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OKLAHOMA COOPERATIVE EXTENSION SERVICE

# Aeration System Design for Cone-Bottom Round Bins

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Before attempting to select, design or manage an aeration system, you should study the following publications: F-1100 "Maintaining Quality Of Stored Grain," and F-1101 "Aeration and Cooling of Stored Grain."

Fact sheet F-1100 discusses the roles of moisture migration and mold growth in grain spoilage. Methods used to prevent these problems are presented. A good understanding of the principles of grain quality maintenance is essential for successful management of stored grain.

Fact sheet F-1101 discusses the importance of choosing the right airflow rate to obtain the desired aeration system capabilities. Power requirements, fan selection, control systems, and management suggestions are also explained.

This fact sheet presents information for the design or selection of aeration system components for cone-bottom round grain bins.

Cone-bottom bins have the advantage of complete and easy unloading. Unloading augers may be set on or under the cone-shaped concrete foundation. The cone provides additional storage capacity in the bin.

Below-grade cone-shaped foundations can only be used in areas of low water tables. If the water table rises to the level of the cone, water may enter the cone and cause grain spoilage. Cone-shaped bin foundations are well suited for use in westen Oklahoma and should be discouraged in eastern Oklahoma.

When only dry grain will enter the bin, a cone slope of 37° or 3 feet fall in a 4 feet run will allow complete unloading, if the concrete is given a smooth finish. When wet grain will be handled through the bin, the cone slope should be 45° or 1 foot fall in a run of 1 foot.

## Aeration Systems

A typical aeration system for a cone-bottom round grain bin is shown in Figure 1. Round metal ducts are used to distribute air in cone-bottom bins. The upper section of the duct is non-perforated with lower sections perforated. The bottom of the duct is usually open.

If a single duct does not have sufficient surface area to avoid excessive operating pressures, a second fan and duct are added as shown in Figure 1, with air volume divided between the two fans. In large bins, three or more fans and ducts are sometimes required to deliver high airflow rates. In general, centrifugal fans with backward-inclined blades are required to deliver efficient air volumes when operating against the higher static pressures encountered in cone-bottom bins.

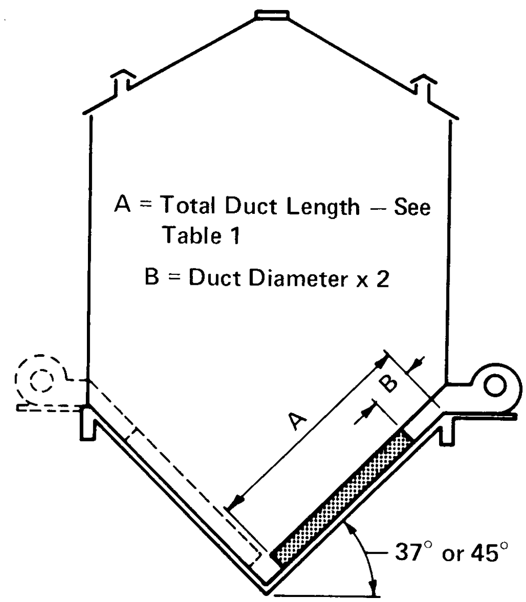



**Figure 1. Aeration system for a cone-bottom round grain bin.**

### Description of Terms

The following terms are used in the design procedure:

fpm = feet per minute, air velocity;
CFM = cubic feet of air per minute, air volume;
CFM/bu = cubic feet of air per minute per bushel, airflow rate; and static pressure is the pressure against which the fan must operate, expressed as inches of water.

### Design Procedure

The desgin procedure for aeration systems involves:

1. Determining bin capacity, selecting air-flow rate, and determining total air volume to be delivered.
2. Selecting ducts on the basis of surface area;
3. Determining operating static pressure; and
4. Selecting fans to deliver the required air volume when operating against the expected static pressure.

## Using Nomographs

Nomographs can simplify the design procedure. Answers are obtained by drawing straight lines On the nomographs instead of solving mathematical equations. Only a straight-edge and sharp pencil are required. While the nomographs may at first appear to be complicated, following the examples will quickly show their advantages.

## Determining Bin Capacity

Bin capacity is the number of bushels which can be stored in the bin plus the number which can be stored in the cone. The capacity of the bin less the cone is determined from Nomograph 1, and the capacity of the cone is given in Table 1. Bin capacity does not include storage in the roof section.

Consider a 30 feet diameter bin with 20 foot sidewalls and a 15° concrete cone shaped foundation. On Nomograph 1, if a straight line is drawn from 30 feet diameter (scale A) to 20 feet sidewall height (scale C), it crosses scale B at about 11,300 bu of bin capacity less cone capacity.

Table 1 gives the capacity of a 30 feet diameter, 45° cone as 2,820 bu. Total capacity, bin plus cone, is 14,120.

Table 1 also gives the maximum length of duct which may be placed down one side of the cone foundation for various bin diameter and the two cone slopes . The maximum length of a duct for a 30 feet diameter, 45˚ cone is 20 feet

As shown in Figure1, the air makes a turn when it leaves the fan and transition and enters the duct. This turning of the air is accompanied by an increase in static pressure in the initial section of the duct. For this reason, the initial section of the duct should be non-perforated for a distance equal to twice the duct diameter. Therefore, if a 12 inch diameter duct is to be used in our example bin, the maximum length of perforated duct is 18 feet. If an 18 inch diameter duct is to be used, the maximum length of perforated duct becomes 17 feet.

**Table 1. Capacities and Duct Lengths for Cone-Shaped Foundations.**

| | 45° Cones 1 in 1 Slope | | 37° Cones 3 in 4 Slope | |
|---|---|---|---|---|
| Bin Diameter (ft) | Capacity (bu) | Max. length of Duct (ft) | Capacity (bu) | Max. Length of Duct (ft) |
| 14 | 280 | 9 | 210 | 8 |
| 18 | 610 | 12 | 450 | 10 |
| 21 | 960 | 14 | 720 | 12 |
| 24 | 1440 | 16 | 1080 | 14 |
| 27 | 2060 | 18 | 1540 | 16 |
| 30 | 2820 | 20 | 2120 | 18 |
| 36 | 4880 | 24 | 3660 | 21 |
| 42 | 7750 | 28 | 5810 | 25 |

## Determining Air Velocity through the Grain

Nomograph 2 is used to determine total air volume and the air velocity through the grain when the desired airflow rate is known. The choice of airflow rate is an important decision. Higher aeration airflow rates give greater management flexibility and allow the storage of grain with higher moisture content. However, higher aeration airflow rates also require larger ducts, involve higher static pressures, and have greater power requirements. For a complete discussion of airflow rates, see F-1101.

Suppose we wish to provide an airflow rate of $^1/_3$ (.2) CFM/bu. for our example. On Nomograph 2, drawing a straight line from 14,100 bu. total capacity, bin plus cone (scale A), through $^1/_5$ CFM/bu. (scale B), and extending the line to scale C gives a total air volume of about 2,800 CFM.

On the same nomograph, drawing a line from 2,800 CFM air volume which we just determined on scale C through 30 feet bin diameter (scale 1), and extending the line to scale E, gives an air velocity through the grain of 4.0 fpm.

## Determining Operating Static Pressure Due to Grain Depth

Nomograph 3 is used to determine the static pressure due to grain depth when the grain depth or bin sidewall height and the air velocity through the grain. It is assumed the bin will be filled to the eaves, making grain depth and bin sidewall height equal. For example, drawing a line from 20 feet sidewall height (scale A), through 4 fpm air velocity (scale B) and extending the line to scales C and D gives static pressures due to grain depth of .6 inches for corn or soybeans and 2.1 inches for wheat, grain sorghum, oats, barley or rye.

## Determining Static Pressure due to Duct and Cone

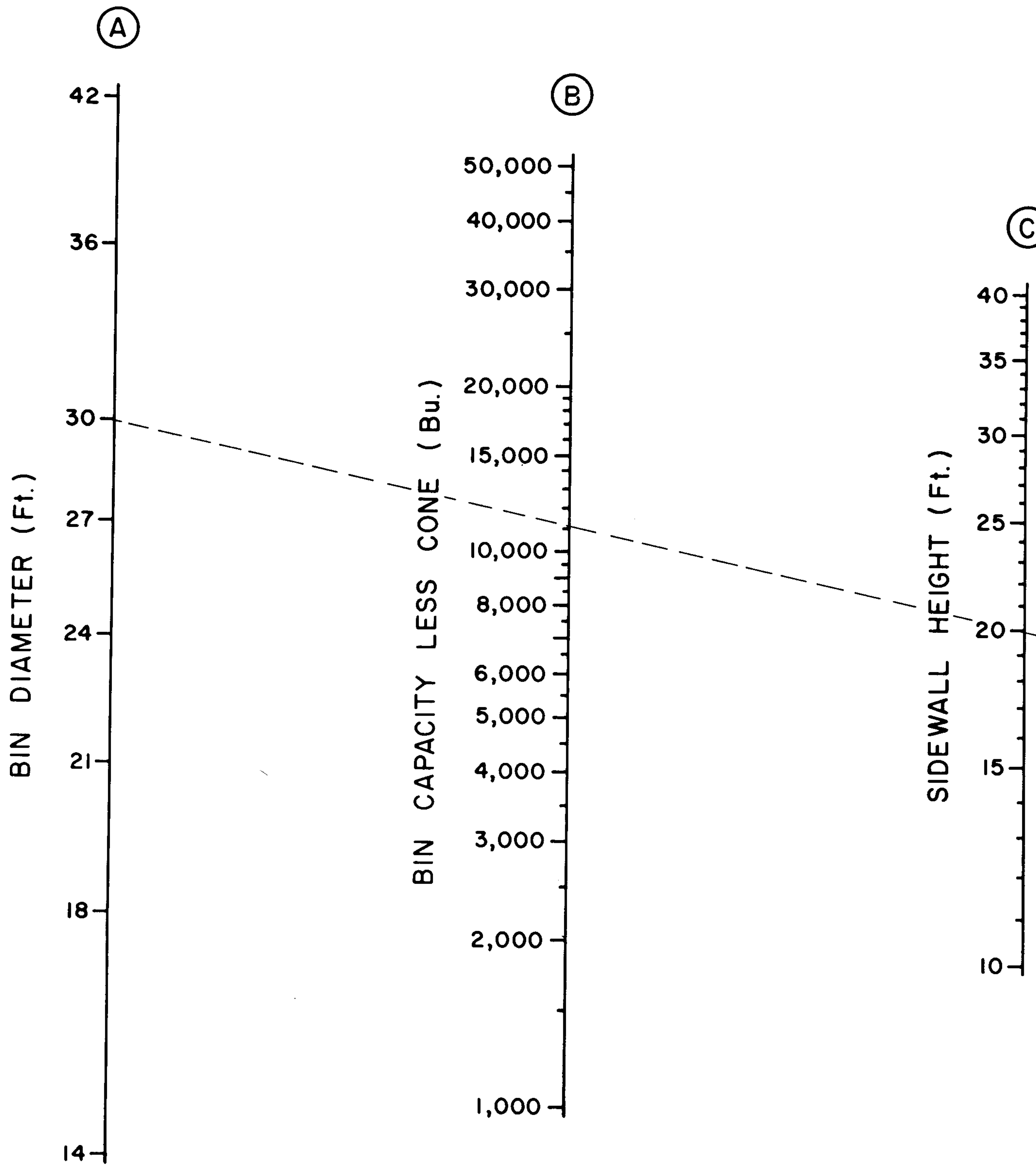
On Nomograph 4, drawing a straight line between 12-inch duct diameter (scale A) and 18 feet duct length (scale C) gives a duct surface area of 45 square feet on scale B. Then a second straight line is drawn from 45 square feet of surface area (scale B), through 2,800 CFM total air volume (scale D), and extended to scales E and F. From scale E, we determine 3.4 inches of static pressure due to duct and cone when corn or soybeans is the grain to be aerated. Scale F shows 7.1 inches of static pressure due to duct and cone when wheat, grain sorghum, oats, barley or rye is the grain.

Total static pressure is determined by adding static pressure due to grain depth to static pressure due to duct and cone. In our example, total static pressure is 4.0 (3.4 + .6) for corn or soybeans and 9.2 (7.1 + 2.1) for wheat, grain sorghum, oats, barley, or rye.When the bin will be used to store more than one grain, the grain which produces the highest static pressure should be used for design purposes.

The static pressure due to duct and cone can be reduced by choosing a larger diameter duct. Table 2 compares the results obtained for a 12-inch diameter duct with those obtained for 18- and 21-inch diameter ducts.

## Selecting Fans

Fans are selected from the manufacturer's rating curves or tables to deliver the required air volume when operating against the expected static pressure. Axial fans (propeher-type) are commonly used for aeration since they produce high air volumes at low static pressures. However, air volumes delivered by axial fans fall off rapidly as static pressures increase through the 3.5 to 5.0 inch range. Above this range, centrifugal fans with backward-inclined blades must be used.




**Nomograph 1. Bin capacity without the cone.**

**Table 2. Static Pressures and Power Requirements Resulting From Three Duct Diameters in the Example.**

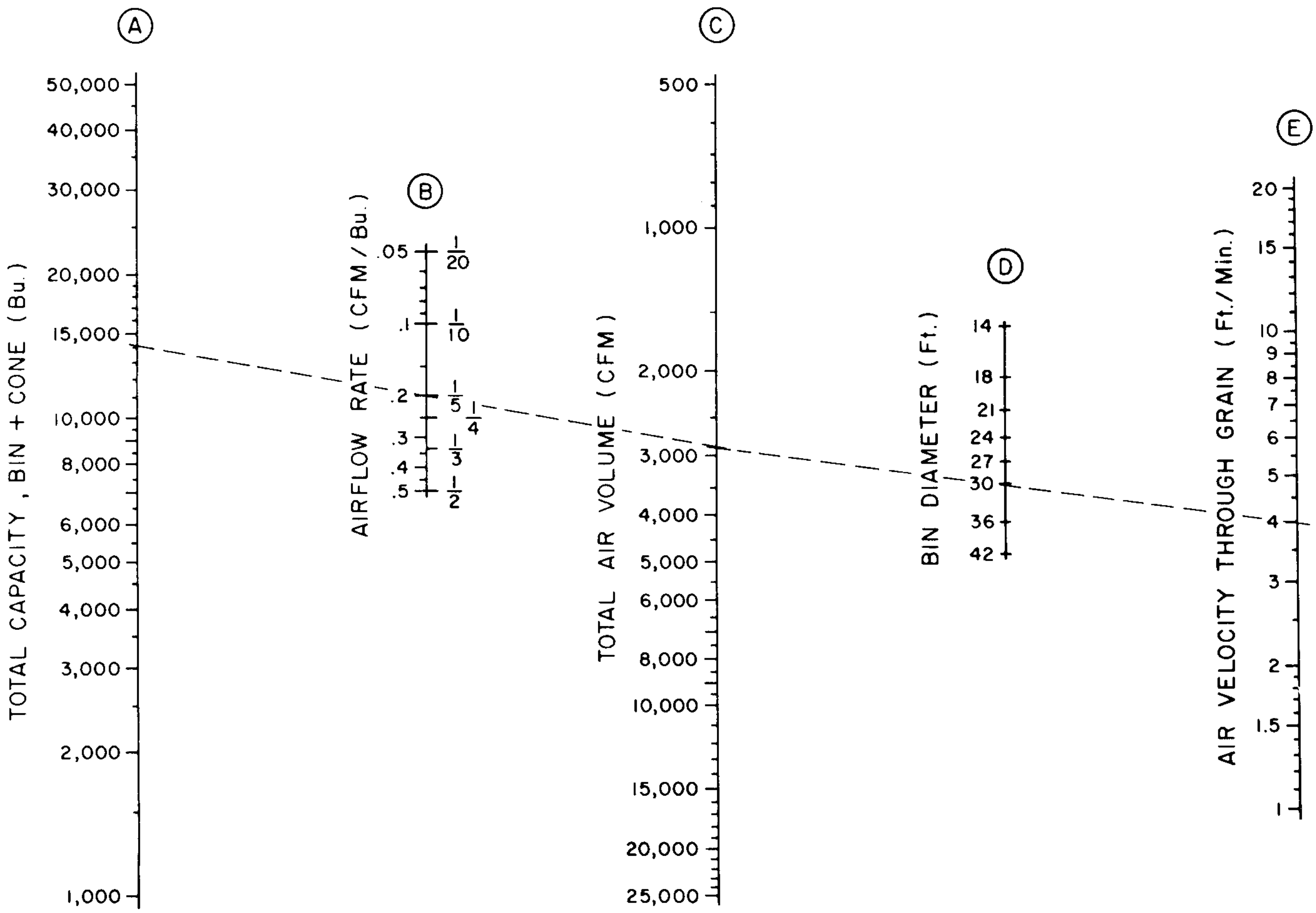
| | Duct Diameter (inches) 12 | 18 | 24 |
|---|---|---|---|
| Maximum Length of Perforated Duct (ft) | 18 | 17 | 16 |
| Static Pressure Due to Duct and Cone (inches of water) | | | |
| For Corn or Soybeans | 3.4 | 2.0 | 1.5 |
| For Wheat, Grain Sorghum, Oats, Barley, or Rye | 7.1 | 4.6 | 3.6 |
| Total Static Pressure (inches of water) (Nomograph 3 plus Nomograph 4) | | | |
| For Corn or Soybeans | 4.0 | 2.6 | 2.1 |
| For Wheat, Grain Sorghum, Oats, Barley, or Rye | 9.2 | 6.7 | 5.7 |
| Power Required assuming 50% Efficiency (Hp) | | | |
| For Corn or Soybeans | 3.5 | 2.3 | 1.9 |
| For Wheat, Grain Sorghum, Oats, Barley, or Rye | 8.1 | 5.9 | 5.0 |

In special designs, centrifugal fans wih operate efficiently at static pressures of 20 inches or more.

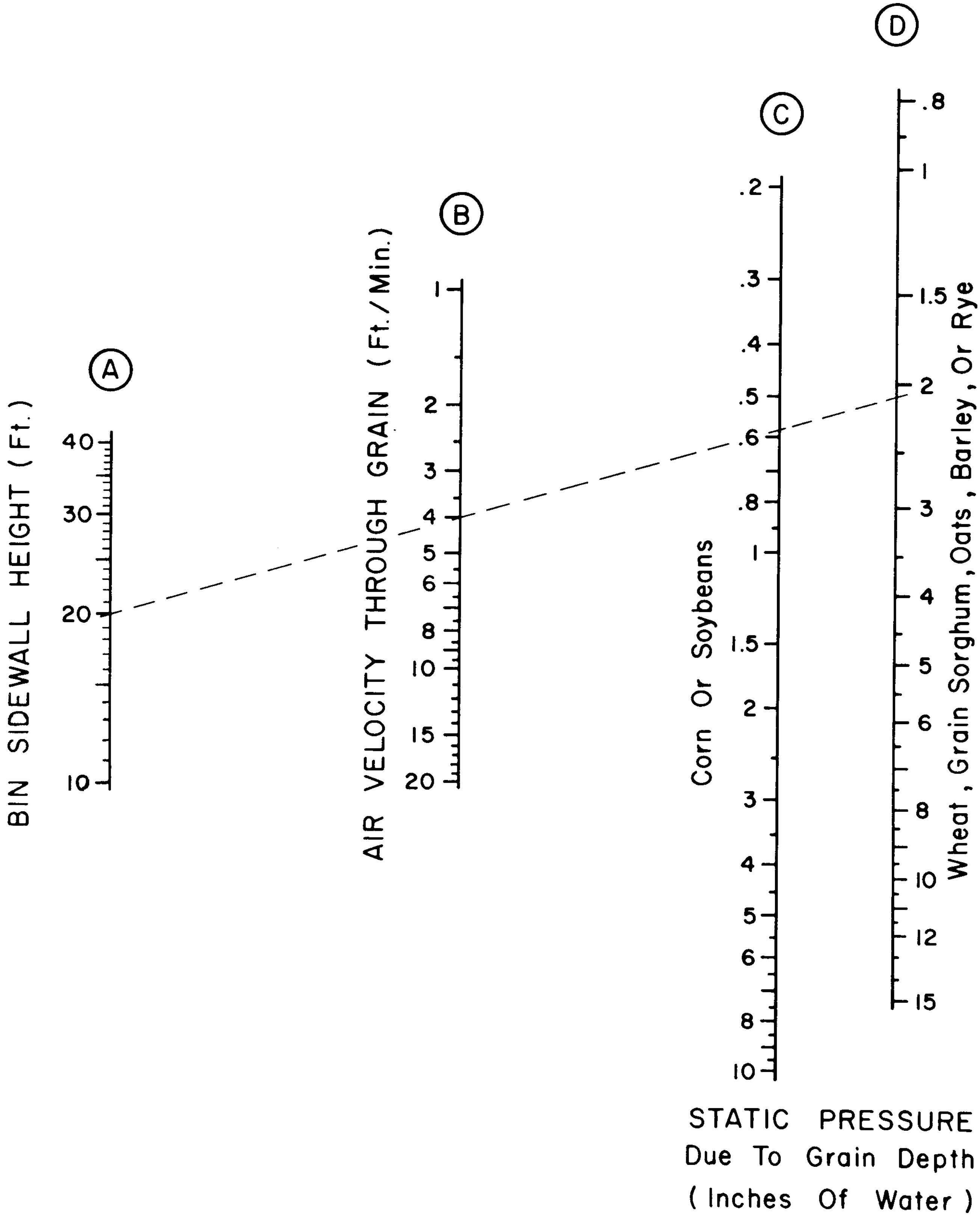
Centrifugal fans operate with less noise than axial fans and should be used whenever fan noise may be a nusiance to neighbors. Centrifugal fans of 3 Hp or less cost 2 to 3 times as much as axial fans of the same Hp rating. Above 5 Hp, centrifugal fans cost 1.5 to 2 times as much as axial fans of the same Hp rating.

The lowest priced fan which will deliver the required air volume when operating at the expected static pressure is, of course, the most economical fan to buy. However, the most economical fan to operate is the fan with the lowest power consumption, measured in watts, while delivering the required air volume at the expected static pressure. Nominal horsepower rating is not a good measure of power consumption.

While final fan selection must be made from manufacturer's data, an estimate of the power requirement may be helpful for planning purposes. Nomograph 5 is used to estimate the power requirement, assuming a fan efficiency of 50%. A straight line is drawn between air volume (scale A) and expected operating pressure (scale C) to determine the approximate power requirement on scale B.




**Nomograph 2. Total air volume and air velocity through the grain.**



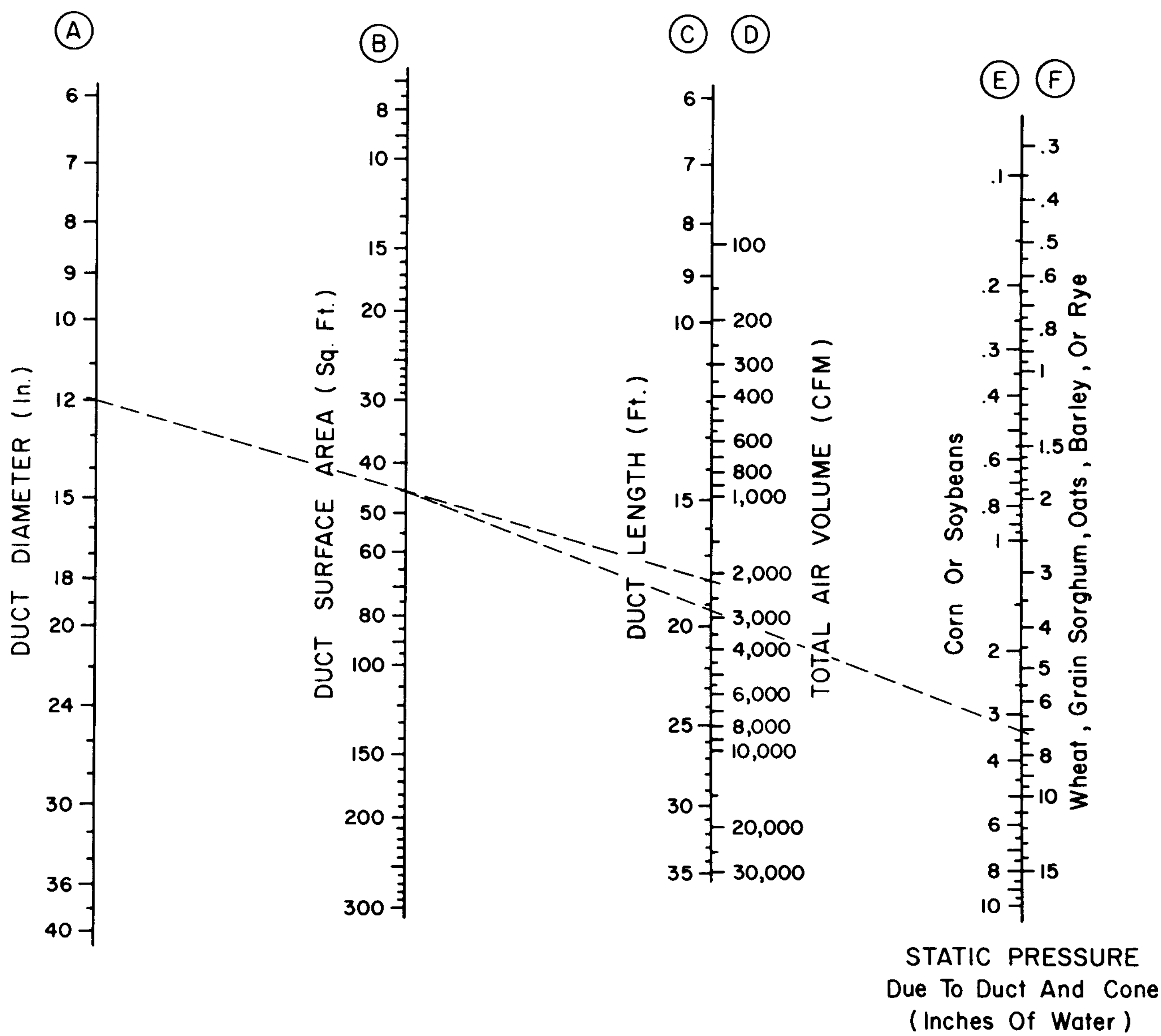

**Nomograph 3. Static pressure due to grain depth.**

Our example calls for an air volume of 2,800 CFM. If the operating pressure is 4.0 inches, the power requirement is about 3.5 Hp. If the operating pressure is 9.2 inches, the power requirement is about 8.1 Hp. Table 2 also compares the power requirements resulting from the use of a 12-inch diameter duct with those resulting from the use of 18- and 24-inch diameter ducts.

When selecting fans, consult the data from several manufacturers. Tables 3 and 4 present typical performance data for axial and centrifugal fans, respectively. One manufacturer's 3 Hp fan may be well matched to your needs while another's 3 Hp fan rnay not. Fan performance data should be certified in accordance,with standard test codes adopted by Air Moving and Conditioning Association, Incorporated and bear the AMCA seal.

**Table 3. Typical Fan Performance Data for Axial Fans.**

| | | Static Pressure (inches of water) | | | | | |
|---|---|---|---|---|---|---|---|
| Hp | RPM | 0.5 | 1.0 | 1.5 | 2.0 | 3.0 | 4.0 |
| | | CFM | | | | | |
| 1 | 3450 | 2,880 | 2,635 | 2,360 | 1,935 | 810 | 455 |
| 3 | 3450 | 7,000 | 6,400 | 5,700 | 5,200 | 3,700 | 2,200 |
| 5 | 3450 | 9,700 | 9,100 | 8,600 | 8,000 | 6,500 | 4,600 |
| $7^1/_2$ | 3450 | 12,800 | 12,300 | 11,600 | 11,000 | 9,800 | 7,400 |

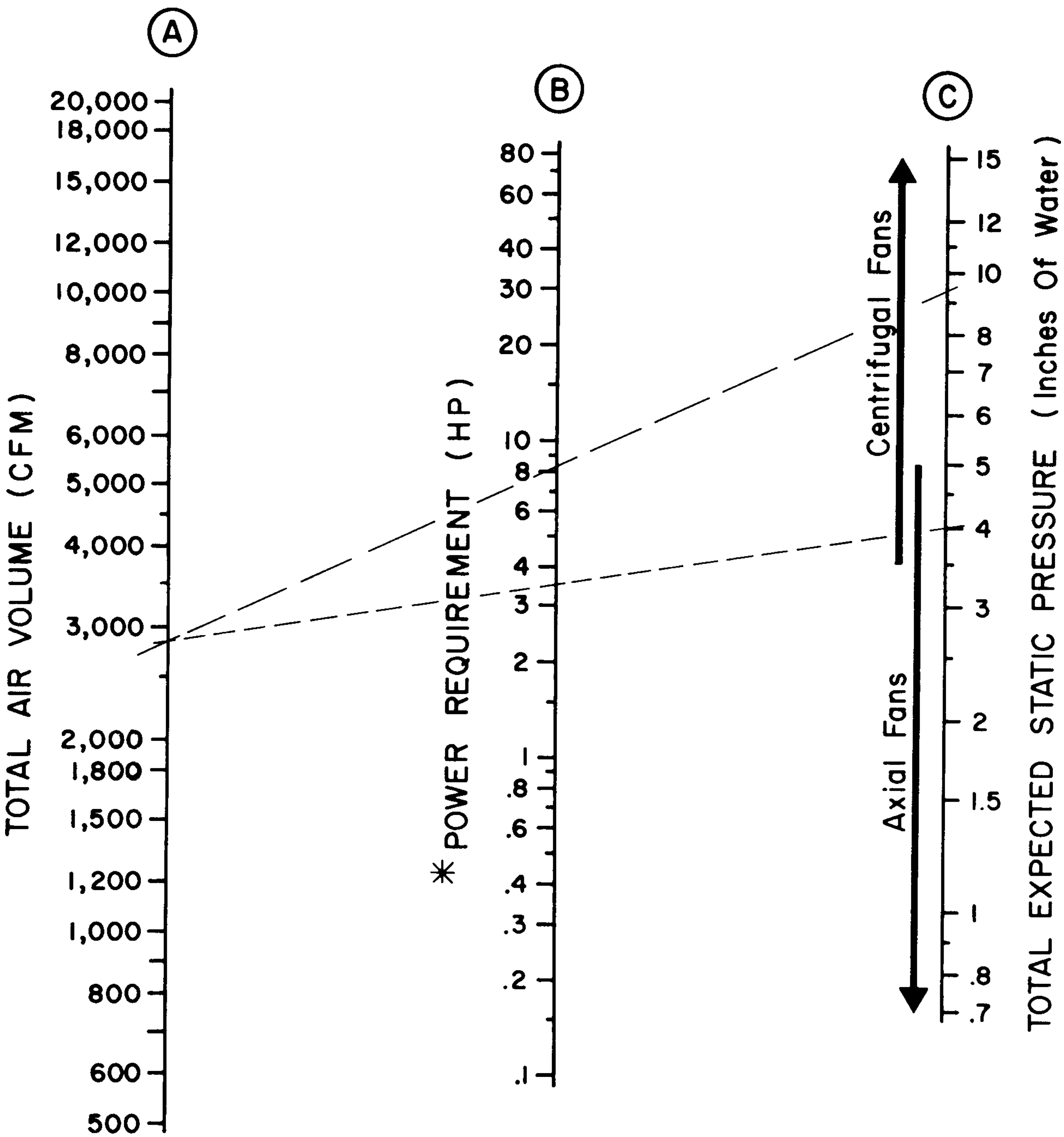



**Nomograph 4. Duct surface area and static pressure due to duct and cone.**

**Table 4. Typical Performance Data for a Centrifugal Fan***

| | Static Pressure (inches of water) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2.0 | | 4.0 | | 6.0 | | 8.0 | | 10.0 | | 12.0 | | 14.0 | |
| CFM | RPM | HP | RPM | HP | RPM | HP | RPM | HP | RPM | HP | RPM | HP | RPM | HP |
| 1520 | 1,364 | 1.15 | 1,753 | 1.96 | 2,064 | 2.77 | 2,332 | 3.60 | 2,574 | 4.47 | 2,794 | 5.37 | 3,000 | 6.30 |
| 2026 | 1,527 | 1.81 | 1,894 | 2.89 | 2,190 | 3.94 | 2,446 | 4.99 | 2,679 | 6.05 | 2,891 | 7.14 | 3,090 | 8.25 |
| 2532 | 1,708 | 2.72 | 2,050 | 4.07 | 2,334 | 5.40 | 2,584 | 6.71 | 2,805 | 8.01 | 3,010 | 9.30 | 3,204 | 10.6 |
| 3039 | 1,906 | 3.93 | 2,221 | 5.5 | 2,490 | 7.15 | 2,730 | 8.75 | 2,946 | 10.3 | 3,145 | 11.8 | 3,333 | 13.4 |

*This table is abbreviated. Intermediate static pressures and a much larger range of CFM values are normally shown.




**Nomograph 5. Approximate power requirement, assuming 50% efficency.**

## Further Examples

An aeration system is desired for a 24 feet diameter bin with 18 feet. sidewalls and 37˚ cone shaped foundation which will be used to store wheat. An airflow rate of $^1/_4$ (.25) CFM/bu is desired. Bin capacity is 7,580 bu or 6,500 bu. (Nomograph 1) plus 1,080 bu. (Table 1). maximum duct length is 14 feet

From Nomograph 2, total air volume is 1,900 CFM and air velocity through the grain is 4.2 fpm. The static pressure due to the 18 feet grain depth is 2.0 inches (Nomograph 3).

If an 18-inch diameter duct is selected, the maximum length of perforated duct is 11 feet since the upper 3 feet of duct much be unperforated. From Nomograph 4, duct is 11 feet since the upper 3 feet of duct and cone is 5.0 inches. Total expected static pressure then is 7.0 inches. From Nomograph 5 the approximate power requirement is to deliver 1,900 CFM at 7.0 inches of static pressure is 4.0 Hp.

As a final example, suppose a farmer wishes to provide $^1/_2$ (.5) CFM/bu. for quick cooling of damp corn during harvest. The bin is 27 feet in diameter, has 20 feet sidewalls and a 45˚ cone shaped foundation.

Total bin capacity is 11,260 bu. or 9,200 bu. (Nomograph 1) plus 2.060 bu. (Table 1). Maximum duct length is 18 feet (Table 1). From Nomograph 2, total air volume is 5,600 CFM and air velocity through the grain is 10 fpm. From Nomograph 3, the static pressure due to the 20 feet grain depth is 2.1 inches of water.

If an 18-inch diameter duct is selected, the maximum length of perforated duct is 15 feet From Nomograph 4, duct surface area is 56 square feet and the static pressure due to duct and cone is 6.6 inches of water. Total expected static pressure then is 6.6 inches of water plus 2.1 or 8.7 inches of water. The approximate power requirements to deliver 5,600 CFM at 8.7 inches of static pressure is 15 Hp (Nomograph 5).

If a 24-inch diameter duct is selected, the maximum length of perforated duct is 14 feet From Nomograph 4, duct surface area is 70 square feet and the dtatic pressure due to duct and cone is 4.8 inches of water. Total expected static preuure becomes 4.8 plus 2.1 or 6.9 inches of water. The approximate power requirment to deliver 5,600 CFM at 6.9 inches of static pressure is 12 Hp.

## Other Considerations

Aeration systems for cone-bottom bins must operate as pressure systems-blowing air upward through the grain. for a complete discussion, see F-1101.

There must be sufficient roof openings to allow the air to escape. The required air escape area, in square feet, is determined by dividing the total air volume by 1,500 fpm. If the bin roof is mounted off the sidewall, the slot under the eaves serves as air escape area. When additional area is required, roof vents should be installed until the air escape area requirement is met.

When aeration systems are operating, the unloading auger tube should be sealed to prevent an escape of air.

Smooth transitions should be used to connect fan outlets with duct inlets. Suden expansions and contractions should be avoided.



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