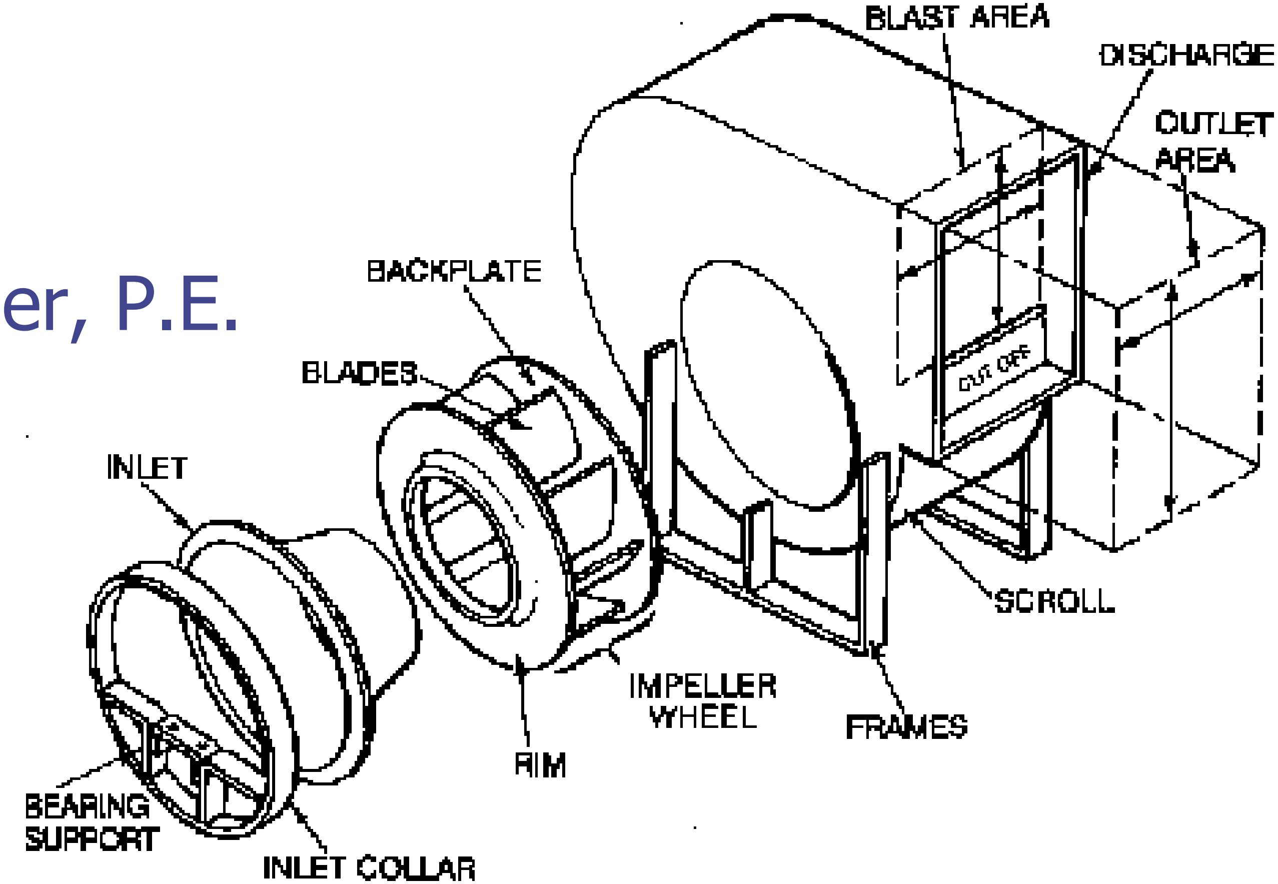
ME 425

Fans

Keith Elder, P.E.



Fan Types

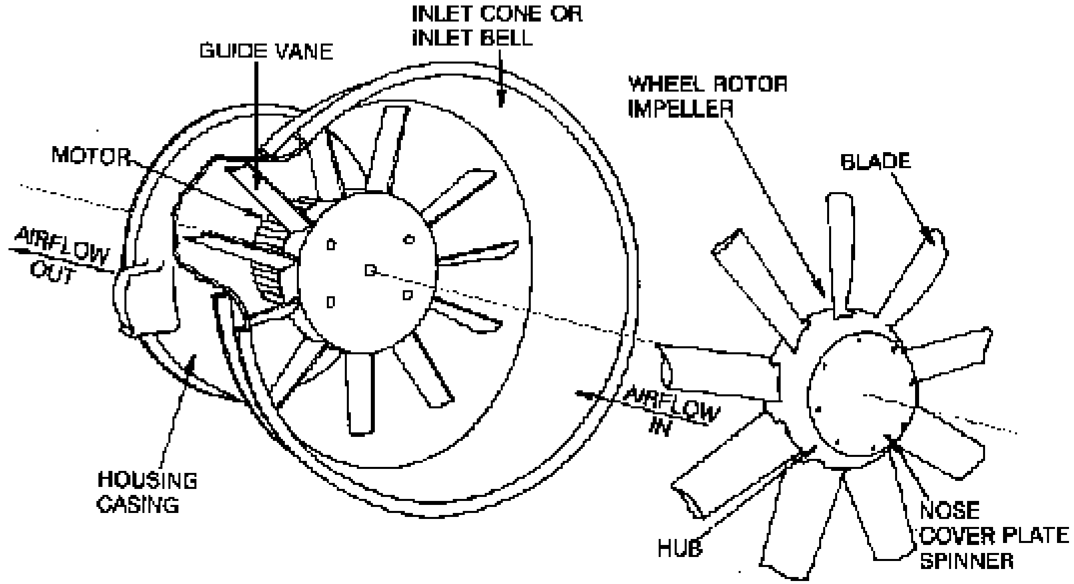
Fans are classified by the direction of air flow relative to the impeller

- Axial Fans
  - Air flow is perpendicular to blade rotation
- Centrifugal Fans
  - Air flow is in the same direction as impeller rotation

Axial Fans

Propeller

- Designed to move air from one enclosed space to another in a wide range of volumes at low pressures.



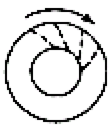
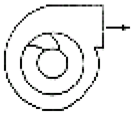
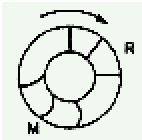
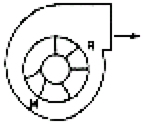
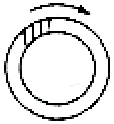
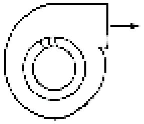
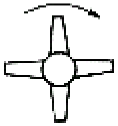
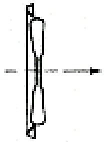
Tube-axial

- An axial flow wheel in a cylinder which moves a wide range of air at medium pressures.

Vane-axial

- Vane-axial fans have a set of air guide vanes mounted in the cylinder before or behind an airfoil-type wheel. They move air over a wide range of volumes and pressures.

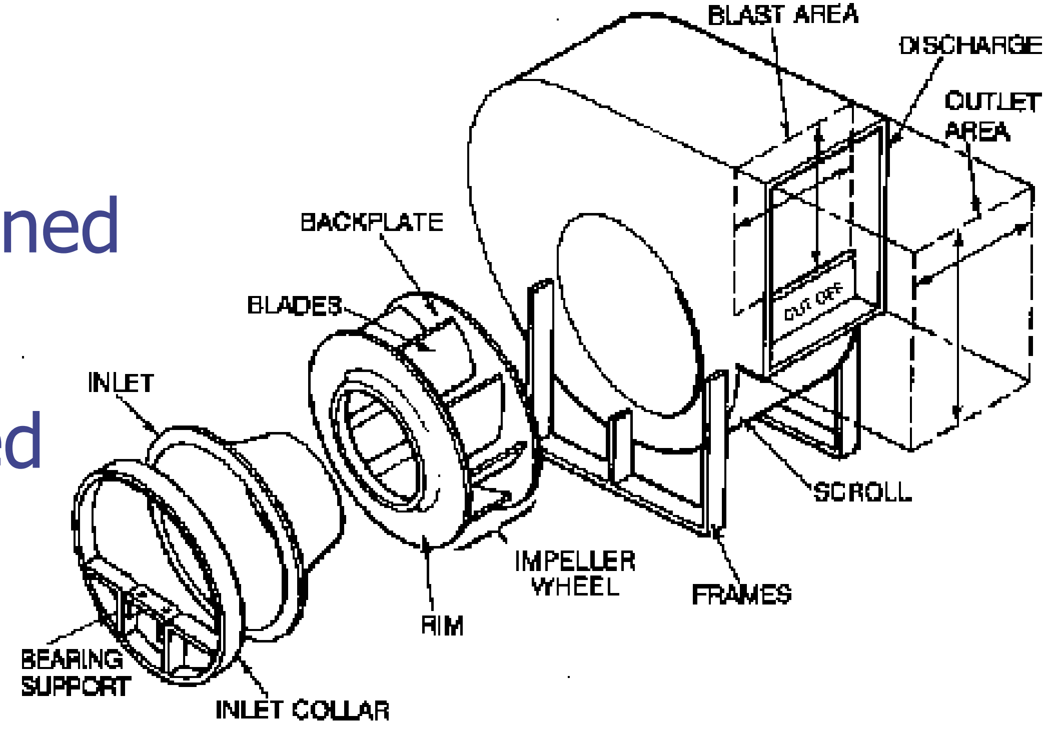
Axial Fan Characteristics

TYPE	IMPELLER DESIGN		HOUSING DESIGN	
BACKWARD-INCLINED BACKWARD-CURVED		• Efficiency only slightly less than airfoil fan. • Ten to 16 single-thickness blades curved or inclined away from direction of rotation. • Efficient for same reasons as airfoil fan.		• Uses same housing configuration as airfoil design.
RADIAL		• Higher pressure characteristics than airfoil, backward-curved, and backward-inclined fans. • Curve may have a break to left of peak pressure and fan should not be operated in this area. • Power rises continually to free delivery.		• Scroll. Usually narrowest of all centrifugal designs. • Because wheel design is less efficient, housing dimensions are not as critical as for airfoil and backward-inclined fans.
FORWARD-CURVED		• Flatter pressure curve and lower efficiency than the airfoil, backward-curved, and backward-inclined. • Do not rate fan in the pressure curve dip to the left of peak pressure. • Power rises continually toward free delivery. Motor selection must take this into account.		• Scroll similar to and often identical to other centrifugal fan designs. • Fit between wheel and inlet not as critical as for airfoil and backward-inclined fans.
PROPELLER		• Low efficiency. • Limited to low-pressure applications. • Usually low cost impellers have two or more blades of single thickness attached to relatively small hub. • Primary energy transfer by velocity pressure.		• Simple circular ring, orifice plate, or venturi. • Optimum design is close to blade tips and forms smooth airfoil into wheel.

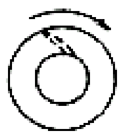
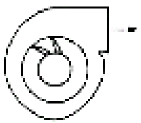
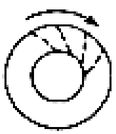
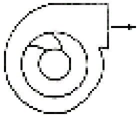
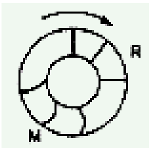
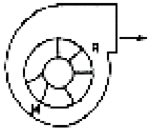
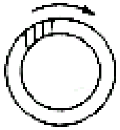
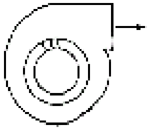
Centrifugal Fans

Designed to move air over a wide volume range. Static pressures can go up to 25 inches. Centrifugal fan wheels come in the following types:

- Airfoil
- Backward Inclined
- Radial
- Forward Curved



Centrifugal Fan Characteristics

TYPE	IMPELLER DESIGN		HOUSING DESIGN	
AIRFOIL		•Highest efficiency of all centrifugal fan designs. •Ten to 16 blades of airfoil contour curved away from direction of rotation. Deep blades allow for efficient expansion within blade passages. •Air leaves impeller at velocity less than tip speed. •For given duty, has highest speed of centrifugal fan designs.		•Scroll-type design for efficient conversion of velocity pressure to static pressure. •Maximum efficiency requires close clearance and alignment between wheel and inlet.
BACKWARD-INCLINED BACKWARD-CURVED		•Efficiency only slightly less than airfoil fan. •Ten to 16 single-thickness blades curved or inclined away from direction of rotation. •Efficient for same reasons as airfoil fan.		•Uses same housing configuration as airfoil design.
RADIAL		•Higher pressure characteristics than airfoil, backward-curved, and backward-inclined fans. •Curve may have a break to left of peak pressure and fan should not be operated in this area. •Power rises continually to free delivery.		•Scroll. Usually narrowest of all centrifugal designs. •Because wheel design is less efficient, housing dimensions are not as critical as for airfoil and backward-inclined fans.
FORWARD-CURVED		•Flatter pressure curve and lower efficiency than the airfoil, backward-curved, and backward-inclined. •Do not rate fan in the pressure curve dip to the left of peak pressure. •Power rises continually toward free delivery. Motor selection must take this into account.		•Scroll similar to and often identical to other centrifugal fan designs. •Fit between wheel and inlet not as critical as for airfoil and backward-inclined fans.

Fan Horsepower

$$AHP = \frac{CFMxTP}{6359} \qquad BHP = \frac{CFMxTP}{6359 x \eta_{fan}}$$

Where:

η_{fan} = Fan Efficiency

AHP = Air Horsepower

BHP = Brake Horsepower

TP = Total Pressure, inches H_2O

Fan Laws

Fan Performance at different speeds from the manufacturer's fan curve can be predicted using the fan laws.

$$\left(\frac{CFM_2}{CFM_1}\right) = \left(\frac{RPM_2}{RPM_1}\right)$$

$$\left(\frac{\mathrm{Pr}essure_2}{\mathrm{Pr}essure_1}\right) = \left(\frac{RPM_2}{RPM_1}\right)^2$$

$$\left(\frac{BHP_2}{BHP_1}\right) = \left(\frac{RPM_2}{RPM_1}\right)^3$$

Fan Law Problem

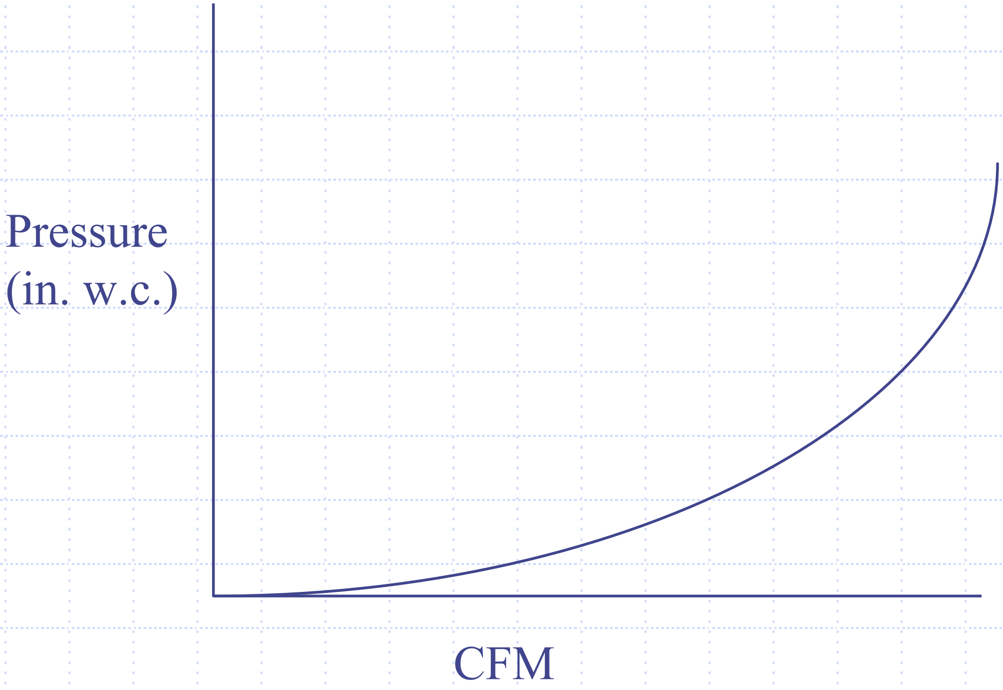
A fan has the following characteristics:

- 5000 CFM
- 1.25 inches static pressure
- 782 RPM
- 1.98 BHP

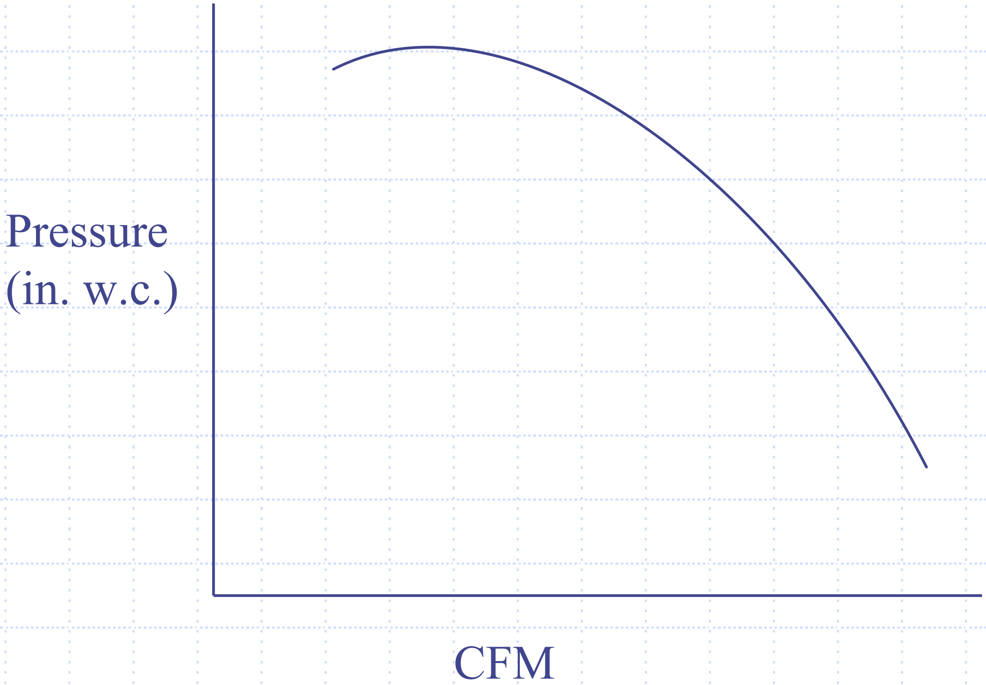
What RPM is necessary to increase the flow to 6,000 CFM?

What BHP is required?

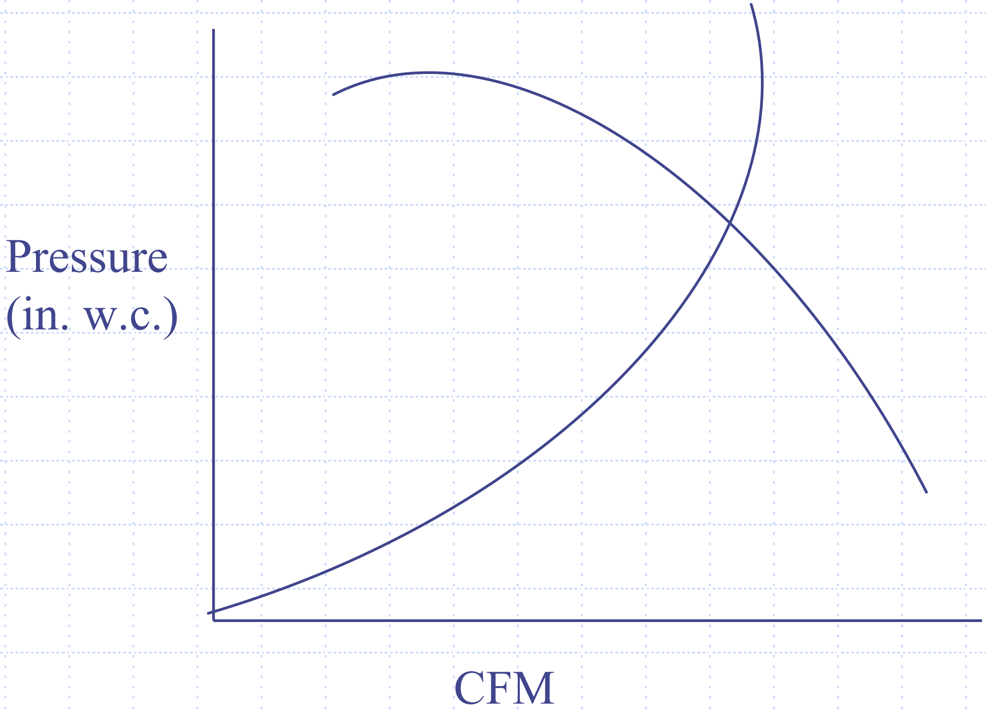
System Curve



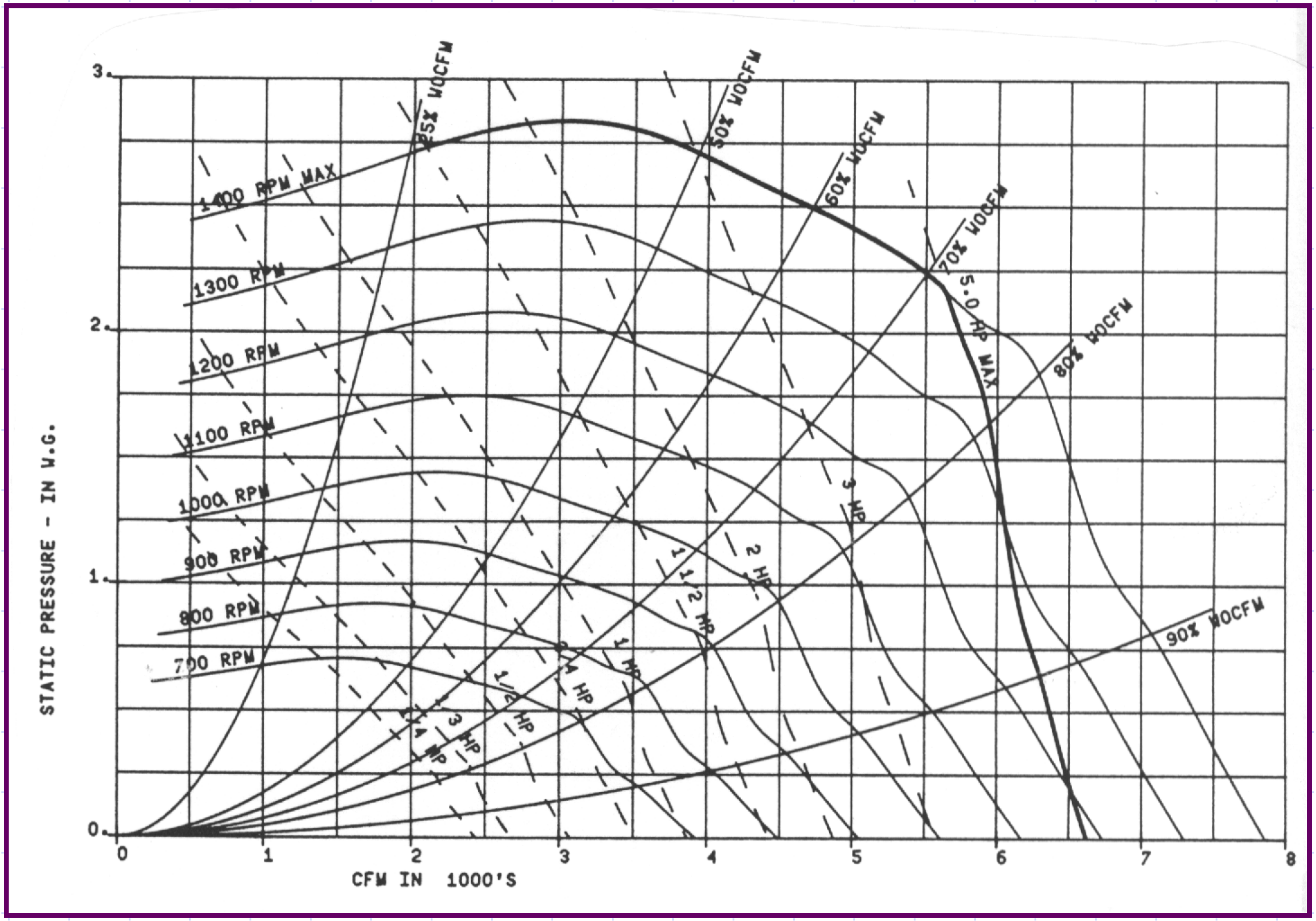
Fan Curve



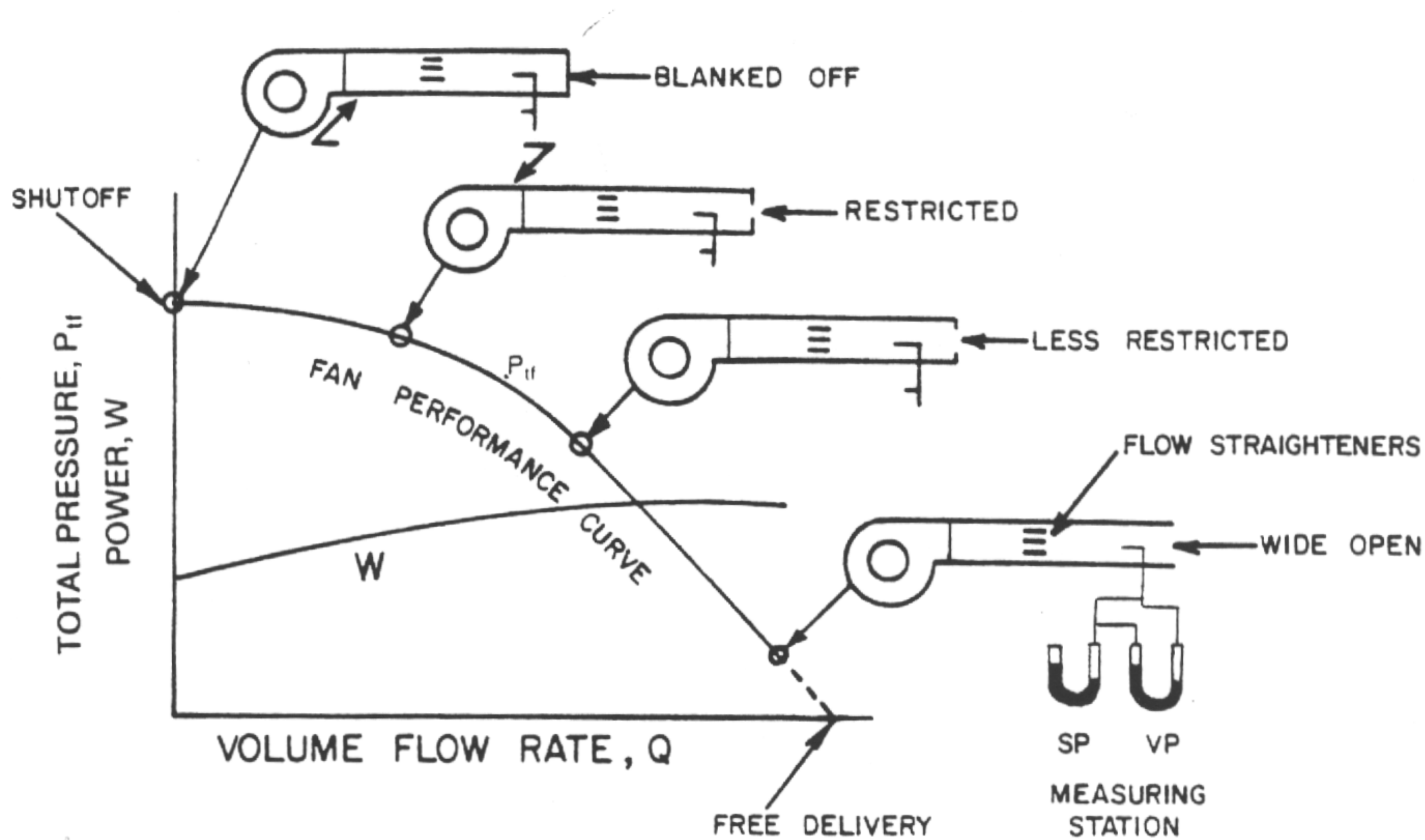
System Operating Point



Catalog Fan Curve

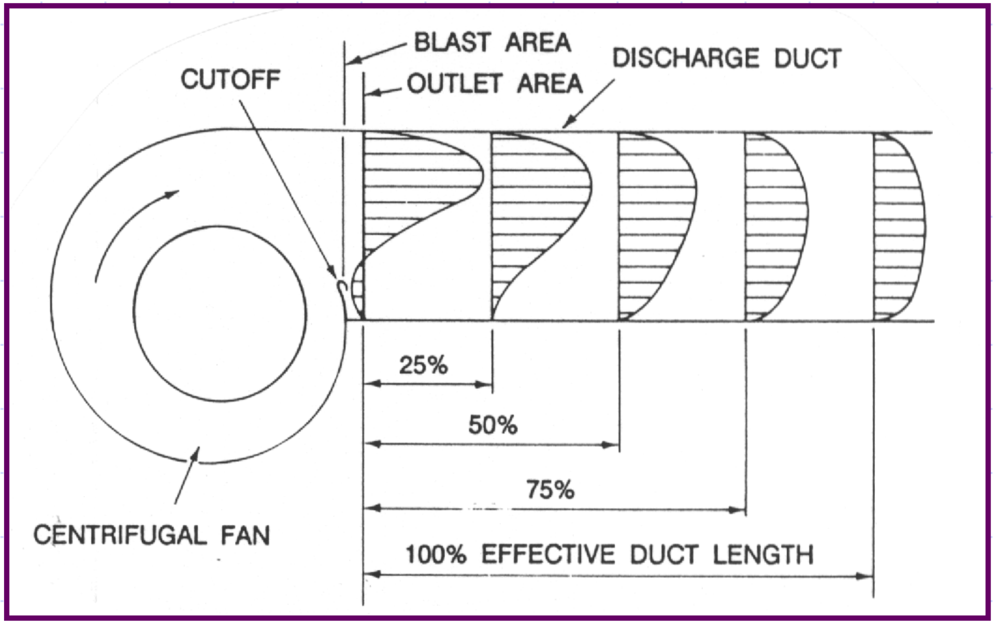


Method of Obtaining Fan Curves

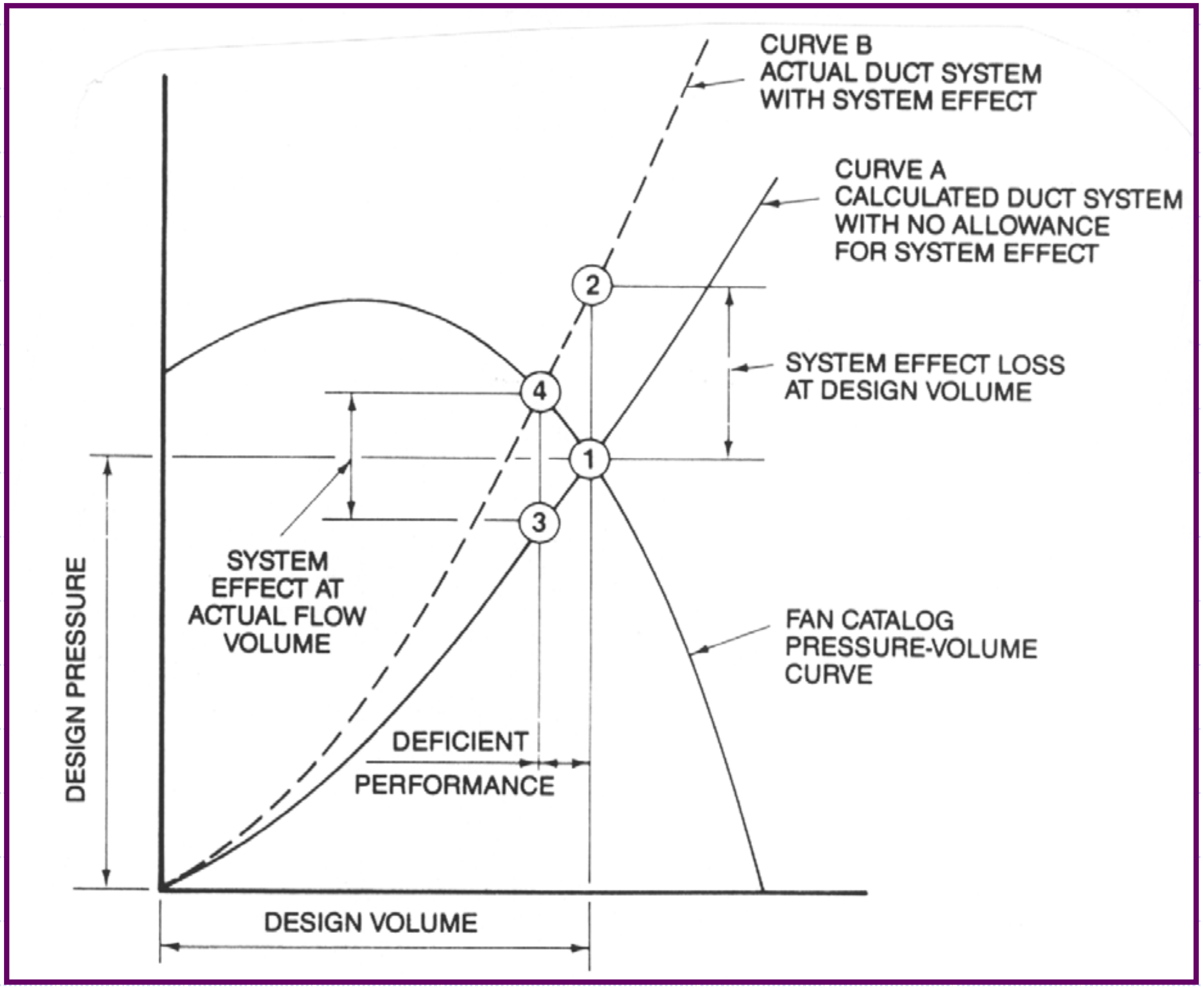


System Effect

Fan data is based upon discharge conditions at the time of testing, including certain minimum. For low velocity systems, the effective duct length is 2 - 1/2 equivalent duct diameters

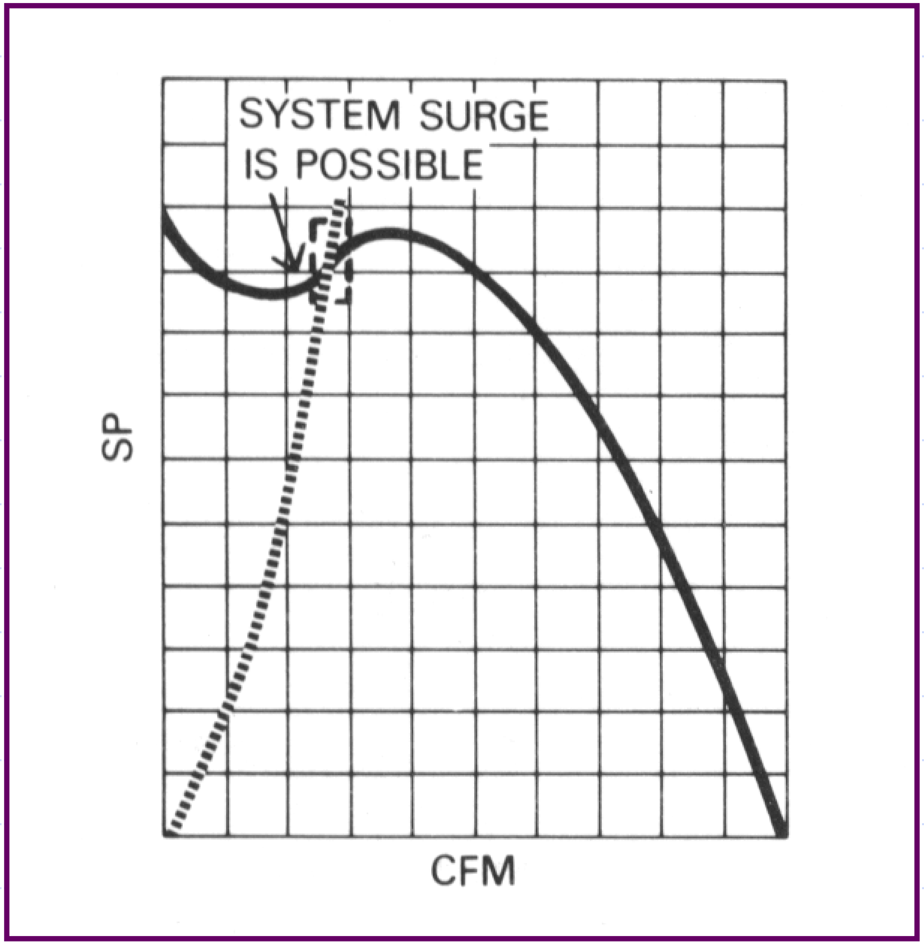


System Effect



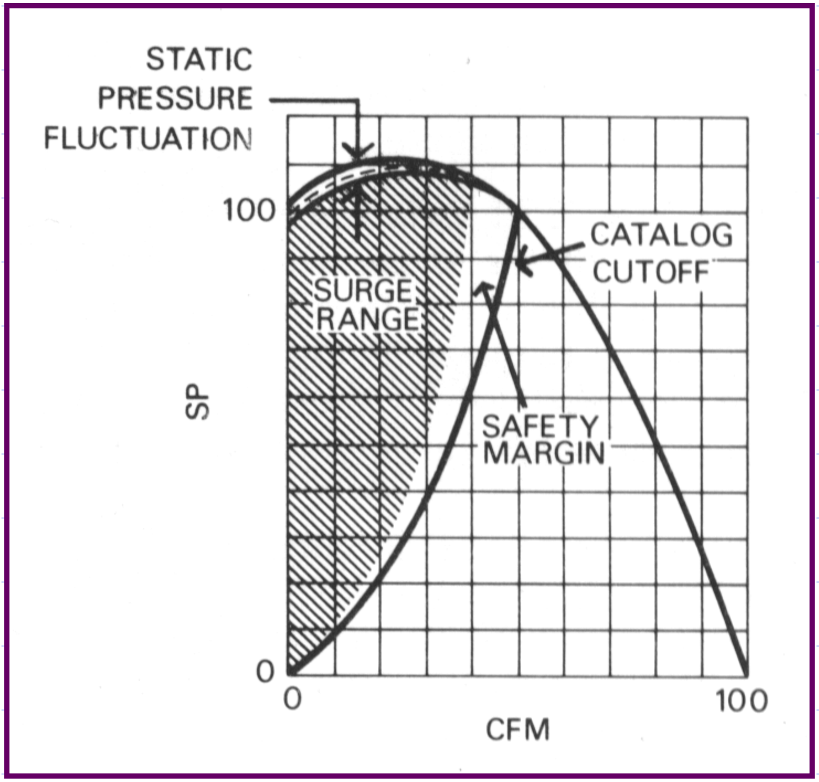
System Surge

Occurs when system resistance and fan performance curves do not intersect at a distinct point but rather over a range of volumes and pressures. - Trane



Fan Surge

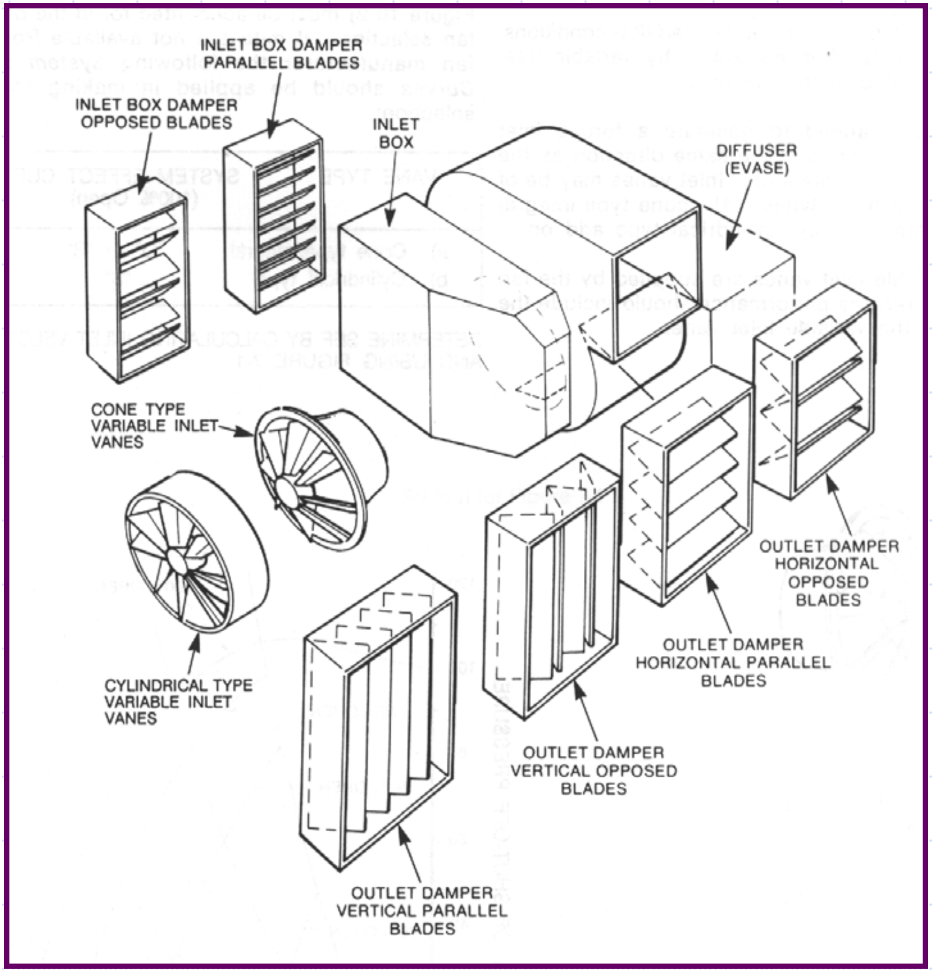
Occurs near "block-tight" conditions when blade rotation is insufficient to overcome pressure difference between wheel center & discharge.



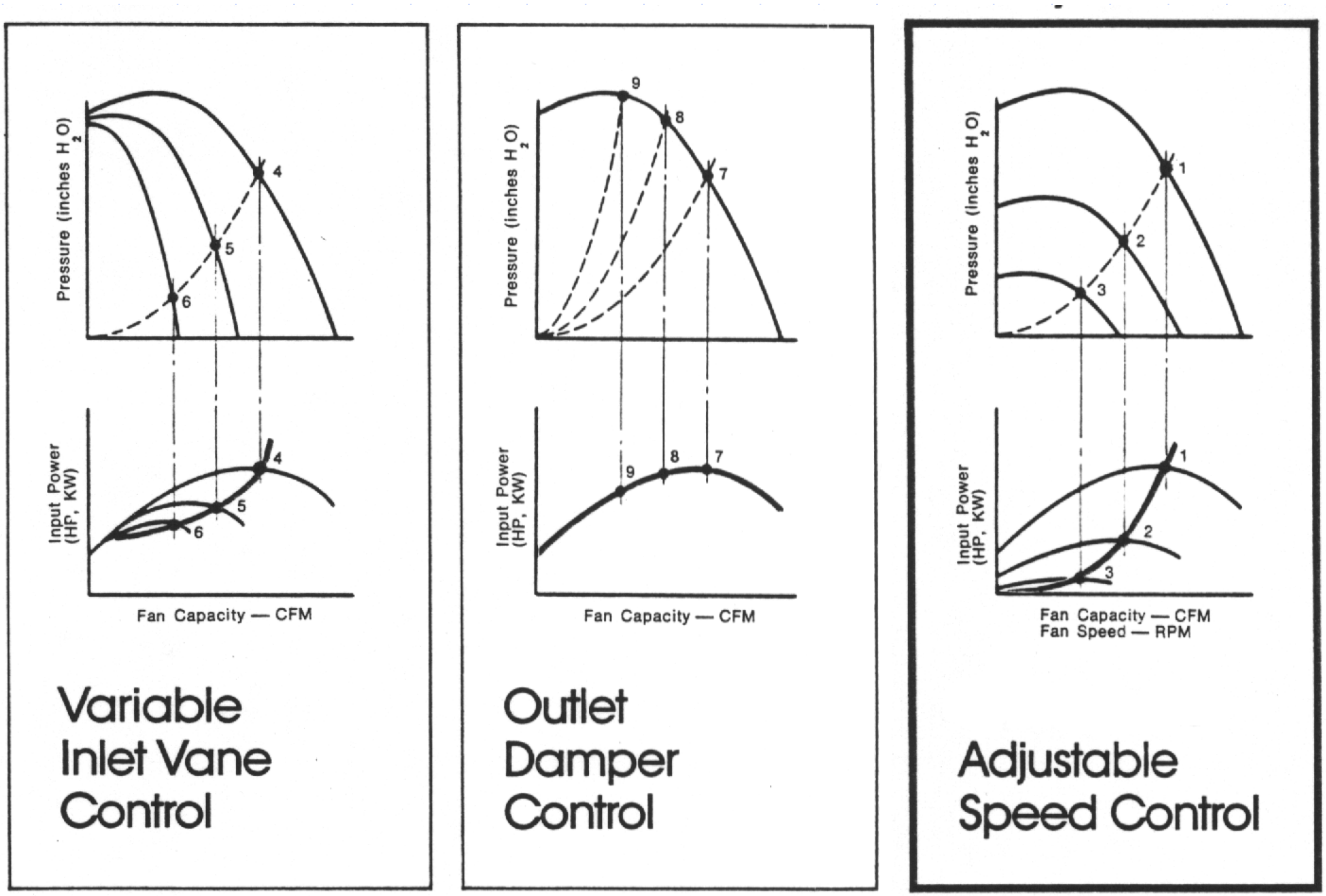
Variable Flow Control Devices

- Bypass circuits
- Discharge Damper
- Variable inlet vanes
- Vari-Cone
- Econo-Cone
- Variable Frequency Drive

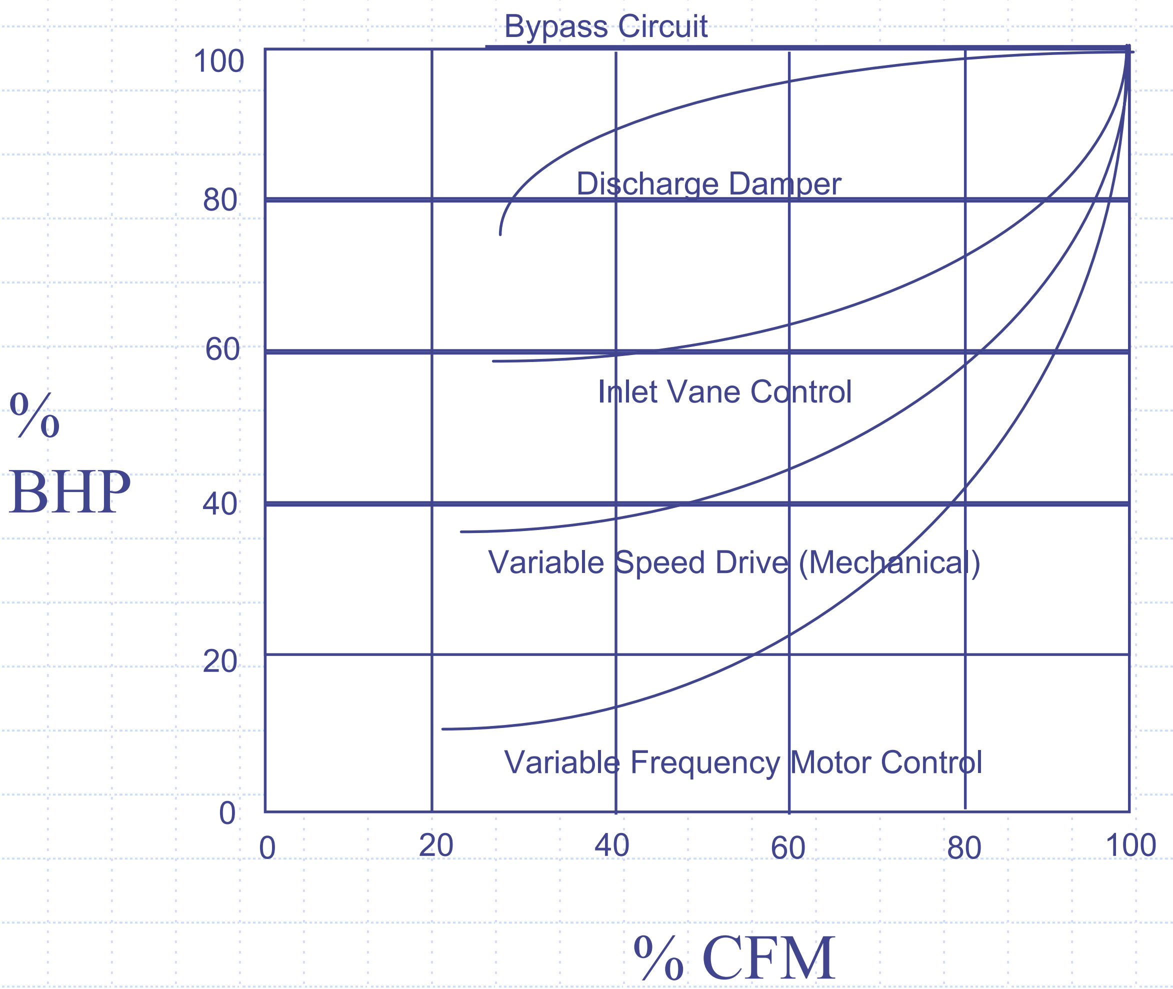
Inlet/Discharge Control Schemes



VAV Control Performance



Variable Flow Device Performance



Discharge System Effect

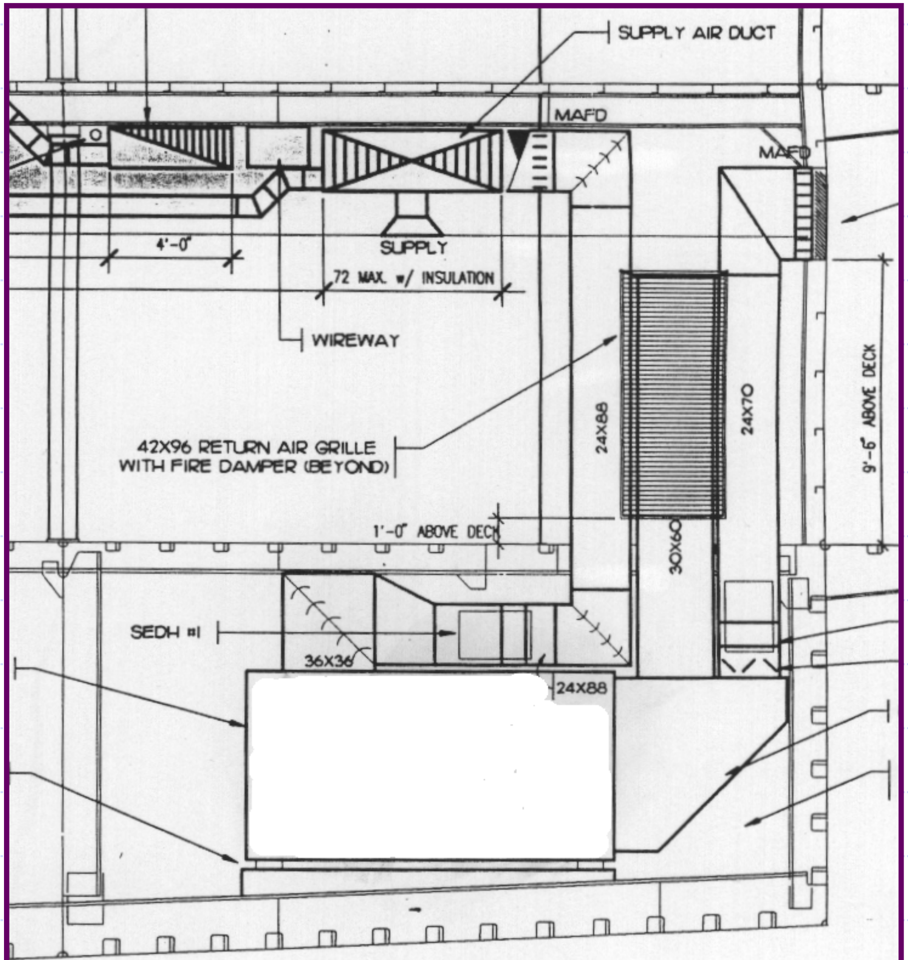
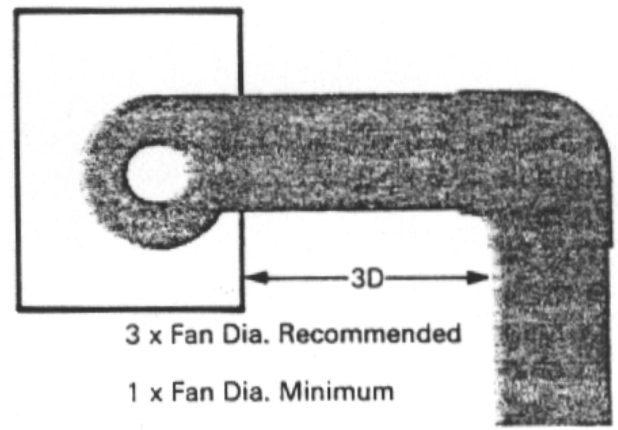


Figure 7-1 — Turn at Discharge



Turns should be in direction of fan rotation.

Table 7-1 — Turn at Discharge

Fan Type	K_t
FC	2.3
BI	2.0
AF	1.5

Note:
The K_t values represent turns in the discharge ductwork one fan diameter from discharge.