Fan Fundamentals

GREENHECK
Building Value in Air.

Introduction to FAN SELECTION

This is a guide to the most basic fan sections, all of which enable you to select the right fan for the job. It will answer the following questions *(and more)*:
- *What is a SONE?*
- *How are model numbers and performance tables used to select a fan?*
- *How are direct drive and belt driven fans different?*
- *What types of motors are used with these fans?*

The goal is to understand and use the Greenheck literature as an important tool in filling a customer's fan order.

TERMS	
cfm	**Cubic Feet Per Minute.** A measure of airflow.
Ps	**Static Pressure.** Resistance to airflow measured in inches of water gauge.
sone	**A measure of loudness.** One sone can be approximated as the loudness of a quiet refrigerator at a distance of 5 feet. Sones follow a linear scale, that is, 10 sones are twice as loud as 5 sones.
Bhp	**Brake Horsepower.** A measure of power consumption. Used to determine the proper motor horsepower and wiring.
hp	**Horsepower.** Used to indicate a fan's motor size.
rpm	**Revolutions Per Minute.** Measure of fan speed.
TS	**Tip Speed.** The speed of the tip of a fan wheel or prop measured in feet per minute.
AMCA	**Air Movement & Control Association.** A nationally recognized association which establishes standards for fan testing and performance ratings. AMCA also license air volume and sound certified ratings.

MODEL DESIGNATION

For Greenheck belt drive models, the model designation tells the model type, size and the motor hp.

EXAMPLE: GB-090-6

Model is GB — hp is 1/6
Nominal Wheel Dia. 9 in.

For direct drive units, the model designation tells the model type, the size and the motor/fan rpm.

EXAMPLE: G-121-B

Model is G — rpm is 1140
Nominal Wheel Dia. 12 in.

BELT DRIVE		DIRECT DRIVE	
Suffix	Motor hp	Suffix	Fan rpm
6	1/6	A	1725
4	1/4	B	1140
3	1/3	C	860
5	1/2	D	1550
7	3/4	G	1300
10	1	E	1050
15	1 1/2	F	880
20	2	P	1625
30	3		
50	5		
75	7 1/2		

This table lists model designation suffixes for motor horsepower and fan rpm.

MOTOR INFORMATION (Belt Drive Only)

When specifying a belt drive fan, the model designation does not completely describe the unit. Additional information about the motor is necessary. These items are listed below:

MOTOR ENCLOSURE
This will be either "Open" (open, drip proof), "TE" (totally enclosed) or "EXP" (explosion-resistant). Open is the most common and will be supplied unless otherwise specified.

DIRECT DRIVE

Selection of direct drive fans (those with the motor shaft connected to the fan wheel or propeller) is nearly the same as belt drive selection. However, **there are two differences worth noting.** Where belt drive fan speed can be altered by adjusting the motor pulley, direct drive fans (since they have no pulleys) must use a different method.

1. To adjust a direct drive fan's speed (also motor speed) or to provide a means of meeting an exact performance requirement, a speed control can be furnished. Speed controls vary the voltage supplied to the fan and slow it down; a principle similar to the way dimmer light switches work.

2. Models CUE and CW, sizes 060-095 and Model SQ, sizes 60-95, are provided with 115 volt, 60 cycle motors.

SPEEDS
Motors are available in either single-speed or two speed. Single-speed motors are 1725 rpm. Two speed motors will be 1725/1140 rpm. Single-speed will be supplied unless otherwise specified.

ELECTRICAL CHARACTERISTICS
Voltage and phase. Voltage can be 115, 208, 230 or 460. Phase is either single-or 3 phase. A 115 volt, single-phase motor is shown as 115/1. Typically, motors of 1/2 hp and less are single-phase. Motors of 3/4 hp and greater are 3 phase.

TYPICAL MOTOR TAG - Electrical Instructions		
Suffix Letter	Motor Speed	Wiring Connections
D	1550 rpm	White to L1 Black to L2
G	1300 rpm	White to L1 Blue to L2
E	1050 rpm	White to L1 Red to L2

The three speeds are 1550 rpm (D), 1300 rpm (G) and 1050 rpm (E). Changing a motor lead is all that is necessary to change speeds. When selecting a model with a 3 speed motor, it is recommended that the G speed be chosen whenever possible. This is the middle speed, which gives the greatest flexibility in air volume because airflow can be increased or decreased simply by changing a motor lead.

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MOTOR HORSEPOWER

The motor horsepower for direct drive fans is always sized by Greenheck and does not require further consideration. For belt drive models, the catalog identifies which horsepower is recommended. However, there are times when it is wise to bump the horsepower one size. For example, the hp recommended for the GB-180 at 810 rpm (2375 cfm @ .5” Ps) is 1/3 hp.

Although a 1/3 hp motor is recommended, it is not necessarily a good motor selection for this application. Our static pressure of 0.5 in. was only an estimate. It may actually turn out to be .625 in.

If this is the case, we will need a 1/2 hp motor because our fan will have to run at almost 810 rpm (refer to performance box - 2052 cfm at 0.625 in. Ps). Therefore, choosing a 1/2 hp motor in this case is exercising good judgement.

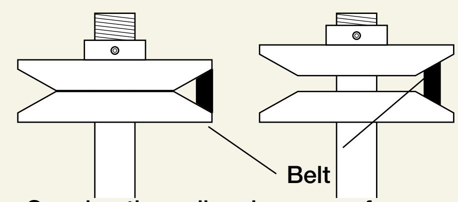
The complete model designation for this application is GB-180-5.

NOTE: The GB-180-5 has an rpm range of 700-940. This means that if the static pressure is less than estimated, say 0.25 in. Ps, the fan can be slowed down to accommodate this condition.

BELT DRIVE

One advantage of choosing a belt drive over a direct drive is that it is capable of adjusting the fan rpm, which enables the fan to move more air if necessary.

Motor pulleys are adjusted by loosening the set screw and turning the top half of the pulley (see illustrations at right). This causes the pulley diameter to change, which results in changing the fan rpm.



Opening the pulley decreases fan rpm.
Closing the pulley increases fan rpm.

APPLICATIONS

Ventilating a building simply replaces stale or foul air with clean, fresh air. Although the ventilation process is required for many different applications, the airflow fundamentals never change:

UNDESIRED AIR OUT, FRESH AIR IN

The key variables that do change depending on applications are the fan model and the air volume flow rate (cfm). Other considerations include the resistance to airflow (static pressure or Ps) and sound produced by the fan (Sones).

Occasionally, a customer will require a fan to perform a particular function, yet does not know which model to use or even what cfm is necessary. In this case, some fan specification work must be done.

Fan specification is usually not a precise science and can be done confidently when the fan application is understood.

Based on the application, four parameters need to be determined. They are:

Fan Model

Cubic Feet per Minute (cfm)

Static Pressure (Ps)

Loudness limit (sones)

The information that follows will help walk you through this type of problem and enable you to select the right fan for the job.

FAN MODEL

Fans all perform the basic function of moving air from one space to another. But the great diversity of fan applications creates the need for manufacturers to develop many different models. Each model has benefits for certain applications, providing the most economical means of performing the air movement function. The trick for most users is sorting through all of the models available to find one that is suitable for their needs.

PROPELLER vs. CENTRIFUGAL WHEEL

Propeller fans provide an economical method to move large air volumes (5,000+ cfm) at low static pressures (0.50 in. or less). Motors are typically mounted in the airstream which limits applications to relatively clean air at maximum temperatures of 110°F.

Centrifugal fans are more efficient at higher static pressures and are quieter than propeller fans. Many centrifugal fan models are designed with motors mounted out of the airstream to ventilate contaminated and high temperature air.

DETERMINING CFM

After the model is known, the cfm must be determined. Consult local code requirements or the table below for suggested air changes for proper ventilation.

The ranges specified will adequately ventilate the corresponding areas in most cases. However, extreme conditions may require “Minutes per Change” outside of the specified range. To determine the actual number needed within a range, consider the geographic location and average duty level of the area. For hot climates and heavier than normal area usage, select a lower number in the range to change the air more quickly. For moderate climates with lighter usages, select a higher number in the range.

To determine the cfm required to adequately ventilate an area, divide the room volume by the appropriate “Minutes per Change” value.

SUGGESTED AIR CHANGES FOR PROPER VENTILATION

$$\text{cfm} = \frac{\text{Room Volume}}{\text{Min./Chg.}} \qquad \text{Room Volume} = L \times W \times H \text{ (of room)}$$

Area	Min./Chg.	Area	Min./Chg.	Area	Min./Chg.
Assembly Hall	3-10	Dance Hall	3-7	Machine Shop	3-6
Attic	2-4	Dining Room	4-8	Mill	3-8
Auditorium	3-10	Dry Cleaner	2-5	Office	2-8
Bakery	2-3	Engine Room	1-3	Packing House	2-5
Bar	2-4	Factory	2-7	Projection Room	1-2
Barn	12-18	Foundry	1-5	Recreation Room	2-8
Boiler Room	1-3	Garage	2-10	Residence	2-6
Bowling Alley	3-7	Generator Room	2-5	Restaurant	5-10
Cafeteria	3-5	Gymnasium	3-8	Restroom	5-7
Church	4-10	Kitchen	1-5	Store	3-7
Classroom	4-6	Laboratory	2-5	Transfer Room	1-5
Club Room	3-7	Laundry	2-4	Warehouse	3-10

SAMPLE PROBLEM

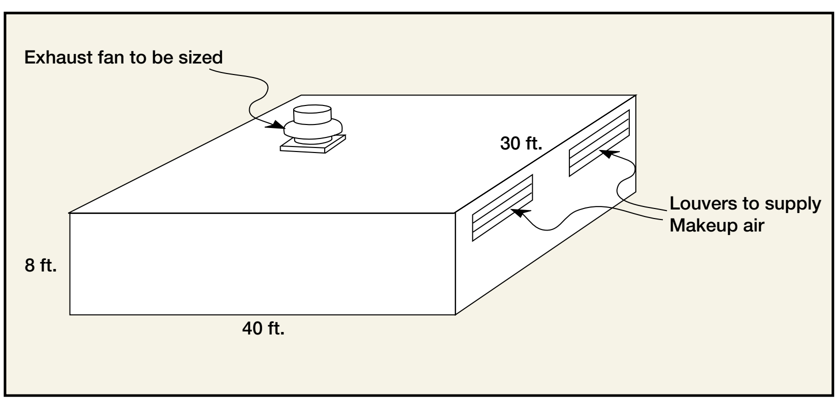
A building requires an exhaust fan to ventilate a general office (see diagram below) which measures 30 ft. x 40 ft. x 8 ft. The office is often crowded.

SOLUTION:
The total room volume is 30 ft. x 40 ft. x 8 ft. = 9600 cubic feet. From the chart, the range for general offices is 2-8 minutes per change. Since the office has heavier than normal usage, 4 minutes per change is recommended. Therefore, the required exhaust is:

$$\frac{9600 \text{ ft}^3}{4 \text{ min.}} = 2400 \text{ cfm}$$

Since the air to be exhausted is relatively clean, this is an ideal application for a model GB fan.

NOTE: In this example, make-up air was provided through a set of louvers at the wall farthest from the exhaust fan. If there were no provisions for make-up air in this room, a supply fan would also have to be sized. The supply cfm should equal the exhaust cfm. Supply fan location should be as far as possible from the exhaust fan.



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DETERMINING STATIC PRESSURE (Ps)

The pressures generated by fans in ductwork are very small. Yet, accurately estimating the static pressure is critical to proper fan selection.

Fan static pressure is measured in inches of water gauge. One pound per square inch is equivalent to 27.7 in. of water gauge. Static pressures in fan systems are typically less than 2 in. of water gauge, or 0.072 Psi. The drawing below illustrates how static pressures are measured in ductwork with a manometer.

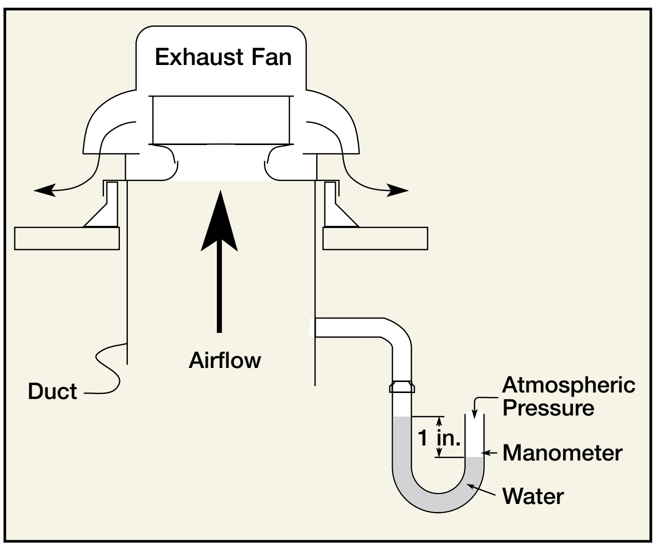
A pressure differential between the duct and the atmosphere will cause the water level in the manometer legs to rest at different levels. This difference is the static pressure measured in inches of water gauge.

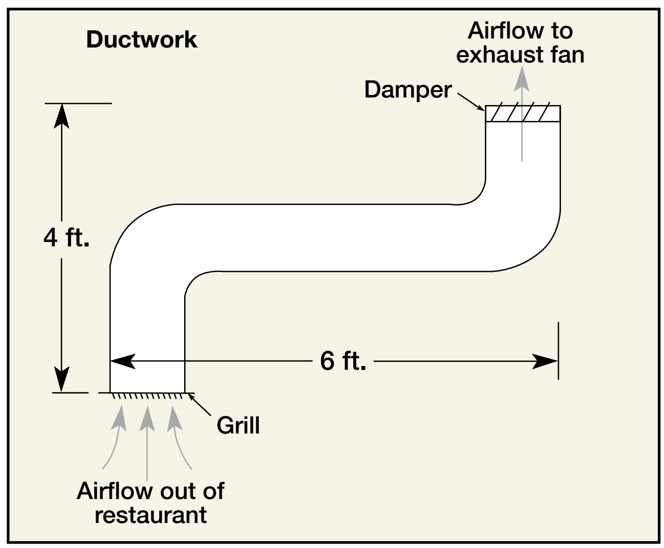
In the case of the exhaust fan below, the air is being drawn upward through the ductwork because the fan is producing a low pressure region at the top of the duct. This is the same principle that enables beverages to be sipped through a straw.

The amount of static pressure that the fan must overcome depends on the air velocity in the ductwork, the number of duct turns (and other resistive elements), and the duct length. For properly designed systems with sufficient make-up air, the guidelines in the table below can be used for estimating static pressure:

STATIC PRESSURE GUIDELINES	
Nonducted	0.05 in. to 0.20 in.
Ducted	0.2 in. to 0.40 in. per 100 feet of duct (assuming duct air velocity falls within 1000-1800 feet per minute)
Fittings	0.08 in. per fitting (elbow, register, grill, damper, etc.)
Kitchen Hood Exhaust	0.625 in. to 1.50 in.

IMPORTANT! Static pressure requirements are significantly affected by the amount of make-up air supplied to an area. Insufficient make-up air will increase static pressure and reduce the amount of air that will be exhausted. Remember, for each cubic foot of air exhausted, one cubic foot of air must be supplied.





To calculate the system losses, one must know the ductwork system configuration *(see Ductwork figure)*.

This duct is sized for air velocities of 1400 feet per minute. Referring to the static pressure chart, that will result in about 0.3 in. per 100 feet. Since we have 10 feet of total ductwork, our pressure drop due to the duct is:

$$\frac{.3 \text{ in.}}{100 \text{ ft.}} \times 10 \text{ ft.} = .03 \text{ in.}$$

There is also a 0.08 in. pressure drop for each resistive element or fitting. For this example, there are 5 fittings: one grill, two duct turns, one damper and louver in the wall of the office. The total pressure drop for fittings is:

$$5 \times 0.08 \text{ in.} = 0.4 \text{ in.}$$

Therefore, the total pressure drop is:

$$0.03 \text{ in.} + 0.40 \text{ in.} = 0.43 \text{ in.}^*$$

** **NOTE:** For convenience in using selection charts, round this value up to the nearest 1/8 in., which would be 0.50 Ps.*

FAN LAWS

In a steady-state system, as the fan rpm changes, cfm, Ps and BHp (horsepower) also change. The equations below, known better as fan laws, show the relationship between these performance parameters.

NOTE: A 25% increase in rpm results in a 95% increase in horsepower. Considering this, initial fan selections should be sized with motor horsepowers greater than necessary if any increase in fan rpm is likely in the future.

$$cfm_{New} = \left(\frac{rpm_{New}}{rpm_{Old}}\right) \times cfm_{Old}$$

$$Ps_{New} = \left(\frac{rpm_{New}}{rpm_{Old}}\right)^2 \times Ps_{Old}$$

$$Bhp_{New} = \left(\frac{rpm_{New}}{rpm_{Old}}\right)^3 \times Bhp_{Old}$$

This equation relates horsepower to rpm. The change in horsepower can be determined when the rpm is increased by 25%. This is shown below:

$$Bhp_{New} = (1.25)^3 \times Bhp_{Old} = 1.95 \times Bhp_{Old}$$

ADJUSTING FAN PERFORMANCE

There is a direct relationship between cfm and rpm within a system. Doubling the fan rpm will double-the cfm delivered.

Sample: The example at the right shows a fan curve at 700 rpm which had an operating point of 1000 cfm at 0.25 in. Ps. What rpm is required to move 2000 cfm through the same system?

Solution: Within a system, cfm is directly related to rpm. Therefore, the new rpm (rpm_2) can be determined from the following equation:

$$rpm_2 = rpm_1 \times \left(\frac{cfm2}{cfm1}\right)$$

$$= 700\text{ rpm} \times \left(\frac{2000\text{ cfm}}{1000\text{ cfm}}\right) = 1400\text{ rpm}$$

Referring to figure at right, this results in sliding up the system resistance curve from 700 rpm to 1400 rpm. Notice that as we doubled our airflow from 1000 cfm to 2000 cfm, the Ps went up from 0.25 in. to 1.0 in. It must be kept in mind that we are not changing the system, only increasing fan speed. Therefore, we must remain on the system resistance curve. Within a system, Ps varies as the square of cfm. Since cfm and rpm are directly proportional, an equation relating Ps and rpm can be derived as follows:

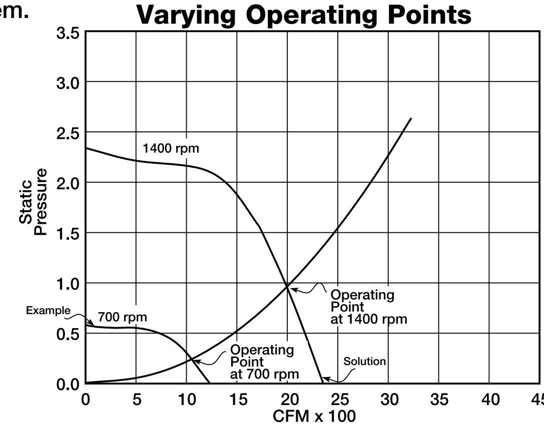
$$Ps_2 = Ps_1 \times \left(\frac{rpm2}{rpm1}\right)^2$$

For our example,

$$Ps_2 = 0.25\text{ in.} \times \left(\frac{1400\text{ rpm}}{700\text{ rpm}}\right)^2 = 1.0\text{ in.}$$

This verifies the operating point on the 1400 rpm curve (2000 cfm at 1.0 in. Ps). With this example, it should be clear how cfm, rpm and Ps tie together in a steady-state system.

Varying Operating Points



SOUND LEVELS

In many cases, the sound generated by a fan must be considered. For the fan industry, a common unit for expressing sound pressure level is the sone. In practical terms, the loudness of one sone is equivalent to the sound of a quiet refrigerator heard from five feet away in an acoustically average room.

Sones are a linear measurement of sound pressure levels. For example, a sound level of 10 sones is twice as loud as 5 sones.

Refer to the Suggested Limits for Room Loudness chart to determine the acceptable sone range for the application. As a general guideline, choose a fan that has a sone value within the range specified.

NOTE: Rooms with a hard construction (concrete block, tile floors, etc.) reflect sound. For these rooms, select fans on the lower end of the range. Rooms with soft construction or those with carpeting and drapes, etc., absorb sound. For these rooms, fans near the higher end of the range may be selected.

For example, an exhaust fan for an office in the "Suggested Limits for Room Loudness" chart below says that offices should have a loudness range from 4 to 12 sones. Comparing a GB-141, GB-161 and GB-180 fan for approximately 3100 cfm at 0" Ps only the GB-180 has a sone value of less than 12. Therefore, the GB-180 is the best selection for this application.

SUGGESTED LIMITS FOR ROOM LOUDNESS

Sones	DBA	
1.3-4	32-48	Private homes (rural and suburban)
1.7-5	36-51	Conference rooms
2-6	38-54	Hotel rooms, libraries, movie theatres, executive offices
2.5-8	41-58	Schools and classrooms, hospital wards, and operating rooms
3-9	44-60	Courtrooms, museums, apartments, private homes (urban)
4-12	48-64	Restaurants, lobbies, general open offices, banks
5-15	51-67	Corridors and halls, cocktail lounges, washrooms and toilets
7-21	56-72	Hotel kitchens and laundries, supermarkets
12-36	64-80	Light machinery, assembly lines
15-50	67-84	Machine shops
25-60	74-87	Heavy machinery

From AMCA Publication 302 (Application of Sone Ratings for Non Ducted Air Moving Devices with Room-Sone-dBA correlations).