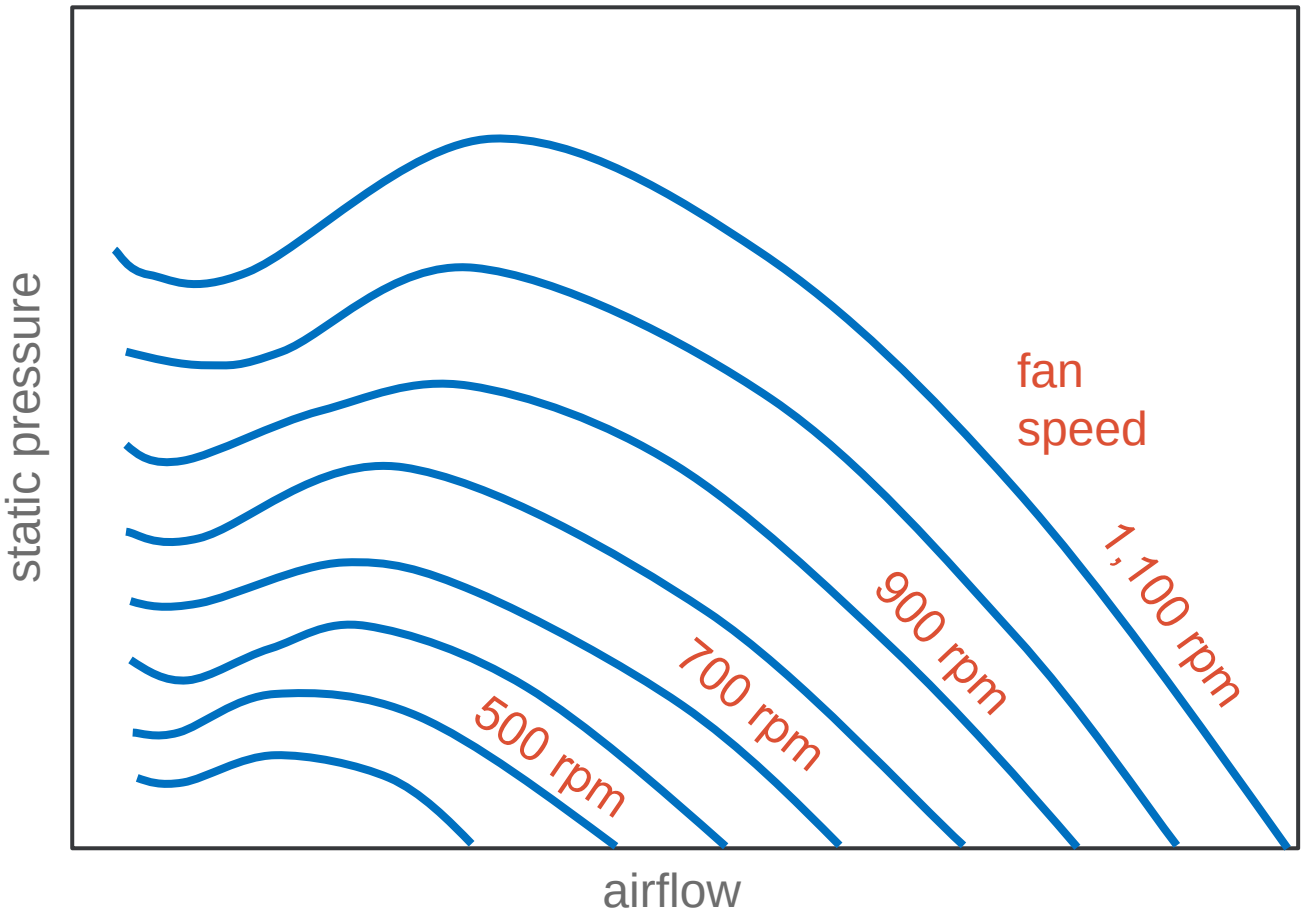


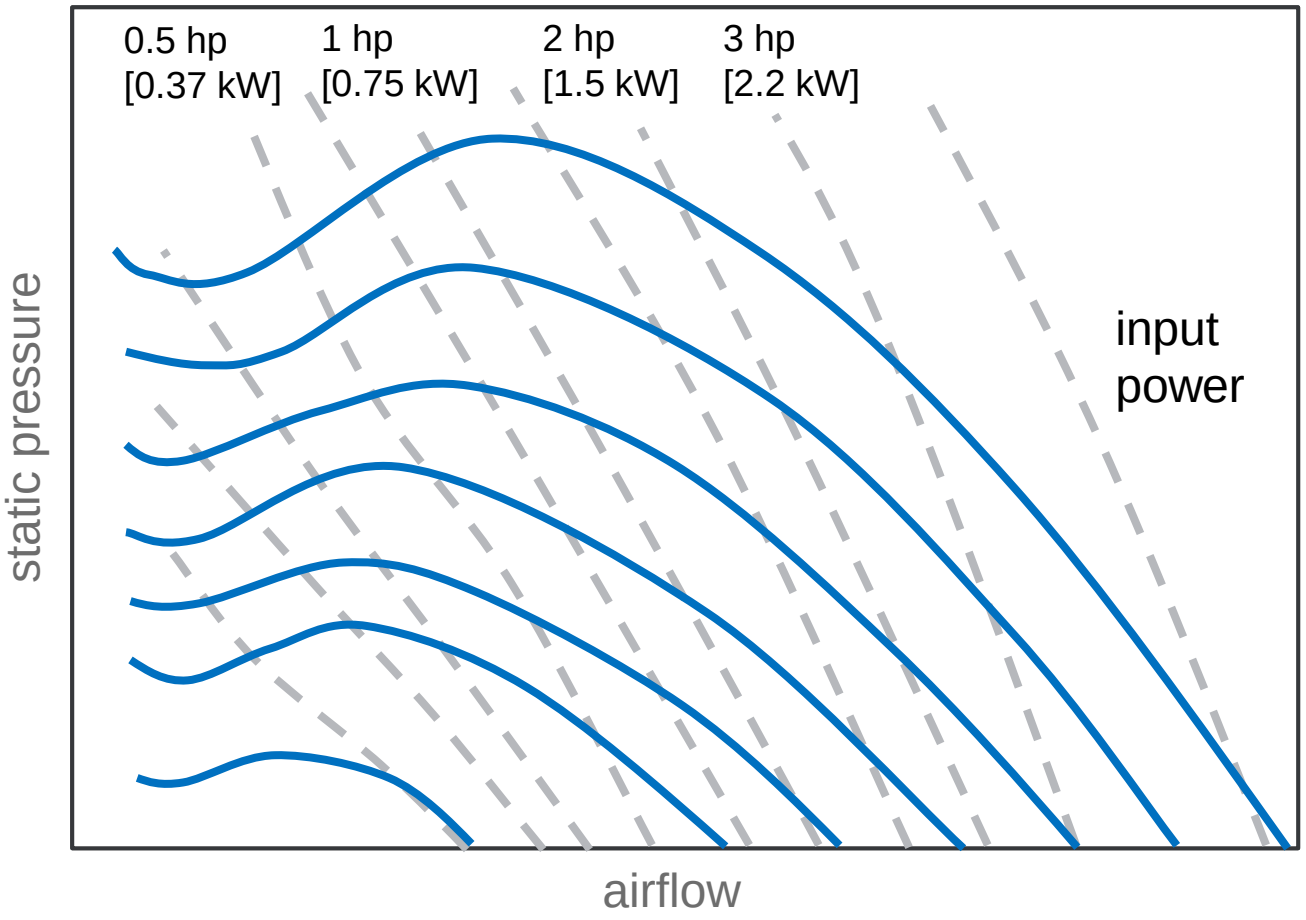
FAN CURVES

FAN CURVES


blocked-tight
static pressure
static pressure
1,100 rpm
airflow
wide-open
airflow

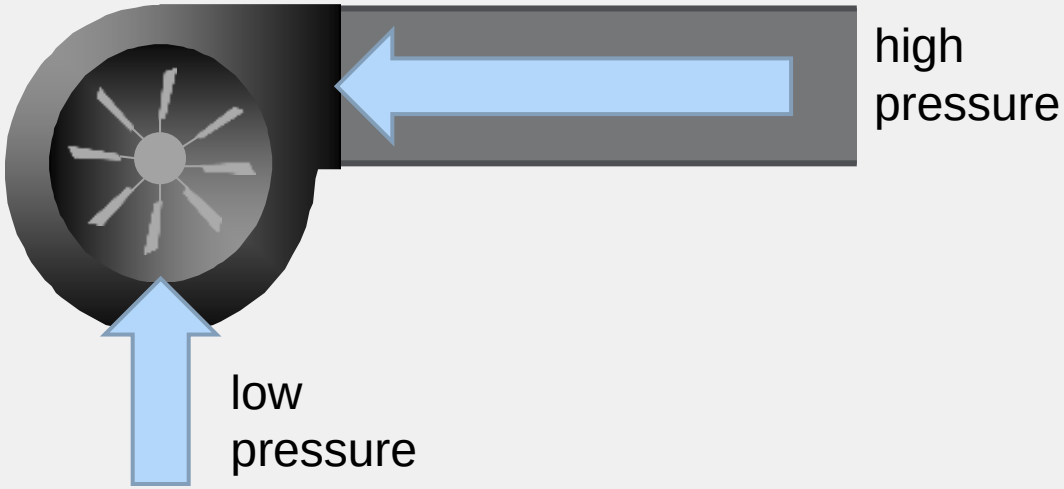
FAN CURVES

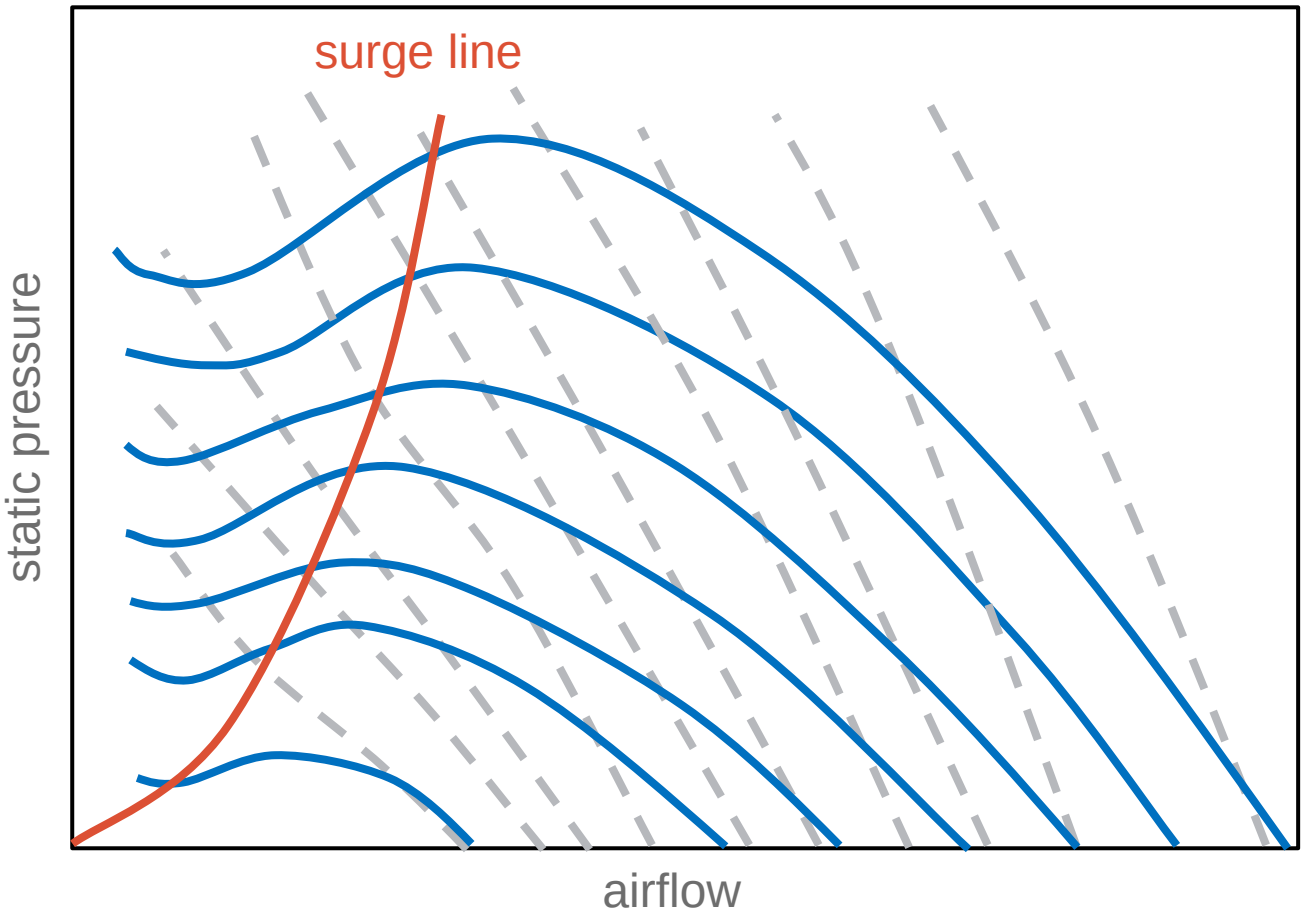

static pressure
airflow
fan
speed
1,100 rpm
900 rpm
700 rpm
500 rpm


0.5 hp
[0.37 kW]
1 hp
[0.75 kW]
2 hp
[1.5 kW]
3 hp
[2.2 kW]
input
power
static pressure
airflow

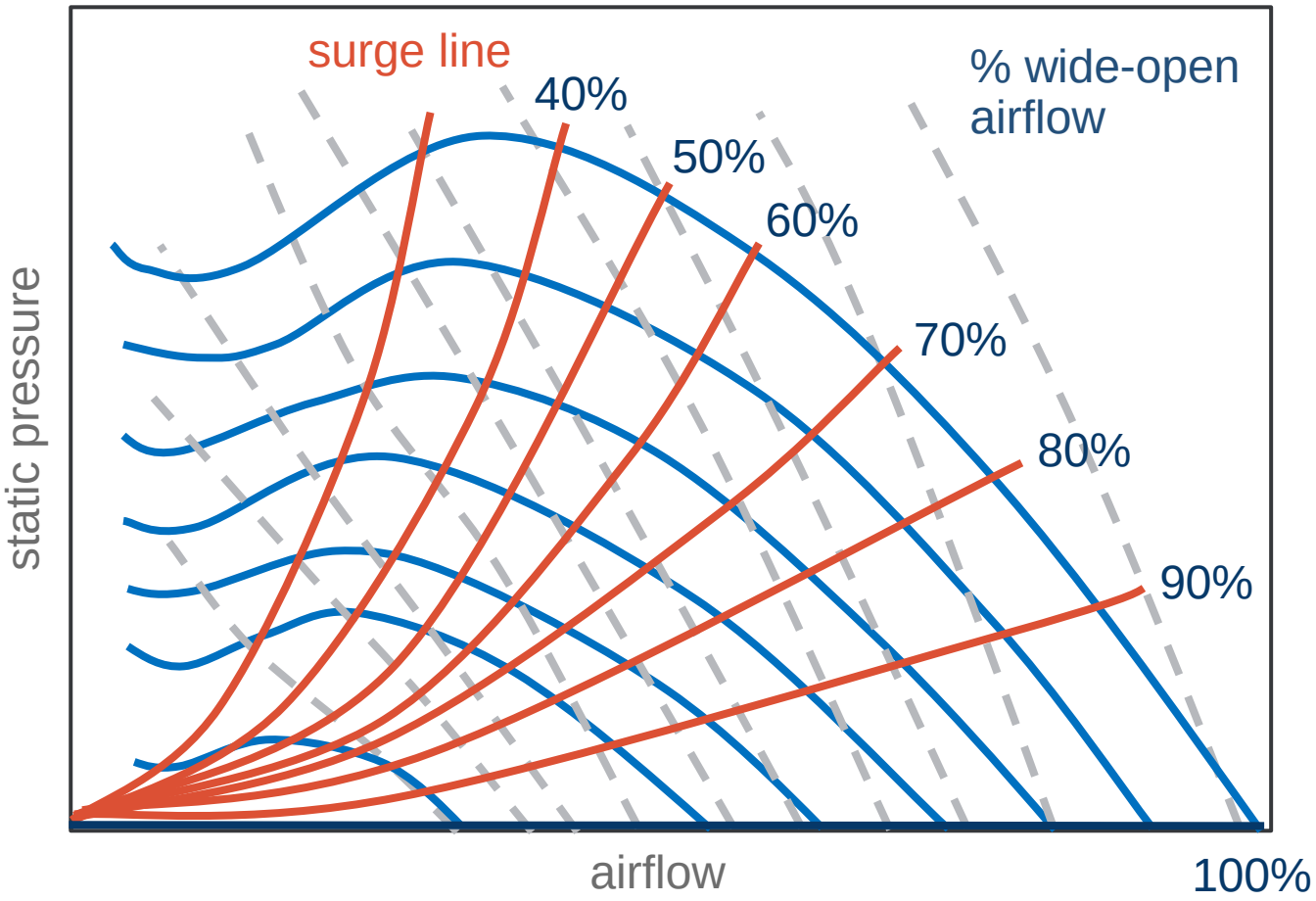
INPUT POWER

FAN SURGE





SURGE LINE



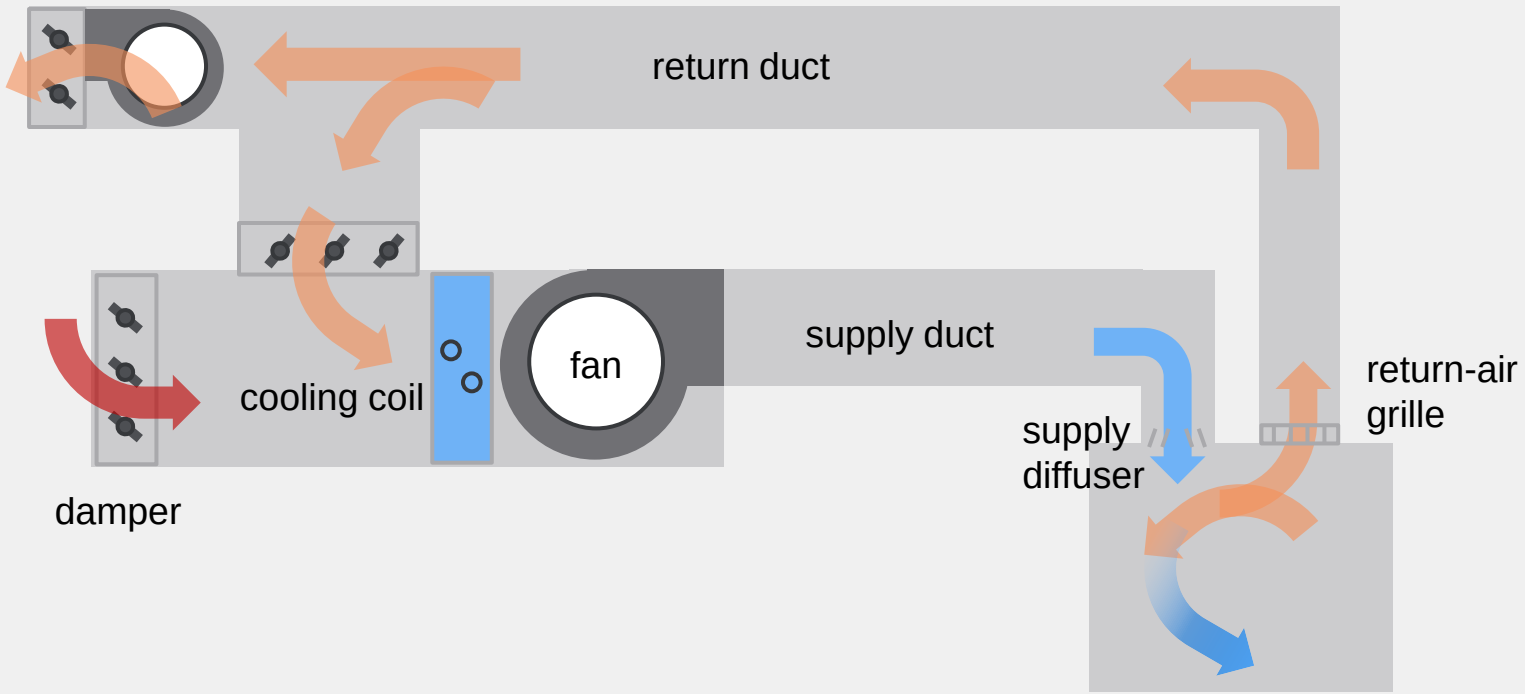
PERCENT WIDE-OPEN AIRFLOW

TABULAR PERFORMANCE DATA

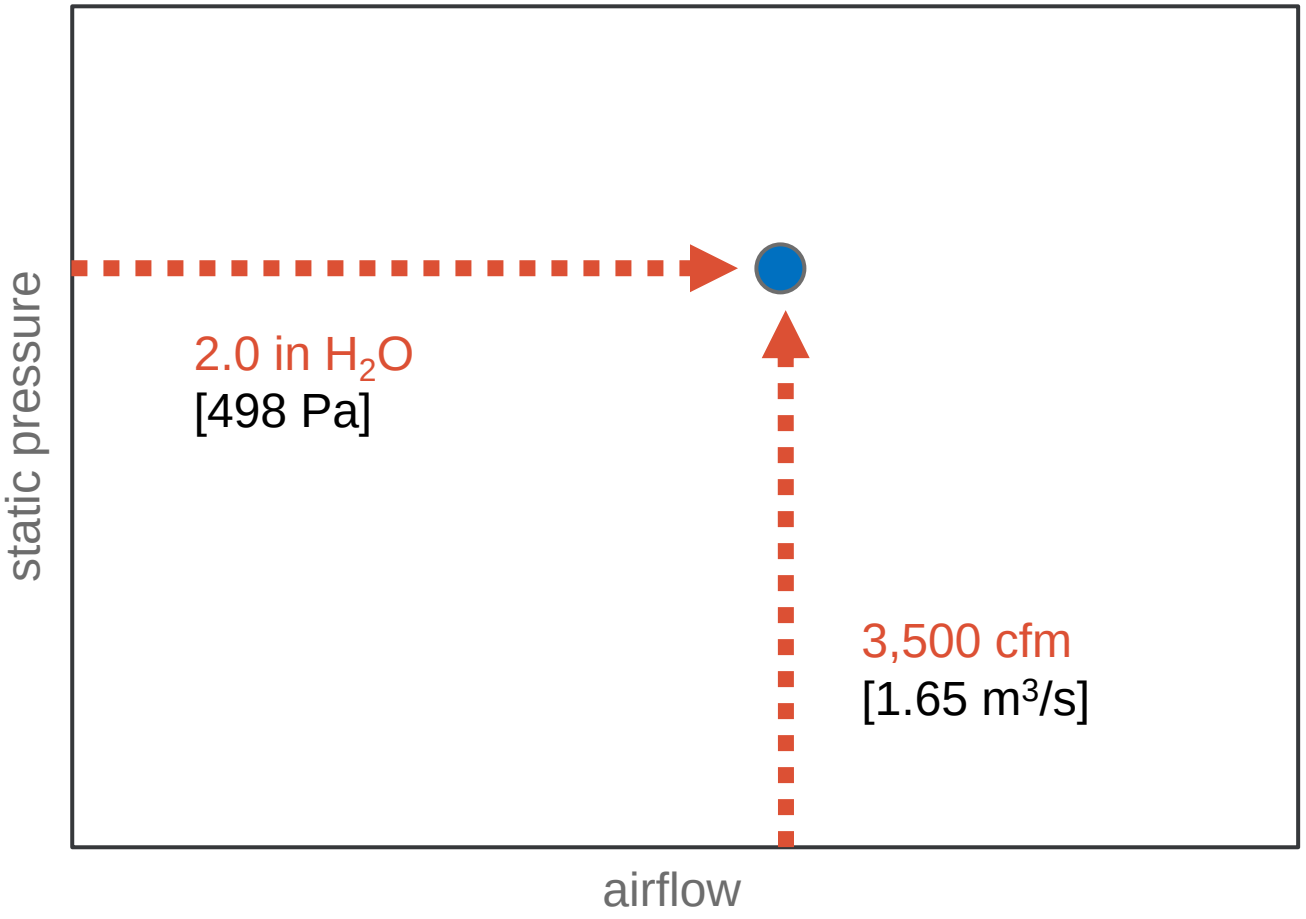
Std. Air Flow (CFM)	Outlet Velocity (ft/min)	Total Static Pressure (in. wg)															
		0.5		1.0		1.5		2.0		2.5		3.0		3.5		4.0	
		RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP
5950	1714	423	1.22	536	1.75	643	2.35	734	2.96	818	3.62	903	4.40	983	5.24	1054	6.21
6800	1959	451	1.64	555	2.22	651	2.89	742	3.56	821	4.25	895	4.98	971	5.81	1044	6.72
7650	2203	479	2.15	576	2.81	664	3.49	750	4.27	831	5.03	901	5.79	969	6.59	1033	7.44
8500	2448	510	2.78	601	3.52	684	4.24	760	5.04	837	5.91	912	6.76	976	7.59	1037	8.45
9350	2693	542	3.53	629	4.34	705	5.14	777	5.93	848	6.87	917	7.82	986	8.76	1047	9.69
10200	2938	575	4.39	657	5.30	730	6.19	799	7.04	863	7.92	928	8.98	992	10.01	1055	11.03

Std. Air Flow (L/S)	Outlet Velocity (m/s)	Total Static Pressure (Pa.)															
		124.55		249.1		373.65		498.2		622.75		747.3		871.85		996.4	
		RPM	kW	RPM	kW	RPM	kW	RPM	kW	RPM	kW	RPM	kW	RPM	kW	RPM	kW
2808	8.71	423	0.91	536	1.31	643	1.75	734	2.20	818	2.70	903	3.28	983	3.91	1054	4.63
3210	9.95	451	1.22	555	1.65	651	2.15	742	2.66	821	3.17	895	3.71	971	4.33	1044	5.01
3611	11.19	479	1.60	576	2.10	664	2.60	750	3.19	831	3.75	901	4.32	969	4.92	1033	5.55
4012	12.44	510	2.07	601	2.62	684	3.16	760	3.76	837	4.41	912	5.04	976	5.66	1037	6.30
4413	13.68	542	2.63	629	3.24	705	3.83	777	4.43	848	5.13	917	5.83	986	6.53	1047	7.22
4814	14.92	575	3.28	657	3.95	730	4.61	799	5.25	863	5.90	928	6.70	992	7.47	1055	8.23

SYSTEM RESISTANCE



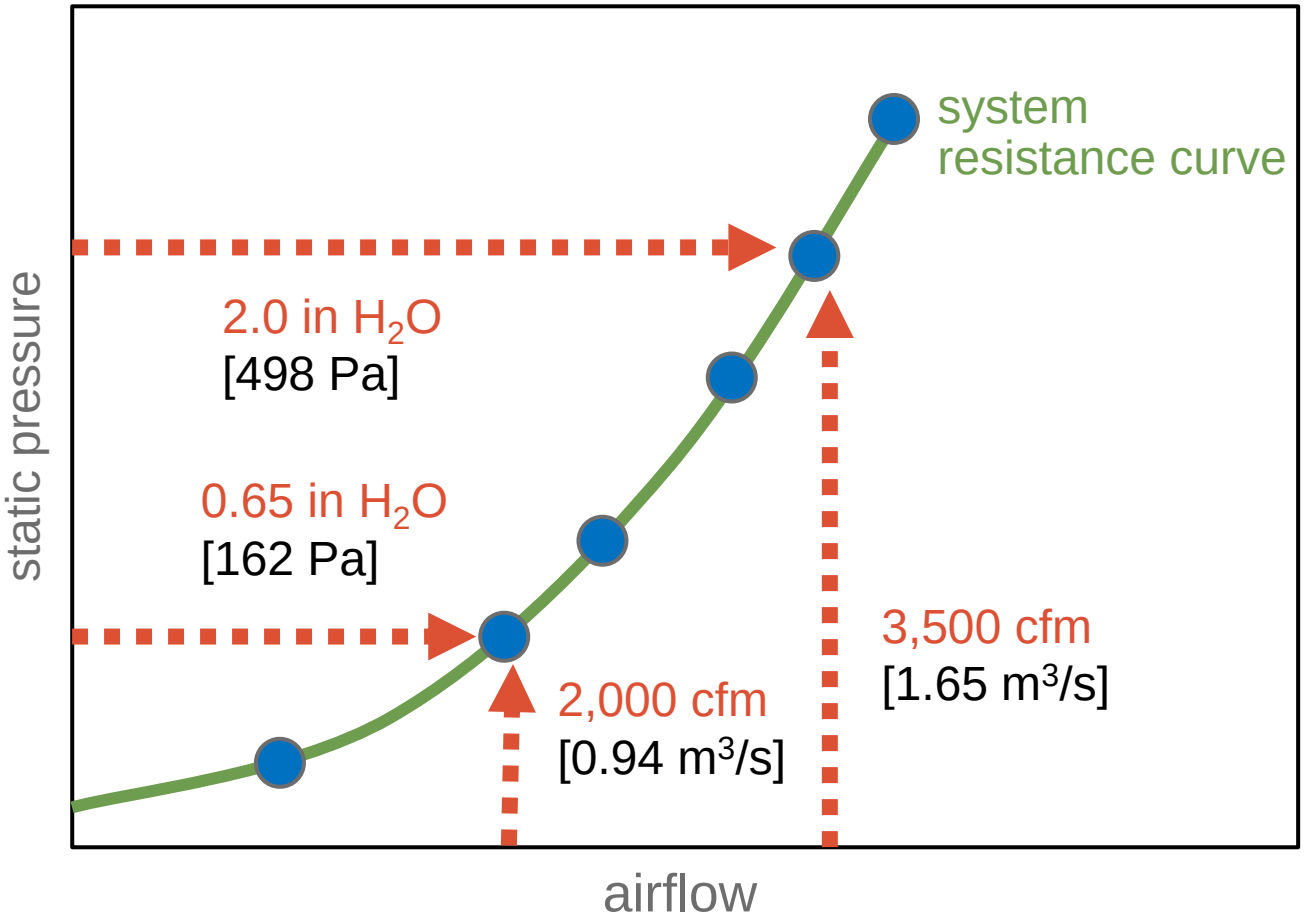
SYSTEM RESISTANCE CURVE

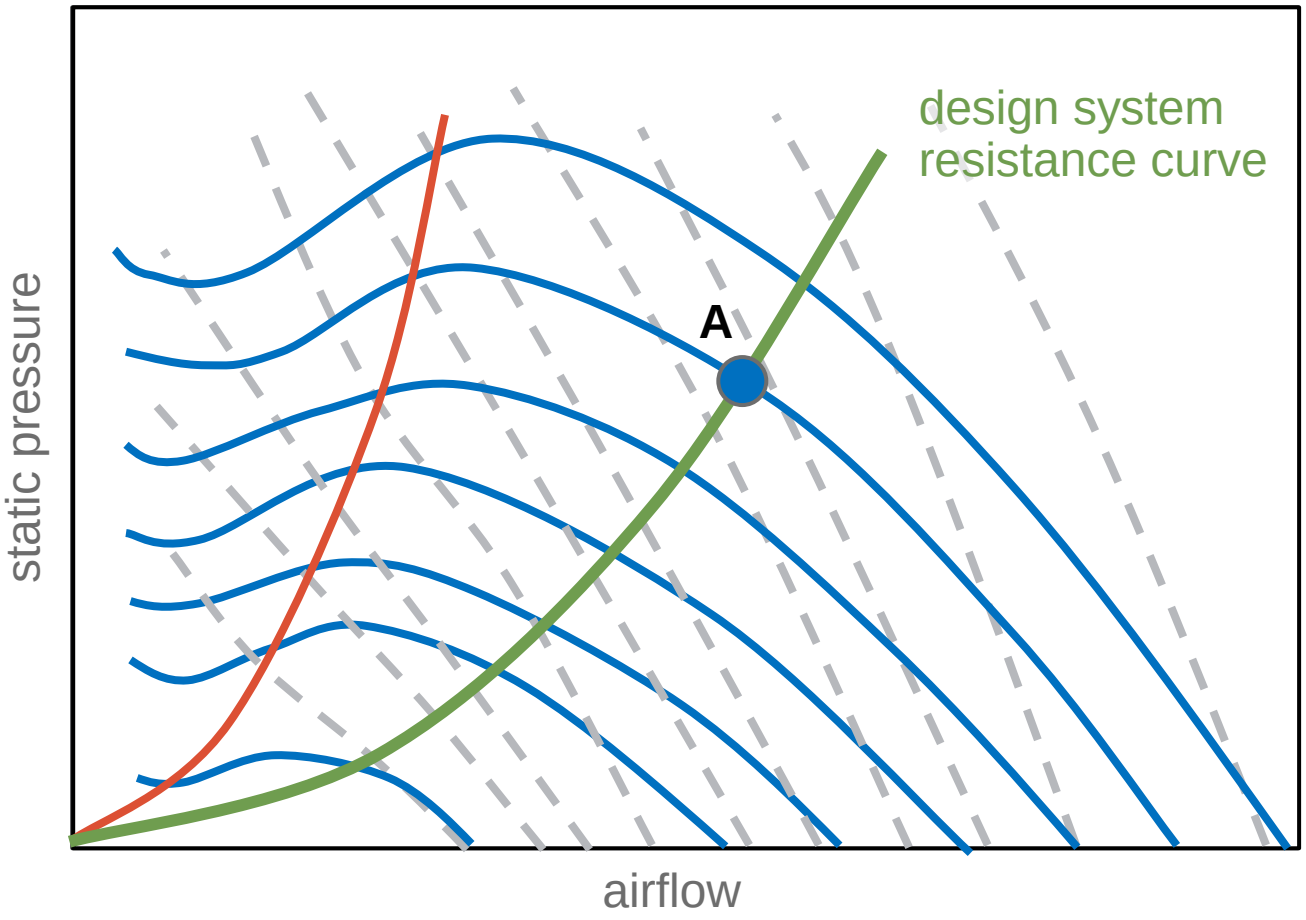


SYSTEM RESISTANCE CURVE

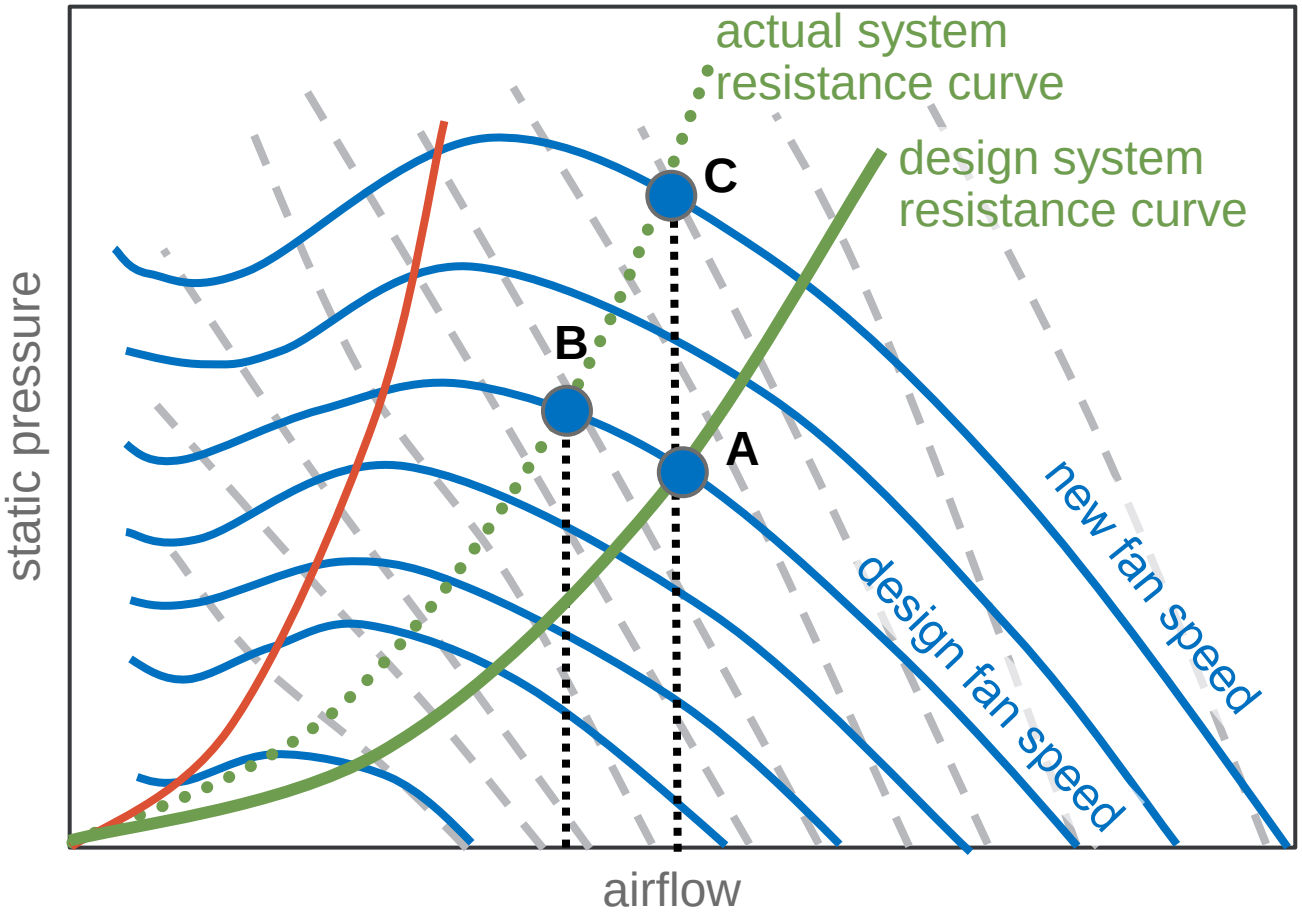
$$\frac{\text{Static Pressure}_2}{\text{Static Pressure}_1} = \left(\frac{\text{Airflow}_2}{\text{Airflow}_1}\right)^2$$

SYSTEM RESISTANCE CURVE

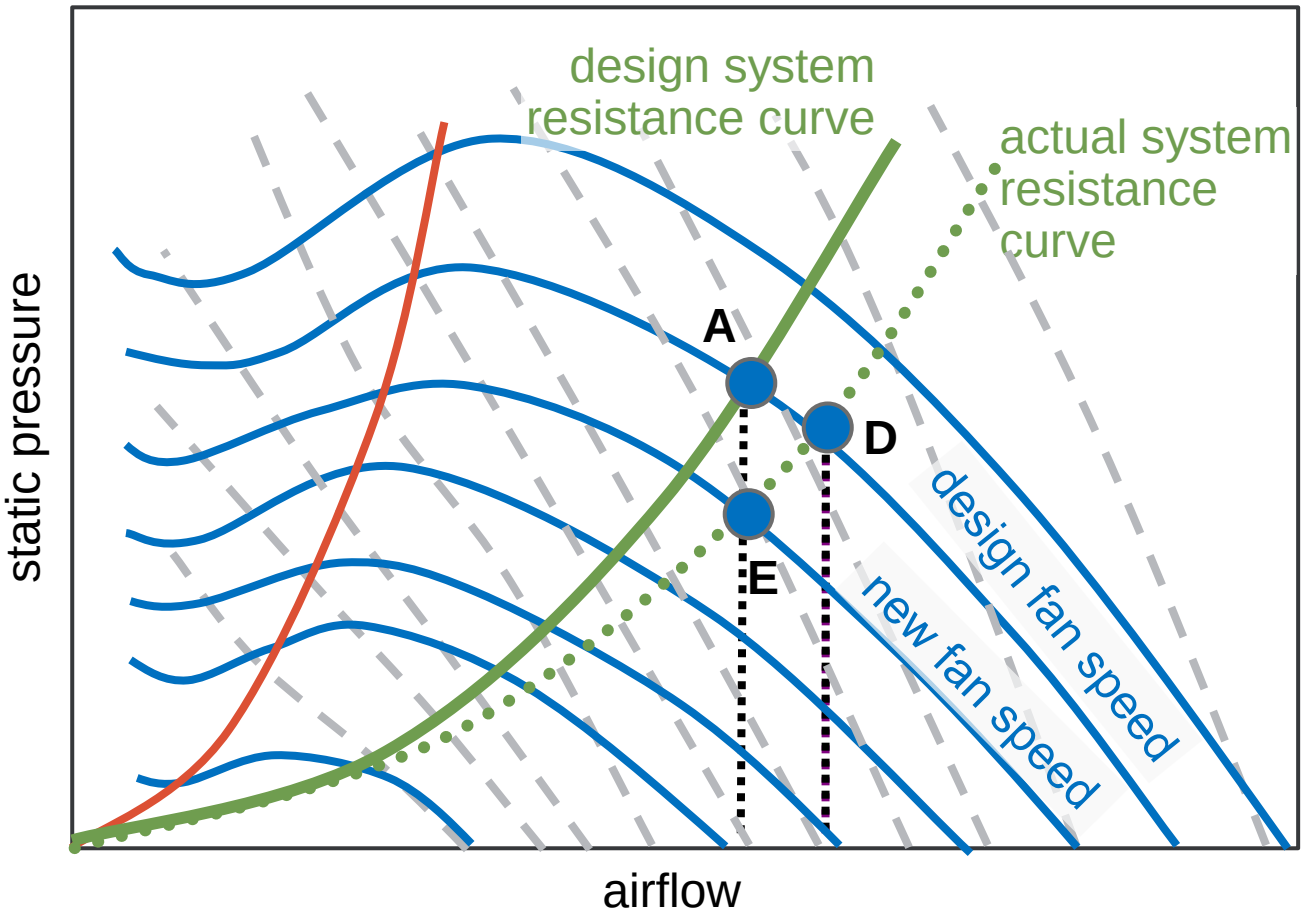




FAN-SYSTEM INTERACTION



HIGHER SYSTEM RESISTANCE



LOWER SYSTEM RESISTANCE

STATIC EFFICIENCY

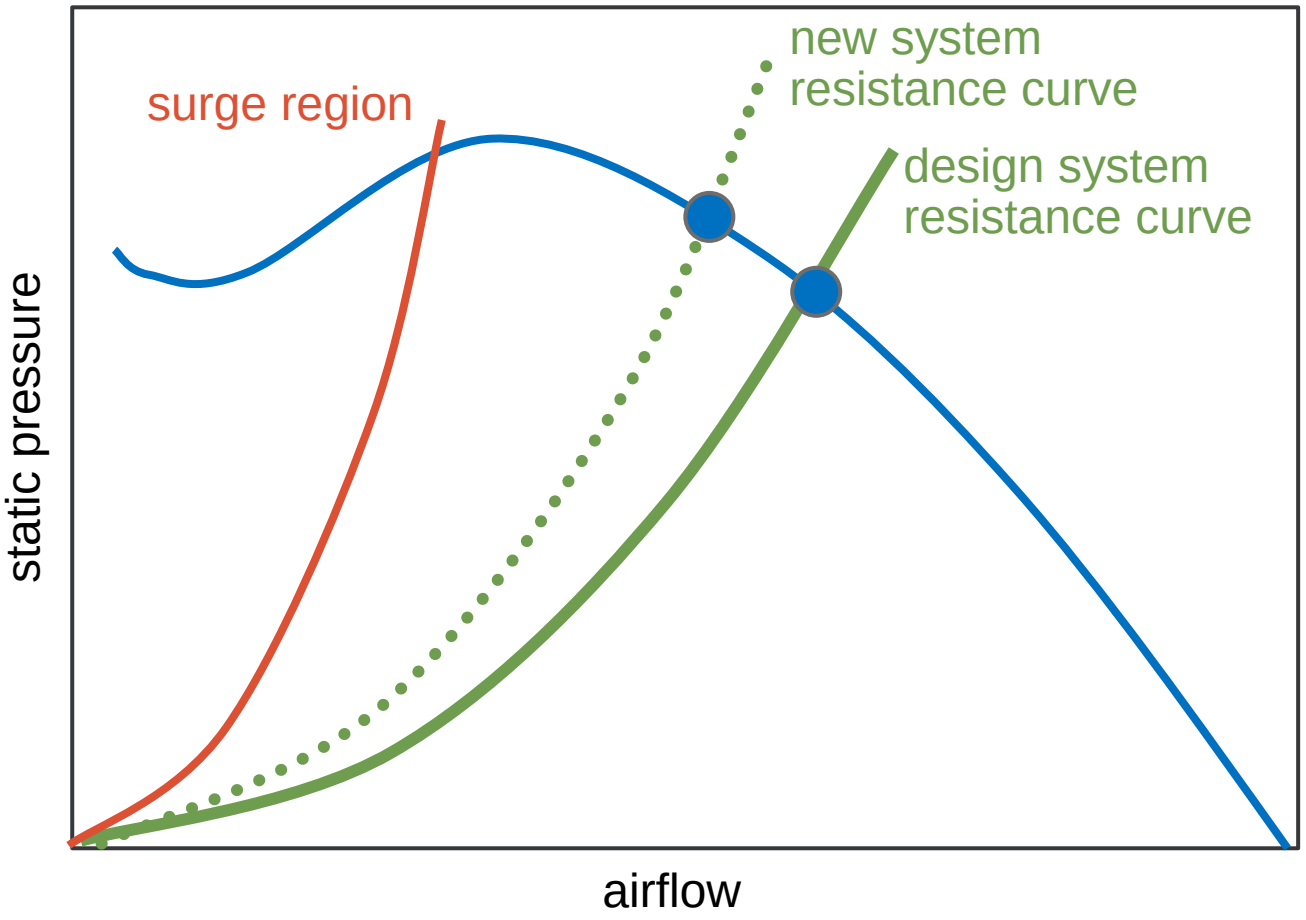
$$\text{Static Efficiency (SE)} = \frac{\text{Power Out}}{\text{Power In}}$$

$$\text{SE} = \frac{\text{Airflow} \times \text{Static Pressure}}{\text{Constant} \times \text{Input Power}}$$

STATIC EFFICIENCY

$$SE = \frac{3{,}500 \text{ cfm} \times 2.0 \text{ in } H_2O}{6{,}343 \times 2.0 \text{ hp}} = 55\%$$

$$\left[SE = \frac{1.65 \text{ m}^3/\text{s} \times 498 \text{ Pa}}{1{,}000 \times 1.5 \text{ kW}} = 55\% \right]$$



SYSTEM RESISTANCE CURVE

VARIABLE-PITCH VANEAXIAL FAN

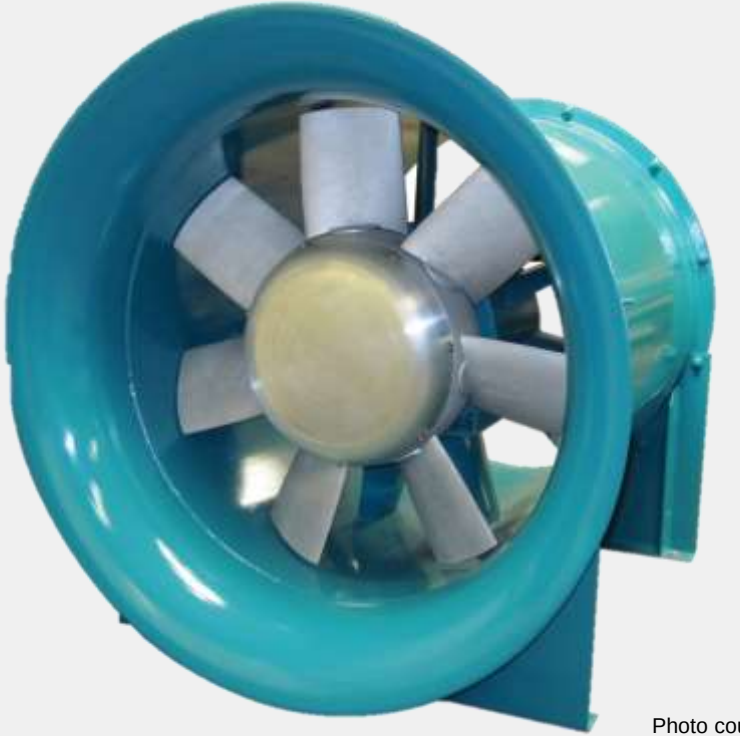
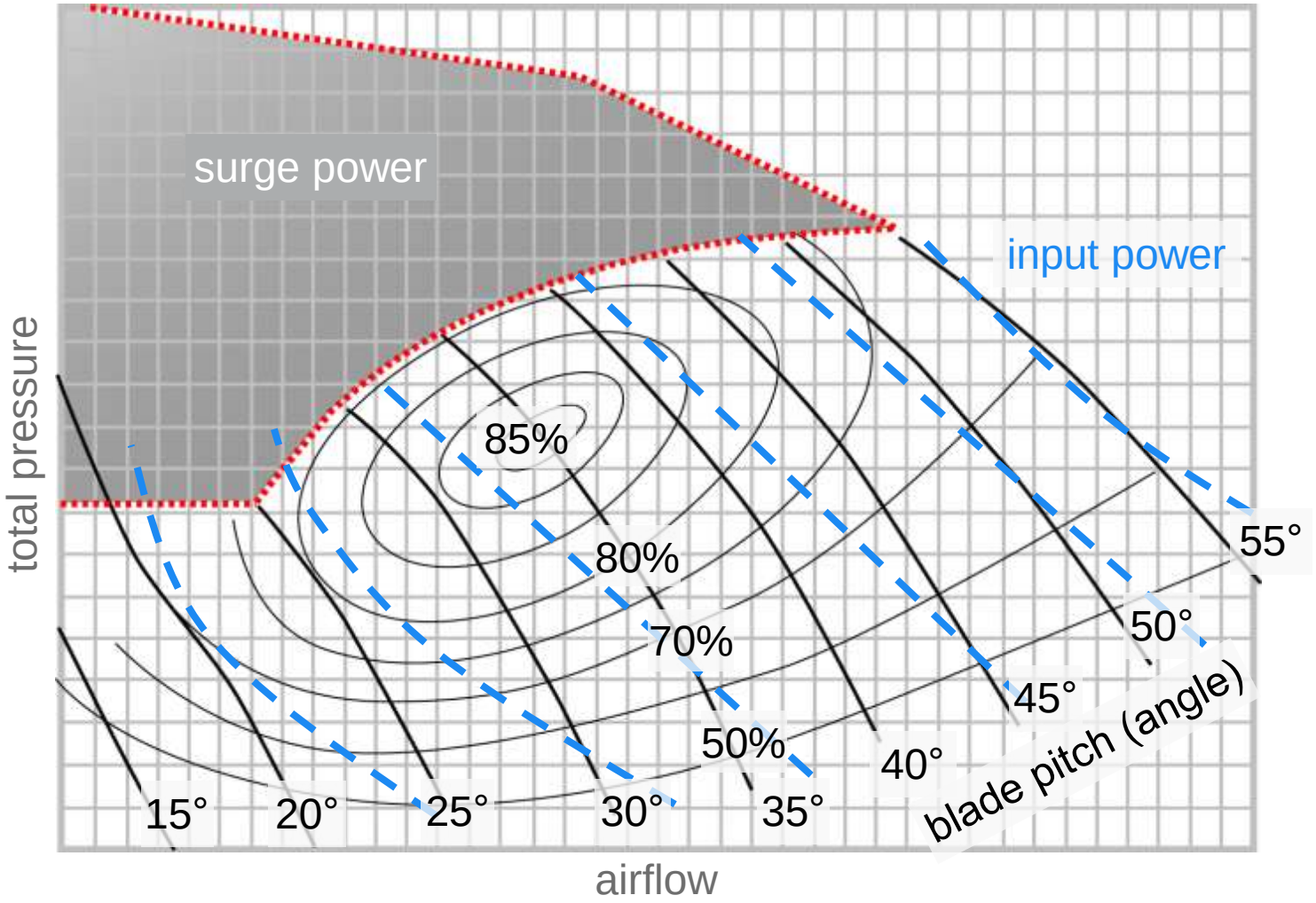
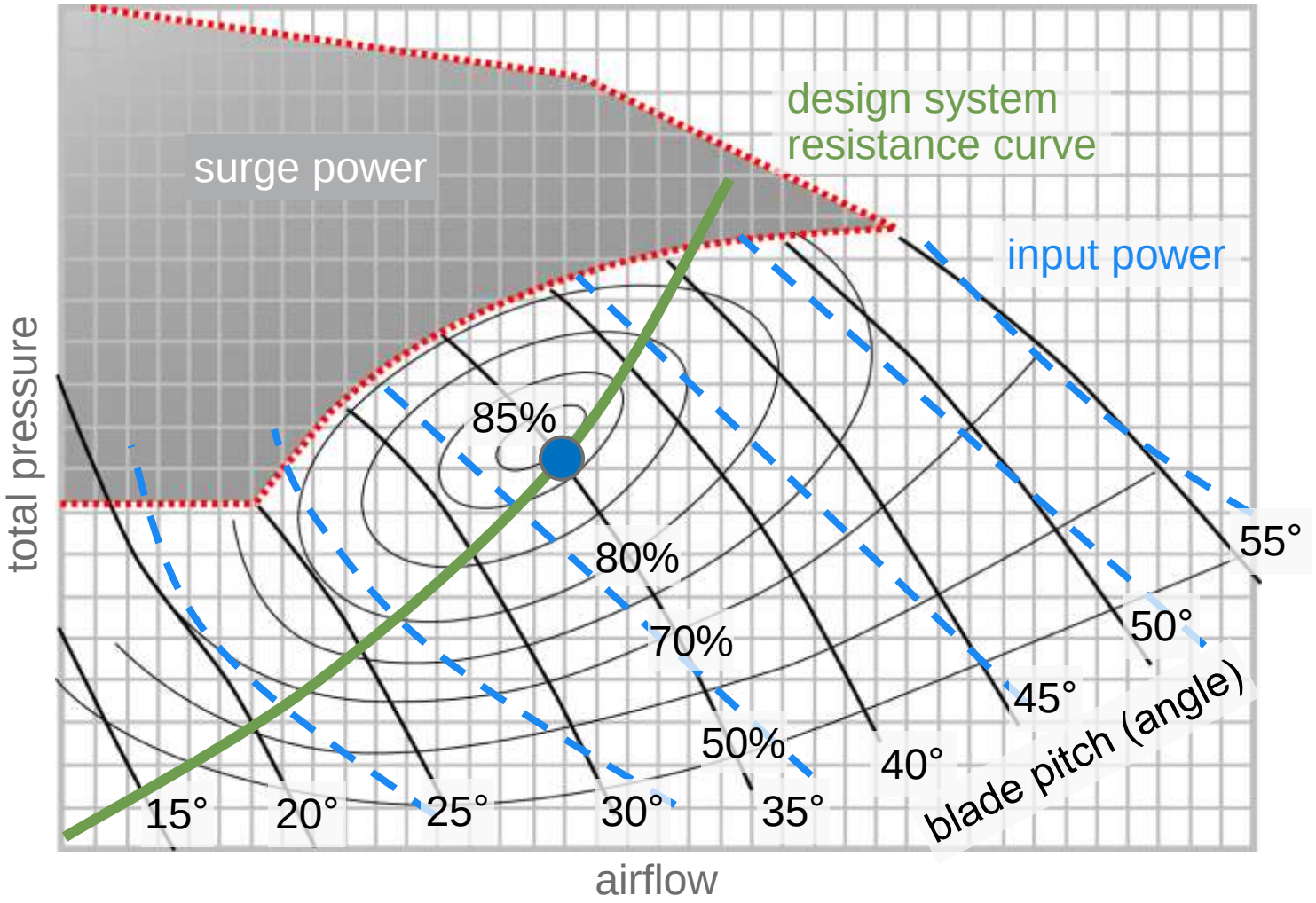


Photo courtesy of Twin City Fan & Blower



VPVA FAN CURVES



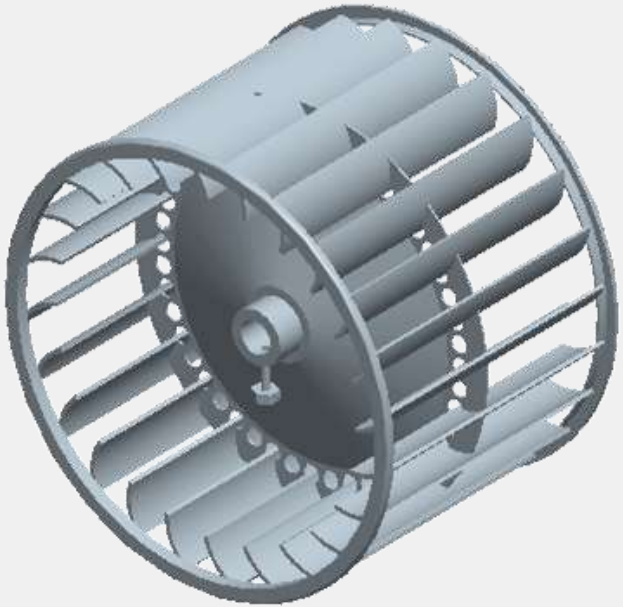
VPVA FAN CURVES

period 2

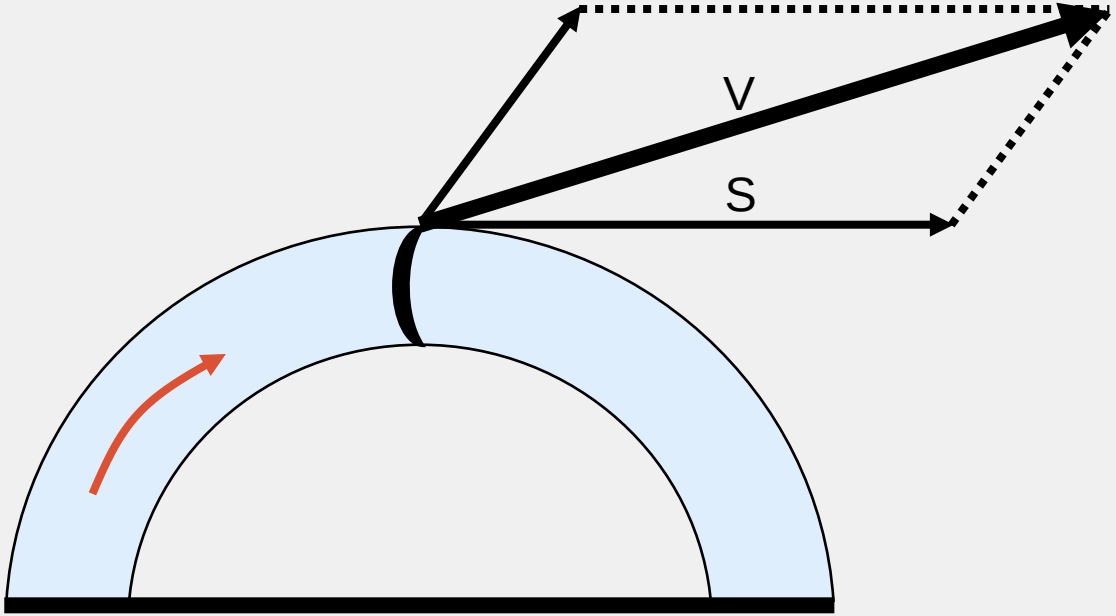
FAN TYPES

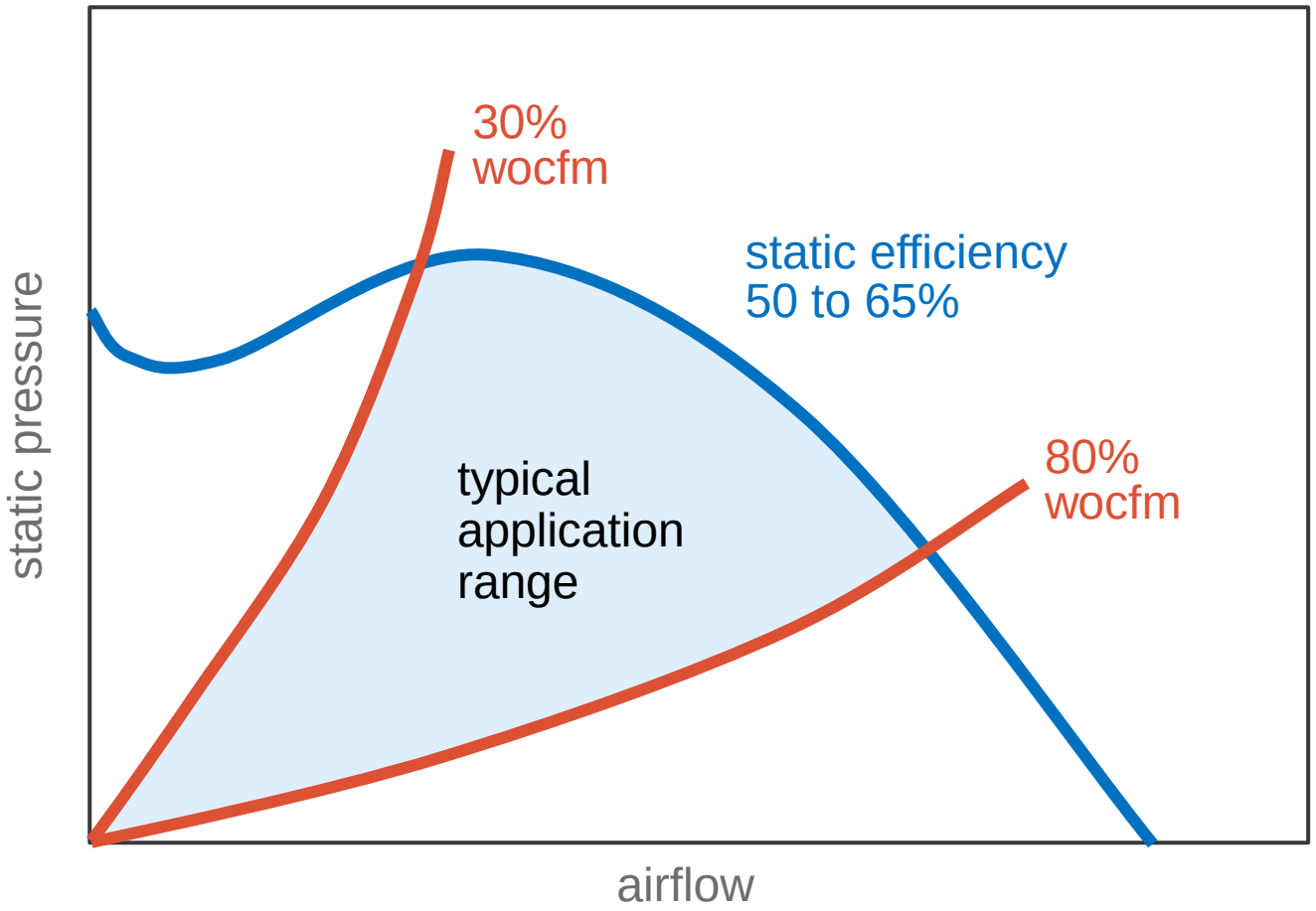
CENTRIFUGAL FAN

FORWARD CURVED FAN

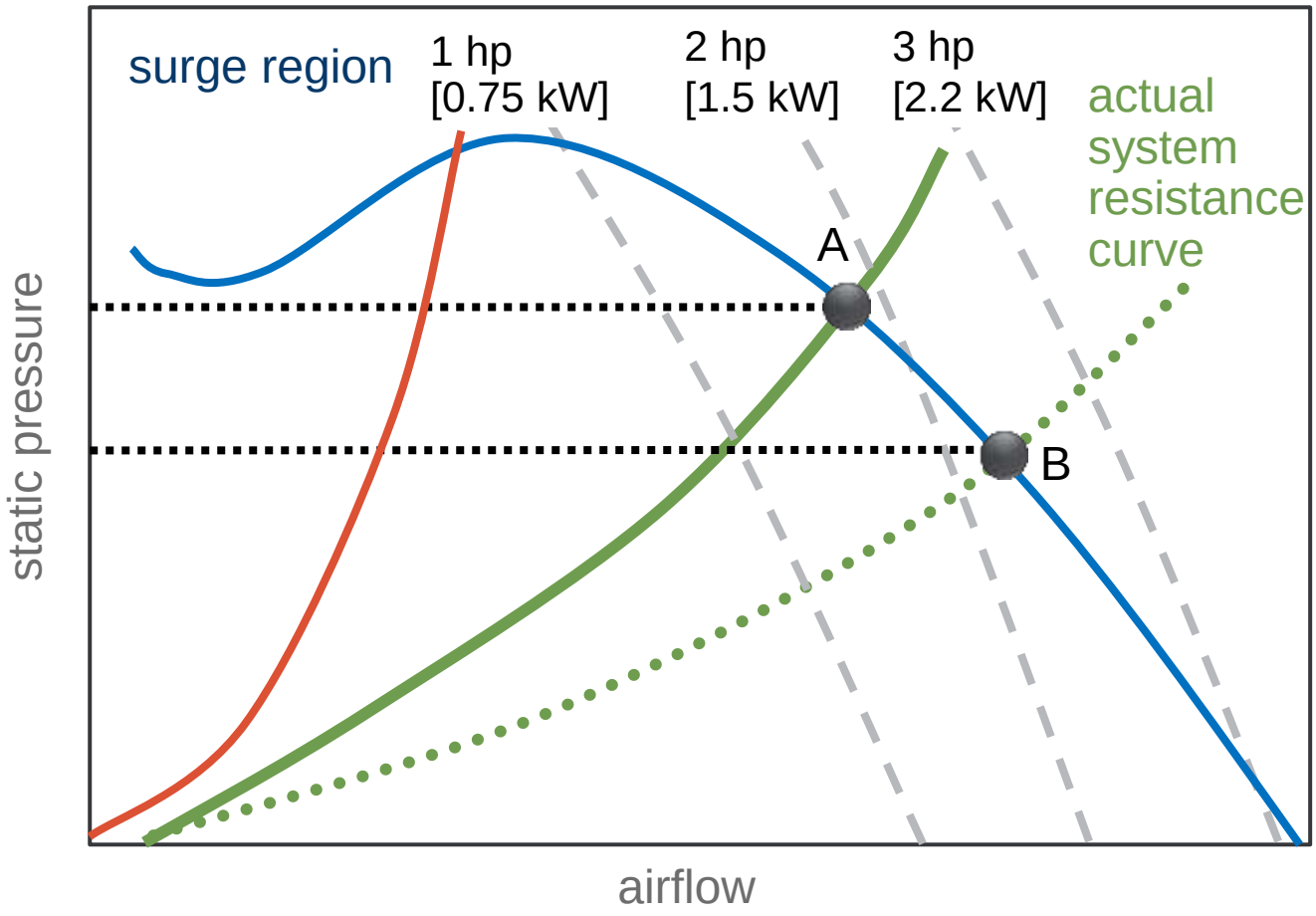


FORWARD CURVED FAN



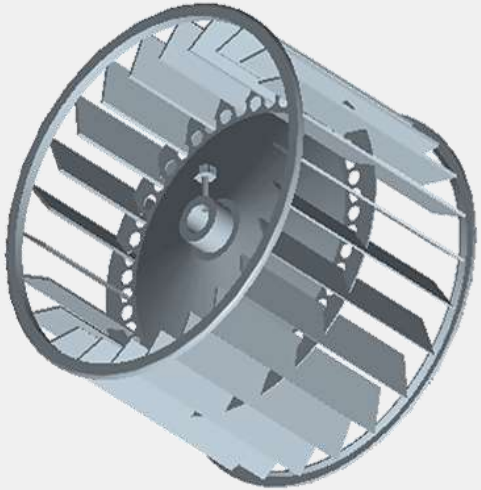


FORWARD CURVED FAN

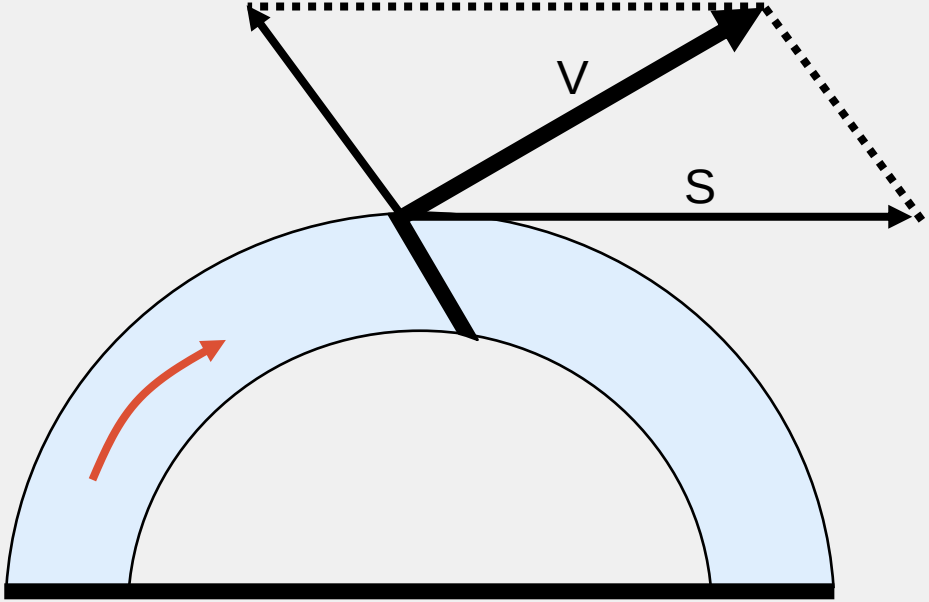


FORWARD CURVED FAN

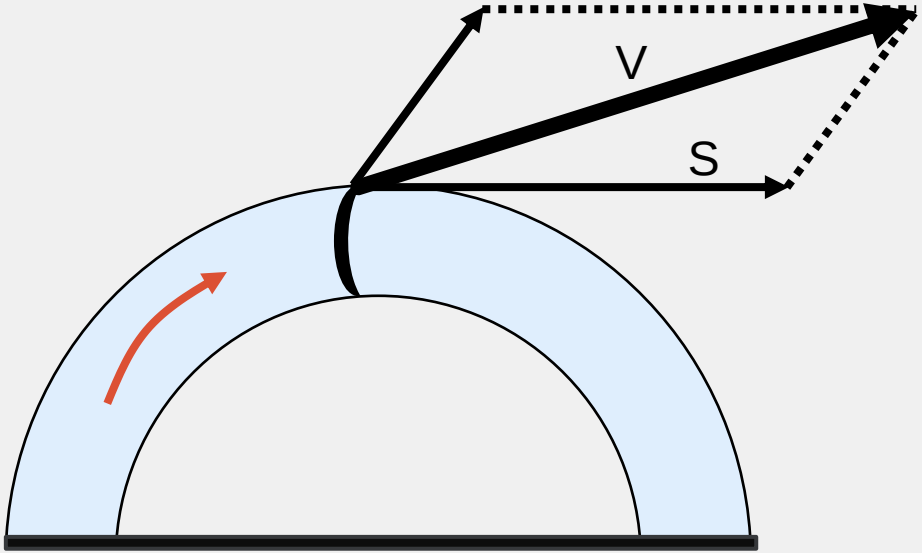
BACKWARD INCLINED FAN

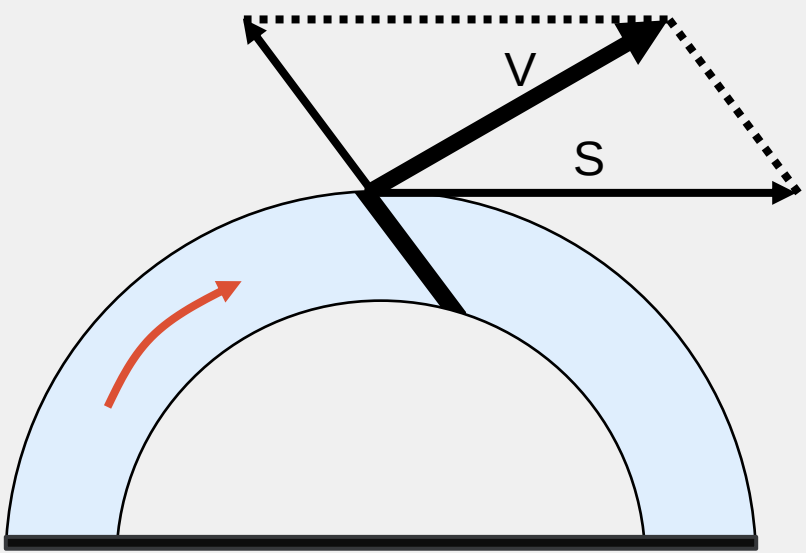


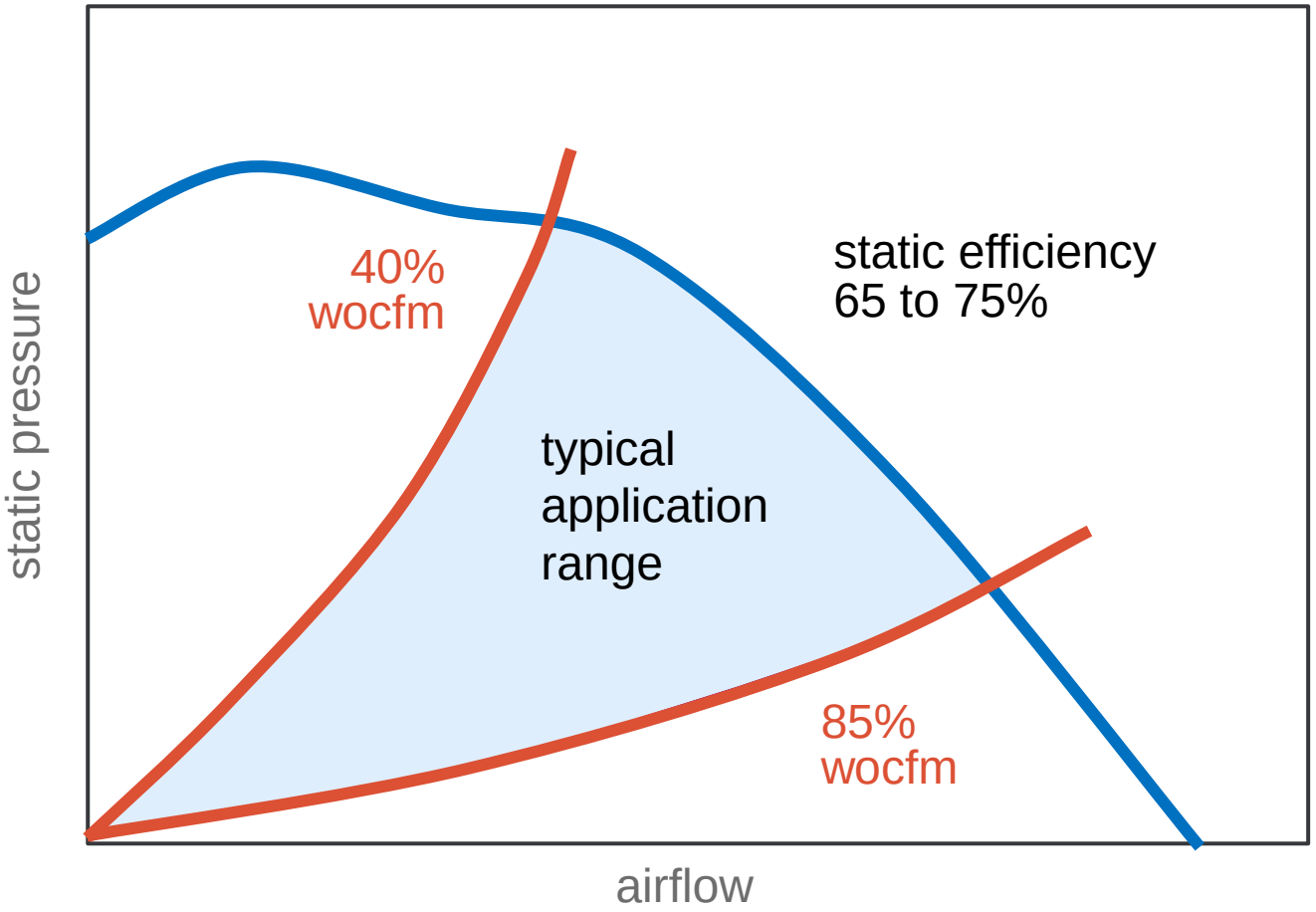
BACKWARD INCLINED FAN



FORWARD CURVED VS. BACKWARD INCLINED FANS

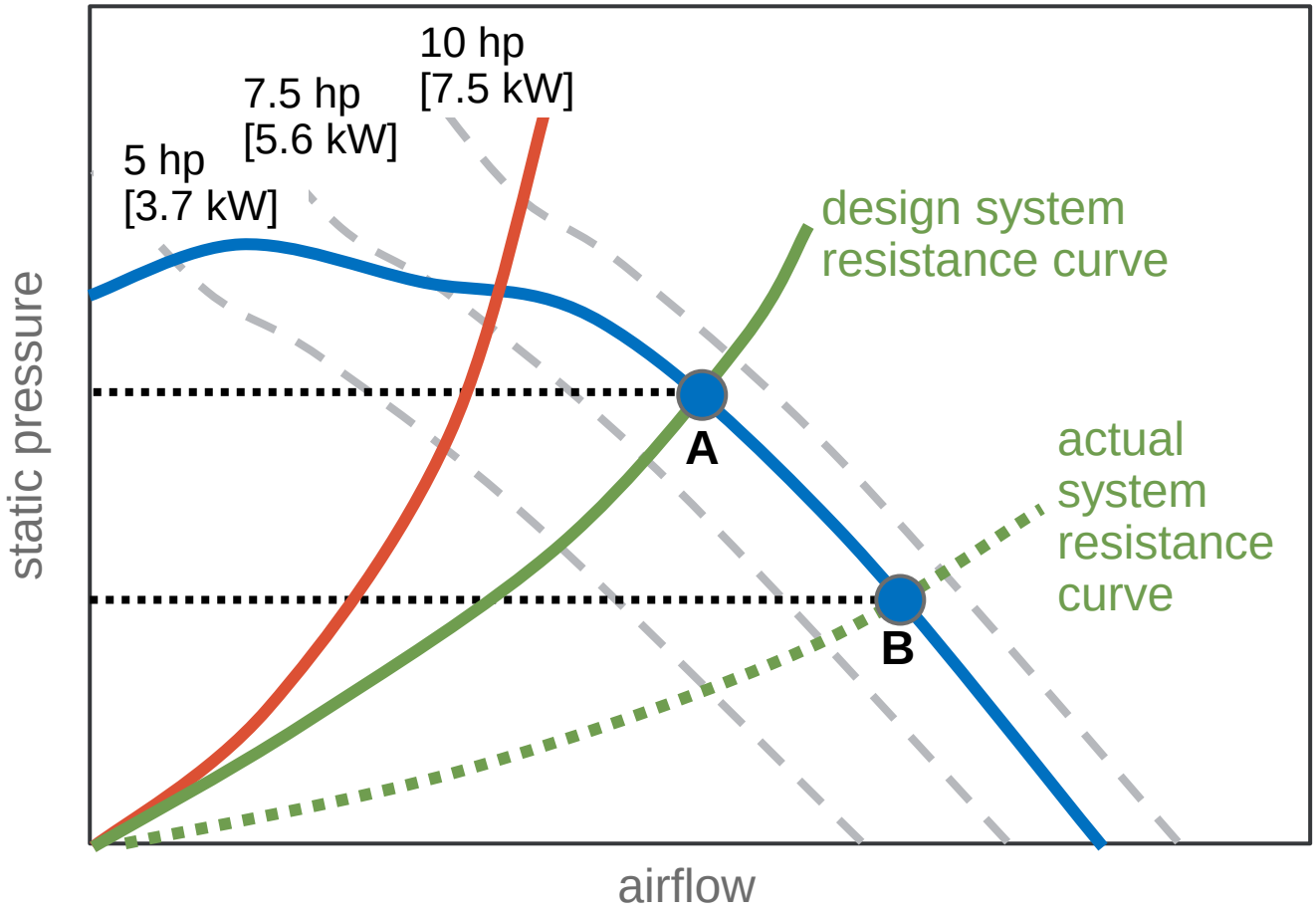




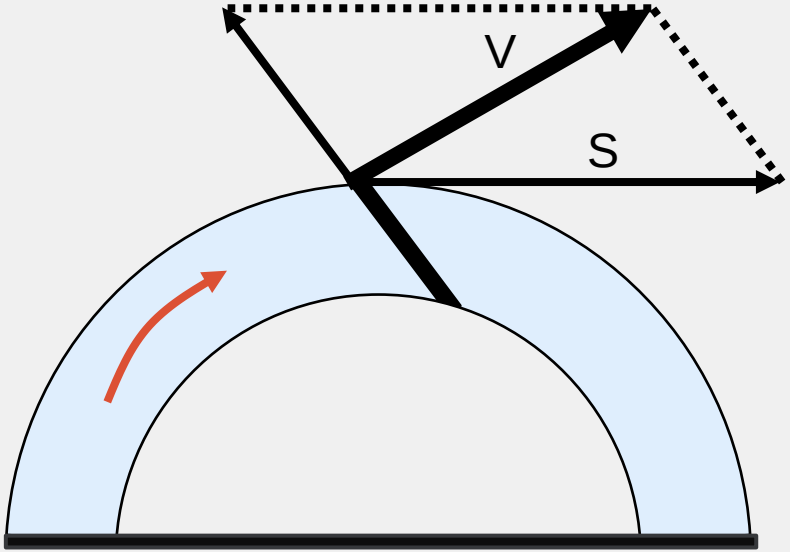


BACKWARD INCLINED FAN

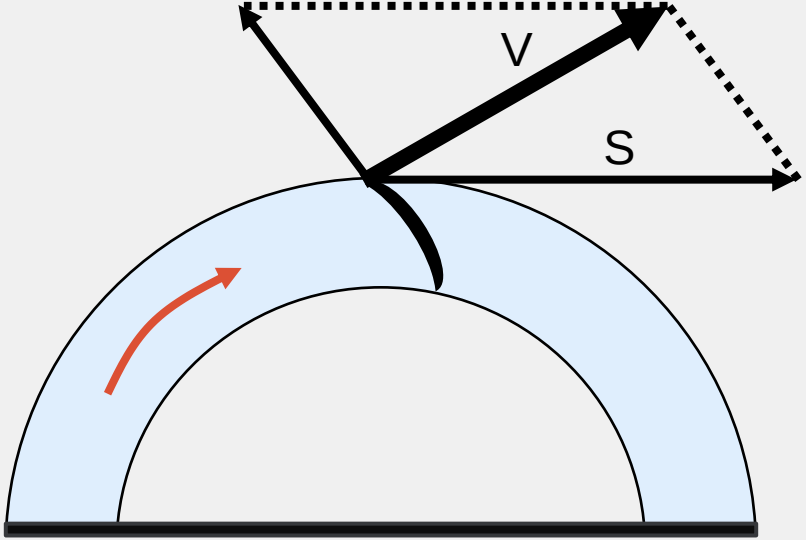
BACKWARD INCLINED FAN



BACKWARD CURVED FAN

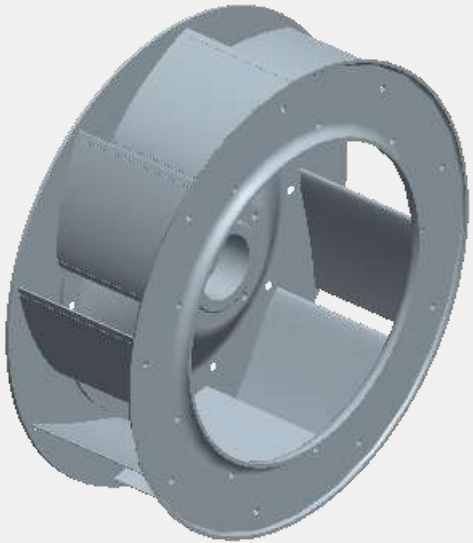


backward inclined

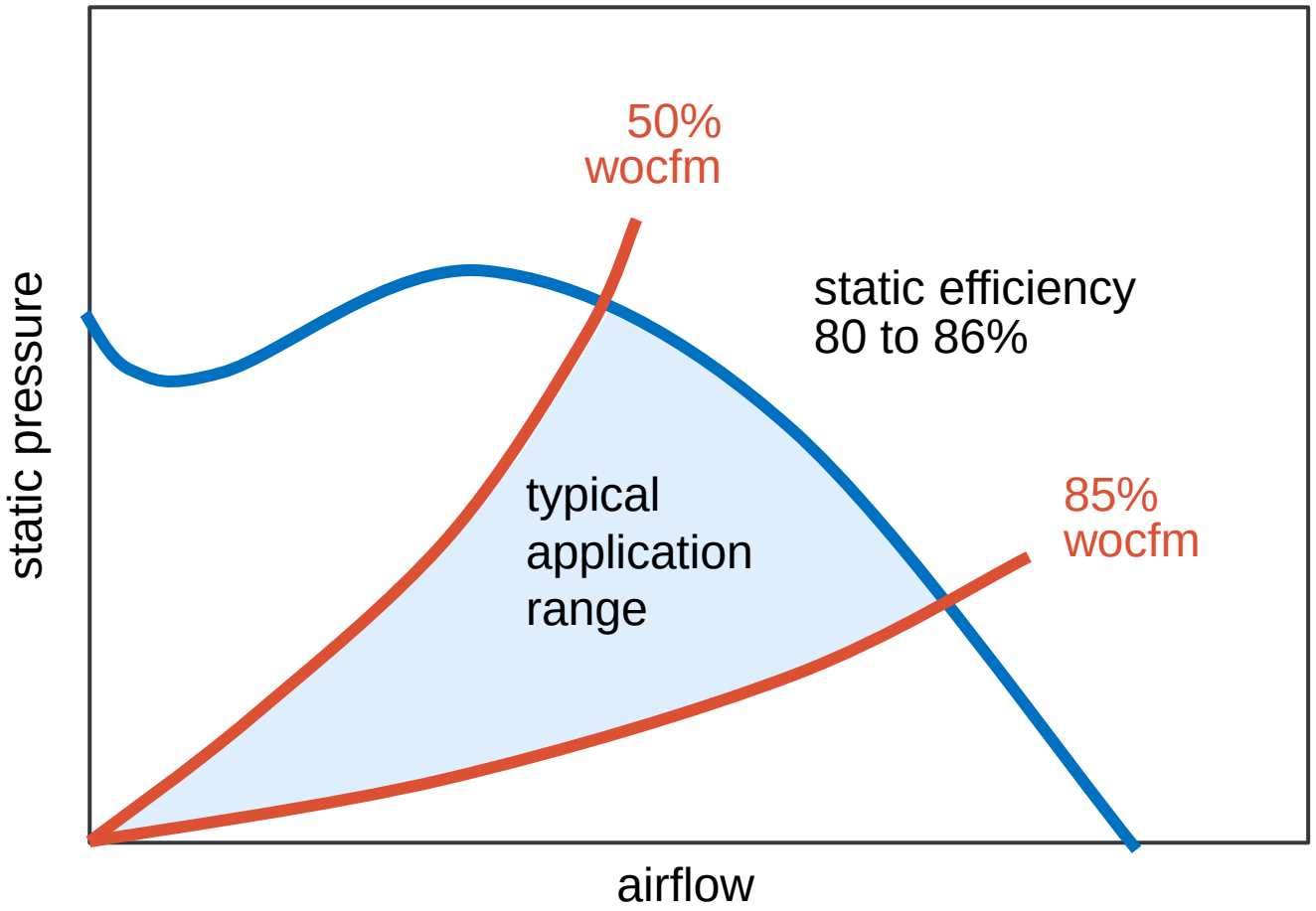


backward curved

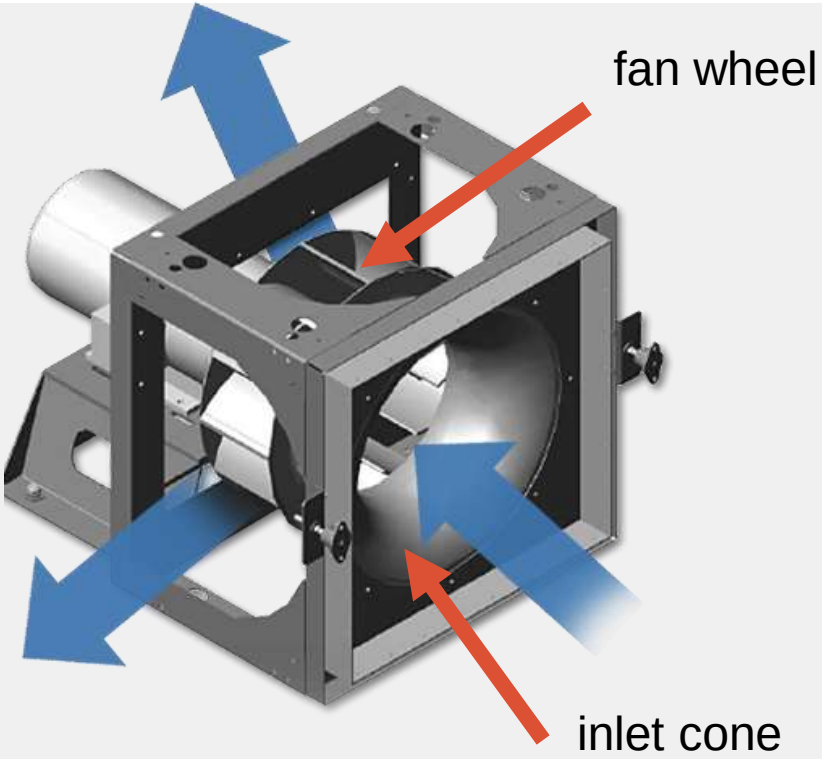
AIRFOIL FAN



AIRFOIL FAN


50%
wocfm
static efficiency
80 to 86%
typical
application
range
85%
wocfm
static pressure
airflow

PLENUM FAN

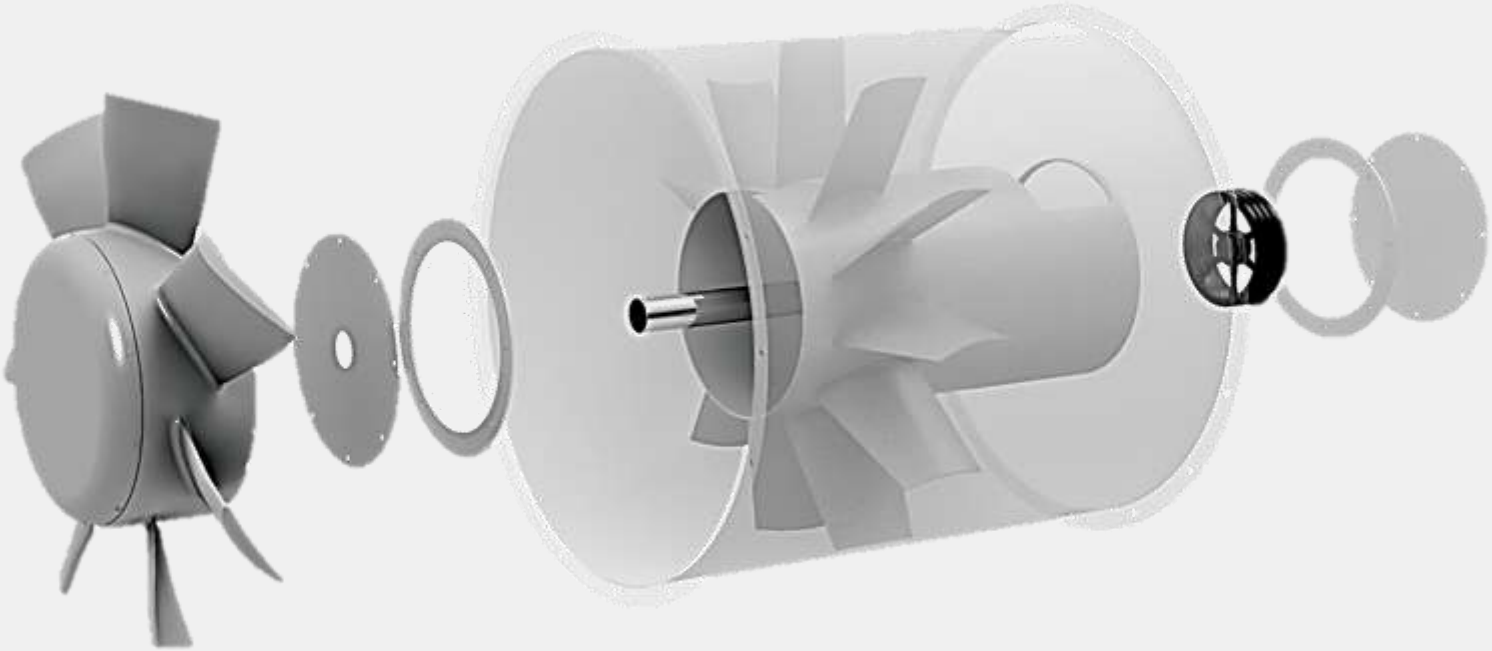


DIRECT-DRIVE PLENUM FAN

Photos courtesy of Twin City Fan & Blower

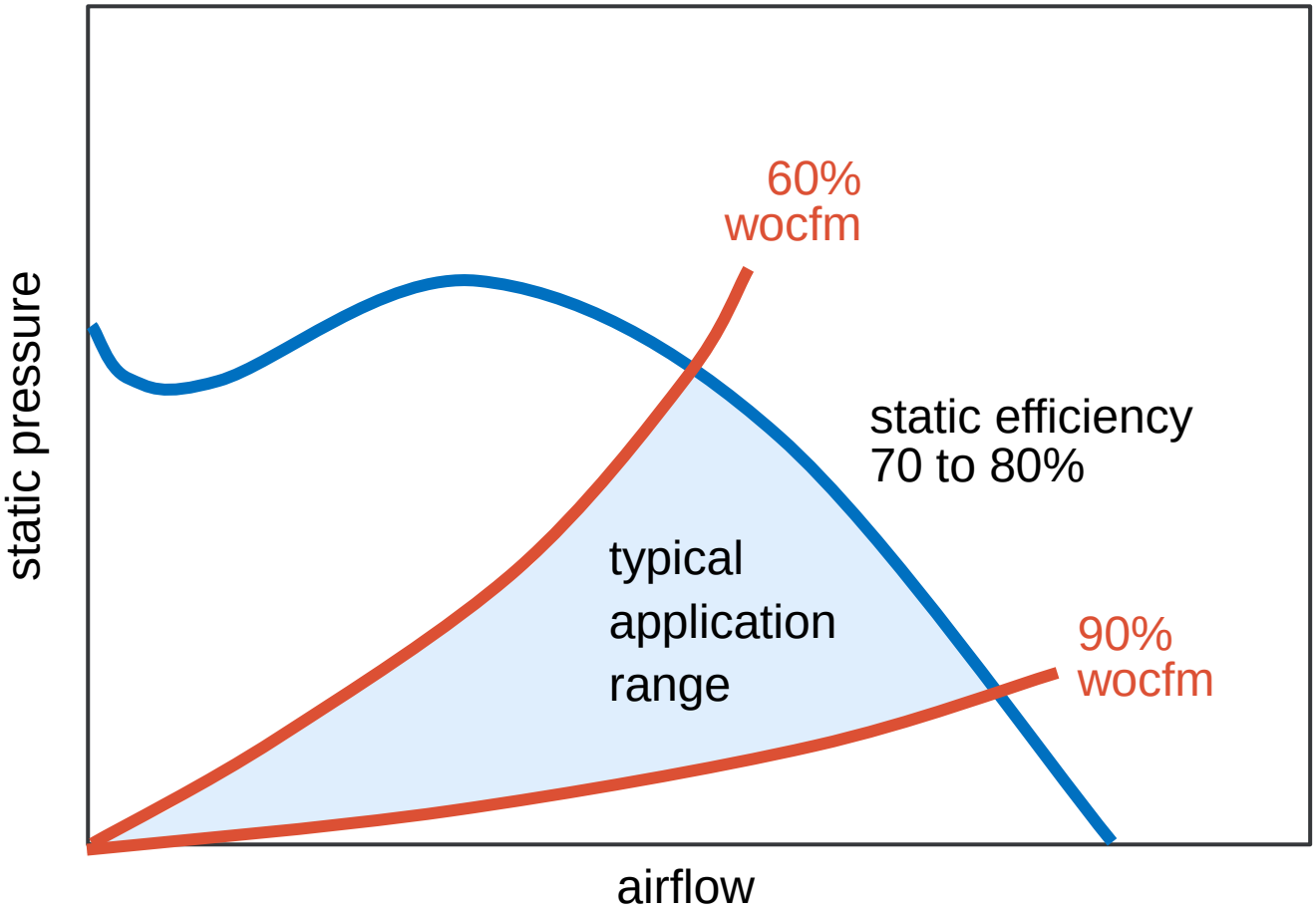
MOTORIZED IMPELLER FANS

VANEAXIAL FAN



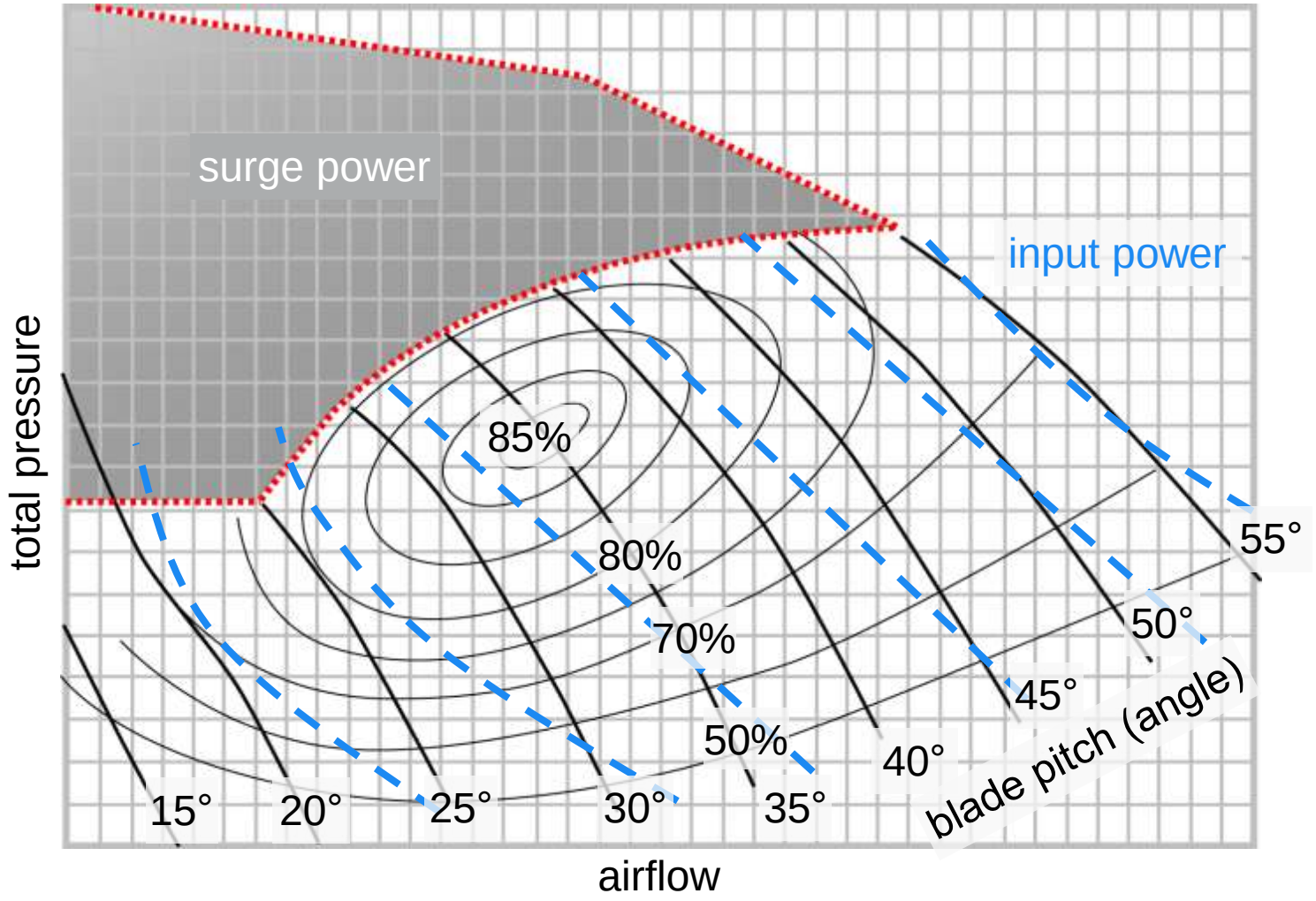
Photos courtesy of Twin City Fan & Blower

VANEAXIAL FAN



VARIABLE-PITCH VANEAXIAL FAN

Photos courtesy of Twin City Fan & Blower


surge power
input power
85%
80%
70%
50%
15°
20°
25°
30°
35°
40°
45°
50°
55°
blade pitch (angle)
total pressure
airflow

VPVA FAN

FAN ARRAY

upstream (inlet) side

downstream (outlet) side

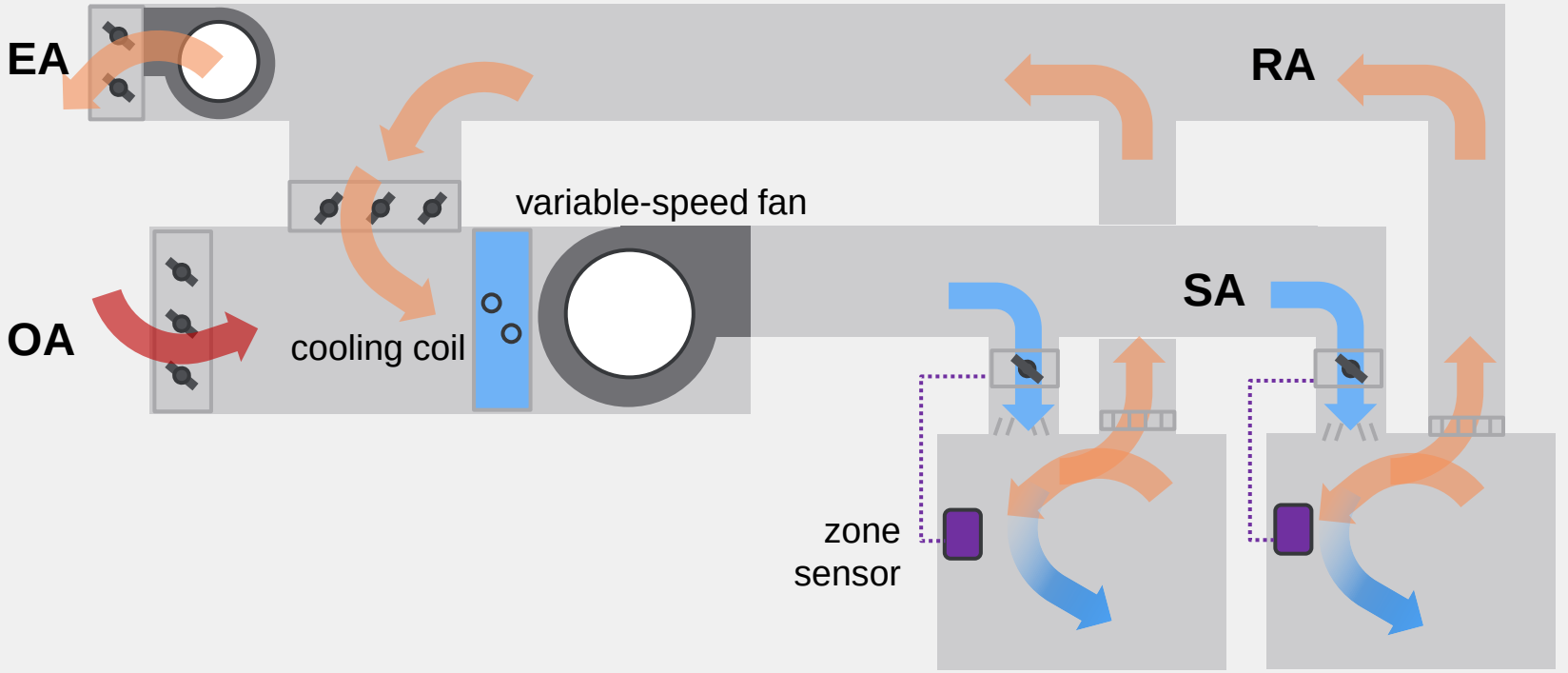
FAN SELECTION

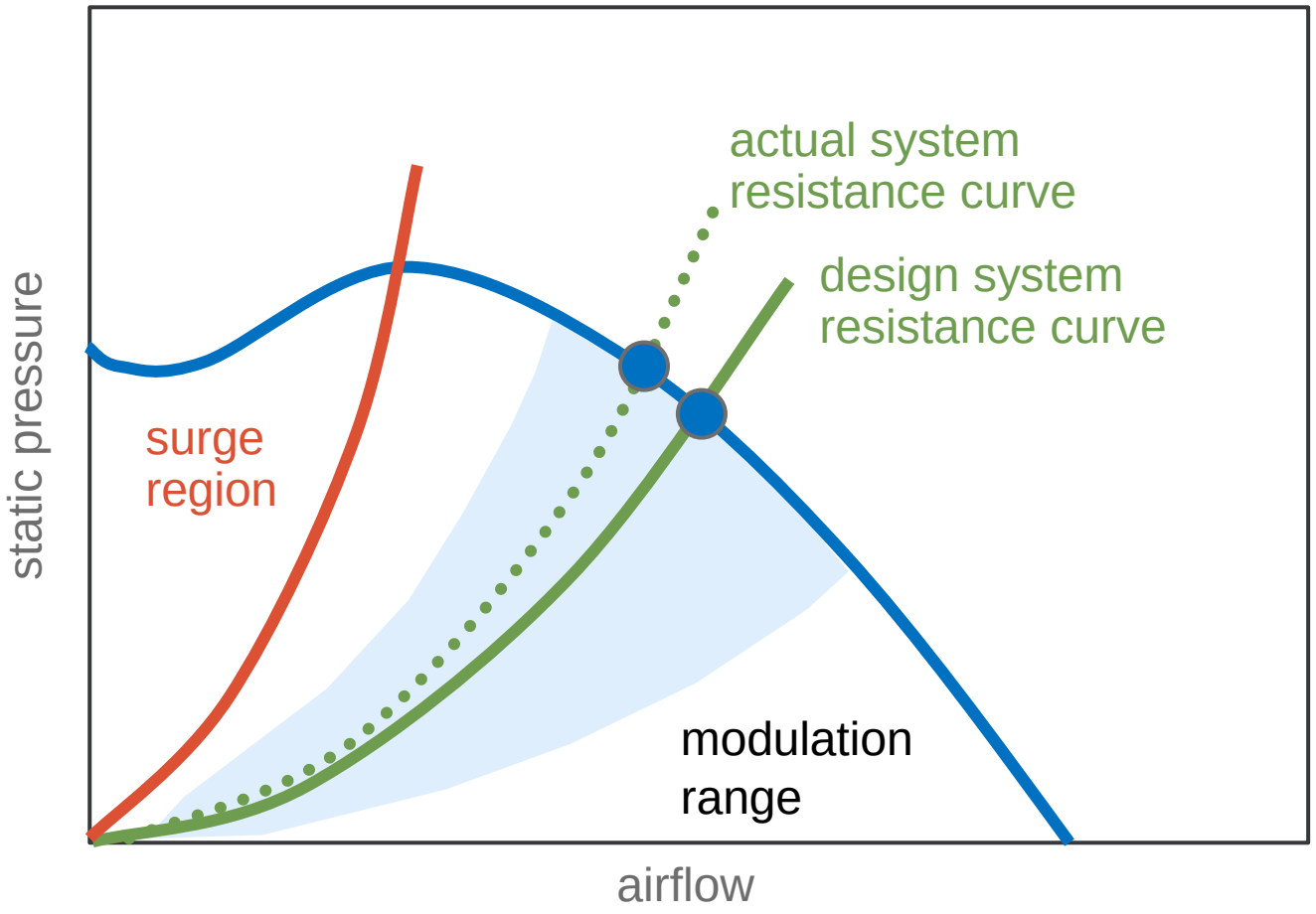
- **Forward curved (FC)**
  - Lower airflow, lower static pressure, lower first cost
- **Backward inclined (BI) or airfoil (AF)**
  - Higher airflow, higher static pressure, higher efficiency
- **Vaneaxial**
  - Limited space, limited availability
- **Variable-pitch vaneaxial (VPVA)**
  - Large systems, higher airflow, limited availability
- **Direct-Drive Plenum Fan**
  - More reliable, able to pressurize a plenum for multiple duct outlets
- **Fan Array**
  - Smaller overall length than direct-drive fans, offers some redundancy

period 3

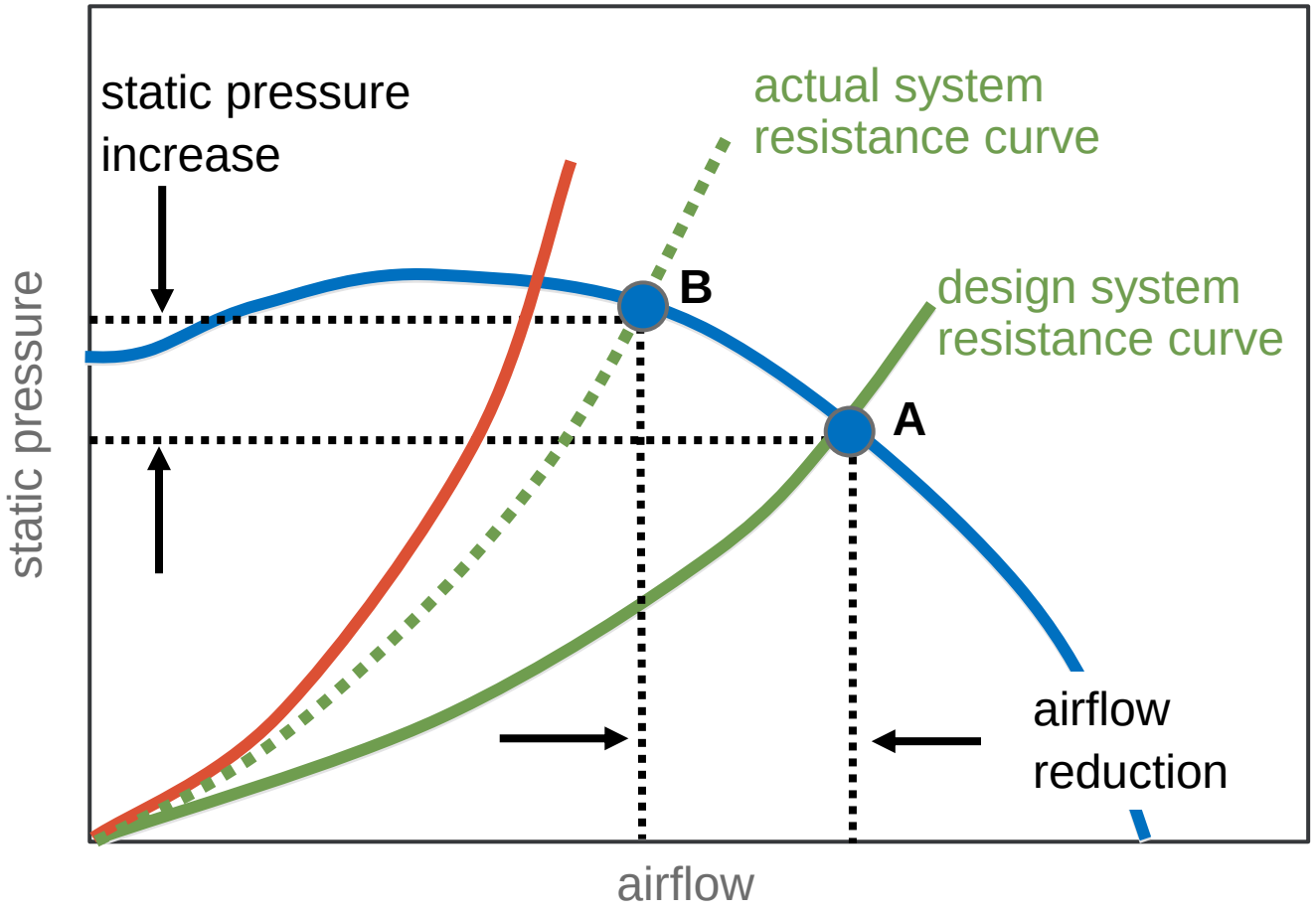
FAN CAPACITY CONTROL

VAV SYSTEM

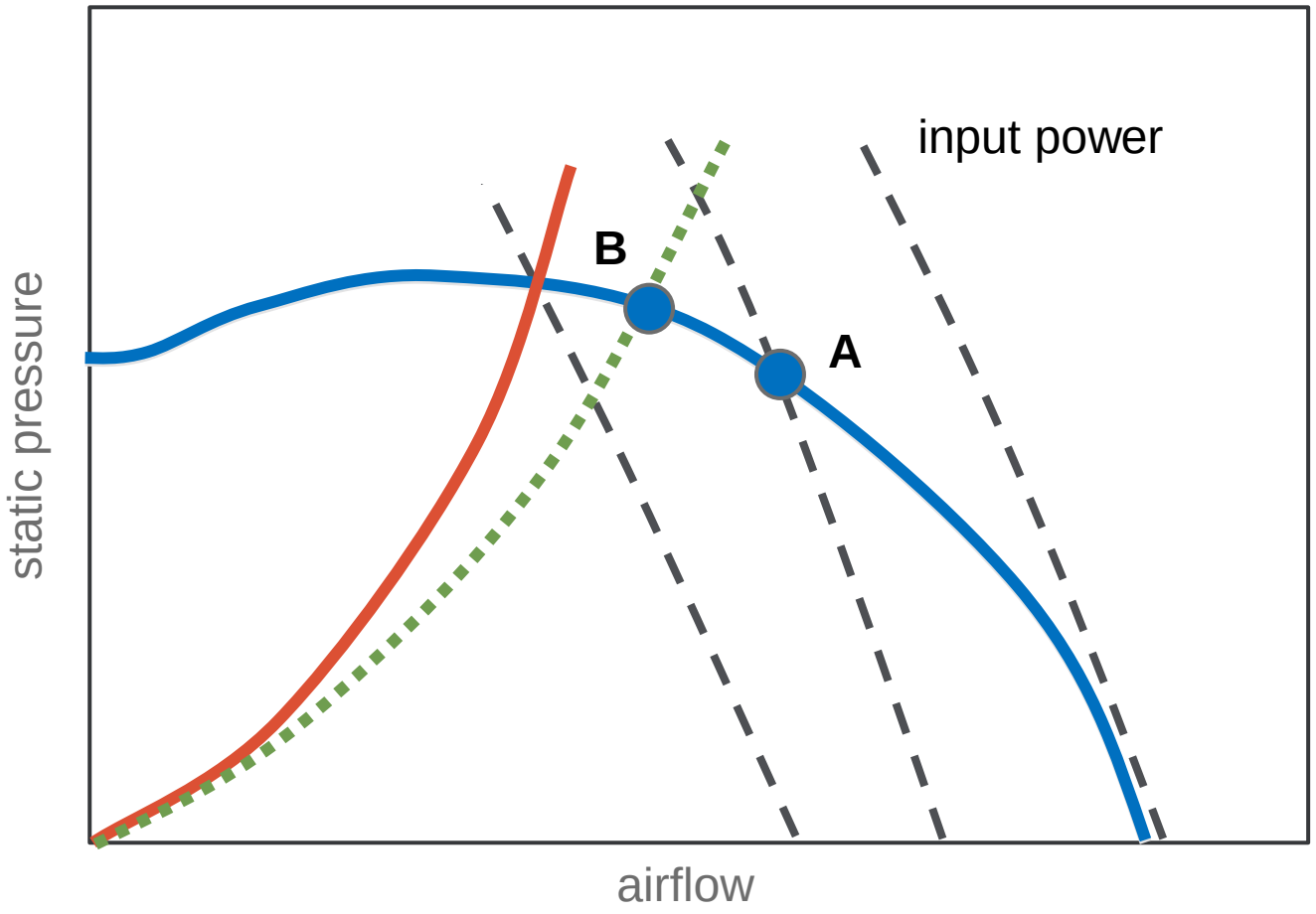



actual system
resistance curve
design system
resistance curve
surge
region
modulation
range
static pressure
airflow

VAV SYSTEM

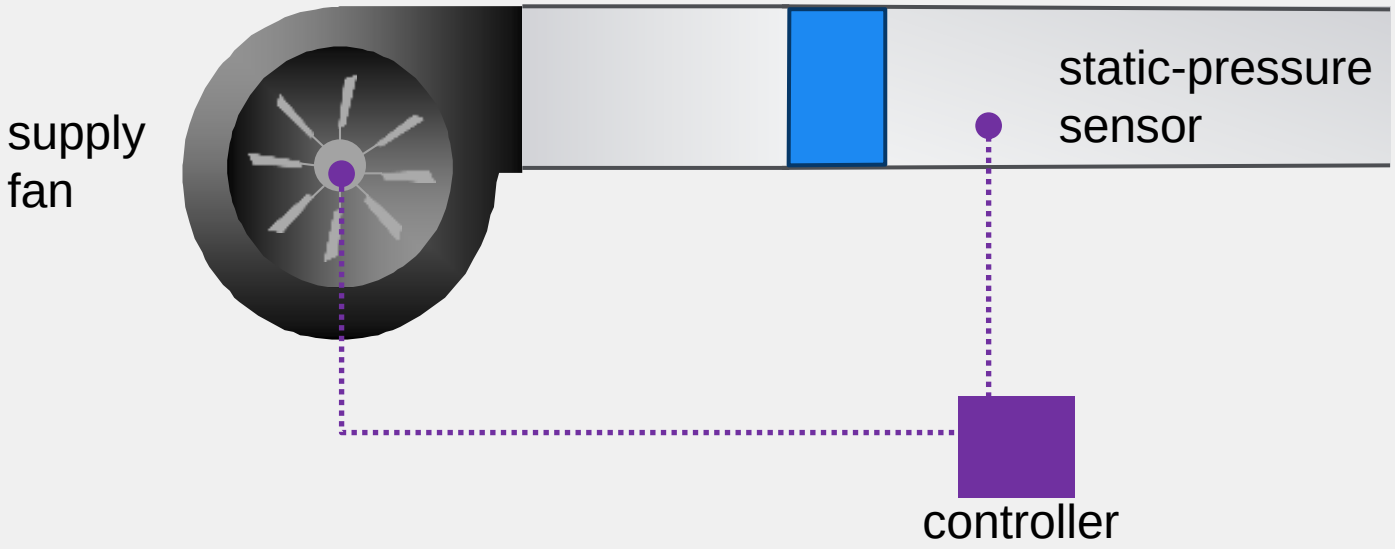

static pressure
increase
actual system
resistance curve
B
design system
resistance curve
A
airflow
reduction
static pressure
airflow

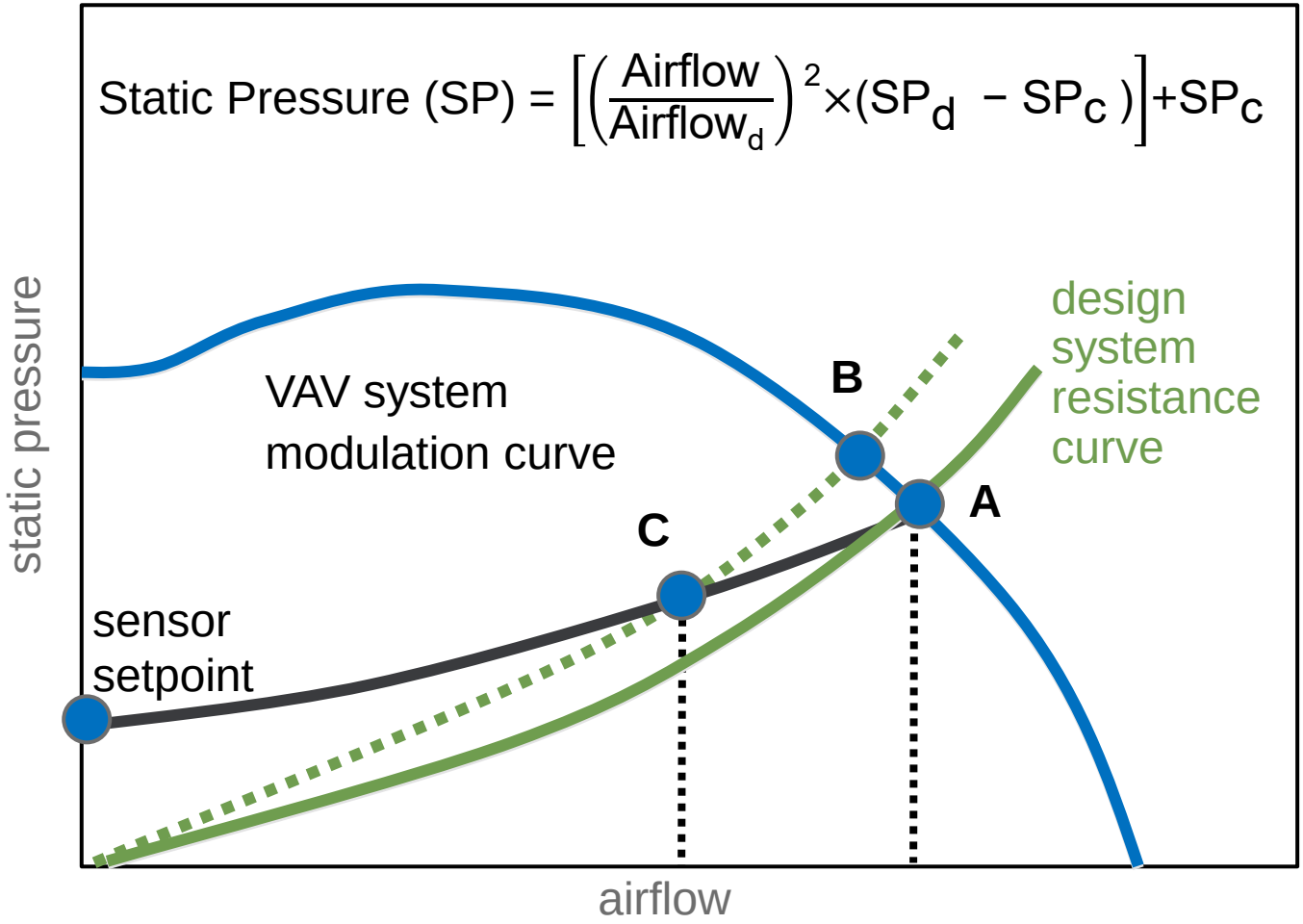
VAV SYSTEM



VAV SYSTEM

FAN CONTROL LOOP

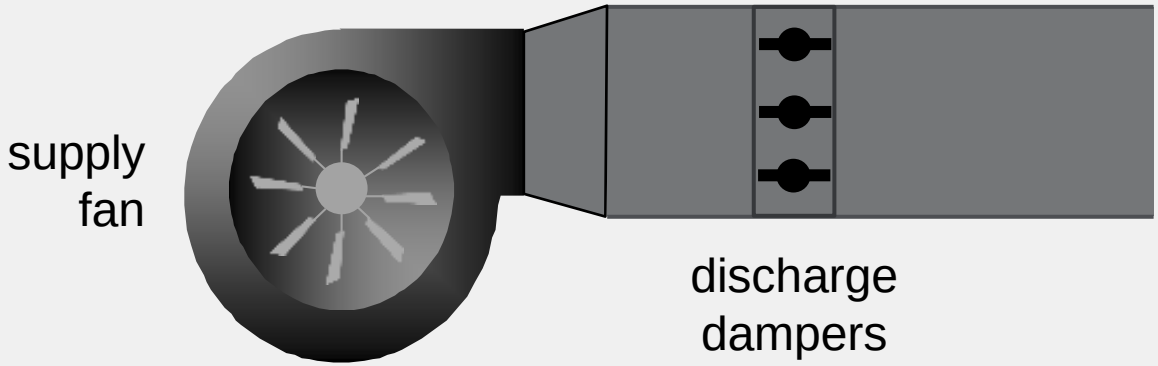


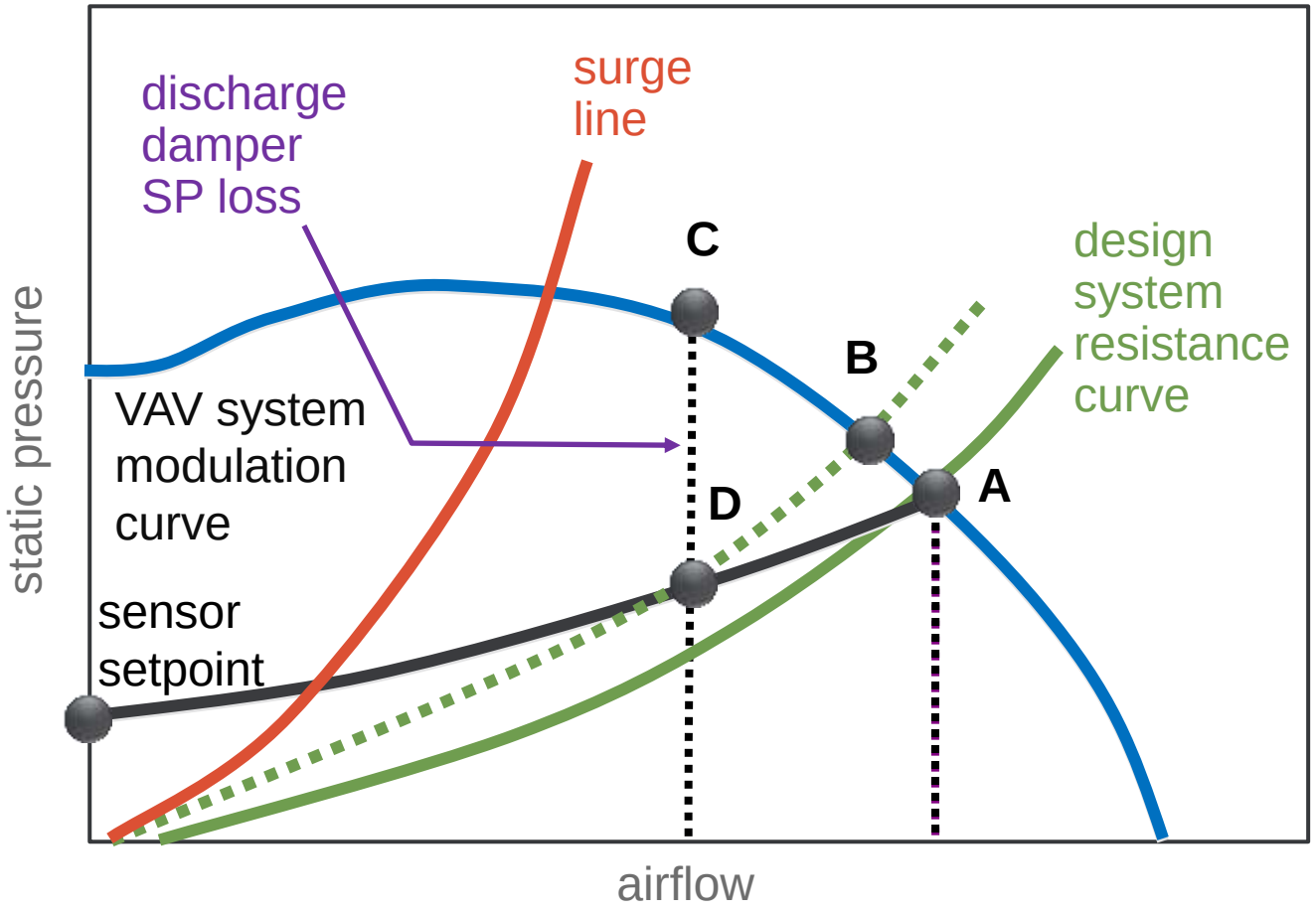

Static Pressure (SP) = [(Airflow / Airflow_d)^2 × (SP_d − SP_c)] + SP_c
static pressure
airflow
VAV system
modulation curve
design
system
resistance
curve
A
B
C
sensor
setpoint

METHODS OF FAN CAPACITY CONTROL

- Discharge dampers
- Inlet vanes
- Fan-speed control
- Variable-pitch blade control

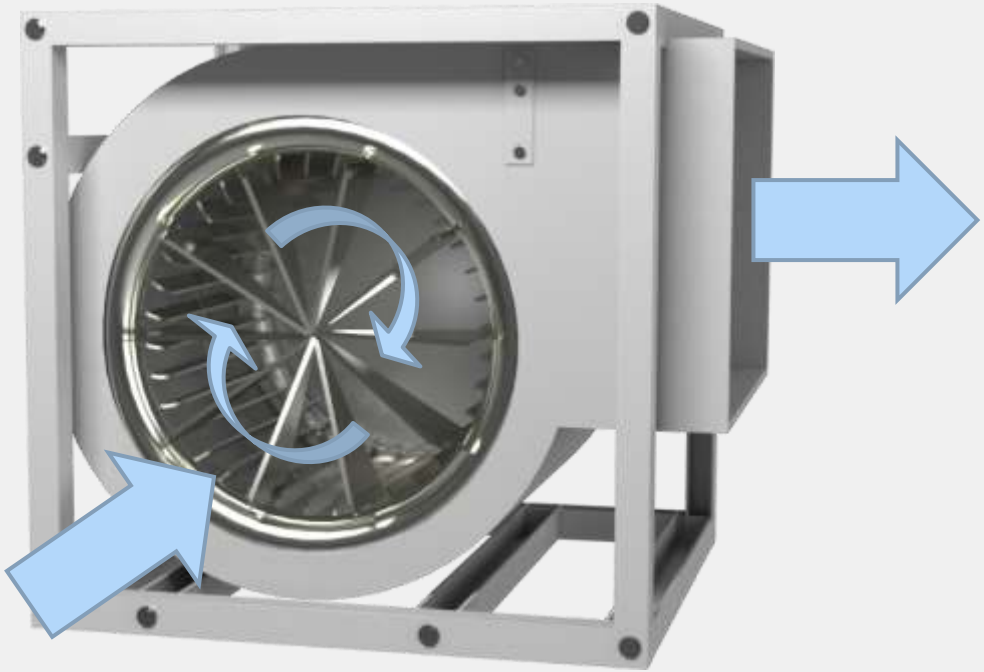
DISCHARGE DAMPERS

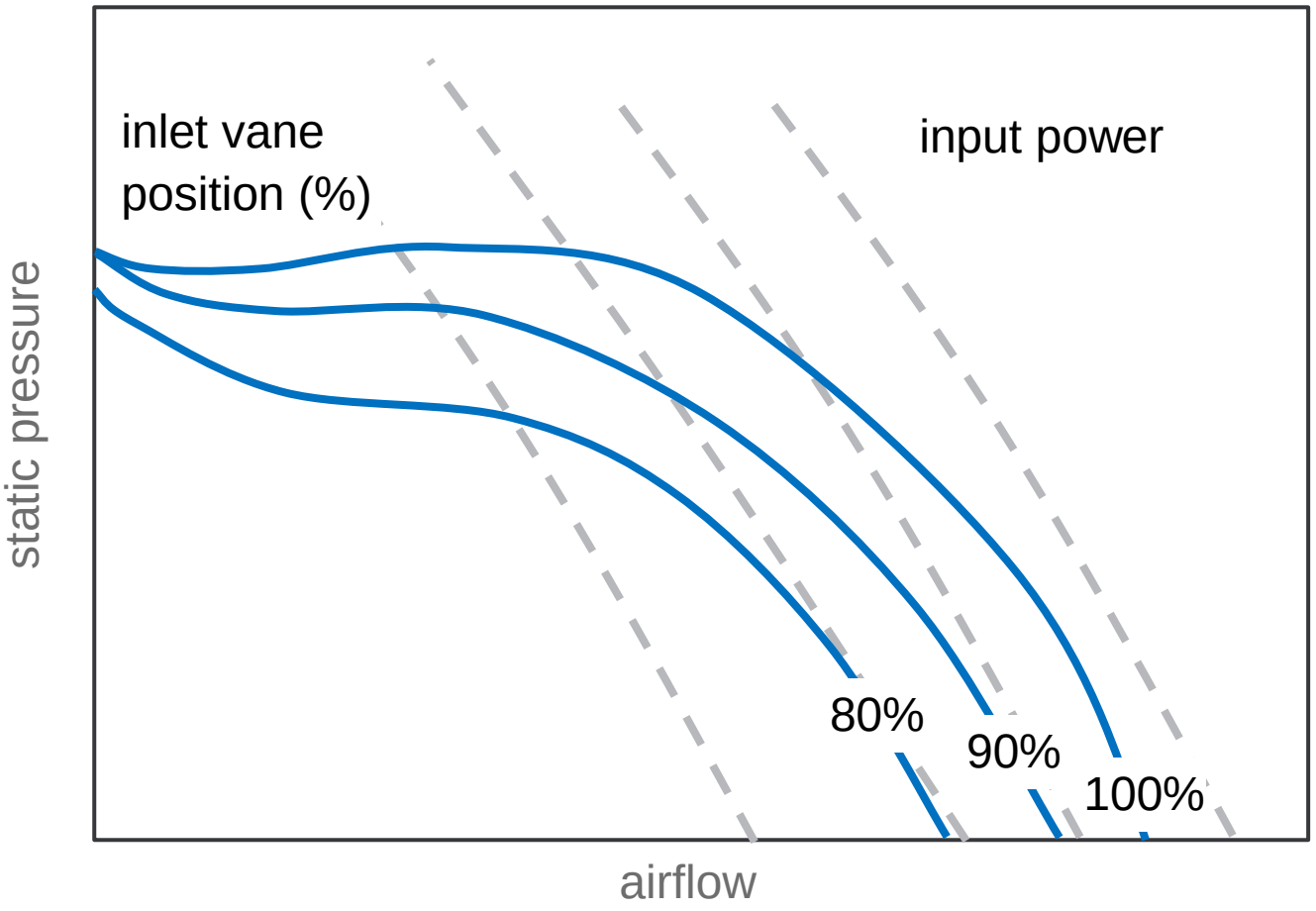




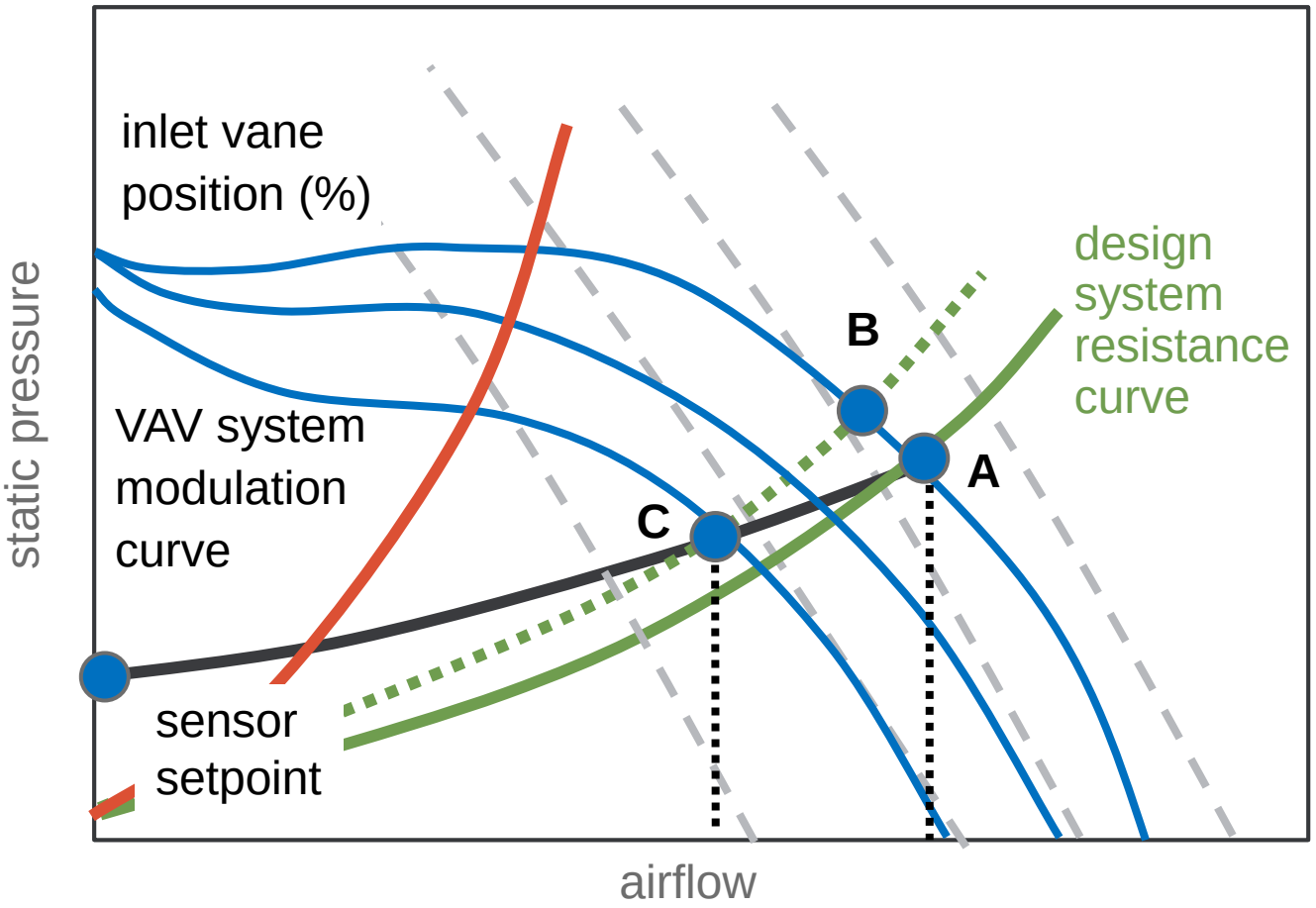
FAN CAPACITY CONTROL WITH DISCHARGE DAMPERS

INLET VANES




inlet vane
position (%)
input power
static pressure
80%
90%
100%
airflow

VAV SYSTEM

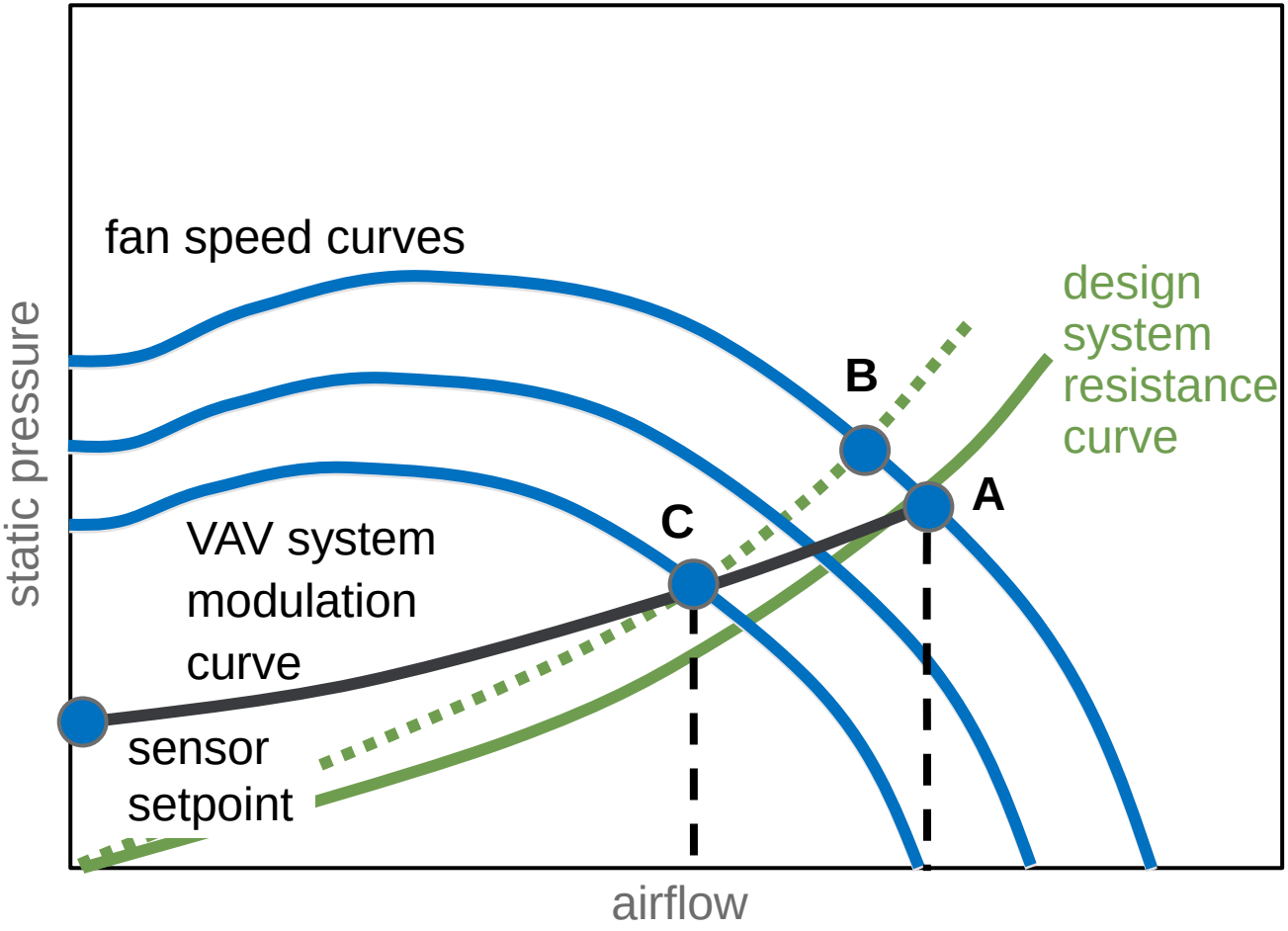


FAN CAPACITY CONTROL WITH INLET VANES

FAN-SPEED CONTROL

Variable-speed drives:

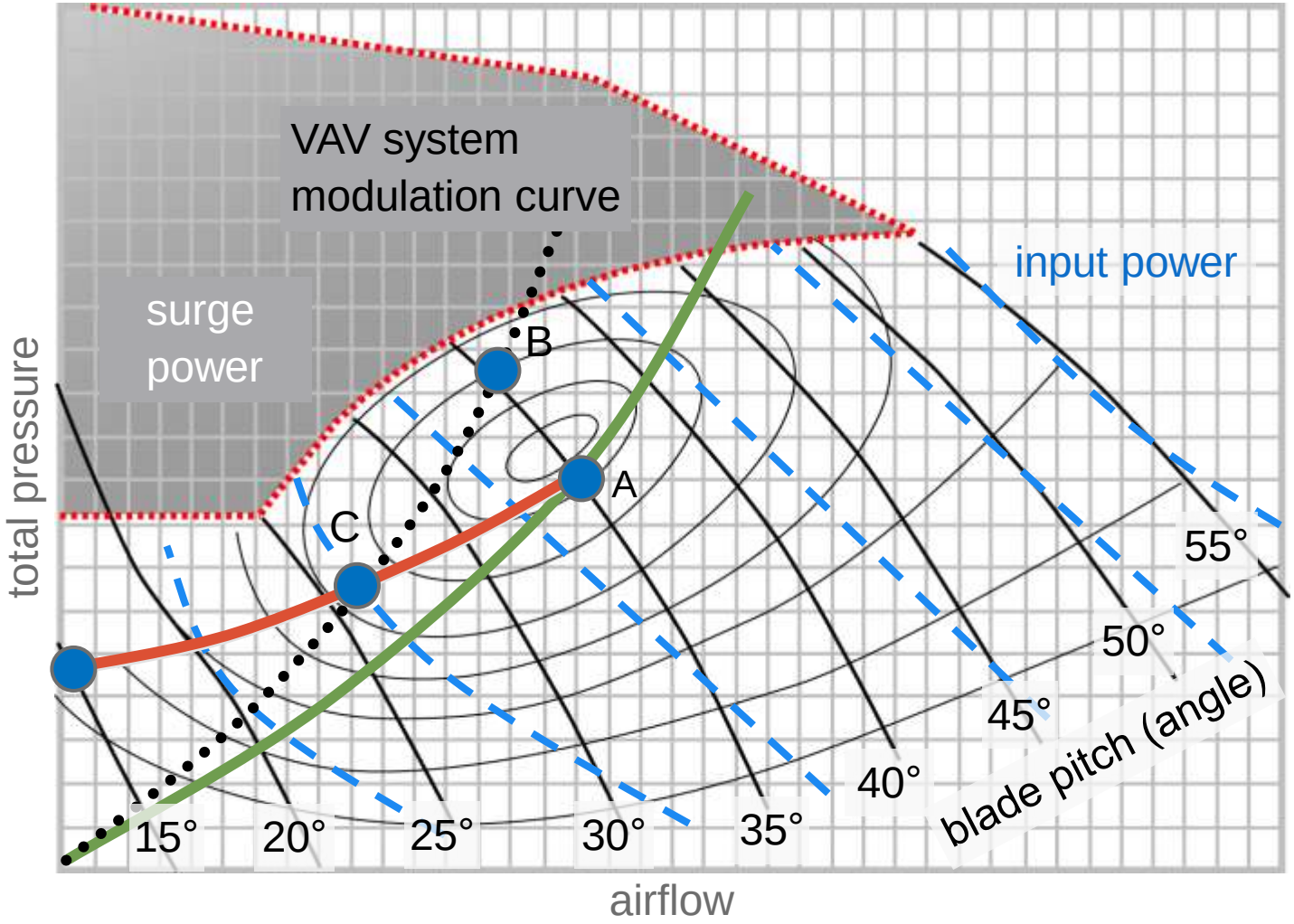
- adjust the frequency that is applied to the motor
- can precisely control the fan motor speed for both design and part-load conditions



FAN CAPACITY CONTROL WITH FAN SPEED CONTROL

VARIABLE-PITCH BLADE CONTROL

Photo courtesy of Twin City Fan & Blower

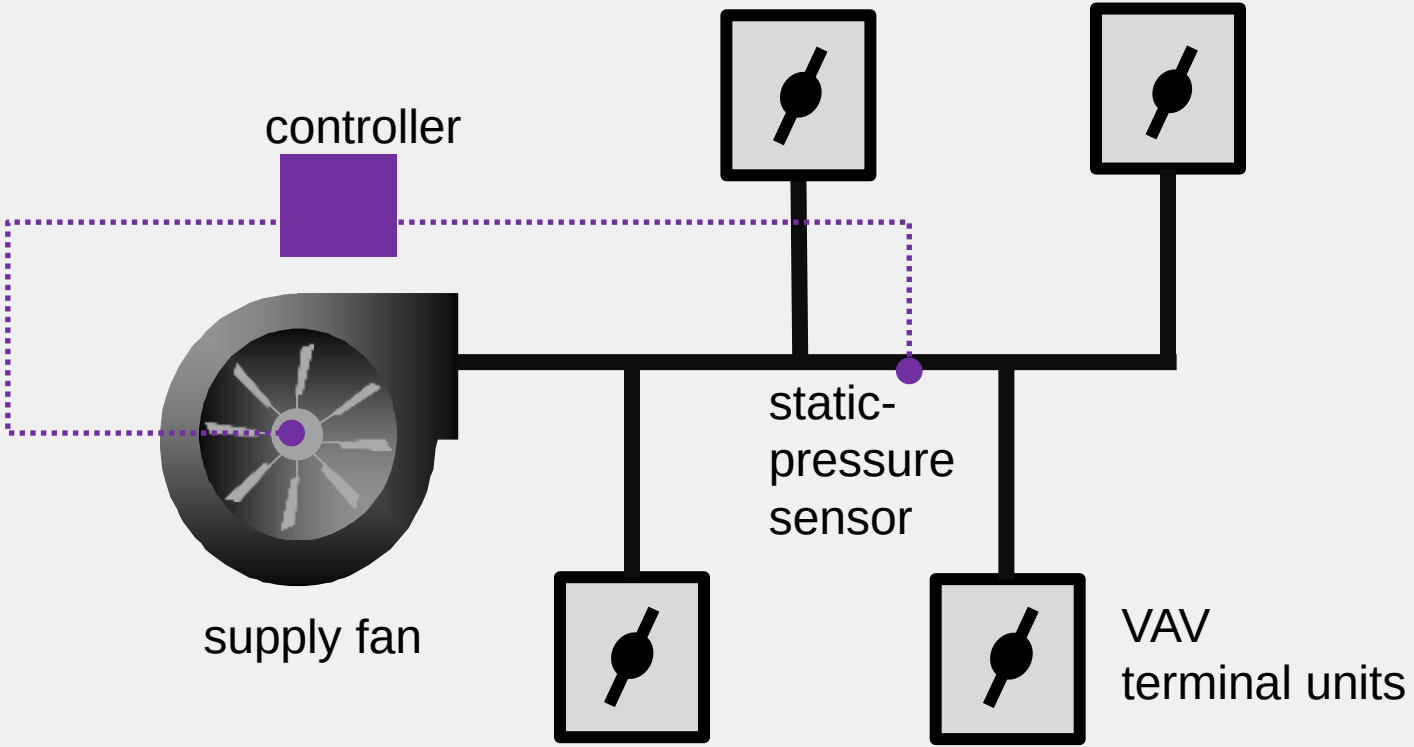

VAV system
modulation curve
surge
power
input power
B
A
C
total pressure
airflow
55°
50°
45°
40°
35°
30°
25°
20°
15°
blade pitch (angle)

VPVA SYSTEM

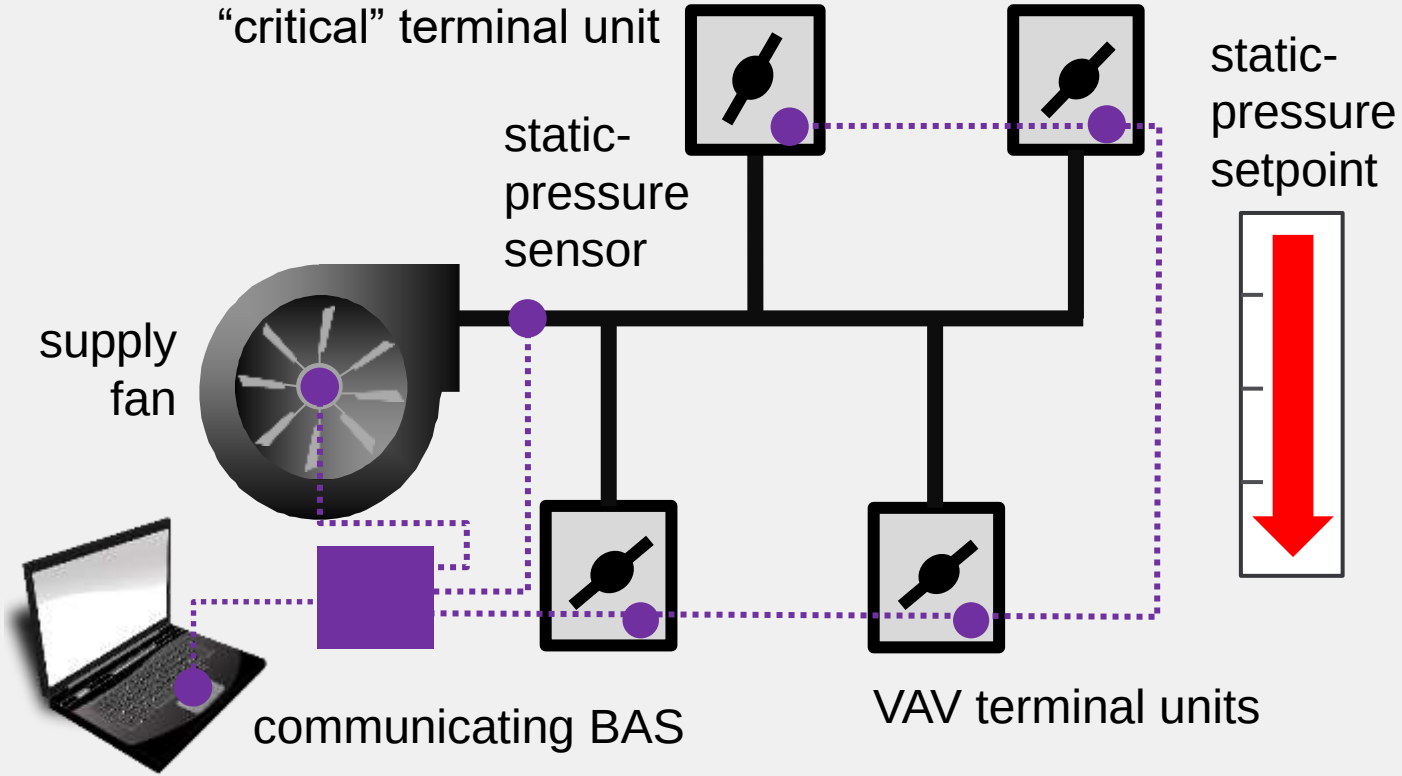
period 4

APPLICATION CONSIDERATIONS

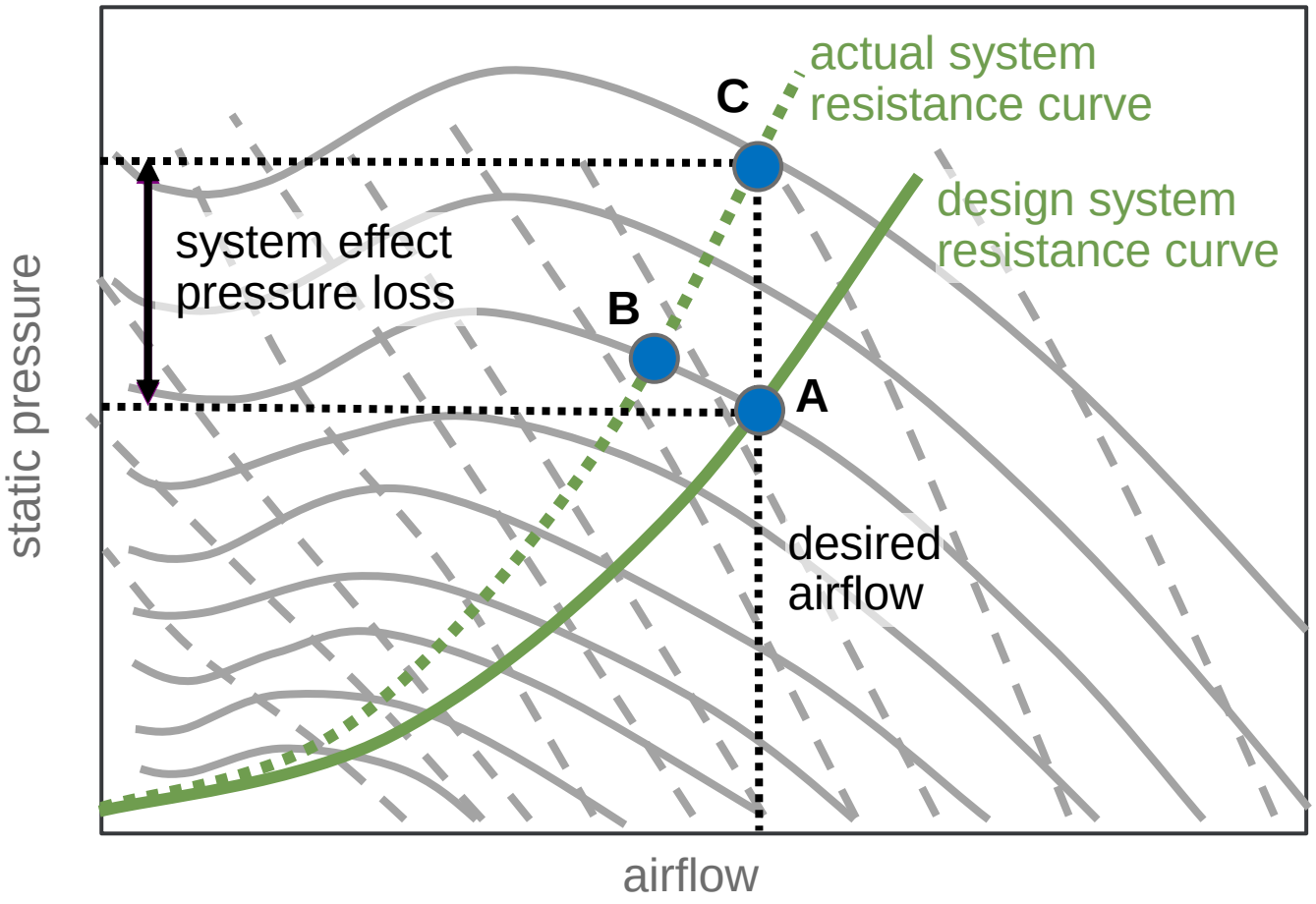
SYSTEM STATIC-PRESSURE CONTROL



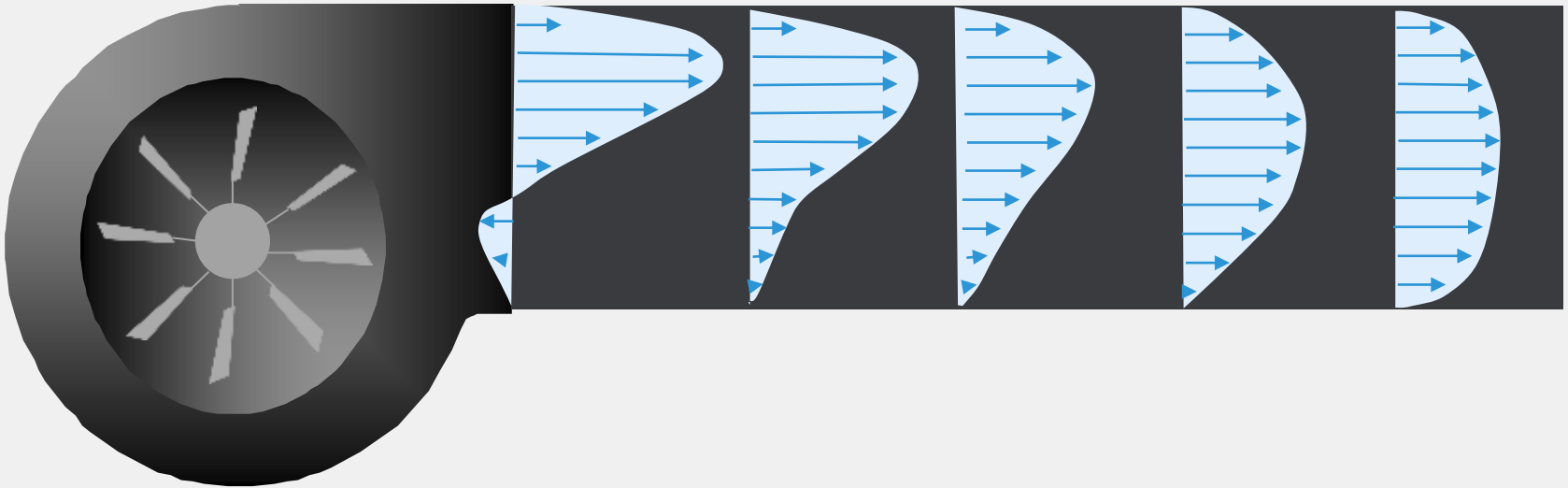
OPTIMIZED STATIC-PRESSURE CONTROL



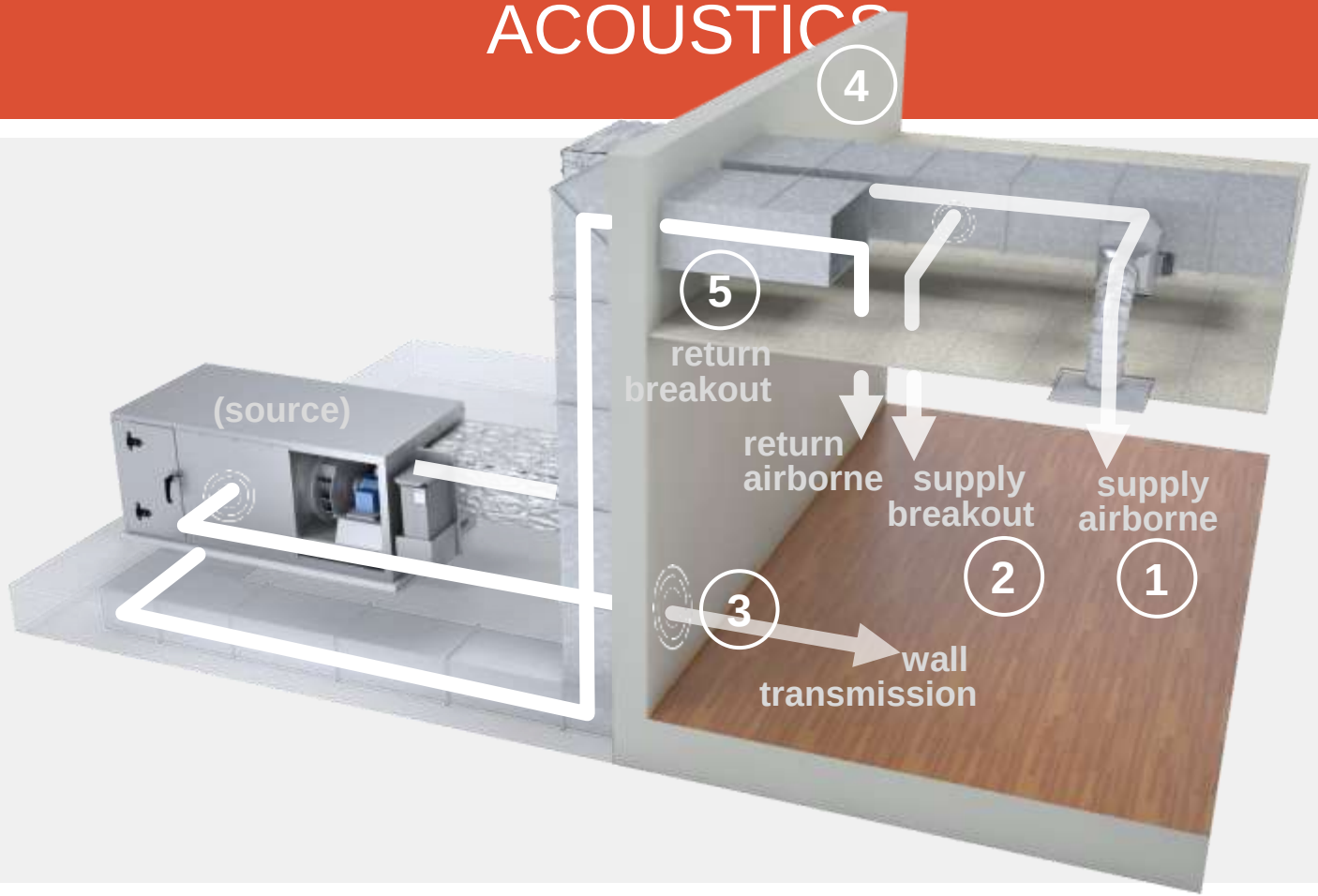
SYSTEM EFFECT



SYSTEM EFFECT



ACOUSTICS


4
5
return
breakout
(source)
return
airborne
supply
breakout
supply
airborne
2
1
3
wall
transmission

ACOUSTICAL GUIDELINES

- Optimize fan and air-handler selection for lowest overall sound
- Select fan to operate safely away from surge region
- Minimize system effects
- Use low-pressure-drop duct fittings (follow SMACNA® recommendations)
- Avoid rectangular sound traps, if possible
- Use adequate vibration isolation

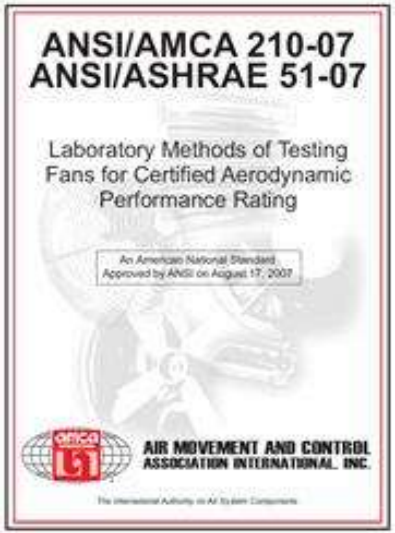
EFFECT OF ACTUAL CONDITIONS

1. $\text{Air Density Ratio} = \dfrac{\text{Density}_{actual}}{\text{Density}_{standard}}$
2. $\text{SP}_{standard} = \dfrac{\text{SP}_{actual}}{\text{Air Density Ratio}}$
3. Use Airflow_{actual} and $\text{SP}_{standard}$ to select fan
4. $\text{RPM}_{standard} = \text{RPM}_{actual}$
5. $\text{Power}_{actual} = \text{Air Density Ratio} \times \text{Power}_{standard}$

EQUIPMENT CERTIFICATION STANDARDS

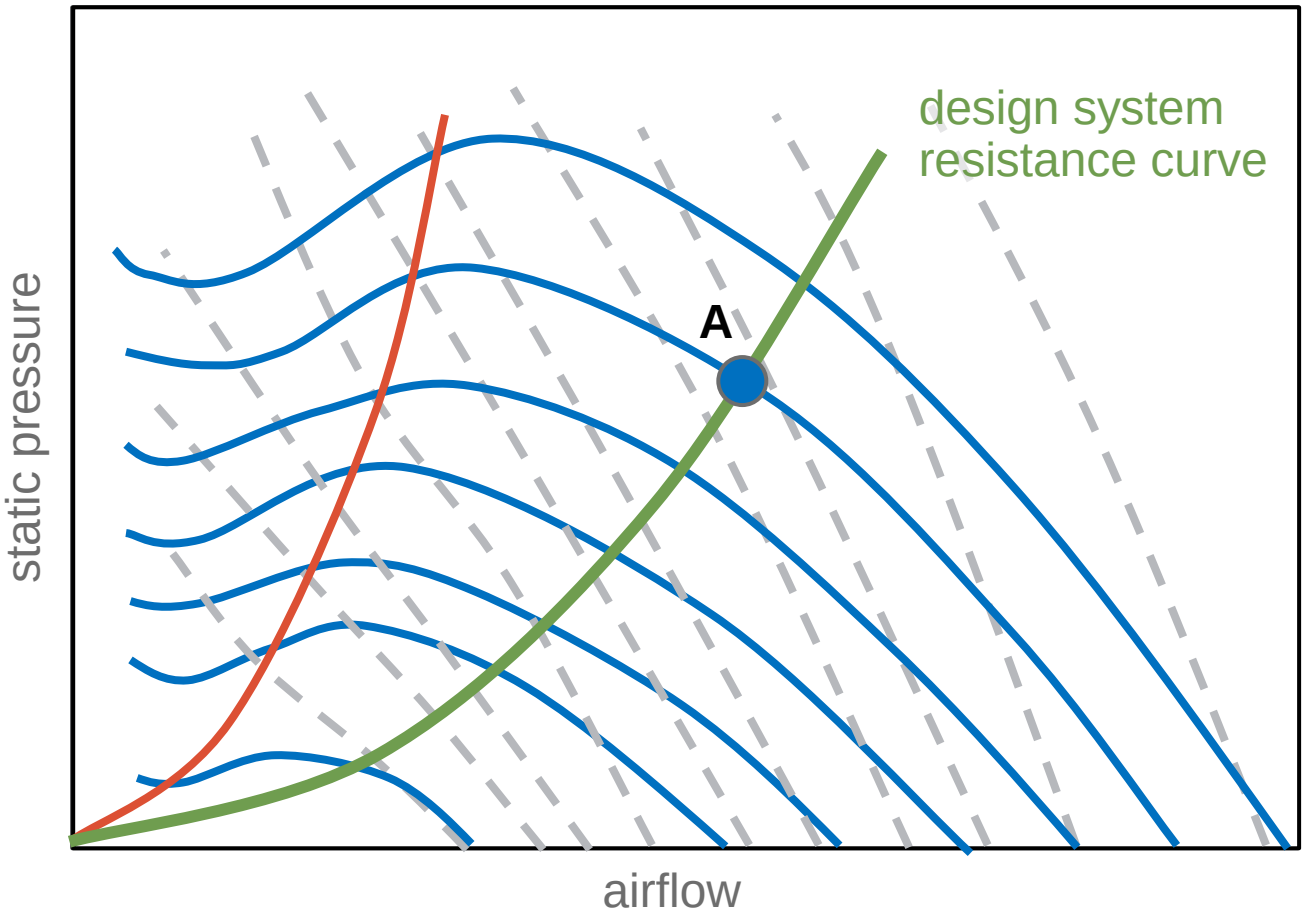
Purpose

Establish methods for laboratory testing of air moving devices



period 5

REVIEW



PERIOD ONE

PERIOD TWO

centrifugal

axial

Photo courtesy of Twin City Fan & Blower

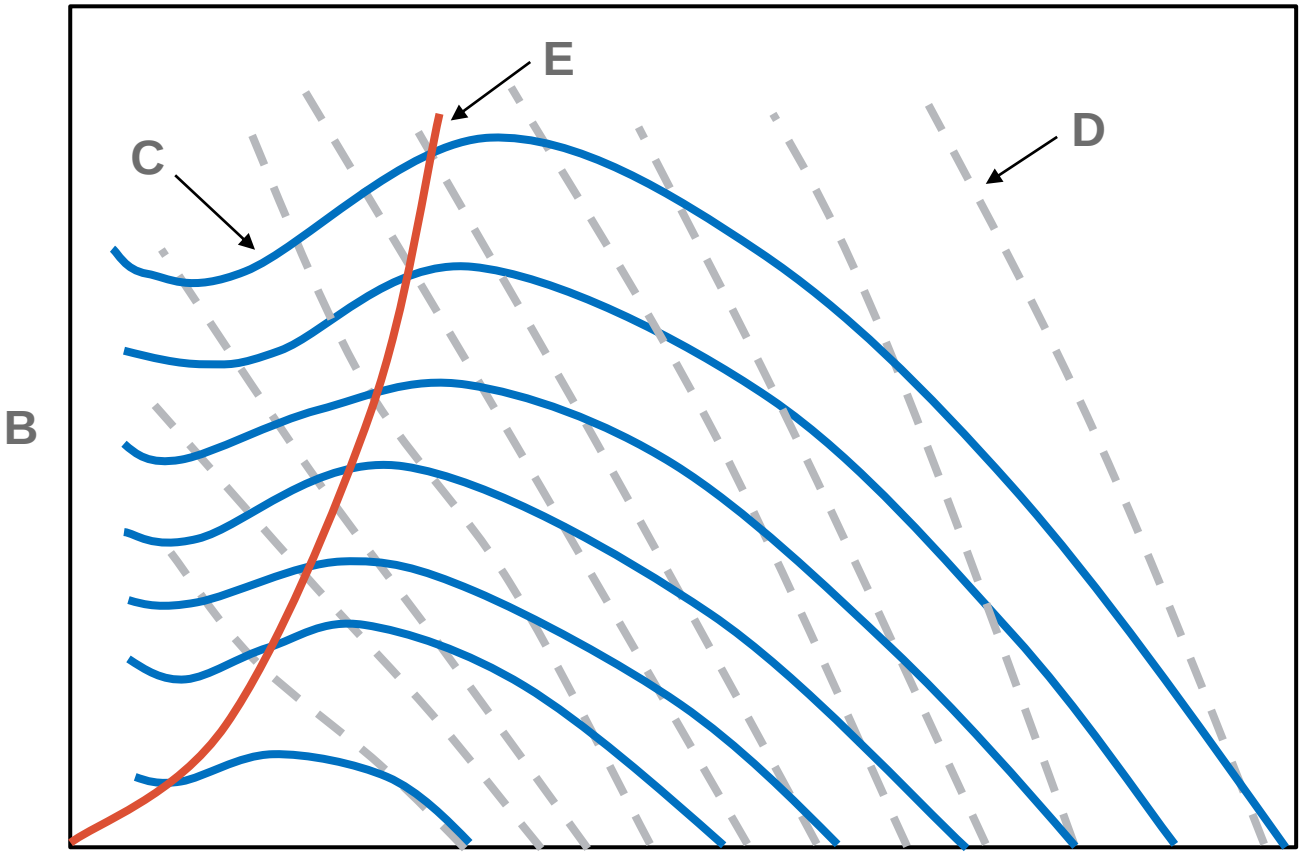
PERIOD THREE

- Riding the fan curve
- Discharge dampers
- Inlet vanes
- Fan-speed control
- Variable-pitch blade control

PERIOD FOUR

- System static-pressure control
- System effect
- Acoustics
- Effect of actual (nonstandard) conditions on fan selection
- Equipment certification standards

Ingersoll Rand


E
C
D
B

FAN MAINTENANCE

BELT-DRIVEN FANS

- Fan shaft(s) are straight
- Fan bearings rotate smooth
- Sheaves are in good working order
- Sheaves are secure to shafts/bushings
- Belts are in good shape
- Belts are tightened properly
- Fan and Motor bearings are greased
- Motor secure to base and isolators are in good cond.

BELT-DRIVEN FANS

- Tightening Belts properly
  - Measuring tension by Deflection
  - Measuring tension by Frequency
  - Using a Tension Finder

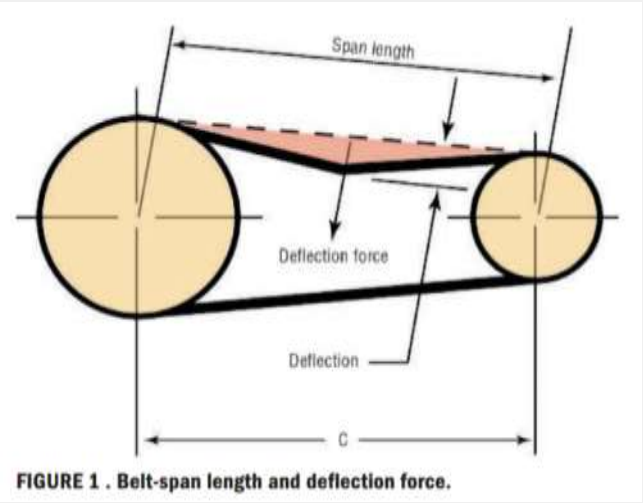


FIGURE 1 . Belt-span length and deflection force.

DIRECT-DRIVE FANS

- Motor is secured to base
- Isolating springs/pads are in good working cond.
- Motor is not overheating
- Motor bearings are running smooth and greased
- Fan wheel is in good working order & in balance

BMS ALARMS

- Do your due-diligence
  - check on equipment after faults are back online
  - don’t assume the electronics know everything

SYSTEM MAINTENANCE

- Check downstream equipment like VAVs
- Check entering and leaving ductwork

RETRO-FITTING SYSTEMS

- Upgrading filters
- Increased airflow
- Change in fan type
- Total Cost of Ownership (design, construction, maintenance, energy)

THANK YOU

- MICHAEL JOHNSON
  - Systems Account Manager, Madison, WI
  - michaeljohnson@trane.com
  - Mobile: 608-440-0989