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G95-1242 Ventilation Fans: Performance

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Ventilation Fans: Performance

This publication describes how to use fan performance and system resistance data to achieve the desired effect and efficiency of a ventilation system.

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Many people perceive ventilation simply as a fan. However, effective ventilation of a livestock building or the aeration of stored grain requires a complete ventilation system.

A simple ventilation system may consist of fans to move the air, inlets or outlets for air distribution, and manual controls. More complex systems may include ducts, perforated floors, automatic controls, and other components. Regardless, all components must be carefully designed, selected, installed, managed, and maintained to achieve satisfactory results.

A fan is a mechanical device that uses energy inputs to move air, and can be thought of as the "heart" of a mechanical ventilation system. A basic understanding of fan performance is important when selecting and managing a mechanical ventilation system, regardless of the application.

Performance Terms and Fan Laws

Two terms used to describe fan performance are *airflow rate and static pressure*.

Airflow rate (frequently designated as Q) is the volume of air moved per unit of time. Airflow rate is usually expressed as cubic feet of air per minute (cfm), cubic meters of air per minute (m^3/min), or liters of air per second (l/s).

Static pressure (s.p.) defines the pressure or suction a fan is capable of developing. Static pressure

measures the resistance to airflow or how much pressure it takes to move air at a certain rate through a system. Static pressure is usually expressed as inches of water (in. H_2O) or millimeters of water (mm H_2O).

A fan is actually an air pump. As such, the theoretical performance of a fan follows certain basic laws of physics:

1. *Airflow rate (Q) varies directly with fan blade speed (rpm)*. For example, if fan speed is doubled, the amount of air moved will also double. If fan speed is reduced by one-half, the amount of air moved is also reduced by one-half. This is how airflow rate is changed with variable speed fans.
2. *Static pressure (s.p.) capability varies as the square of fan speed (rpm^2)*. This means that if fan speed is doubled, the pressure or suction that the fan can develop or the resistance against which the fan can operate is four times greater ($2^2 = 2 \times 2 = 4$). This is one reason many grain drying fans operate at high speeds.
3. Conversely, if the speed of a fan is reduced by one-half, the static pressure capability of the fan is reduced to one-fourth of its original value (1/2 x 1/2 = 1/4). This relationship illustrates a problem that can occur, particularly with variable speed exhaust fans. Wind blowing at a fan creates additional static pressure that the fan must work against. If the fan is operating at less than full speed, static pressure capabilities are often not sufficient to overcome this increased resistance, and airflow through the system is greatly reduced and/or becomes very erratic. With strong winds, air can flow backwards through the fan, even though the blades continue to rotate.

4. *Power (hp) required varies as the cube of fan speed (rpm^3)*. This means the power required to operate a fan is a function of the speed cubed or to the "third power." In practical terms, if the speed of a fan is doubled, the power required to operate the fan will be eight times greater ($2^3 = 2 \times 2 \times 2 = 8$). Conversely, if fan speed is reduced by one-half, the power will be reduced to one-eighth of the original value (1/2 x 1/2 x 1/2 = 1/8).

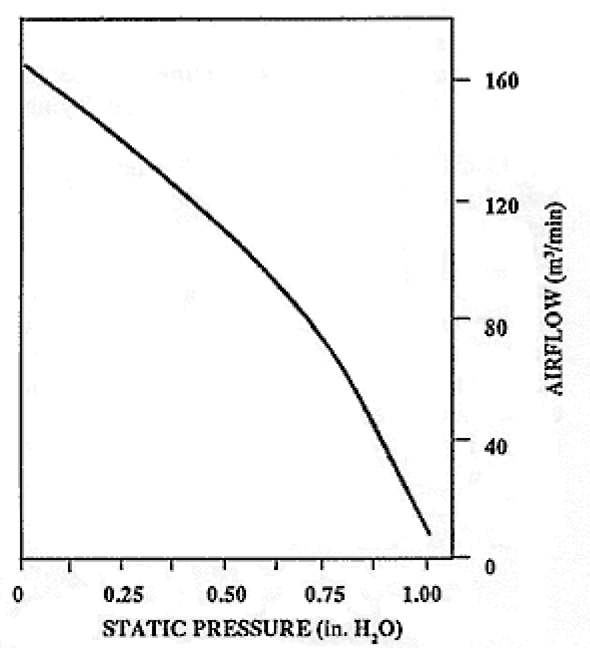

Figure 1. Fan performance curve (typical, for one fan)

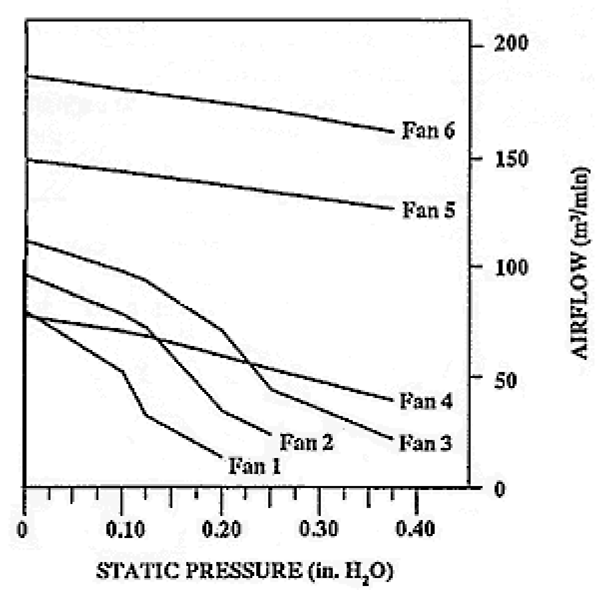

Figure 2. Performance curves for six 20-inch diameter propeller fans equipped with 1/4 hp motors.

The relationship between speed and power is frequently overlooked, and is a common reason for motor failure when pulleys are changed and a different size pulley is installed. A smaller pulley on the fan or a larger pulley on the motor will cause the fan blades to turn faster which greatly increases power requirements, often resulting in motor overload.

Fan Performance Data

Airflow rate and static pressure are closely related for both fans and ventilation systems. As the static pressure (resistance to airflow) increases, airflow rate decreases. Or, greater pressure is required to force a high volume of air through a ventilation system than to move a low volume through the same system.

The relationship between static pressure and airflow for a given fan can be represented by a tabulation of performance values or by a fan performance curve. Examples of these methods of data presentation for a specific fan are shown in *Table I* and *Figure 1*. The fan in this example has an airflow rate of 5,318 cfm when operating against a static pressure of 0.125 in. H_2O; but the airflow drops to 2,466 cfm when the static pressure is increased to 0.75 in. H_2O.

Table I. Tabulation of fan performance values.

Static pressure (in. H_2O)							
0	0.125	0.25	0.375	0.50	0.625	0.75	1.0
Airflow rate (cfm)							
5,756	5,318	4,870	4,372	3,864	3,287	2,466	389

Table II. Performance data for six, 20-inch diameter fans equipped with 1/4 hp motors.

	Static pressure (in. H_2O)					
Fan No.	**0**	**0.10**	**0.125**	**0.20**	**0.25**	**0.375**
Airflow rate (cfm)						
1	2,807	1,849	1,149	481	NR*	NR*
2	3,391	2,773	2,551	1,230	847	NR*
3	3,929	3,433	3,277	2,502	1,570	767
4	2,738	2,488	2,403	NR*	1,898	1,400
5	5,247	5,052	5,002	NR*	4,743	4,464
6	6,605	6,383	6,339	NR*	6,061	5,711
NR*--Performance not rated at this static pressure.						

Fan performance data are used to determine what airflow rate a fan will deliver when operating at or

against a given static pressure. Since the performance of fans can be very different, comparison of performance data for all makes or models being considered is imperative. As an illustration, performance data for six different fans are presented in *Table II*, and shown graphically in *Figure 2*. All these fans are 20 in. in diameter and equipped with 1/4 hp motors. At a static pressure of 0.125 in. H_2O, which would be typical for a livestock building ventilation system, airflow rates range from 1,149 to 6,339 cfm.

The most significant difference in these six fans is blade speed. Fans 1, 2, 3, and 4 have rotational speeds of 600 to 1,160 rpm and tip speeds from 3,140 to 4,400 feet/minute (fpm). Fans 5 and 6 have rotational speeds of 1,700 and 1,725 rpm, respectively, with tip speeds of 8,900 and 9,030 fpm. Despite their more consistent airflow with increasing static pressure ("flatter" performance curves), fans 5 and 6 would be considered undesirable for ventilating livestock buildings because of high noise levels. As a general rule, any fan with a tip speed in excess of about 4,500 fpm* is undesirable in livestock housing because of the noise. High speed fans are better for grain drying and aeration where greater static pressures are required and noise is often less of a concern.

The performance curve of a comparable variable speed fan operating at less than maximum speed will usually be even "steeper" than those shown in *Figure 2*, meaning that for a given increase in static pressure, airflow reductions will be even greater. In general, variable speed fans have an unpredictable airflow capacity except at maximum speed.

System Resistance Data

Each component of a ventilation system adds some resistance to airflow moving through the system. The fan must overcome this resistance. In a livestock building, inlet screens, exterior air inlets, baffled inlet slots, building space, fan safety screen, turbulence as air enters the fan, fan housing, fan blades, louvered shutters, and exterior weather hood all contribute to system resistance. Typically, system resistance, or static pressure, in a mechanically ventilated livestock building is about 0.10 to 0.125 in. H_2O.

Table III. Relationship between air speed and static pressure.

Airspeed					**Static Pressure**
mph		**fpm**			**(in. H_2O)**
5		440			0.012
10		880			0.048
15		1,320			0.108
20		1,760			0.195
25		2,200			0.302
30		2,640			0.432

In a grain bin, resistance to airflow occurs as the air enters and moves through the fan, transition duct, perforated floor, grain mass, and roof vents and/or hatches. The grain mass usually has the greatest influence except when grain depths are less than about 2 ft. Static pressures can vary greatly in grain drying or aeration systems, ranging from about 0.25 in. H_2O for low airflow rates and shallow grain depths, to 10 in. H_2O or more for high airflow rates and deep grain depths.

For any ventilation system, the resistance to airflow increases as greater airflow rates are moved through the system due to the air being moved at greater velocity which increases air turbulence. The influence of airspeed on static pressure is illustrated in *Table III*. Increasing air velocity two-fold will increase the static pressure due to air velocity four-fold.

Wind also creates static pressure which can affect ventilation system and fan performance (*Table III*). For example, if a 20 mph wind is blowing directly at the exhaust side of a ventilation fan, the fan must overcome an additional 0.195 in. H_2O static pressure. If the resistance of the ventilation system is 0.125 in. H_2O with no wind, then the total resistance becomes 0.320 in. H_2O (0.125 + 0.195 = 0.320). Most fans used to ventilate livestock buildings are not capable of developing a static pressure of this magnitude. In all cases, airflow rate will decrease because of the increased pressure. Weather hoods and/or windbreaks can reduce the influence of wind on fan performance.

The relationship between airflow rate and static pressure for a ventilation system can be represented by a system resistance curve similar to the one shown in *Figure 3*. For grain drying and/or aeration systems, this information is usually available from the manufacturer or from some computer programs.

Fans and Systems

To achieve satisfactory performance of the total ventilation system, fan performance must be matched to the system resistance. This can be done by combining the fan performance curve and the system resistance curve as illustrated in *Figure 4*. The intersection of these two curves (point A) determines the operating conditions of the overall ventilation system. In this example, the fan must operate against a static pressure of 0.48 in. H_2O (point B) while delivering an airflow rate of 3,900 cfm (point C) through the total system. For a given fan and system, there is always a unique set of operating conditions. Changing the fan and/or changing some other component of the system results in a new set of operating conditions. This is especially true in grain drying bins, where system performance changes markedly with grain depth. *Figure 5* shows performance curves for two fans and resistance curves for two systems. Selected operating conditions are tabulated in *Table IV*.

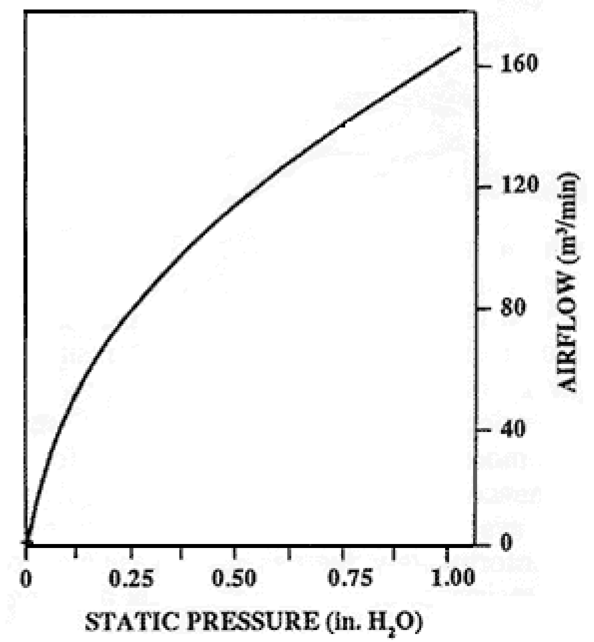

Figure 3. Ventilation system resistance curve (typical, for one system).

Table IV. Tabulation of operating conditions illustrated in Figure 5.			
Fan No.	**System No.**	**Static Pressure (in. H_2O)**	**Airflow (cfm)**
1	1	1.7	5,500
1	2	1.2	6,050
2	1	3.6	8,600
2	2	2.7	10,200

The system resistance curves in *Figure 5* could represent a 30-foot diameter natural air corn drying bin. System 1 is for a grain depth of 25 feet and System 2 is for a grain depth of 13 feet. Fan 1 is a typical 3 horsepower tube-axial fan and Fan 2 is a 10 horsepower model. For each fan, it is apparent that as the system resistance (or grain depth) increases, the airflow rate decreases. Also, for the same system (System 1), it can be seen that even though the fan horsepower was 3.3 times greater for Fan 2 than for Fan 1, the airflow only increased 1.6 times, from 5,500 cfm to 8,600 cfm. Because of the fan laws, a given change in fan horsepower does not result in the same magnitude of airflow change.

By using fan performance and system resistance curves, two or more designs can be compared for their overall performance. As noted, fan performance and grain drying or aeration system data are usually available from the manufacturer. Unfortunately, there is not an easy way to predict the system resistance curve for a livestock building ventilation system. Consequently, unless ducts or other special components are a part of the ventilation system, overall system resistance is usually assumed to be 0.10 to 0.125 in. H_2O, and fans are selected based on their airflow capabilities at one of these static pressures. Air inlets are adjusted to control air velocities at the inlet and to maintain static pressure in the desired range, thus achieving the desired airflow rate. Inlet velocities typically range from 500 to 1,500 feet per minute. The appropriate velocity depends on weather conditions, desired interior conditions, design of the inlet system, and arrangement of the animal space within the building.

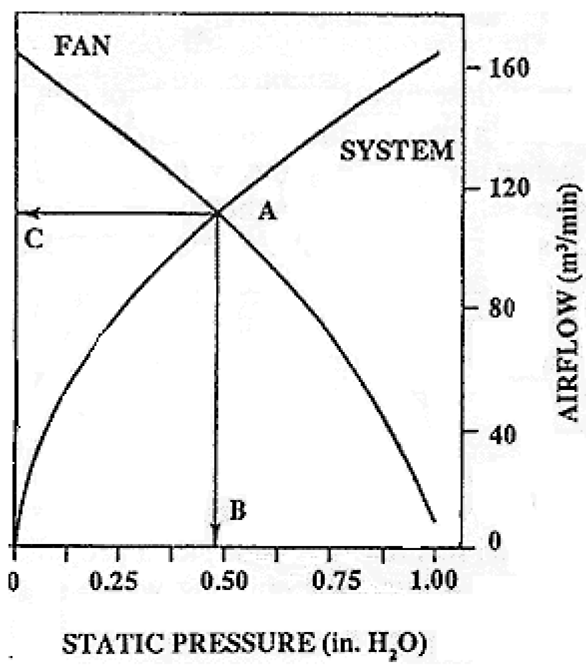

Figure 4. Fan performance and system resistance curves (typical, for one fan and one system).

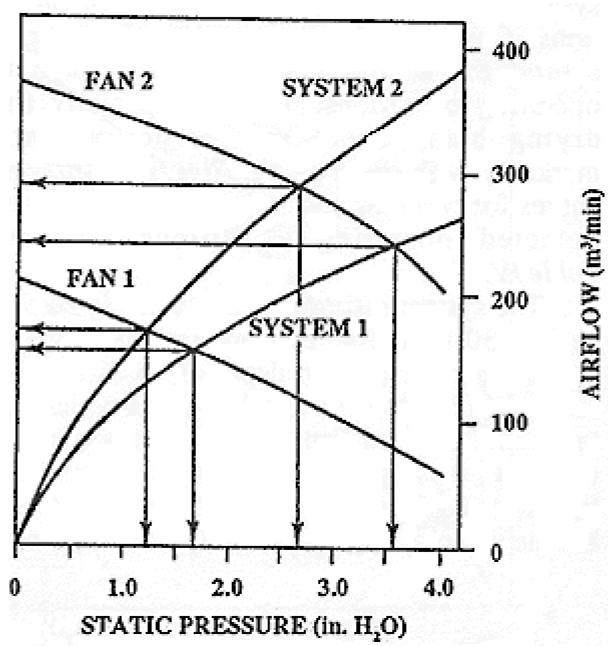

Figure 5. Fan performance and system resistance curves for two fans and two systems (typical).

A fan must be matched to the overall system to achieve the desired results. For example, a propeller fan is usually suitable for a livestock building where static pressures are relatively low, but a centrifugal fan may be required for a grain drying application due to the higher static pressure requirements. As a general rule, a propeller fan is adequate for static pressures less than about 0.5 in. H_2O. For static pressure between 0.5 and 3.5 in. H_2O either a tube-axial or vane-axial fan is best, and for static pressures over about 4.0 in. H_2O, a centrifugal ("squirrel cage") fan is usually most efficient. System resistance data, if available, can be used to help make this selection.

Certified Ratings

The sole function of a fan is to move air. To meet design objectives, the ability of a fan to move air under design conditions must be known. Many manufacturers have their fans rated by a standard test procedure certified by the Air Movement and Control Association (AMCA), an independent testing laboratory.

A recommended practice is to buy only fans bearing an AMCA "Certified Rating" seal. Fans having an AMCA seal are more certain to perform in accordance with information printed in the manufacturer's literature. All AMCA rated fans have a blue and gold seal, similar to the one shown in *Figure 6*, attached to the fan housing. The AMCA "Certified Rating" seal assures that airflow from the fan, under test conditions, is not less than the manufacturer's claims, although it may be greater.

Figure 6. AMCA "Certified Rating" Seal.

Testing fan performance is difficult and requires precision testing facilities and equipment if accurate performance data are to be derived. However, a technique developed by one of the authors to estimate fan capacity in field installations has shown the estimated performance of AMCA rated fans to generally be within 10 percent of the specifications listed in the manufacturer's literature. The estimated performance of many non-AMCA rated fans has differed from the manufacturer's literature by as much as 50 percent. To help assure reliable performance and a sound investment, buy only AMCA rated fans.

Summary

Fan performance and system resistance data are essential for fan selection and to determine how a ventilation system will perform. Fan performance data should be certified by the Air Movement and Control Association (AMCA).

For additional information on ventilation fans, refer to *NebGuides G95-1243, Ventilation Fans: Types and Sizes, and G95-1244, Ventilation Fans: Efficiency and Maintenance*, available from the Cooperative Extension office serving your area.

*fpm = 0.26 x fan diameter (in.) x fan speed (rpm).

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