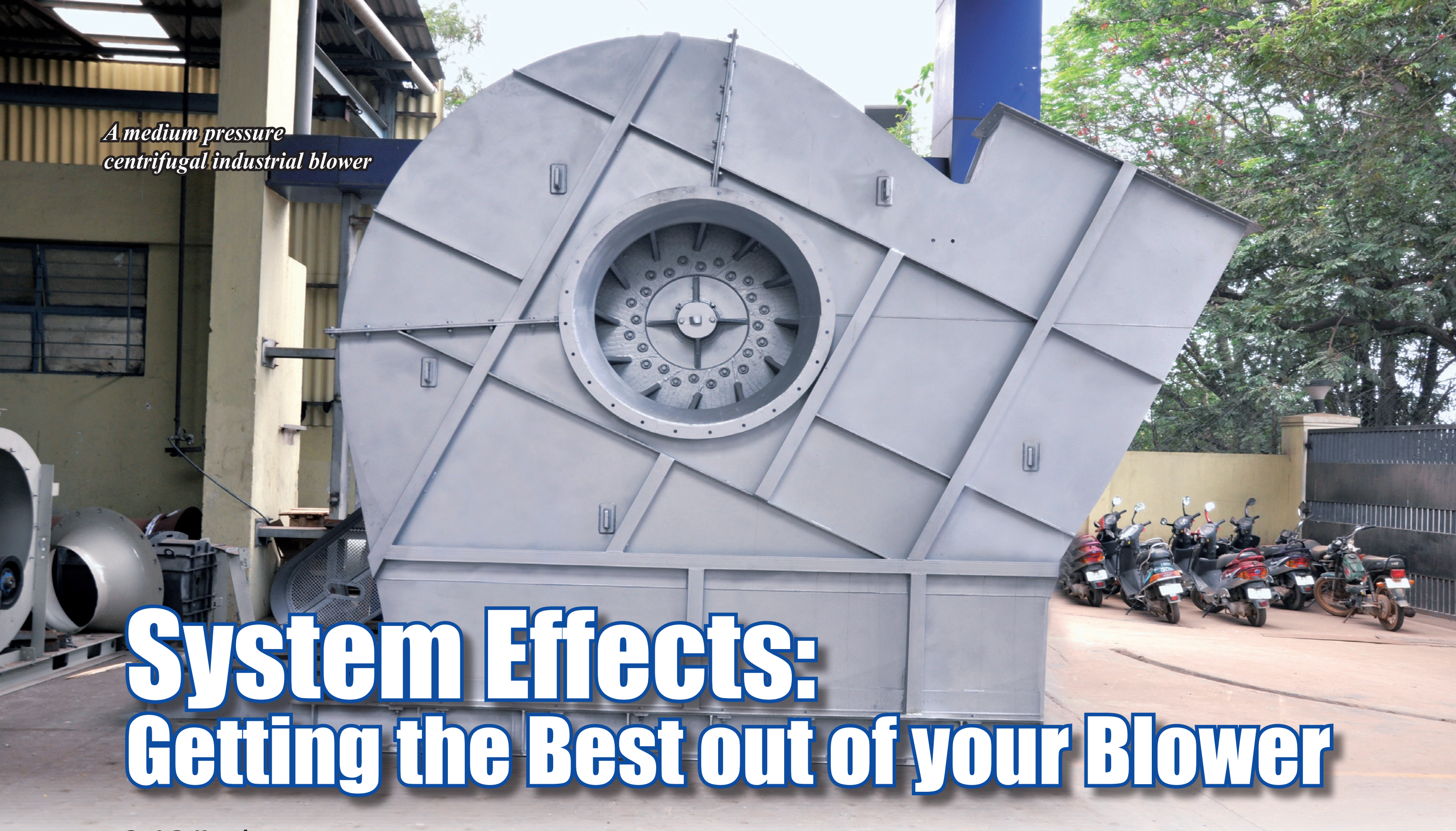

A medium pressure centrifugal industrial blower

System Effects: Getting the Best out of your Blower

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Introduction

A blower is an important component of an HVAC system. If it is not installed properly, it would invariably lead to a reduction in performance. This reduction is due to system effects, defined as the variation in performance between a fan tested under laboratory conditions and in actual installation. It is up to the system designer to predict this variation and factor it in when specifying the blower.

There are two approaches to system effects. The first is to identify the flow resistance losses for each component in the system, and the second is to place the blower in such a position in the system so as to minimize system effects. This can be achieved in several ways at the time of designing the ducting system.

Inlet Ducting/ Connections

In order for a fan to attain the performance stated by the manufacturer, airflow at the inlet must be fully developed, symmetrical and free from swirl. There are several methods *(Figure 1)* of obtaining this airflow, and these should be incorporated at the time of duct design.

A few points are to be noted during inlet duct design. There should be no sudden radical changes in duct area. If changes in duct cross-sectional area cannot be avoided, a transition with a total included angle of 15° or less must be used. Any bends in ducting should be kept as far away from the inlet as possible in order to avoid swirl in the airflow. Since bends cannot be totally avoided in a system, precautions should be taken to ensure that there are no sharp bends as they increase system resistance considerably. If bends are near the inlet, vanes should be used to reduce swirl. Bends should be located at a minimum distance of three times the duct diameter from the inlet in order to eliminate the system effect of the bend.

Outlet Ducting/ Connections

Ducting at the fan outlet needs to be designed such that the asymmetrical flow profile from the fan is allowed to diffuse and approach fully developed flow *(Figure 2)*.

Other precautions and considerations that need to be adopted are similar to those for the inlet duct *(Figure 3)*. Effective duct length can be considered to be 2.5 times the duct diameter when the airflow is 2500 fpm or less, with a further one duct diameter to be added for every additional 1000 fpm. A centrifugal fan requires 100% effective duct length at its outlet to avoid system effect, whereas a vane-axial fan requires 50% of the effective duct length.

When these considerations for optimum airflow development are not met, system effects need to be considered. *AMCA Publication 201-02* quantifies system effects for a number of the more common causes, and offers recommendations for avoiding or reducing these.

About the Author

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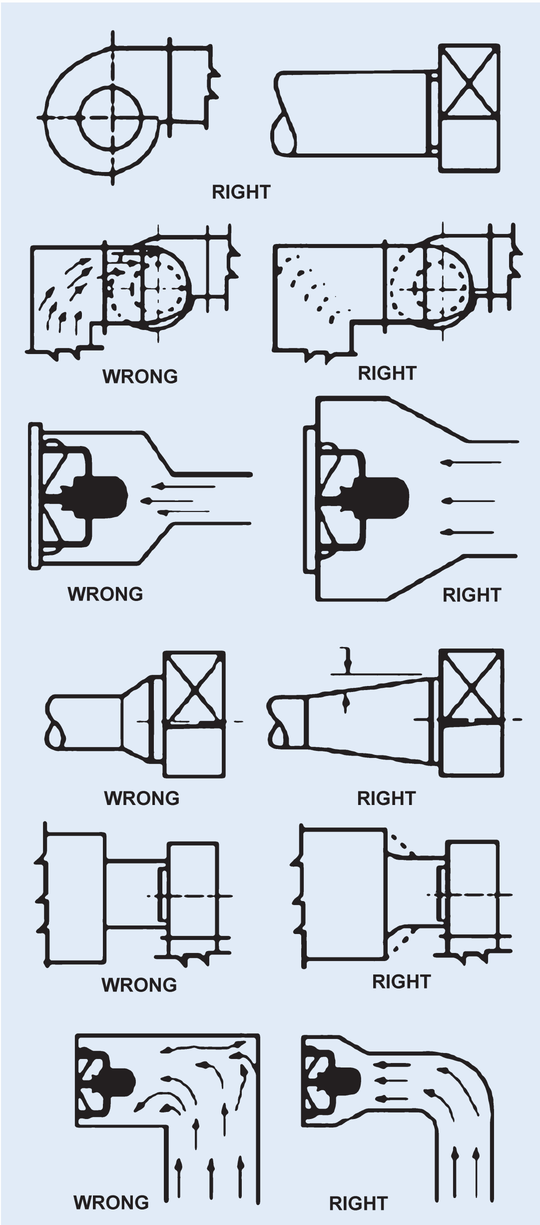

Figure 1: Inlet ducts/connections

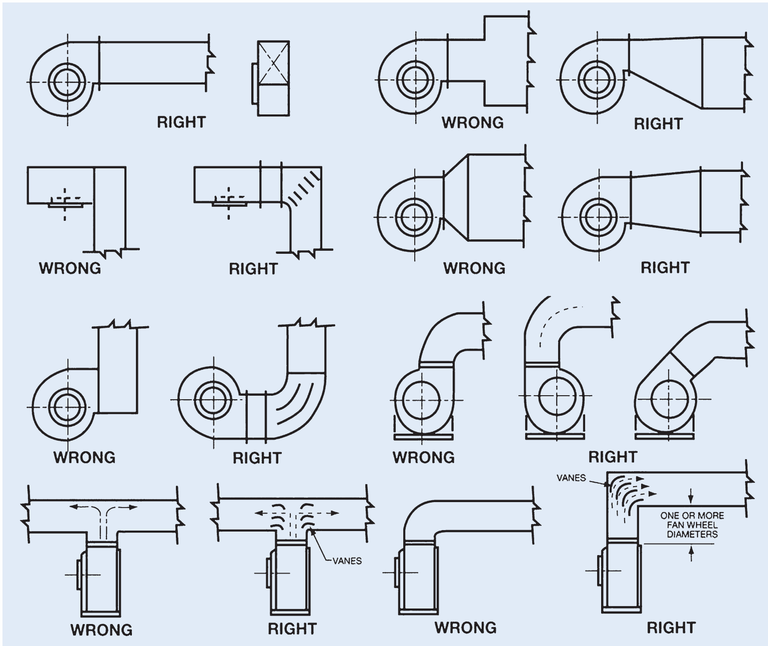

Figure 3: Outlet ducts/connections

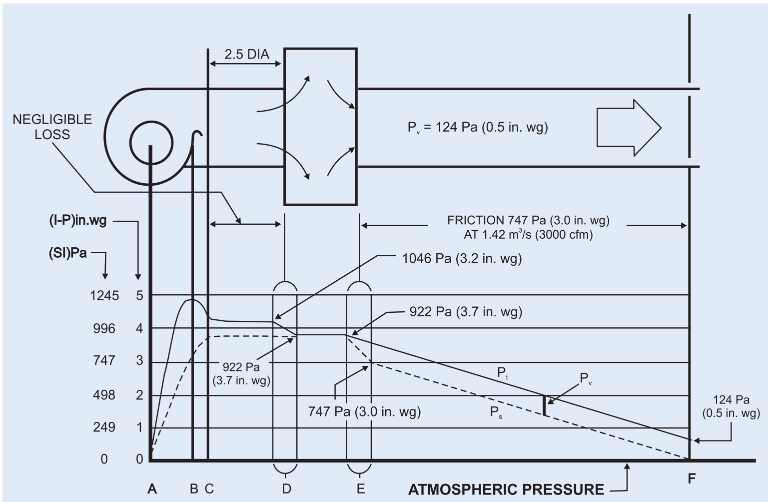

Figure 4: Computing system effect: Case 1

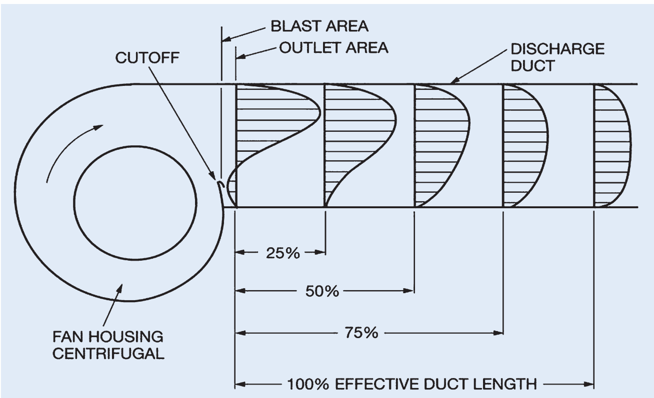

Figure 2: Airflow development at fan outlet

Quantifying System Effects

As seen above, optimum conditions for airflow cannot always be met due to constraints in area at the site of installation. In order to compensate for this lack of optimum airflow, AMCA has suggested computing system effects as follows:

Case 1: Short outlet duct connected to a plenum chamber that has a much larger cross–sectional area *(Figure 4)*

If we consider pressure losses in the opposite direction of flow, the velocity in the duct from E to F is 14.4 m/s, equal to a velocity pressure of 124.5 Pa. At point F, the P_V is 124.5 Pa, the P_S is 0.0 Pa, and the P_t is 124.5 Pa. The friction of the duct will cause a gradual increase in P_s and P_t back to point E. If the duct has a uniform cross-sectional area, P_v will be constant throughout this part of the system.

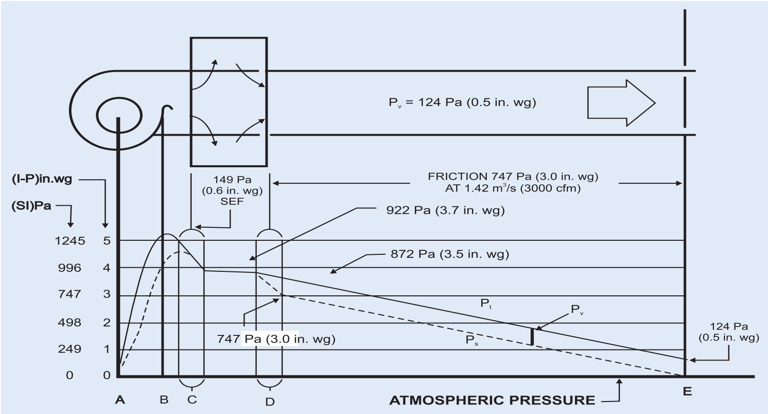

Figure 5: Computing system effect: Case 2

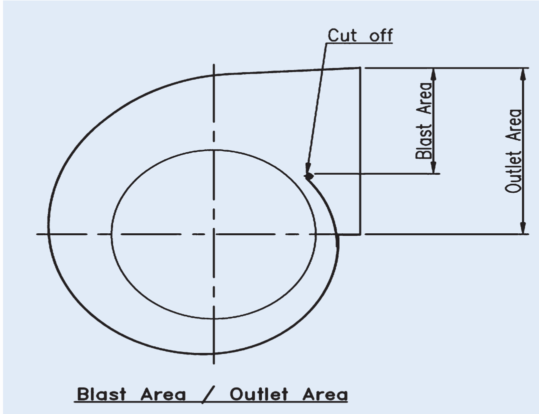

Figure 6: Blast area / outlet area

Table 1: System effect based on blast area ratio

	No Duct	12% Effective Duct	25% Effective Duct	50% Effective Duct	100% Effective Duct
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	-	-	-	-	-

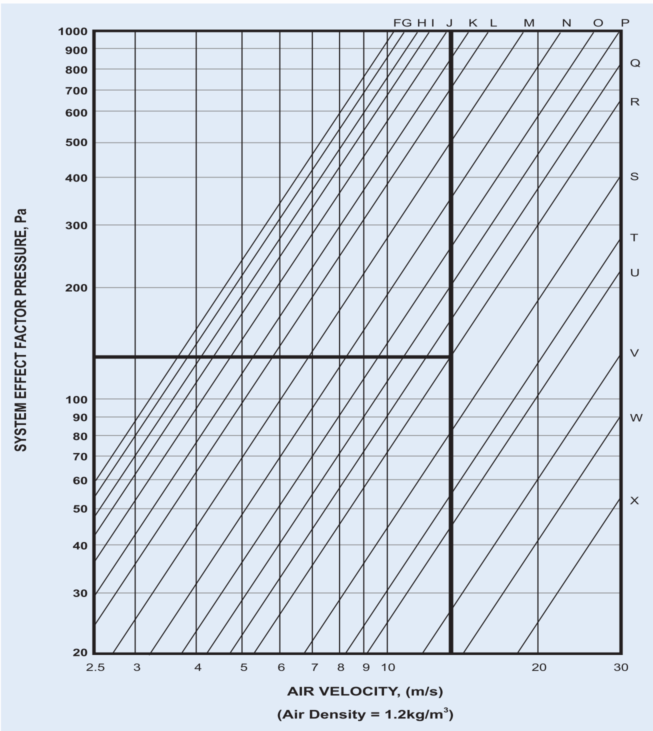

Figure 7: System effect curves

Since there is an energy loss of 49.8 Pa as a result of the abrupt contraction from the plenum to the duct, P_t requirement in the plenum is 921.3 Pa, or $P_t = P_s$ (747 Pa) + P_v (124 Pa) + Contraction (49.8 Pa).

Air flowing across the plenum from D to E will have a relatively low velocity, P_v in the plenum will be 0.0 Pa, and $P_s = P_T$ = 921.3 Pa.

At point D, there is an abrupt expansion energy loss equal to the entire P_v in the duct discharging into the plenum. The outlet duct between the fan and the plenum is 2.5 equivalent diameters long, which is the same as used during the fan rating test. P_s in the outlet duct is the same as P_s measured during the rating test.

		Pressure
C-D	Outlet duct on fan as tested	0 Pa
D	P_v loss (also P_t loss) as a result of air velocity decrease	
	P_s does not change from duct to plenum at D	0 Pa
E	Contraction loss – plenum to duct	49.8 Pa
E	P_s energy required to create velocity at E	124.5 Pa
E-F	Duct friction at Q = 1.42 m³/s	747 Pa
	Required fan P_s	921.3 Pa

Case 2: Fan outlet directly connected to a plenum chamber that has a much larger cross-sectional area *(Figure 5)*

		Pressure
B - C	SEF	149.4 Pa
B - C	P_v loss (also P_t loss) as a result of air velocity decrease.	
	P_s does not change from duct to plenum at C.	0 Pa
D	Contraction loss – plenum to duct	49.8 Pa
D	P_s energy required to create velocity at D	124.5 Pa
D - E	Duct friction at Q = 1.42 m³/s	747.0 Pa
	Required Fan P_s	1070.7 Pa

The system effect loss for the above case is obtained from the ratio of blast area to outlet area *(Figure 6)* based on Table 8.3 of *AMCA Publication 201 (Table 1).*

In this case we assume the blast area/ outlet area = 0.6, and the system effect for this ratio can be obtained from *Table 1* under no duct conditions.

This R-S curve can be obtained from the System Effect Curves as published in *AMCA 201* shown in *Figure 7*.

It is important to note that if the same fan is used in both the above cases, the system effect can be overcome by merely increasing the fan speed. However, when fan speed is to be increased, there are several factors to be considered.

i) Every fan has a maximum speed for which it is designed. This speed must always be considered when increasing the fan speed.

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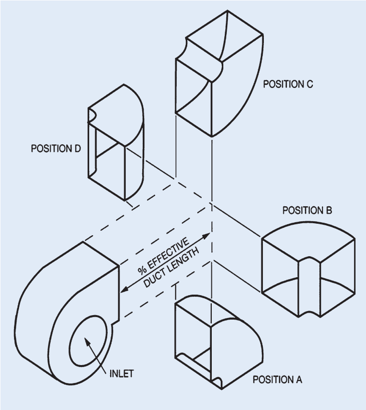
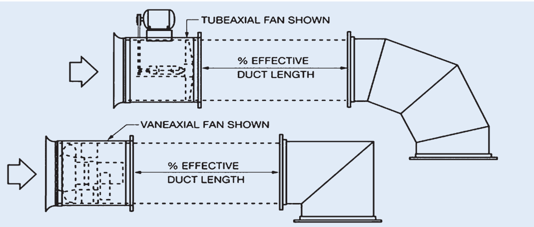


The speed is linked to the class of construction of the fan and as the speed increases, the class of construction increases and hence the material used will increase in thickness which will result in an increase in the power required to drive the fan.

ii) The percentage increase in speed is directly proportional to the square of the percentage increase in pressure as per fan laws.

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	

Figure 8: System effect for bends on outlet duct



	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	—	—	—	—

Figure 9: Two and four piece bends

iii) The percentage increase in speed is directly proportional to the cube of the percentage increase in power required to drive the fan as per fan laws.

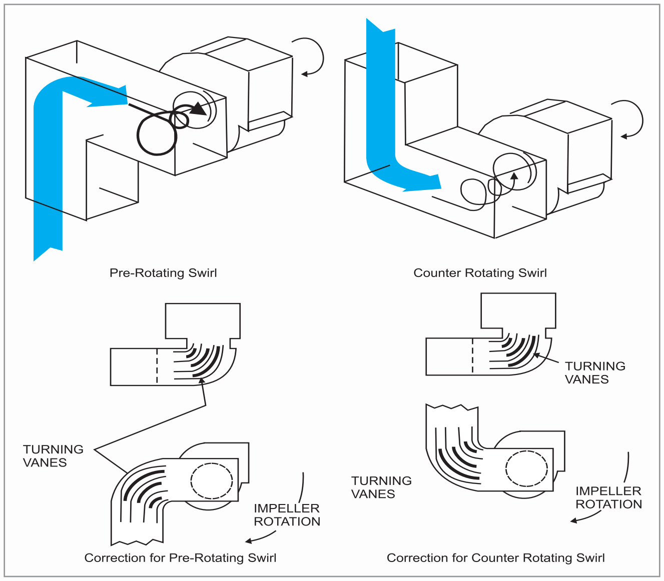


Figure 10: Effect of swirl

Hence, very often a change in speed within the same class of construction will involve an increase in the power of the motor selected.

Improving a System to Reduce System Effects

There are several other precautions a system designer can take to improve the efficiency of a fan and to accurately calculate the system effect. When the outlet of a fan is connected to a bend, the system effects can be computed as in *Figure 8*.

When considering bends in the ducts, system resistance can be reduced by using bend sections to reduce the sharpness of the bends. As the number of bend sections increases, the resistance offered by the system reduces. *Figure 9* shows the comparison between a 2 piece bend and a 4 piece bend. When a 4 piece bend is used, there is no system effect on a vane axial fan at a distance as low as 12% of the effective duct length.

The effect of swirl *(Figure 10)* on a fan can be easily reduced by the addition of turning vanes. There are two types of swirl. Pre-rotating swirl is when the air is swirling in the direction of rotation of the impeller. If the direction of rotation of the impeller is opposite to the direction of swirl, it is known as a counter-rotating swirl. Both kinds of swirl would cause a deviation from the rated performance of the fan. Pre-rotating swirl would lead to an increase in the output volume, while counter-rotating swirl would lead to an increase in the power required to drive the fan. Conversely, the use of an inlet guide vane would help increase the uniformity in airflow and hence reduce system effects.

Conclusion

Due to the space constraints in most establishments, it is very difficult to incorporate an optimum ducting system for use in coordination with the fan. However, by making minor adjustments to the ducts and the location of the fan, system effect can be reduced. This is very important in the current scenario where there is an emphasis on efficient systems and reducing power consumption. If system effect can be computed accurately, the margin on performance when selecting the fan can also be reduced. This would further aid the efficiency of the system. ❖