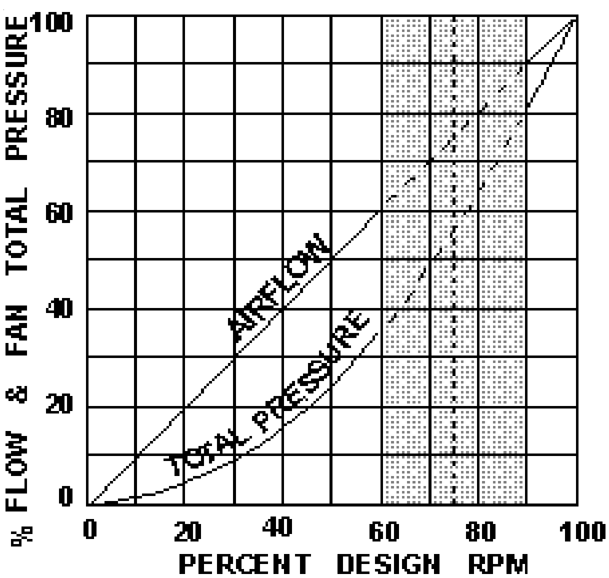
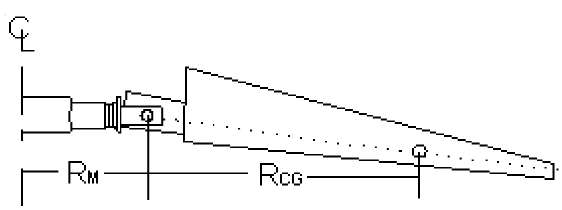
THE ADVANTAGES OF PIVOTED “HELICOPTER” BLADES

It is generally recognized that variable speed motors offer an efficient means of precisely controlling airflow, reducing energy use and lowering noise level, but . . .

The Problem: API Standard 661 *Air-Cooled Heat Exchangers for General Refinery Service*, 3rd edition, requires that the resonant frequency of the fan or fan components shall not be within 20% of the blade pass frequency. When used on a variable speed drive, a fan with one or more component resonances within the speed range of operation will require all speeds within 20% of any resonant frequency of the fan to be “locked out” within the motor controller. These resonances typically originate from the “first bending moment”, with the blade bending at its attachment to the hub and the tip deflecting vertically (in a horizontal cooler). The illustration at left shows the effect of using a fan whose resonant frequency equals 75% of the design RPM. The shaded area represents the prohibited range of fan speeds. Note that airflow cannot be controlled in the range from 60% to 90% of design flow, and fan total pressure cannot be controlled in the range from 36% to 81% of design pressure.This effect severely limits the inherent advantage of a variable speed fan drive: smooth, continuous process control.





The Solution: In Moore fans, with the blades attached to the hub by a resilient mount, or pivot, this common vibration mode is eliminated by the very dynamics of the blade/pivot combination. Moore has prepared an Engineering Paper which analyzes the dynamics of the blade motion. (See “Moore for the Asking”). The result of this analysis can be simplified as follows:

The illustration at left shows a hub/blade/pivot arrangement typical of a Moore fan in operation. The mount (pivot) is located at a radial distance $\mathbf{R}_M$. The center of gravity of the blade is located at a radial distance $\mathbf{R}_{CG}$ from the pivot. It can be shown that the blade resonant frequency ($\mathbf{f}_N$) is related to the fan rotation frequency ($\mathbf{f}$) as follows:

Note that the blade resonant frequency is a function only of the rotational frequency and two geometric properties of the fan. Also note that the blade resonant frequency can never equal the rotation speed: it is always higher. The blade resonant frequency would only coincide with the rotation frequency if the mount radius $\mathbf{R}_M$ were equal to zero, which is never the case on Moore fans. As process conditions change and fan rotation speed varies. This resonant frequency will always vary along with the rotation speed, remaining a fixed percentage away. It is this feature that makes Moore fans ideal for variable speed drives.

The figure at right illustrates how the first mode resonant frequencies of various series of Moore fans vary with fan diameter. The +/- 20% "caution zone" is shaded. The upper family of curves depicts the ratio:

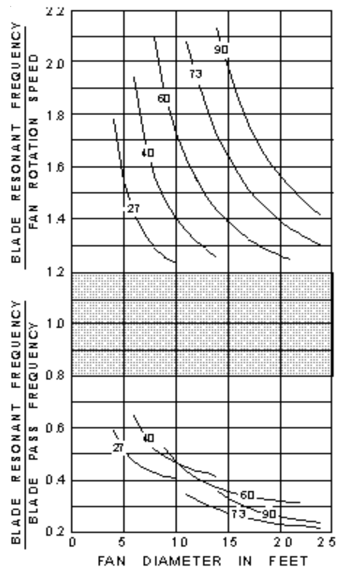
Blade Resonant Frequency / Fan Rotation Speed

The lower family of curves represents the ratio:

Blade Resonant Frequency / Blade Pass Frequency

The lower family of curves assumes a fan with the fewest number of blades offered in each series, resulting in values closest to the "caution zone".

These curves illustrate the fact that regardless of the fan series or diameter chosen, Moore fans will not have a resonance within 20% of either the fan rotation speed or the blade pass frequency, making Moore fans ideally suited for use with variable speed drives.



$$\mathbf{f}_N = \mathbf{f} \left(\left(\mathbf{R}_M + \mathbf{R}_{CG} \right) / \mathbf{R}_{CG} \right)^{1/2}$$