DIVISION OF AGRICULTURE
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Selection, Performance and Maintenance of Grain Bin Fans

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Introduction

Grain bin fans are the devices producers use every season to dry and condition their grains. Grain producers try to select the best fan that fits their farm needs from several manufactured fans. Overestimation of the fan size selection leads to unnecessary energy consumption. On the other hand, underestimation of the fan size selection may lead to grain spoilage. As a result, producers are asking several essential questions. Which fan size is suitable to dry and condition a certain grain efficiently? How much air could be delivered by a specific fan? What is the methodology for evaluating the performance of grain bin fans? Should two fans be connected in parallel or series configurations? How much should grain bin drying cost during the grain-drying season? This fact sheet will provide answers to these questions in the simplest possible format.

Grain Bin Fan Classifications

Grain bin fans are classified as **axial flow** and **centrifugal flow** fans, according to the manner in which air enters and exits from the impeller (Figures 1 and 2). Each of these classifications could be used under certain conditions to maximize airflow rate and minimize energy consumption in order to maintain grain quality. Both types push air to move within the grain against resistance caused by the whole system.

In axial flow fans, air moves almost parallel to the axis or impeller shaft. The impeller has a number of blades attached to a central hub. Axial flow fans can be divided into two types – propeller fans and vane-axial fans. Normally, propeller fans have two to seven long blades attached to a small hub. Propeller fan diameter is usually larger than its thickness.

FIGURE 1. Axial flow fan

FIGURE 2. Centrifugal fan

Some are belt-driven, and others have the impeller hub attached directly to the motor shaft. Propeller fans are used to handle a large volume of air against low pressure heads, typically less than 2 inches of water pressure. As a result, these fans are normally installed in walls or plenum dividers for ventilation, for exhausting air from attics or overhead spaces or for general air circulation. They are rarely used for grain drying or aeration.

Vane-axial flow fans consist of 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 airstream. As a result, air captures the waste heat given off by the motor. Vane-axial fans have guide vanes inside the fan housing to help reduce air turbulence. This is the most common type of fan used for grain drying and aeration. Vane-axial fans are relatively inexpensive and efficient when static pressure is less than 4 inches of water. However, the main disadvantage of these fans is that they are very noisy.

The second major type of grain bin fan is the centrifugal fan. Some dealers call them squirrel cage fans. The centrifugal fan impeller is a wheel that consists of two rings with a number of blades attached between them. Air enters one end of the impeller parallel to the shaft and exits from the 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). Centrifugal fans used for grain drying and storage generally have backward-curved blades. They are expensive compared to axial flow fans but are also quiet. They are usually the most efficient type of fans when static pressure is greater than 4 inches of water. The motor on centrifugal fans is normally located outside the airstream. It should be mentioned that the motors on these fans could be overloaded and burn out when the fans are operated above their pressure ranges. This characteristic makes them unsuitable for some crop drying and storage applications.

In the majority of grain handling systems, only one single fan is selected for the required design rating. In some specific cases, producers need to install more than one fan to deliver the required amount of air or to provide high pressure to this system. Reasons for using multiple fans include:

- Total airflow, pressure or power requirements exceed the capabilities of the largest fan available from the 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, producers have the option of turning some of the fans off and operating with a lower airflow when necessary.

Therefore, it is advantageous to use more than one fan in a system and to configure them in parallel or series arrangement. In the parallel arrangement, two fans are installed side-by-side or at several points along the manifold. While in series arrangement, fans are fastened in line or end-to-end. When a series arrangement 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 rarely used with centrifugal fans. The fans may be located close to each other (mounted on a common shaft) or separated by quite a distance (supply and exhaust fans).

Grain Bin Fan Performance

Grain producers are interested in knowing the performance of the fan(s) installed on their farms or the one they would like to purchase. Fan performance is normally illustrated in a graphical or tabulated format. Fan performance curve or table is the correlation between airflow rates (cubic feet per minute, cfm) this fan can deliver and static pressure (inches of water). Performance of a fan depends on the size, shape and speed of the impeller and the size and power (HP) rating of the motor driving this fan. Performance differs widely among brands and models, even for fans with the same size motor. Tables 1 and 2 show examples of several axial and centrifugal fans' performance, respectively.

TABLE 1. Example of fan performance data for axial flow fans

	Static pressure (inches of water)					
	1.0	2.0	3.0	4.0	5.0	6.0
HP	Airflow rate (cubic feet per minute, cfm)					
1.5	3,675	3,275	2,425	1,375		
3.0	6,400	5,200	3,700	2,200		
5.0	9,600	7,600	6,150	4,200		
7.5	13,400	11,500	9,000	6,200	2,250	650
10.0	15,700	14,200	12,600	10,500		

This data is provided as an illustration only; these fans may be unavailable commercially.

TABLE 2. Example of fan performance data for centrifugal fans

	Static pressure (inches of water)					
	1.0	2.0	3.0	4.0	5.0	6.0
HP	Airflow rate (cubic feet per minute, cfm)					
5.0	7,600	6,700	5,800	4,800	3,500	1,500
7.5	9,600	8,900	8,000	7,200	6,100	5,000
10.0	13,450	12,720	11,960	11,120	10,180	9,040
15.0	16,000	15,100	14,200	13,100	11,800	10,000
20.0	21,725	20,430	19,140	17,750	16,140	14,120

This data is provided as an illustration only; these fans may be unavailable commercially.

In addition, Figure 3 shows the graphical performance of an axial fan and a centrifugal fan.

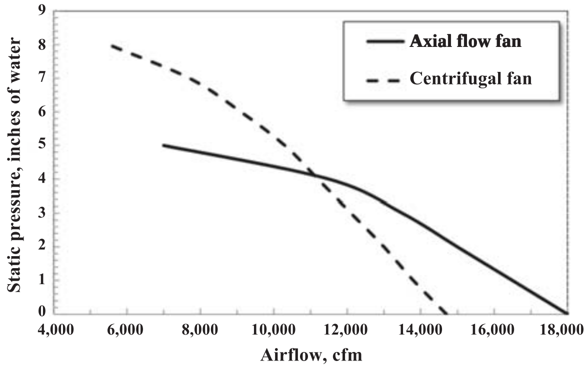

FIGURE 3. Example of axial and centrifugal fans' curves

From the graph or the tables, it is advisable to use a centrifugal fan in most cases, particularly with medium to high static pressure. As the depth of the grain increases, the value of static pressure required to move the air through the grain increases (as will be discussed later). Fan performance illustration will allow producers to compare two different fans in terms of airflow rate, static pressure and airflow rate per horsepower. Thus, producers will make educated comparison between various types of fans. Producers who are purchasing new fans should search for fans tested using procedures specified by the Air Movement and Control Association International, Inc. (AMCA). The manufacturers can provide producers with the performance data in the form of tables or graphs. Producers should avoid purchasing fans for which performance data is not available.

As mentioned earlier, producers sometimes need to connect two fans together in a series or parallel configuration. Two fans in series are normally rated as a single unit under AMCA rating definitions and ratings. To simplify selection and control, two fans of the same size are typically used with the required flow rate defined by the inlet conditions of the first fan. The combined pressure across both fans will be the sum of the individual pressure of each fan, as shown in Table 3. In this case, the total pressure should be used instead of static pressure because the fans can actually be different sizes and a change in fan or connecting duct areas has an influence on static pressure values. For simplification, only static pressure was used in Table 3.

On the other hand, two identical fans connected in parallel configuration to a drying bin will almost double the airflow rate while maintaining the static pressure, as shown in Table 4. This configuration is needed when the required total airflow is large but pressure is moderate. Practically, when installing fans in parallel configuration, producers should have some form of isolation damper to prevent the air (backflow into the nonworking fan) from energizing the nonworking fan to run backward. The damper also serves to minimize the shock during startup of bringing a fan from running backward to stopping and then up to speed again in the forward direction. A mechanical backstop clutch can also be used to eliminate the shock of fans installed in parallel configuration.

TABLE 3. Static pressure (inches of water) for fans in series configuration

Static pressure (inches of water) for single fan (7.5 HP)				
1.0	**2.0**	**3.0**	**4.0**	**5.0**
Airflow rate (cubic feet per minute, cfm)				
13,400	11,500	9,000	6,200	2,250
Static pressure (inches of water) for two fans (7.5 HP each) in series configuration				
2.0	**4.0**	**6.0**	**8.0**	**10.0**
Airflow rate (cubic feet per minute, cfm)				
13,400	11,500	9,000	6,200	2,250

TABLE 4. Static pressure (inches of water) for fans in parallel configuration

Static pressure (inches of water) for single fan (7.5 HP)				
1.0	**2.0**	**3.0**	**4.0**	**5.0**
Airflow rate (cubic feet per minute, cfm)				
13,400	11,500	9,000	6,200	2,250
Static pressure (inches of water) for two fans (7.5 HP each) in parallel configuration				
1.0	**2.0**	**3.0**	**4.0**	**5.0**
Airflow rate (cubic feet per minute, cfm)				
26,800	23,000	18,000	12,400	4,500

System Performance

In grain drying systems, as the grain depth increases, the airflow resistance increases. As mentioned earlier, airflow resistance can be represented as the system pressure. The fan should overcome the airflow resistance in the grain bin in order to allow air to pass through and dry or condition the grain. The intersection of the fan performance curve (described earlier) and the system performance curve (Figure 4) would help to obtain the optimum fan size for this system under these particular conditions.

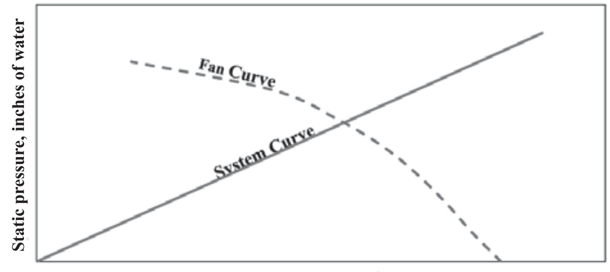

FIGURE 4. The system and fan performance curves

Static pressure in a grain bin is measured with a manometer, which is connected to the air plenum of a grain bin (air space below the bin floor). An operating fan creates a pressure in the plenum great enough to push air up through the grain. This pressure also pushes on the open end of the manometer tube, causing the fluid in the manometer to move down one leg of the U-shaped tube and up the other. The difference in the level of the two columns (measured in inches of water) is the static pressure supplied by the fan. The static pressure a fan operates against in grain bins is affected by factors related to the grain itself, airflow rate and the system design.

- **Grain type:** Any changes in the grain characteristics; e.g., size and shape, as well as the spaces between grains affect airflow resistance. Finer-sized grains cause higher airflow resistance compared to larger-sized grains.
- **Grain compaction:** The degree of grain compaction depends on moisture content and filling method. As grain compaction increases, the airflow resistance increases.
- **Grain depth:** Airflow resistance increases with grain depth. Each added foot of grain adds about the same amount of airflow resistance.
- **Amount of foreign materials:** The existence of foreign material increases airflow resistance if the foreign material is finer than the grain.
- **Exhaust opening area:** Any reduction in the exhaust airflow area increases airflow resistance. As a result, providing at least 1 ft^2 of exhaust or inlet area per 1,000 cfm is recommended.
- **Airflow:** Higher airflow rates result in higher pressure.
- **Fan transition and duct air velocities:** The more fan transition, the higher the airflow resistance.

Fan Selection Procedure

The simplest way to select the grain bin fan is to (1) calculate the required total airflow rate, (2) estimate the static pressure, (3) estimate the fan power requirements and (4) select the suitable fan from the manufacturer's list.

The first step in selecting a fan or multiple fans is to determine the total airflow rate required for the process. Researchers reported that the required amount of air varies between 0.1 cfm and 125 cfm, based on the system configurations and process requirements. Table 5 shows the various drying and storage processes with the corresponding airflow rates. As a result, producers should choose an airflow rate, estimate the total quantity of grain to be served by the fan and then multiply the airflow rate by grain quantity to get total airflow requirement.

TABLE 5. Airflow rates for grain drying and storage processes

Process	Airflow rate range cfm/bu
Aeration	0.1 - 0.5
Dry aeration	0.5 - 1.0
Natural air drying	1 - 3
Low temperature drying	1 - 3
Layer drying	1 - 3
Batch-in-bin drying	5 - 15
In-bin continuous drying	1 - 20
Continuous flow drying	75 - 125

For example, assume that a producer decided to supply 1 cfm/bu to natural air dry corn in a 30-foot diameter by 20-foot deep bin that has a full perforated floor. Calculate the required airflow.

Bin capacity $= (\pi)/4 \times (\text{diameter})^2 \times \text{depth} \times 0.8\ \text{bu/ft}^3$
$= 3.14/4 \times 30\ \text{ft} \times 30\ \text{ft} \times 20\ \text{ft} \times 0.8\ \text{bu/ft}^3$
$= 11{,}310$ bu

Total airflow = Number of bushels × airflow rate per bushel
= 11,310 × 1 = 11,310 cfm

The second step in selecting a fan is to estimate the static pressure the fan will overcome. Researchers developed methods to determine the static pressure in a grain bin, which is shown in table format in Table 6. Continuing the previous example shows that static pressure in this case will be approximately 3.58 inches of water. As was mentioned earlier, several factors might contribute to the changes in static pressure.

TABLE 6. Static pressure (inches of water) for corn at different airflow rates

Grain depth (ft)	Airflow rate (cfm/bushel)*					
	0.25	0.5	0.75	1.0	2.0	3.0
2	0.52	0.51	0.51	0.52	0.54	0.56
4	0.54	0.53	0.55	0.58	0.68	0.80
6	0.57	0.58	0.63	0.69	0.95	1.29
8	0.61	0.65	0.75	0.86	1.40	2.10
10	0.66	0.75	0.91	1.09	2.04	3.28
12	0.73	0.87	1.12	1.41	2.90	4.90
14	0.80	1.03	1.39	1.81	4.02	7.00
16	0.89	1.21	1.71	2.30	5.41	9.63
18	1.00	1.43	2.10	2.88	7.10	12.86
20	1.11	1.69	2.55	3.58	9.11	16.72
22	1.24	1.98	3.08	4.38	11.47	
24	1.39	2.32	3.68	5.31	14.20	
26	1.55	2.69	4.36	6.35	17.32	
28	1.73	3.11	5.12	7.53		
30	1.92	3.58	5.97	8.85		

*0.5" water column has been added to static pressure to account for ducts and vents

The third step is to estimate the fan power. Fans are usually described by the horsepower (HP) rating of the motor used to drive the impeller. It is helpful when selecting fans to estimate the power requirement 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 65 percent. If we assume an average value of 60 percent, we can use the following formula to estimate the fan power requirement.

Fan power (HP) = airflow (cfm) × static pressure (inches of water) ÷ 3,814

In our example:

Fan power = 11,310 cfm × 3.58 inches water ÷ 3,814
= 10.6 HP

There are two rules of thumb with regard to the size selection of the drying fan:

(1) Doubling the cfm/bu airflow rate on the same depth of grain requires five times more horsepower and
(2) Doubling the grain depth at the same cfm/bu airflow rate requires ten times more horsepower.

The last step is to start looking at performance data for a fan having a motor rated just slightly under the power value you calculated. If this fan provides more than enough airflow, look at the next size smaller. If your first pick is too small, try the next larger size.

Fan Maintenance

It is essential to provide the required amount of air needed to dry grain to a safe moisture level. The duration of delivering the required amount of air would be extended significantly if the airflow rate is reduced due to low quality maintenance of the fan. In other words, the energy cost to dry grain would increase accordingly. It takes the same amount of horsepower to run a 40-horsepower fan whether it is delivering its full capacity or half its capacity. Therefore, the following steps may help maximize the airflow rate and minimize the energy cost required to deliver air to the grain bin.

- **Inspect air delivery system periodically.** It is advisable to perform an annual inspection of the air delivery system by tightening the belt or replacing it. In addition, repair the motor or replace it and remove the corrosion of the fan blades.
- **Clean the fan.** It is important to keep the fan blades clean because the existence of dust and grease disturbs the airflow around the blades. Additionally, it is preferable to put a new coat of paint on the blades, if needed. This will make the surface of the blades smooth and the fan more efficient.
- **Lubricate the bearings.** It is advisable to lubricate the bearings but not to over lubricate them. Lubrication will minimize the bearing friction. Conversely, excess lubrication that runs out of the side of the bearing will accumulate on the blades. This causes the blades to accumulate more dust and other contaminants that change their surface shape. As a result, excess lubricant needs to be wiped off so it is not tossed outward when the fan is turned on.
- **Cover the intake of the fan when not in use.** It is recommended to cover the intake of fans when they are not in use. If the grain temperature is higher than the atmospheric air temperature, natural air will move through the fans and up through the floor into the grain bringing moisture. Therefore, putting a cover over the intake of the fans is recommended. It is a very inexpensive way to avoid this issue.
- **Check the exhaust outlets.** Many bins do not have enough outlets on the top, which leads to an increase in the airflow resistance due to the restriction of air exit. It is advisable to open the whole cover and make sure that it opens easily, an indication that no pressure builds up inside the bin. It is essential to ensure that the only resistance to the airflow is the grain itself, not the design of the bin.

Energy Consumption

Fan motor cost ($/h) = fan HP × (0.7475 kW/HP) × ($/kW h)

Example:

Assume that you have a 20 HP fan with electricity costs at $0.10/kW h and no demand charges are applied. Determine the cost to run this fan per hour of operation.

Fan motor cost ($/h) = 20 HP × (0.7475 kW/HP) × ($0.10/kW h) = $1.50

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