BASIC PERFORMANCE FEATURES OF PROPELLER FANS
LITTLE HINTS TO MAKE THEM WORK BETTER

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Gentlemen, I thank you for inviting me as a representative of Aerovent, Inc. to participate in your meeting. I'll try to make this presentation interesting and informative to you.

As users of propeller fans in dry kilns, you are aware of the necessity of reliable performance. In order to help understand how we can better obtain reliable performance, I would just like to give you a quick rundown on what fans are. What is a propeller fan - the type that you normally use in a dry kiln? Perhaps we ought to distinguish the difference between a propeller fan and the other types of fans that we talk about. We generally divide fans into two categories: axial flow and centrifugal fans.

Let's just take a quick review of centrifugal fans. The first centrifugal fan was probably the radial-bladed wheel. This usually has six or eight paddles on it and is in wide use today for high pressures and for applications conveying materials. Illustration 1 shows a typical performance curve on the radial bladed fan and a sketch on what the wheel configuration looks like.

The next most common centrifugal fan is the forward curved. You are most familiar with these because of the widespread use in air-conditioning units, furnace blowers and many other miscellaneous applications. Quite often they're referred to as squirrel cage blowers. These basically run slower than the other types of fans and are the quietest in operation. Figure 2 shows the typical fan curve for the forward curved and a sketch of the wheel configuration.

Both the radial and the forward curved wheels use higher horsepower at low resistance than other types of wheels, and the least amount of horsepower at the higher pressures and low flows. These are the types they refer to as overloading type wheels. You probably have heard this term used, and what it means is that if the resistance on a fan system or the resistance a fan operates against is reduced the horsepower will increase, and unless you have adequately designed the motor to handle the full requirement with no resistance to flow you could have a terrific overload on the motor.

The third type of centrifugal fan that we commonly use is the backward inclined or the backward curved. These are built in two different styles with flat blades and airfoil blades. Figure 3 shows a typical curve on these, and you can see that they start out at a lower horsepower, rise to a peak on the horsepower curve near the point of highest efficiency on the fan performance curve and then drop off again. This we call nonoverloading type as we can predict the maximum load point on the curve and design accordingly.

Now we come to the axial flow fans. Axial flow fans move the air along the axis of rotation. Normally they are called propel-
ler fans and they come in many variations. The most commonly used propeller fan that your industry is familiar with is the low pressure panel fan. Figure 4 shows a typical fan curve and also the sketch of what a typical panel fan looks like. The blades that are used can vary widely for the type of application, but the basic principle of a curved entrance and a structural mounting frame are all that is incorporated in the panel fan.

This same type of propeller or a propeller with a larger diameter hub and stubbier blades is commonly used in what we call a tubeaxial fan. This is a tubular housing, hence the term "tube axial flow axial." The illustration in figure 5 shows a typical tubeaxial type configuration.

The next type that we consider in an axial flow fan is the vaneaxial. This incorporates a slightly more complex wheel with straightening vanes immediately adjacent to the discharge area of the propeller that take the energy lost from the swirl and converts it to usable velocity energy. The vaneaxial fans in a similar condition are almost always slightly more efficient than the standard tubeaxial fan. There are many variations on the vaneaxial design. The ratio of the hub to the blades changes continuously. The number of blades change and allows quite a selection of performances. (See fig. 6.)

Now, what greatly affects the performance of a fan? A fan in free air or working against little or no resistance is quite tolerant of many physical restraints. However, an unobstructed pattern of airflow to the blade is always the most efficient configuration. When there is no resistance to the flow, the air will take a normal path through the fan blade and entrain other air with it. However, as the resistance to flow changes, the configuration around the fan blade, the clearance between the blade and the housing that it's mounted in, and the approach of air to the fan become quite important. The higher the velocity is moving through the fan, the more important this becomes, as the losses are expressed as a function of velocity pressure. Figure 7 shows the different entrance configurations around the fan. As you can see, if we just have a straight pipe type configuration we have as much as 90% velocity pressure loss. However, if we have a well-rounded entrance orifice to the fan our velocity pressure drops to 5%. This is why a given propeller may operate well in one situation and not well in another because the conditions of airflow to the fan have been changed.

A case in point to illustrate this would be the use of the reversible propellers quite commonly used in lumber kilns. If you have a standard panel which has a curved orifice coming from one direction, and you reverse the flow so that the air is coming the other direction, you have created a very poor entrance condition as opposed to the almost ideal entrance condition in the opposite flow direction.

As I just indicated, the reversible fan is what your industry most commonly utilizes so that the air pattern can be continually reversed through the stack of lumber. A look at the propeller shows a special design as opposed to a standard propeller fan for air movement in a single direction. Normally, we use an airfoil blade for highest efficiency and best performance range in a standard propeller fan; however, since we now must have a fan that performs well in both the forward and reverse direction, a
compromise is necessary and as a result we have slightly lower efficiencies to accomplish the balanced flow condition.

Now let's discuss some of the other things that make airflow important. We have the method necessary to support the fan in the orifice. The closer we put supports to the fan blade the more interference we'll have to flow, the higher the resistance to flow will be, the higher the noise level and also the higher the vibration potential. However, if we don't have adequate support, we have a less stiff member and we are prone to vibration problems again. So it becomes a compromise on design of the total system. One of the biggest problems we have experienced in lumber kiln designs has been the lack of stiffness in the dividing panels and support members for the fans. With the dividing panels not being of the proper stiffness they act as an amplifier to the vibration and re-induce vibration back into the propeller and drive assembly. Improper design on the driving shaft and bearing supports also will aid in this same type phenomena. A fan rotating at a given speed will generate a certain frequency of vibration no matter how well it is balanced. If this given frequency happens to be the natural frequency of one of the components, it will set this component in motion. So it is necessary that this be considered in the design, or through trial and error be found and minimized or eliminated.

An example of what I'm trying to point out here is - I am sure that many of you have had a car that you hit a certain speed and you get a vibration but at no other speed and it's impossible to completely detect. This is one of these resonant vibrations that occur, and if allowed to persist, particularly in a fan operation where you run at the same speed all the time, can become detrimental and cause damage to the structure and the propeller itself.

Obstructions to airflow or turning the air direction too rapidly affect performance. The more gradually we can turn the air, the slower we can move the air when we turn it, the less the resistance is, and the greater volume of air the fan will move or less horsepower will be required to move it. We all know economics are very important to us to keep the cost of our products down. So if we can design the proper system to reduce horsepower over a period of many operating hours, it will show improved profit; however, certain resistances are required for proper flow of air so that we can control it such as through your stack of lumber. It is important that the air approach the stack of lumber uniformly and that the resistance through the stack of lumber be uniform so that the heated air passes through or around every piece of wood and dries it out uniformly. The main point I'm trying to make here is to restrict airflow only where it is necessary to restrict it. When you are traveling through the air plenum, which is the chamber immediately ahead of and on the leaving side of the fan, keep your restrictions to a minimum. Across the heating coils you usually have quite adequate space, and where the air goes down into the drying chamber and back up from the drying chamber, this is where to make sure you have adequate space and allow the proper turn of air.

An additional point that I would like to discuss is the horsepower required to operate the fan at varying speeds. We have a set of rules that we follow in the fan industry, and we call
them FAN LAWS. Essentially, when we have a fan of a given diameter the laws of cfm varying directly as the rpm apply. In addition to this, the static pressure varies as the square of this ratio, while the horsepower requirement varies as the cube of this ratio. The main point I wish to make here is that if you were trying to get more air through a particular device, in your case it's the kiln, you don't say well, we'll just double the fan speed and get twice as much air. This is true; you will get twice as much air; however, you will require eight times the horsepower. So this basic physical law that we rely on is very important to remember. Too often people who have worked with fans before even make the mistake of forgetting that the horsepower requirement varies as the cube of the speed ratio. Now, conversely, if you have a little too much air and can get by with less air, the horsepower will be reduced as a cube of the speed ratio, and this could be of great value to you. DON'T OVERSIZE YOUR SYSTEM. (See fig. 8.)

This covers I think the basic points of fan operation that I wanted to discuss with you. The things I didn't touch on - We can drive these fans directly on a motor shaft or with an extended shaft and a belt drive to that shaft to control the speed. Your operating conditions usually determine that the motor be mounted outside and we use a belt driven shaft arrangement. Other than this, if there are some points I have overlooked I would be glad to answer questions and get into further discussion regarding any applications you have with air movement. Thank you very much for inviting me.
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Figure 1. Characteristic performance of radial-blade centrifugal fan.

Figure 2. Characteristic performance of forward-curve centrifugal fan.

Figure 3. Characteristic performance of backward-curve centrifugal fan.
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Figure 4. Characteristic performance of vaneaxial fan.
## Typical Entrance Losses
### For Various Types Of Orifices

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*Loss is given in percent of Velocity Pressure (% VP).

Fig. 7

### CHANGE OF FAN SPEED (fan size and air density constant)

\[
\begin{align*}
\text{CFM}_2 &= \frac{\text{RPM}_2}{\text{RPM}_1} \times \text{CFM}_1 \\
\text{SP}_2 &= \left(\frac{\text{RPM}_2}{\text{RPM}_1}\right)^2 \times \text{SP}_1 \\
\text{HP}_2 &= \left(\frac{\text{RPM}_2}{\text{RPM}_1}\right)^3 \times \text{HP}_1
\end{align*}
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Fig. 8

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