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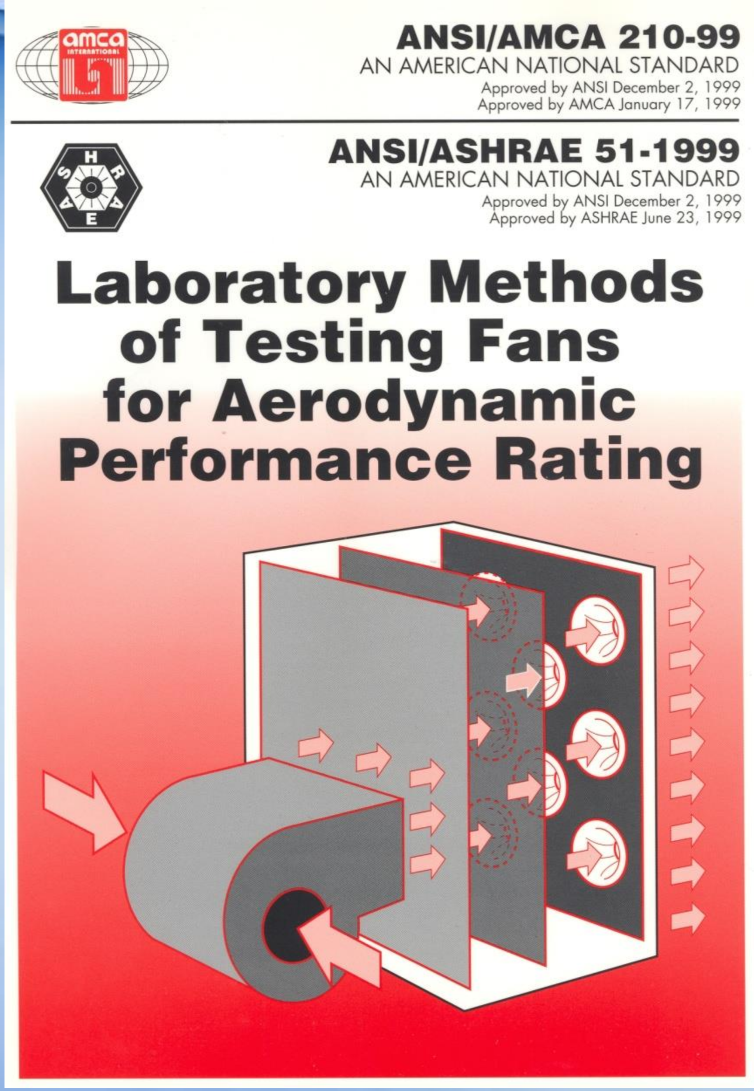
Fan System Effects

Outline

- Fan Testing Review
- Definition of System Effect
- Old ASHRAE guidelines
- AMCA 201 System Effect Factors
- Examples
- Demonstration
- Aimed at the fan system designer
- There are two goals:
  - Avoid poor fan system configurations
  - When optimum conditions cannot be met, use the "system effect" factors to estimate any losses during system design

AMCA Publication 210-99



- Defines standard methods of testing fans for rating purposes

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Fan Ratings

- Fan ratings are established using AMCA 210 test codes that are close to ideal conditions
  - Straight, uniform flow directed only in the axial direction entering the fan
  - Discharge duct long enough to allow flow to fully develop

- Uniform airflow conditions ensure consistency and reproducibility of test results AND permit the fan to develop its maximum performance.

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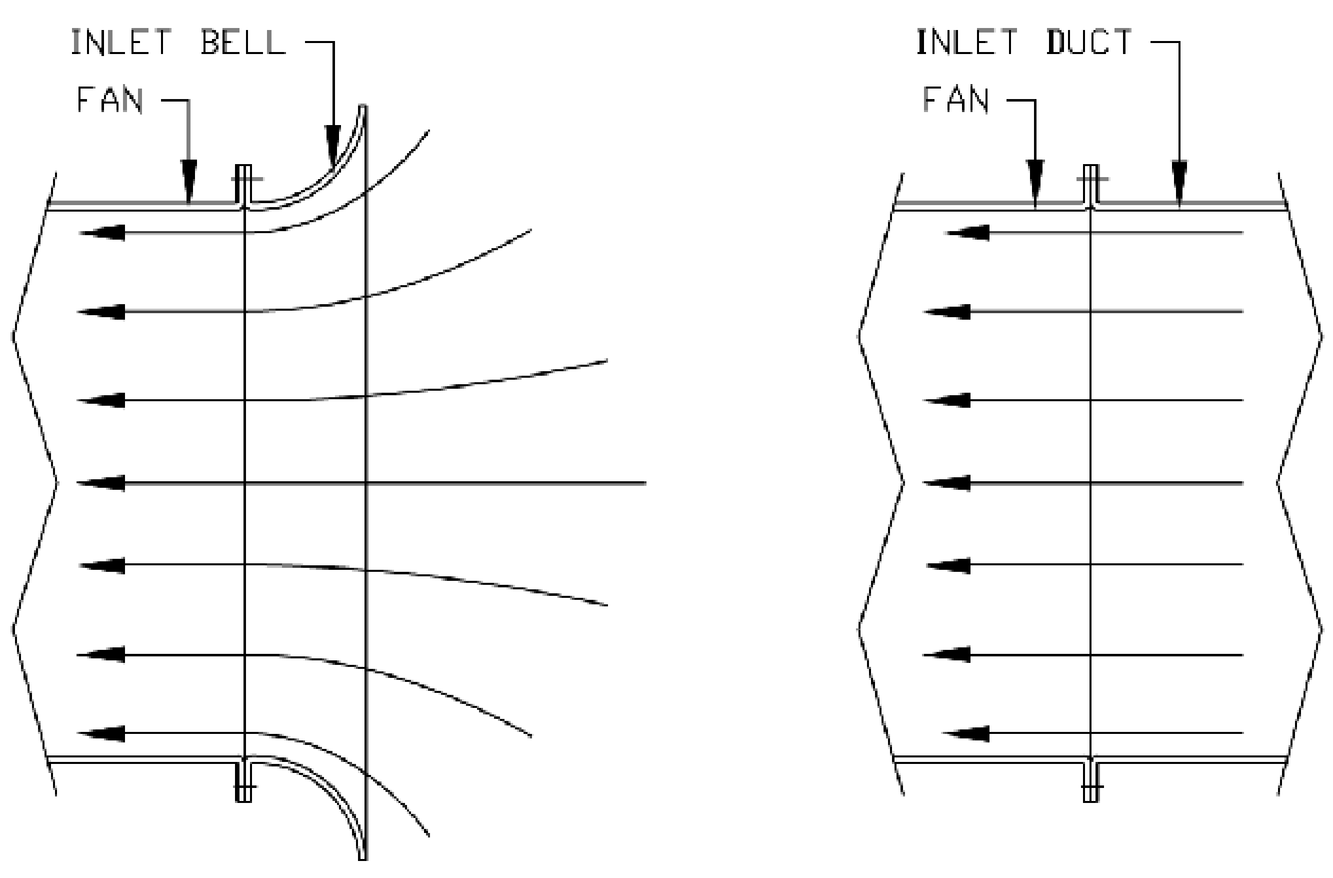
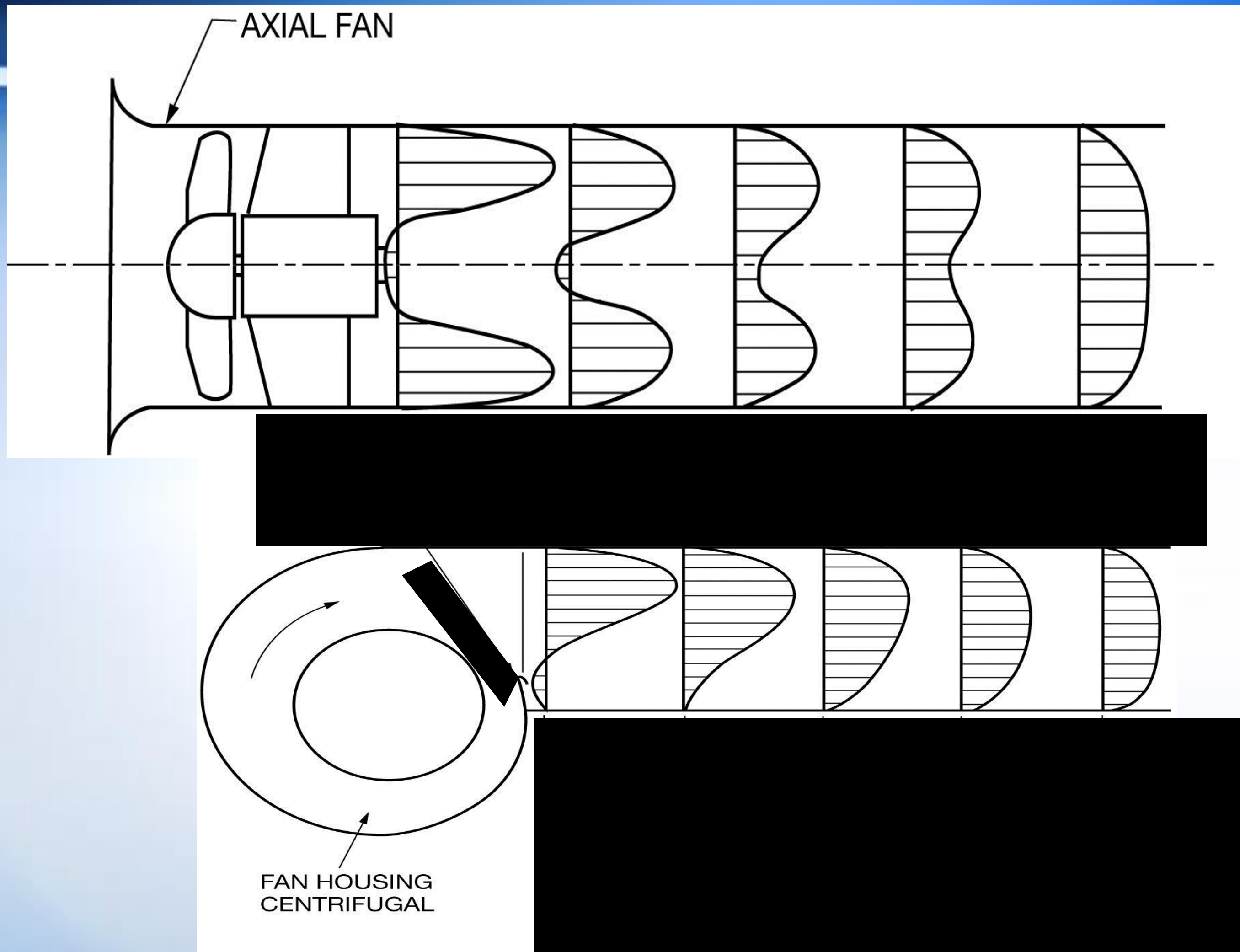
Inlet Velocity Profile



Discharge Velocity Profile



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Typical AMCA 210 Test Set-up

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What is System Effect?

- Fans in actual systems are often less than ideal
- When an installation produces airflow that is not uniform, the fan's performance will be measurably reduced.
- The difference in performance for the same fan tested in both conditions is the "System Effect"
- In other words, anything that is placed in close proximity before or after the fan that effects the catalogued performance.
- System Effect Factors (SEF): A factor used to correct for system induced installation effects

Why System Effect is Important

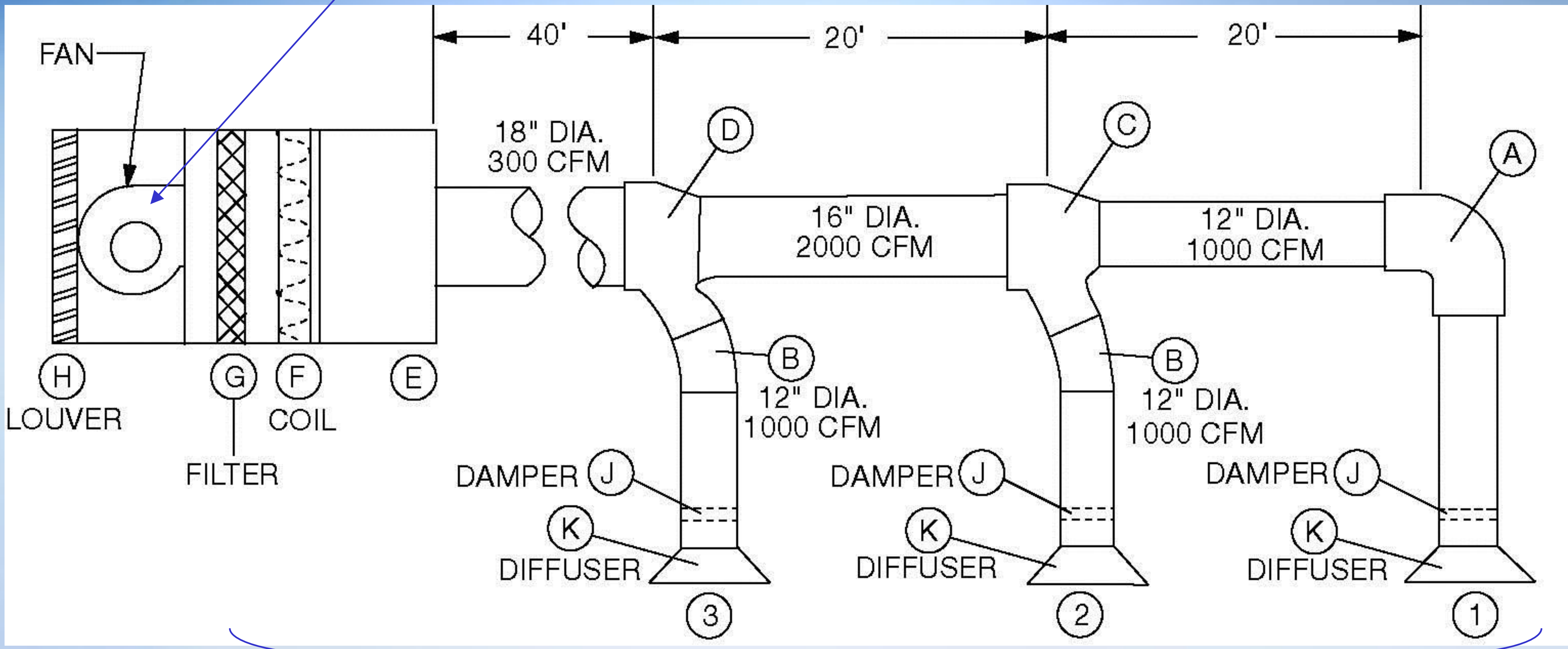
- If not accounted for, must accept deficient performance, or...
  - Speed up the fan (if possible)
  - May require more energy to meet performance
  - May exceed motor horsepower limit
- Many cause excessive noise
- Many cause excessive vibration

Two Components of System Design

- Calculate flow resistance losses for each component in the system
- Select and position fan to avoid system effect loss
  - If loss cannot be avoided, estimate loss and select fan for higher pressure

Ductwork Example

System Effect Controlled by Inlet and Outlet Conditions



System Resistance

Causes of Non-Performing Systems

- System resistance has been miscalculated
- Fan not properly selected
- Defective fan (or fan rating)
- There is a system effect loss

Fan Manufacturer's Responsibility

- Provide accurate fan performance ratings
- Provide a fan built within tolerance so that it is capable of meeting its rating
- Manufacturer is not responsible for system resistance or system effect

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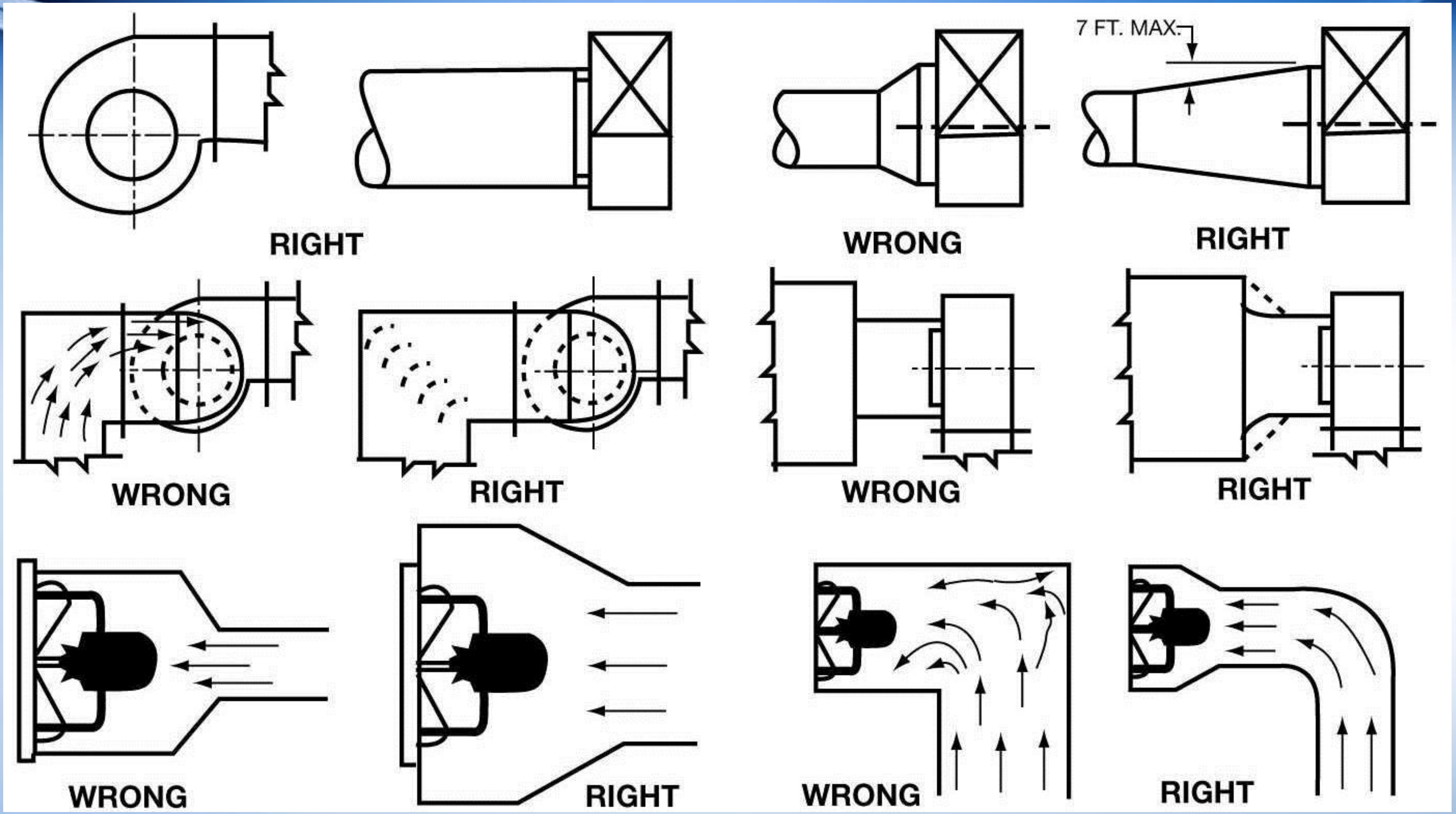
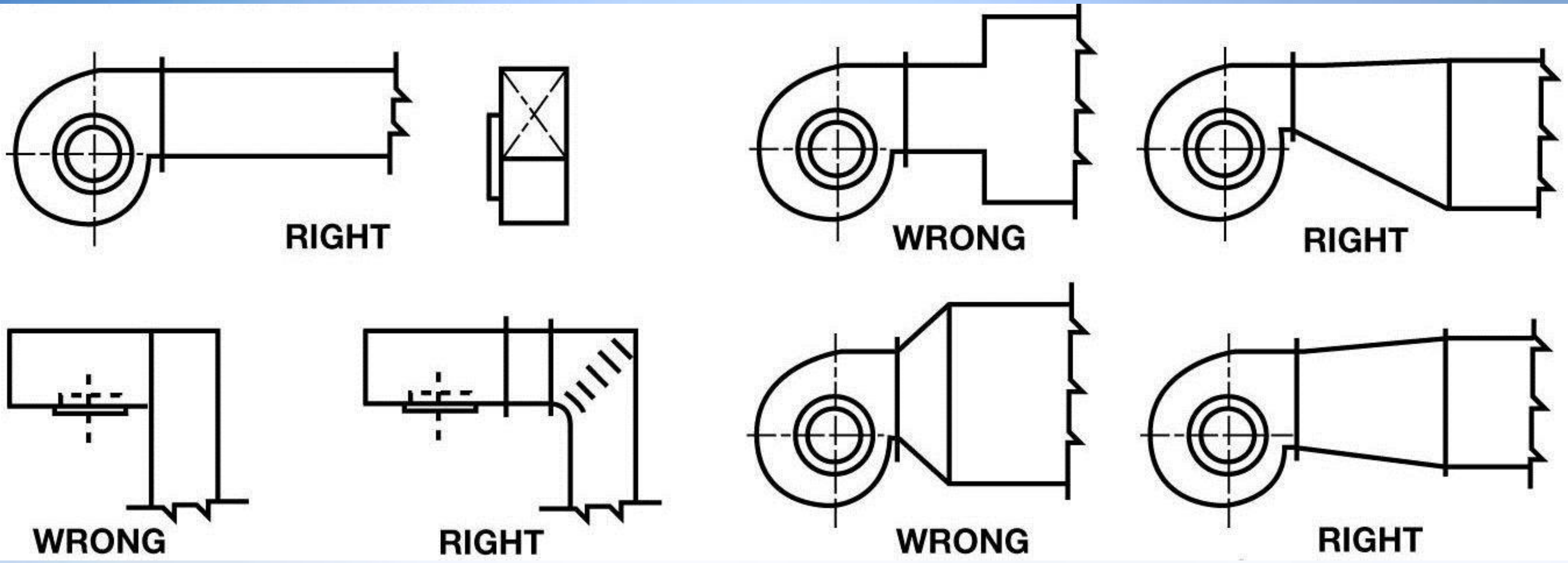
In the past…

- ASHRAE published guidelines for avoiding losses in fan performance (~1950s)
- Labeled as “Right” or “Wrong” – only qualitative

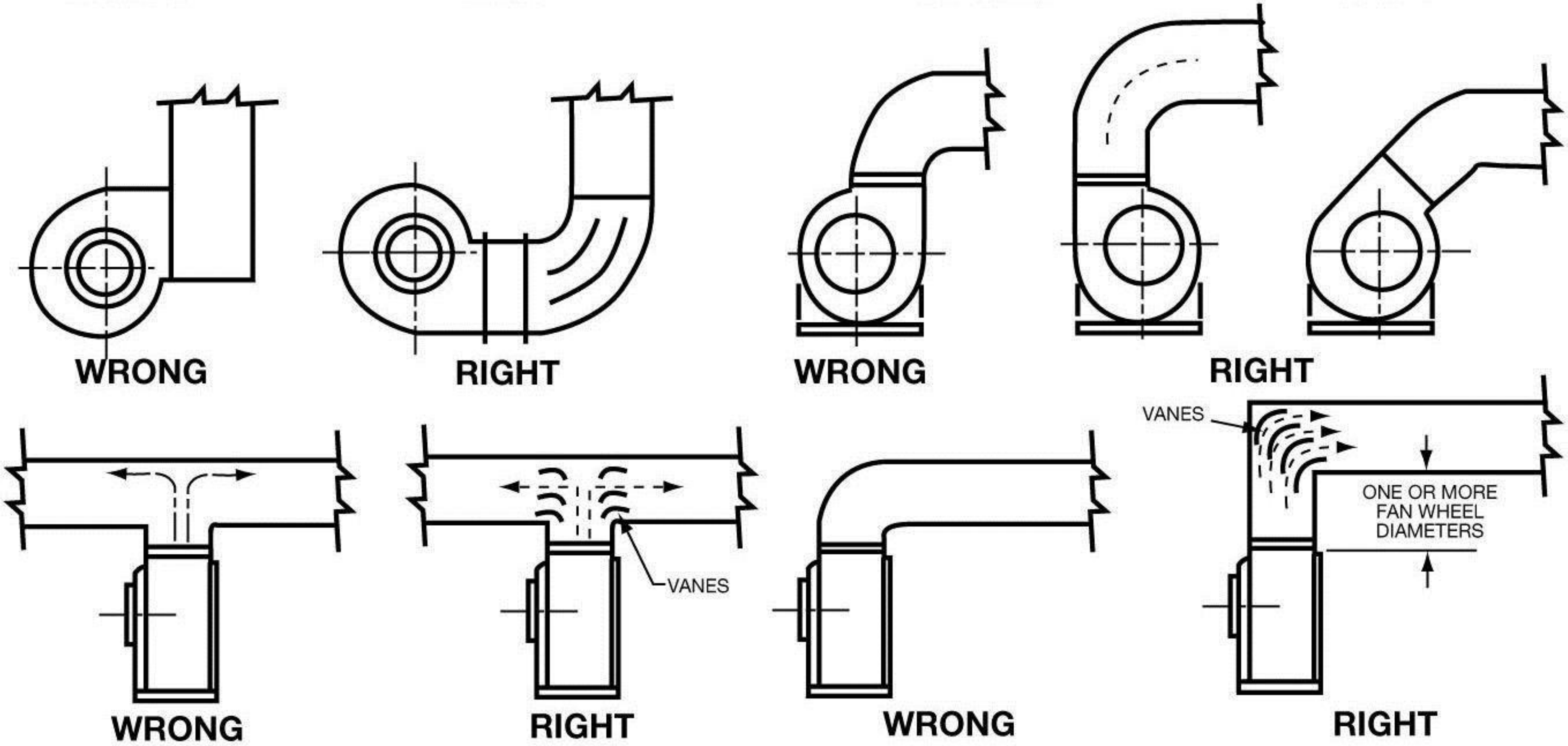
Inlet Connections



Outlet Connections



Outlet Connections



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What was missing?

- Only guidelines to avoid losses
- No way to quantify losses

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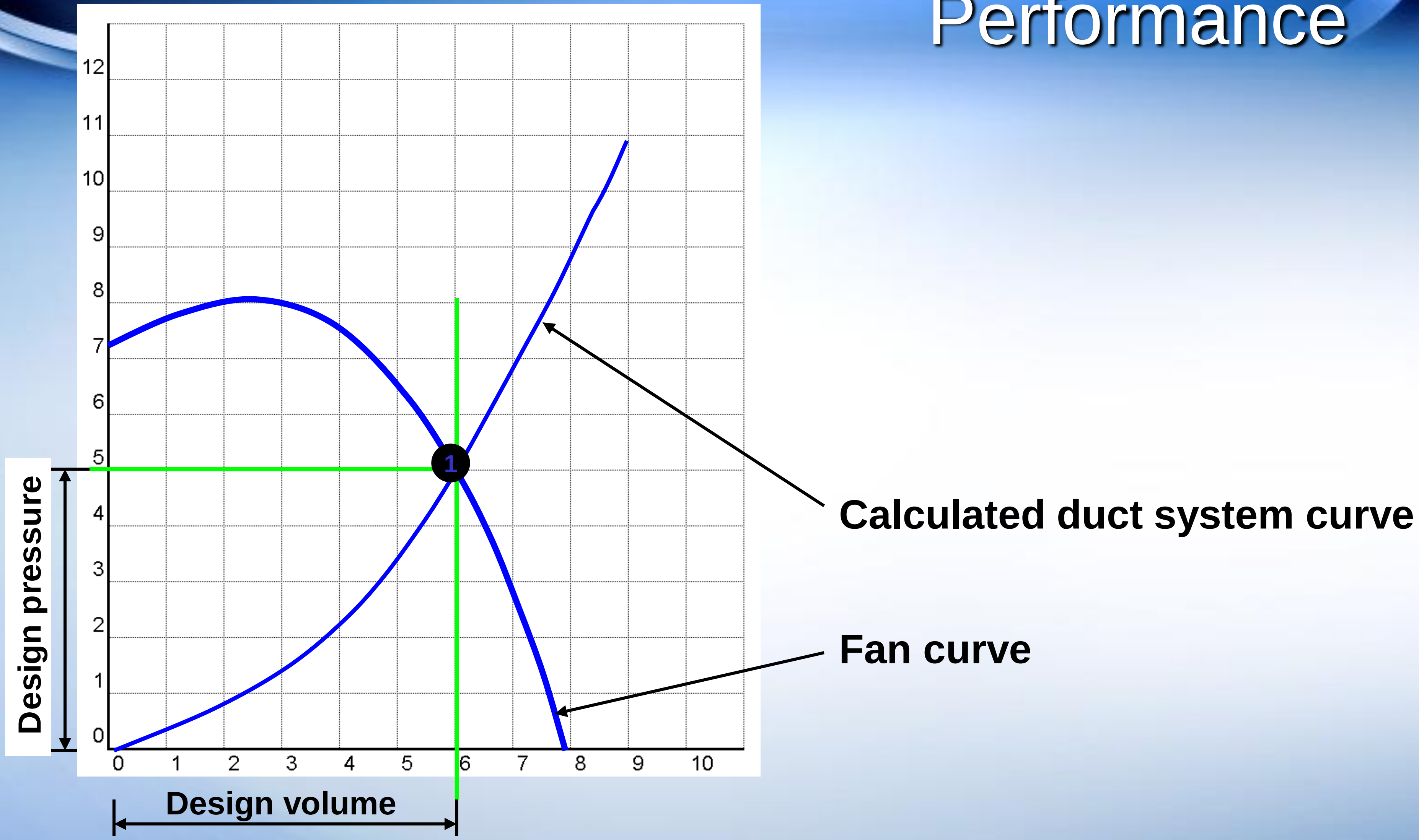
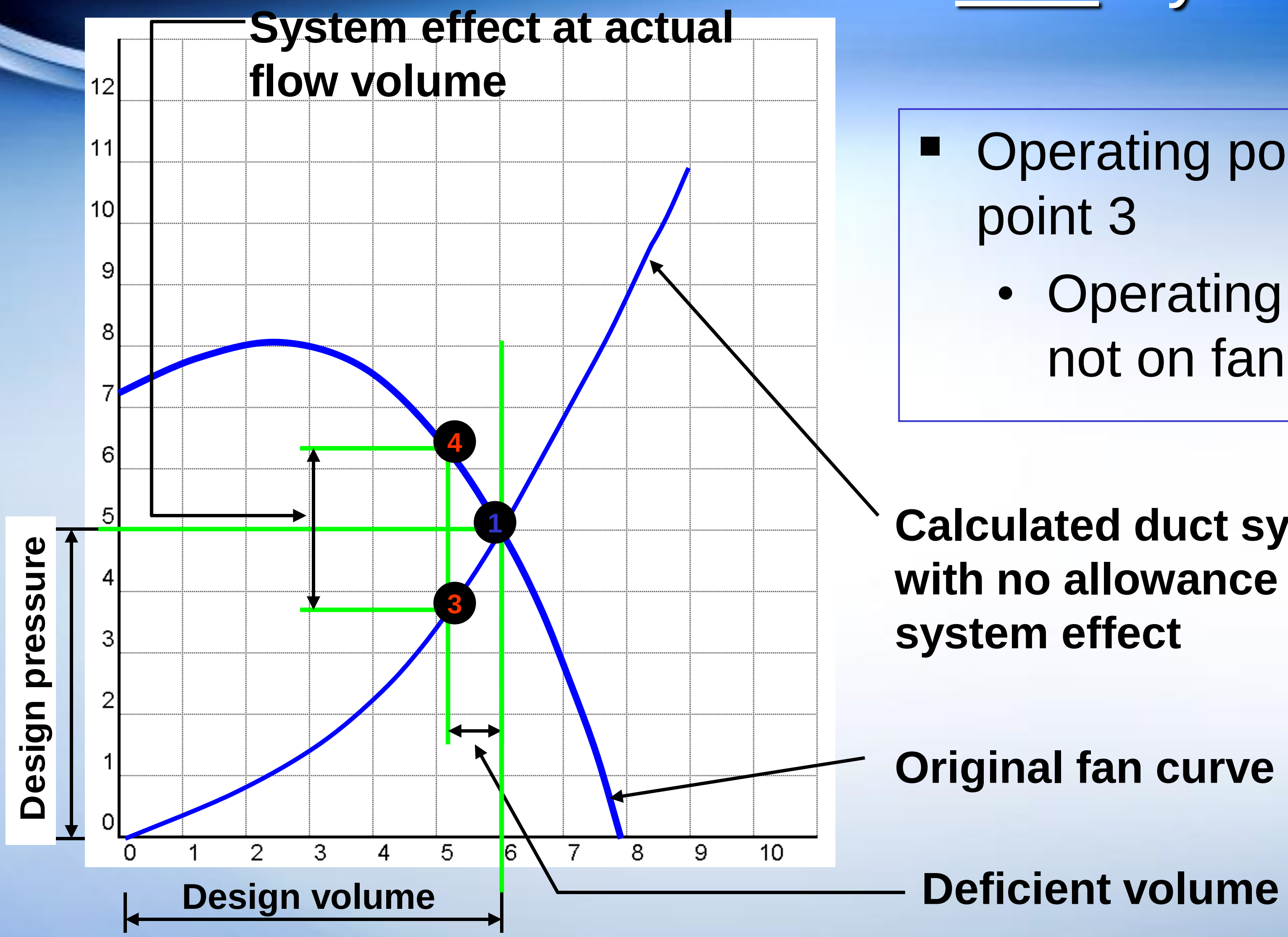
AMCA Publication 201:2002

- Generated in 1973 from ASHRAE funded research.
- Quantifies duct system design effect on performance.
- Known as the bible of system effects.

Normal System Performance

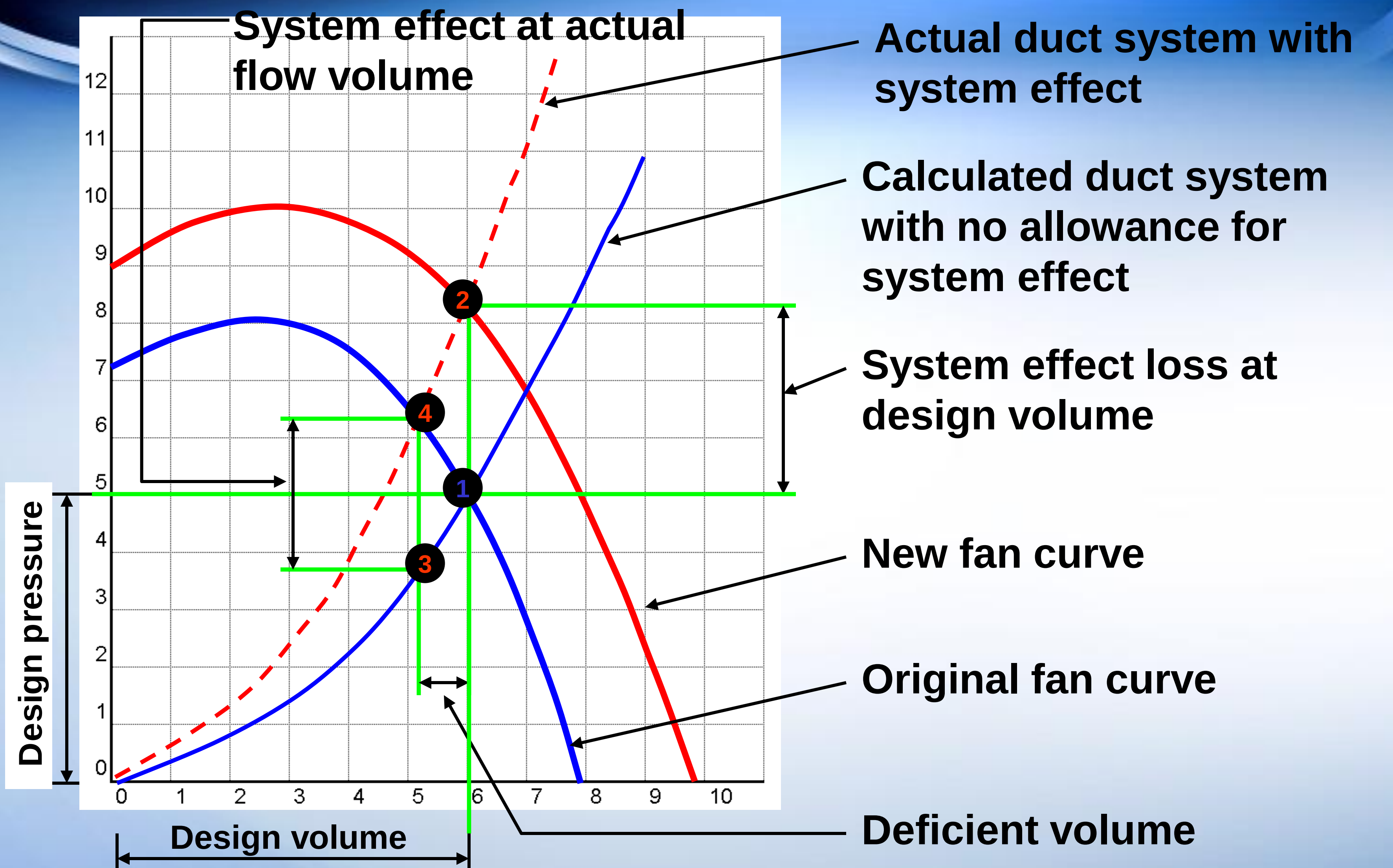


Deficient Performance With System Effect



- Operating point is at point 3
  - Operating point is not on fan curve!

Correcting For System Effect



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With System Effects Added

- The fan will be selected for the higher pressure (no need to speed up)
- The motor will be selected to include the anticipated loss

Causes of Losses

- Inlet losses are caused by:
  - Unequal loading of the fan blades (eccentric flow)
  - Improper fan blade attack angle
  - Turbulence which disrupts the flow
- Outlet losses are caused by:
  - Loss of conversion of local high velocity into pressure

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Inlet vs. Outlet Losses

- Inlet induced losses tend to be higher than outlet losses
- Losses induced on the inlet can often exceed 20%
- Losses as high as 50% have been reported

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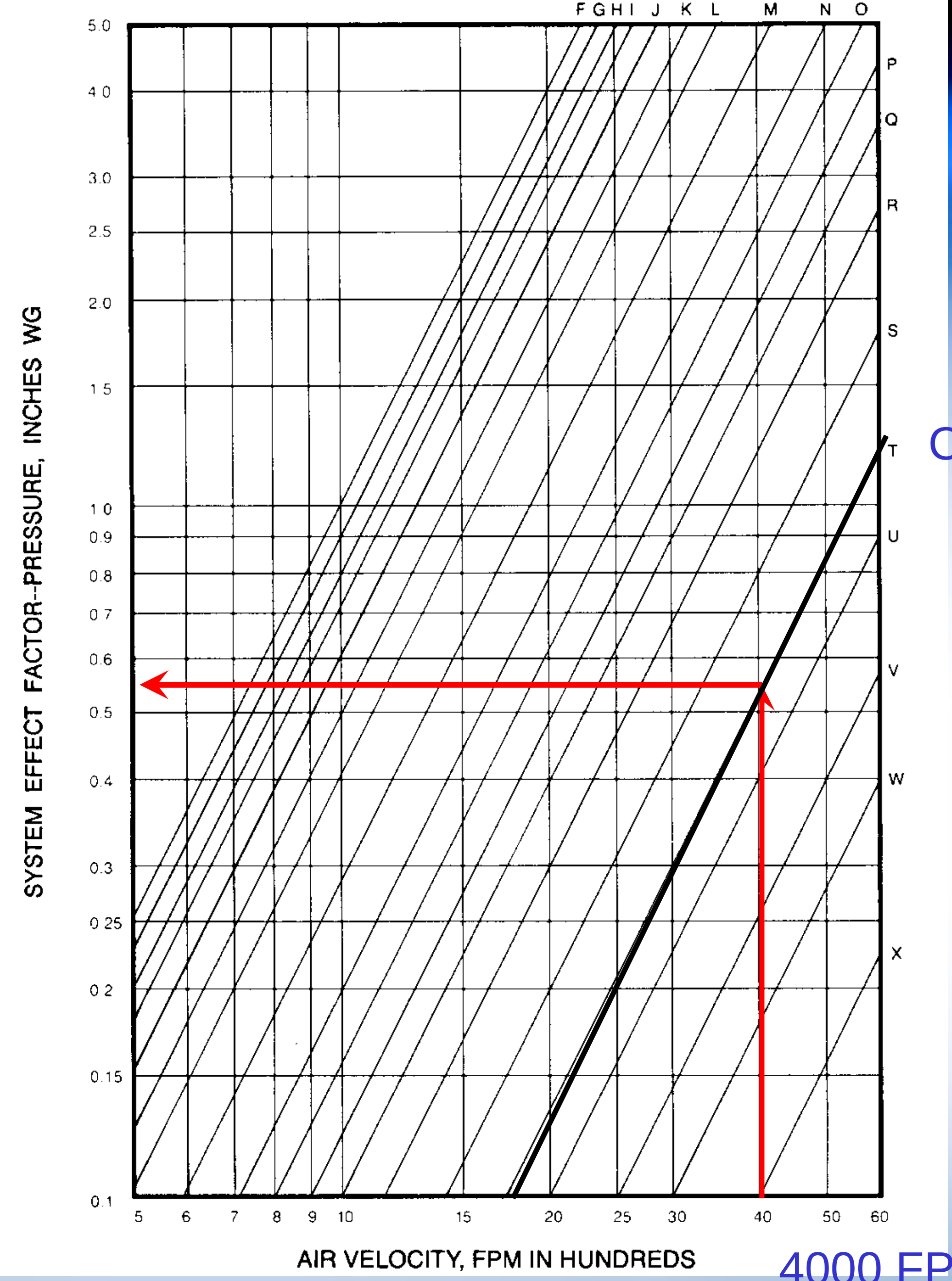
How Losses are Quantified

- AMCA 201 publishes data for a variety of configurations
- Most identify a “Loss Curve” which is based on the configuration and identified by a letter
  - Most also need the air velocity as a parameter

System Effect Curves

Add 0.55 to Static Pressure



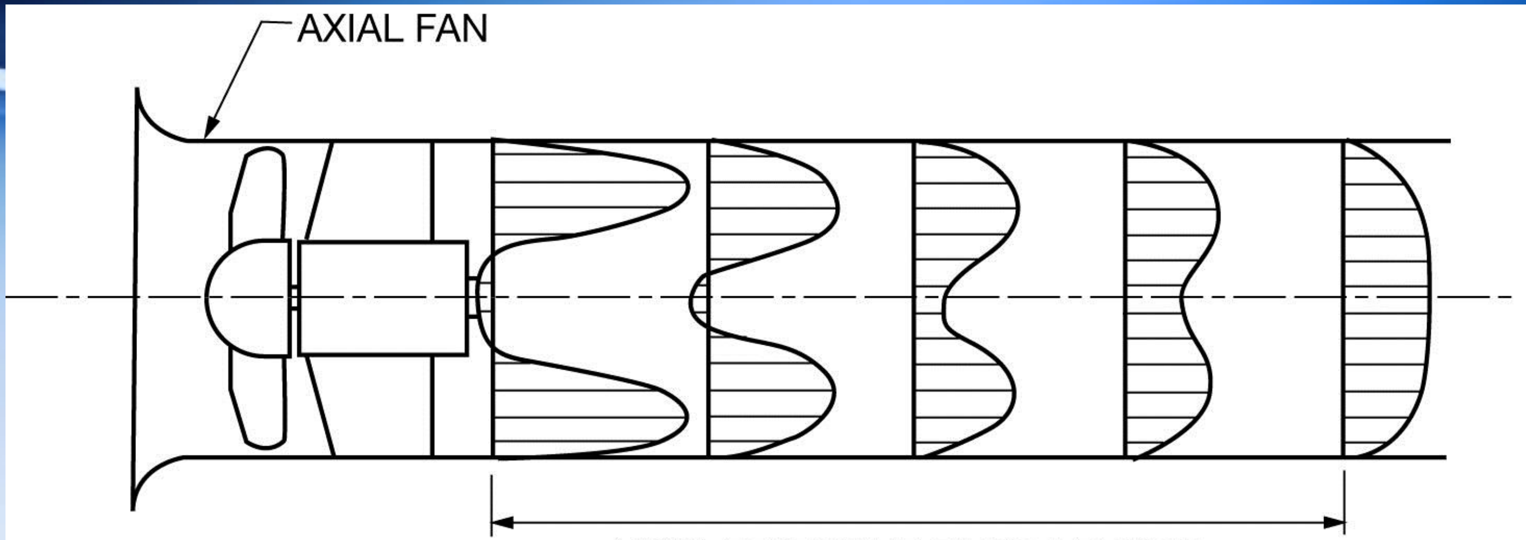
Curve T

4000 FPM

Outlet System Effects

- In addition to the flow velocity, may need to know:
  - effective duct length
  - blast area for centrifugal fans

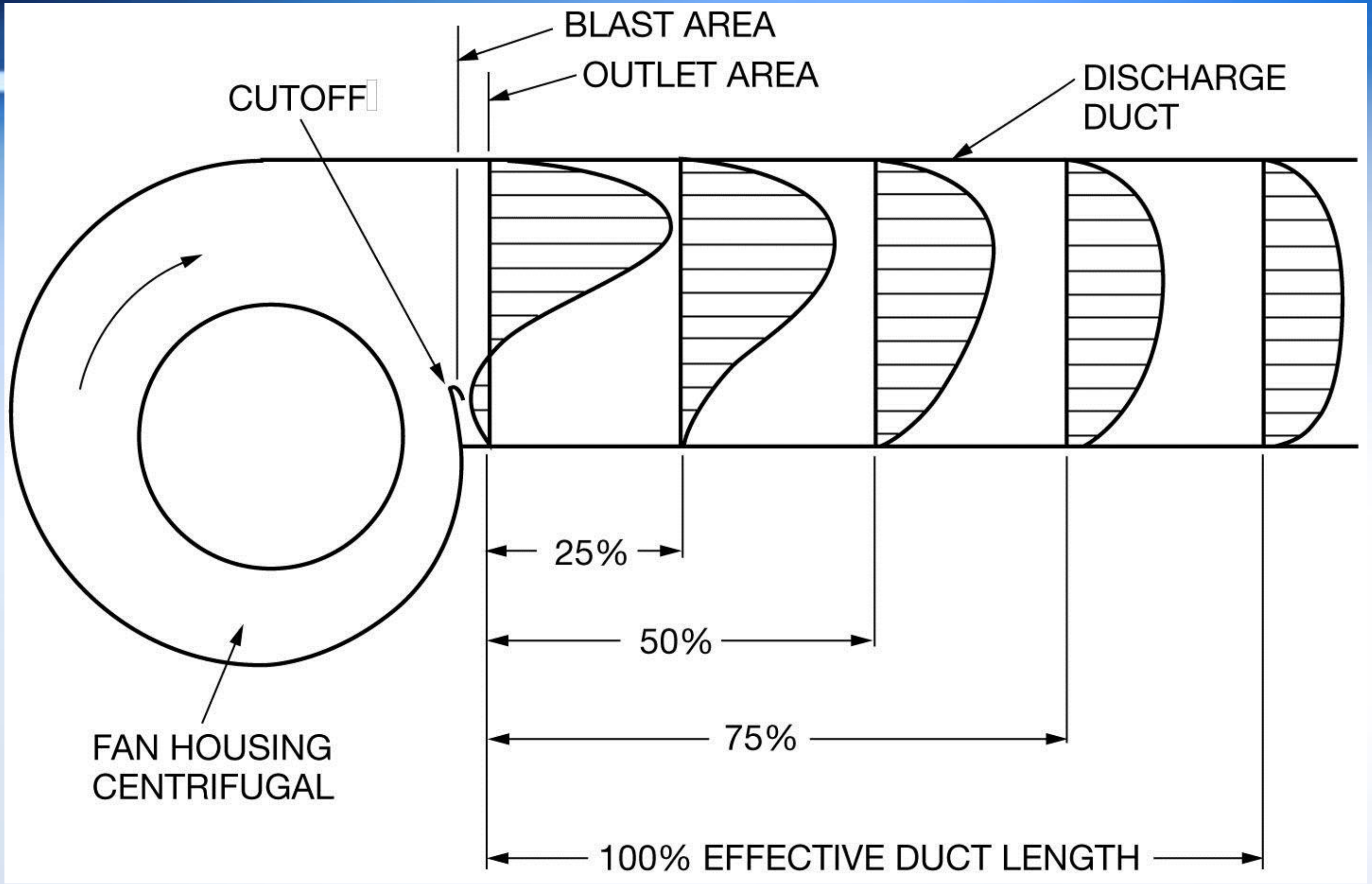
System Effect Curves for Outlet Ducts – Axial Fans



TO CALCULATE 100% EFFECTIVE DUCT LENGTH, ASSUME A MINIMUM OF 2 1/2 DUCT DIAMETERS FOR 2500 FPM OR LESS. ADD 1 DUCT DIAMETER FOR EACH ADDITIONAL 1000 FPM.

	NO DUCT	12% EFFECTIVE DUCT	25% EFFECTIVE DUCT	50% EFFECTIVE DUCT	100% EFFECTIVE DUCT
Tubeaxial Fan	—	—	—	—	—
Vaneaxial Fan	U	V	W	—	—

Fan Outlet Velocity Profile - Centrifugal



- If duct is rectangular with side dimensions a x b, the equivalent duct diameter is equal to $(4*a*b/\pi)^{0.5}$

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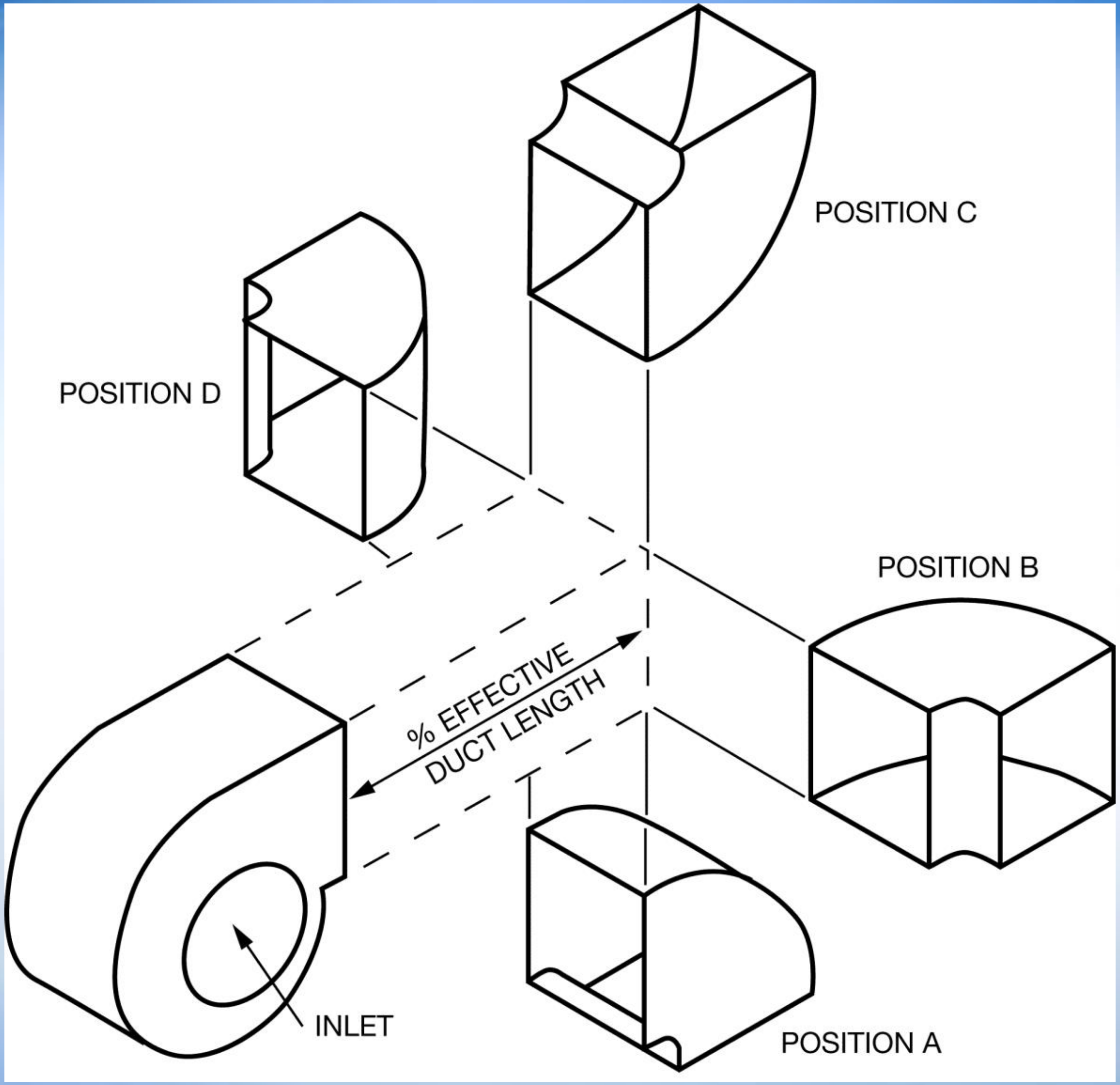
System Effect Curves for Outlet Ducts - Centrifugal Fans

	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	SYSTEM EFFECT CURVE				
0.4	P	R-S	U	Q	—
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	—	—	—	—	—

Outlet Duct Elbows - Centrifugal Fans



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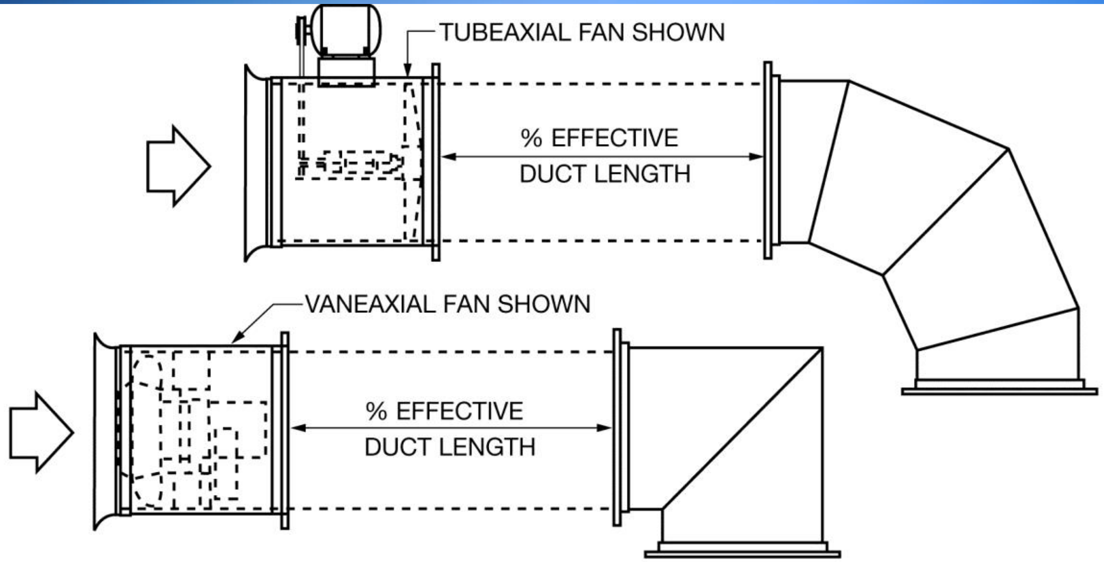
System Effect Curves for SWSI Fans

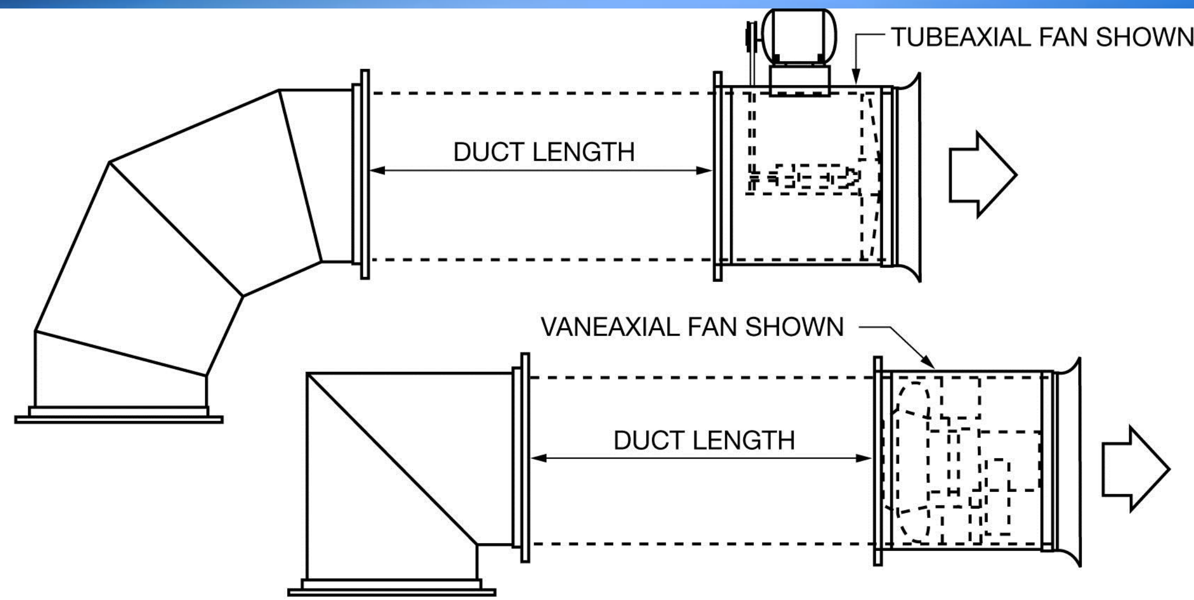
BLAST AREA / OUTLET AREA	OUTLET ELBOW POSITION	NO OUTLET DUCT	12% EFFECTIVE DUCT	25% EFFECTIVE DUCT	50% EFFECTIVE DUCT	100% EFFECTIVE DUCT
0.4	A	N	O	P-Q	S	NO SYSTEM EFFECT FACTOR
	B	M-N	N	O-P	R-S	
	C	L-M	M	N	Q	
	D	L-M	M	N	Q	
0.5	A	O-P	P-Q	R	T	
	B	N-O	O-P	Q	S-T	
	C	M-N	N	O-P	R-S	
	D	M-N	N	O-P	R-S	
0.6	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	

System Effect Curves for Outlet Duct Elbows - Axial Fans



	90# ELBOW	NO DUCT	12% EFFECTIVE DUCT	25% EFFECTIVE DUCT	50% EFFECTIVE DUCT	100% EFFECTIVE DUCT
Tubeaxial Fan	2 & 4 Pc	—	—	—	—	—
Vaneaxial Fan	2 Pc	U	U-V	V	W	—
Vaneaxial Fan	4 Pc	W	—	—	—	—

System Effect Curves for Inlet Duct Elbows - Axial Fans

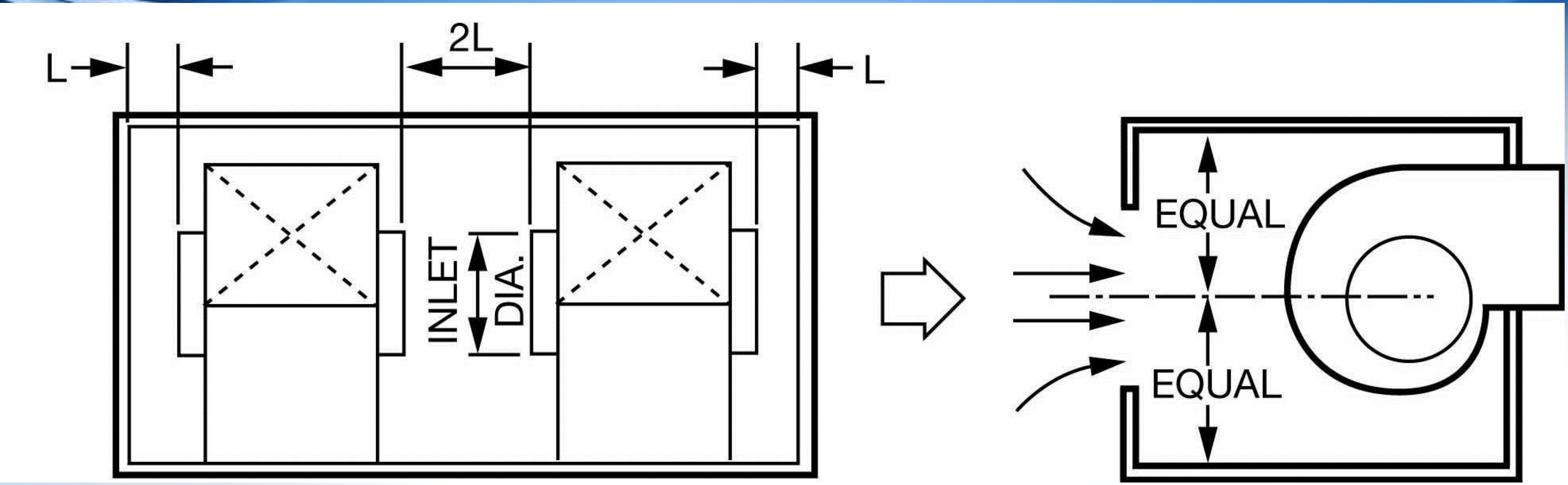


	H/T	90° ELBOW	NO DUCT	0.5 D [1] [2]	1.0 D [1] [2]	3.0D
Tubeaxial Fan	0.25	2 Pc	U	V	W	—
Tubeaxial Fan	0.25	4 Pc	X	—	—	—
Tubeaxial Fan	0.35	2 Pc	V	W	X	—
Vaneaxial Fan	0.61	2 Pc	Q-R	Q-R	S-T	T-U
Vaneaxial Fan	0.61	4 Pc	W	W-X	—	—

Percentage of Unobstructed Inlet Area

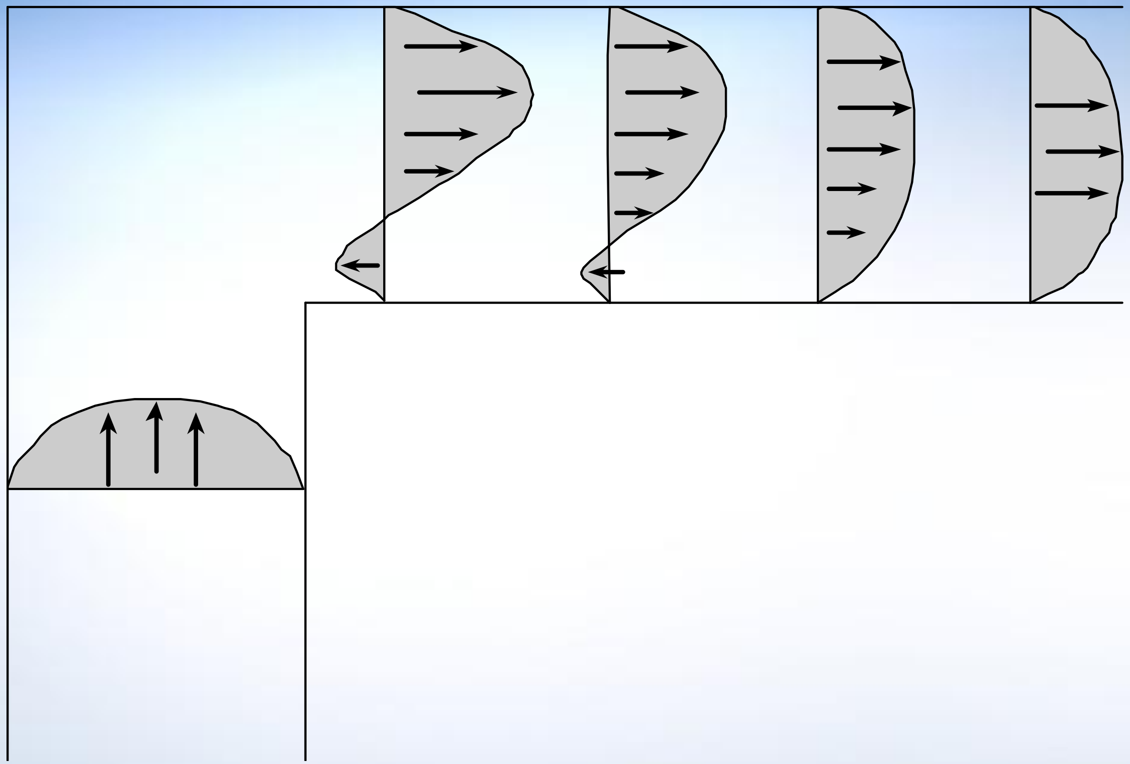
PERCENTAGE OF UNOBSTRUCTED INLET AREA	SYSTEM EFFECT CURVE (FIGURE 4)
100	NO LOSS
95	V
90	U
85	T
75	S
50	Q
25	P

Fans and Plenum



L	System Effect Curve
0.75 x Inlet Dia	V-W
0.50 x Inlet Dia	U
0.40 x Inlet Dia	T
0.30 x Inlet Dia	S

Elbows Change the Velocity Profile



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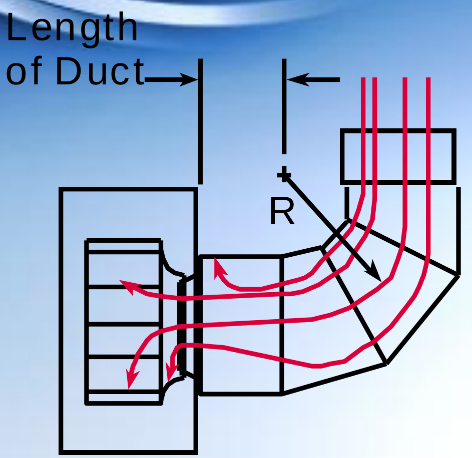
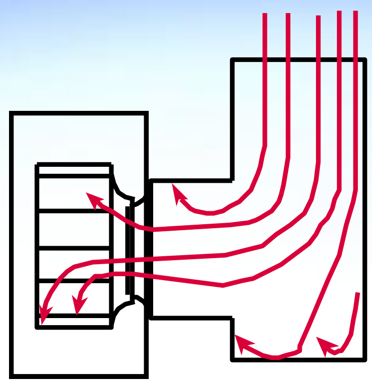
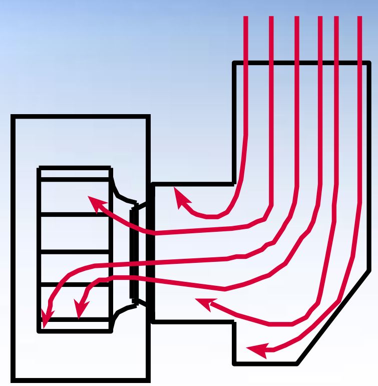
Right Angle Turns At Fan Inlet



Inlet with 3-piece elbow



Inlet with rectangular inlet Duct



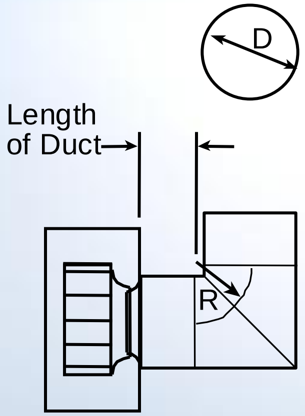
Inlet with special designed inlet box

All methods will induce some system effect loss.
Some methods are better than others

System Effect - Round Inlet Ducts

System Effect Curves

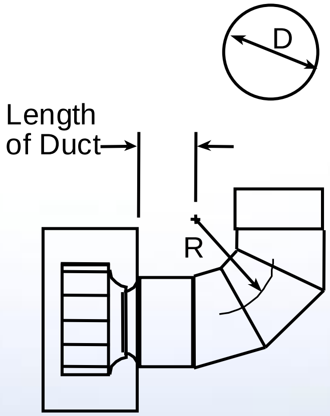
R/D	No Duct	2D Duct	5D Duct
--	N	P	R-S



2 piece mitered round section

System Effect Curves

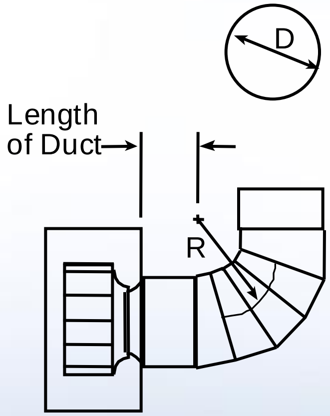
R/D	No Duct	2D Duct	5D Duct
0.5	O	Q	S
0.75	Q	R-S	T-U
1.0	R	S-T	U-V
2.0	R-S	T	U-V
3.0	S	T-U	V



3 piece mitered round section

System Effect Curves

R/D	No Duct	2D Duct	5D Duct
0.5	P-Q	R-S	T
0.75	Q-R	S	U
1.0	R	S-T	U-V
2.0	R-S	T	U-V
3.0	S-T	U	V-

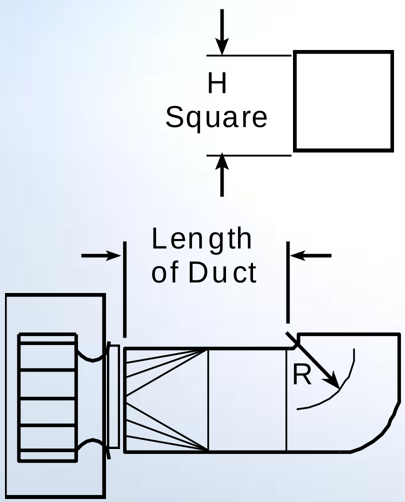


4 or more piece mitered round section

System Effect
- Square Elbow and Turning Vanes

System Effect Curves

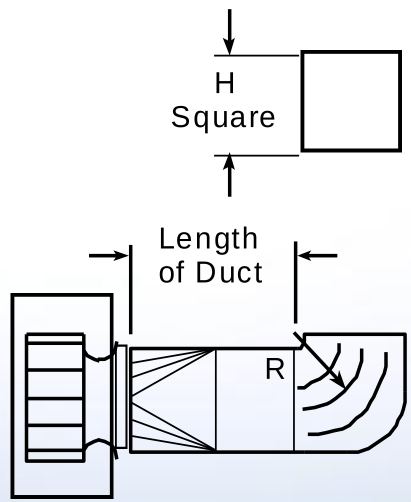
R/D	No Duct	2D Duct	5D Duct
0.5	O	Q	S
0.75	P	R	S-T
1.0	R	S-T	U-V
2.0	S	T-U	V



Square elbow -
no turning vanes

System Effect Curves

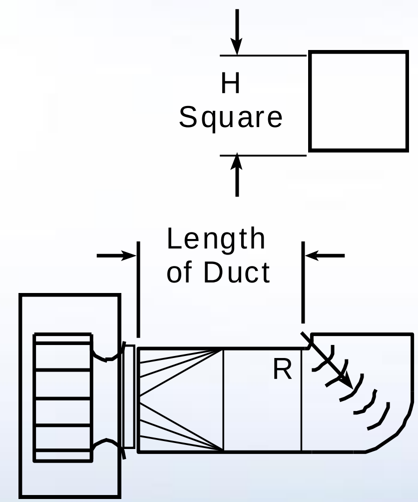
R/D	No Duct	2D Duct	5D Duct
0.5	S	T-U	V
1.0	T	U-V	W
2.0	V	V-W	W-X



Square elbow -
long turning vanes

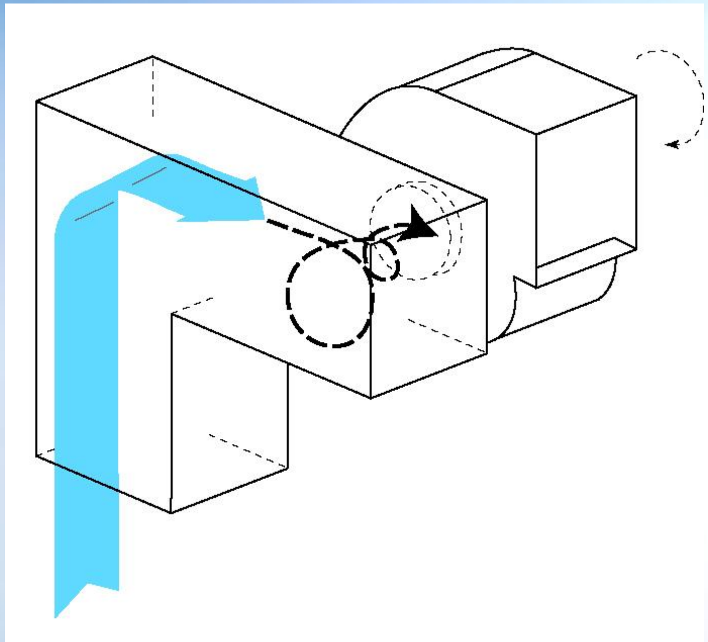
System Effect Curves

R/D	No Duct	2D Duct	5D Duct
0.5	S	T-U	V
1.0	T	U-V	W
2.0	V	V-W	W-X

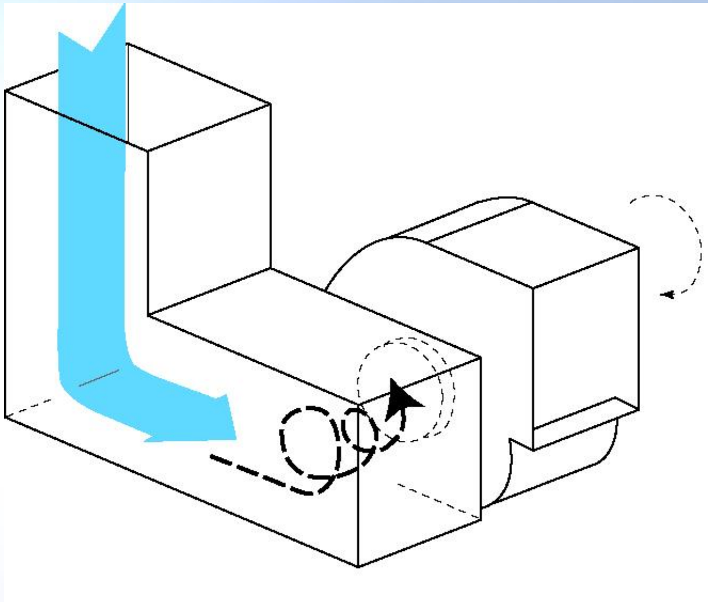


Square elbow -
short turning vanes

Forced Inlet Vortex (Inlet Spin or Swirl)

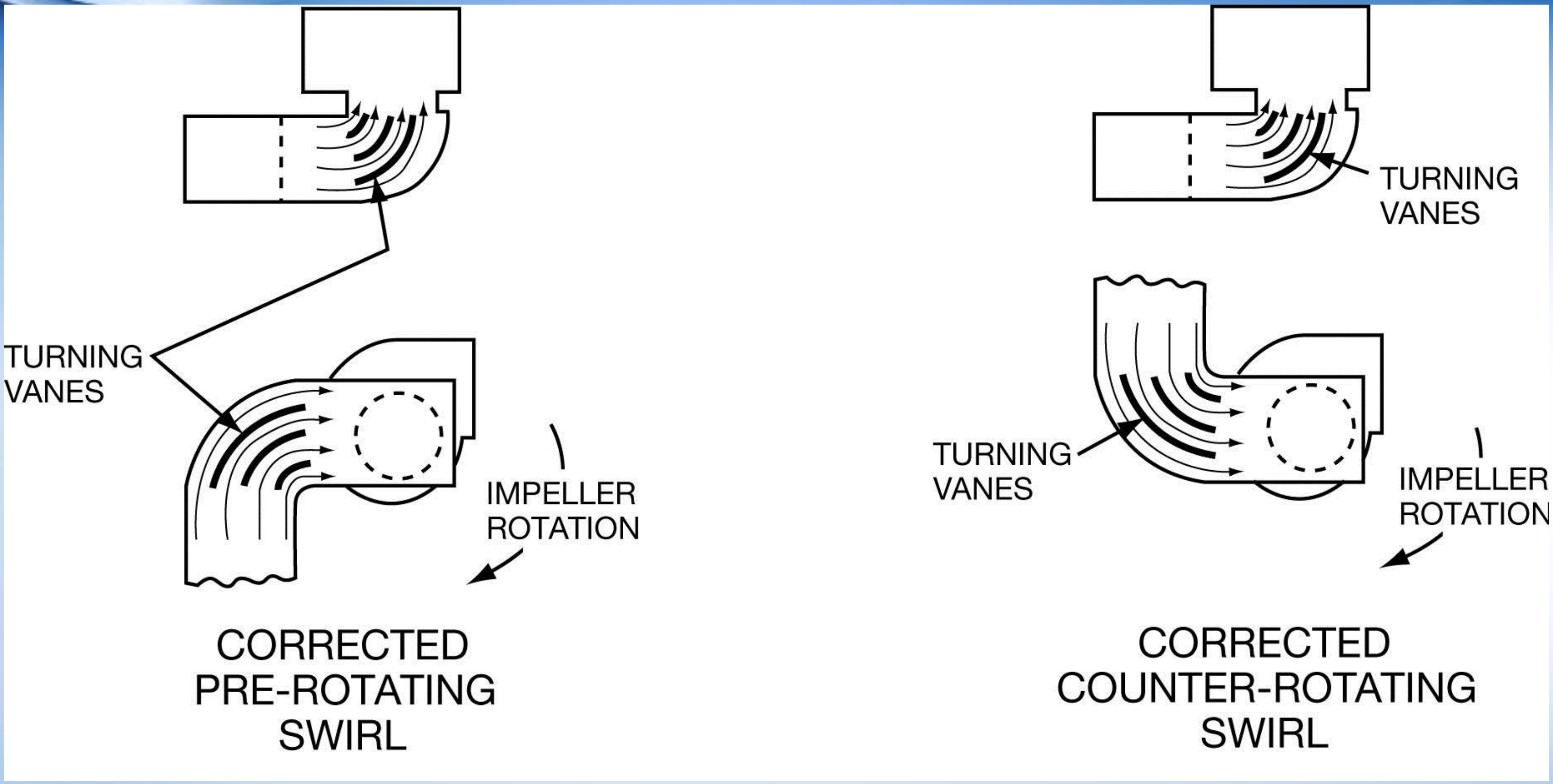


Pre-Rotating
Inlet Swirl

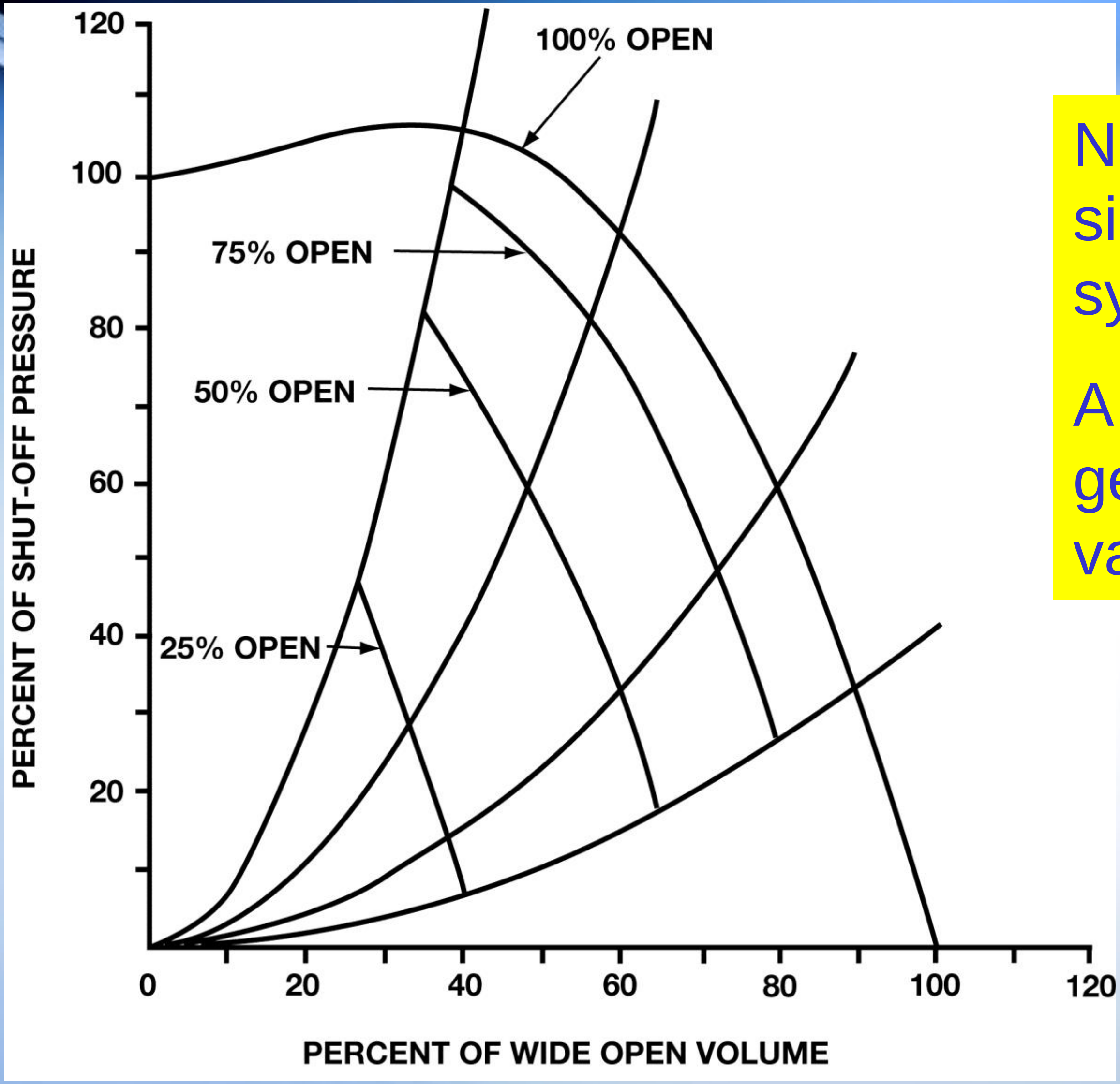


Counter-Rotating
Inlet Swirl

Corrections for Inlet Swirl



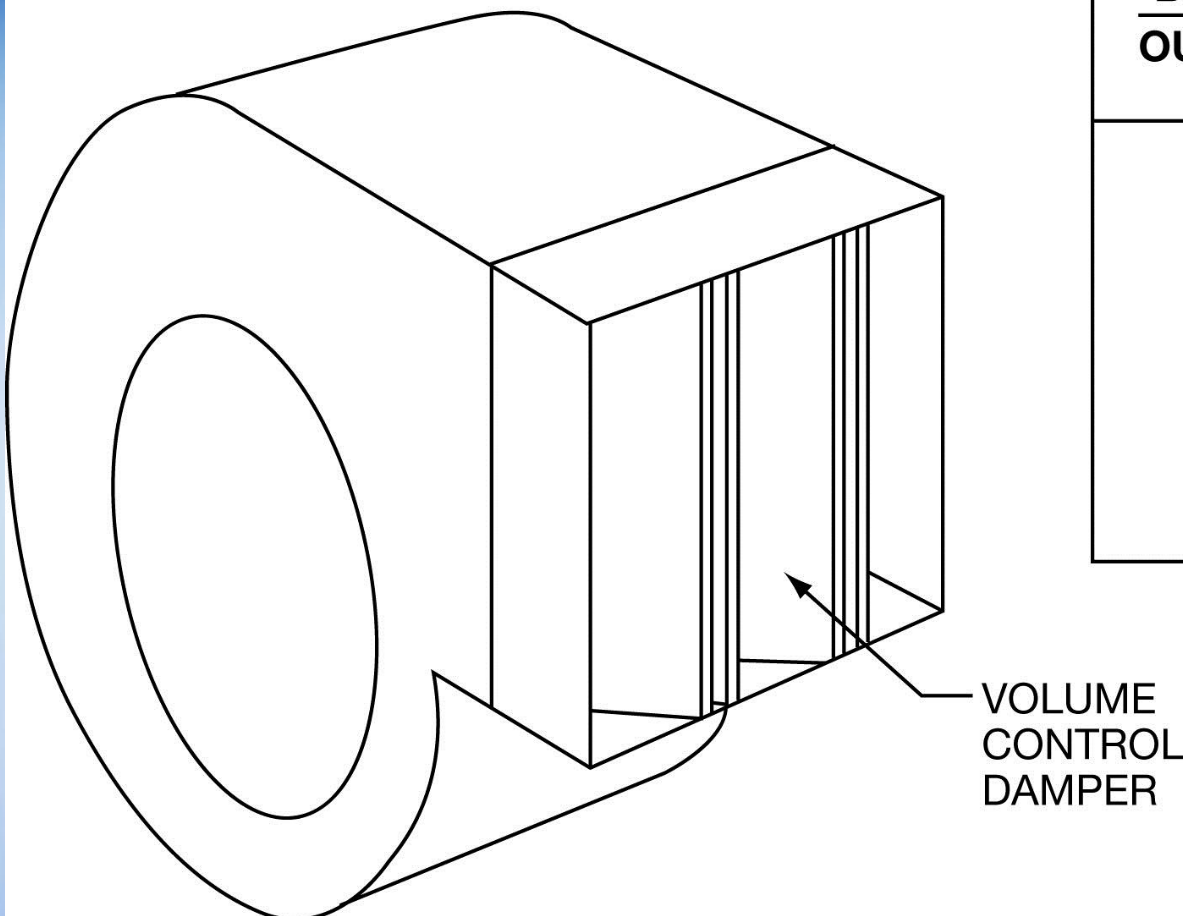
Normalized Pressure -Volume Curve



Note that this is similar to a variable system effect.

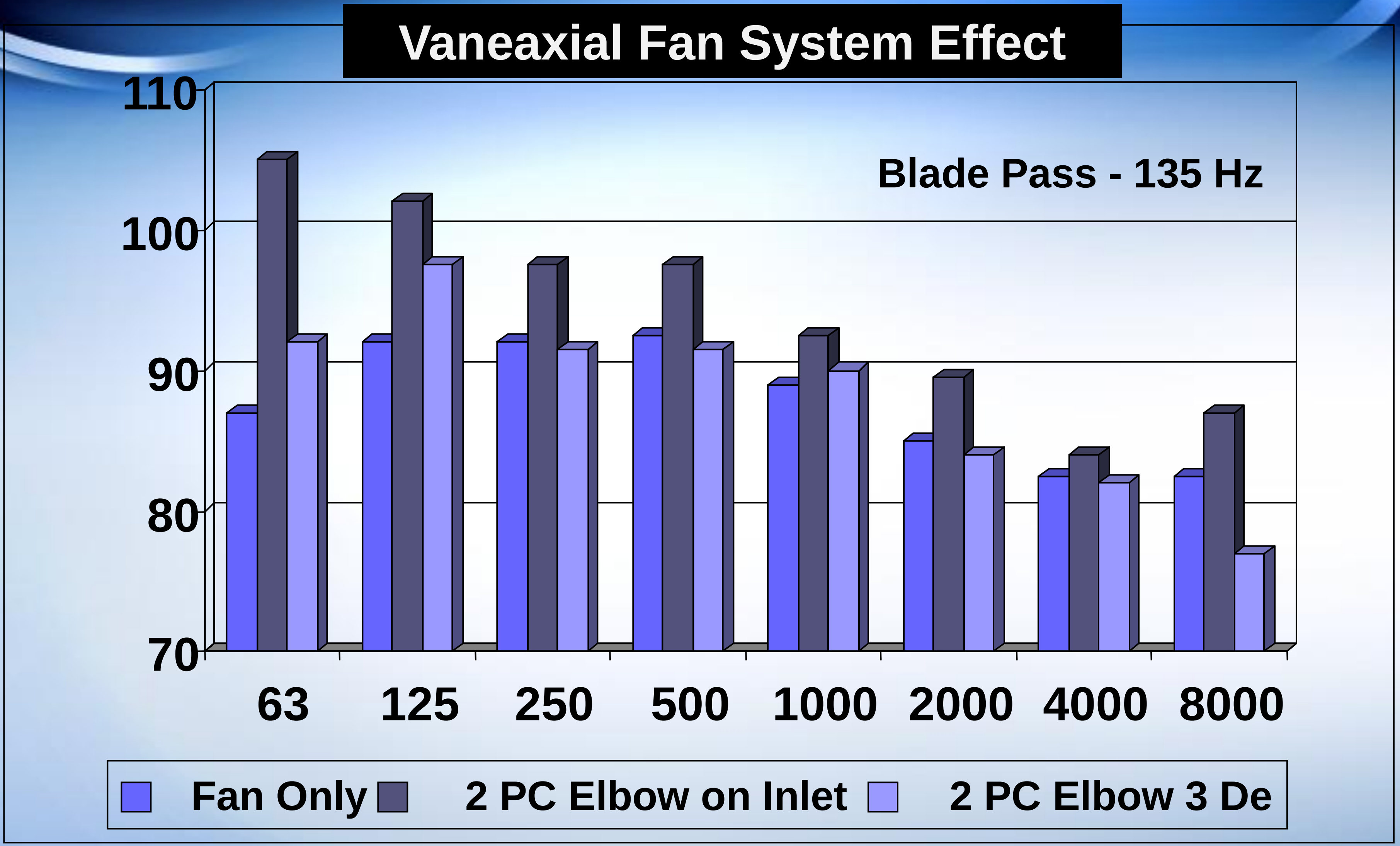
A new curve is generated at each vane setting

Pressure Drop Multipliers for Volume Control Dampers on a Fan Outlet



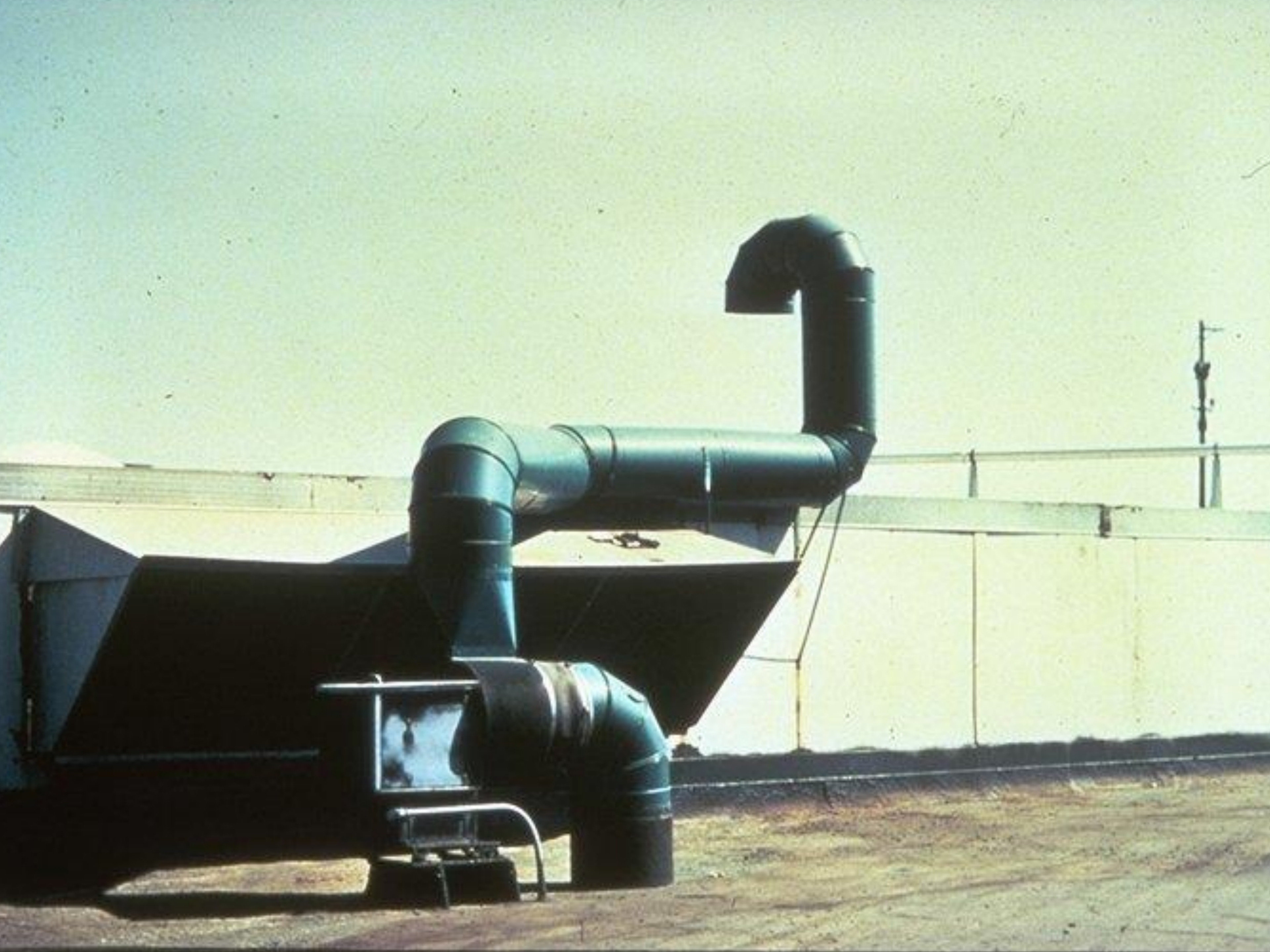
BLAST AREA / OUTLET AREA	PRESSURE DROP MULTIPLIER
0.4	7.5
0.5	4.8
0.6	3.3
0.7	2.4
0.8	1.9
0.9	1.5
1.0	1.2

Measured Inlet Sound Power

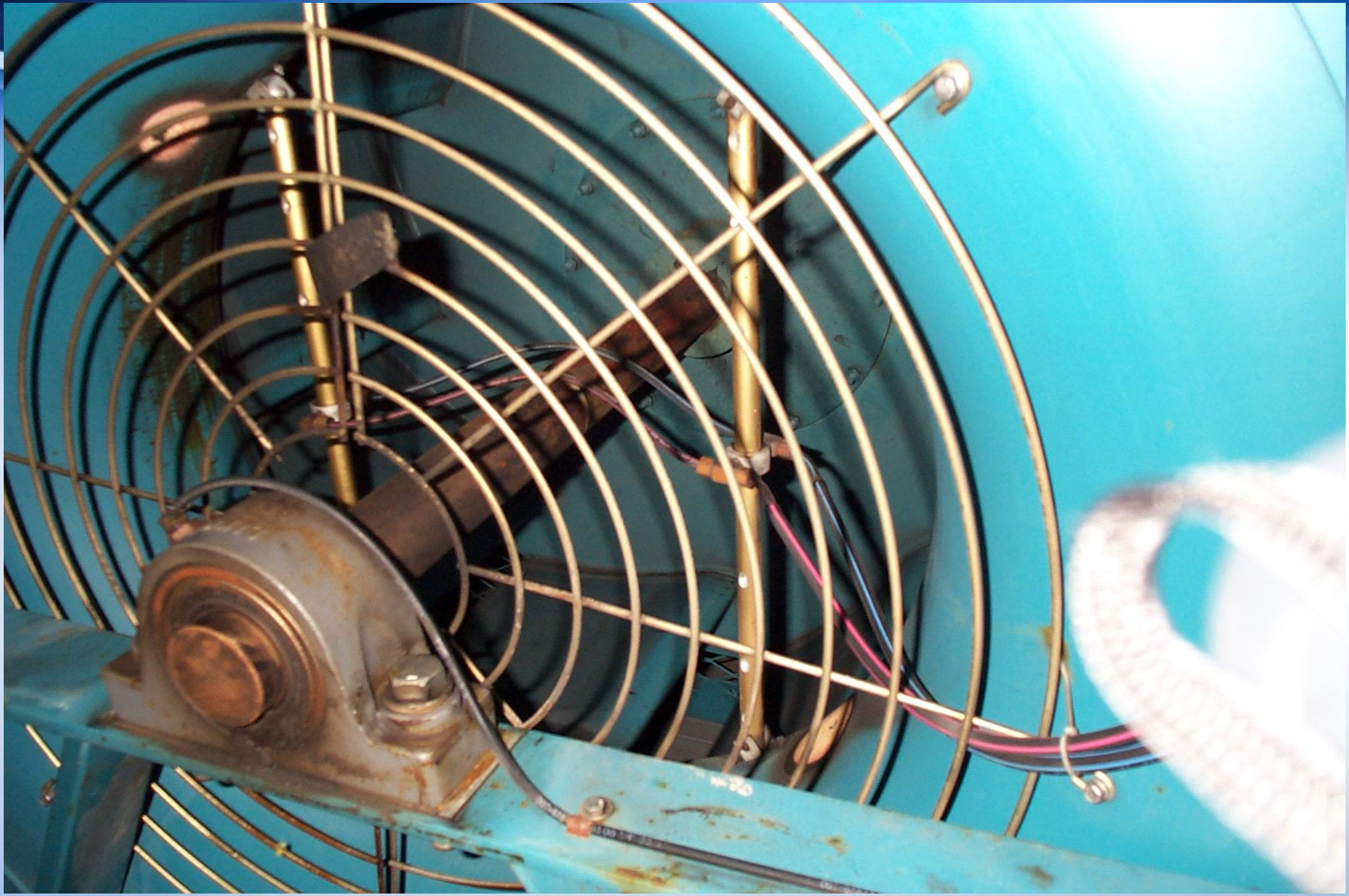


System Effect Factors are Real

- When designing your fan/system, do everything possible to avoid a “system effect” for efficient use of energy
- When conditions leading to system effect cannot be avoided, add the calculated loss to the fan pressure requirement at the system design stage



Flow Tube Example



Reference Materials

- AMCA Publication 201:2002, Fans and Systems
- Twin City Fan ED-100, Fan Performance Troubleshooting Guide