Selecting Fans and Determining Airflow for Grain Drying and Storage

William F. Wilcke
University of Minnesota

R. Vance Morey
University of Minnesota

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SELECTING FANS AND DETERMINING AIRFLOW FOR GRAIN DRYING AND STORAGE

William F. Wilcke
Associate Professor
Extension Agricultural Engineer
University of Minnesota, St. Paul

R. Vance Morey
Professor and Head
Department of Agricultural Engineering
University of Minnesota, St. Paul

Using fans to force air having the proper temperature and relative humidity through a crop is a valuable technique for maintaining quality after harvest. The air helps maintain the moisture and temperature of a crop at levels that prevent growth of harmful fungi and insects.

Airflow Requirements

Total airflow provided by a fan is usually expressed as cubic feet of air per minute (cfm). Recommendations for drying or aerating grain are given as airflow per unit of grain being served by the fan, or cfm per bushel (cfm/bu). Typical airflow recommendations are 0.75 to 1.5 cfm/bu for natural-air corn or soybean drying (depending on corn moisture) and 0.05 to 0.5 cfm/bu for aerating dry stored grain. Airflows that are greater than these recommendations require larger fans and lead to greater costs, while lower airflows could result in unacceptable crop quality.

Airflow Resistance

Grain

When air is forced through bulk grain, it must travel through narrow paths between individual particles. Friction along air paths creates resistance to airflow. Fans must develop enough pressure to overcome this resistance and move air through the crop.

Airflow resistance and fan pressure are usually expressed in inches of water column (in. water, or in. H₂O). This term comes from gages called u-tube manometers that are sometimes used to measure pressure (Figure 1). You can make a u-tube manometer by fastening a clear plastic tube and a ruler to a board. Then pour some water, or water plus a small amount of antifreeze, into the tube. Since manometers are used to measure pressure relative to atmospheric pressure, leave one end of the tube open to the atmosphere. Attach the other end to the duct or plenum where you want to measure pressure.
When a fan generates pressure, it forces water in the tube to move in the direction of lower pressure. The height difference between the water levels on the two sides of the tube, measured in inches, is the fan static pressure with the units of inches of water. In negative pressure or suction systems, pressure between the crop and the fan is less than atmospheric pressure and water in the manometer tube moves toward the fan. In positive pressure systems, water moves away from the fan. You can buy dial-type pressure gages that operate on a different principle but that are calibrated to give readings in in. water.

The airflow resistance of a crop and the fan pressure required to overcome it depend on how fast the air is moving and how long and narrow the paths are. For grains and oilseeds, these factors are a function of the particular crop (size and shape of seeds), crop depth, and airflow rate (cfm/bu) you’re trying to provide.

As you can see from Tables 1 and 2, at a given airflow rate, crop depth has a large effect on static pressure. Static pressure, in turn, greatly affects fan power requirements. Short, large diameter bins are recommended for natural-air grain drying because static pressure and required fan size are smaller than they would be in tall, narrow bins. Even though short bins cost more to install than tall ones that have the same grain capacity, total drying costs are less because smaller fans use less electricity.
Table 1. Airflow resistance data for shelled corn.
Values in the table have been multiplied by 1.5 to account for fines and packing in the bin.
(If corn is stirred, which tends to decrease airflow resistance, divide table values by 1.5.) Add 0.5 in. water to the table values if air is distributed through a duct system.

<table>
<thead>
<tr>
<th>Grain depth (ft)</th>
<th>Airflow (cfm/bu)</th>
<th>Expected static pressure (in. water)</th>
</tr>
</thead>
<tbody>
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</tr>
<tr>
<td>50</td>
<td>0.7 1.6 5.3 14.0 25.6 39.9 * * *</td>
<td></td>
</tr>
</tbody>
</table>

* Static pressure is excessive—greater than 50 in. water.

Table 2. Airflow resistance data for soybeans.
Values in the table have been multiplied by 1.5 to account for fines and packing in the bin. Add 0.5 in water to the table values if air is distributed through a duct system.

<table>
<thead>
<tr>
<th>Grain depth (ft)</th>
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<tr>
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<tr>
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<td></td>
</tr>
<tr>
<td>14</td>
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<tr>
<td>16</td>
<td>0.1 0.1 0.1 0.3 0.8 1.1 1.3 1.6 2.3</td>
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<tr>
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<td>0.1 0.1 0.3 0.8 1.2 1.8 2.0 3.3 4.3</td>
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<td></td>
</tr>
<tr>
<td>40</td>
<td>0.4 0.9 2.5 5.9 10.3 15.4 21.4 28.0 43.4</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>0.6 1.4 4.1 10.0 17.6 26.7 37.2 49.1 *</td>
<td></td>
</tr>
</tbody>
</table>

* Static pressure is excessive—greater than 50 in. water.
Floors and ducts

The full perforated floors used in grain bins generally have negligible resistance to airflow. Airflow resistance of bin floors isn't significant unless open area is less than about 7%; most commercially available floors have more than 10% open area.

Air supply ducts, tunnels, and perforated air distribution ducts offer greater resistance to airflow than do full perforated floors. This resistance can be quite large if ducts are too small or too long. Use ducts that are large enough that air velocity is less than about 1500 feet per minute. (Divide duct airflow in cfm by duct cross sectional area in square feet to get velocity.) Also, try to keep duct length less than 100 ft. Unless you have better information, use 0.5 in. water as an estimate of airflow resistance for duct systems. Be aware that corrugated plastic ducts designed for air distribution have only 1 to 3% open area, and ordinary plastic tile designed for field drainage has less than 1% open area. Because plastic ducts have so little area for air exit, their airflow resistance can exceed 0.5 in. water.

Air inlet and exhaust openings

When outdoor air is used to ventilate a bin or building, you need to provide adequately-sized openings for air to move in and out of the structure. If openings are too small, they restrict airflow and increase fan pressure requirements. Provide at least one square foot of inlet area per 1000 cfm and an equal exhaust area, and make sure these vents or doors are open anytime the fan is operating.

Fan Performance

Because of the way fan impellers (blades or rotors) are designed, the amount of air they can move decreases as the pressure they are working against increases. The airflow vs. pressure information for a particular fan is called the fan performance data. Performance depends on the size, shape, and speed of the impeller, and the size of the motor driving it. Performance differs widely among brands and models, even for fans with the same size motor.

Access to fan performance data is essential for selecting fans and for determining airflow provided by existing fans. Most manufacturers sell fans that have been tested using procedures specified by the Air Movement and Control Association (AMCA). The manufacturers can provide you with performance data in the form of tables or graphs. Avoid fans for which AMCA data is not available.

Fan Types

Most fans can be categorized as either axial-flow or centrifugal (Figure 2). Axial-flow fans are sometimes called propeller fans, although that's really just one type of axial-flow fan. Air
moves in a straight line through axial-flow fans parallel to the axis or impeller shaft. The impeller has a number of blades attached to a central hub.

![AXIAL-FLOW FANS](image)

- Vane-axial
- Tube-axial
- Propeller

![CENTRIFUGAL FANS](image)

- Backward-inclined centrifugal
- In-line centrifugal

Figure 2. Types of fans used for drying or aerating crops.

Centrifugal fans are sometimes called blowers or squirrel cage fans. The impeller is a wheel that consists of two rings with a number of blades attached between them. Air enters one or both ends of the impeller parallel to the shaft and exits one side perpendicular to the shaft. The blades can be straight, slanted in the direction of airflow (forward-curved), or slanted opposite the airflow direction (backward-curved or backward-inclined).
Propeller fans (panel fans)

These are axial-flow type fans that have from 2 to about 7 long blades attached to a small hub. Fan diameter is usually large relative to the fan's length or thickness. Some propeller fans are called panel fans and are designed for mounting in a wall or plenum divider. Some are belt-driven and some have the impeller hub attached directly to the motor shaft (direct-driven). Propeller fans normally can't generate more than about 2 in. water pressure. They are most commonly used for livestock building ventilation, potato ventilation, forced-air produce cooling, hay drying, exhausting air from attics or overhead spaces, or general air circulation. They are seldom used for grain drying or aeration.

Tube-axial, vane-axial

These axial-flow fans have a barrel-shaped housing and an impeller that has a large hub with a number of short blades attached to it. They are generally direct-driven and the motor is cooled by the air stream. In positive pressure systems, the air stream captures the waste heat given off by the motor. Vane-axial fans have guide vanes inside the fan housing to help reduce air turbulence. Tube-axial and vane-axial fans are the most common types used for grain drying and aeration. They are relatively inexpensive and fairly efficient when static pressure is less than about 4 in. water. The main disadvantages of these fans are that they are very noisy and they won't work against high static pressures.

Centrifugal

The centrifugal fans used for crop drying and storage generally have backward-curved or backward-inclined blades. They are expensive, but are also quiet and are usually the most efficient type of fan when static pressure is greater than about 4 in. water. For some high pressure applications, centrifugal fans might be the only type that will work. The motor on centrifugal fans is normally outside the air stream; you need to install a special housing around the motor if you want to capture the heat it gives off.

Forced-air heating and ventilating systems often use centrifugal fans that have forward-curved blades. Motors on these fans can be overloaded and burn out when the fans are operated outside certain pressure ranges. This characteristic makes them unsuitable for many crop drying and storage applications.

In-line centrifugal

These fans have axial airflow, but use a centrifugal-type impeller. Price and operating characteristics are between those of backward-inclined centrifugal and tube-axial fans.
Multiple Fans

It is sometimes necessary or desirable to install more than one fan to provide air to a common plenum or supply manifold for a duct system. Fans can be arranged in parallel or series (Figure 3). Reasons for using multiple fans include:

- Total airflow, pressure, or power requirements exceed the capabilities of the largest fan available from your dealer.
- The starting current for a single large fan motor is greater than the electrical system can handle. The maximum starting current is lower if several small fans are started one at a time.
- When multiple fans are installed, you have the option of turning some of the fans off and operating with a lower airflow when conditions allow.
- Air distribution is sometimes more uniform when several small fans are used in place of one large one.

Parallel

Parallel arrangement means fans are installed side-by-side or at several points along a manifold or plenum. The most common applications are where total airflow requirement is large, but pressure is moderate. When fans are installed in parallel, they all face the same pressure. Total airflow is estimated by adding the airflow provided by each fan at the expected pressure.

Series

Series arrangement, where fans are fastened in line or end-to-end, is not used very often. When it is used, it generally involves tube-axial or vane-axial fans in situations where pressure is
relatively high, such as in deep grain bins. Series arrangement is seldom used with centrifugal fans and seldom are more than two axial-flow fans connected in series. When fans are arranged in series, each fan handles the same airflow. Total pressure is estimated by adding the pressure developed by each fan at the expected airflow.

Determining Airflow Provided by Existing Fans

Knowledge of the airflow that a fan is providing allows you to estimate the time it will take to dry or cool a crop. This in turn, helps you determine whether steps need to be taken to prevent unacceptable quality loss before the task is completed.

The first step in determining airflow is to measure static pressure in the duct or plenum between the fan and the crop (Figure 1). Drill a small hole (1/8 in. should be adequate) in the wall of the duct or plenum and press a tube from one side of a pressure gage or u-tube manometer against the hole. Then, take the pressure reading and use its absolute value (this means assume the reading is positive even if it's a negative pressure system) to determine the airflow. Use the AMCA performance data for that model fan at that pressure. To get airflow rate (cfm/bu), divide the airflow by the amount of crop being served by the fan.

Because airflow resistance and static pressure vary with type of crop, crop depth, amount of fines present, and the way the crop is piled, you need to repeat the above procedure and determine a new airflow anytime conditions change.

Selecting Fans

Calculate total airflow needed

The first step in selecting a fan is to determine the total airflow it must provide. Choose an airflow rate, estimate the total quantity of crop to be served by the fan, and then multiply the airflow rate by crop quantity to get total airflow requirement.

For example, if you want to supply 1 cfm/bu to natural-air dry corn in a 27-ft diameter by 16 ft deep bin that has a full perforated floor,

Bin capacity = \((\pi + 4) \times \text{(diameter)}^2 \times \text{depth} \times 0.8 \text{ bu/cubic ft}\)

= 0.785 \times 27 \text{ ft} \times 27 \text{ ft} \times 16 \text{ ft} \times 0.8 \text{ bu/cubic ft}

= 7325 \text{ bu}

Total airflow = 1 \text{ cfm/bu} \times 7325 \text{ bu} = 7325 \text{ cfm}
Estimate static pressure

The next step in selecting a fan is to estimate the pressure the fan will be operating against. For corn or soybeans, use the desired airflow rate and expected crop depth and read the appropriate pressure value from Table 1 or 2. Remember to add 0.5 in. to the value from the table if air is distributed through a duct system.

Continuing our example, Table 1 indicates that the expected pressure for 16 ft of corn and an airflow rate of 1 cfm/bu is 2.4 in. water.

Estimating fan power requirements

Fans are usually described by the horsepower (hp) rating of the motor used to drive the impeller. It's helpful when selecting fans to estimate the power requirement first so you know where to start looking in the manufacturer's catalog.

Fan motor size depends on the total airflow being delivered, the pressure developed, and the impeller's efficiency. Impeller efficiencies generally range from 40% to 60%. If we assume an average value of 50%, we can use the following formula to estimate the fan power requirement.

\[ \text{Fan power (hp)} = \text{airflow (cfm)} \times \text{static pressure (in. water)} + 3178 \]

In our example,

\[ \text{Fan power} = 7325 \text{ cfm} \times 2.4 \text{ in. water} + 3178 = \text{about 5.5 hp}. \]

Selecting the best fan available

Purchase cost and noise during operation can be important factors in selecting a fan, but the most critical factor is whether the fan can provide enough airflow at the expected operating pressure. In our example, we would look for a fan that can deliver 7325 cfm against a static pressure of 2.4 in. water. Start by looking at performance data for a fan having a motor rated just under the power value you calculated. For the example situation, you would probably start by looking at a 5-hp fan. If this fan provides more than enough airflow, look at the next size smaller. If your first pick is too small, try the next size larger.

Sometimes fans produced by one manufacturer won't meet your needs and you'll have to look at another manufacturer's fans. Or, if you are having trouble finding a fan that is big enough, you might consider using several smaller fans. (See the section on multiple fans.)
Computerized fan selection

The fan selection procedure that was just described is not too difficult, but there is an easier way to select fans for grain bins. You can use the FANS2 computer program available from extension agricultural engineers at Iowa State University or the University of Minnesota. The program is user friendly and guides you through the fan selection process by asking some simple questions about your grain drying or storage bin. The program allows you to select fans from a list of over 200 commercially available models and see if the selected models provide the desired airflow.

Summary

Selection of proper fans and determination of actual airflow provided by existing fans are important steps in preserving quality of crops after harvest. Make sure you have fans that provide enough airflow to dry or cool crops before unacceptable quality loss occurs.