



Air Systems Design

Fan Basics



What you will Learn in this Lesson

- Fan standards
- Fan efficiency
- Fan types
- System effect on fan performance

Fans

- A “fan” is not someone cheers for the local sports team.
- A Fan is a device to generate a pressure difference in air in order to cause that air to move from one place to another.

Fans

- Air Movement and Control Association (AMCA) sets the standard for determining fan efficiency
- AMCA Standard 201 Fans and Systems describes the “system effect” which alters Fan performance
- ASHRAE Standard 90.1 also puts a limit on the size of the motor on fans

ANSI/ASHRAE/IES Standard 90.1-2010

- Table 6.5.3.1.1A of the standard lists the maximum fan horsepower allowed for moving air through a system
 - For the name plate horsepower:
 - Constant volume system: $hp \leq CFM * 0.0011$
 - Variable volume system: $hp \leq CFM * 0.0015$
 - For the brake horsepower:
 - Constant volume system: $hp \leq CFM * 0.00094 + A$
 - Variable volume system: $hp \leq CFM * 0.0013 + A$
 - $A = \sum (PD * CFM/4131)$

Where:

PD = a pressure drop adjustment from Table 6.5.3.1.1B

CFM = flow through each device

Fan Efficiency

- The fan efficiency is one component of the total wire-to-air cooling efficiency
- Fan efficiency is the ratio of the air horsepower to the actual shaft horsepower of the fan wheel
- Shaft horsepower is difficult to measure so the efficiency tends to include the motor efficiency and the drive train efficiency such as from belt drives

Air Horsepower

$$P_{air} = Q * \Delta p / 6350$$

$$P_m = W_{in} * \eta_m$$

$$\eta_t = P_{air} / P_m$$

Where

P_{air} = air horsepower, ahp

Q = air flow rate (CFM)

Δp = fan total pressure rise, inches wg

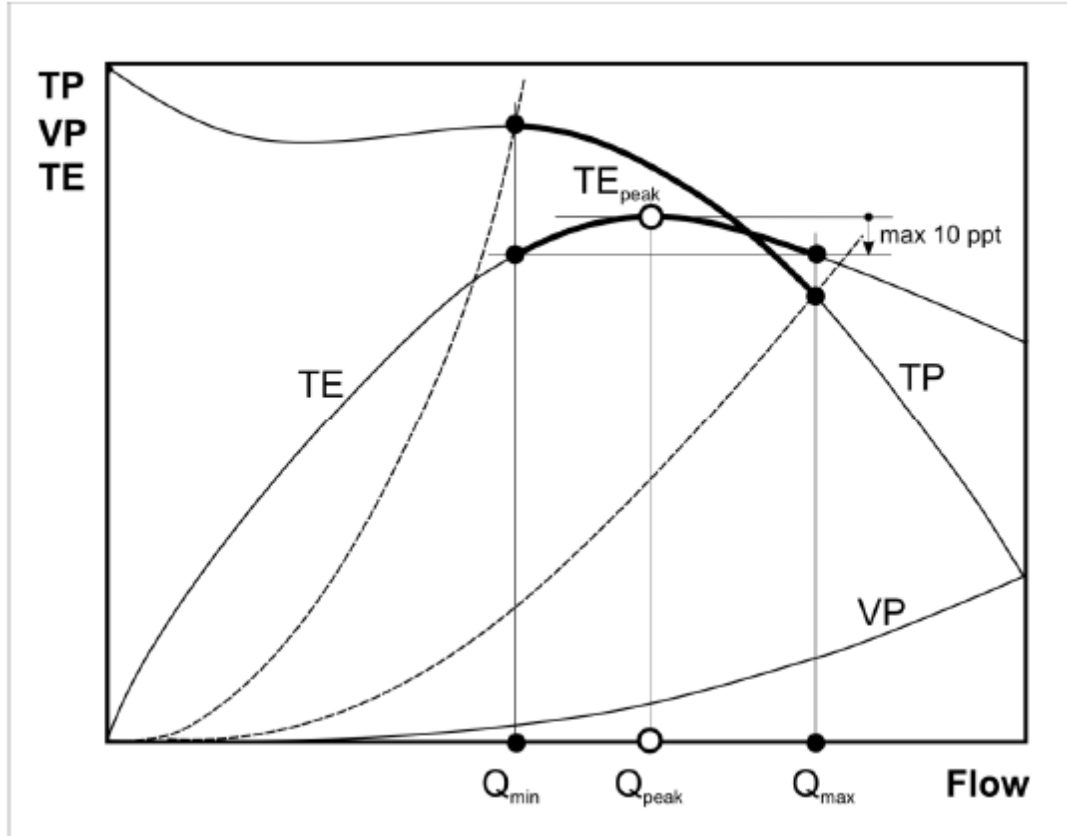
η_t = fan total efficiency

W = power into motor

P_m = brake horsepower, bhp

Fan Curves

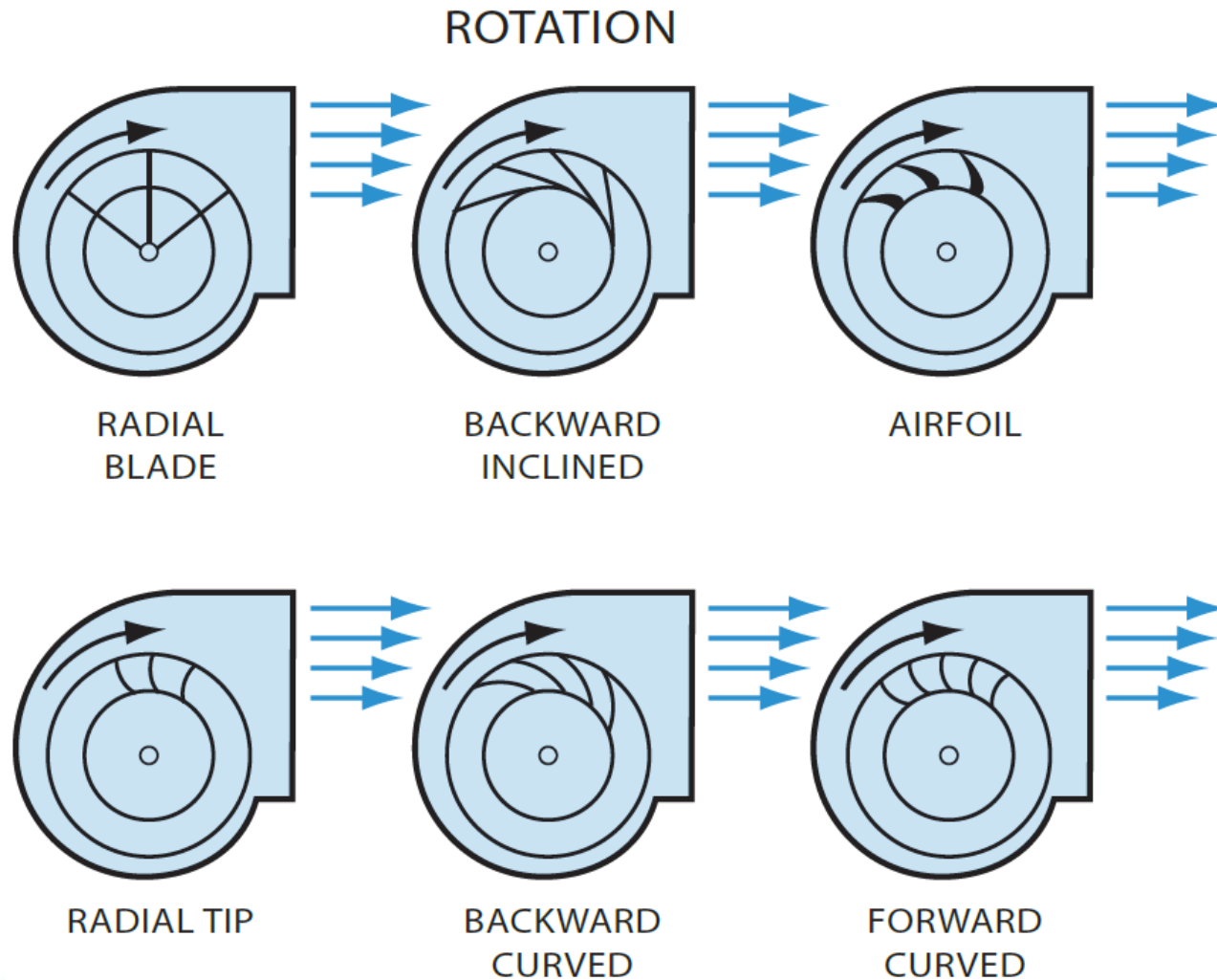
$$TP = SP + VP$$



Legend:

TP	fan total pressure
VP	fan velocity pressure
TE	fan total (energy) efficiency
Q	flow
Q _{min} , Q _{max}	flow range for the allowable fan efficiency range

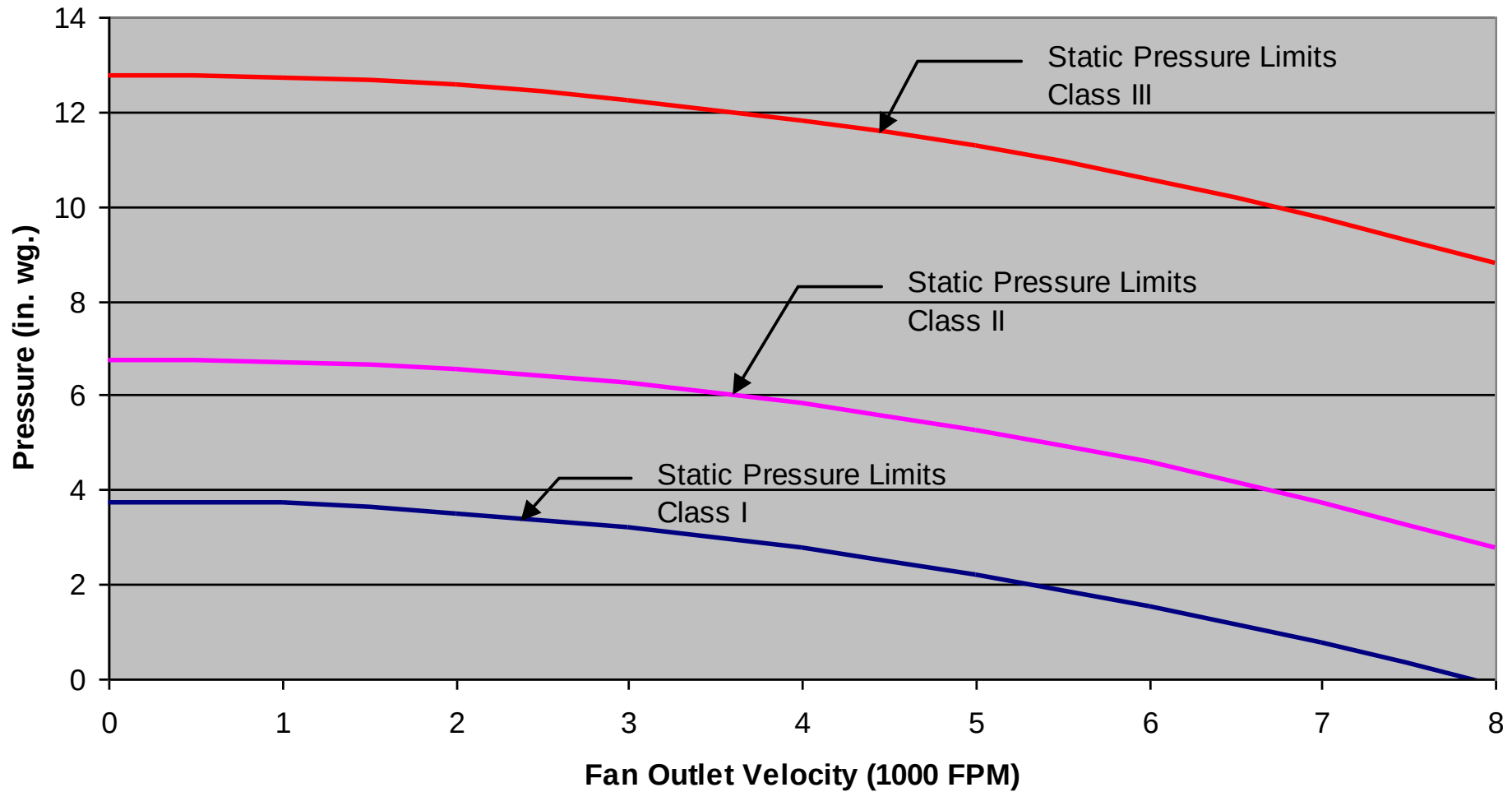
Centrifugal Fan Wheel Types



Fan Classes

Class	Maximum Total Pressure
I	3 $\frac{3}{4}$ inch wg
II	6 $\frac{3}{4}$ inch wg
III	12 $\frac{3}{4}$ inch wg
IV	More than 12 $\frac{3}{4}$ inch wg

Construction Class Pressure Limits AMCA



Fan Classes

- AMCA rating on fans are for construction
- Housings
- Bearings
- Wheels
- \$ goes up with class:
 - More steel = more \$
- In some applications it may be possible to go up a fan size and drop down from Class II to Class I

Fan Arrangements - Axial

AMCA Publication 201-90

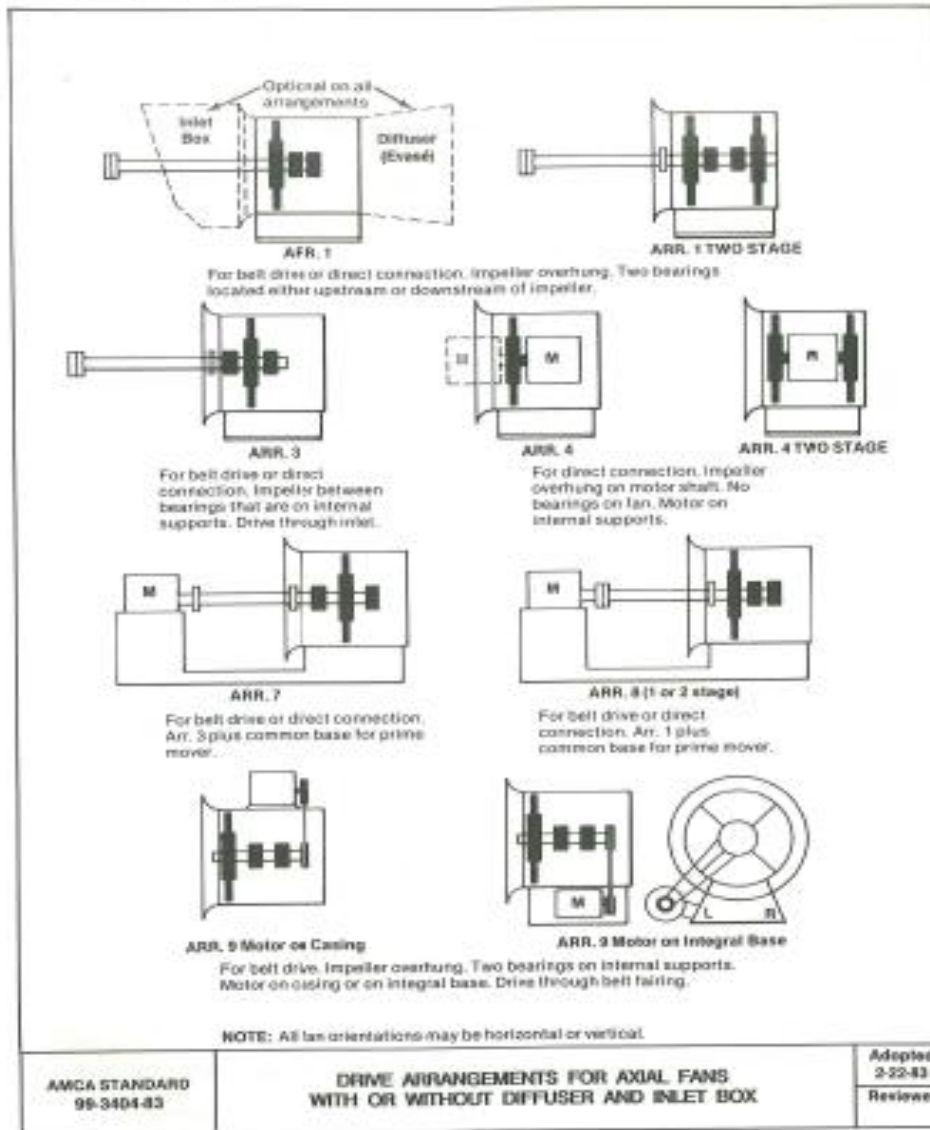


Figure 3-7

Arrangements

- Arrangement Numbers
- Bearing number and arrangement
- Motor position

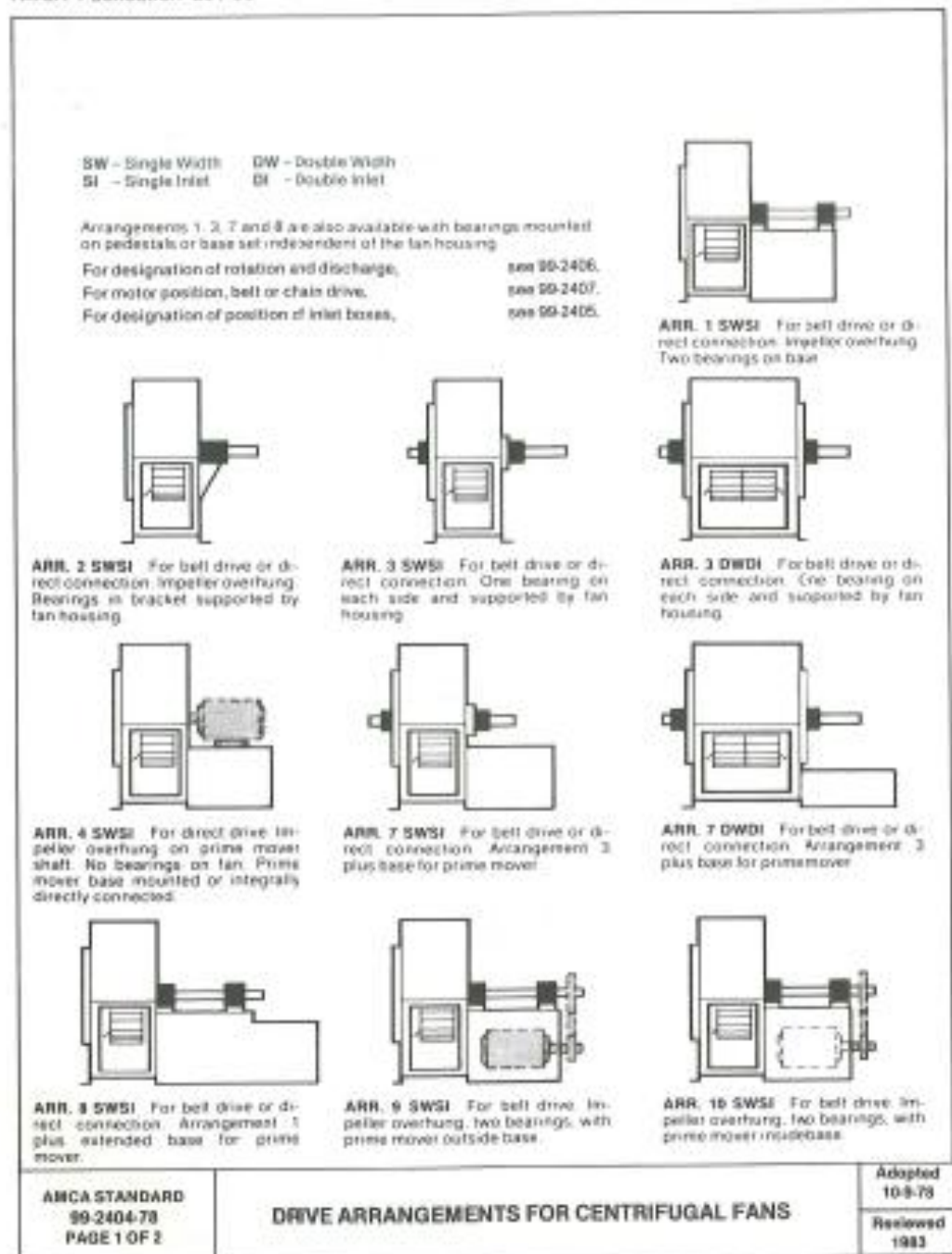


Figure 3-5

Discharge Posit

UB

TAU

TH

TAD

DB

BAD

BH

BAU



Notes:

1. Direction of rotation is determined from drive side of fan.
2. On single inlet fans, drive side is always considered as the side opposite fan inlet.
3. On double inlet fans with drives on both sides, drive side is that with the higher powered drive unit.
4. Direction of discharge is determined in accordance with diagrams. Angle of discharge is referred to the vertical axis of fan and designated in degrees from such standard reference axis. Angle of discharge may be any intermediate angle as required.
5. For fan inverted for ceiling suspension, or side wall mounting, direction of rotation and discharge is determined when fan is resting on floor.

System Effect

- System effect is a combination of installed conditions that affect the flow of air presented to the fan at design flow conditions

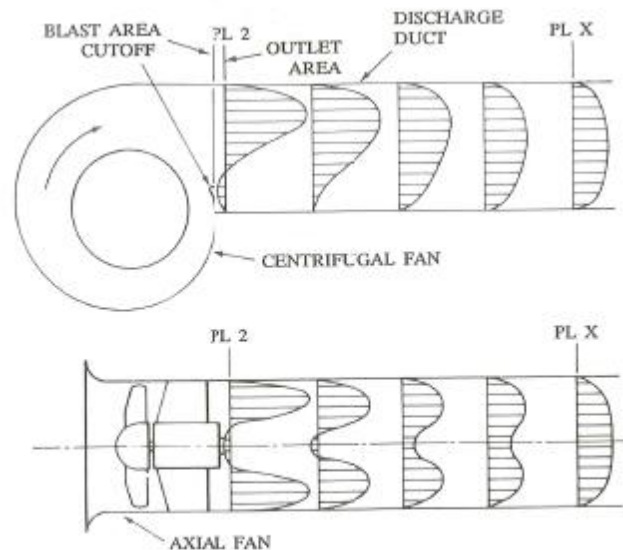


Figure 3-3 Controlled Diffusion and Establishment of a Uniform Velocity Profile in a Straight Length of Outlet Duct

Effective Duct Length

- For 100% recovery of velocity pressure, the duct must run straight or have equivalent lengths from fittings equal to 100% of the effective duct length ($L_e = PL \times$). The effective duct length is given by:

For $V_0 > 2500\text{fpm}$

$$L_e = \frac{V_0 A_0^{0.5}}{10,600}$$

For $V_0 \leq 2500\text{fpm}$

$$L_e = \frac{A_0^{0.5}}{4.3}$$

Where:

V_0 = duct velocity, fpm

L_e = effective duct length, ft

A_0 = duct area, sq.in

System Effect

- Reductions in the length of the discharge duct below 100% of effective duct length can impact the velocity pressure by as much as 50% in extreme cases
- Spin (either in the direction of wheel rotation or contrary to wheel rotation) alters the pressure developed by the centrifugal effect of the wheel. An asymmetrical velocity profile in the duct has a similar effect

Spin Affects Fan Performance

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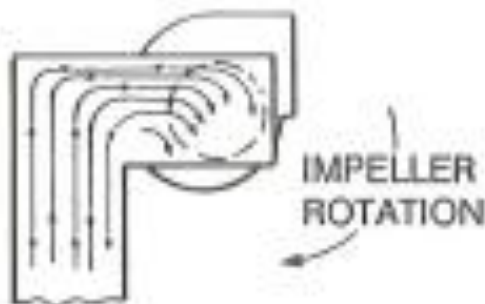
**Spin in rotation
reduces
pressure curve**

Pre-Spin

Acts like

Speed

Reduction



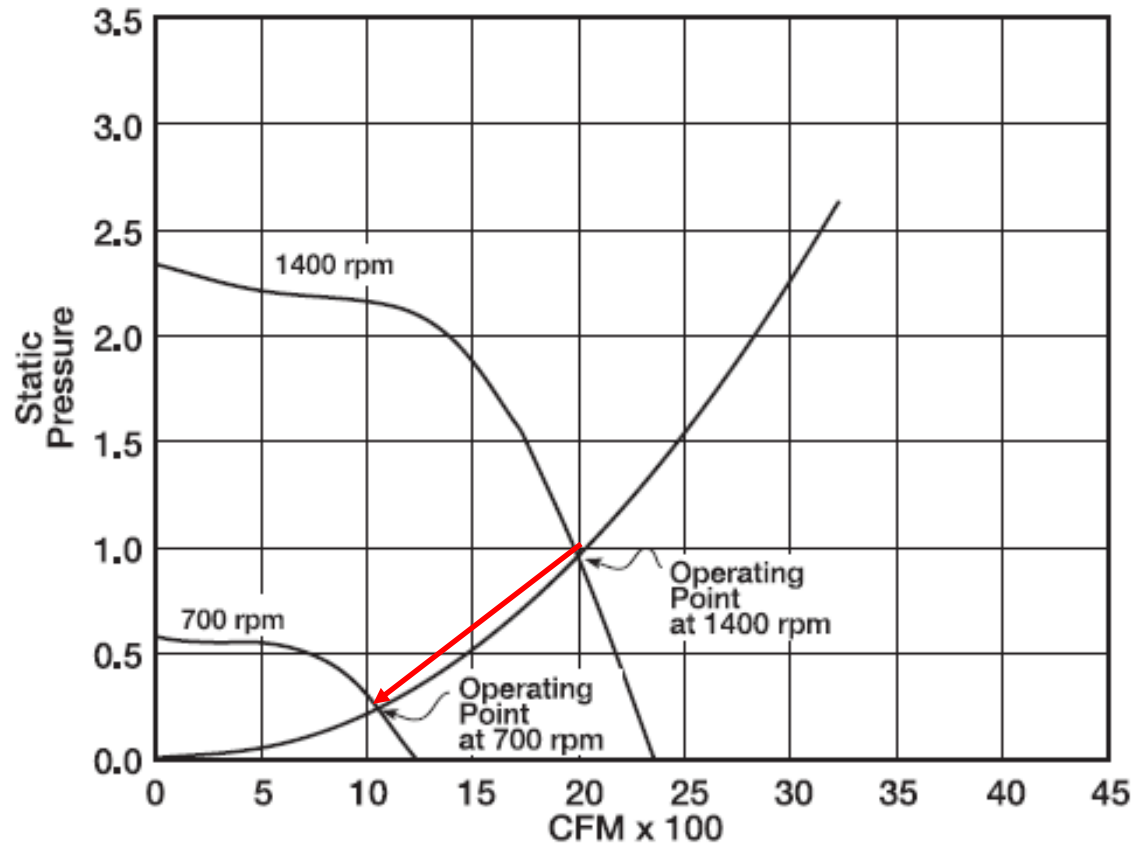
PRE-ROTATING SWIRL

COUNTER-ROTATING SWIRL

Figure 9-8 Inlet Duct Connections Causing Inlet Spin

Pre Spin Changes the Curve

Varying Operating Points



Spin Affects Fan Performance

**Counter
Rotation
Raises HP
and
possibly
Surge!**

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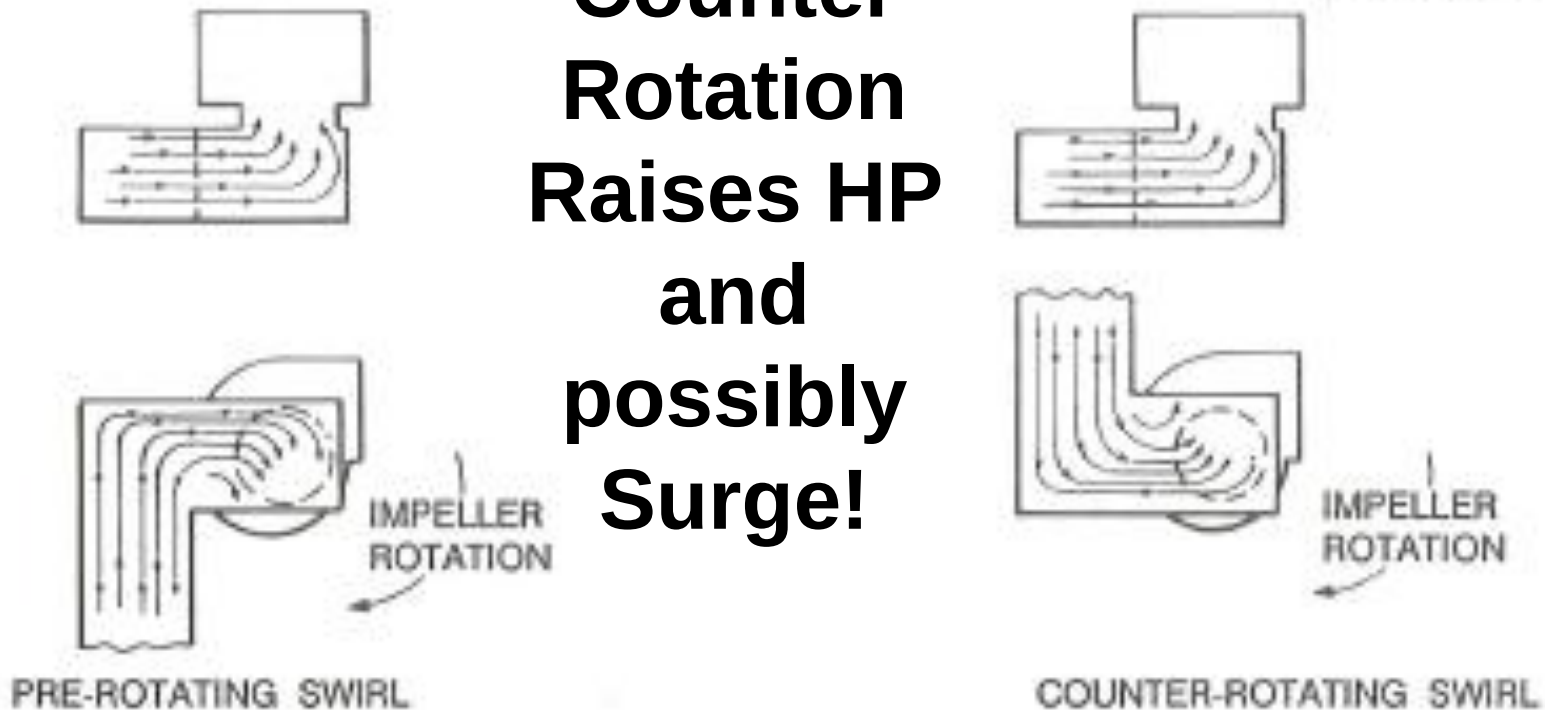
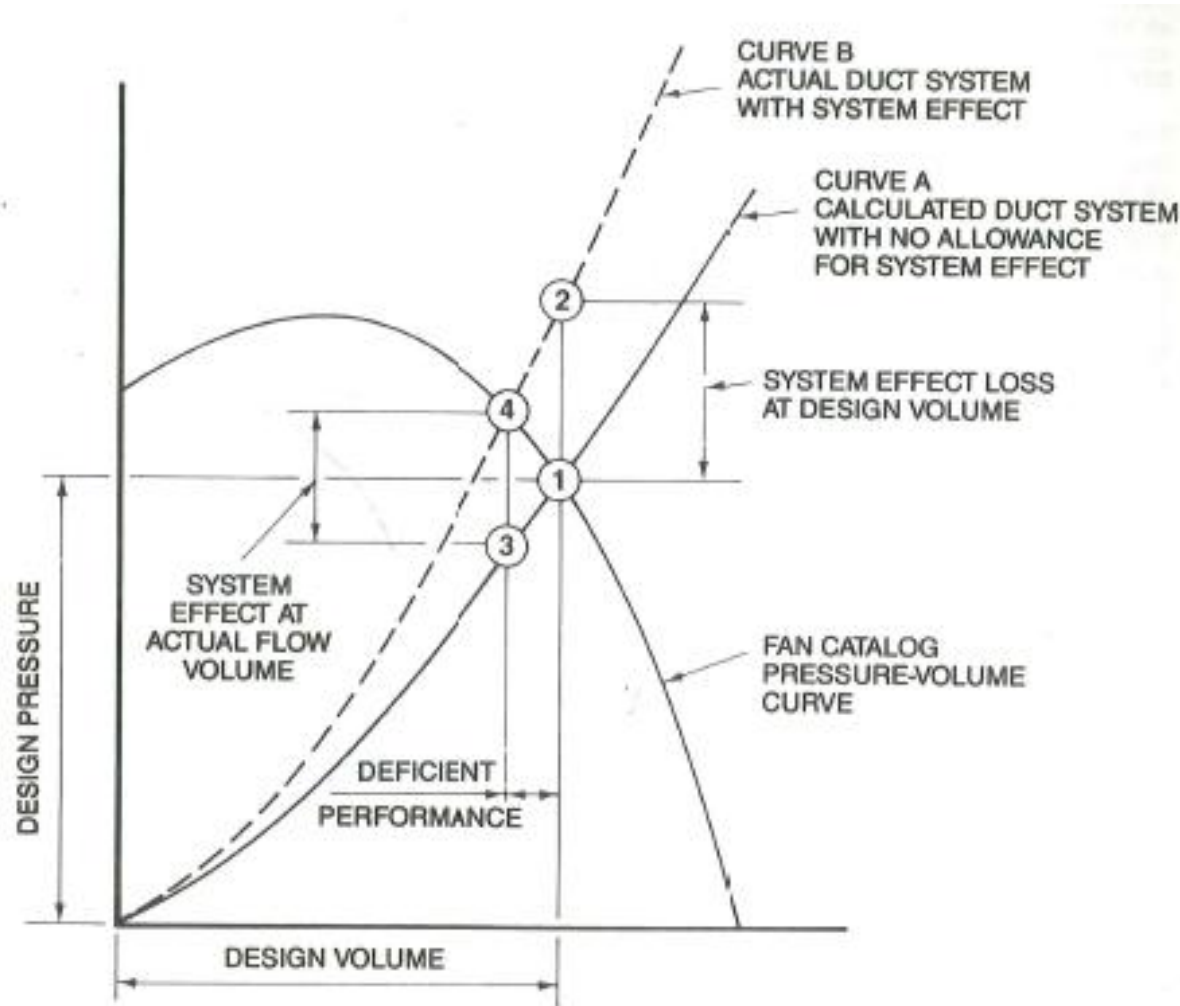


Figure 9-8 Inlet Duct Connections Causing Inlet Spin

System Effect on Performance



Calculating System Effect

Although an accurate determination of system effect is only possible by measuring performance of a fan after it has been installed in a real duct system, it is possible to make a reasonable estimate of the system effect in a design. When physical constraints require less than ideal conditions for duct design around a fan, the effect of the design upon the performance of the system and fan can be estimated using some tables created by AMCA.

For Discharge Duct Length

	No Duct	12% Effective Duct	25% Effective Duct	50% Effective Duct	100% Effective Duct
Pressure Recovery	0	50	80	90	100
Blast area/Outlet area Ratio					
0.4	P	R-S	U	W	-
0.5	P	R-S	U	W	-
0.6	R-S	S-T	U-V	W-X	-
0.7	S	U	W-X	-	-
0.8	T-U	V-W	X	-	-
0.9	V-W	W-X	-	-	-
1.0	-	-	-	-	-

For a Discharge Elbow

Blast area/Outlet Area Ratio	Outlet Elbow Position	No Outlet Duct	12% Effective Duct	25% Effective Duct	50% Effective Duct	100% Effective Duct
0.4	A	N	O	P-Q	S	NO SYSTEM EFFECT FACTOR
	B	M-N	N	O-P	R-S	
	C	L-M	M	N	Q	
	D	L-M	M	N	Q	
0.5	A	O-P	P-Q	R	T	
	B	N-O	O-P	Q	S-T	
	C	M-N	N	O-P	R-S	
	D	M-N	N	O-P	R-S	
0.6	A	Q	Q-R	S	U	
	B	P	Q	R	T	
	C	N-O	O	Q	S	
	D	N-O	O	Q	S	
0.7	A	R-S	S	T	V	
	B	Q-R	R-S	S-T	U-V	
	C	P	Q	R-S	T	
	D	P	Q	R-S	T	
0.8	A	S	S-T	T-U	W	
	B	R-S	S	T	V	
	C	Q-R	R	S	U-V	
	D	Q-R	R	S	U-V	
0.9	A	T	T-U	U-V	W	
	B	S	S-T	T-U	W	
	C	R	S	S-T	V	
	D	R	S	S-T	V	
1.0	A	T	T-U	U-V	W	
	B	S-T	T	U	W	
	C	R-S	S	T	V	
	D	R-S	S	T	V	

SEF Curves

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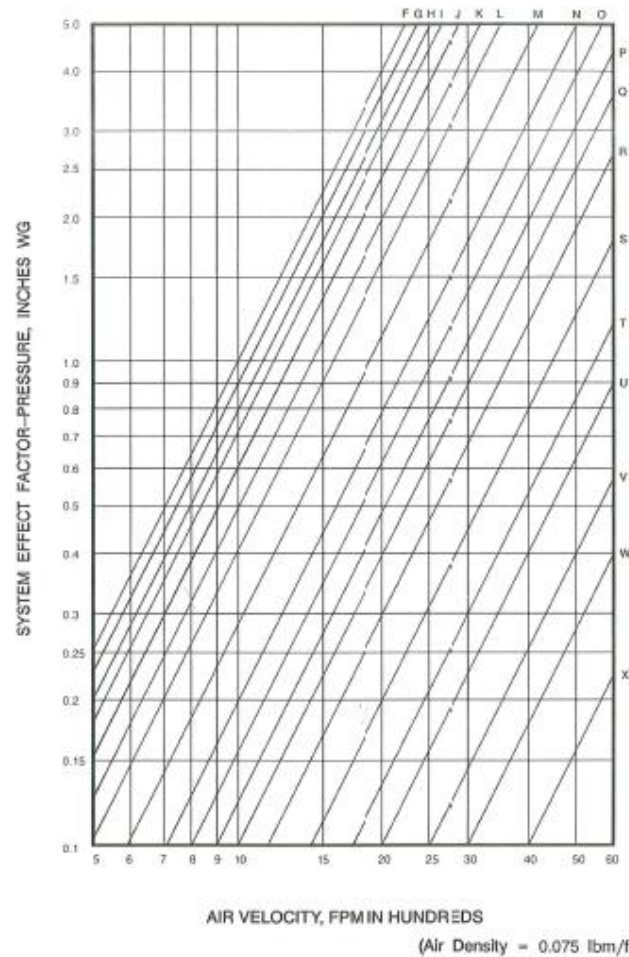


Figure 7-1 System Effect Curves

Enter the chart at the appropriate air velocity (on the abscissa) read up to the applicable curve, then read across from the curve (to the ordinate) to find the SEF at standard air density.

End of Lesson

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