System Effects: AMCA Pub. 201– Changing the Curve

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- Has served AMCA as a lab technician, quality manager and lab manager
- Responsible for outreach, business development and education, specification review and the AMCA Speakers Network

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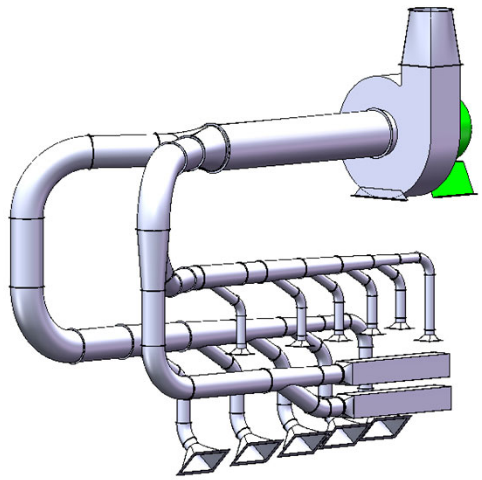

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The AMCA Mission:

To advance the knowledge of air systems and uphold industry integrity on behalf of AMCA members worldwide.

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William Howarth

Consultant, Ventilation & Fan Consulting Service International

- Independent Consultant since 2017
- 30-yrs Fan Engineering & Sales at Illinois Blower and Hartzell Fan
- Instructor NC Industrial Ventilation Conference
- Member US delegation for ISO Technical Committee 117 Fans
- ASHRAE Member

System Effects: AMCA Pub. 201– Changing the Curve

Purpose and Learning Objectives

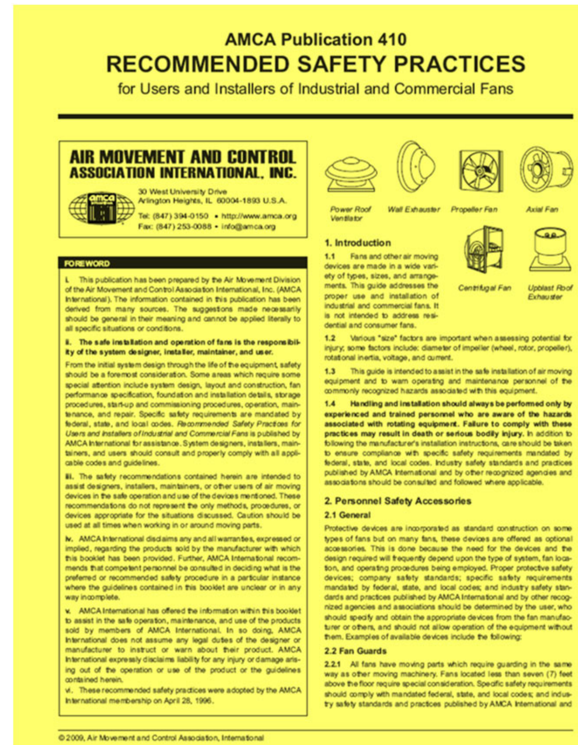
The purpose of this presentation is to inform industry professionals on AMCA Publication 201 Fans and Systems, System Effects and their impact on fan performance. Fan selection, fan curves, and Fan Energy Index (FEI) will be introduced.

At the end of this presentation you will be able to:

1. Identify System Effects from AMCA Publication 201 and their impact on fan performance curve.
2. Calculate System Effect on fan inlet or outlet, and the System Effect impact on power consumption.
3. Identify practices for avoiding System Effects.

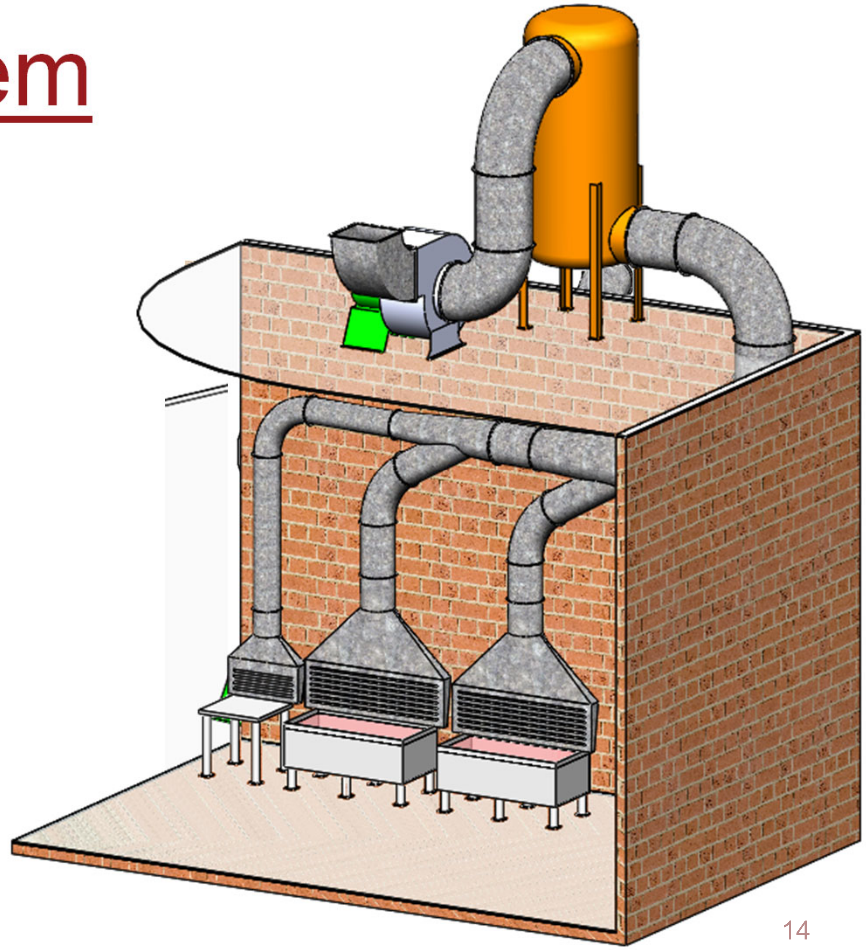
Fan Safety

- Fans contain moving parts and can be dangerous
  - Install guards
  - Know the “Hidden Dangers”
    - Suction and Pressure
    - Windmilling
    - Temperature
    - Noise and Environment
    - Stroboscopic Effect
    - Special Purpose Fans and Systems
  - Have a “lock out” procedure
- AMCA Publication 410, "Recommended Safety Practices For Users and Installers of Industrial and Commercial Fans" is an excellent resource.


AMCA Publication 410
RECOMMENDED SAFETY PRACTICES
for Users and Installers of Industrial and Commercial Fans
AIR MOVEMENT AND CONTROL ASSOCIATION INTERNATIONAL, INC.

Basic Air Moving System

- Pollution Control System
  - Worktable with Slotted Hood
  - Dip Tank with Slotted Hood (two)
  - Air Wash Scrubber
  - Centrifugal Fan
  - Associated Ductwork
- Duty point:
  - 15,000 CFM
  - 6.0 In H_20 Total Pressure
  - 0.075 lb/ft^3 air density, 70°f.
- System Effects neglected
- Not shown replacement air system

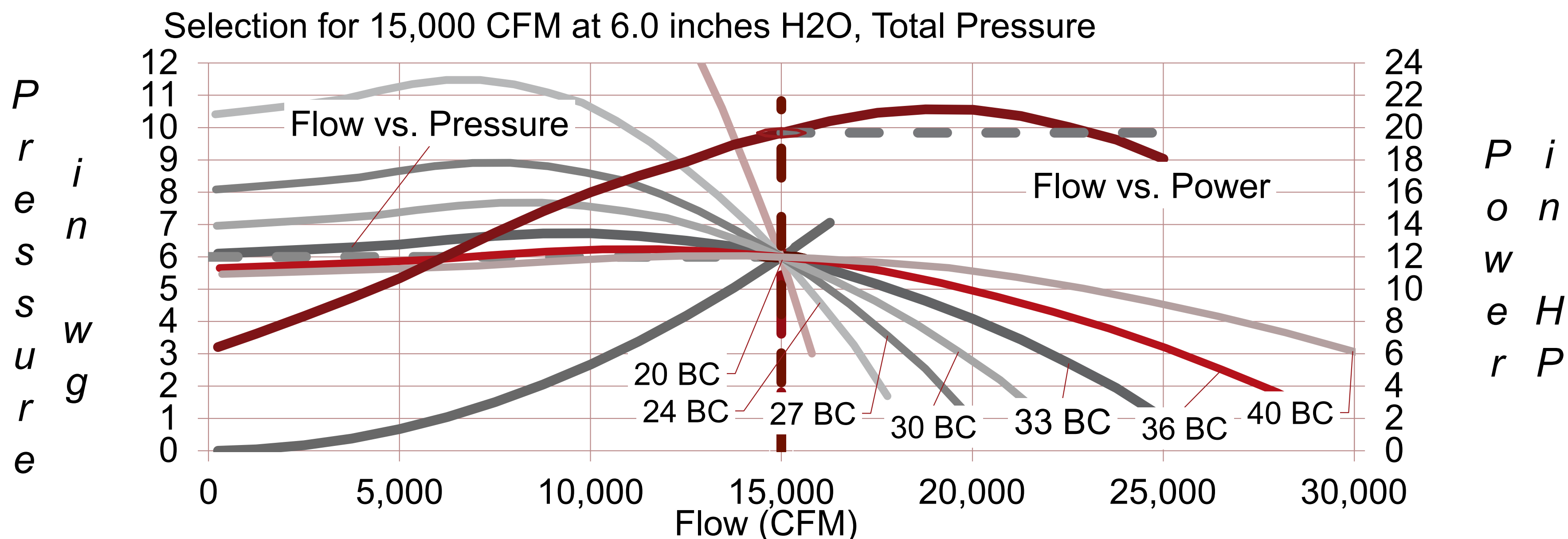


Fan Selection Choices

- **Manufacturers provide software to select fans**
- **Duty point of 15,000 CFM at 6.0 in H_20 at 0.075 lb/ft^3 at 70° f.**
- **Many fans will hit the duty point**
- **Other models will also hit the duty point**
- **Size, duty point on the curve, efficiency, velocity, RPM, noise all will impact choice**

Size	RPM	BHP	Out. Vel.	TE	SE
20 BC	3,602	46.3	6,472	31%	17%
24 BC	2,148	28.5	4,313	50%	40%
27 BC	1,686	25.0	3,423	57%	50%
30 BC	1,434	23.4	2,876	61%	55%
33 BC	1,205	19.7	2,377	72%	68%
36 BC	1,049	19.7	1,943	72%	69%
40 BC	935	20.9	1,598	68%	66%

Fan Selection Choices

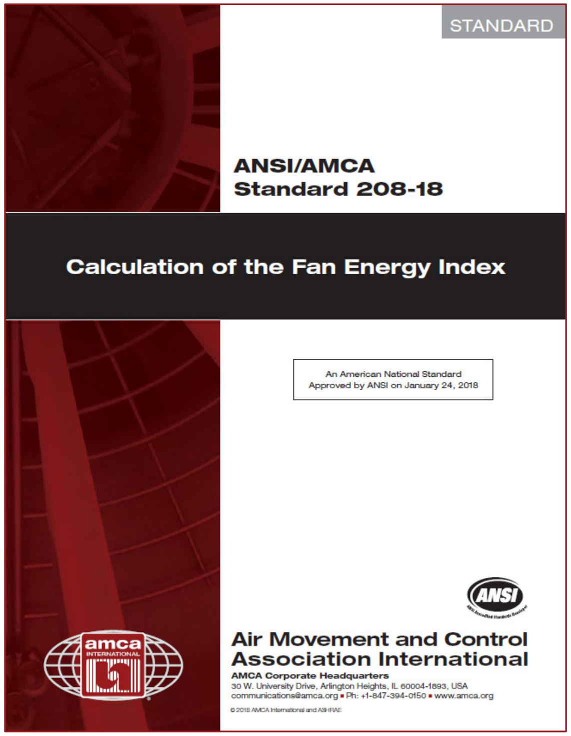


Notes: Performance certified for installation Type D: ducted inlet/ducted outlet. Power ratings (BHP) do not include transmission losses. Performance ratings do not include the effects of appurtencaces (accessories).

- Many fans sizes and types will provide the correct flow and pressure.
- Fan Energy Index (FEI) is new metric to help make more efficient selections.

FEI – Fan Energy Index – AMCA 208

- **Introduction to FEI**
  - FEI is a relative measure of power required for a given duty point – relative to the Reference Fan
- **Benefits of FEI**
  - Reflects energy consumption
  - Establishes compliant range of operation
  - Provides comparison tool for fan selection
- **FEI Reference Fan calculation**
  - Reference fan is 60% Static Efficiency, or 66% Total Efficiency based on application.
  - Motor Loss based on “Fan Power & Belts” Standardized IE3 level for a four-pole 60 Hz motor
  - Small additional flow, 250 cfm, and pressure, 0.40 in. wg, added to reference fan



Fan Energy Index Primer

- Higher FEI is desirable
  - Identifies more efficient fan & drives for actual operating point.
- FEI seeks to improve fan sizing and selection.
- Enables comparisons of:
  - Different fan types
  - Different fan sizes
  - Different motor and drive combinations
- Given a statutory or design requirement and duty point, FEI defines “compliant ranges of operation”.

Comparison of Fan Sizes

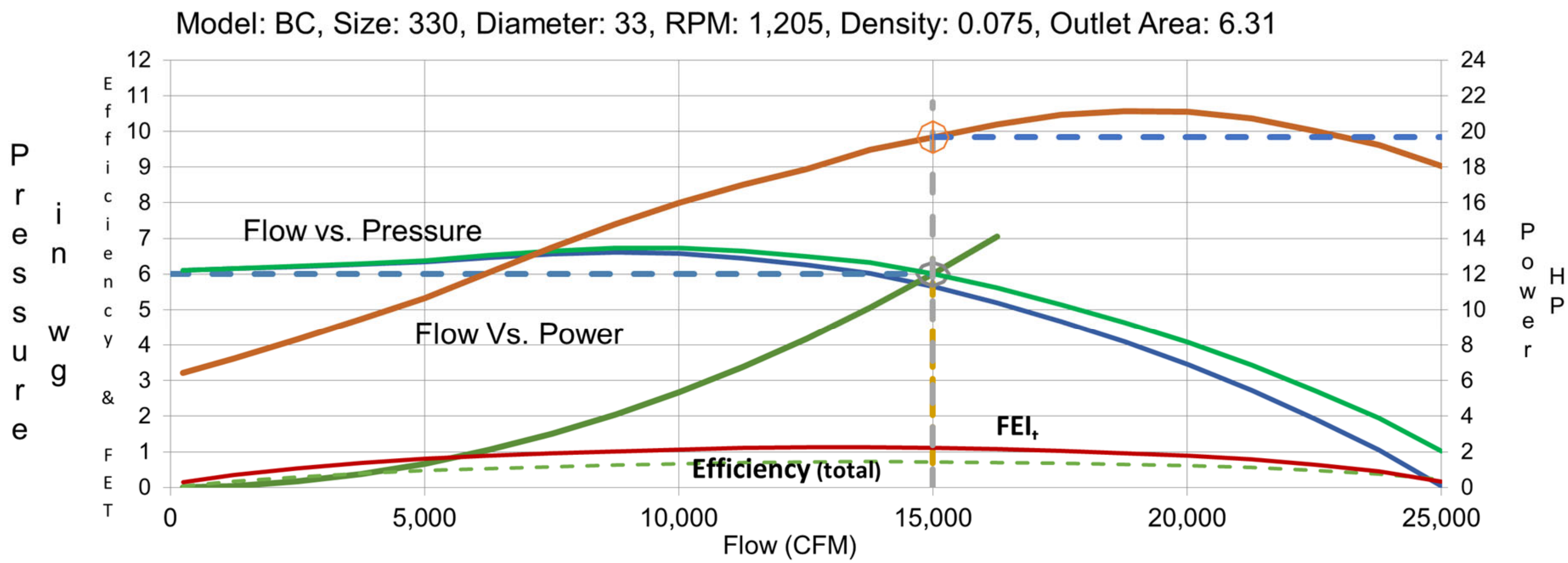
- Duty Point, i 15,000 cfm at 6.0” P_t (FEP in kW)

Size	RPM	BHP	Out. Vel.	TE	$FEP_{ref,i}$	$FEP_{act,i}$	$FEI_{t,i}$
20 BC	3,602	46.3	6,473	31%	19.45	36.05	0.54
24 BC	2,148	28.5	4,313	50%	19.45	22.23	0.87
27 BC	1,686	25.0	3,423	57%	19.45	19.51	1.00
30 BC	1,434	23.4	2,876	61%	19.45	18.27	1.06
33 BC	1,205	19.7	2,377	72%	19.45	15.36	1.27
36 BC	1,049	19.7	1,943	72%	19.45	15.41	1.26
40 BC	935	20.9	1,598	68%	19.45	16.29	1.19

Compliant

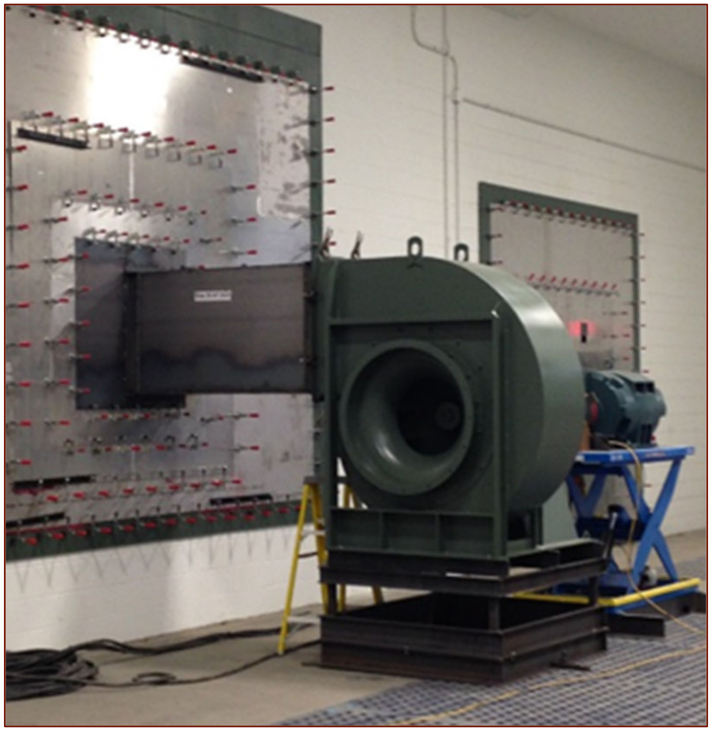
Best

The Fan Curve



Performance certified for installation Type D: ducted inlet/ducted outlet. Power ratings (BHP) do not include transmission losses. Performance ratings do not include the effects of appurtencaces (accessories). FEI_T values are calculated in accordance with ANSI/AMCA Standard 208 and are based on default motor efficiencies. FEI_T values for fans with specific motors will vary slightly from those shown.

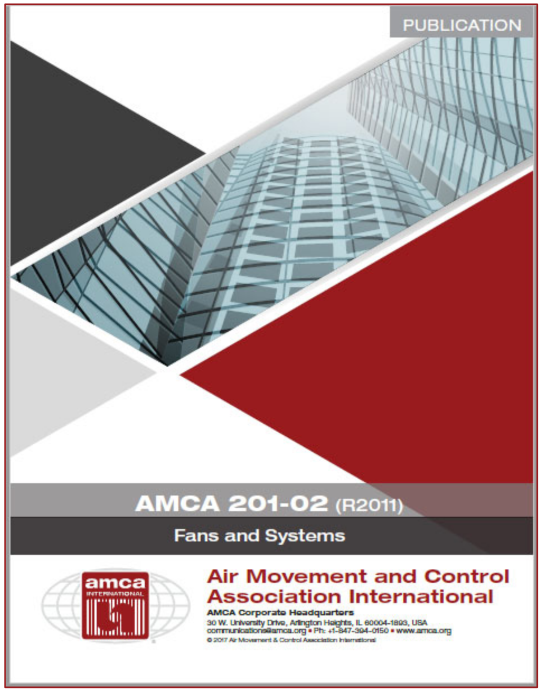
Test Arrangement Different



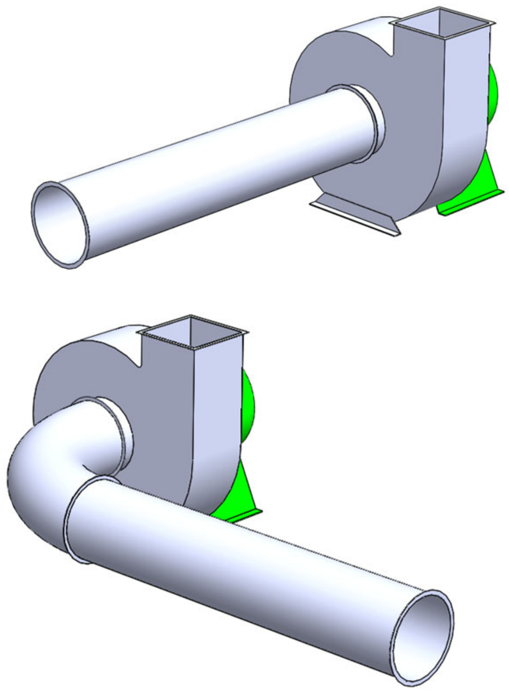
- Fans are tested in test laboratory
- ANSI/AMCA 210 Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating
- Ideal conditions give the fans the best performance.

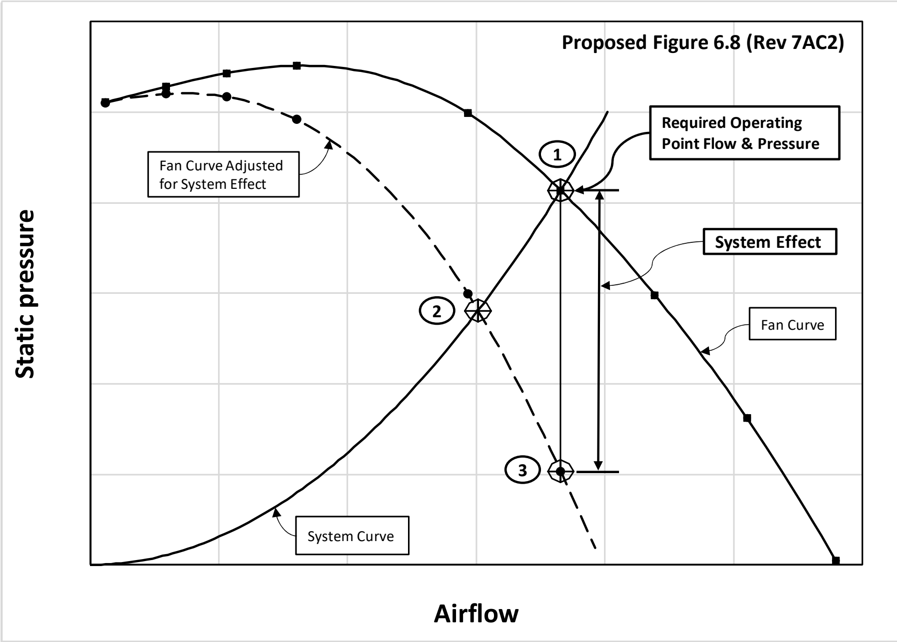
System Effect Definition

- **System Effect**: The effect on the performance of the fan resulting from the difference between the fan inlet and outlet connections to the installed system and the standardized connections used in laboratory tests to obtain fan performance ratings. *(AMCA Publication 200-95 (R2011))*
- **System Effect Factor**: A decrease in fan performance capability, observed as a pressure loss that results from the effect of fan inlet restrictions / obstructions, fan outlet restrictions or other conditions influencing the performance of the fan when it is installed in a system. *(ANSI/AMCA Standard 99-16)*

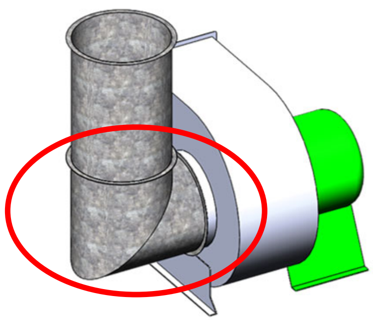


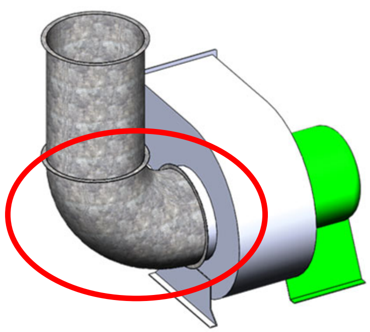
Example of Inlet System Effect

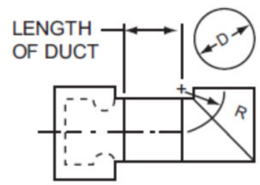




Determination of Inlet System Effect







SYSTEM EFFECT CURVES

R/D	NO DUCT	2D DUCT	5D DUCT
—	N	P	R-S

Figure 9.4A - Two Piece Mitered 90° Round Section Elbow - Not Vaned

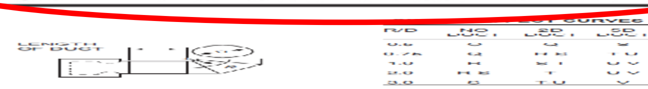
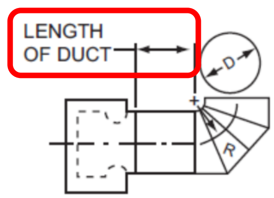


Figure 9.4B - Three Piece Mitered 90° Round Section Elbow - Not Vaned



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-W

Figure 9.4C - Four or More Piece Mitered 90° Round Section Elbow - Not Vaned

Calculation of Inlet System Effect

- System Effect is velocity related and is calculated for the flow velocity of the fan inlet or outlet.

$$SE = C\left(\frac{V}{1.414}\right)^2 \rho$$

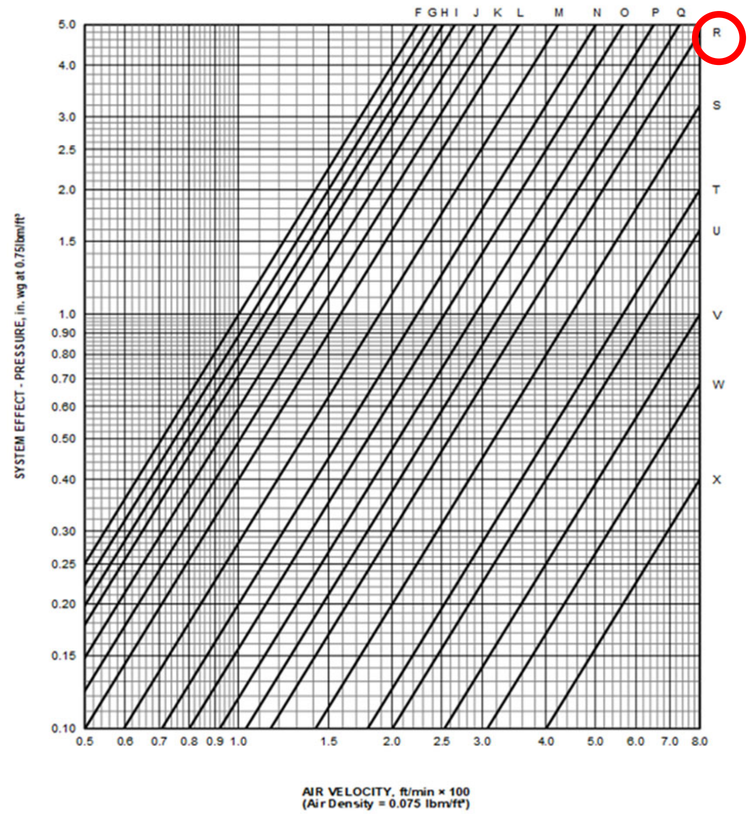
SI

$$SE = C\left(\frac{V}{1097}\right)^2 \rho$$

I-P

Table 7.1 - System Effect Coefficients

Curve in Figure 7.1	Dynamic Pressure Loss Coefficient C
F	16.00
G	14.20
H	12.70
I	11.40
J	9.50
K	7.90
L	6.40
M	4.50
N	3.20
O	2.50
P	1.90
Q	1.50
R	1.20
S	0.80
T	0.50
U	0.40
V	0.25
W	0.17
X	0.10

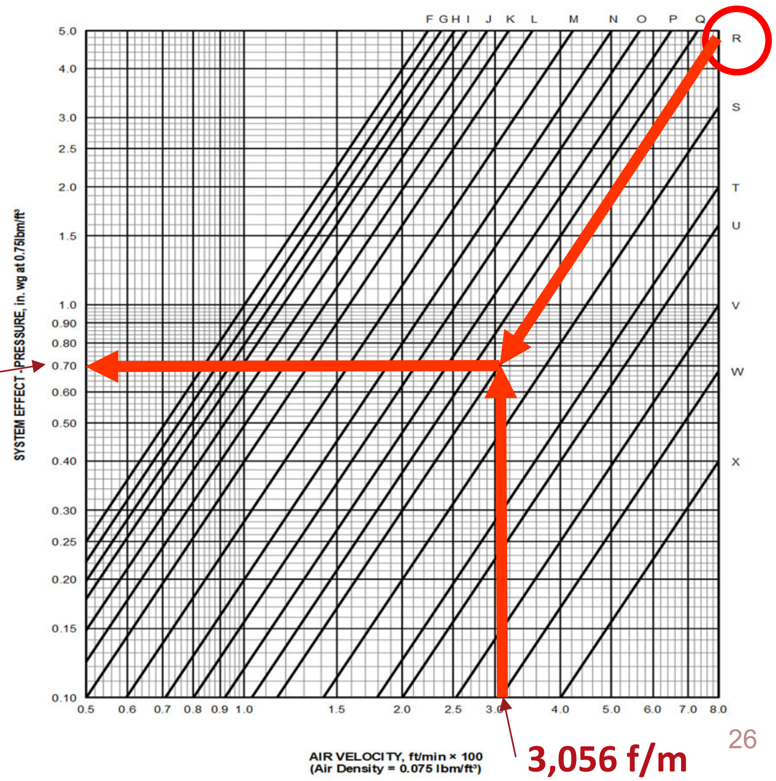


Calculation of Inlet System Effect

- For a fan flow of 15,000 CFM in a 30-inch diameter fan inlet at standard density of 0.075 lbm/ft^3.
- Fan Inlet Area is 4.91 ft^2.
- Fan Inlet Velocity is 3,056 f/m.
- Using curve R on figure 7.1 (I-P) we find the intersection at 3,056 f/m.
- We read horizontally to the left to a system effect of 0.70 inches H_2O at standard density of 0.075 lbm/ft^3.

Using line R from Figure 7.1

SE=0.70 in. H_2O



Calculation of Inlet System Effect

- For a fan flow of 15,000 CFM in a 30-inch diameter fan inlet at standard density of 0.075 lbm/ft^3
- Fan Inlet Area is 4.91 ft^2
- Fan Inlet Velocity is 3,056 f/m is V
- Using R Dynamic Pressure Loss Coefficient 1.20 from table 7.1 is C. ρ = 0.075
- We calculate a system effect of 0.70 inches H_2O at standard density of 0.075 lbm/ft^3 and 3,056 f/m velocity

Using System Effect Coefficients and table 7.1 formula

$$SE = C\left(\frac{V}{1097}\right)^2 \rho$$

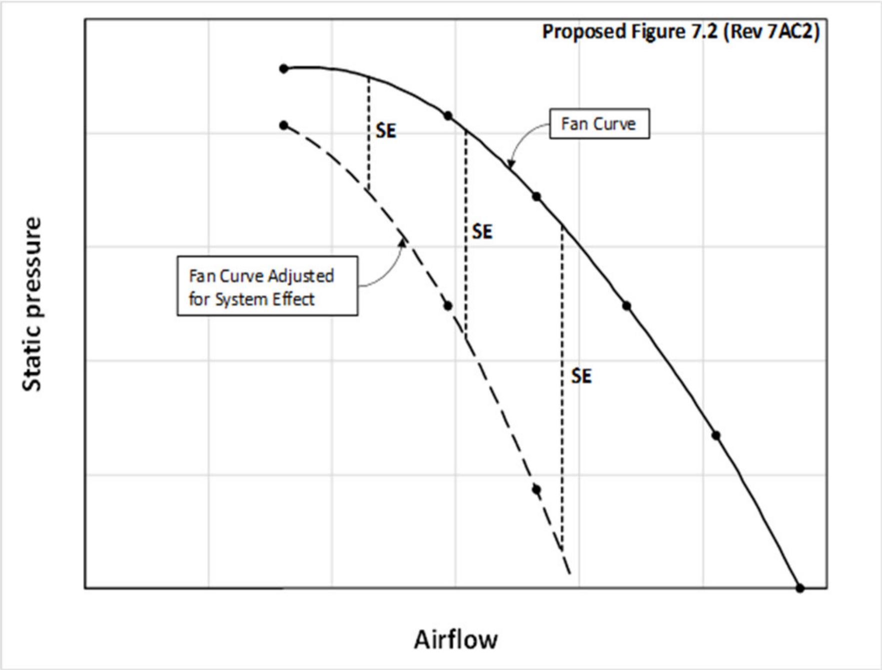
$$SE = 1.20\left(\frac{3056}{1097}\right)^2 0.075$$

$$SE = 0.70$$

Calculation of System Effect on Curve

- System Effect is velocity related and is calculated for the velocity of the fan inlet or outlet.
- Calculations have been for flow point.
- The System Effect can be calculated for each point of the fan curve and new curve created.

$$SE = C\left(\frac{V}{1097}\right)^2 \rho$$



Few non-manufacturers will generate curves

System Effect is Changing the Curve

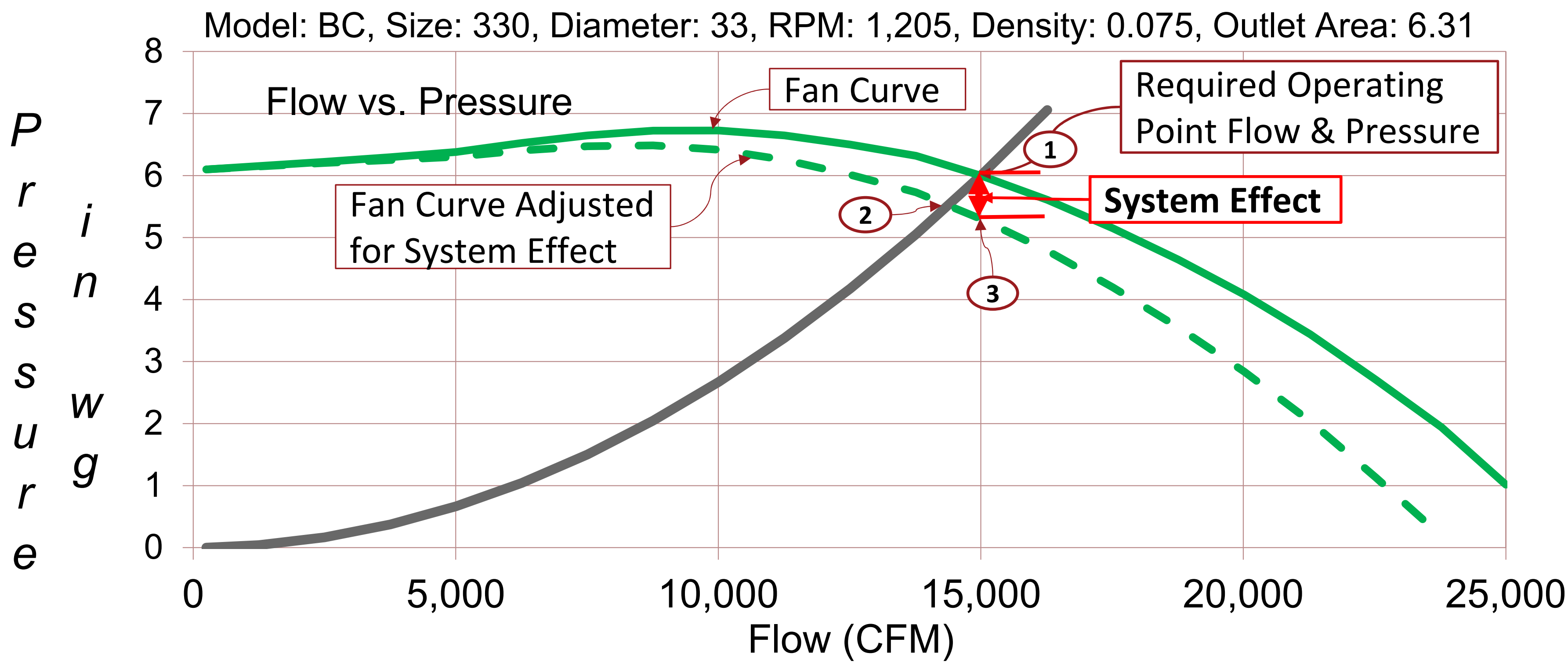
- The formula for calculating the loss at the duty point can be applied to each flow point on the fan curve.
- A pressure loss is calculated for each flow point

$$SE = C\left(\frac{V}{1097}\right)^2 \rho$$

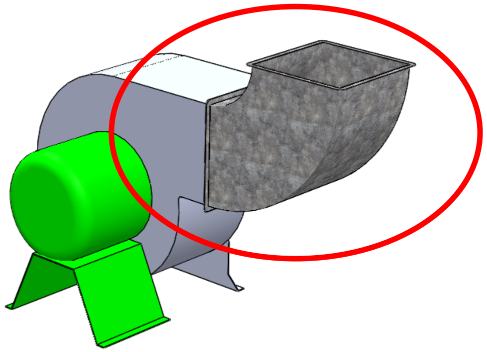
$$SE = 1.20\left(\frac{CFM/Area}{1097}\right)^2 0.075$$

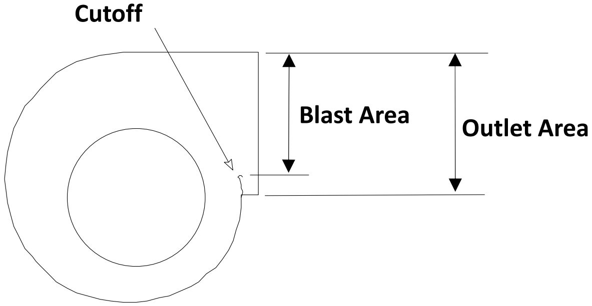
CFM	Total Pressure	Velocity	SE Loss	Adjusted Total Pressure
251	6.10	51	0.00	6.10
1,252	6.15	255	0.00	6.15
2,502	6.22	510	0.02	6.20
3,754	6.30	765	0.04	6.25
5,006	6.38	1,020	0.08	6.30
6,257	6.53	1,275	0.12	6.40
7,508	6.65	1,530	0.17	6.47
8,760	6.72	1,784	0.24	6.49
10,011	6.73	2,039	0.31	6.42
11,262	6.65	2,294	0.39	6.25
12,514	6.50	2,549	0.49	6.01
13,765	6.32	2,804	0.59	5.73
15,016	6.00	3,059	0.70	5.30
16,268	5.61	3,314	0.82	4.79
17,519	5.15	3,569	0.95	4.19
18,770	4.64	3,824	1.09	3.55
20,021	4.08	4,079	1.24	2.83
21,273	3.44	4,334	1.40	2.04
22,524	2.71	4,589	1.57	1.13
23,775	1.94	4,843	1.75	0.19

Inlet System Effect - Changing the Curve



Fan Outlet Example





- Centrifugal Fan
  - Elbow directly on outlet
  - High turbulence
  - Flow profile not developing
- Airflow Rate
  - 15,000 CFM
- Blast Area/Outlet Area Ratio
  - 0.8 (from Manufacturer)
- Outlet Velocity
  - 2,377 f/m

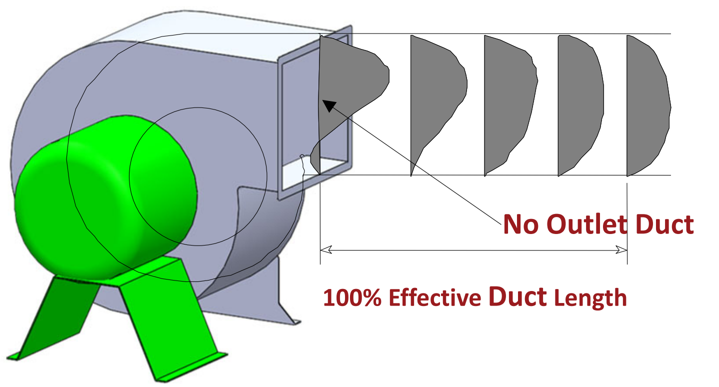
Outlet Duct Avoids System Effect

- Outlet duct allows velocity pressure recovery in outlet flow profile
- Effective Duct length based on outlet velocity in feet/minute
  - 2½ duct diameters for velocity <2,500
  - 1 additional diameter for each additional 1,000 f/m
- In our example selection 6.31 ft^2 outlet is equivalent to 30.14” duct diameter and 100% effective duct length would be 75.5 inches long
- Blast Area/Outlet Area ratio required to calculate (0.8 in this example from Manufacturer)

	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	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	—	—	—	—	—

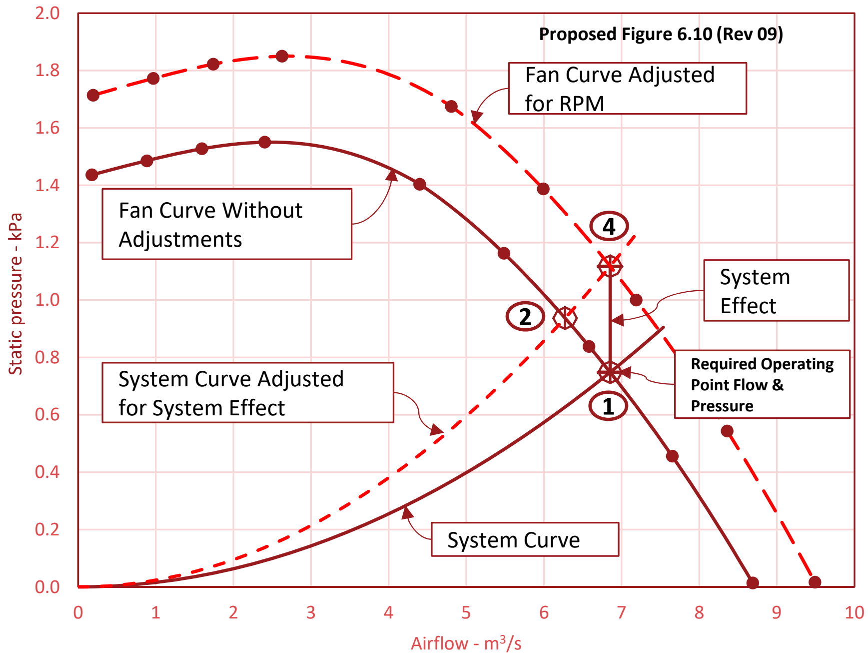
Determine *SEF* by using Figure 7.1

Figure 8.3 - System Effect Curves for Outlet Ducts - Centrifugal Fans



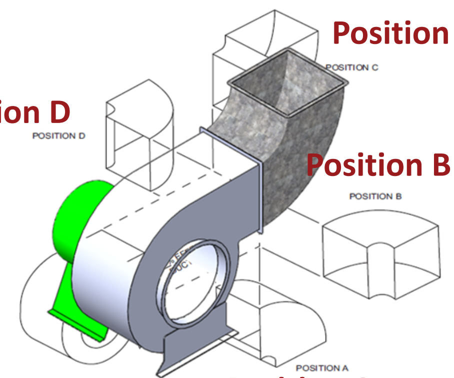
Outlet System Effect Due to Elbow

- Elbow on discharge acts as a restriction
- Additional pressure loss for system effect is added to the duty point
- Fan must be reselected, possibly at higher RPM, to achieve the desired flow
- Power impact not shown here
- Different elbow positions and effective duct length have different system effect



Outlet System Effect Due to Elbow

- Blast Area/Outlet Area ratio impacts loss
- Elbow Position impacts loss
- Effective Duct Length impacts loss
  - With100% effective duct length there is no System Effect
- In this example:, Blast Ratio 0.8, Elbow C, No Outlet Duct



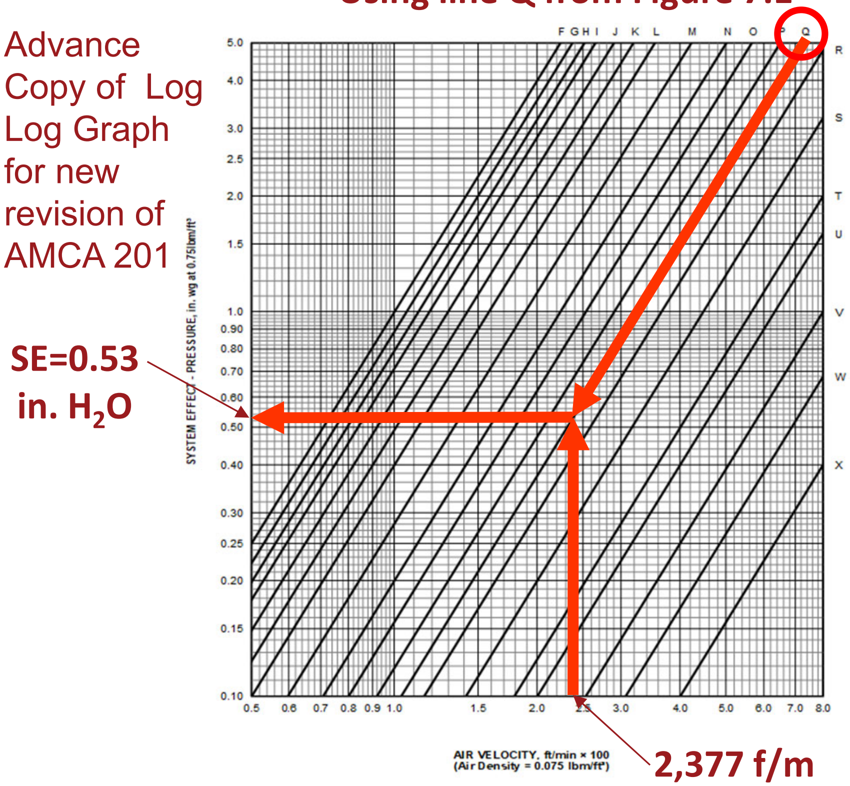
Blast Area / *Outlet Area*	Outlet Elbow Position	No Outlet Duct	12% Effective Duct	25% Effective Duct	50% Effective Duct	100% Effective Duct
0.4	A B C D	N M-N L-M L-M	O N M M	P-Q O-P N N	S R-S Q Q	
0.5	A B C D	O-P N-O M-N M-N	P-Q O-P N N	R Q O-P O-P	T S-T R-S R-S	
0.6	A B C D	Q P N-O N-O	Q-R Q O O	S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

AMCA 201 Figure 8.5 - Outlet Elbows on SWSI Centrifugal Fans

Calculation of Outlet System Effect

Using line Q from Figure 7.1

Advance Copy of Log Log Graph for new revision of AMCA 201



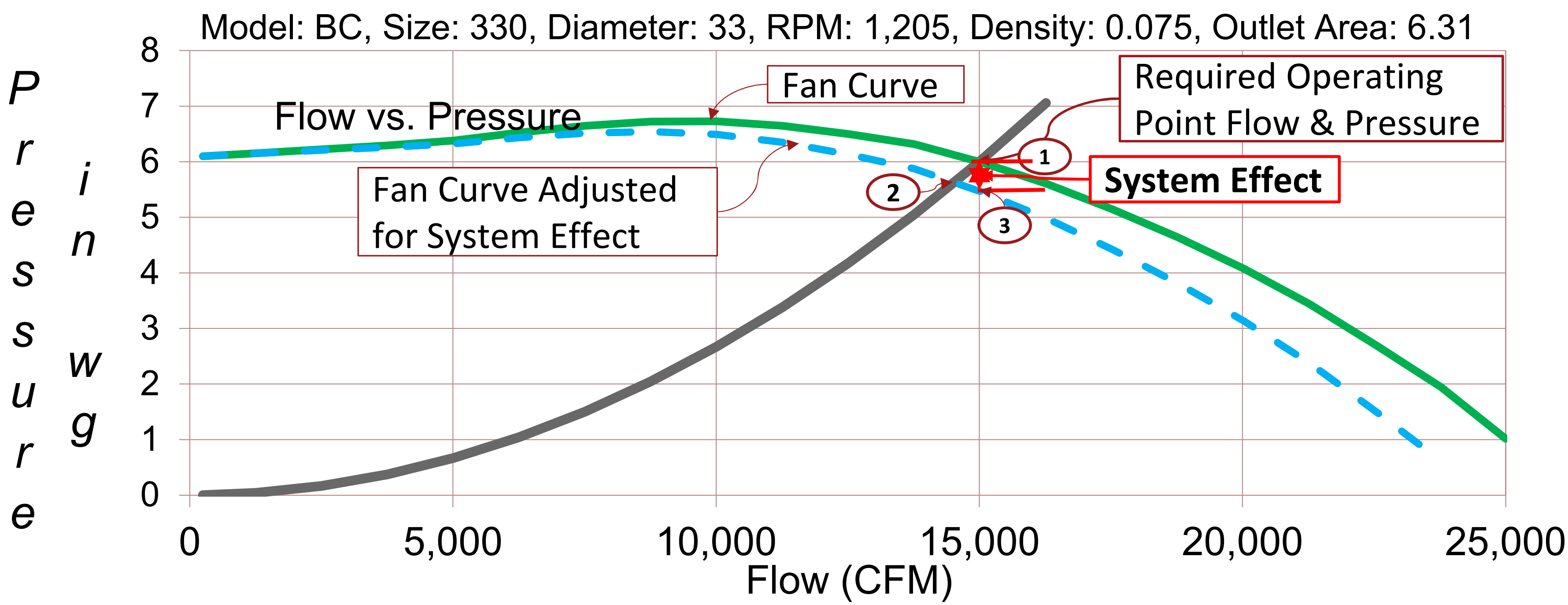
Using System Effect Coefficients and table 7.1 formula

$$SE = C\left(\frac{V}{1097}\right)^2 \rho$$

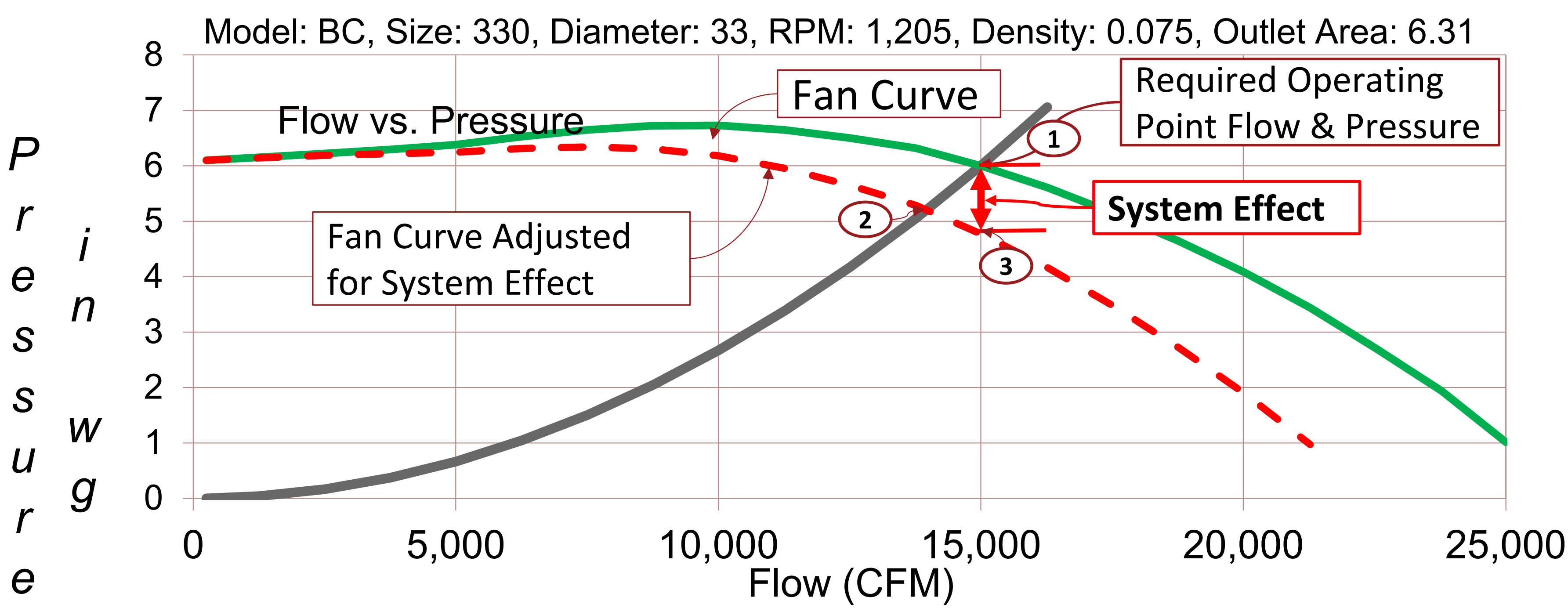
$$SE = 1.50\left(\frac{2377}{1097}\right)^2 0.075$$

$$SE = 0.53$$

Outlet System Effect - Changing the Curve



Combined System Effect - Changing the Curve



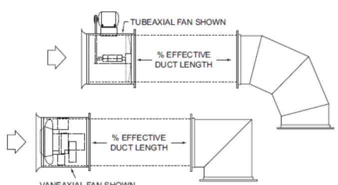
Resulting flow is 13,975 CFM at 5.21 inches H2O. A 7% deficit in flow.

System Effect Configurations in 201

- **Outlet System Effect Factors**
  - Outlet ducts
  - Outlet diffusers
  - Outlet duct elbows
  - Turning vanes
  - Volume control dampers
  - Duct branches

- **Inlet System Effect Factors**
  - Inlet ducts
  - Inlet duct elbows
  - Inlet vortex (spin or swirl)
  - Inlet turning vanes
  - Airflow straighteners
  - Enclosures (plenum and cabinet effects)
  - Obstructed inlets

- **Effects of Factory Supplied Accessories**
  - Bearing and supports in fan inlet
  - Drive guards obstructing fan inlet
  - Belt tube in axial fan inlet or outlet
  - Inlet box
  - Inlet box dampers
  - Variable inlet vane (VIV)



	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	---	---	---	---

Determine *SEF* by using Figures 7.1 and 8.1

Figure 8.4 - System Effect Curves for Outlet Duct Elbows - Axial Fans

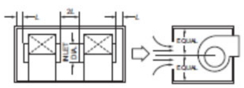


Figure 9.11A - Fans and Plenum

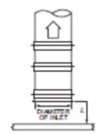


Figure 9.11B - Axial Fan Near Wall

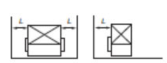


Figure 9.11C - Centrifugal Fan Near Wall(s)

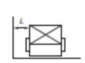


Figure 9.11D - DWDI Fan Near Wall on One Side

L - DISTANCE INLET TO WALL	For Figures 9.11A, B & C SYSTEM EFFECT CURVES	For Figures 9.11D SYSTEM EFFECT CURVES
0.75 x DIA. OF INLET	V-W	X
0.50 x DIA. OF INLET	U	V-W
0.40 x DIA. OF INLET	T	V-W
0.30 x DIA. OF INLET	S	U

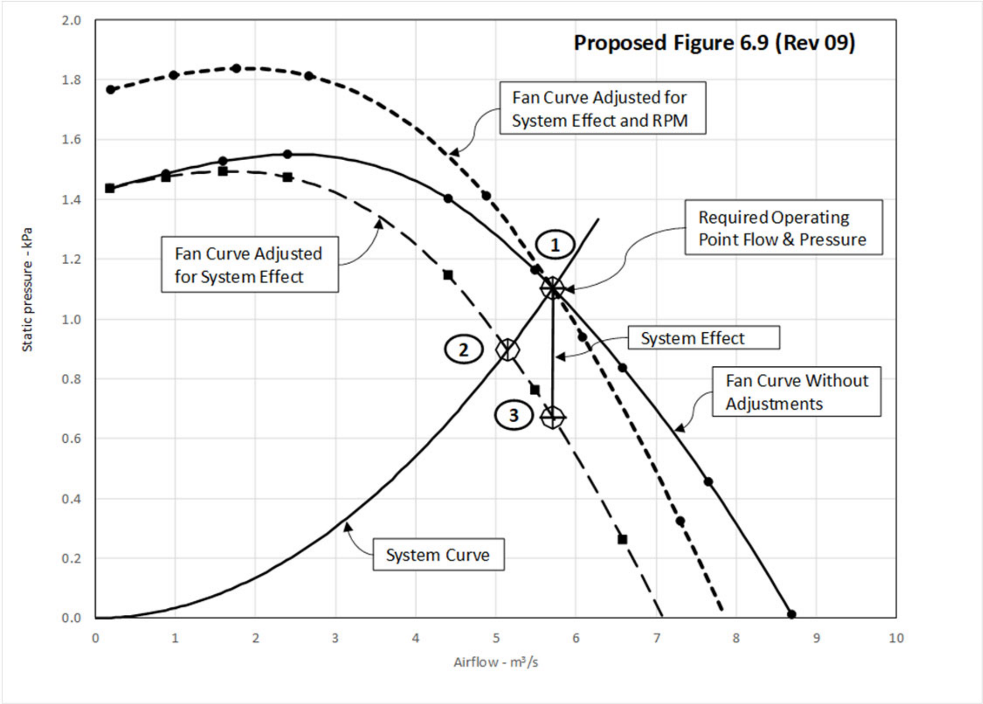
Determine SEF by calculating inlet velocity and using Figure 7.1

Required Flow is Required Flow

- To provide the required flow an adjustment will be required.
  - **The system configuration revised to eliminate the System Effects.**

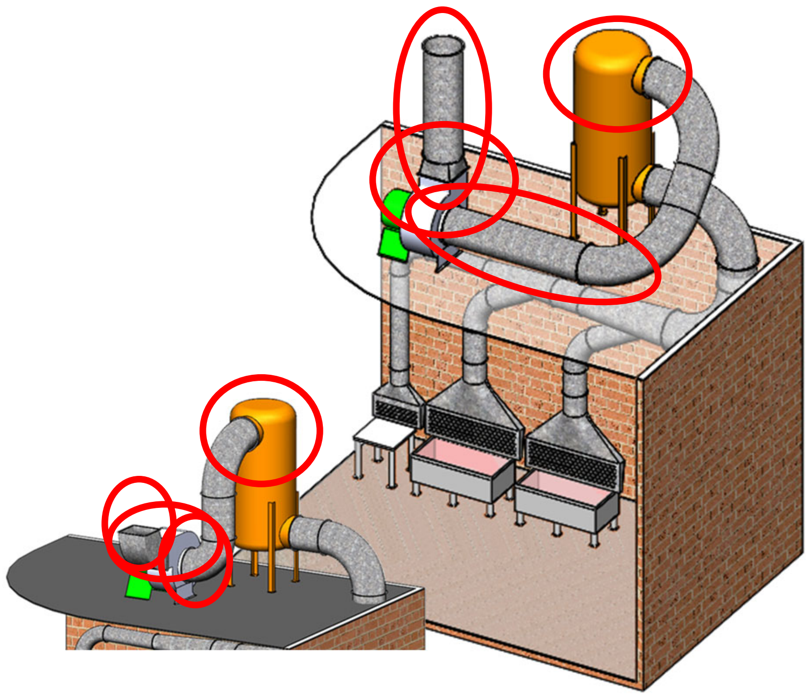
  -OR-
  - The system effect pressure must be added to the pressure requirement at the required flow.

  -OR-
  - The fan must be selected based on a curve with system effect.
- An RPM increase will require a power increase.



System Layout to Avoid System Effect

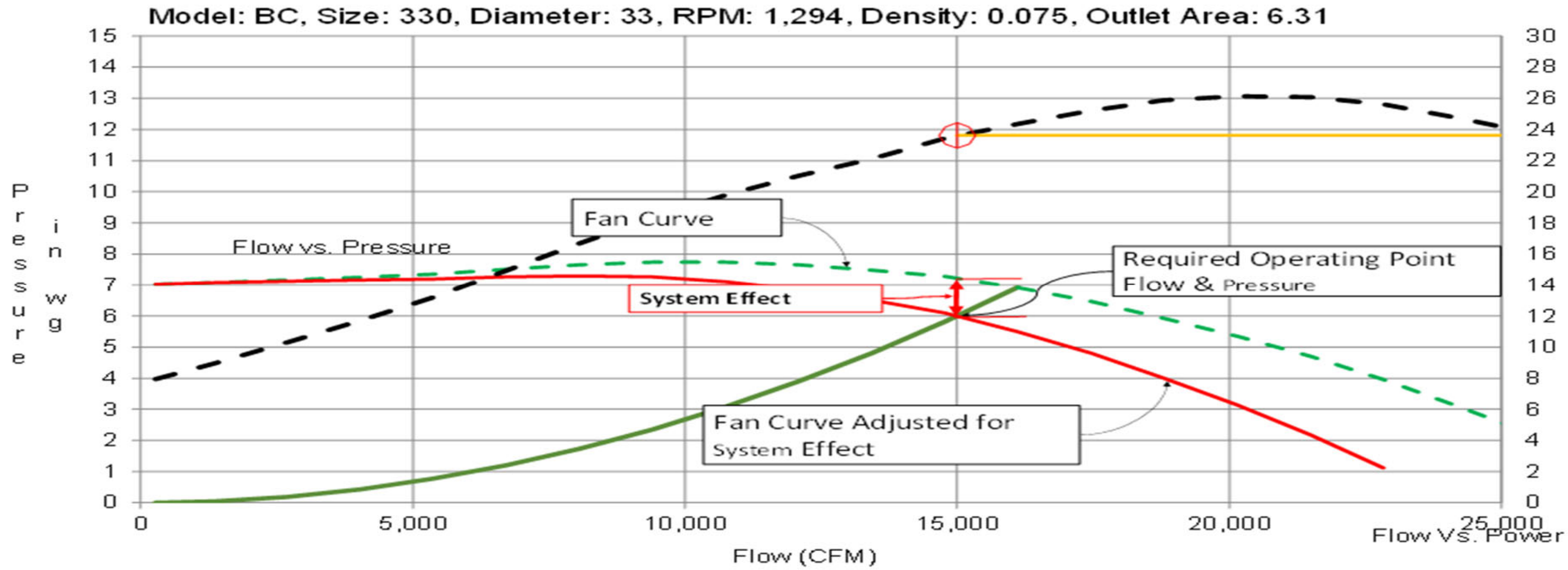
- Revisions to the system
  - Turned Air Washer discharge 90° to facilitate spacing of equipment
  - Added straight inlet duct with long radius elbow at fan inlet
  - Changed fan discharge position from top horizontal to up blast (add drain to housing)
  - Added transition and outlet duct to fan



Speed Changes

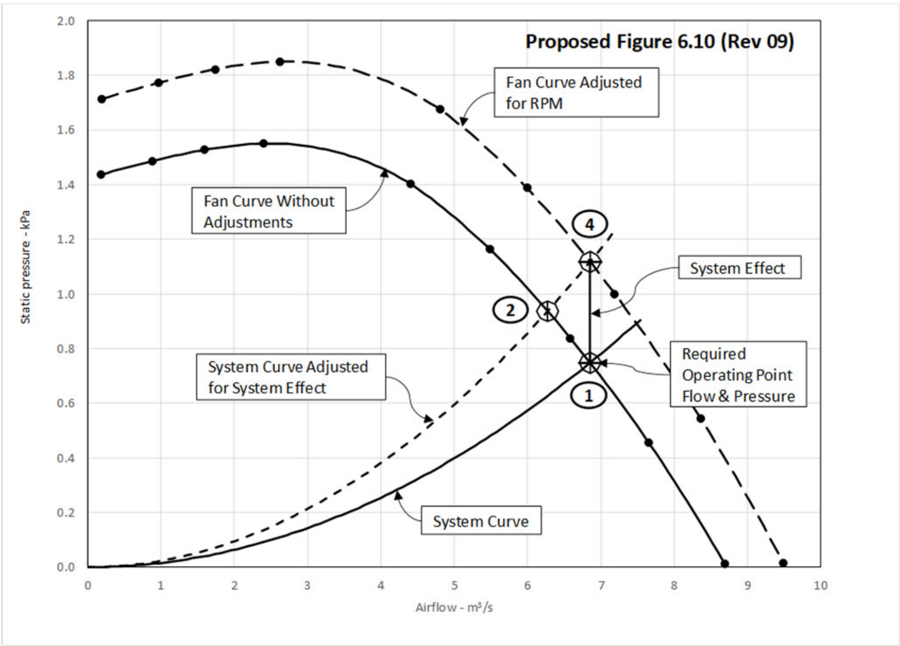
- Before Increasing Speed:
  - **Investigate measures to reduce the system effect.**
- If speed must be increased:
  - **Check with the manufacturer for max safe operating speed.**
  - Determine expected power increase
    - Motor size
    - Electric Service
  - Expect more noise
  - Expect more power required

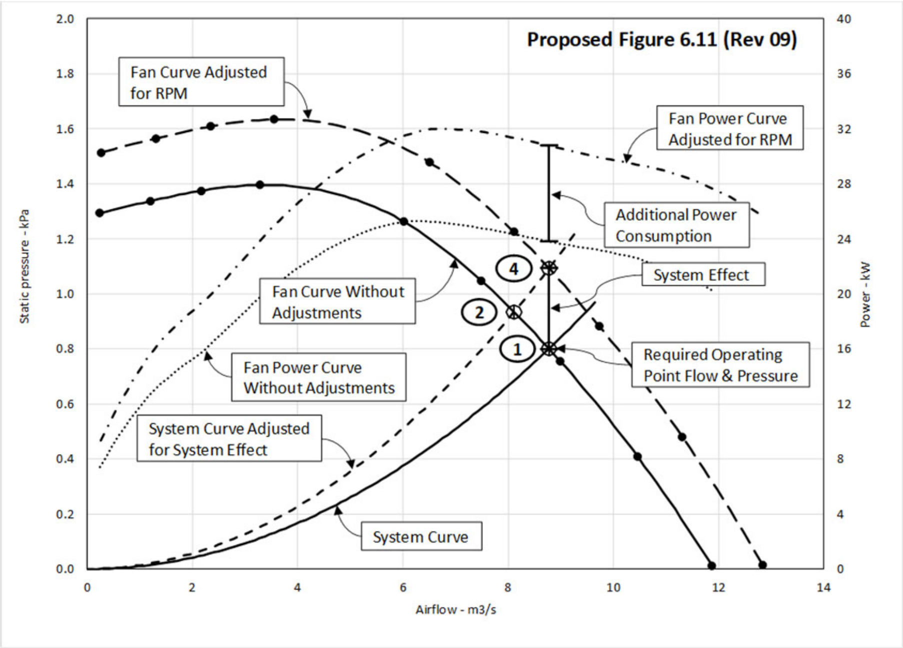
Speed Adjustment



- To overcome System Effects new selection is calculated:
  - Speed Increased from 1,205 to 1,294 RPM
  - Power increased from 19.7 to 23.6 BHP

System Effects cost Energy



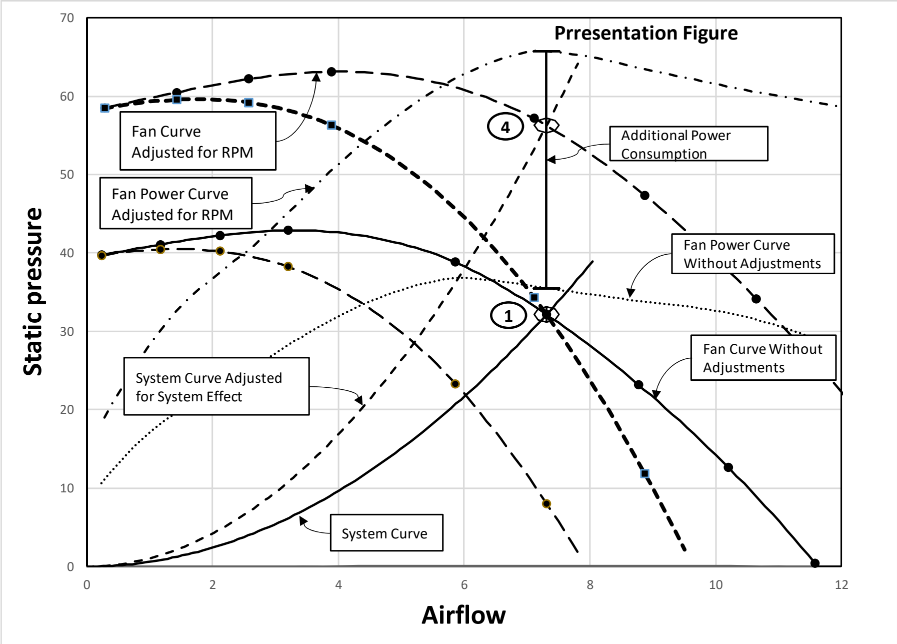


System Effect and Fan Energy Index

- System Effect changes the fan curve.
  - If manufacturer's selection includes adjustment for System Effect, it will:
    - Increase the speed for a required operating point
    - Increase the power required for the operating point
    - Reduce the Fan Energy Index
- System Effect must be accounted for in fan selection or in fan specified operating point.
- When operating point is adjusted for system Effect the installed fan should:
  - Deliver the required flow
  - Develop the pressure as identified on the Fan Curve Adjusted for System Effect and RPM.

AMCA Catalog Ratings

- "Performance certified is for installation type:
  - A: Free inlet, Free outlet"
  - B: Free inlet, Ducted outlet"
  - C: Ducted inlet, Free outlet"
  - D: Ducted inlet, Ducted outlet"
- The curves shown here are all based on the fan laws



Avoiding System Effect Rules of Thumb

1. Minimum 2.5 duct diameters on Outlet
2. Minimum 3 to 5 duct diameters on Inlet
3. Avoid inlet swirl

System Effect Recommendations

1 Allow enough space in the building design to allow for appropriate fan connections to the system

2 Use allowances in the design calculations when space or other factors dictate less than optimum arrangement of the fan outlet and inlet connections

3 Include adequate allowance for the effect of all accessories and appurtenances on the performance of the system and the fan

System Effect Conclusions

- System Effects can be identified in the design stage.
- System Effects should be minimized in the design stage.
- System Effects will change the performance and required power of the fan.
- Estimates of System Effects can be calculated for a point or curve.

Resources

- **AMCA International**: *www.amca.org*
- **AMCA Publications**: *www.amca.org/store* (available for purchase)
  - > 201-02 (R2011) – Fans and Systems
- **ANSI/AMCA Standards:** *www.amca.org/store* (available for purchase)
  - > 208-18: Calculation of the Fan Energy Index
- **AMCA certifying FEI ratings**: *www.amca.org/certify*
- **AMCA microsite for FEI training, technical papers, PowerPoints, and regulatory status**: *www.amca.org/fei*

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Questions?

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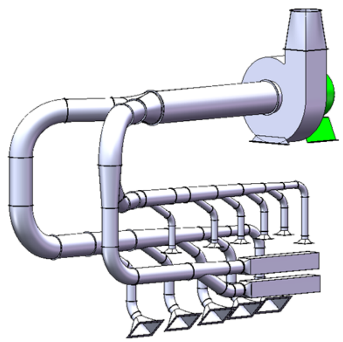

Ventilation & Fan Consulting Service

NEXT PROGRAM

Join us for our next AMCA *insite* Pop-Up Webinar:

- Thursday, April 30
- 10:00-11:00 a.m. CDT
- ***TOPIC: Design Tips for Fire and Smoke Barriers***
- Presenter: Bill Koffel, PE, FSFPE
  - Committee member for Underwriters Laboratory and the International Code Council (ICC)

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