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How you modulate or vary the flow of your fan systems may be hurting your bottom line. This author runs you through important calculations.

Fans are designed to be capable of meeting the maximum demand of the system in which they are installed. Quite often, though, the actual demand varies and may be much less than the designed capacity.

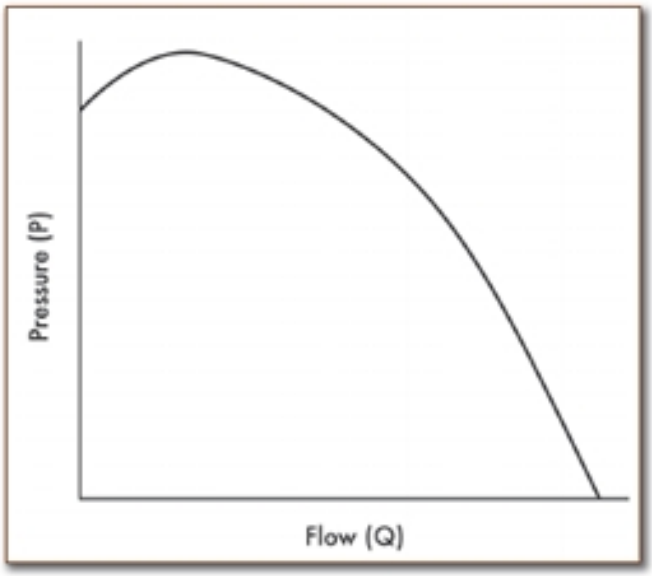


Fig. 1. This curve is an example of what a typical centrifugal fan can produce at its outlet at a given speed. It is a plot of outlet pressure in static inches of water versus the flow of air in cubic feet per minute.

The centrifugal fan imparts energy into air by centrifugal force. This results in an increase in pressure and produces airflow at the outlet of the fan. An example of what a typical centrifugal fan can produce at its outlet at a given speed is shown by the curve in Fig. 1. This curve is a plot of outlet pressure in static inches of water versus the flow of air in cubic feet per minute (CFM). Standard fan curves usually will show a number of curves for different fan speeds and include fan efficiency and power requirements. These are useful for selecting the optimum fan for any application, and are required to predict fan operation and other parameters when the fan operation is changed.

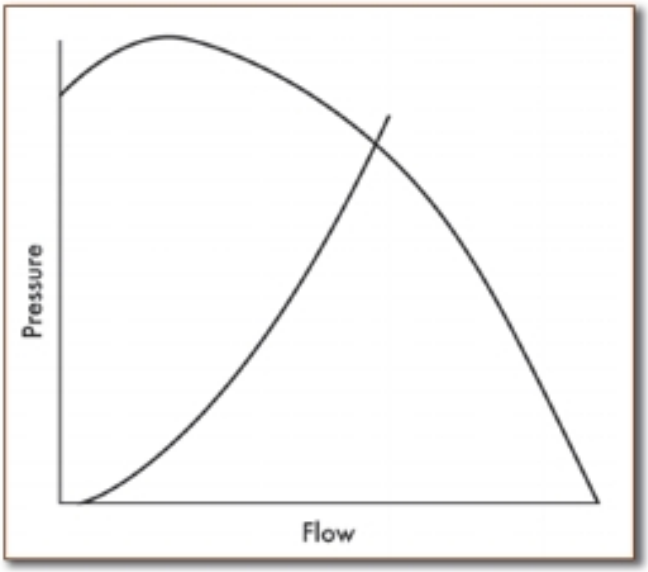


Fig. 2. This system curve shows the requirements of a vent system on which a fan is used. The intersection of the fan and the system curve is the natural operating point.

[redacted]

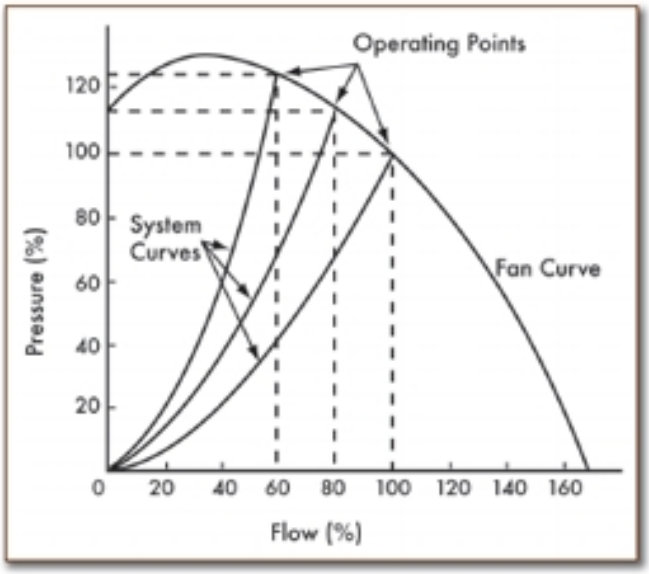


Fig. 3. Several different system curves indicate different outlet damper positions.

[redacted] affect the system curve by increasing the resistance to airflow. The system [redacted]

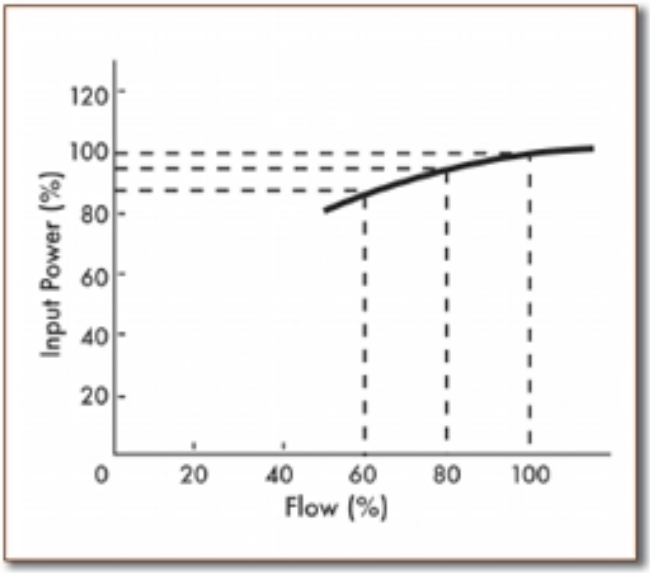


Fig. 4. Power requirements for the system in Fig. 3 decrease gradually as flow is decreased.

$$\frac{Q_2}{Q_1}=\frac{N_2}{N_1} \qquad \frac{P_2}{P_1}=\left(\frac{N_2}{N_1}\right)^2 \qquad \frac{HP_2}{HP_1}=\left(\frac{N_2}{N_1}\right)^3$$

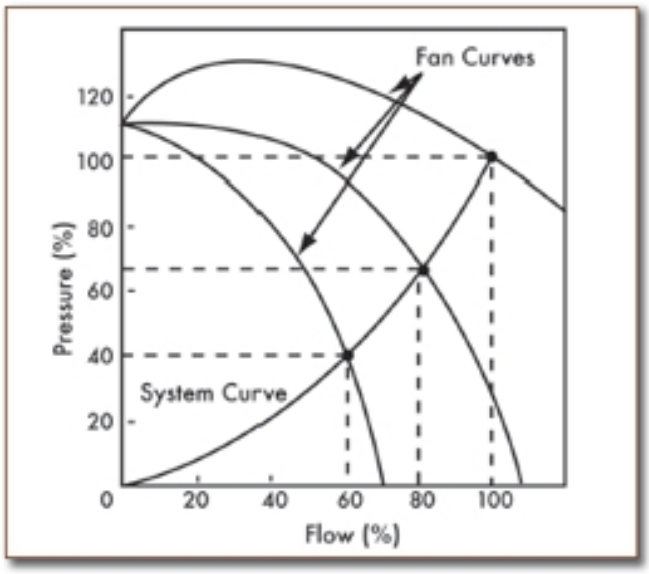


Fig. 5. The changes in a fan curve for different inlet vane settings.

[illegible] are combined, the result is a formula that matches

$$P_2=P_1X\left(\frac{N_2}{N_1}\right)^2$$

$$\frac{Q_2}{Q_1}=\frac{N_2}{N_1}\longrightarrow\left(\frac{Q_2}{Q_1}\right)^2=\left(\frac{N_2}{N_1}\right)^2$$

Substituting $(Q_2/Q_1)^2$ for $(N_2/N_1)^2$ in the first equation gives us:

$$P_2=P_1X\left(\frac{Q_2}{Q_1}\right)^2 \quad or \quad P_2=\left(\frac{P_1}{(Q_1)^2}\right)X\,(Q_2)^2$$

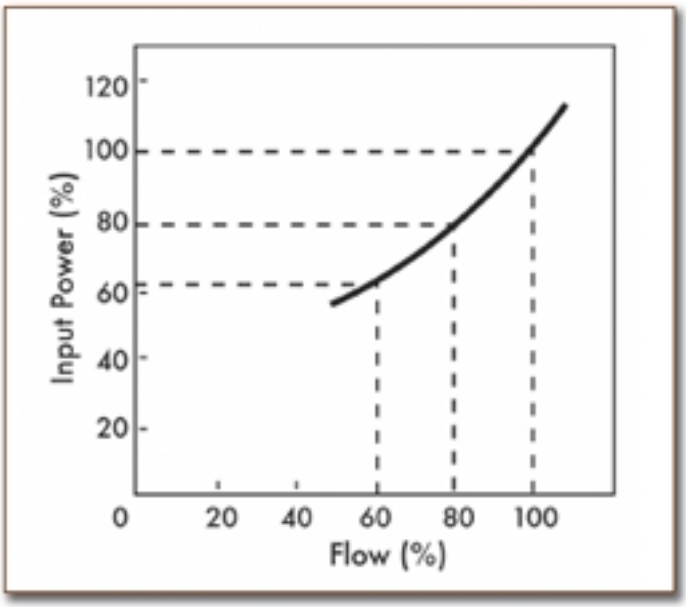


Fig. 6. When using variable inlet vanes, power requirements decrease as airflow decreases, and to a greater extent than when using outlet dampers.

[illegible]

CFM	Duty Cycle (% of Time)
100%	10%
80%	40%
60%	40%
40%	10%

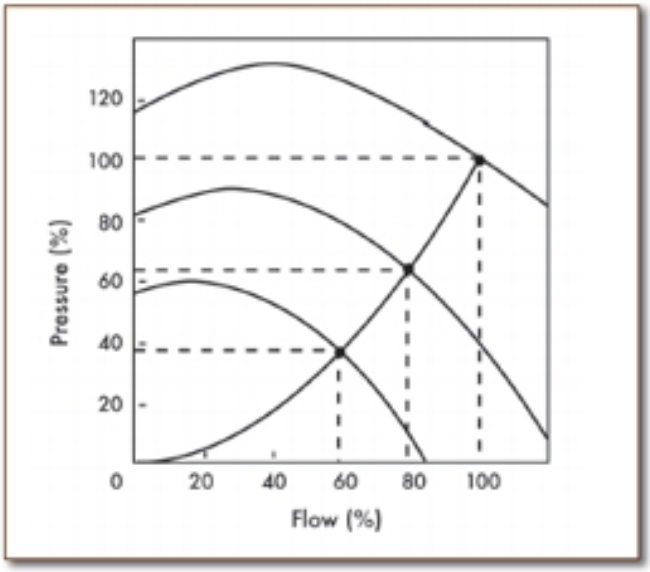


Fig. 7. Because the quantity $P_1/(Q_1)^2$ coincides with the system constant, K, the fan follows the system curve when its speed is changed.

[illegible]

Outlet Damper Method			
CFM	Duty Cycle	Horsepower	Weighted HP
100	10	35	3.5
80	40	35	14.0
60	40	31	12.4
40	10	27	2.7
			Total 32.6

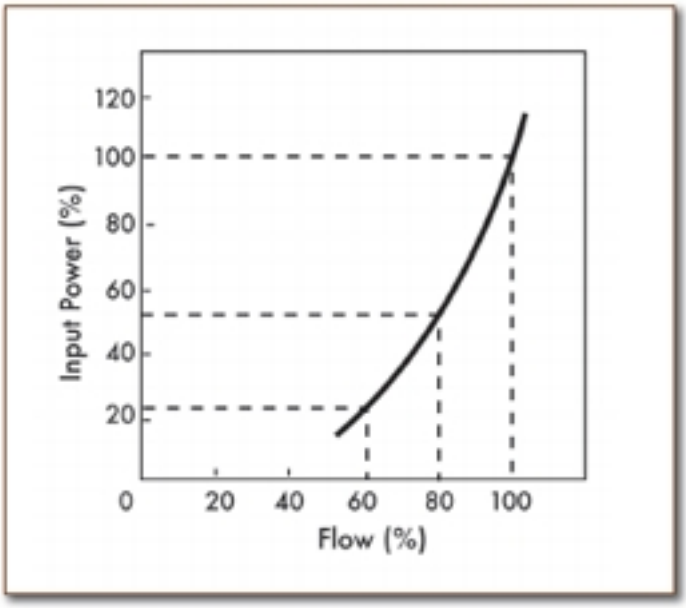


Fig. 8. As the speed of the fan in Fig. 7 is reduced, a significant reduction in power requirement is achieved.

[illegible] $HP_2/HP_1 = (N_2/N_1)^3$ can be substituted into the horsepower formula, [illegible] The

$$\frac{HP_2}{HP_1} = \left(\frac{Q_2}{Q_1}\right)^3$$

When Q_1 = 100% and HP_1 = 35 HP, Q_2 and HP_2 will have the following values:

$$Q_2 = 80$$

$$\frac{HP_2}{35} = \left(\frac{80}{100}\right)^3$$

$$HP_2 = 18$$

Fig. 9. An actual load profile

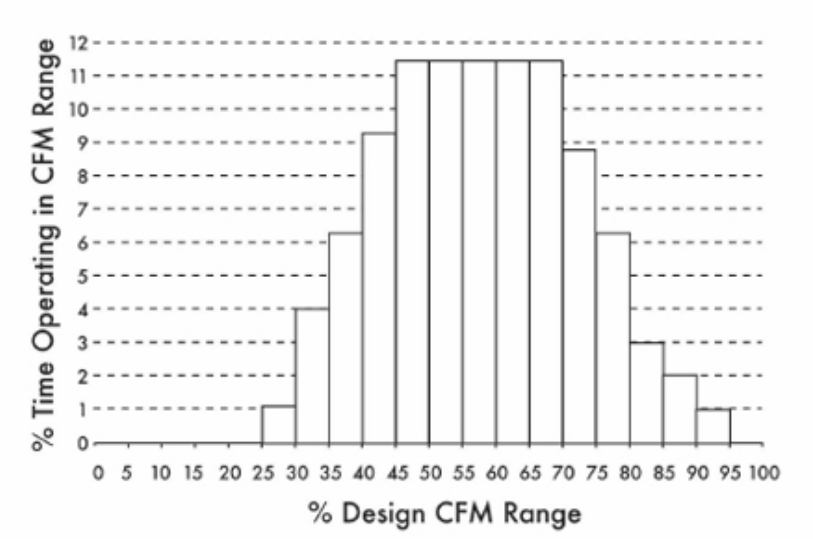
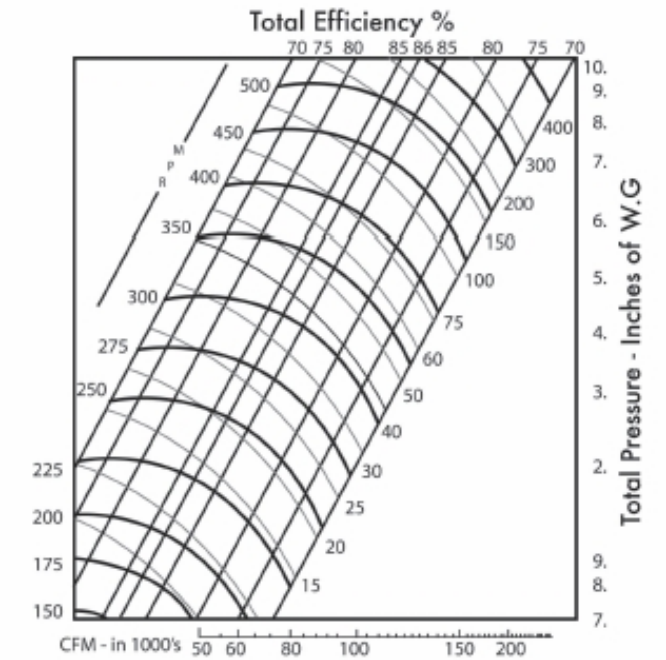


Fig. 10. An actual fan curve



[illegible]

Variable Speed Method			
CFM	Duty Cycle	Horsepower	Weighted HP
100	10	35	3.5
80	40	18	7.2
60	40	7.56	3.024
40	10	2.24	0.224
			Total 13.948

Example Table		
	Outlet Damper	Variable Speed (ASD)
Weighted HP	32.6	13.948
X kW / HP	0.746	0.746
X Hours per Month	730	730
= kWH per month	17,753	7596
X Cost	$0.07	$0.07
= Total Cost	$1242.73	$531.07

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