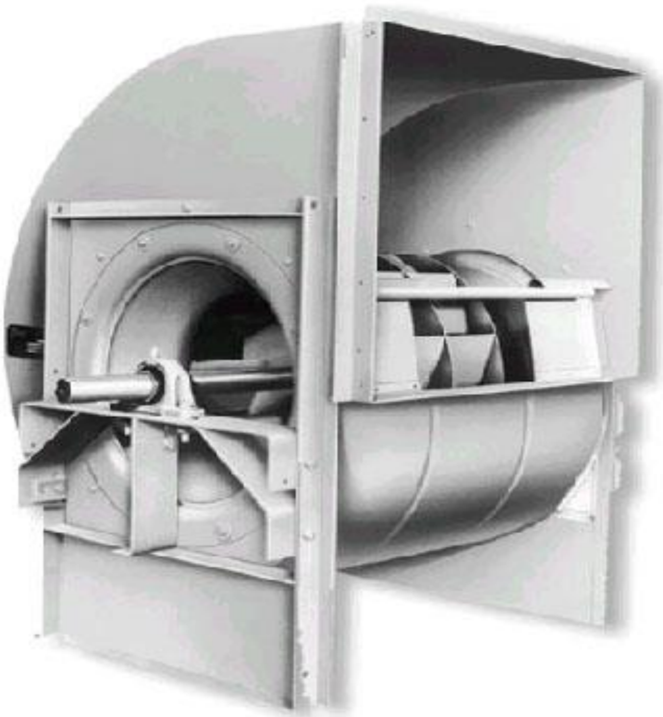
Air Conditioning Fans & VAV System

ACES Training
K Y Yow
23 Jan 2015

Air Conditioning Fans

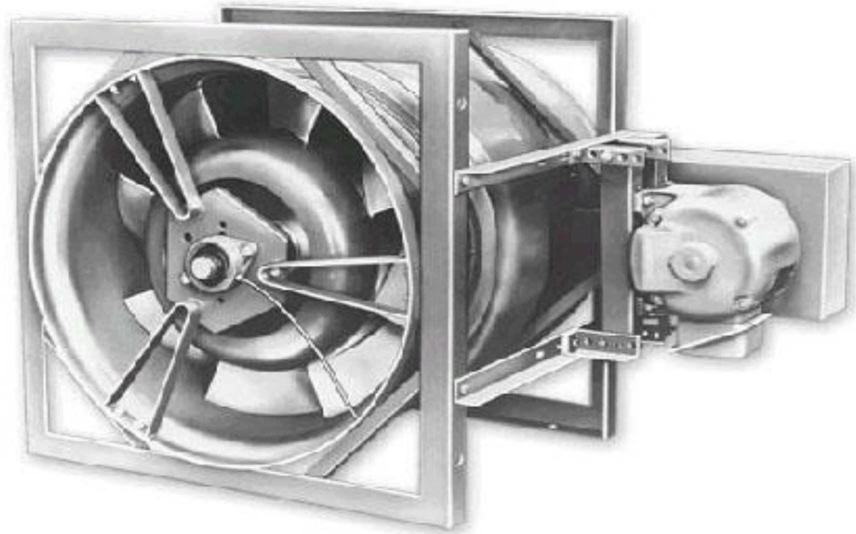
- Fundamentals
- Fan Types
- Fan Capacity Control
- Application Considerations

Air Conditioning Fans



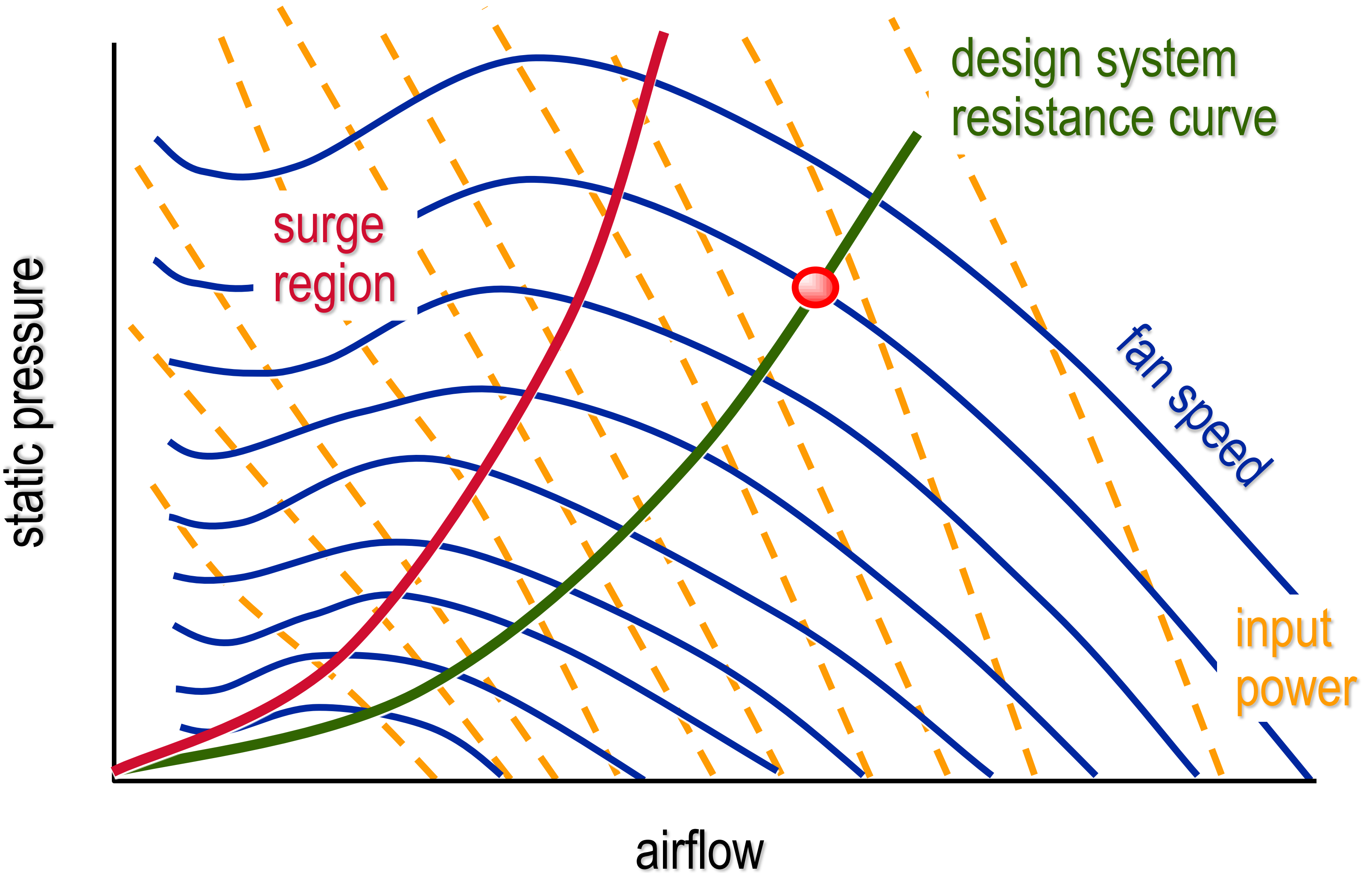
centrifugal

axial



Test Setup - Model ADA 710

Fan Curve



design system
resistance curve
surge
region
fan speed
input
power
static pressure
airflow

Fan Law 1

$$\frac{\text{Airflow}_2}{\text{Airflow}_1} = \left(\frac{\text{Fan RPM}_2}{\text{Fan RPM}_1}\right)$$

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

$$\frac{\text{Input Power}_2}{\text{Input Power}_1} = \left(\frac{\text{Fan RPM}_2}{\text{Fan RPM}_1}\right)^3$$

Determining Fan Airflow

$$\text{Velocity Pressure } (P_v) = P_t - P_s$$

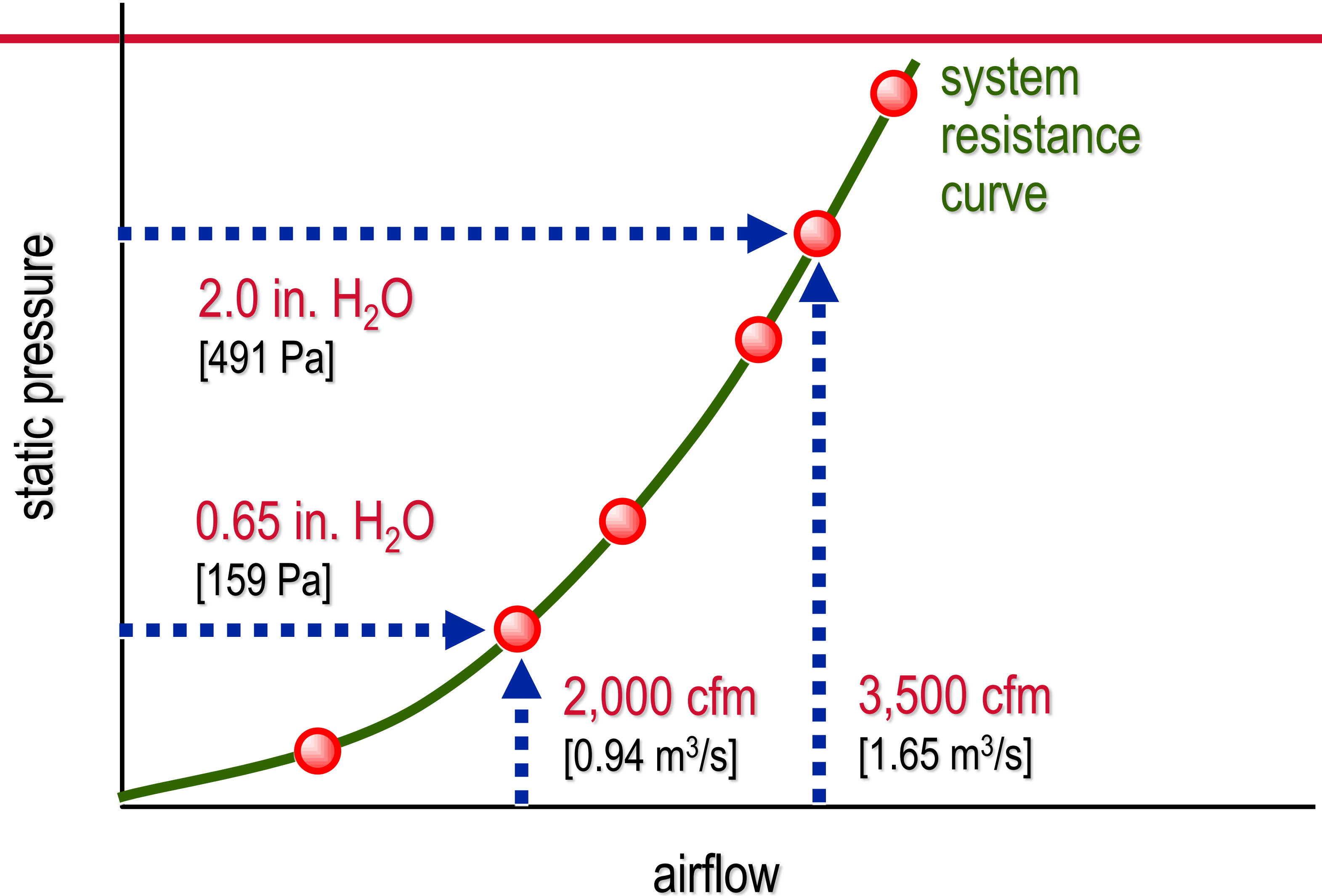
$$\text{Velocity (V)} = \text{Constant} \times \sqrt{\frac{P_v}{\rho}}$$

$$\text{Airflow} = \text{Velocity} \times \text{Fan Outlet Area}$$

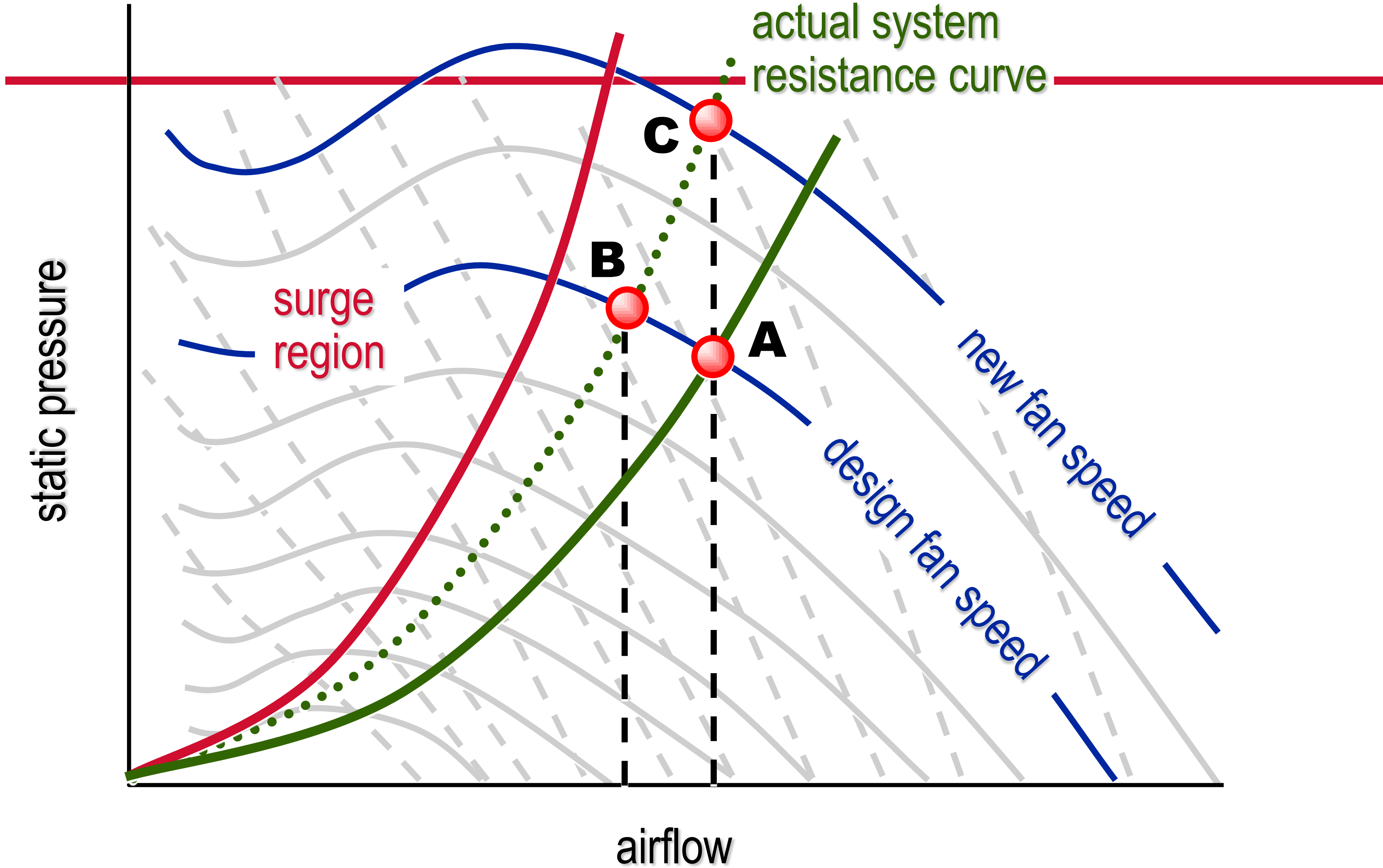
System Resistance Curve

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

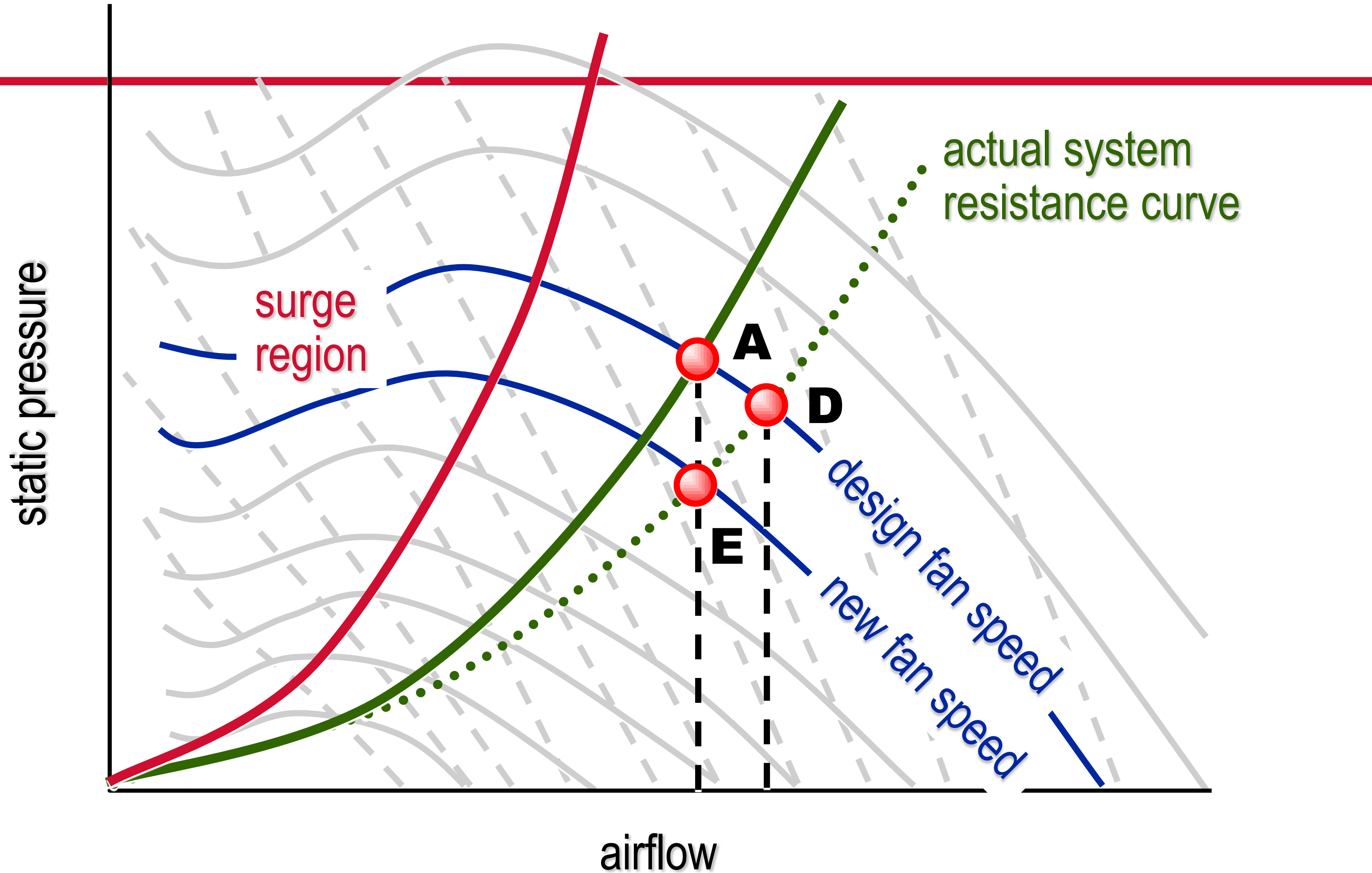
System Resistance Curve



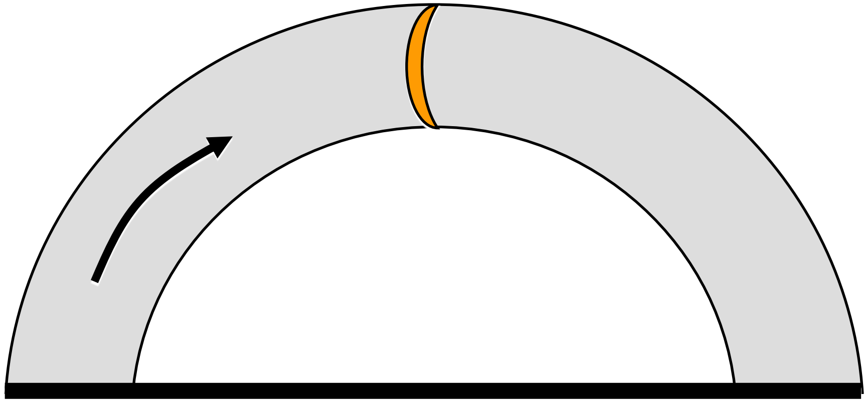
Higher System Resistance

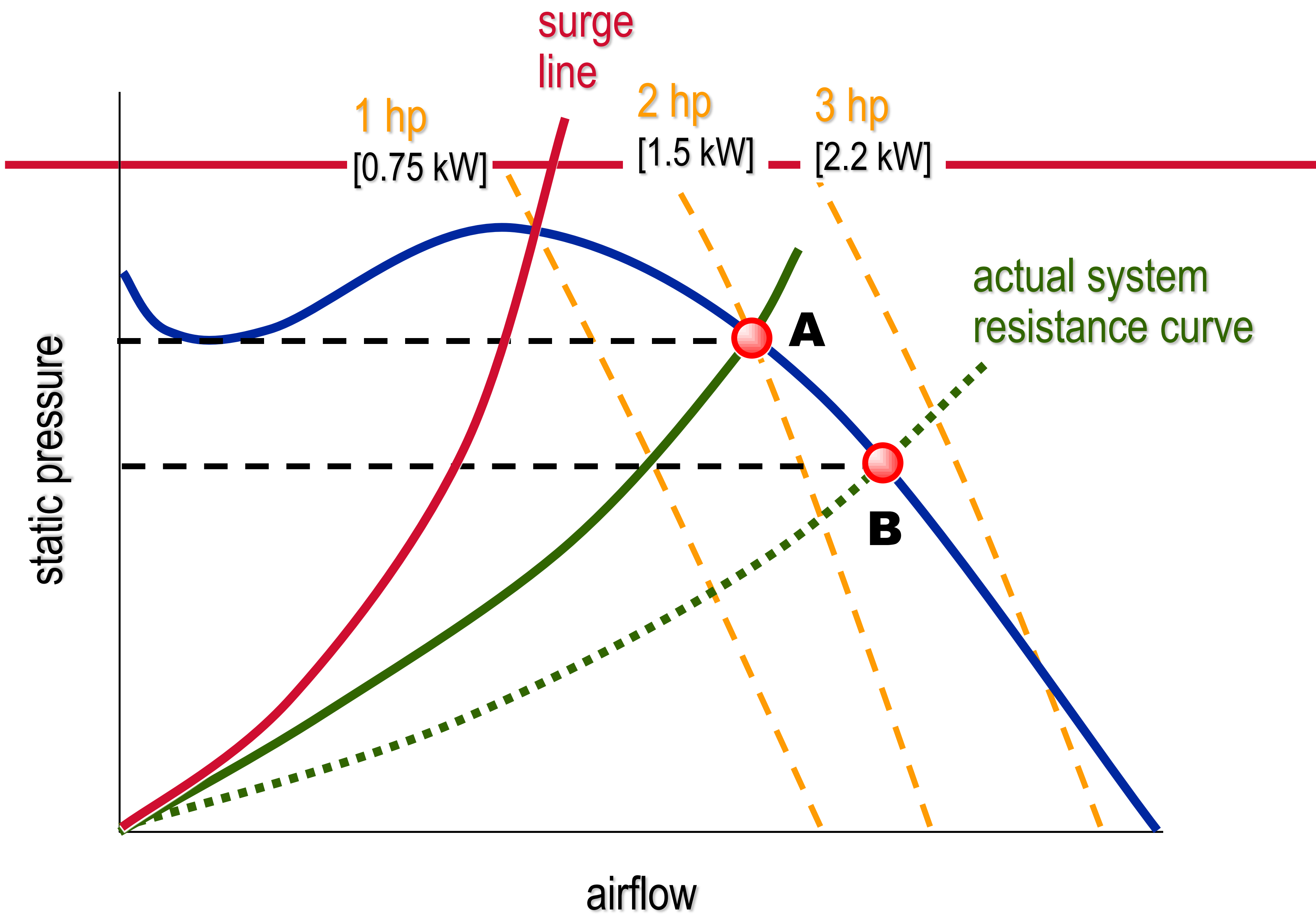


Lower System Resistance

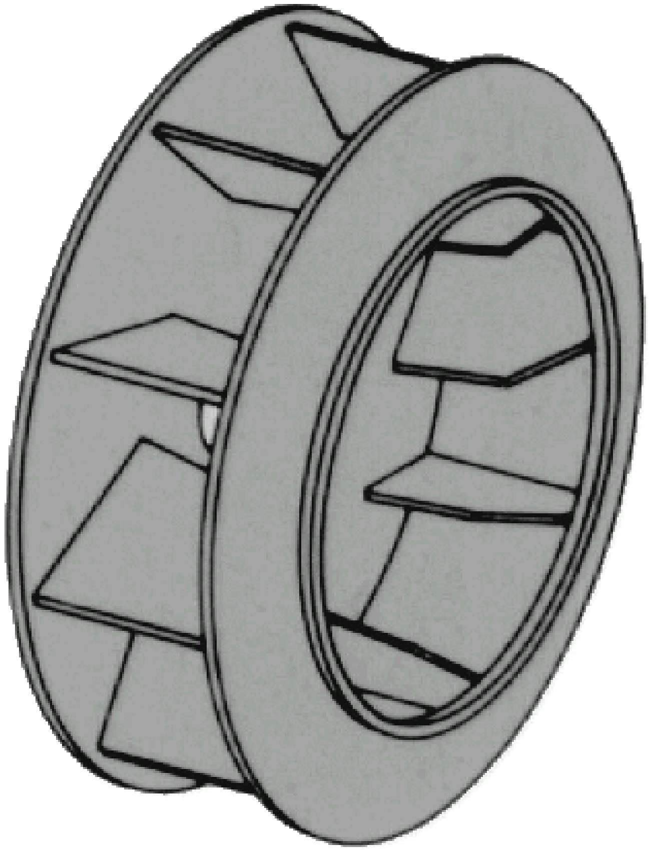


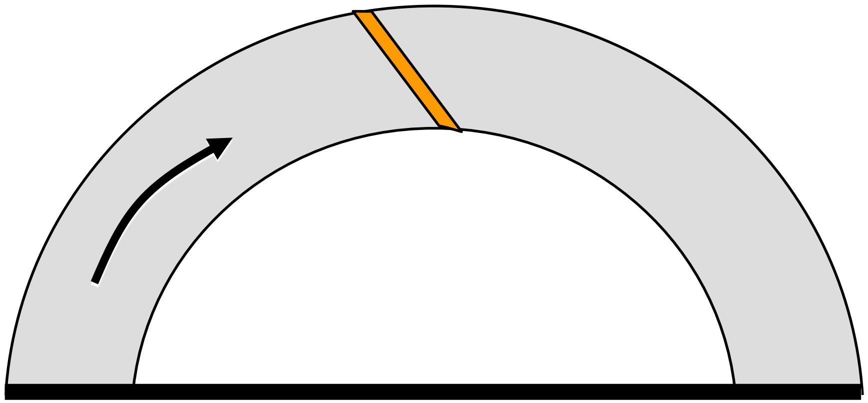
Forward Curved Fan



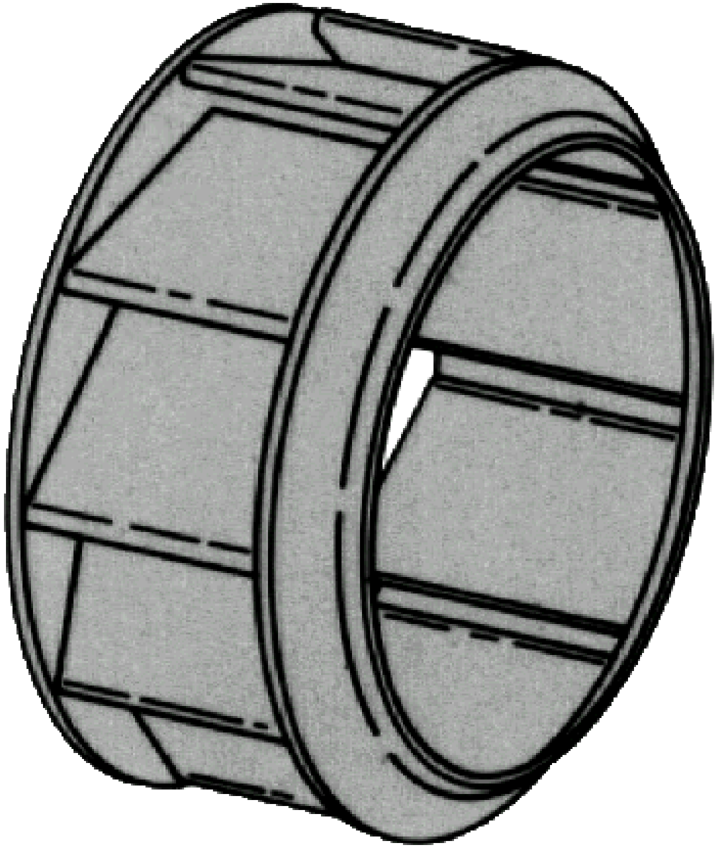

surge
line
1 hp
[0.75 kW]
2 hp
[1.5 kW]
3 hp
[2.2 kW]
A
B
actual system
resistance curve
static pressure
airflow

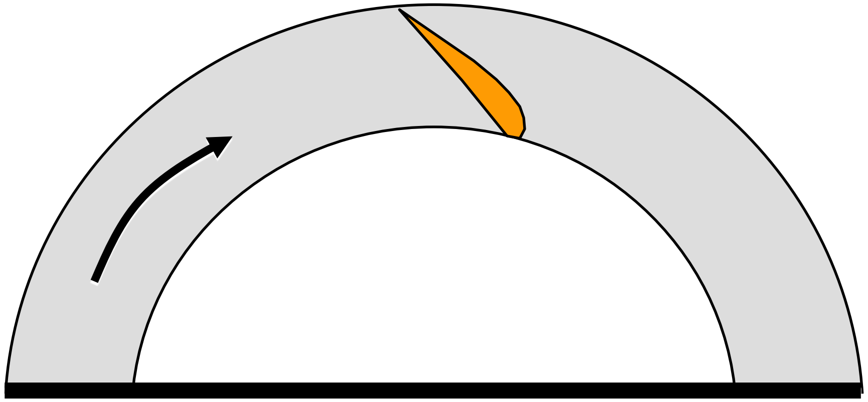
Backward Inclined Fan

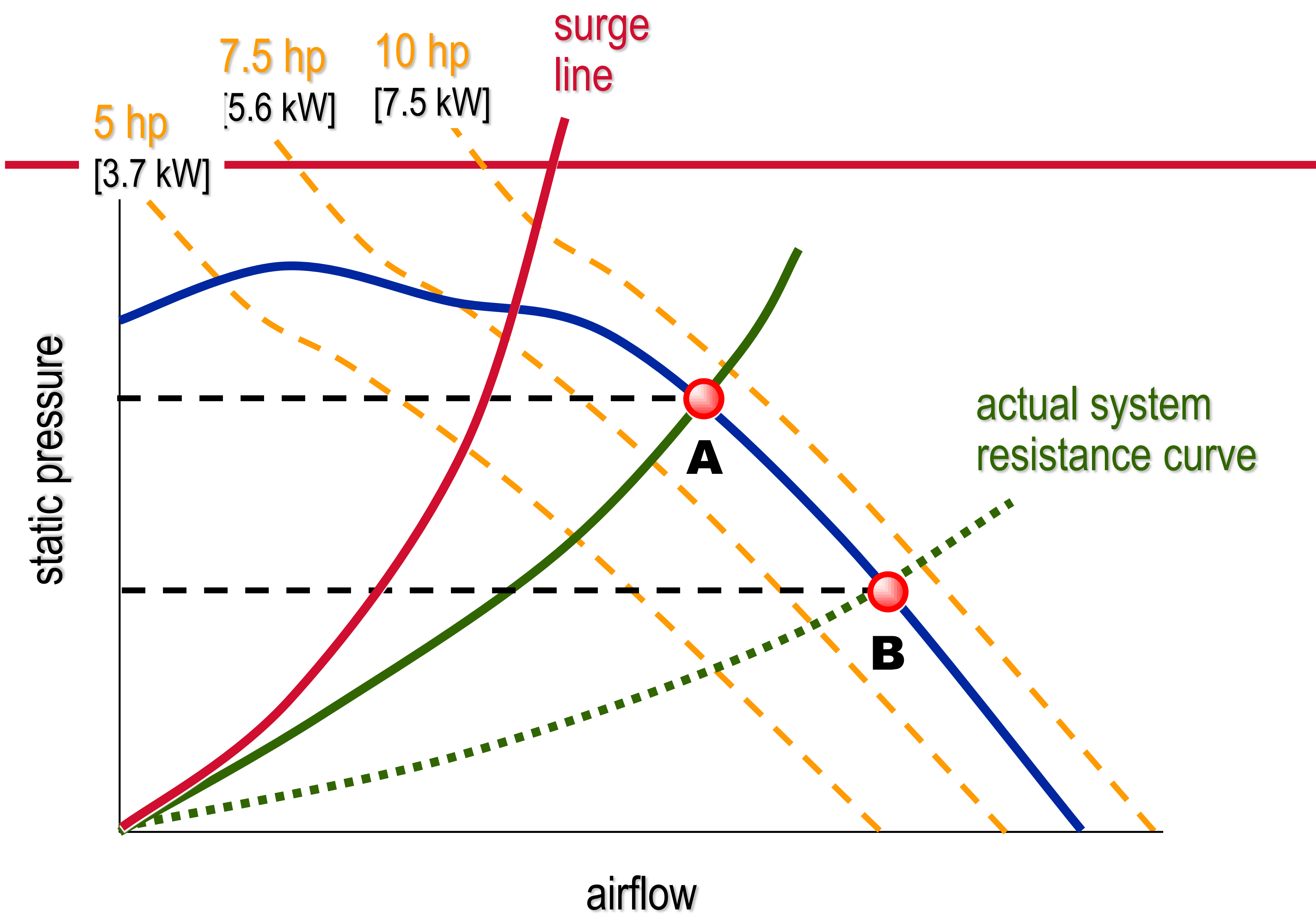




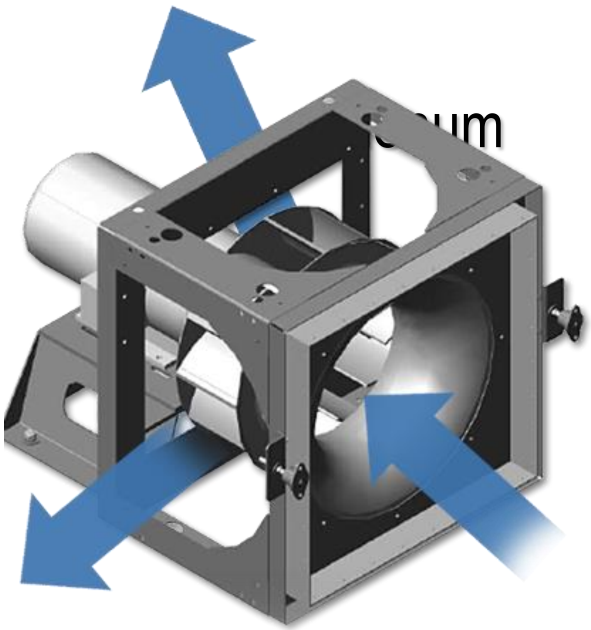
Airfoil Fan

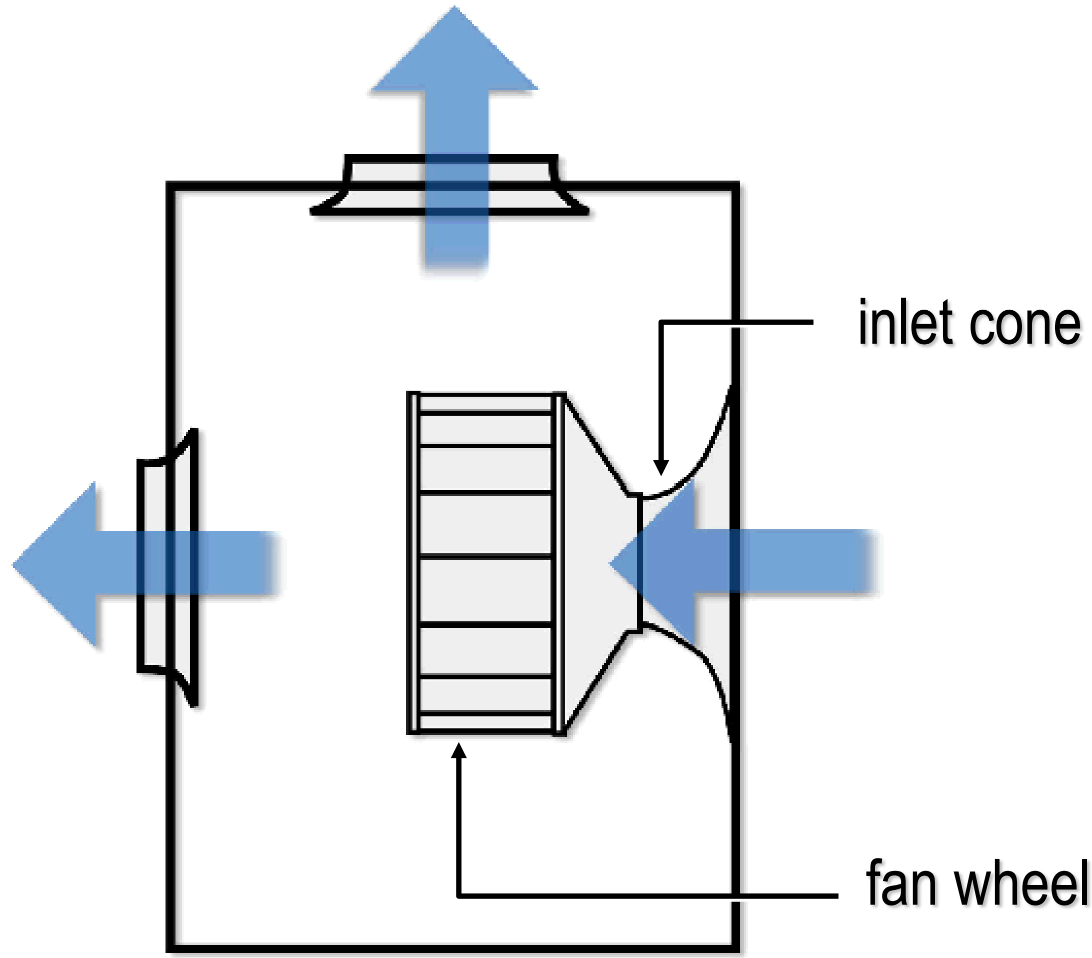





surge line
7.5 hp
[5.6 kW]
10 hp
[7.5 kW]
5 hp
[3.7 kW]
static pressure
A
B
actual system resistance curve
airflow

Plug (or Plenum) Fan





Fan Selection

- **Forward curved (FC)**
  - Airflow with low static pressure
  - Low Speed
  - Not suitable for high static application
- **Backward inclined (BI) or airfoil (AF)**
  - Airflow with higher static pressure
  - Higher efficiency
  - Twice the speed of FC
  - Magnitude of surge is greater

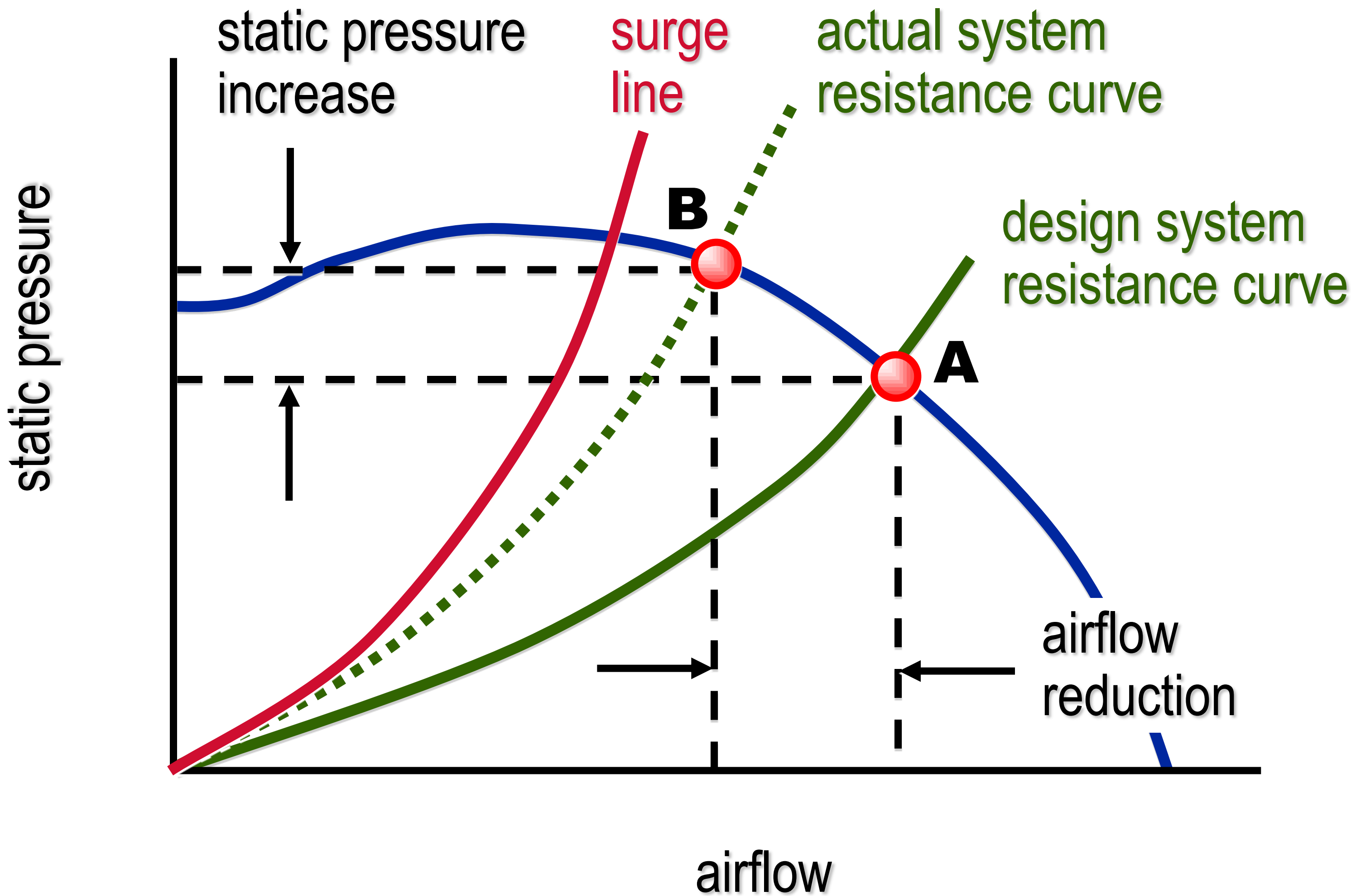
Air Conditioning Fans

Fan Capacity Control

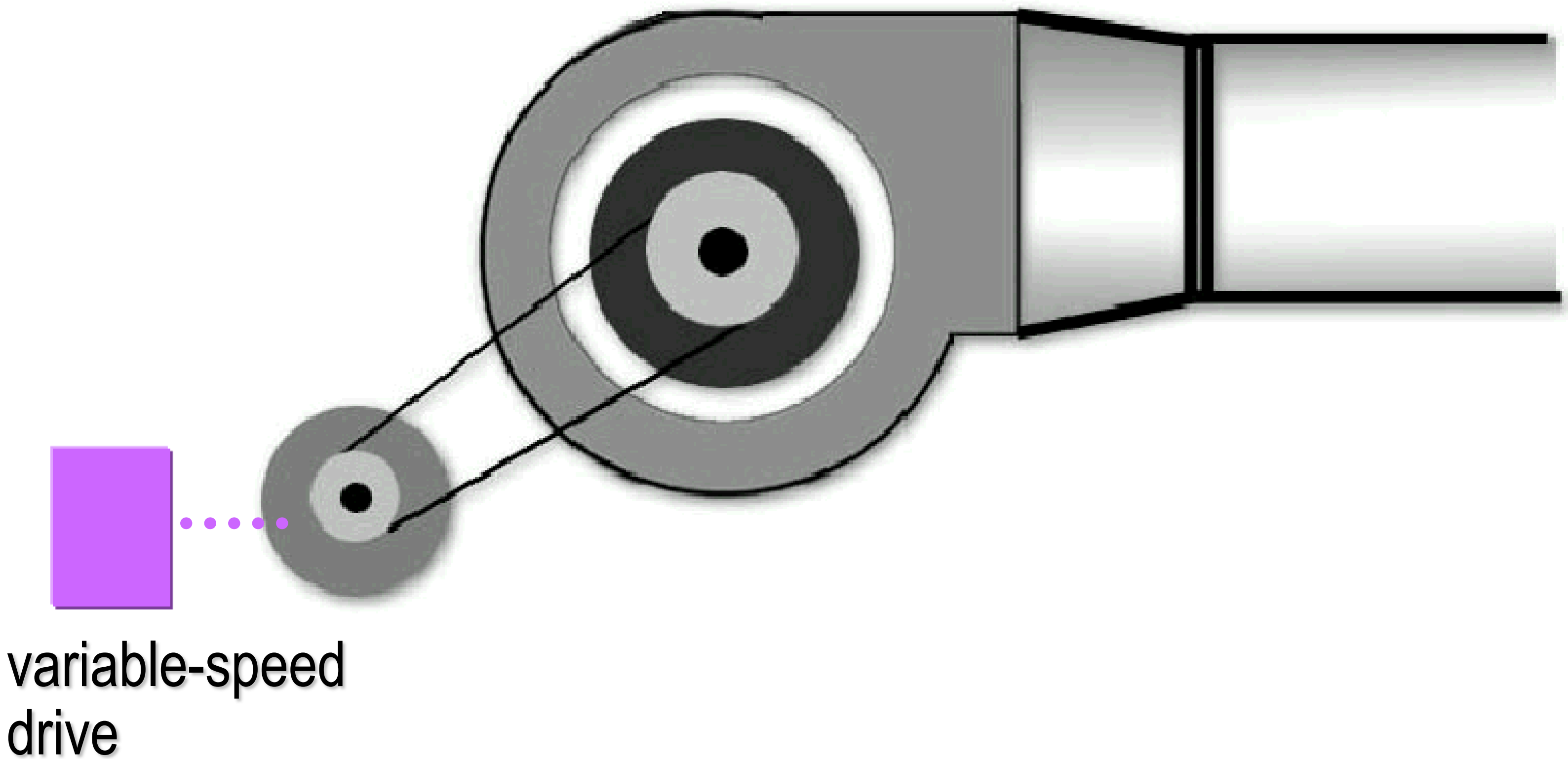
Fan Capacity Control

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

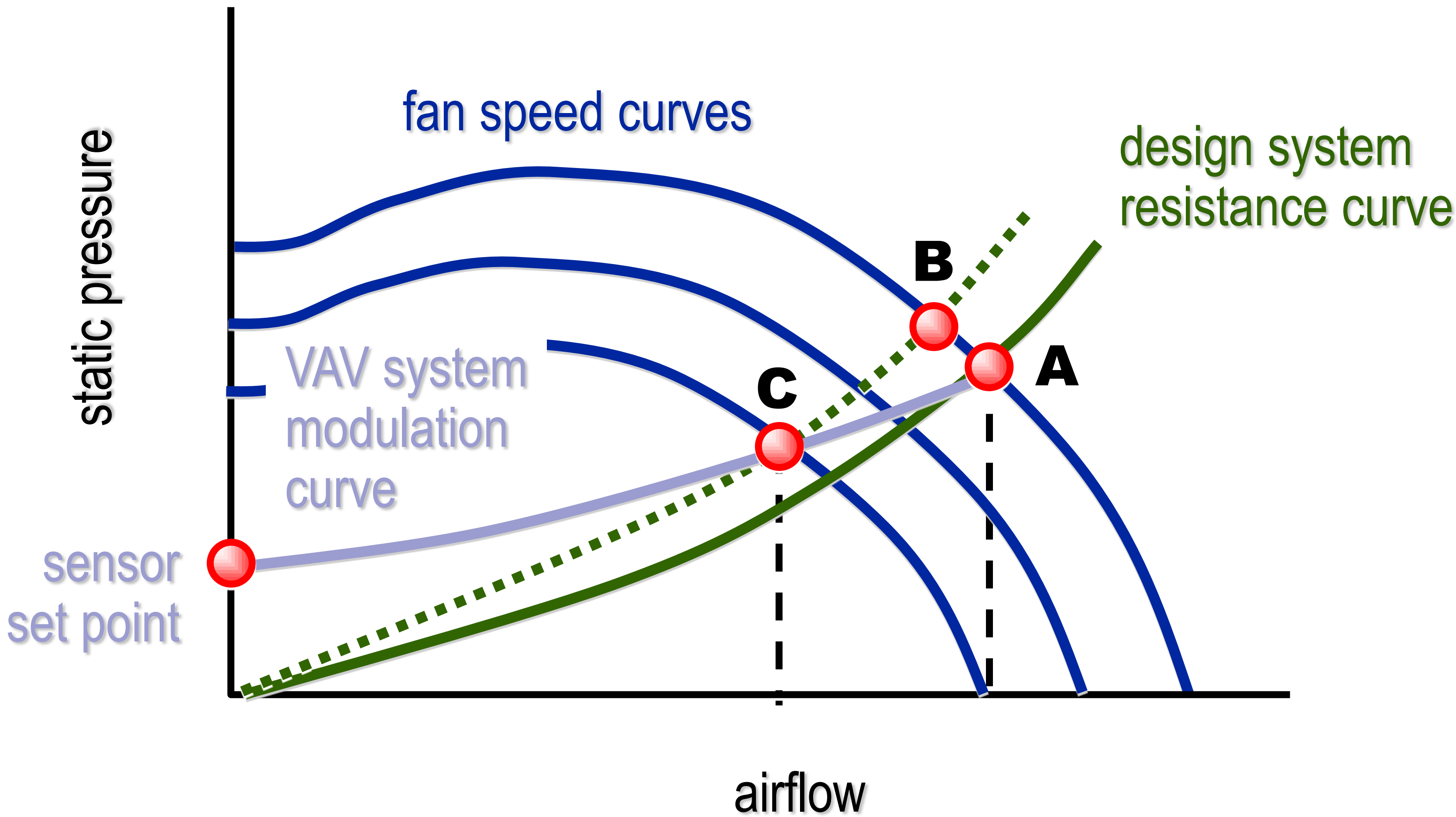
"Riding the Fan Curve"



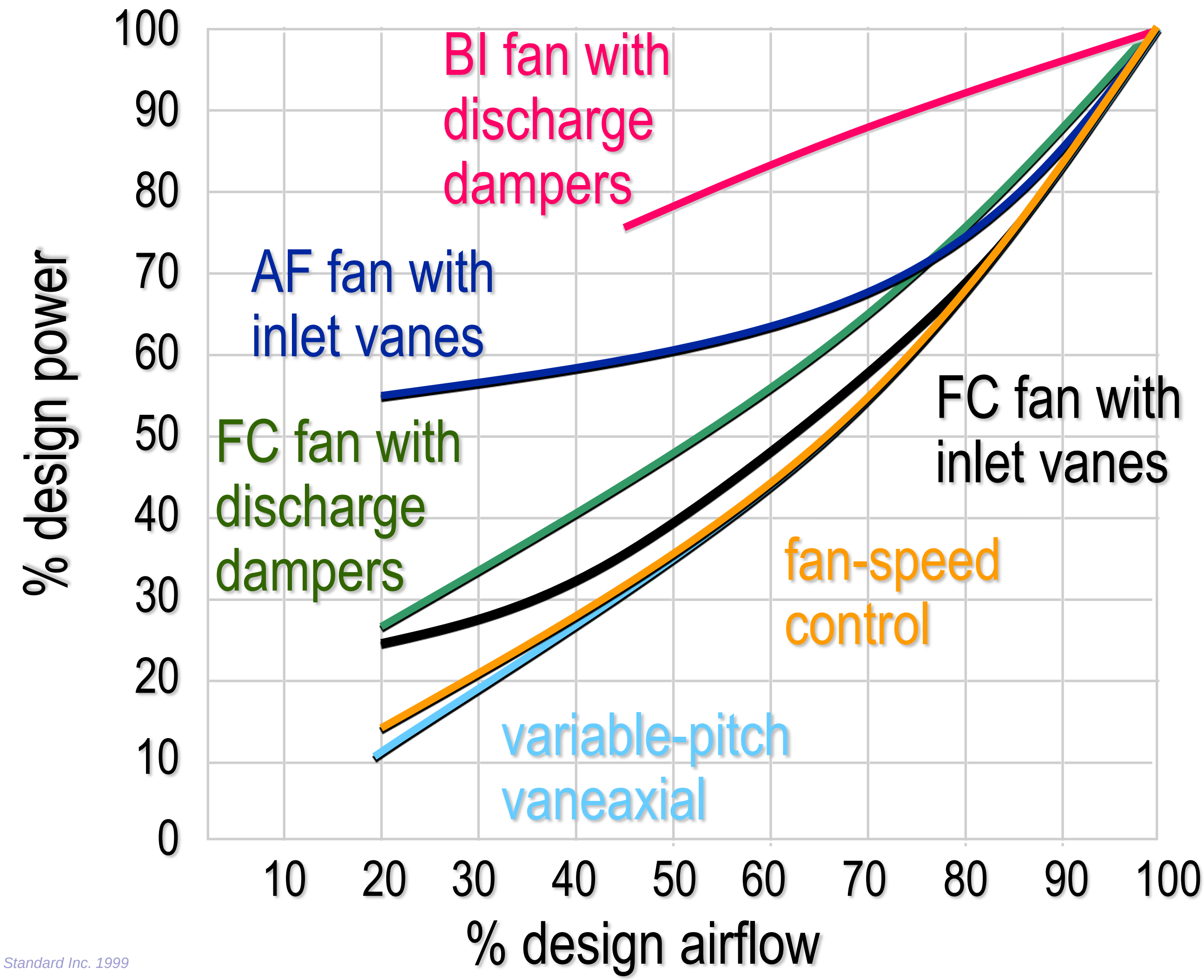
Fan-Speed Control



Fan-Speed Control



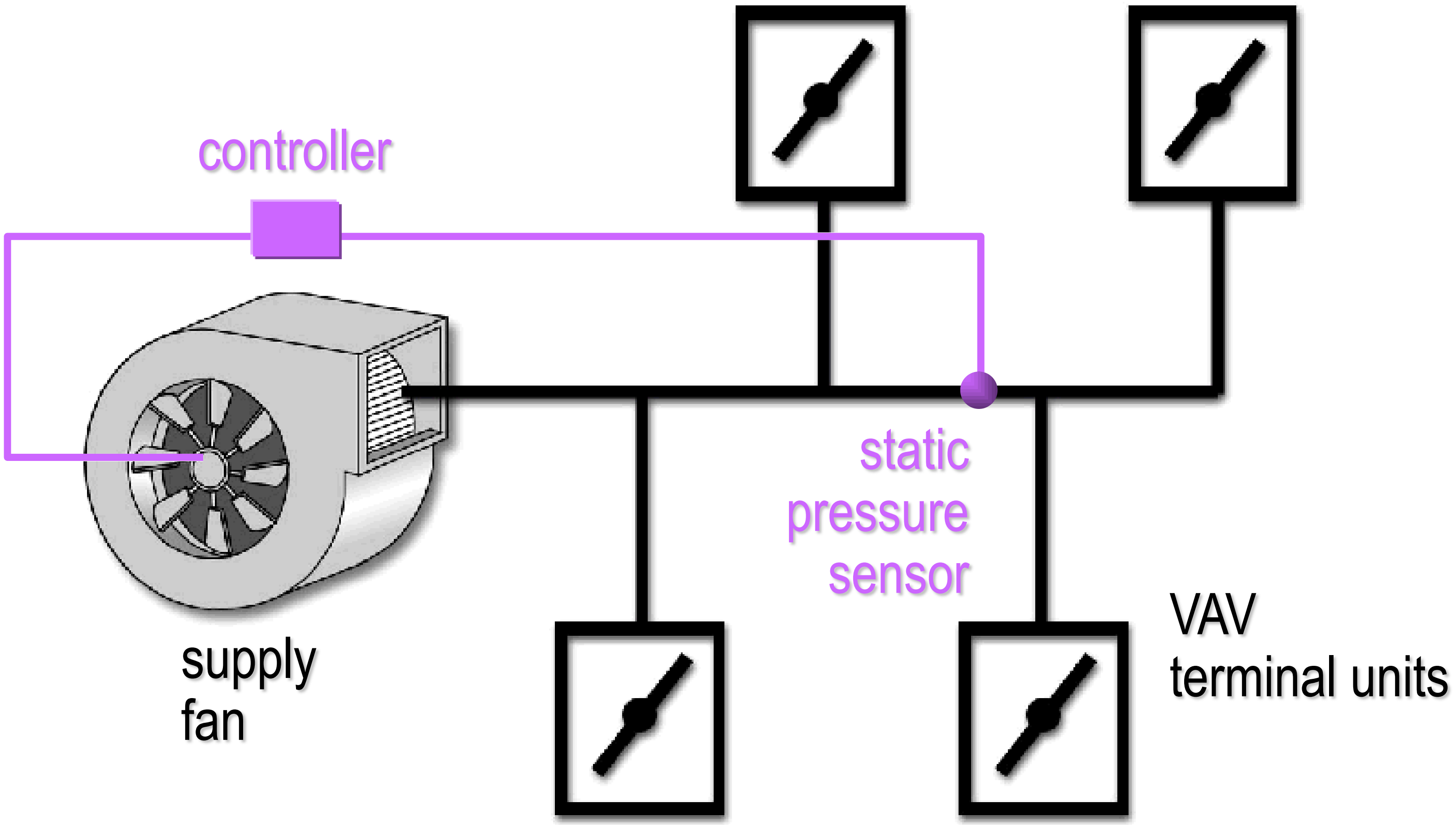
Fan Control Comparison



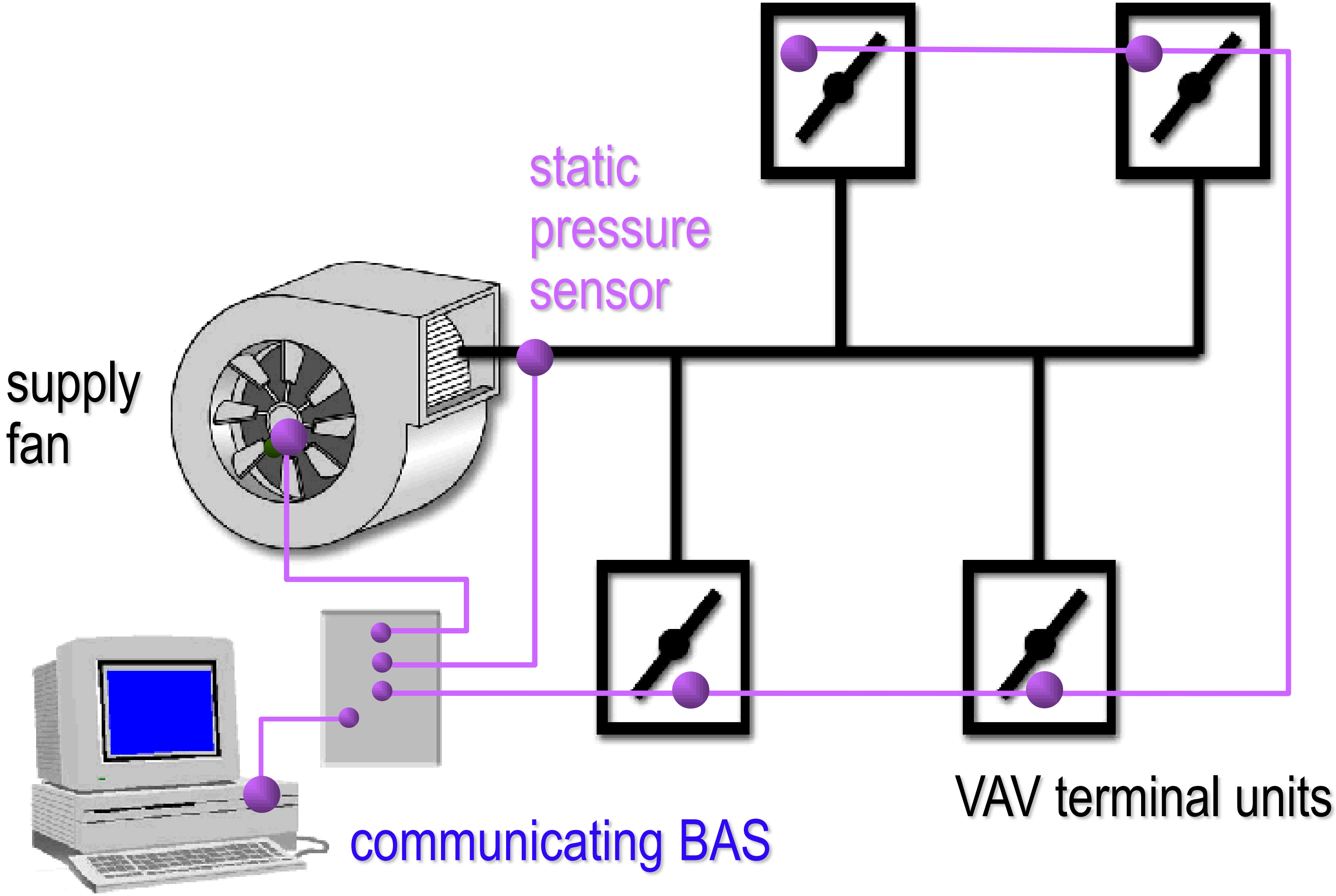
Air Conditioning Fans

Application Considerations

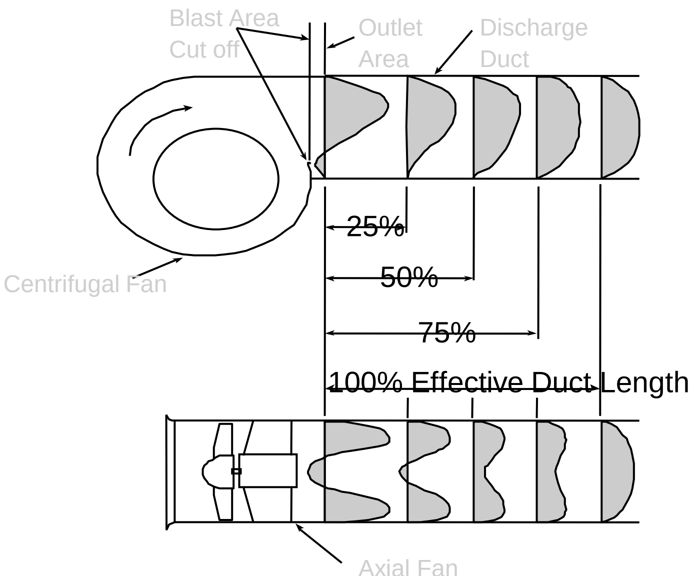
System Static-Pressure Control

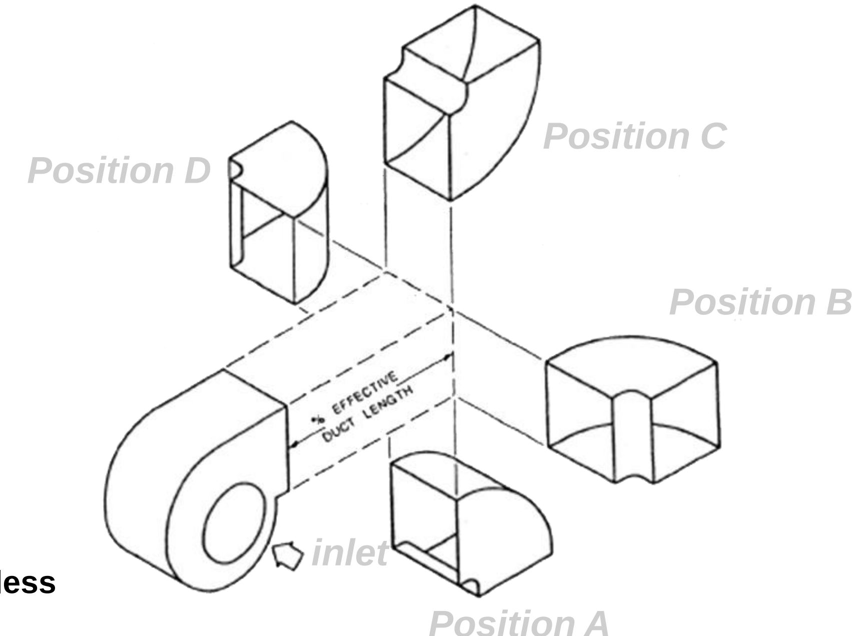


Optimized Static-Pressure Control



System Effect





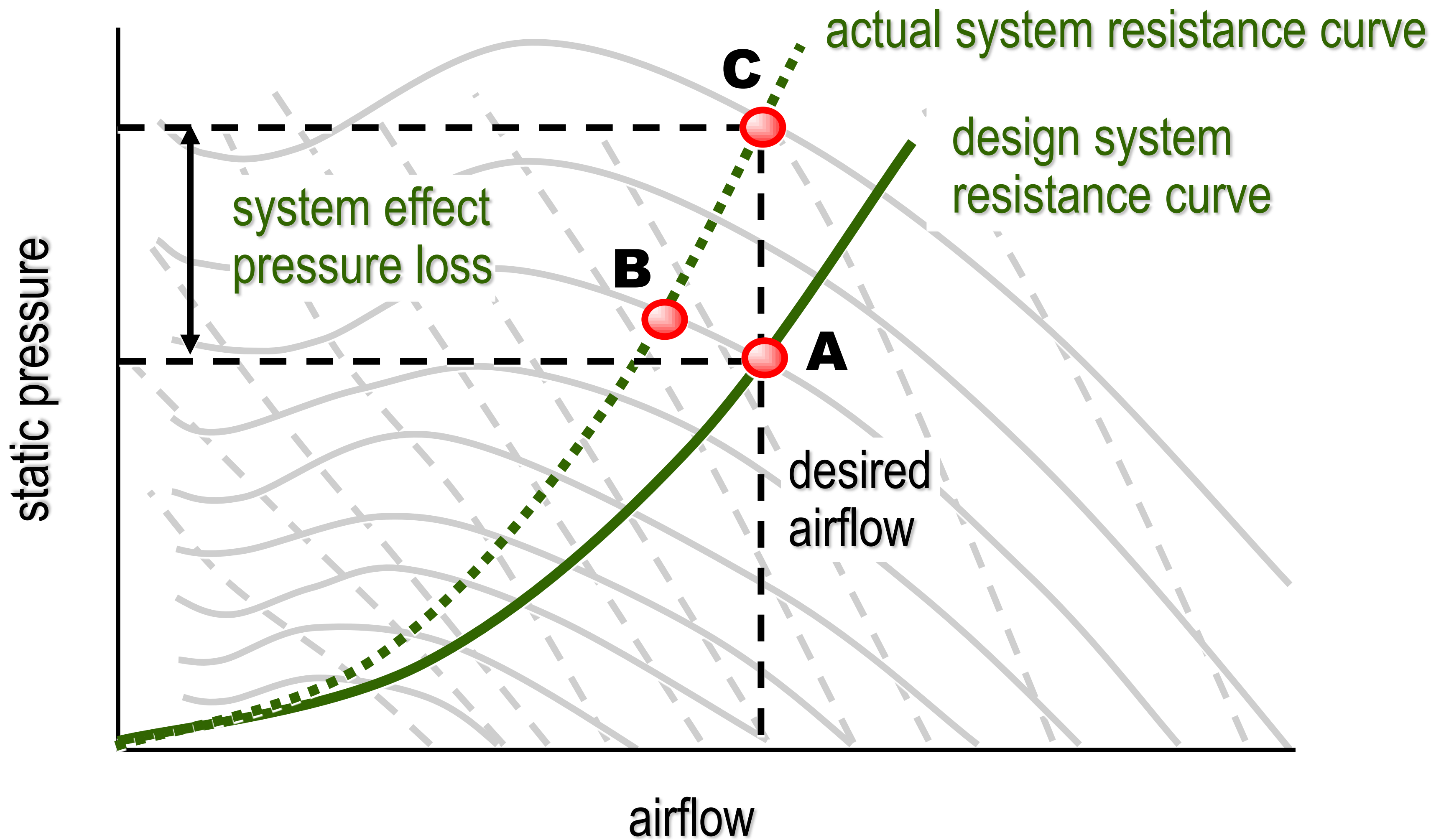
Effective Duct Length = 2.5 Duct Diameters for 2,500 FPM or less

Add 1 duct diameter for each additional 1,000 FPM

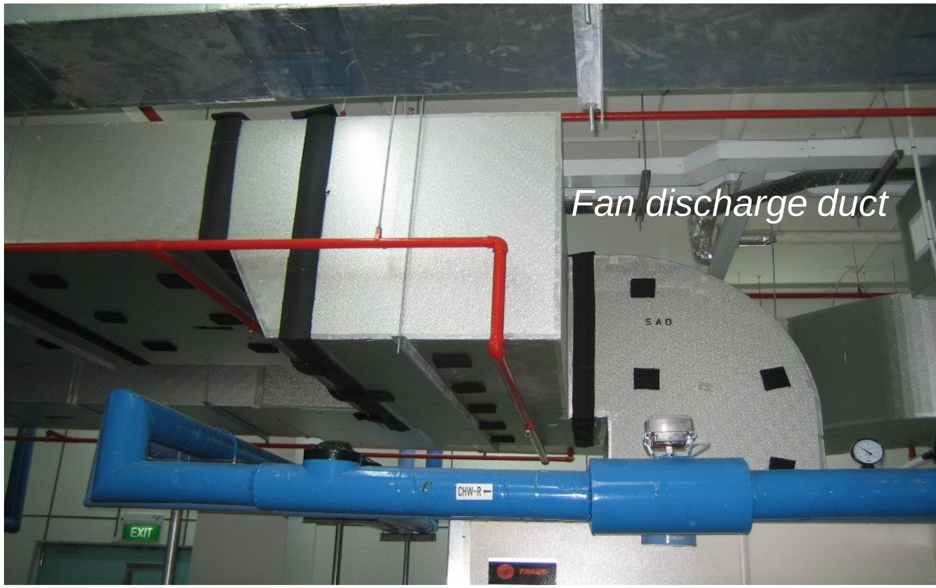
For rectangular ducts, the equivalent duct diameter is

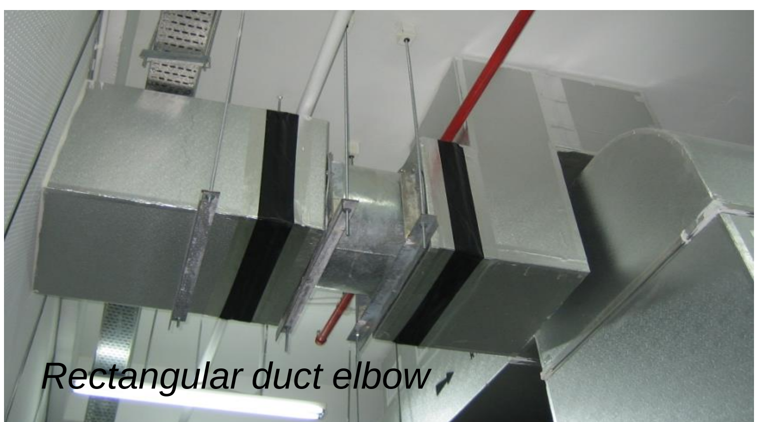
(4 x width x length / 3.14) ^ 0.5

System Effect



System Effect Factors are Real



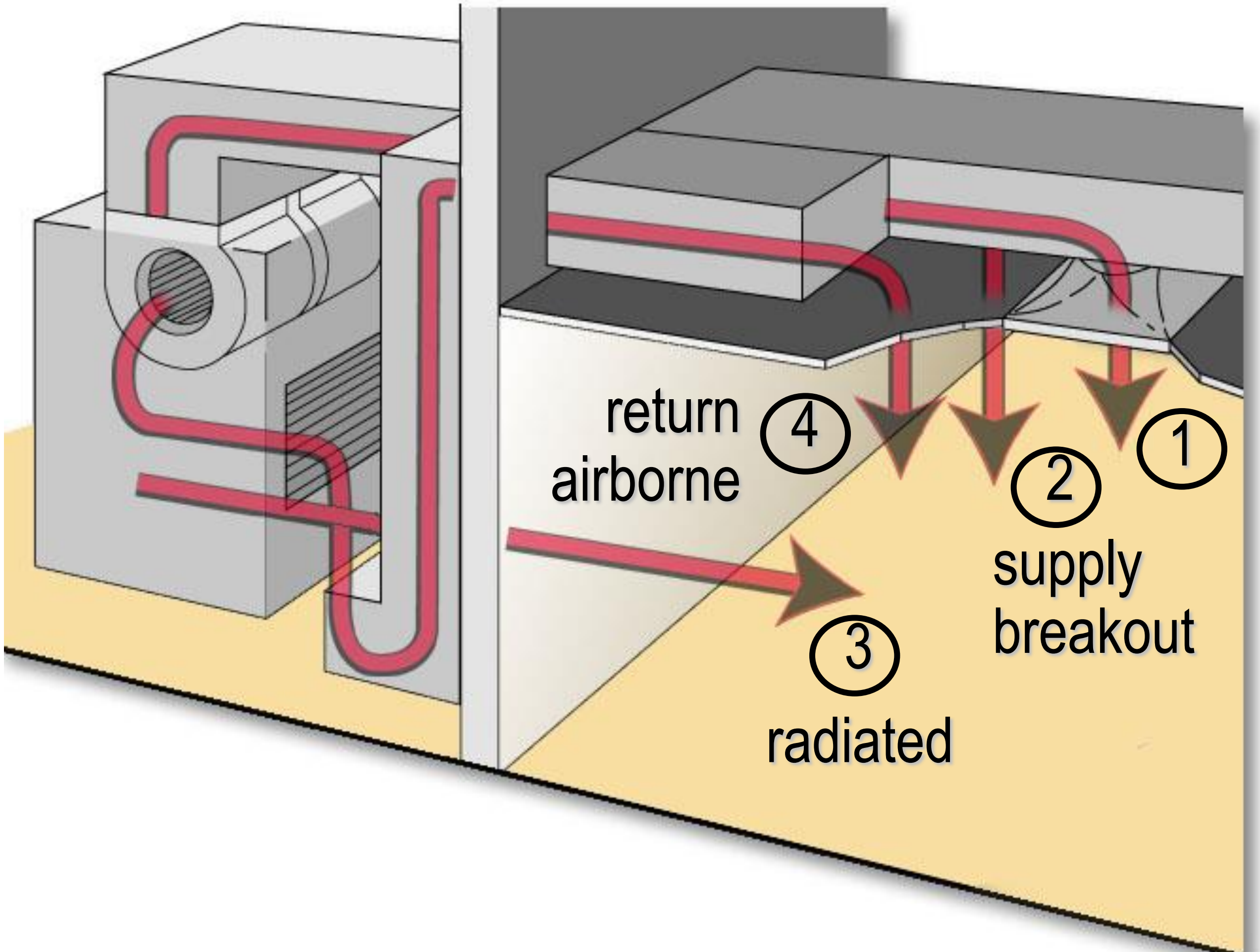


Recommendations

- Minimum 2.5 duct diameters on Outlet
- Minimum 5 to 8 duct diameters on Inlet
- Avoid inlet swirl

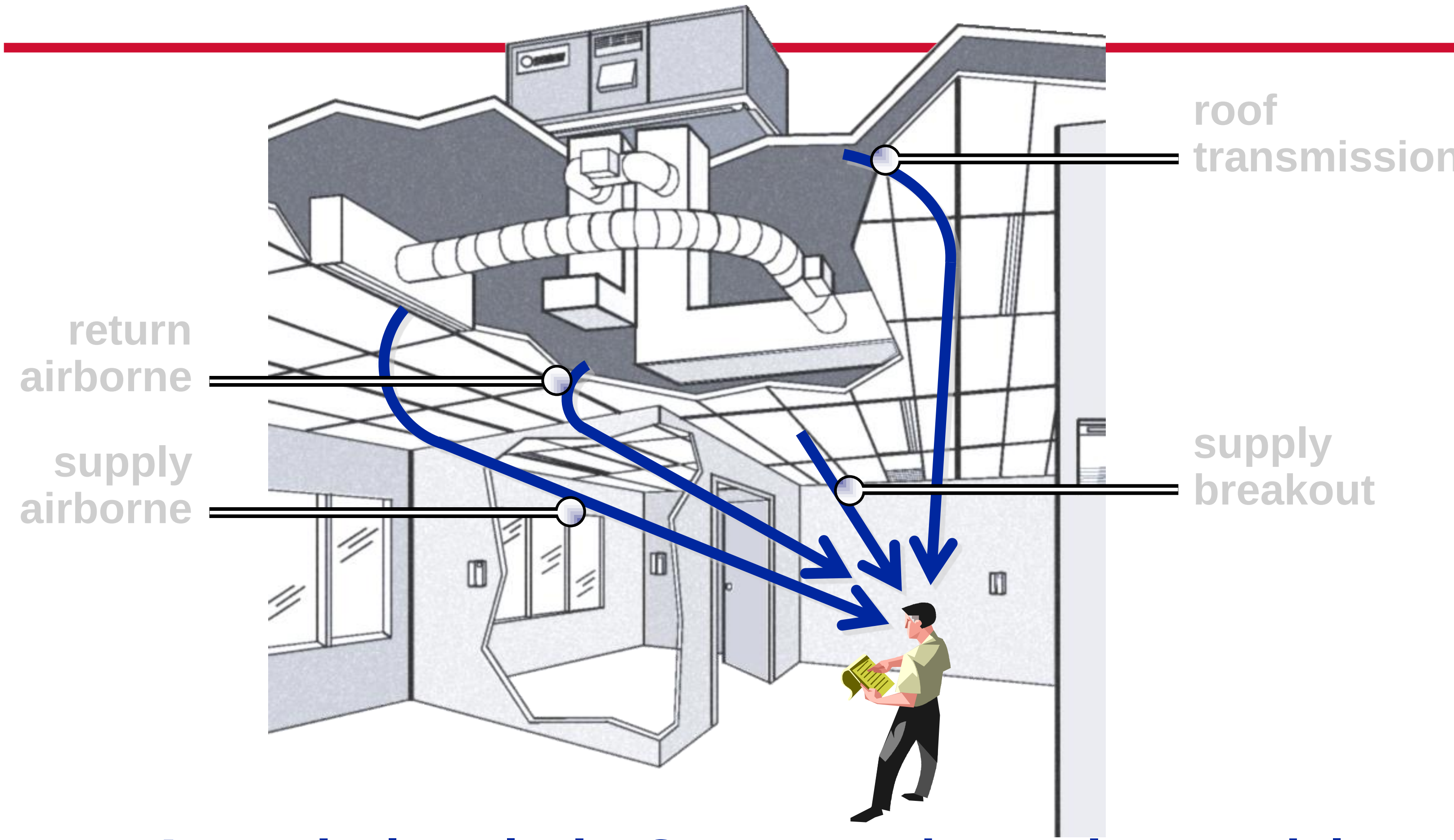
  - If any of these general rules are broken, make sure to take system effect into account.

Acoustics



return airborne
4
2
1
supply airborne
supply breakout
3
radiated

Sound Transmission Paths



Acoustical analysis: Source–path–receiver model

fan application
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 (Nonstandard) Conditions

1) $$\text{Air Density Ratio} = \frac{\text{Density}_{\text{actual}}}{\text{Density}_{\text{standard}}}$$

2) $$\text{SP}_{\text{standard}} = \frac{\text{SP}_{\text{actual}}}{\text{Air Density Ratio}}$$

3) Use $\text{Airflow}_{\text{actual}}$ and $\text{SP}_{\text{standard}}$ to select fan

4) $\text{RPM}_{\text{standard}} = \text{RPM}_{\text{actual}}$

5) $\text{Power}_{\text{actual}} = \text{Air Density Ratio} \times \text{Power}_{\text{standard}}$

Equipment Certification Standards
AMCA – Air Movement and Control Association

- **Purpose**
  - Establish methods for laboratory testing of air moving devices

VAV Systems

A Trane Air Conditioning Clinic

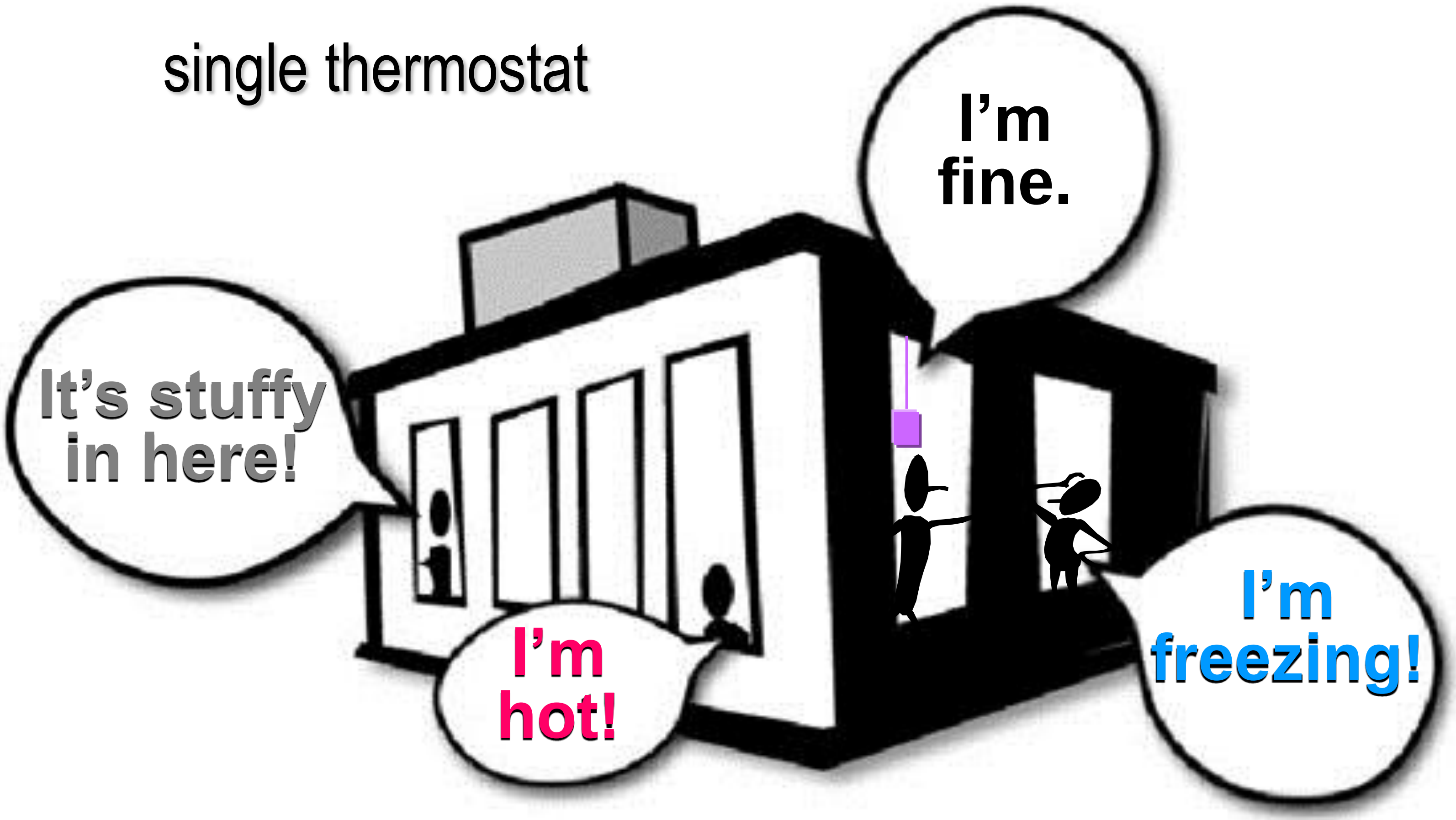
VAV Systems

period one

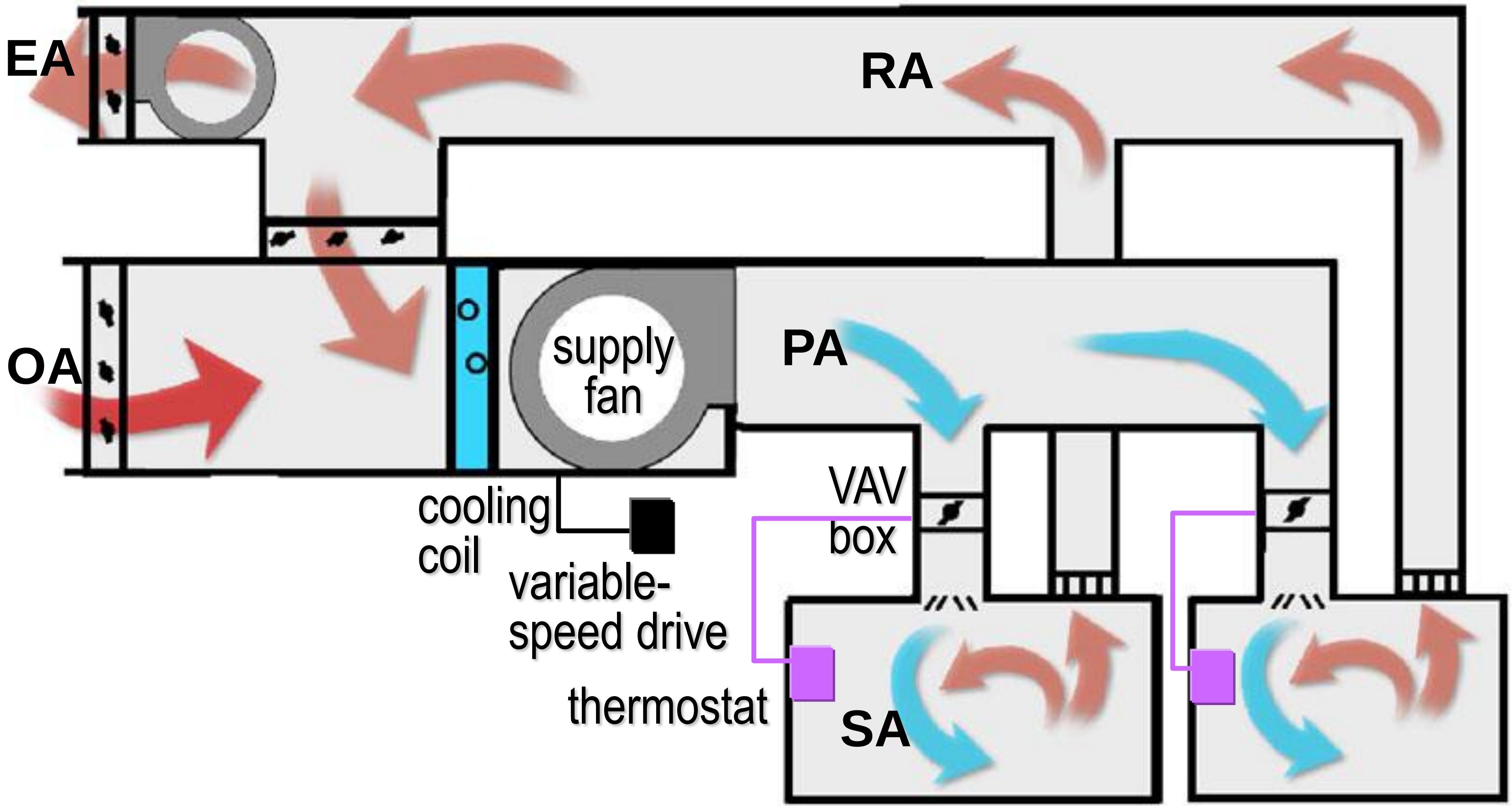
What Is Variable Air Volume?

constant-volume, variable-temperature system …

Applied To Multiple Spaces



Variable-Air-Volume System



variable-air-volume (VAV) system …
Full Load

With these design conditions …

space sensible heat gain = 40,000 Btu/hr

space dry-bulb temperature = 75°F

supply air dry-bulb temperature = 55°F

$$\text{Supply Airflow} = \frac{40{,}000 \text{ Btu/hr}}{1.085 \times (75°\text{F} - 55°\text{F})} = 1{,}840 \text{ cfm}$$

variable-air-volume (VAV) system …

Part Load

With these part load conditions …

space sensible heat gain = 20,000 Btu/hr

space dry-bulb temperature = 75°F

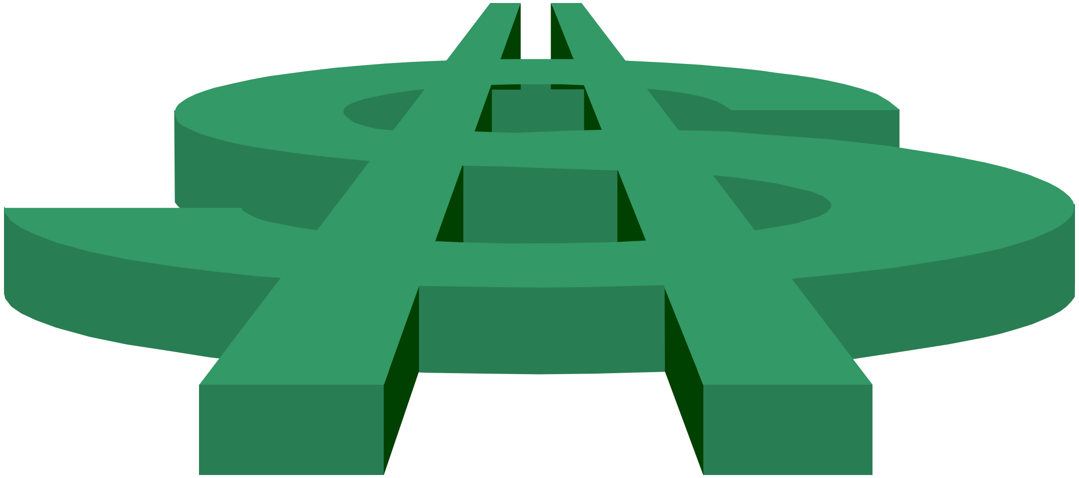
supply air dry-bulb temperature = 55°F

$$\text{Supply Airflow} = \frac{20{,}000 \text{ Btu/hr}}{1.085 \times (75°\text{F} - 55°\text{F})} = 920 \text{ cfm}$$

why VAV?

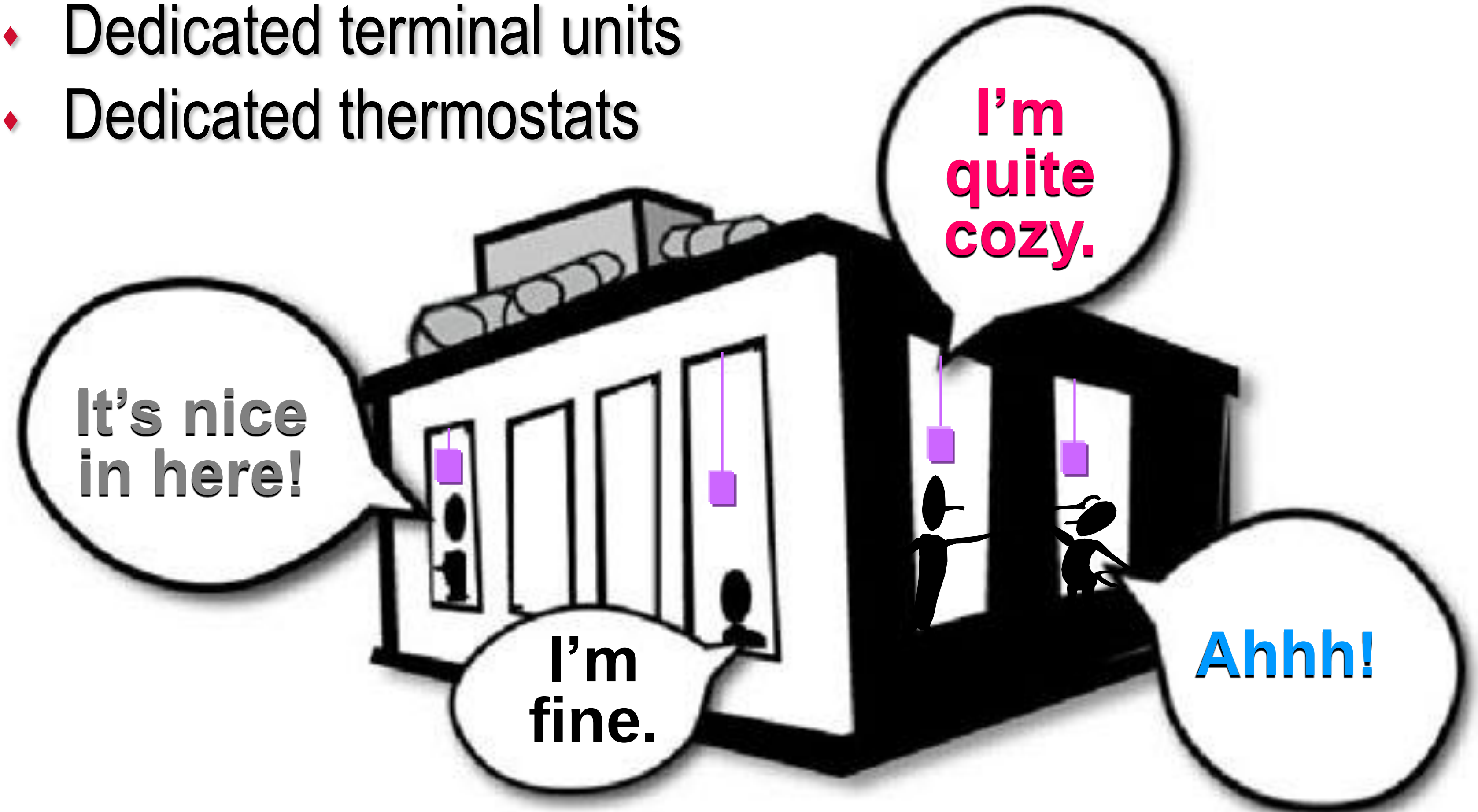
Part-Load Energy Savings

- Reduced fan energy
- Reduced refrigeration energy



why VAV?
Comfort

- Dedicated terminal units
- Dedicated thermostats



System Comparison

constant-volume,
single zone

- Constant fan energy
- Refrigeration energy savings
- Delivers comfort to only one thermal zone

VAV

- Fan energy savings
- Refrigeration energy savings
- Delivers comfort to many spaces efficiently

Building Characteristics

- Variable thermal load profiles
- Multiple, independently-controlled spaces
- Common return air path

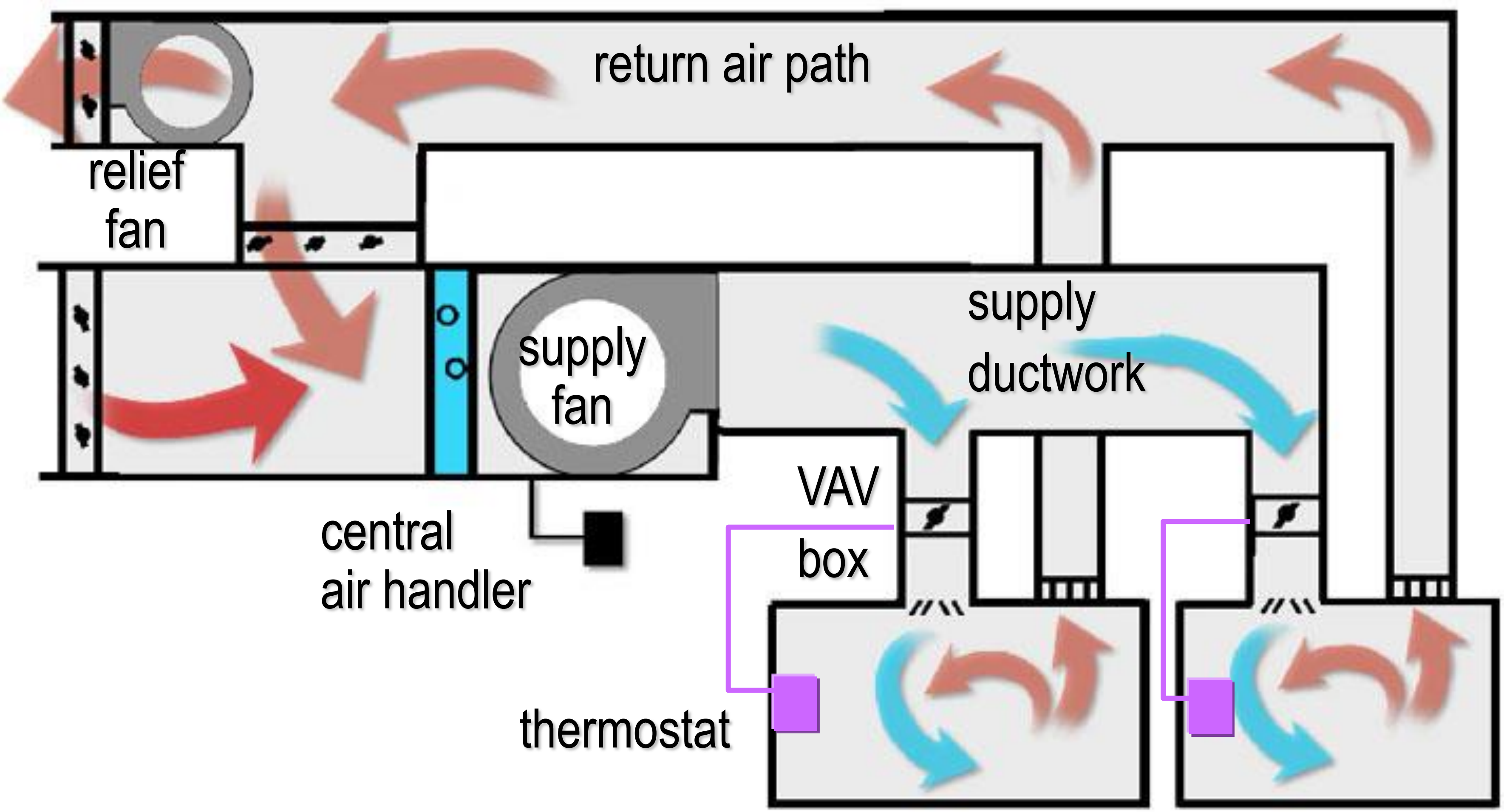
VAV Systems

period two

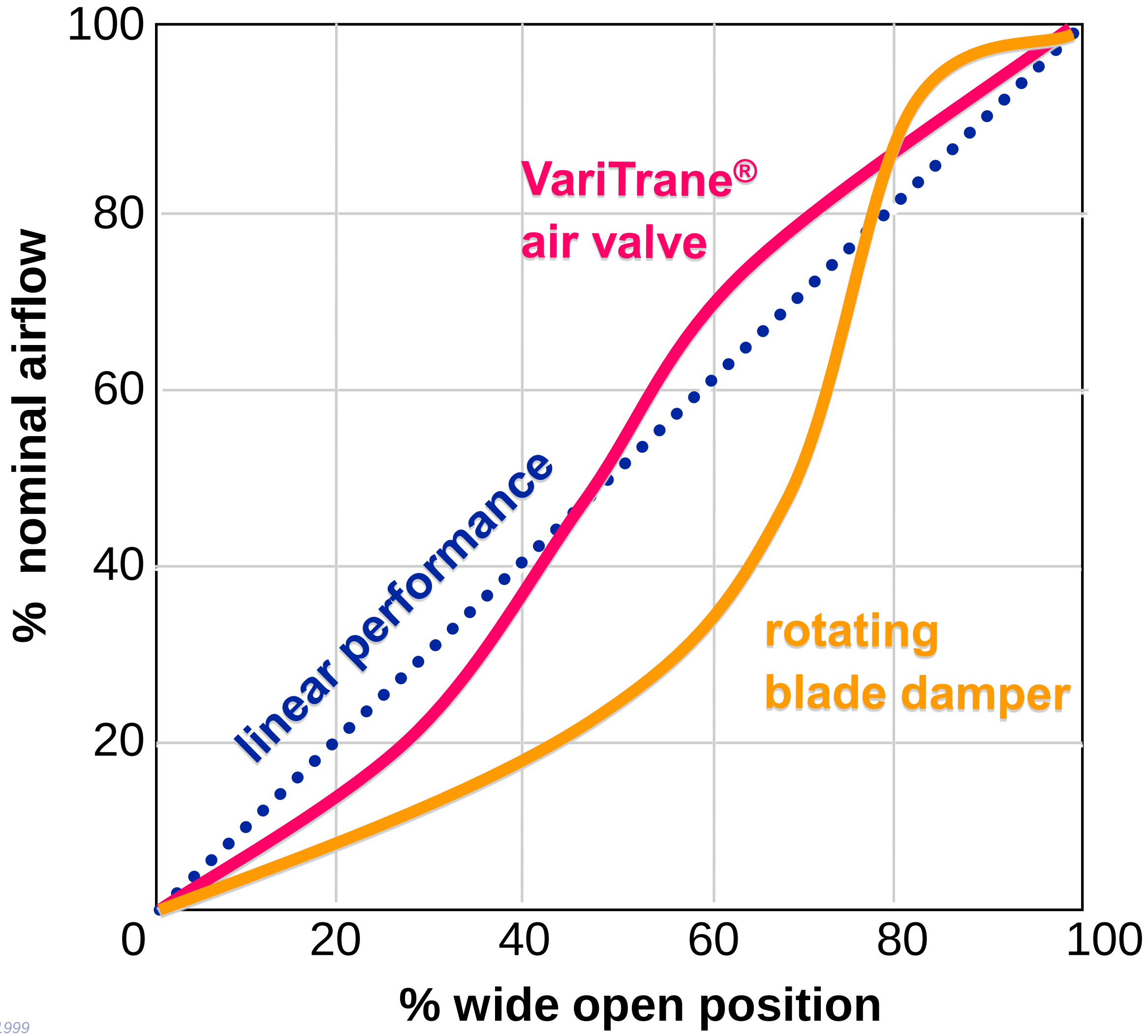
Components Of A VAV System

components of a

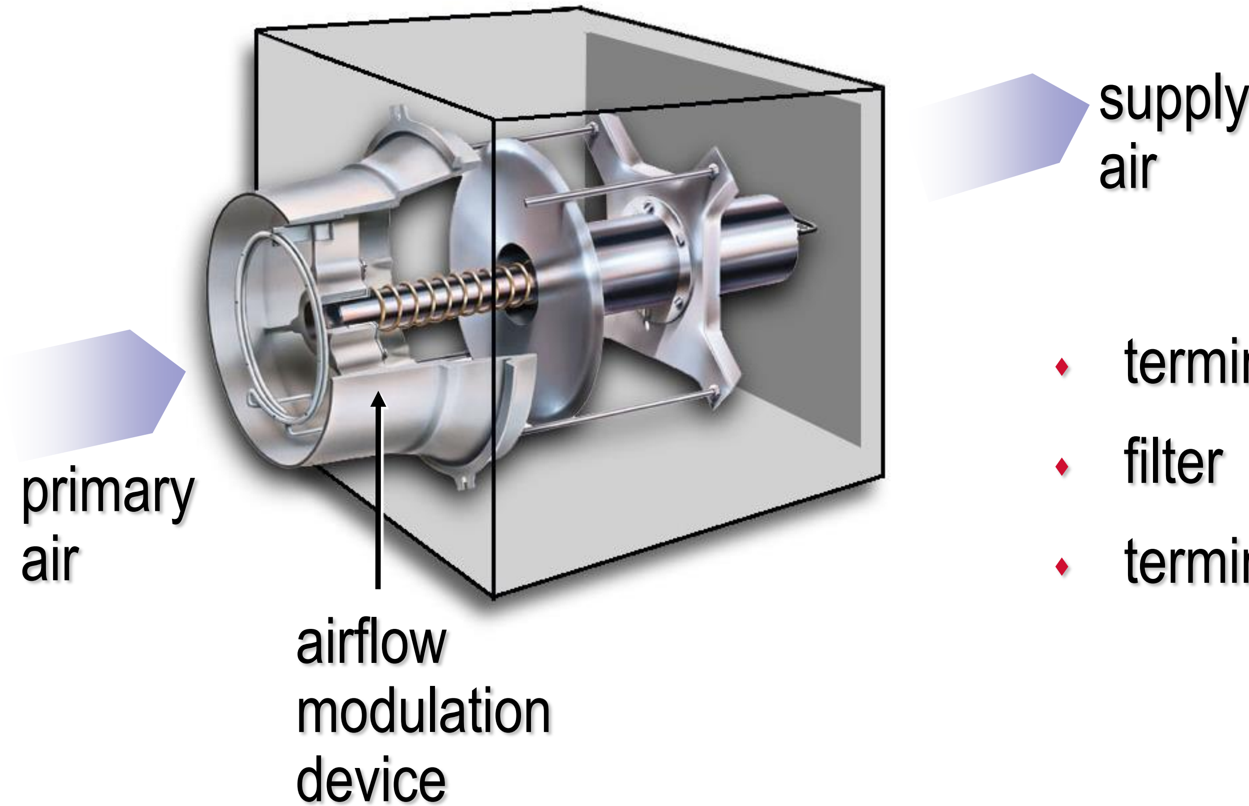
VAV System



Near-Linear Performance

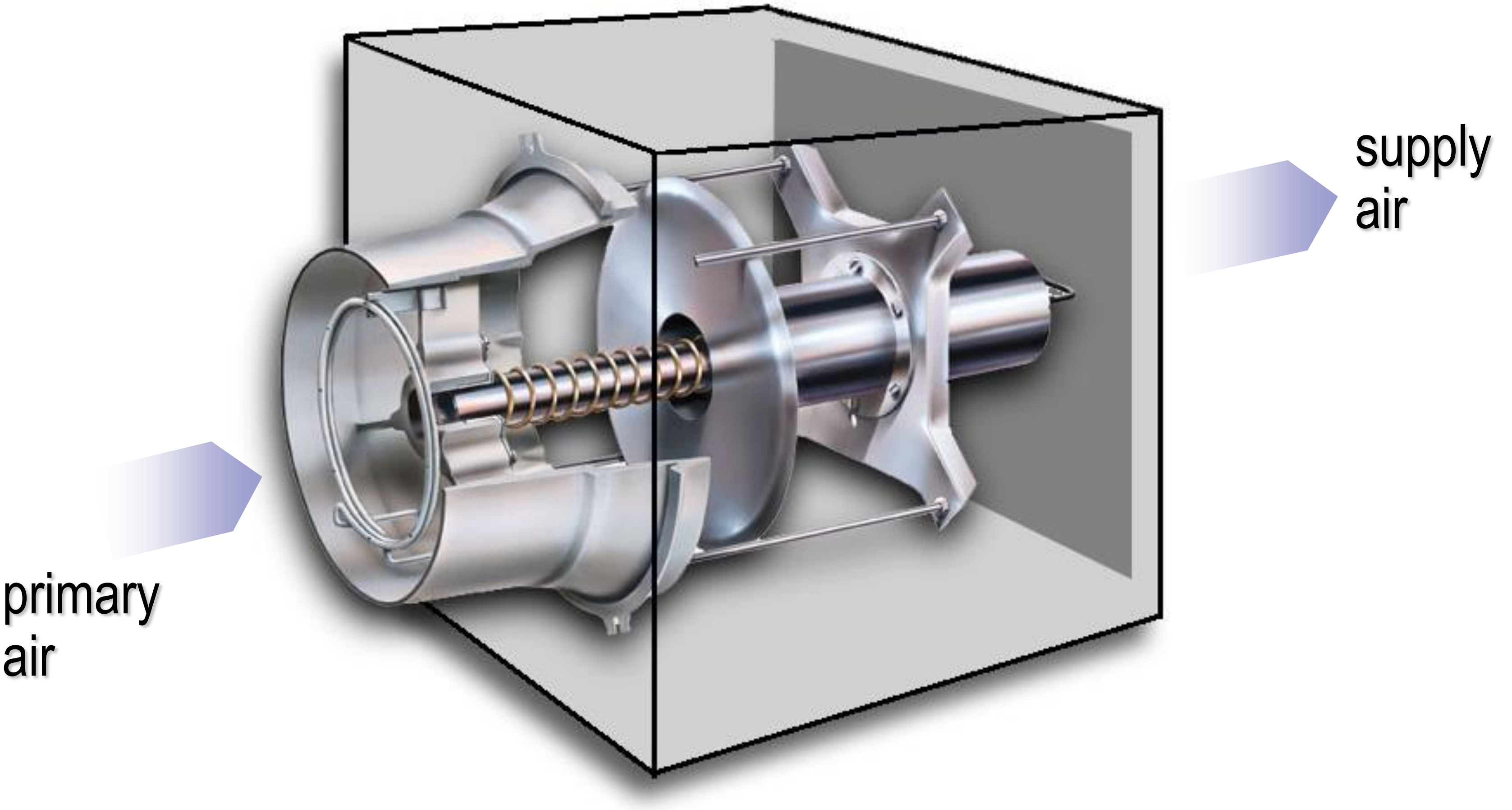


VAV Terminal Units



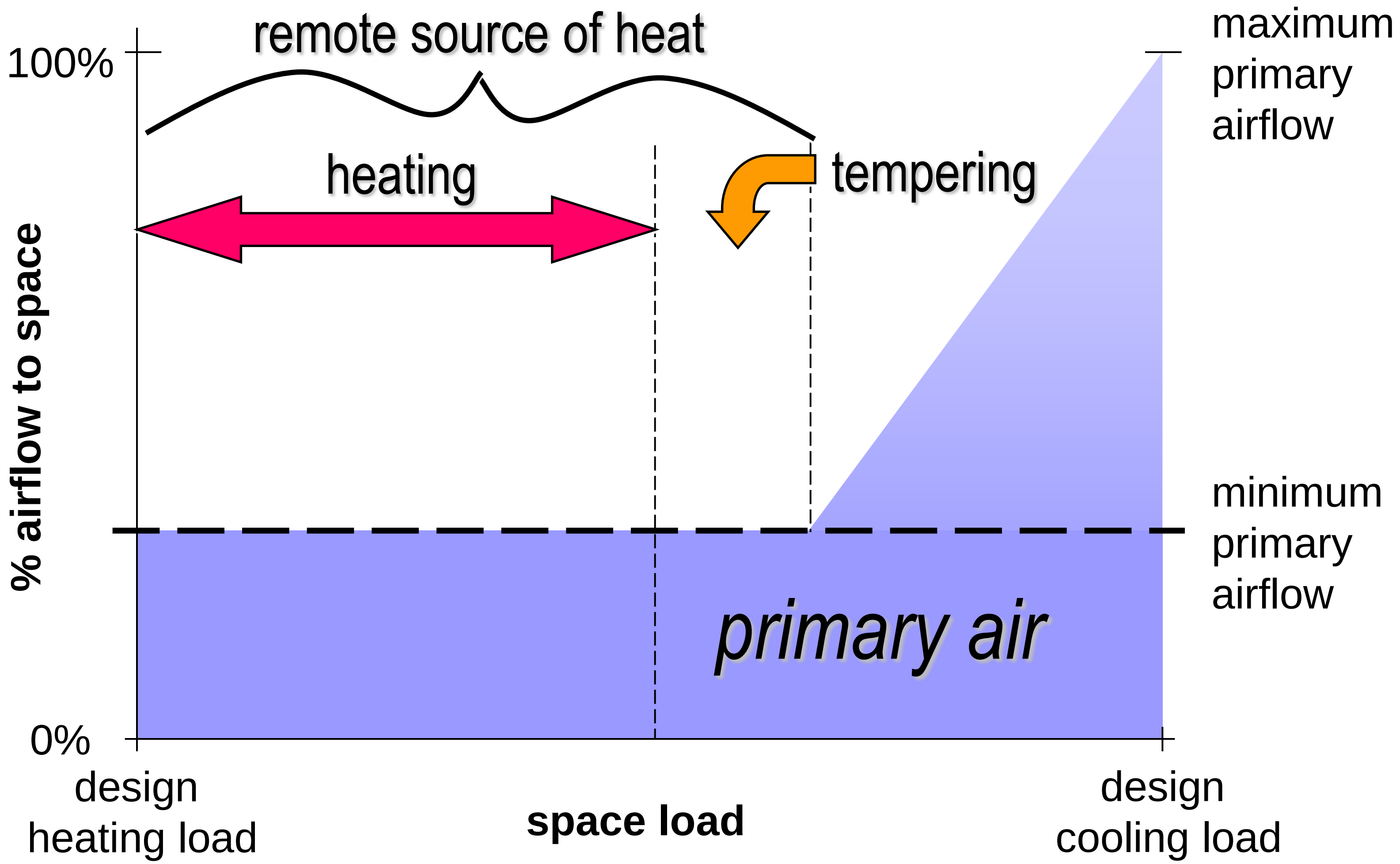
- terminal heating coil
- filter
- terminal mixing fan

VAV terminal unit types …
Single-Duct, Cooling-Only

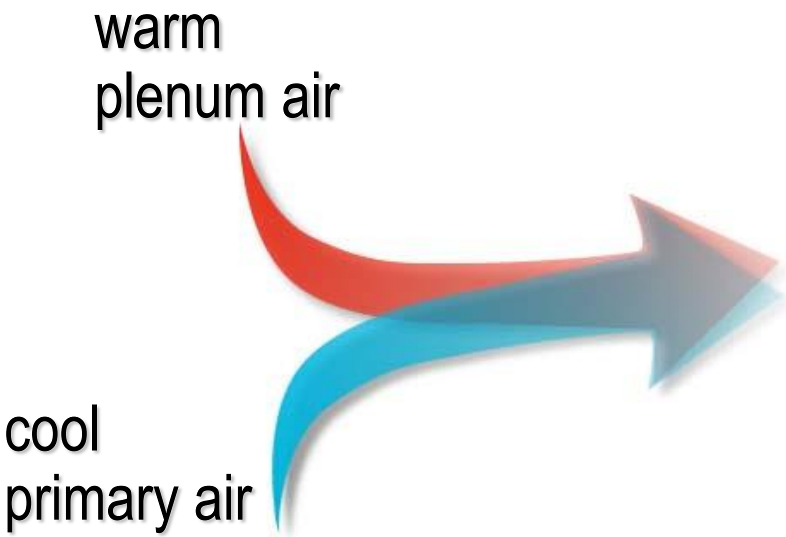


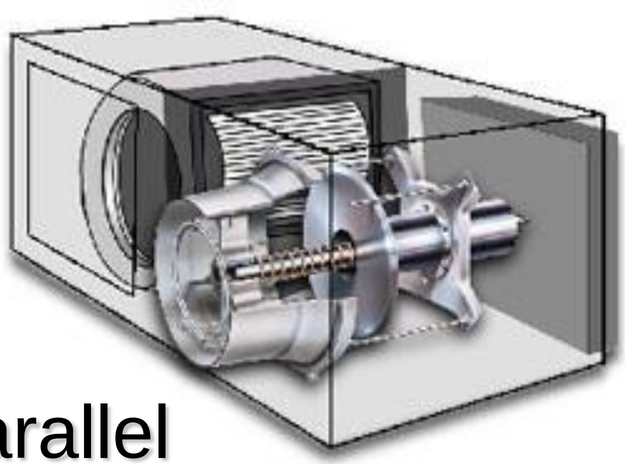
VAV terminal unit types …

Single-Duct, Cooling-Only

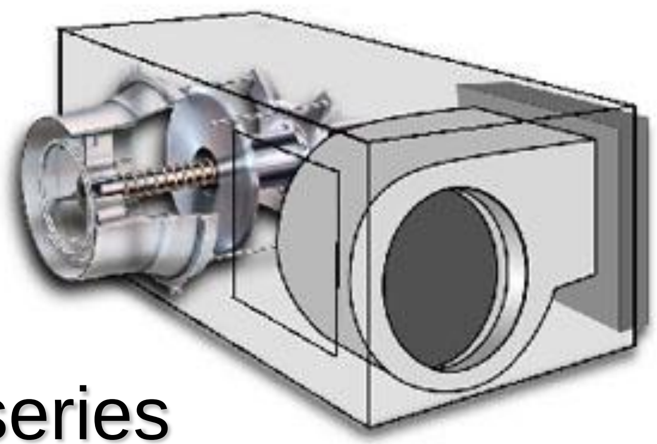


VAV terminal unit types …
Fan-Powered





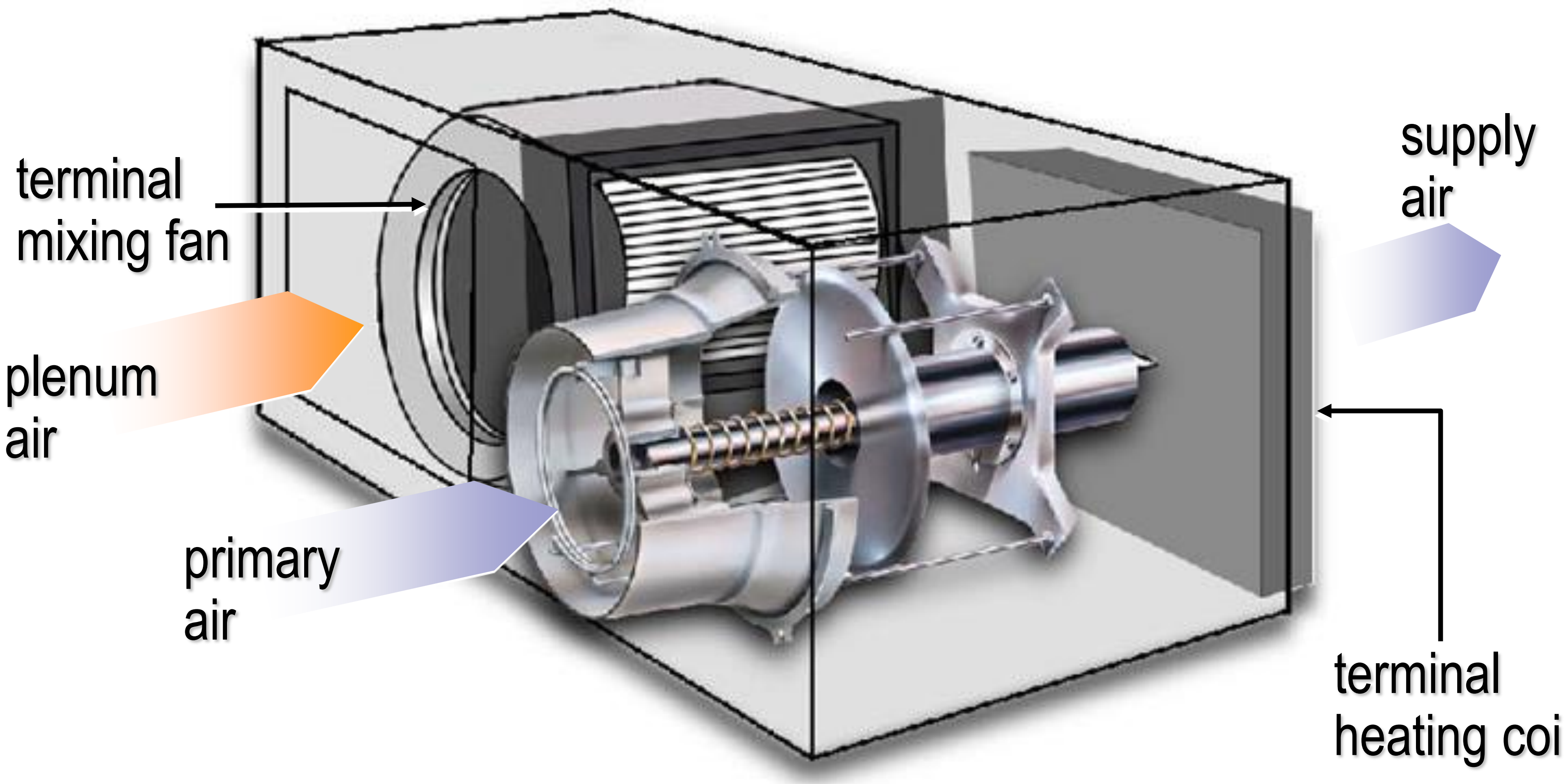
parallel



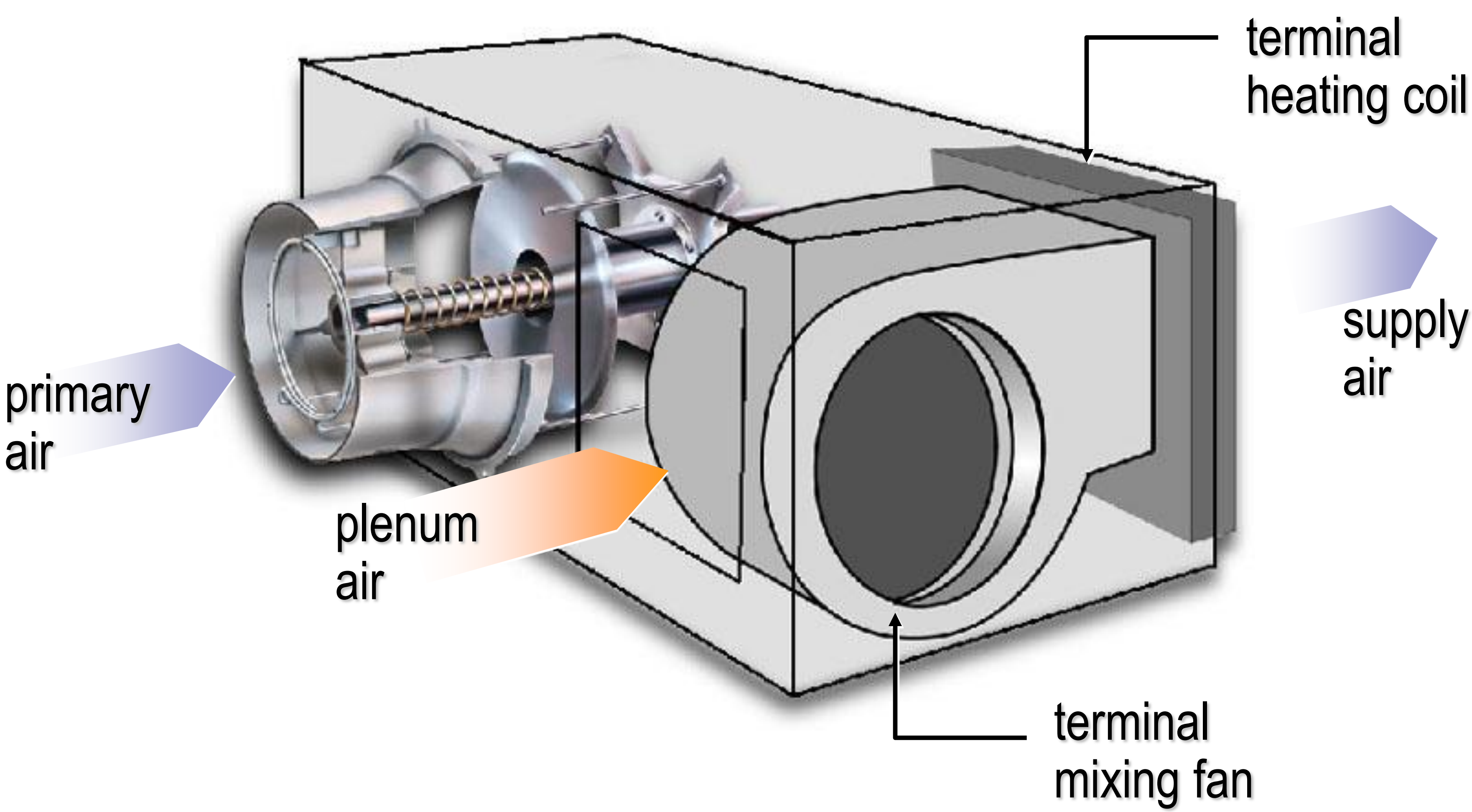
series

VAV terminal unit types …

Parallel, Fan-Powered



VAV terminal unit types …
Series, Fan-Powered



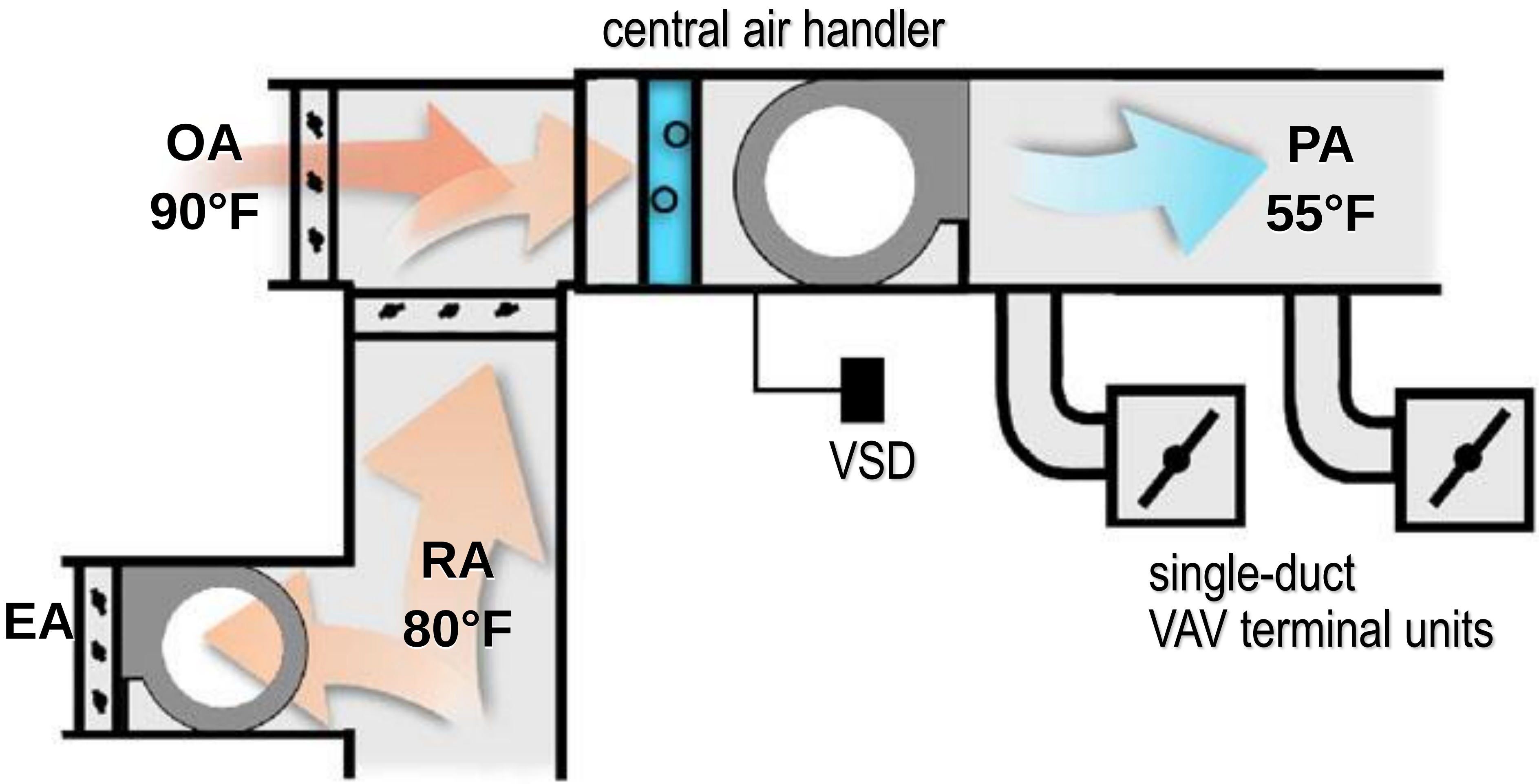
VAV terminal unit types …

Parallel vs. Series Fan-Powered

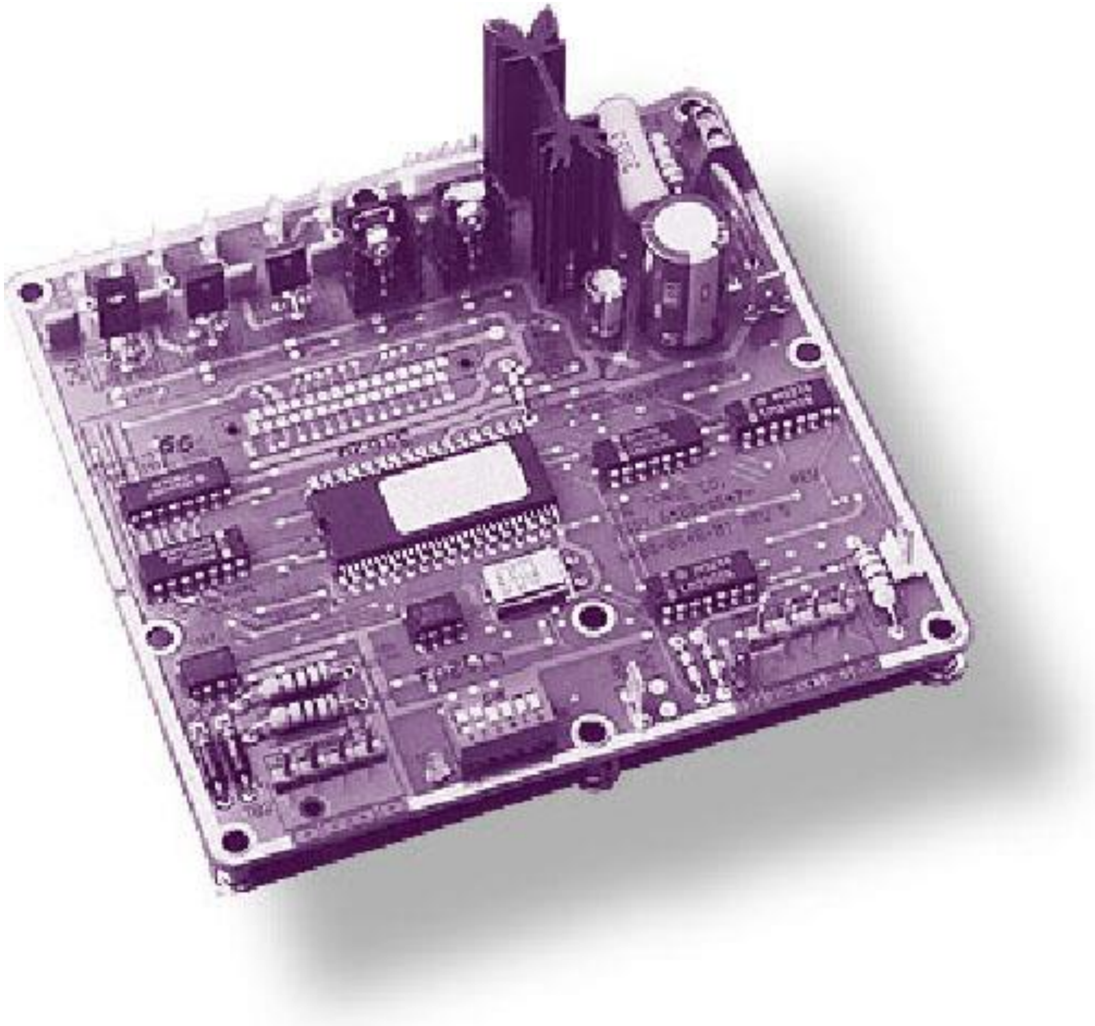
- Constant airflow to the space
- Acoustics
- Fan energy consumption

VAV terminal unit types …

Single-Duct VAV Systems



VAV Terminal Unit Controls



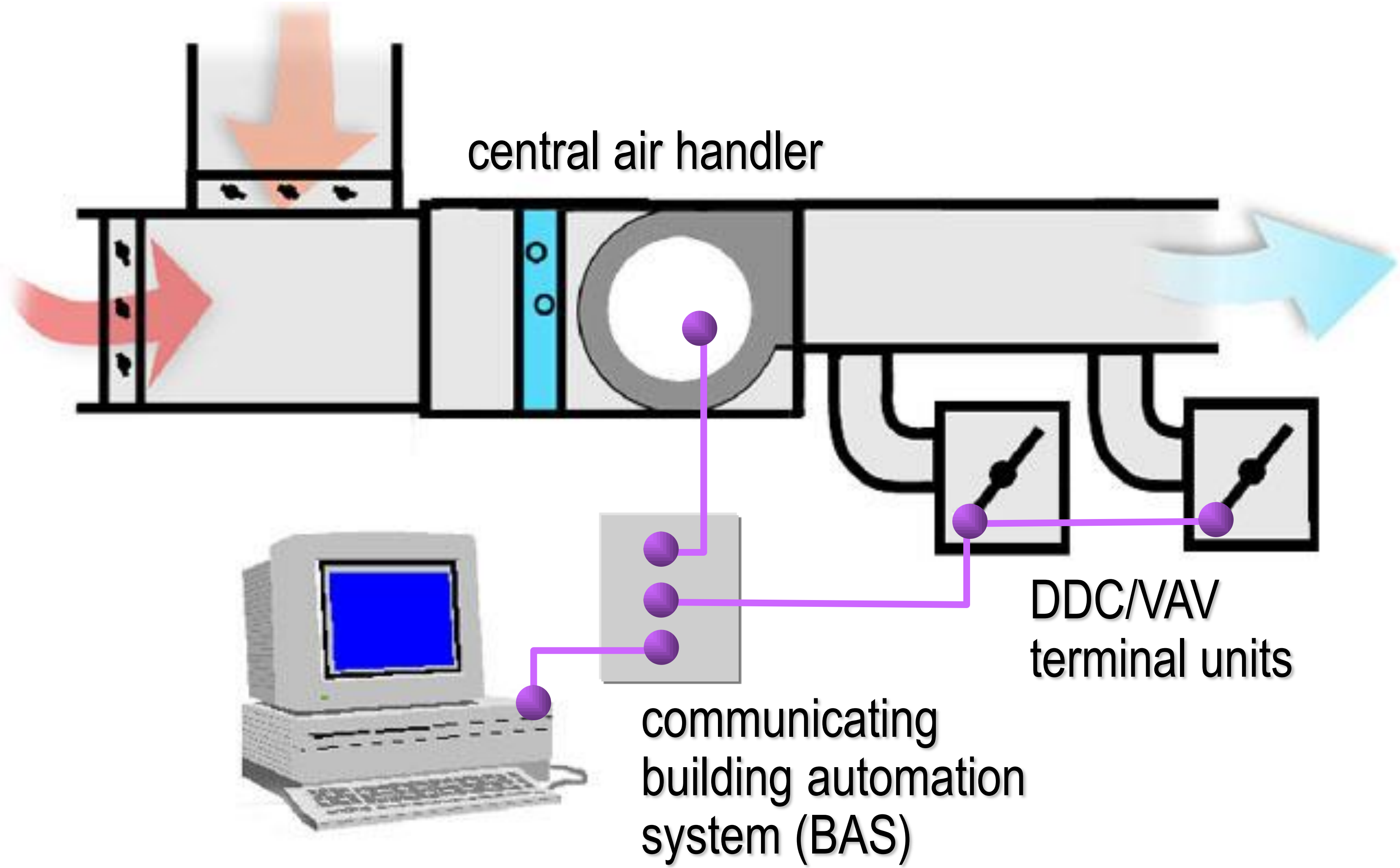
VAV terminal unit controls …

Terminal Unit Control Technologies

- Pneumatic control
- Electronic control
- Direct digital control (DDC)

VAV terminal unit controls …

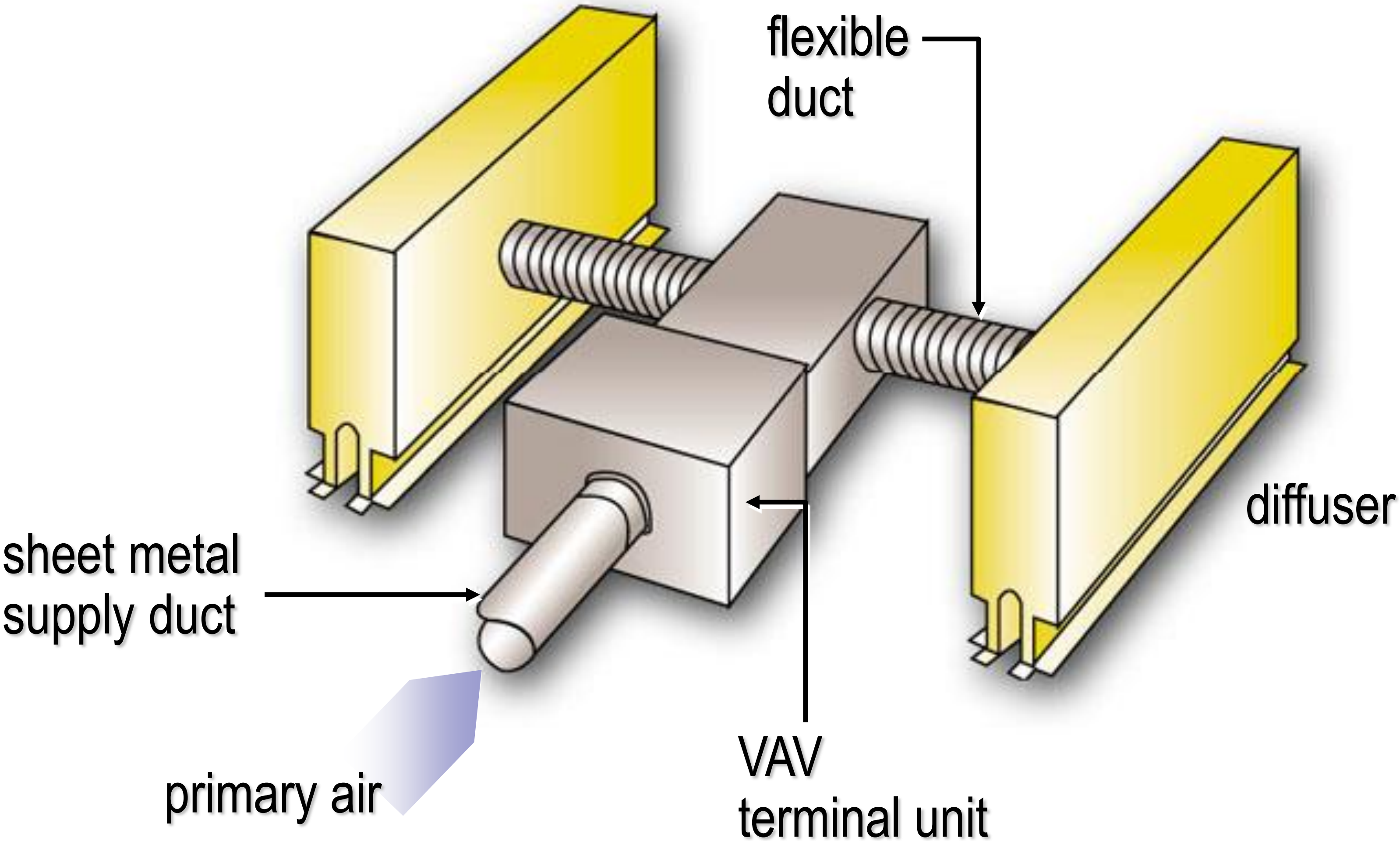
Direct Digital Control (DDC)



VAV terminal unit controls …
Direct Digital Control (DDC)

- Electronic pressure transducer provides pressure-independent control
- Digital controller positions modulation device, controls terminal fan and heat source
- Minimum and maximum airflow settings adjusted through communication link
- Electric power supply operates modulation device and electronic controller

Diffusers

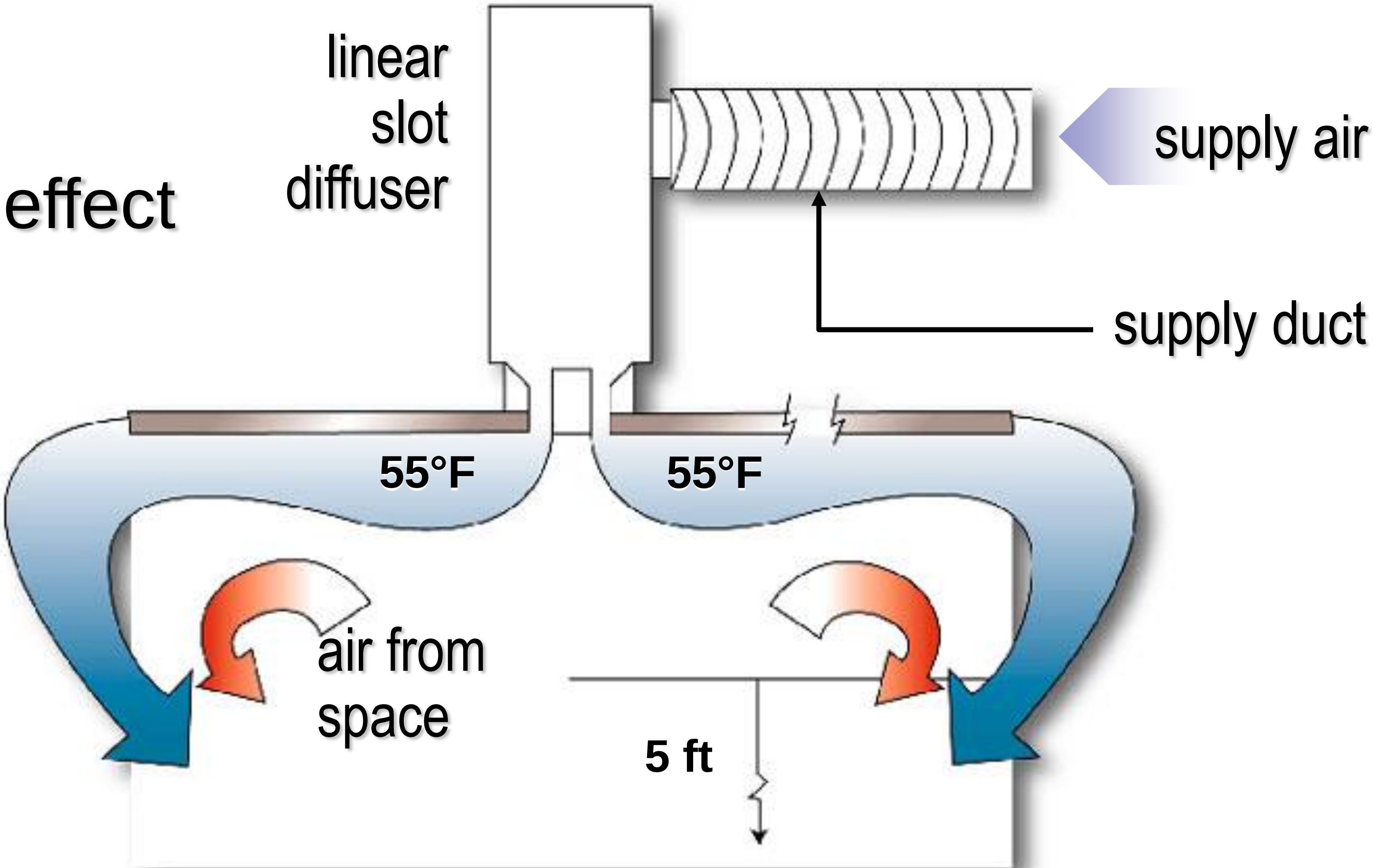


flexible duct
diffuser
sheet metal supply duct
primary air
VAV terminal unit

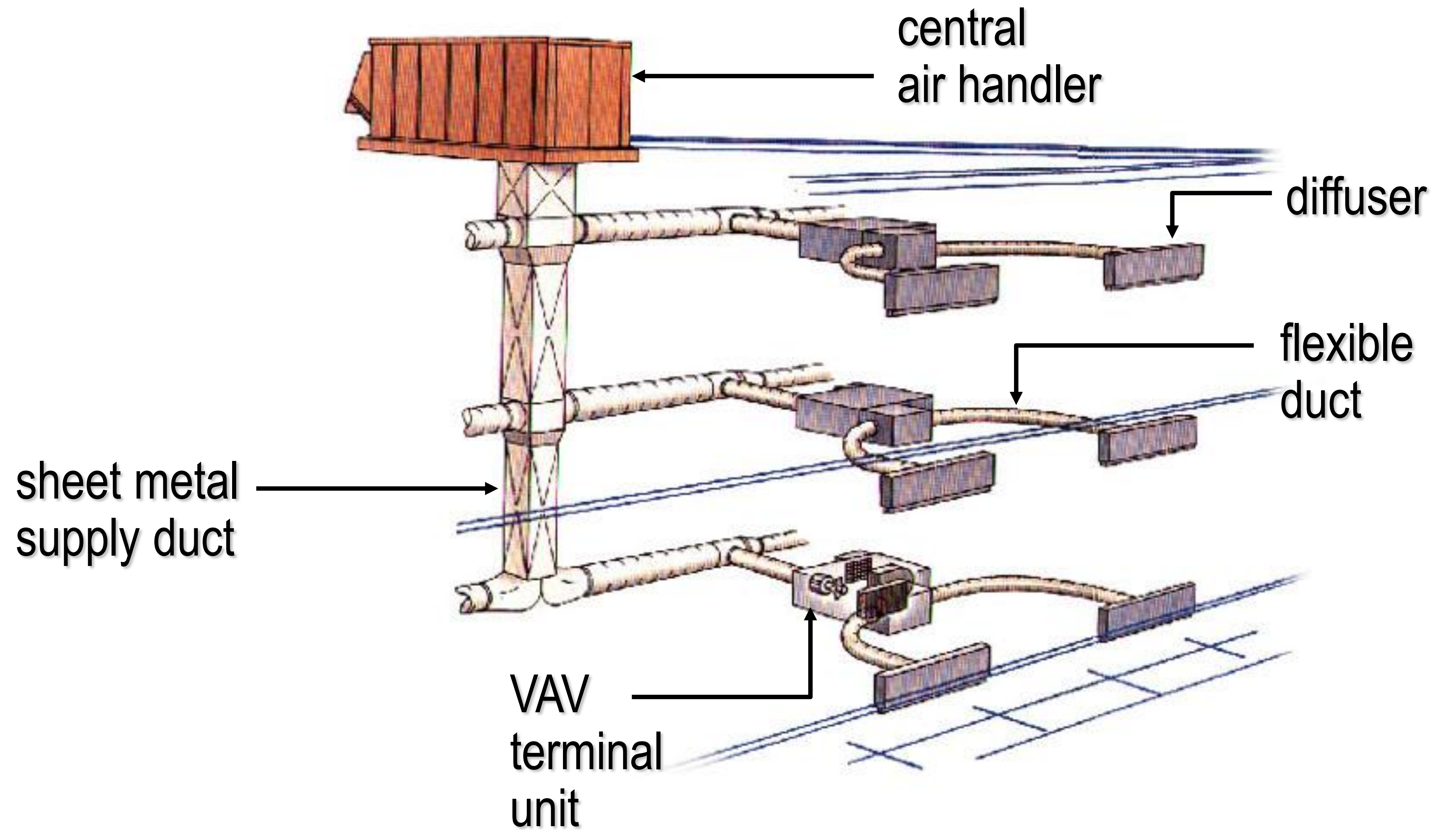
diffusers …

Linear Slot

Coanda effect



Supply Duct System



Duct Design

- **Equal friction method**
  - equal static pressure drop per unit length of duct
  - design can be performed by hand
- **Static regain method**
  - relatively constant static pressure throughout system
  - desirable for VAV system duct design
  - design often requires a computer program

Duct Design Recommendations

- Keep as simple and symmetrical as possible
- Locate main runs, branch runs, and terminal units above hallways or unoccupied spaces
- Minimize use of flexible ductwork upstream of terminal units
- Use duct lining or a duct silencer in first duct section to attenuate supply fan noise
- Place balancing dampers upstream of diffusers in all noncritical branches
- Reducing transitions should be several duct diameters upstream of terminal units

VAV Systems

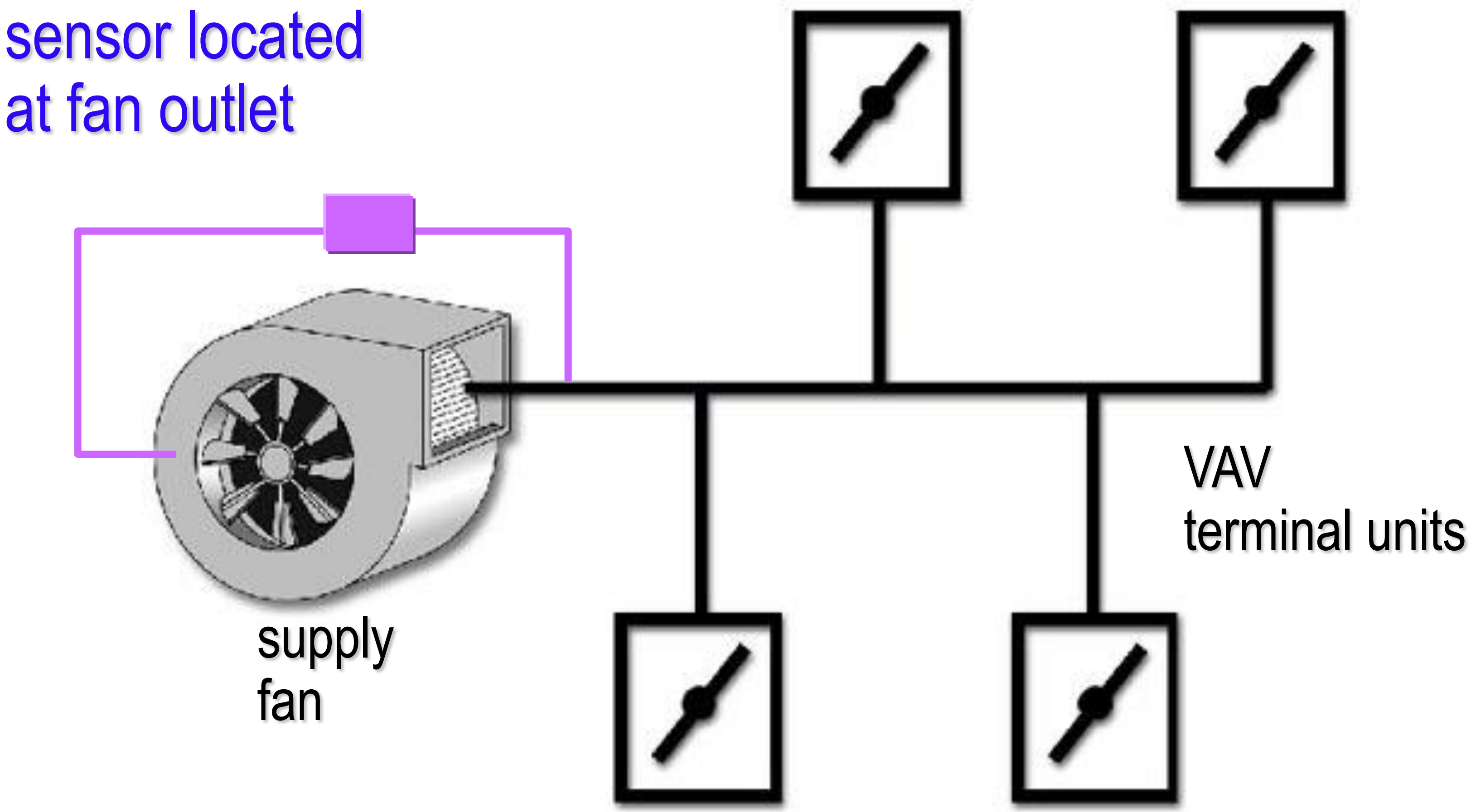
period four

Fan Modulation

Controlling System Static Pressure

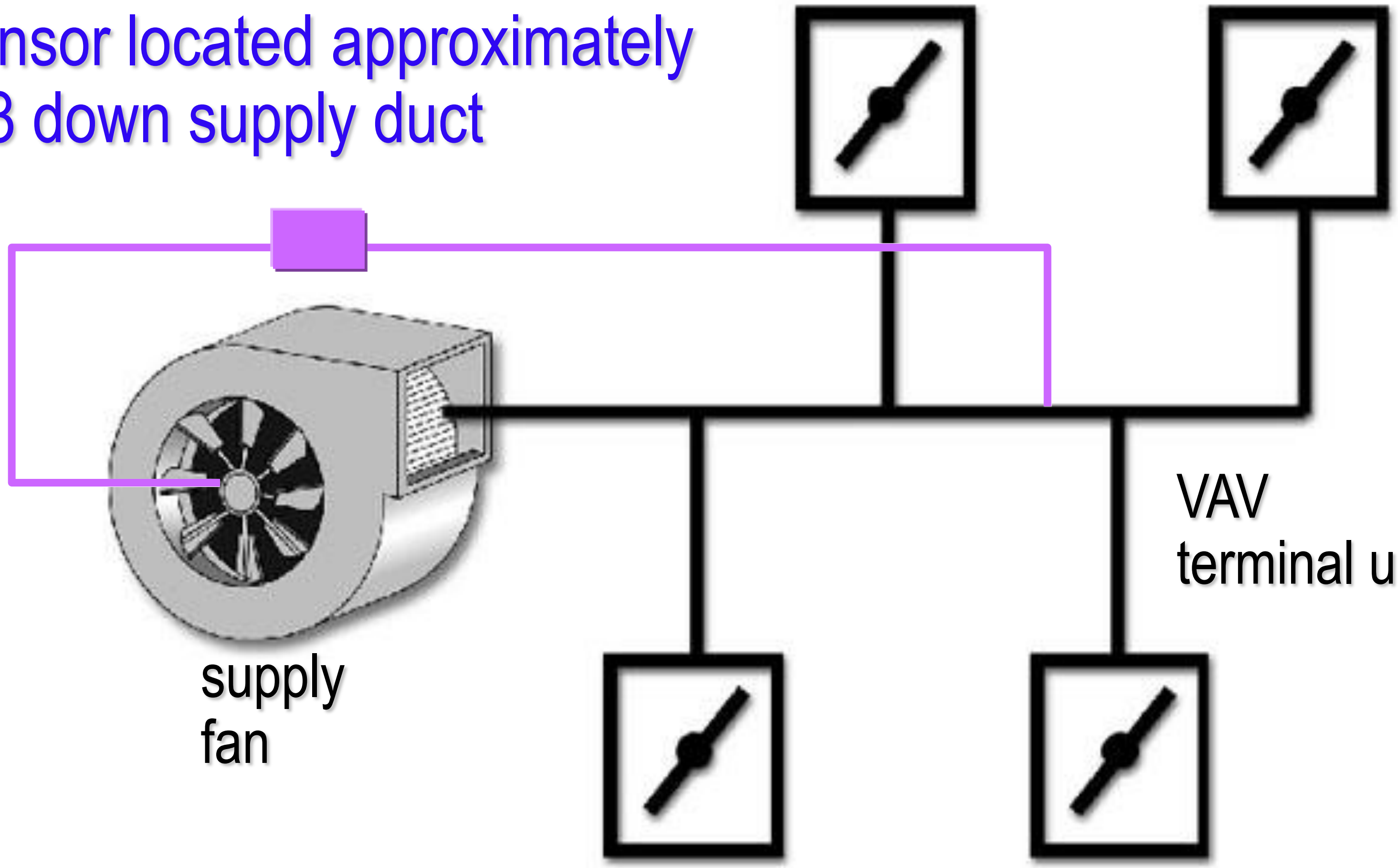
- Fan outlet static pressure control
- Supply duct static pressure control
- Optimized static pressure control

Fan Outlet Static Pressure Control

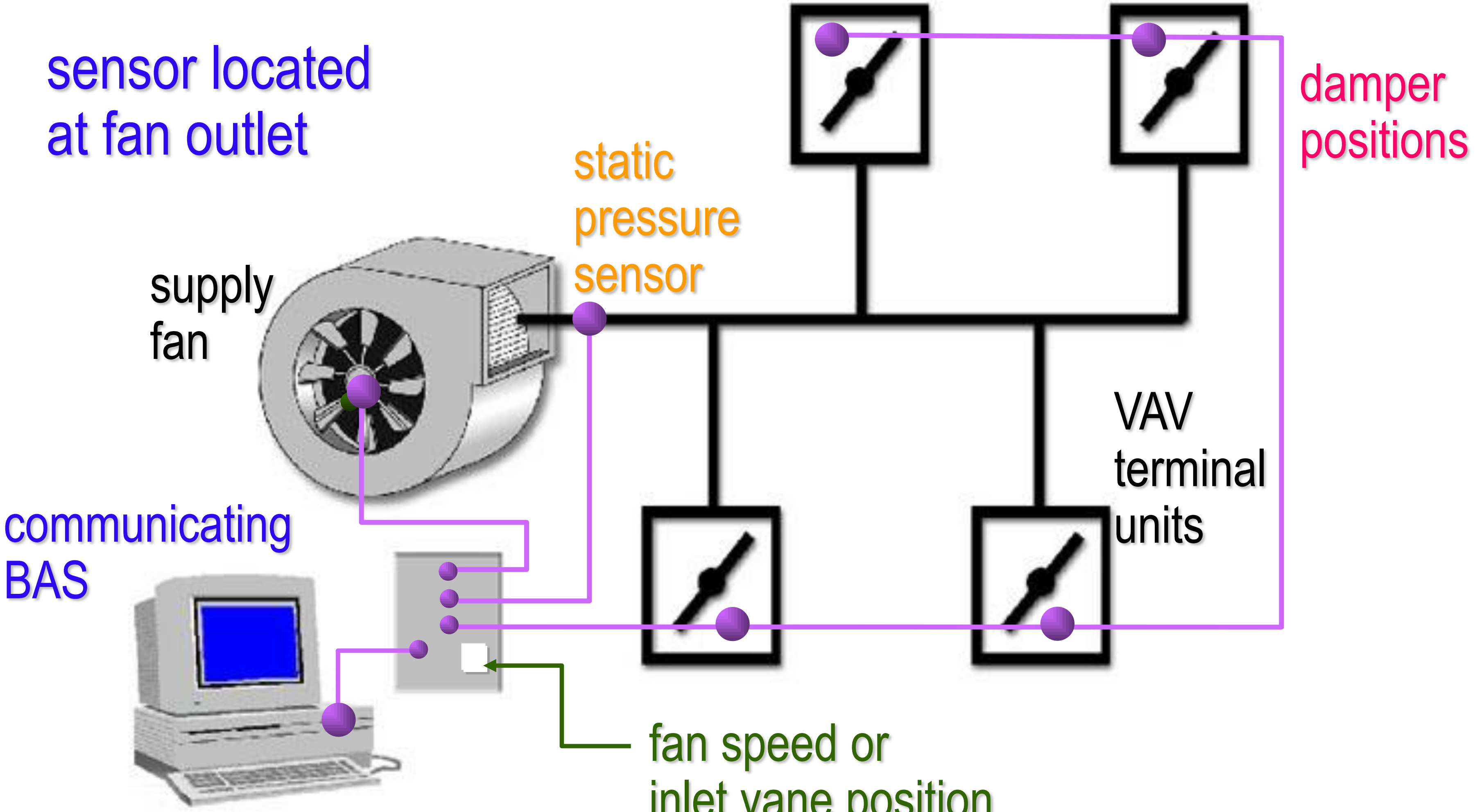


Supply Duct Static Pressure Control

sensor located approximately
2/3 down supply duct



Optimized Static Pressure Control



VAV Systems

A Trane Air Conditioning Clinic