Fan Performance and Selection

By Henry Mathis *

FOR A long time a fan manufacturer advertised his product somewhat along this line: "Since the fan in a system represents less than 5% of the cost, but is 100% accountable for the successful operation of the system, surely it is good business to use the proper size and type of fan." Economical and competitive conditions often are the cause for using a fan too small or of the wrong type, but there are some well-known measures that can be followed to good advantage.

In ventilating or air conditioning systems, fans are seldom used for pressures exceeding 2" water and usually for pressures below this. This paper is concerned with fans operating at these low pressures. Fans naturally fall into two groups:

1. Propeller and Disc Fans
2. Centrifugal Fans and Blowers

Disc and Propeller Fans

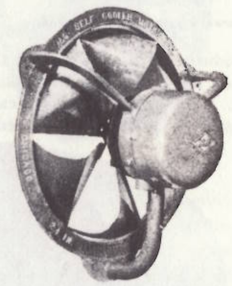
There is not a great difference between the propeller fan and disc fan, either in appearance or performance. Disc fans have smooth, flat blades whereas propeller fans have curved surfaces usually at the outside end of the blade. Disc fans differ structurally because they are heavier and stronger in construction with a heavy steel disc on center hub. The blades of a disc fan are supported by the disc or hub center plate. Rims are seldom used in disc fans. Propeller fans have smaller and lighter hubs with the blades curved or turned at the tip and supported with a wire rim or band. These fans move air by the thrust or beating action of the blade and move air in a column parallel to the fan shaft or axially. The air quantity is largely produced at the outer area of the fan wheel with a continual falling of delivery as the center or the hub of the wheel is approached. We can understand this very easily if we will take a 24" fan, i. e., two feet in diameter, operating at 900 r.p.m. At the tip of the blade the fan travels 5700 feet in a minute; half way between the center and tip the blade travels 2850 feet per minute; at the hub very little speed is obtained. It is desirable to increase the pitch of the blades toward the center of the fan to partially overcome the effect of the reduced blade speed. This type of fan should not be used for pressure work because of the low speed travel in the center or hub area which permits air to flow backwards through the fan more easily than overcoming resistance in the system.

This type of fan operates at a comparatively high speed at the periphery even at free air delivery and when speed is applied to it to overcome resistance, we find noise and increased power consumption resulting.

Propeller and Disc Fans are simple, economical and compact, and have decided advantage when used in their proper place. They are ideal for:

a. Free air delivery
b. Large capacity at low resistance
c. Low resistance applications.

From the pressure curve of a propeller fan it is seen that the capacity of these fans is highest when the resistance is the lowest, and that the power used is lowest when the air delivery is the maximum. As an example, we are all familiar with this type of fan exhausting air from a restaurant, the fan located in the outside wall without any duct connections whatsoever. If we measure the air capacity we will find this to be at the peak and if we measure the power used, it would be at the low point. Anything we add for this fan to work

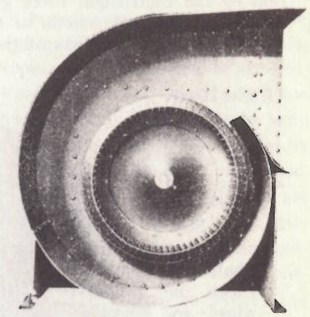


Propeller Fan.

against is going to reduce its capacity and increase its power. For instance, if we would install a hood over a range with a short connection to this fan, we would not be adding much resistance, but the fan would be very sensitive toward this additional burden; its capacity would drop quickly and its power load would increase.

It is best to consult with the propeller manufacturer when using these fans with or against resistance, as the manufacturer will furnish the proper size motor for such service.

These fans have a splendid efficiency at little or low resistance and are equal to a good centrifugal



Cross Section Thru a Centrifugal Fan.

fan. But as they are applied to work against resistance, the efficiency drops off so that their use becomes rather impractical. The common example of this type of fan operating against a low resistance successfully and commercially, is in the wall type unit heater. The total resistance in these unit heaters seldom exceeds ⅛ of an inch and propeller and disc fans are used because they are compact, low in cost, deliver splendidly at low resistance and lend themselves perfectly to direct connected motors.

Manufacturers of propeller fans show in their capacity sheets a high and low motor speed for free air delivery. They do this because at the low speed the fan is quiet; but there are many places where some noise with more air is preferable. These fans require very little attention because the fan wheel in the common sizes is supported on the motor shaft so that the oiling of the motor is the only care.

Propeller fans have been most helpful in popularizing ventilation for small stores, restaurants, factories, etc., and for a low cost system present some attractive features. For instance, in a factory building, or in a store that is satisfactorily heated but has no air supply nor air exhaust propeller fans can be installed reasonably and effectively to accomplish this. In using fan equipment you will

*Vice-President, The New York Blower Co.

MEMBER
National Association of Fan Manufacturers and Industrial Unit Heater Association

The NEW YORK BLOWER COMPANY
GENERAL OFFICES 32nd STREET & SHIELDS AVENUE · CHICAGO
FACTORIES at LAPORTE, IND. and CHICAGO, ILL

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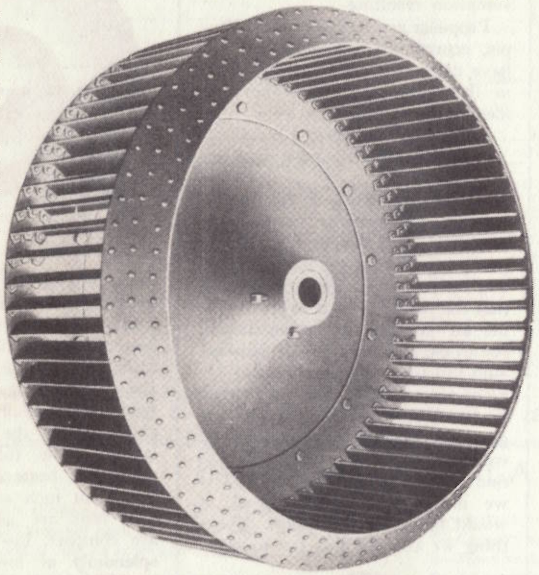
find most companies today rating the fans according to the Standard Code for the Testing of Centrifugal and Disc Fans as adopted by the American Society of Heating and Ventilating Engineers and the National Association of Fan Manufacturers. This has been a splendid instrument for the indsutry because in the past Disc and Propeller Fan ratings were anything but accurate, whereas today the companies using the Test Code give us reliable information.

Centrifugal Fans

Centrifugal fans produce air motion by the centrifugal force generated in a rotating column of air. A centrifugal fan consists of three essential parts:

1. The Housing enclosing the fan wheel.
2. The Fan Wheel.
3. The Supporting Shaft on which the wheel rotates.

To know how a centrifugal fan performs, picture a fan wheel operating by itself without any housing. It would throw the air at all points on the circumference in the same manner as an auto tire throws off water picked up from wet pavements. In order to control and use this air discharged from the fan wheel a housing of spiral shape is used with its largest capacity at the housing discharge. The velocity of the air leaving the wheel is reduced in the housing, changing a portion of the kinetic energy or motion into static pressure. This is the useful duty of a good fan housing as it gives the static pressure to the air stream for overcoming resistances or friction existing in all systems. This is shown in the cut of the cross section through a fan.

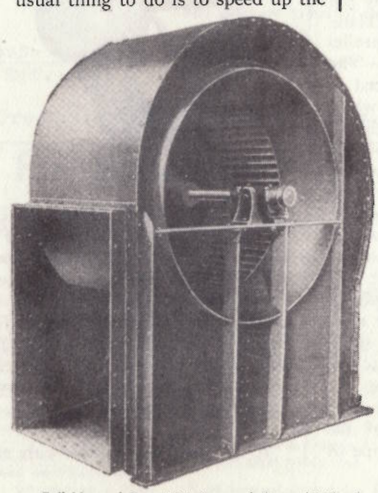


Multiblade Wheel, Forward Curved, Slow Speed.

High speed photography is recently developed so we soon expect photographic records of air flowing through a fan. This will be of great value to the industry.

Although these fans are used in some cases without a housing, we are considering the common centrifugal fan of the housing type. The housings have not undergone as many changes in the past as the centrifugal wheel. Today the housings have larger outlets and larger inlets. Different proportions are recommended and advised by manufacturers, all of which has some bearing depending on the type of fan wheels inside the housings.

Centrifugal fans, as a class, behave similarly as both the capacity and power decreases as the resistance increases. As an example, let us take a fan installed in an air conditioning system against ¾" pressure with ducts, air washer and accessories. Without changing the speed of the fan, it is decided to add another heater in the duct to obtain a higher temperature. We should find that our capacity would decrease and that our power would go down because our resistance has increased by the addition of the heater and the friction loss from the air passing thru it. In this particular case, the usual thing to do is to speed up the fan enough to take care of the additional resistance, which requires more power.



Full Housed Fan With Forward Curved Wheel.

Centrifugal Fan Wheels

In the design and construction of the fan wheel itself is found the real difference in centrifugal fans. The curvature or angularity of the fan blades defines the class of the tan and determines the fan speed. The multi-blade fan wheel with forward curved blades operates at the lowest speed; the paddle wheel or straight blade fan at a higher speed; the partially backward blade and the full backward blade at the highest speed.

The fan in common use some years ago was known as the paddle wheel type or steel plate fan as shown in the picture. This fan is not used to any extent in ventilation or air conditioning work today as the multi-blade fan is far superior for this class of work. The paddle wheel type fan, however, is still used where small quantities of air are needed at high pressures and will develop a very high efficiency in this work. Its principal use, however, is in the handling of materials or abrasives as its few, deep strong blades give long life and oppose corrosion and the clinging of materials. It is the multiblade fan that is used entirely today in ventilating and air conditioning and it is with them that we are interested. We show three characteristic curves of the well known type of multi-blade fans:

The forward curve or the slow speed fan.

The full backward wheel or the highest speed fan.

The partial backward wheel or the high speed fan.

The forward curve multiblade fan is well known for its many shallow cupped blades tipped forward in the direction of rotation. It will deliver more air, occupy less space, weigh less and cost less. It costs less to manufacture because of its low speed and design permitting the use of lighter materials. Its maximum efficiency occurs approximately at the point of maximum static pressure which means that this fan delivers air most efficiently at or near the point where it develops its greatest pressure. This is important as the conversion of the air motion into static pressure produces a large volume with low outlet velocities. Being a slow speed fan, it requires the least attention and its maintenance cost is lowest. It is necessary to calculate pressure losses carefully

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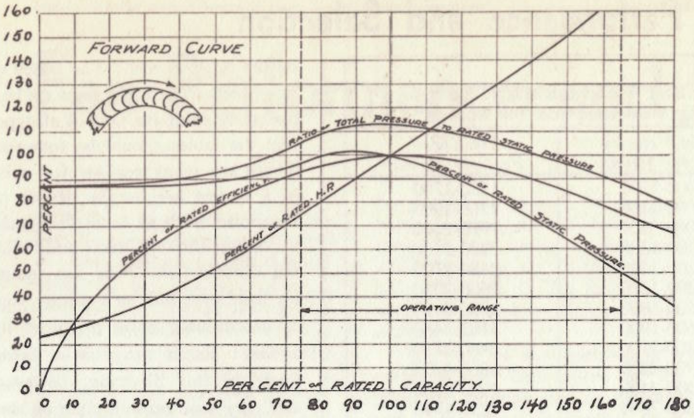
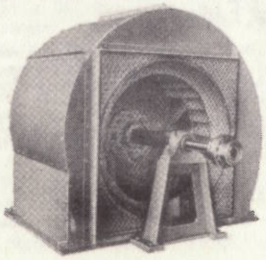


when determining the proper size motor if the motor is to be closely rated. This fan has a gradual rising horsepower curve which detracts from its use in parallel systems or those having fluctuating resistances. This seldom occurs in air conditioning installations. Only the smaller sizes can be direct connected economically because of the low speed, but the new type of leather and rope drives with the short centers have more than overcome the space-saving advantages of direct-connected high speed fans. The use of steam engines is almost obsolete, but the low speed of this fan permitted its effective use with a direct connected engine.

This fan has a wide operating range as the characteristic curve shows. This has been shown by any fan capacity table. Manufacturers give complete figures for a given size fan showing the capacities, outlet velocities, r.p.m., etc. The efficient operating point is shown in the tables by bold face or underscored figures. Higher capacities for a given pressure are possible at higher speeds, but the question of noise and efficiency arises when the higher capacities are used. The table on page 4 shows the best performances using the lower operating velocities and tip speeds:

High Speed Multi-Blade Fans

The full backward multi-blade fan has fewer blades, large and deep, curved backward in direction

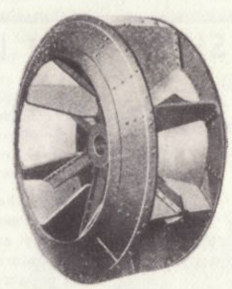


High Speed Fan With Full Backward Wheel.

of rotation. Its pressure curve drops off rapidly and its horsepower curve rises to a maximum and then drops off. This behavior has value in systems where the resistance varies, as the horsepower load cannot exceed a certain point. This is particularly true in mechanical draft, drying, or where fans are used in parallel operation.

It is a high speed fan, as it operates about two and one-half times as fast as the forward curved fan. This higher speed makes it a more expensive fan to manufacture because heavier materials are used thruout and it is a larger fan in bulk. It also requires more maintenance attention.

Its high speed permits of easy direct connection to motors of com-



Steel Plate or Paddle Type.

mercial speed and good efficiency. In commercial work it is the only fan that can be direct connected to turbines for practically all duties.

In air conditioning work, this fan is not used so frequently because it occupies more space and costs more. It is used by engineers when they desire a certain power load maximum. Manufacturers publish complete capacity tables showing the entire operating limits.

Partial Backward Multi-Blade Fans

This is a high speed fan, operating about twice as fast as the forward curve fan. It retains part of the horsepower characteristics of the full backward fan, that is, its horsepower tends to reach the high point and remain there. In appearance it is more like the forward curved fan, as the wheel has many floats, slightly deeper with construction and materials slightly heavier than the forward curved. But remember that the blades are tipped back in direction of rotation. In ventilating and air conditioning work this fan can be easily direct connected to motors and is usually furnished this way. Due to its higher speed, it is best to use this fan one or two sizes larger than the forward curved fan.

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General

The subject of noise and efficiencies of fans is so controversial that no comparisons are drawn here of the respective types. It is axiomatic that any moving machinery has some noise. It is possible to have quiet fans and the sensible thing is to select a fan of the proper size regardless of the type used. Trouble usually arises when an attempt is made to overwork the product. The cost of a fan in a system is not large and it is unwise and expensive to permit the use of a fan too small just to save

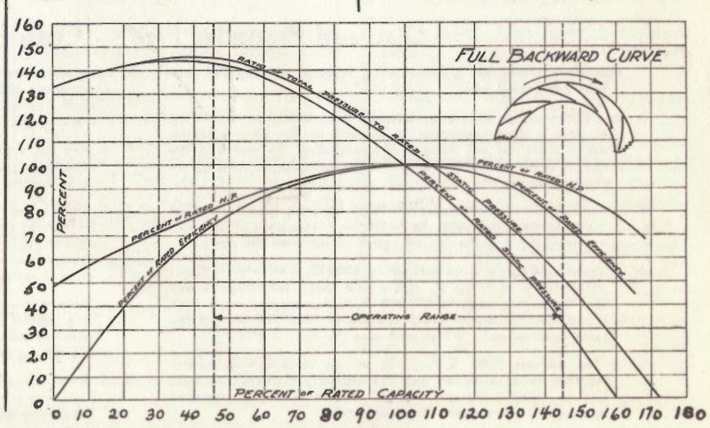

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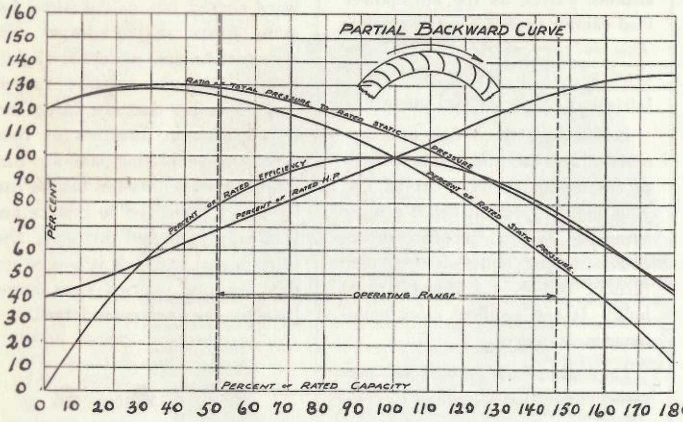
TABLE SHOWING BEST PERFORMANCES
Using the Lower Operating Velocities and Tip Speeds.

Static Pressure In Inches of Water	*Outlet Velocity Feet per Minute*	*Tip Speed Feet per Minute*
1/4	1000-1100	1520-1700
3/8	1000-1100	1760-1900
1/2	1000-1200	1970-2150
5/8	1100-1300	2225-2450
3/4	1200-1400	2480-2700
7/8	1300-1600	2660-2910
1	1500-1800	2820-3120
1 1/4	1600-1900	3162-3450
1 1/2	1800-2100	3480-3810
1 3/4	1900-2200	3760-4205
2	2000-2400	4000-4500
2 1/4	2200-2600	4250-4740
2 1/2	2300-2600	4475-4970
3	2500-2800	4900-5365



on the original cost. The tables of manufacturers clearly show the best operating point for fans of all types and the tables should be followed. There are many reasons for noise in a system besides the danger of fan noise, such as acoustics, sound vibrations thru the ducts and building construction. The fan industry has never had an accurate way of determining noise produced by a fan. Rapid progress is being made in this direction, however, and very soon noise measuring machines will be available that will help decide this question.

The standard code for testing centrifugal and disc fans as adapted by the A. S. H. V. E. and National Association of Fan Manufacturers should be known by fan users and engineers. Most manufacturers rate and test fans according to this code so dependable facts on fan performances and efficiencies are available.

Copies of the code may be obtained without charge from fan manufacturers or from National Association of Fan Manufacturers.

PHYSICAL FAN LAWS

In the selection and operation of fans, the size, speed, capacity, horsepower, and pressure each has a fixed and definite relation to the other, which may be expressed as follows:

For a given fan size, piping system, and air density—

1—Capacity varies directly as speed.
2—Velocity varies as speed or capacity.
3—Pressure varies as the square of the speed.
4—Speed and capacity vary as square root of the pressure.
5—Horsepower varies as cube of the speed or capacity.
6—Horsepower varies as $(\text{pressure})^{3/2}$

For a constant pressure and at rated capacity—

7—Capacity and horsepower vary as square of the size.
8—Speed varies inversely as size.
9—At constant pressure the speed, capacity and horsepower vary as the square root of the absolute temperature.

10—At constant capacity and speed, the horsepower and pressure will vary directly as the density of the air and approximately inversely as the absolute temperature. Thus increasing the temperature from 50° to 550° practically cuts the horsepower and pressure in half if the speed and capacity remain the same.

$$HP = \frac{CFM \times Tot.Press.^*}{6356 \times Mech.\ Eff.} \qquad Mech.Eff. = \frac{CFM \times Tot.Press.^*}{6356 \times HP}$$

*Total Pressure = Static Pressure plus Velocity Pressure.

Lesson 6 -- Fan Performance and Selection

Disc and Propeller Fans -- Centrifugal Fans

1. Enumerate briefly the differentiating features of propeller fans from centrifugal fans.
2. In a kitchen range exhaust system with a propeller fan exhausting air thru a duct connected to a hood on the kitchen range, would there be any danger of overloading the motor if the duct is removed and the propeller fan exhausts air direct from the room?
3. If a small direct connected centrifugal fan were used instead of the propeller fan would the motor be over-loaded if the duct was removed and the fan exhausted direct from the room?
4. A centrifugal fan is used exhausting 4000 C. F. M. with a direct connected 2 H. P. motor. On a slow speed centrifugal speed fan the motor operates at 600 R. P. M., whereas on a high speed fan, the motor would operate at 1200 R. P. M. but the same horse-power. Which unit uses the most watts?
5. A fan delivers 5000 C. F. M. in an air conditioning system. Another room is added and the capacity increased to 6000 C. F. M. This is the only change. Should the fan be speeded up and will more power be necessary?
6. In a school building, there are two fans of the same size each delivering 6000 C. F. M., one to the north half and one to the south half of the building. Both fans get their air from the same intake. What type of fan should be used?
7. A man has a propeller fan exhausting air from his kitchen. He decides to put this fan in the recirculating duct to his furnace as a booster. Will this be good practice? Why?
8. A high speed fan of the full backward type delivers 10,000 C. F. M. at 1100 R. P. M. with a direct connected 3 H. P. motor against 3/4" static pressure. Will the motor over-load if changes are made to reduce the resistance to 3/8" or 1/2 the original resistance?
9. A forward curved fan 600 R. P. M. with a 2 H. P. motor is used in a system delivering 5000 C. F. M. If a partial backward wheel is substituted in the same housing at the same speed, will the capacity and the power move up or down?
10. A direct connected fan unit has an overall efficiency of 60%. It is delivering 10,000 C. F. M. against 1/2" total pressure What horsepower will be required?

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