PRODUCT APPLICATION GUIDE

A technical bulletin for engineers, contractors and students in the air movement and control industry.

The basics of fan performance tables, fan curves, system resistance curves and fan laws

Engineers and designers who select and specify fans should have a good basic knowledge of the content of this article. An understanding of these subjects is vital for verifying the original fan selection, trouble shooting after the installation, and understanding future flexibility.

Fan performance tables

Manufacturers typically publish catalogs containing performance or rating tables for each specific fan size. These tables are printed in a compact format, showing only the minimum information necessary to select a fan to match a desired performance. Performance tables are very easy to use for making an initial selection, and in most cases, only include stable operating points.

Rating tables are published in one of two basic formats arranged with pressure columns and rows of either RPM or CFM. At the bottom of the table, qualifying statements describe how the fan was tested and what losses are included in the performance rating. In many cases, these tables also show sound ratings in either sones or LwA.

Using the Performance Tables

The following is a portion of a typical performance table as published for low to medium pressure fans. This table is common to most centrifugal and axial fans used for roof mounting, wall mounting and inline applications.

To use the table, find the required static pressure on the upper horizontal axis (example .375 inches wg.), then read down the static pressure column and find the required CFM (example 13791 CFM). Directly below the CFM is the required BHP for that performance (example 1.99). Also shown in this example is the sound rating for the selected performance (11.7 sones). Reading to the left of the selected CFM, you will find the fan RPM, the motor size and the model identifier.

MODEL	HP	RPM	STATIC PRESSURE IN INCHES OF W.G.													
			0		0.125		0.25		0.375		0.50		0.75		1.00	
			Sones	BHP	Sones	BHP	Sones	BHP	Sones	BHP	Sones	BHP	Sones	BHP	Sones	BH
420-5	1/2	220	9353		7846		5075									
			6.5	0.31	6.0	0.37	5.5	0.35								
		245	10416		9104		7304									
			7.2	0.43	6.7	0.50	6.1	0.53								
420-7	3/4	280	11904		10785		9418		7419							
			8.3	0.64	7.7	0.73	7.1	0.78	6.6	0.77						
420-10	1	305	12966		11959		10781		9272							
			9.4	0.82	8.8	0.94	8.0	1.00	7.3	1.02						
420-15	1 - 1/2	350	14879		14037		13050		11925		10562					
			11.9	1.24	11.2	1.38	10.1	1.46	9.4	1.52	8.6	1.54				
420-20	2	385	16367		15629		14731		13791		12701		9246			
			14.4	1.65	13.5	1.81	12.4	1.91	11.7	1.99	10.7	2.05	8.5	1.92		
		415	17643		16982		16148		15303		14363		12028			

Unstable performance points are not printed

Model Size

RPM required

Motor horsepower size required

BHP at selected performance

CFM selected

Sones at selected performance

The following performance table is typcial for higher pressure fans, such as housed centrifugal fans. There are individual tables for each fan size and wheel type. In most cases, these tables will have shaded areas representing Class I, II and III RPM limits. To use this table, find the required CFM

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CFM	OV	Static Pressure In Inches																	
		2.50		3.00		3.50		4.00		4.50		5.00		5.50		6.00		6.50		7.00	
		RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP
10000	1597	848	5.01	905	5.99	960	7.04	1017	8.21	1071	9.41										
11000	1757	878	5.62	931	6.62	983	7.69	1032	8.80	1084	10.1	1135	11.3	1184	12.7						
12000	1916	908	6.29	960	7.35	1009	8.44	1056	9.59	1103	10.8	1148	12.1	1197	13.5	1243	14.9	1287	16.3	1330	17.8
13000	2076	938	7.02	990	8.15	1038	9.30	1083	10.5	1127	11.7	1171	13.0	1213	14.3	1256	15.7	1300	17.2	1343	18.8
14000	2236	969	7.81	1020	9.01	1068	10.2	1113	11.5	1155	12.7	1196	14.0	1237	15.4	1277	16.8	1315	18.2	1356	19.8
15000	2396	1000	8.67	1051	9.94	1098	11.2	1143	12.5	1185	13.9	1225	15.2	1263	16.6	1301	18.0	1339	19.5	1376	21.0
16000	2555	1035	9.59	1082	10.9	1129	12.3	1173	13.7	1215	15.1	1254	16.5	1293	17.9	1329	19.4	1364	20.8	1401	22.4
17000	2715	1071	10.6	1116	12.0	1160	13.4	1204	14.9	1245	16.4	1285	17.8	1322	19.3	1359	20.8	1394	22.4	1427	23.9
18000	2875	1108	11.7	1151	13.2	1192	14.7	1235	16.2	1276	17.7	1315	19.3	1352	20.8	1388	22.4	1423	24.0	1457	25.6
19000	3035	1145	12.8	1187	14.4	1228	16.0	1266	17.6	1307	19.2	1346	20.8	1383	22.4	1419	24.1	1453	25.7	1486	27.4
20000	3194	1184	14.0	1224	15.7	1264	17.4	1301	19.0	1338	20.7	1377	22.4	1414	24.1	1449	25.8	1483	27.6	1517	29.3
21000	3354	1222	15.3	1262	17.1	1300	18.9	1337	20.6	1373	22.4	1408	24.1	1445	25.9	1480	27.7	1514	29.5	1547	31.3
22000	3514	1262	16.7	1300	18.6	1337	20.4	1373	22.3	1408	24.1	1442	25.9	1476	27.8	1511	29.7	1545	31.5	1577	33.4
23000	3674	1302	18.3	1339	20.1	1375	22.1	1410	24.0	1444	25.9	1478	27.8	1510	29.8	1543	31.7	1576	33.7	1608	35.6
24000	3833	1342	19.9	1378	21.8	1413	23.8	1448	25.8	1481	27.9	1514	29.9	1546	31.9	1576	33.9	1608	35.9	1640	37.9
25000	3993	1383	21.7	1418	23.7	1452	25.7	1486	27.8	1518	29.9	1550	32.0	1581	34.1	1612	36.1	1641	38.3	1671	40.4

required static pressure

Performance shown is for model AFSW arrangement 1, installation type B - free inlet, ducted outlet. Performance ratings do not include the effects of appurtenances in the airstream. Power rating (BHP) does not include drive losses.

outlet velocity at given CFM

required CFM

required fan RPM

BHP @ selected performance

Class I

Class II

Class III

along the left vertical axis (example 14,000 CFM), then move horizontally to the right to the required static pressure column (example 6.00 inches wg.). At this intersection, you can read both the fan RPM and the BHP (example 1277 RPM and 16.8 BHP). Notice these points are located on the lightly shaded portion of the table, indicating that a Class II fan is required.

With the use of electronic fan selection programs the trend is to further reduce the amount of printed data and to print only a range of performance for each fan size. There's little doubt that a good electronic selection program such as CAPS can pinpoint a precise selection with minimal effort.

It's also becoming common to see fan performance curves (actually a family of RPM curves) covering the full range of performance printed on the same or adjacent page to the performance table. This format provides a quick snapshot of the total capabilities of one given fan model and size. Locate the desired flow along the x-axis and the specified pressure on the left y-axis. At the point of intersection, you can determine the approximate Fan RPM required. To find the motor size required, move upward to the closest HP line (dotted line). You can quickly review charts for several different fan sizes to determine the most desirable selection.

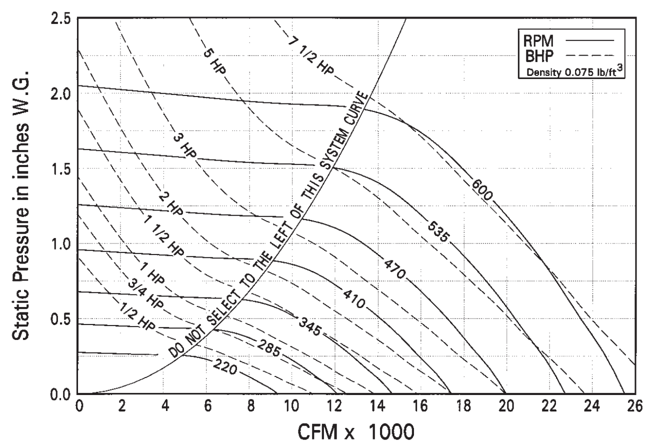


Chart represents a family of RPM curves.

Fan Curves

One of the most valuable pieces of information supplied by fan manufacturers is the fan performance curve. Curves are normally supplied for each specific fan on a given project. These curves show the relationship between the quantity of air a fan will deliver and the pressure generated at various air quantities. The curves also show horsepower for a given quantity of flow.

Figure 1 represents the performance for a given fan size and RPM. The flow scale is presented along the x-axis. The pressure scale is presented along the left y-axis. Find the required CFM and move vertically to the SP curve. Read horizontally to the left to read the pressure at that flow.

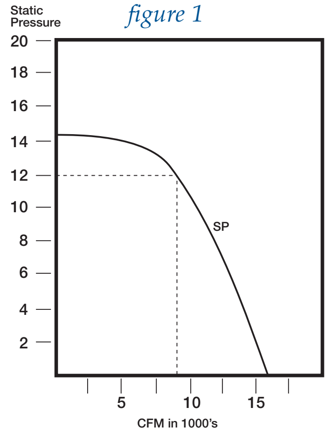


figure 1

Figure 2 illustrates the effects of speed change. According to the fan laws, CFM varies directly with RPM. The result of reducing the speed is a similar curve in a lower position. Increasing speed results in a similar curve in a higher position.

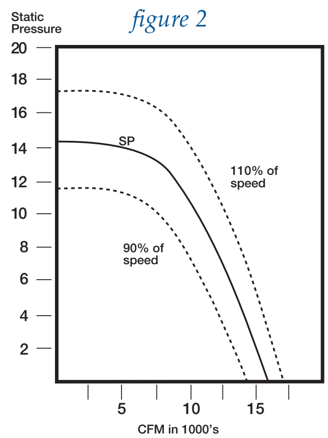


figure 2

Figure 3 illutrates the addition of the BHP curve. The power scale is presented along the right y-axis. Find the volume on the SP curve and move vertically to the BHP curve. At this intersection, move horizontally to the right-hand scale to read the BHP at that flow.

The curve shapes in figures 1-3 are typical of centrifugal wheels. Other impeller types have both fan and power curve shapes that vary from those shown. However, the principle of reading the curves is the same.

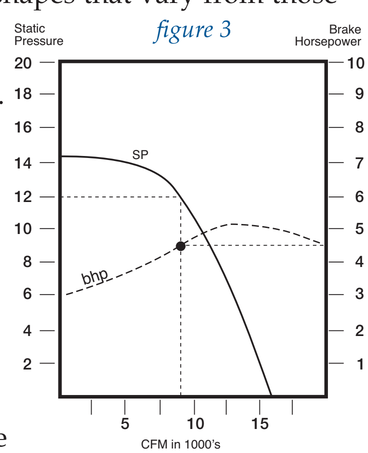


figure 3

System Resistance Curves

System resistance curves are a graphical representation of how a system reacts to a given airflow. The system resistance is the sum of all pressure losses through the duct, all elbows, filters, dampers, coils and any other device that resists flow.

Figure 4 shows that the system curve always starts at the origin where flow and pressure are zero. The fan will operate at the point where the system resistance curve intersects the fan curve. For a constant system, with no change in damper settings, etc. the pressure at a given flow varies as the square of the airflow.

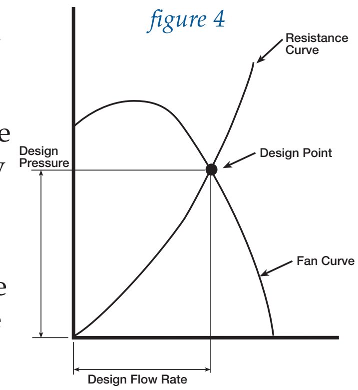


figure 4

The only time the shape of the system resistance curve changes is when the system physically changes. For instance, if a damper is opened, the system resistance is reduced. The result is a lower pressure drop. Closing a damper, or when filters become dirty, increases the systems resistance.

Figure 5 illustrates how the system resistance curve changes with a decrease or an increase in resistance. The new curve shows that as the systems resistance changes, so does the air volume the system pressure at a constant fan RPM.

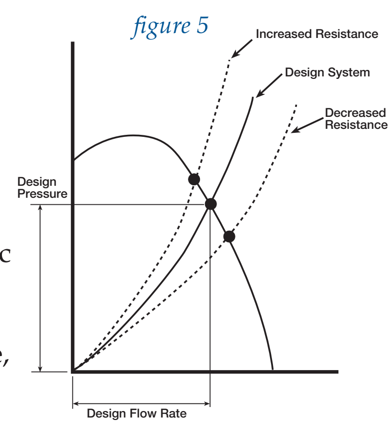
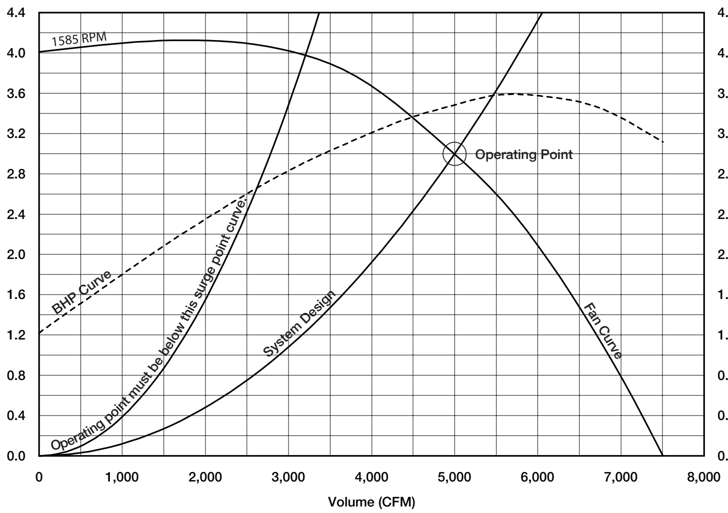


figure 5

Figure 6: is a sample print-out from Greenheck's CAPS program for a specific fan selection. This illustrates the fan curve, the BHP curve, the system design curve, plus a fan surge curve. Fan selection close to, or to the left of the surge curve, is not recommended. Referring to this surge curve aids the designer in selecting fans that are stable and will not go into surge with a minor change to the system.

We have learned that a fan curve is the series of points at which a given fan model and size can operate at a constant RPM. The system resistance curve is the series of points at which the system can operate. The operating point is where these two curves intersect. Any changes to the fan RPM will cause the point of operation to move along the system curve and changes to the system resistance will cause the point of operation to move up or down the fan curve.

figure 6



Fan Laws

Our next step is to understand fan laws. Fan laws, can be used to accurately predict changes (assuming the fan diameter and air density are constant).

Fan law equations

$$CFM_2 = \frac{RPM_2}{RPM_1} \times CFM_1$$

$$SP_2 = \left(\frac{RPM_2}{RPM_1}\right)^2 \times SP_1$$

$$BHP_2 = \left(\frac{RPM_2}{RPM_1}\right)^3 \times BHP_1$$

Subscript 1: Describes the existing conditions
Subscript 2: Describes the new conditions

The following example is typical of how the fan laws are applied:

A fan installed in a fixed system is operating at:

- CFM = 10,000
- SP = 1.50 in. wg
- BHP = 5.00
- RPM = 1,000

What RPM is required to move 25% more air (12,500 CFM) through this system?

NOTE: You can view this example as either the installation now desires more air than planned, or the balancing report showed 25% less air than specified.

By rearranging the cfm fan law:

$$RPM_2 = \left(\frac{CFM2}{CFM1}\right) \times RPM_1$$

$$RPM_2 = \left(\frac{12{,}500}{10{,}000}\right) \times 1000 = 1250 \text{ RPM}$$

The corresponding static pressure is:

$$SP_2 = SP_1 \left(\frac{RPM2}{RPM1}\right)^2$$

$$SP_2 = 1.50 \left(\frac{1250}{1000}\right)^2 = 2.34 \text{ in. wg}$$

The resulting BHP is:

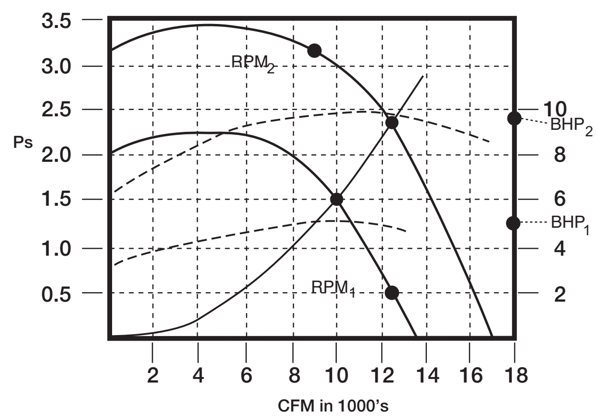
$$BHP_2 = BHP_1 \left(\frac{RPM2}{RPM1}\right)^3$$

$$BHP_2 = 5.00 \left(\frac{1250}{1000}\right)^3 = 9.77 \text{ BHP}$$

According to the fan laws, in order to use the original fan, the speed must be increased from 1000 RPM to 1250 RPM, the motor must be changed from a 5 HP to 10 HP.

Figure 7 illustrates fan curves for both the original and new fan performance.

figure 7



Important: Check to make sure that the new RPM does not exceed the maximum allowable RPM for the existing fan. Maximum RPMs are shown in fan catalogs. You should consult the fan manufacturer for additional information or if you would like to review the application.

More detailed information on these subjects can be found in both AMCA and ASHRAE publications.