

CHAPTER 3

TYPES OF FANS, TERMINOLOGY, AND MECHANICAL CONSTRUCTION

SIX FAN CATEGORIES

This book will discuss the following six categories of fans:

1. Axial-flow fans
2. Centrifugal fans
3. Axial-centrifugal fans
4. Roof ventilators
5. Cross-flow blowers
6. Vortex or regenerative blowers

AXIAL-FLOW FANS

There are four types of axial-flow fans. Listed in the order of increasing static pressure, they are

1. Propeller fans (PFs)
2. Tubeaxial fans (TAFs)
3. Vaneaxial fans (VAFs)
4. Two-stage axial-flow fans

Propeller Fans

The *propeller fan*, sometimes called the *panel fan*, is the most commonly used of all fans. It can be found in industrial, commercial, institutional, and residential applications. It can exhaust hot or contaminated air or corrosive gases from factories, welding shops, foundries, furnace rooms, laboratories, laundries, stores, or residential attics or windows.

Sometimes several propeller fans are installed in the walls of a building, operating in parallel and exhausting the air. Figure 3.1 shows two propeller fans with

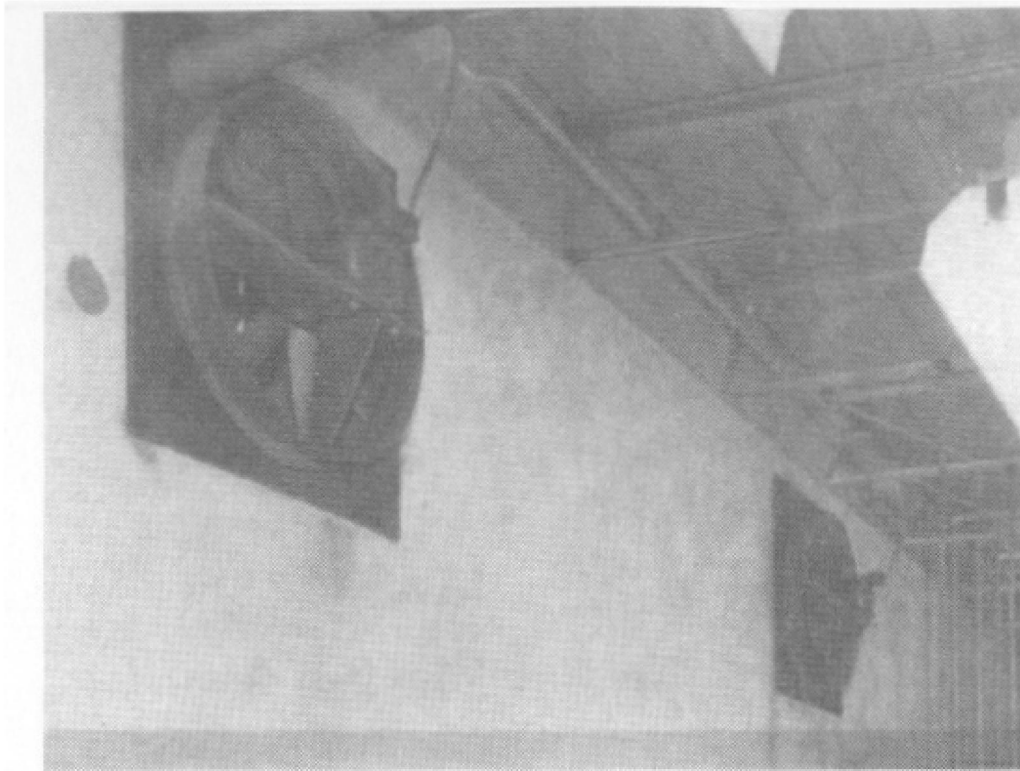


FIGURE 3.1 Two 21-in propeller fans with direct drive, mounted in a wall and exhausting air from a factory building.

direct drive mounted in the wall of a factory, near the ceiling where the hot air is located.

Figures 3.2 and 3.3 show the general configuration for a propeller fan with a belt drive from an electric motor. The units consist of the following eleven components: a spun venturi housing, a bearing base (plus braces), two bearings, a shaft, a motor base, an electric motor, two pulleys, a belt, and a fan wheel. In Fig. 3.2 the fan wheel

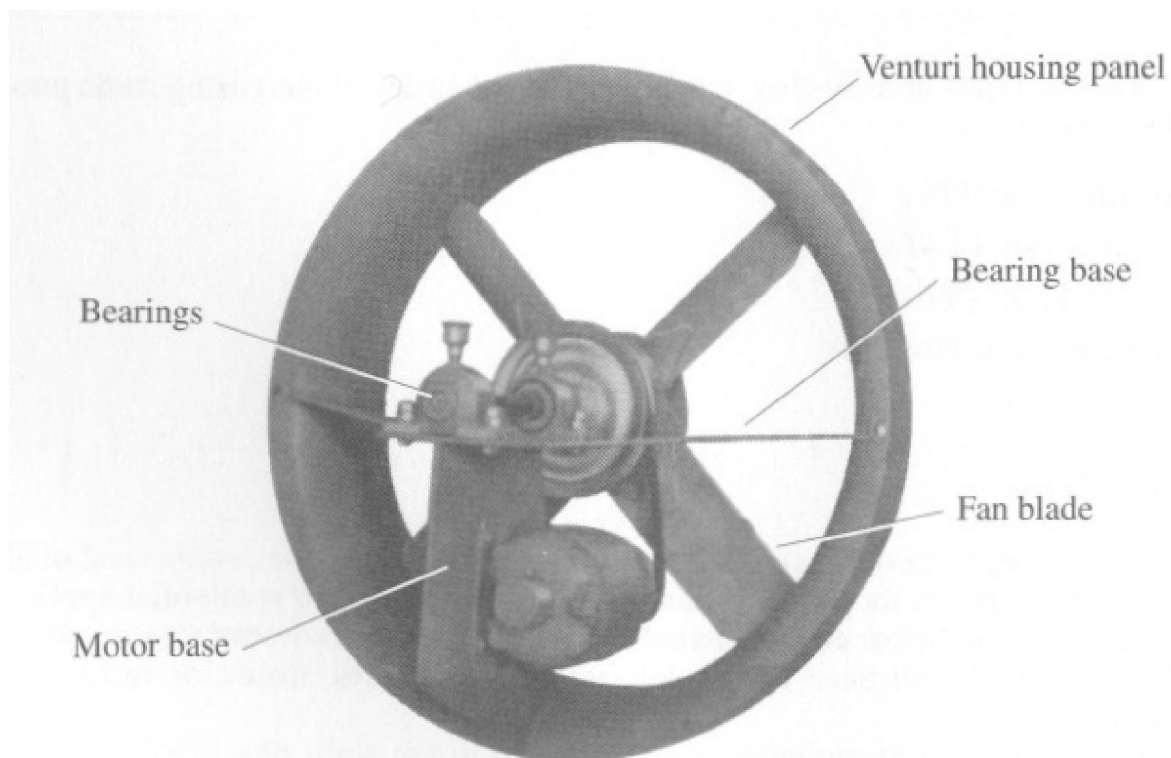


FIGURE 3.2 A 24-in propeller fan with belt drive. Note the location of the motor opposite the rotating blades.

has four blades, and the motor is mounted on a separate, vertical motor base. In Fig. 3.3 the fan wheel has six blades, and a horizontal base supports both the motor and the two bearings. In both figures, however, the motor is located opposite the rotating fan blades. This results in good motor cooling but some obstruction to the airflow.

Figure 3.4 shows the simpler configuration of a propeller fan with direct drive from an electric motor. This unit consists of only four components: a spun venturi housing, a motor base (plus braces), an electric motor, and a four-bladed fan wheel.

The belt-drive arrangement has the following three advantages:

1. It results in flexibility of performance, since any speed (rpms) can be obtained for the fan wheel by selection of the proper pulley ratio. However, when the speed is increased to boost the flow (cfm), the brake horsepower will increase even more, as the third power of the rpm ratio, as will be explained later.
2. In large sizes, belt drive is preferable, since it will keep the speed of the fan wheel low or moderate while keeping the motor speed high, for lower cost. (High-speed motors are less expensive than low-speed motors of the same horsepower.)
3. The motor will get good cooling from the air stream passing over it.

The direct-drive arrangement has the following five advantages:

1. It has a lower number of components, resulting in lower cost.
2. It requires no maintenance and regular checkups for adjustment of the belt.
3. It has a better fan efficiency, since a belt drive would consume an extra 10 to 15 percent of the brake horsepower.

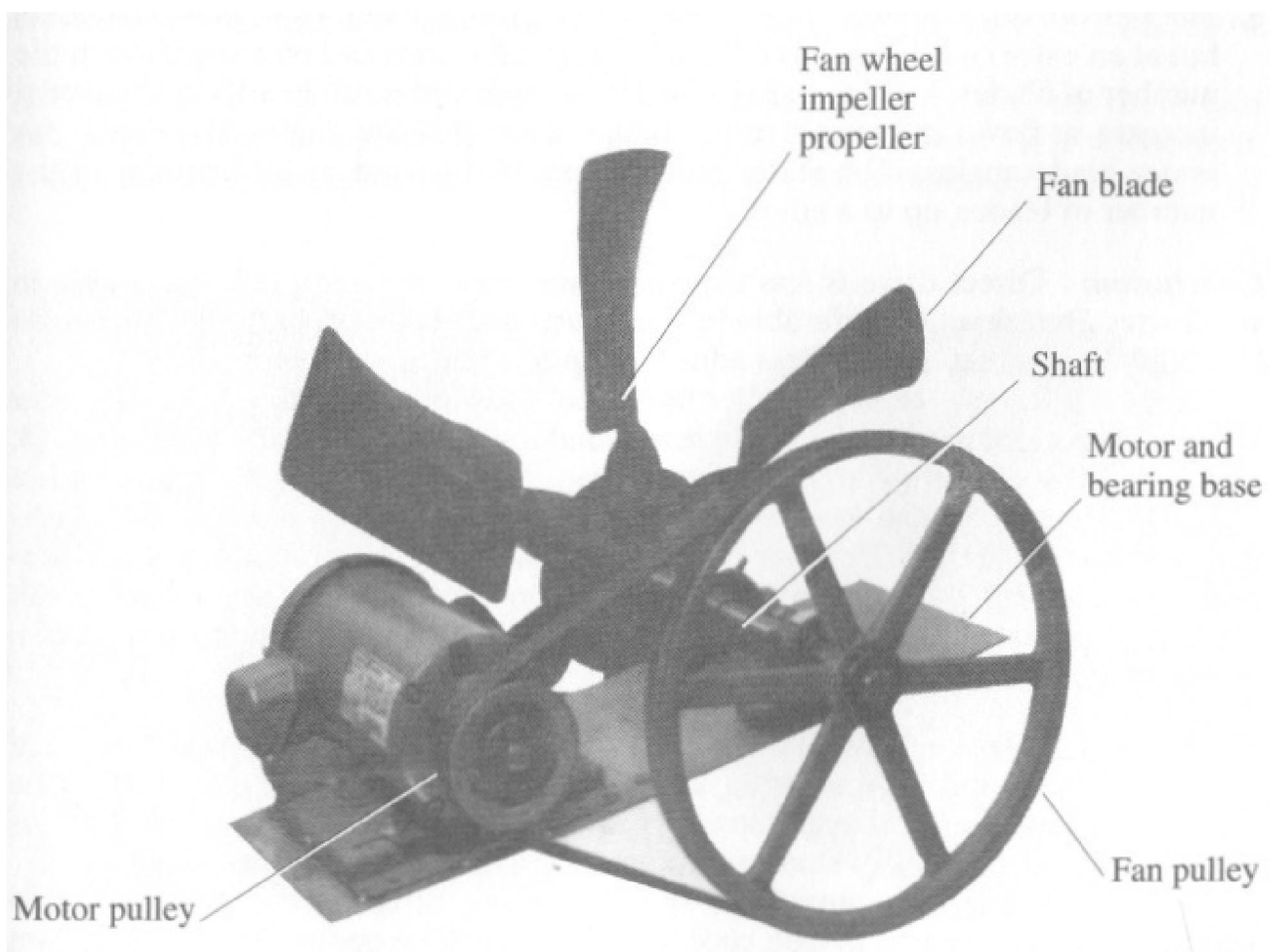


FIGURE 3.3 A 36-in propeller fan with belt drive. Note the large pulley ratio for a low speed of the fan wheel. (Courtesy of Chicago Blower Corporation, Glendale Heights, Ill.)

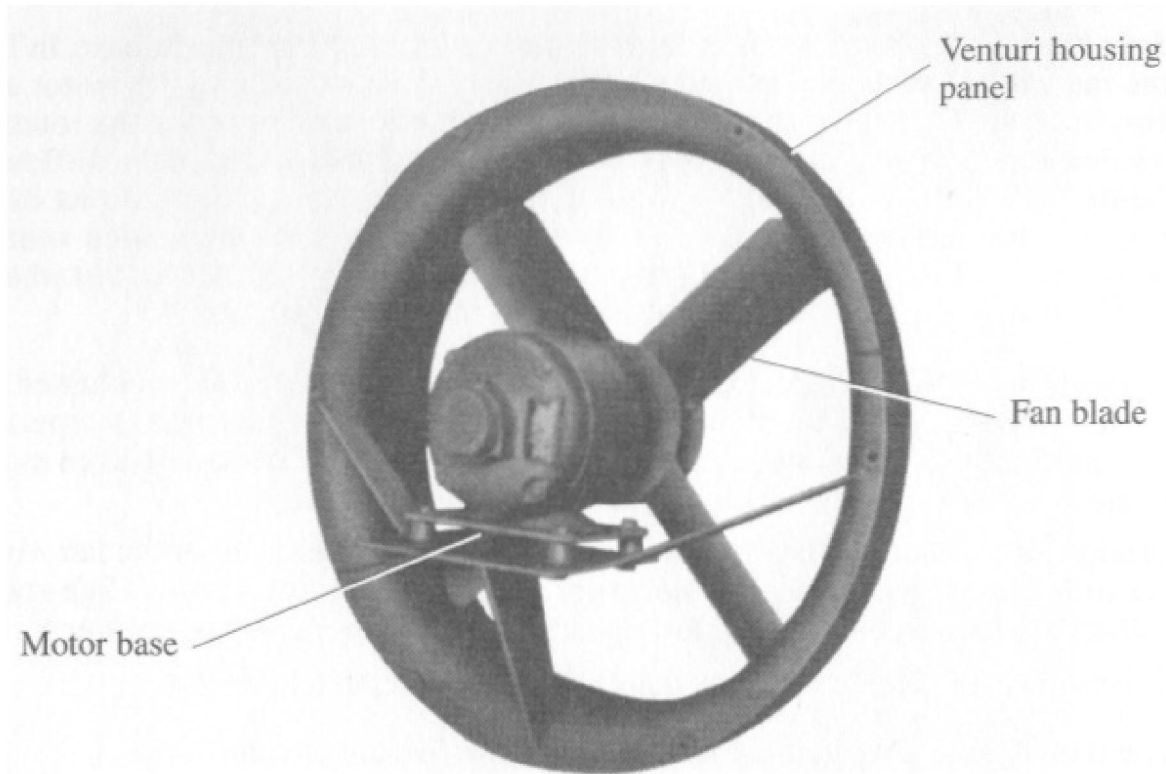


FIGURE 3.4 A 24-in propeller fan with direct drive. Note the height adjustment of motor base for an even tip clearance.

4. It results in more flow (cfm) because the central location of the motor does not obstruct the airflow.
5. The performance flexibility of the belt-drive arrangement also can be obtained, but at an extra cost, by means of adjustable-pitch blades and by a variation in the number of blades. A 3° increase in the blade angle will result in a 10 to 15 percent increase in flow (15 percent in the range of small blade angles, 10 percent for larger blade angles). The static pressure can be boosted by an increase in the number of blades, up to a point.

Conclusion: Direct drive is less expensive and more efficient. It is preferable in small sizes. Belt drive is preferable in large sizes and results in better performance flexibility than direct drive, unless adjustable-pitch blades are used.

Figure 3.5 shows a 46-in propeller fan wheel of aluminum with a 13-in-diameter hub and with eight narrow airfoil blades welded to the hub. The hub-tip ratio is 0.28, a good ratio for a propeller fan. This is an efficient but expensive propeller-fan wheel. Most propeller-fan wheels have sheet metal blades riveted to a so-called spider, as shown in Fig. 3.6. This is a lightweight, lower-cost construction that is somewhat less efficient but adequate in small and medium sizes. Many propeller-fan wheels are plastic molds. In very small sizes, where cost is more important than efficiency, one-piece stampings are sometimes used.

Shutters. Most propeller fans are used for exhausting from a space. They are mounted on the inside of a building, with the motor located on the inlet side, inside the building, and the air stream blowing outward. A shutter is mounted on the outside. There are two types of shutters: automatic shutters and motorized shutters.

Figure 3.7 shows an automatic shutter having three shutter blades linked together and mounted on hinged rods. The shutter will be opened by the air stream on start-up of the fan. It will be closed by the weight of the shutter blades when the fan is turned off. The motorized shutter, used mainly in larger sizes, is opened and

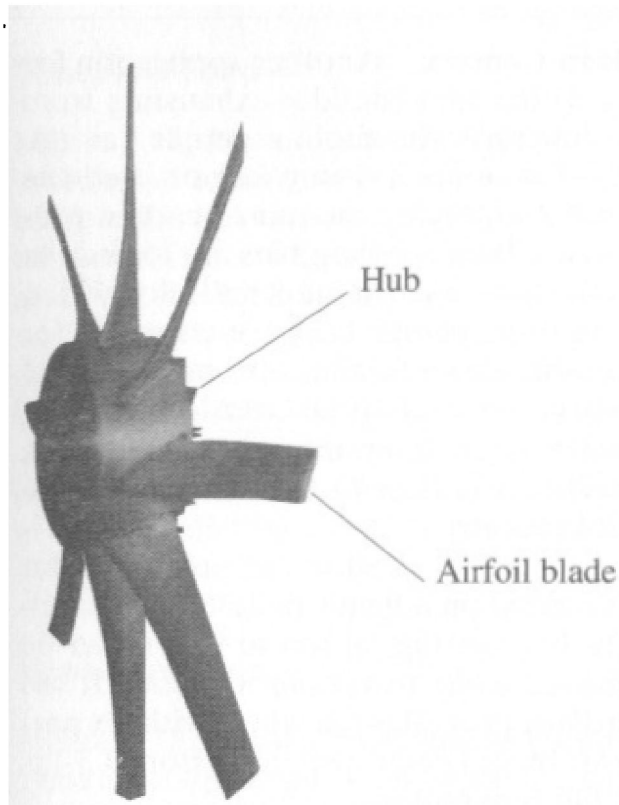


FIGURE 3.5 Cast-aluminum propeller-fan wheel with a 46-in o.d., 13-in hub diameter, and eight narrow airfoil blades welded to hub.

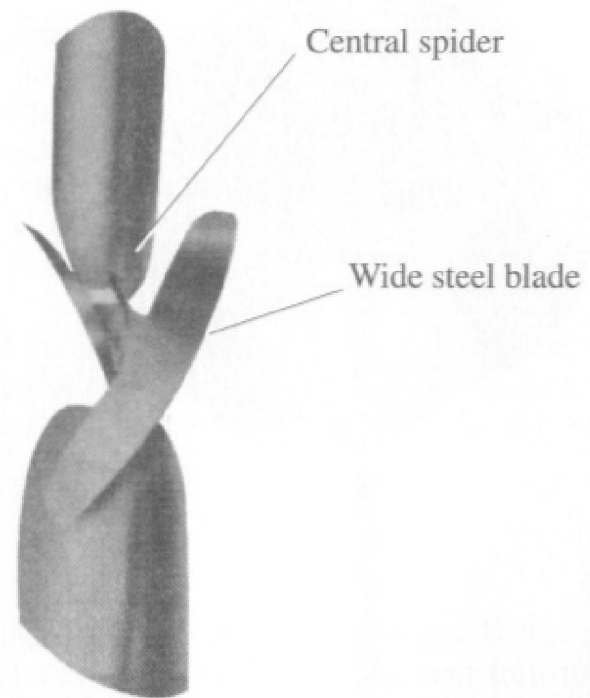


FIGURE 3.6 A 24-in propeller-fan wheel with four wide steel blades riveted to central spider.

closed by a separate small motor mounted on the shutter frame. When the shutter is closed, it will prevent heat losses due to backdraft and keep out wind, rain, and snow.

Screen Guards. Figure 3.8 shows a fan guard, sometimes fitted over the motor side of a propeller fan for safety, whenever the fan is installed less than 7 ft from the floor. It uses a steel mesh, designed for minimum interference with the air stream.

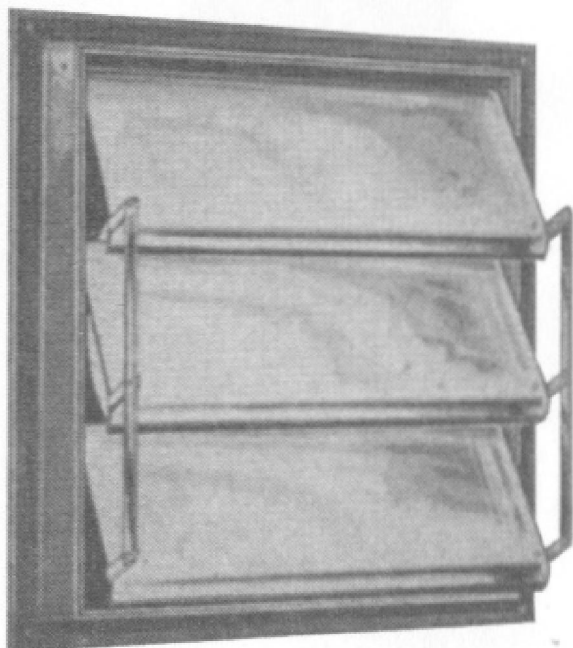


FIGURE 3.7 Automatic shutter having a square frame and three shutter blades linked together for simultaneous opening and closing.



FIGURE 3.8 Fan guard, used for safety and mounted on the inlet side of a propeller fan.

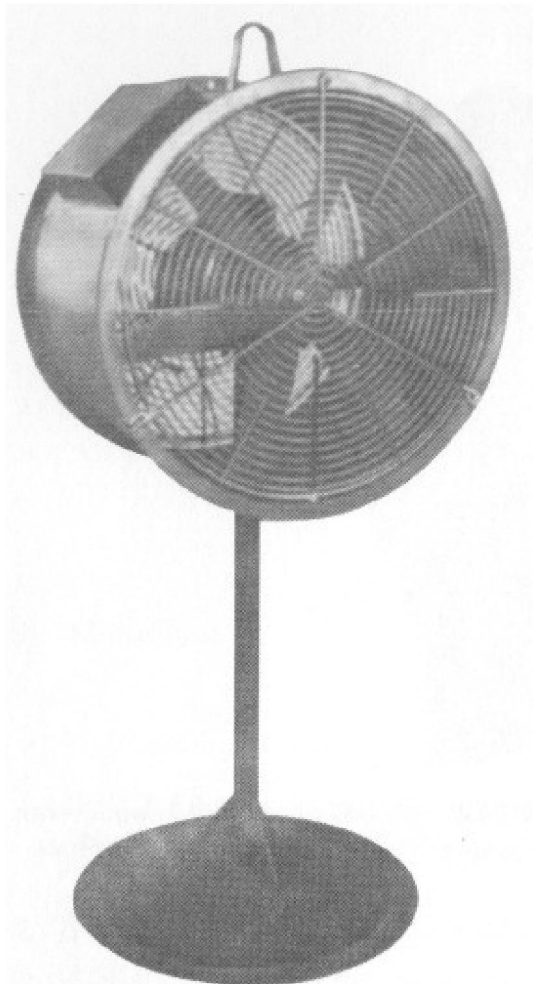


FIGURE 3.9 Man cooler mounted on a pedestal for cooling people, products, or processes. (Courtesy of Coppus Engineering Division, Tuthill Corporation, Millbury, Mass.)

Man Coolers. Another application for propeller fans (besides exhausting from a space) is for cooling people (as the term *man coolers* implies) or products or for supplying cool air to certain processes. These cooling fans are located in hot places, such as steel mills, foundries, and forge plants. They are also used for cooling down furnaces for maintenance work, for cooling electrical equipment (such as transformers, circuit breakers, and control panels), or for drying chemical coatings.

Figure 3.9 shows a man cooler mounted on a heavy pedestal for stability. It has a lug on top so that it can be moved easily to various locations. It has a 30-in propeller-fan wheel with six narrow blades and direct drive from a 3-hp, 1740-rpm motor.

Figure 3.10 shows a similar type of man cooler. It has a 30-in propeller-fan wheel with eight narrow blades and direct drive from a 3-hp, 1150-rpm motor. It has a bracket for mounting it on a wall, up high enough so that it cannot be damaged by trucks and the wires cannot be cut by wheels. As a special feature, this unit has a conical discharge nozzle that boosts the outlet velocity for deeper penetration.

The nozzle contains some straightening vanes, almost like a vaneaxial fan, to prevent excessive air spin at the narrow end of the cone.

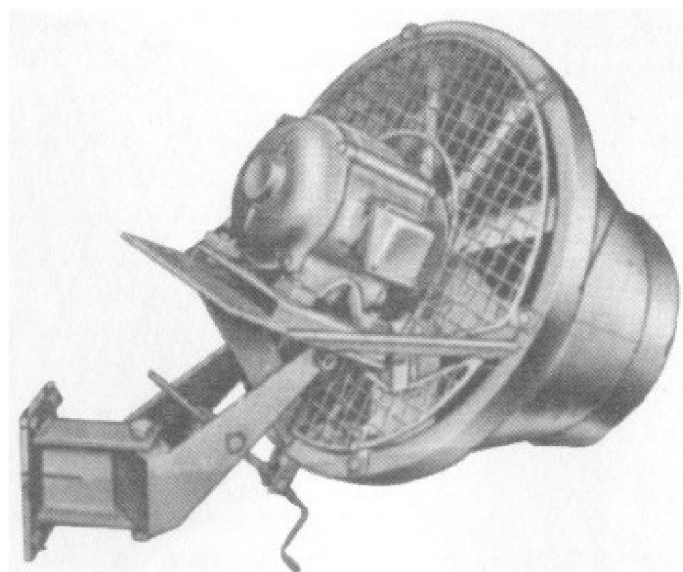


FIGURE 3.10 Man cooler with a bracket for mounting it on a wall, with conical discharge nozzle for deeper penetration. (Courtesy of Bayley Fan Group, Division of Lau Industries, Lebanon, Ind.)

Tubeaxial Fans

Figure 3.11 shows a tubeaxial fan with direct drive from an electric motor. It has a cylindrical housing and a fan wheel with a 33 percent hub-tip ratio and with ten blades that may or may not have airfoil cross sections. The best application for tubeaxial fans is for exhausting from an inlet duct. A short outlet duct can be tolerated, but the friction loss there will be larger than normal because of the air spin. If no inlet duct is used, a venturi inlet is needed to prevent a 10 to 15 percent loss in flow and an increased noise level. Figure 3.11 shows the motor on the inlet side, but it could be located on the outlet side as well.

In case of belt drive, the motor is located outside the cylindrical housing, and a belt guard is needed. Direct drive has fewer parts and therefore lower cost, the same as for propeller fans, and the performance flexibility again can be obtained by means of adjustable-pitch blades.

Vaneaxial Fans

Figure 3.12 shows a vaneaxial fan with belt drive from an electric motor. It has a cylindrical housing (like a tubeaxial fan) and a fan wheel with a 46 percent hub-tip ratio and with nine airfoil blades. It also has eleven guide vanes, neutralizing the air spin, so that the unit can be used for blowing (outlet duct) as well as for exhausting (inlet duct). Again, direct drive is simpler and less expensive than belt drive. Also, performance flexibility for direct drive can be obtained by means of adjustable-pitch blades. Again, a venturi inlet is needed if no inlet duct is used.

Figure 3.13 shows an axial-flow fan wheel with a 42 percent hub-tip ratio and with eight single-thickness steel blades. It could be used in a tubeaxial fan or in a vaneaxial fan.

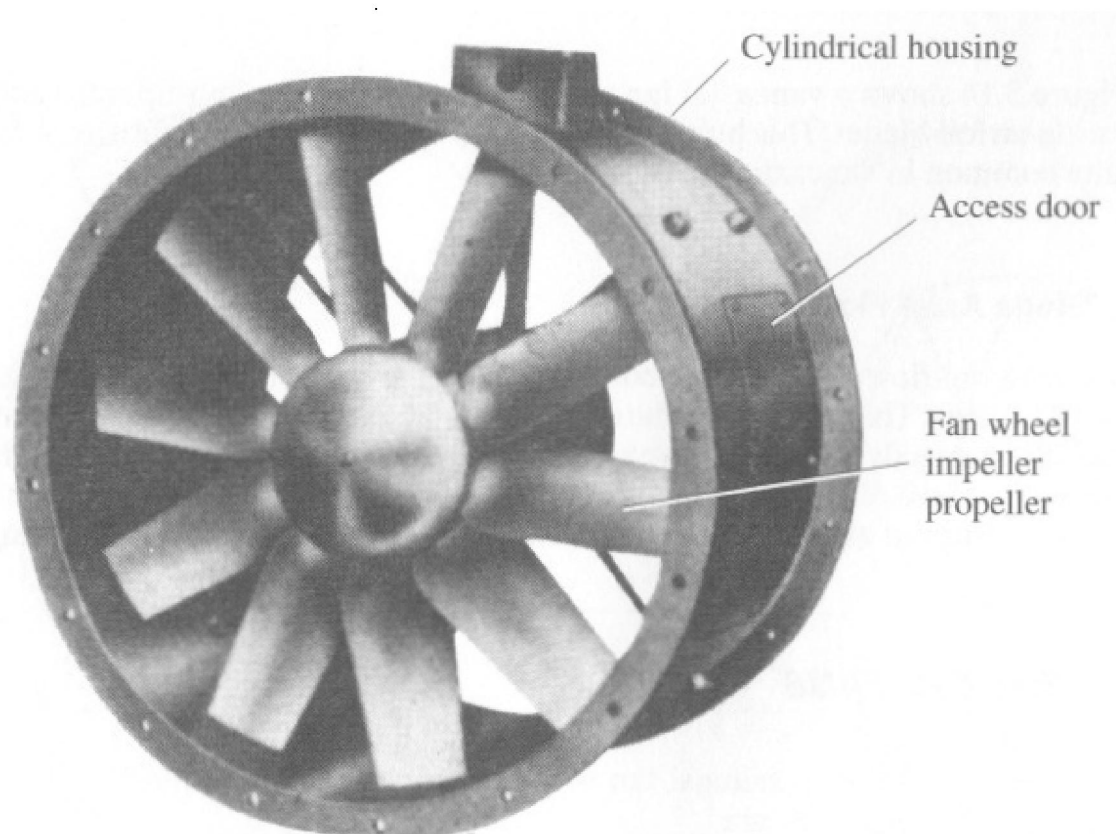


FIGURE 3.11 Tubeaxial fan with direct drive from an electric motor on the inlet side (in the background) and with a fan wheel having a 33 percent hub-tip ratio and with ten blades. (Courtesy of General Resource Corporation, Hopkins, Minn.)

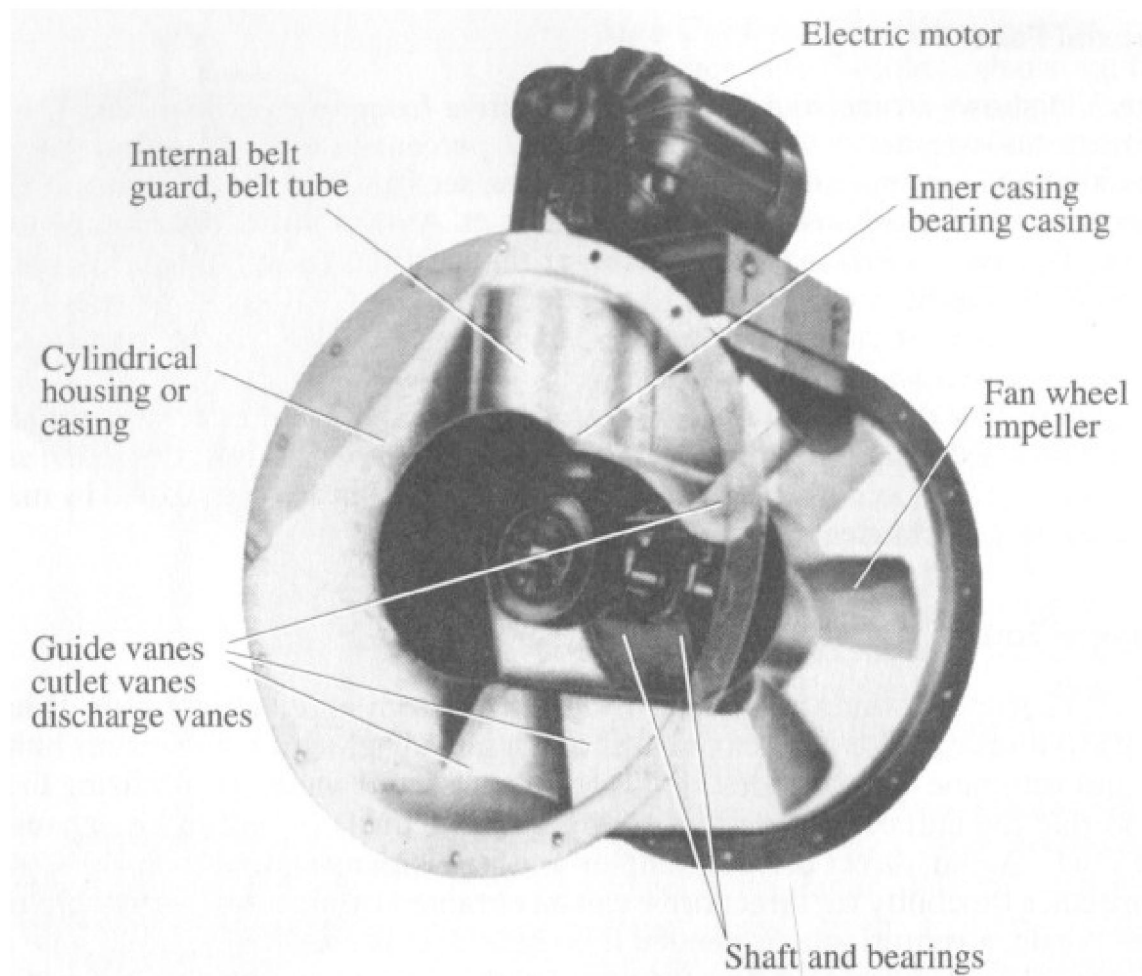


FIGURE 3.12 Vaneaxial fan with belt drive from an electric motor and with a fan wheel having a 46 percent hub-tip ratio and nine airfoil blades. (Courtesy of General Resource Corporation, Hopkins, Minn.)

Figure 3.14 shows a vaneaxial fan wheel with a 64 percent hub-tip ratio and with five wide airfoil blades. This hub-tip ratio would be too large for a tubeaxial fan but is quite common in vaneaxial fans.

Two-Stage Axial-Flow Fans

Two-stage axial-flow fans have the configuration of two fans in series so that the pressures will add up. This is an easy solution when higher static pressures are needed, but excessive tip speeds and noise levels cannot be tolerated. The two fan wheels may rotate in the same direction, with guide vanes between them. Or they may be counterrotating, without any guide vanes, as will be explained in more detail in Chap. 4.

CENTRIFUGAL FANS

There are six types of centrifugal fan wheels in common use. Listed in the order of decreasing efficiency, they are

1. Centrifugal fans with airfoil (AF) blades
2. Centrifugal fans with backward-curved (BC) blades

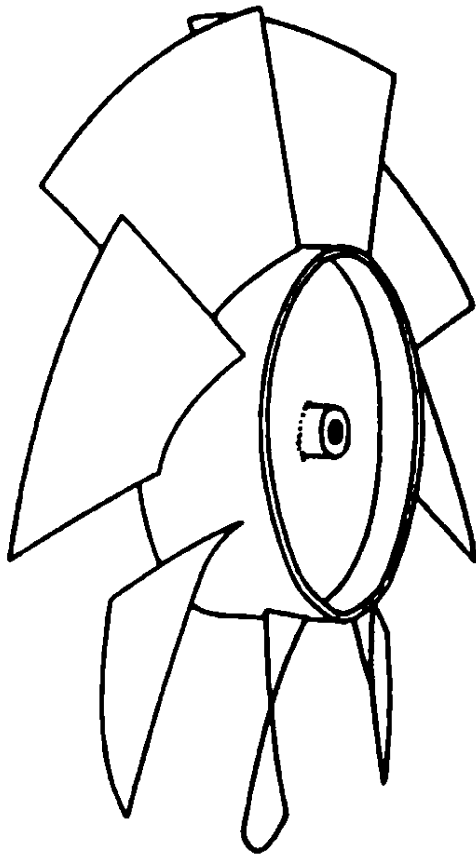


FIGURE 3.13 Axial-flow fan wheel with a 42 percent hub-tip ratio and with eight single-thickness steel blades for use as a tubeaxial fan wheel or as a vaneaxial fan wheel.

3. Centrifugal fans with backward-inclined (BI) blades
4. Centrifugal fans with radial-tip (RT) blades
5. Centrifugal fans with forward-curved (FC) blades
6. Centrifugal fans with radial blades (RBs)

These six types are used in a variety of applications, as will be discussed in more detail in Chap. 7.

Centrifugal Fans with AF Blades

The centrifugal fan with AF blades has the best mechanical efficiency and the lowest noise level (for comparable tip speeds) of all centrifugal fans. Figures 3.15 and 3.16 show two constructions for centrifugal fan wheels with AF blades. Figure 3.15 shows hollow airfoil blades, normally used in medium and large sizes. Figure 3.16 shows cast-aluminum blades, which are often used in small sizes and for testing and devel-

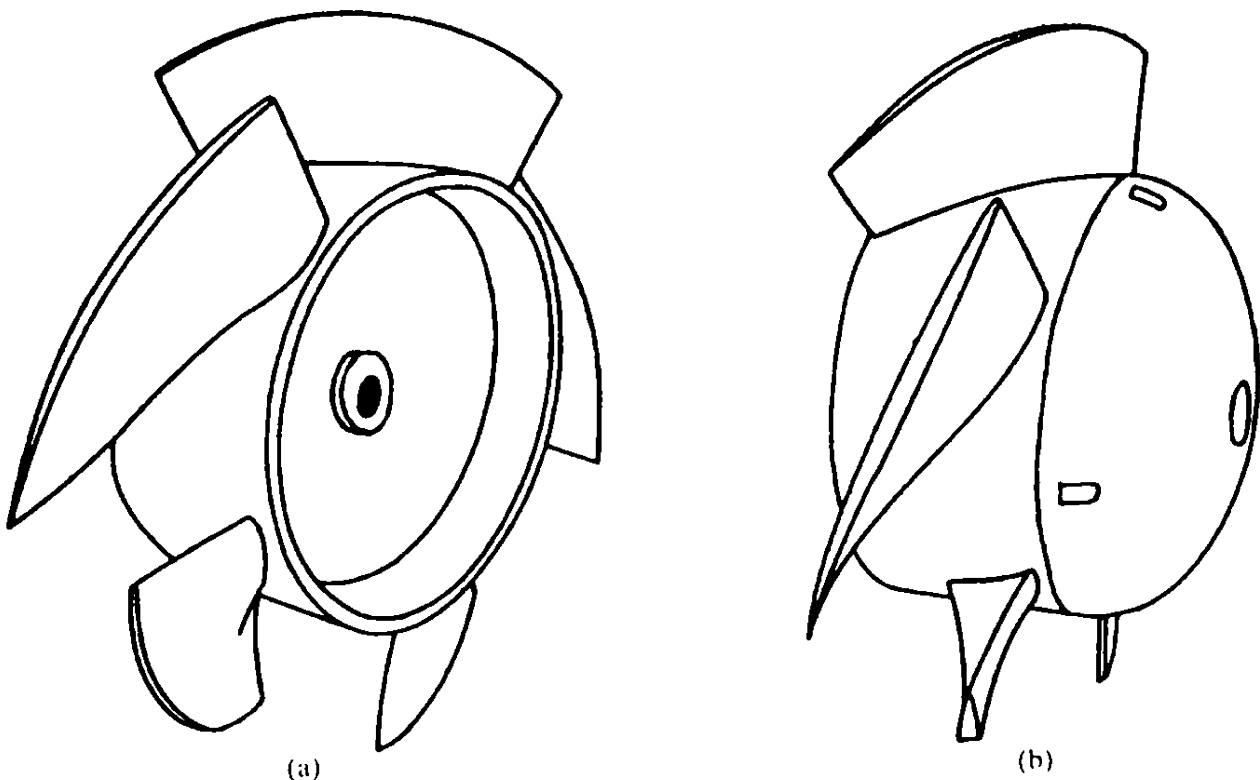


FIGURE 3.14 Vaneaxial fan wheel with a 64 percent hub-tip ratio and with five wide cast-aluminum airfoil blades: (a) without inlet hood; (b) with inlet hood.

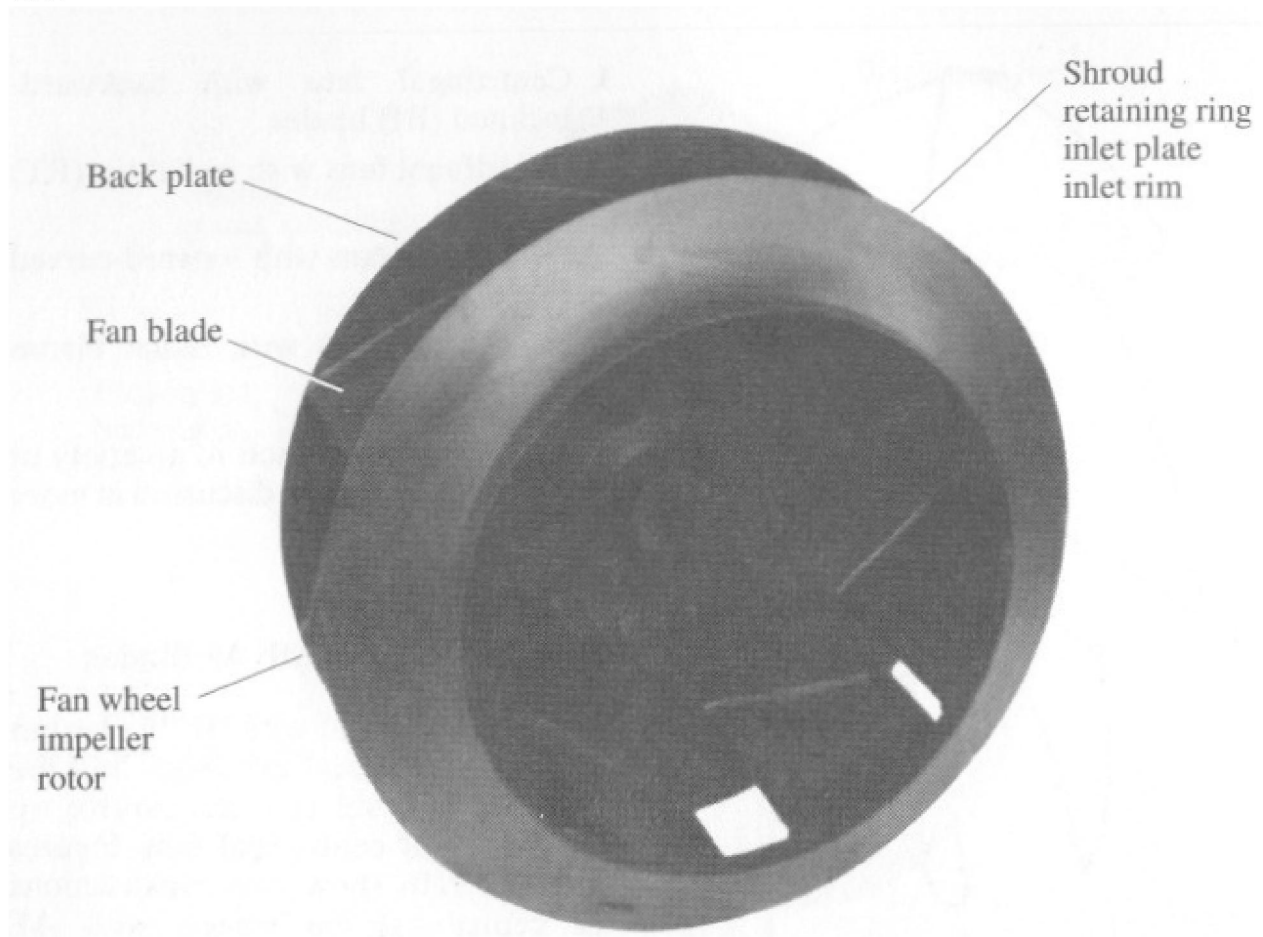


FIGURE 3.15 Centrifugal fan wheel, SISW, with nine hollow airfoil steel blades welded to back plate and shroud. (Courtesy of General Resource Corporation, Hopkins, Minn.)

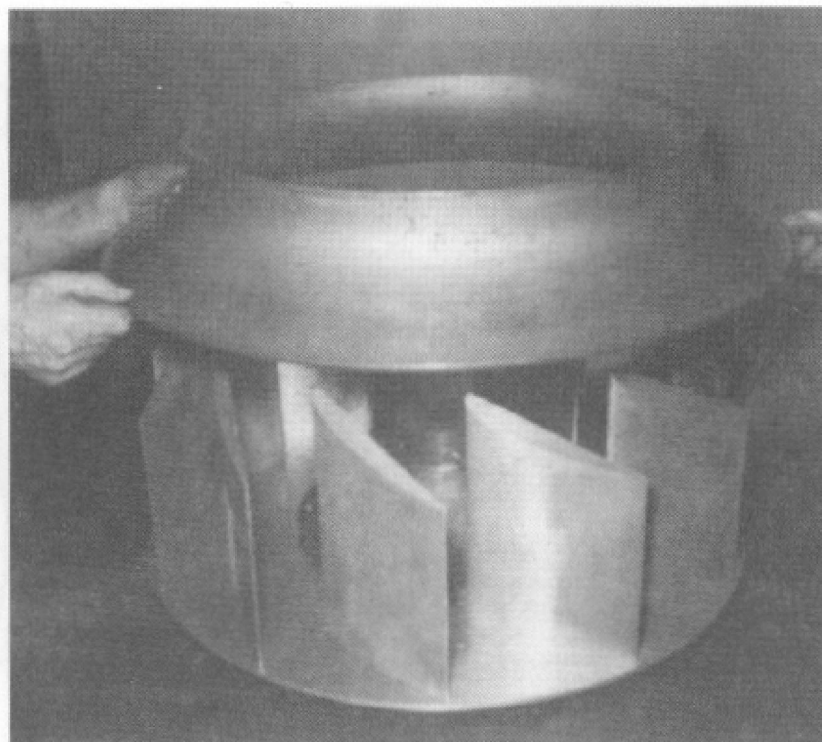


FIGURE 3.16 Experimental centrifugal fan wheel, SISW, with eleven cast-aluminum airfoil blades welded to the back plate but not yet welded to the shroud (held above the blades).

opment work, with the shroud held above the airfoil blades prior to welding it to the blades.

Centrifugal Fans with BC Blades

BC blades are single-thickness steel blades but otherwise are similar to AF blades with respect to construction and performance. They have slightly lower efficiencies but can handle contaminated air streams because the single-thickness steel blades can be made of heavier material than can be used for hollow airfoil blades.

Centrifugal Fans with BI Blades

Figure 3.17 shows a sketch of an SISW (single inlet, single width) centrifugal fan wheel with BI blades. These are more economical in production, but they are somewhat lower in structural strength and efficiency. Figure 3.18 shows the same fan wheel in a scroll housing. Figure 3.19 shows a BI centrifugal fan with scroll housing, noting the terminology for the various components.

Incidentally, scroll housings are not always used in connection with centrifugal fan wheels. Centrifugal fan wheels also can be used without a scroll housing, in such applications as unhusd plug fans, multistage units, and roof ventilators. An exception is FC centrifugal fan wheels. They require a scroll housing for proper functioning, as will be explained in Chap. 7.

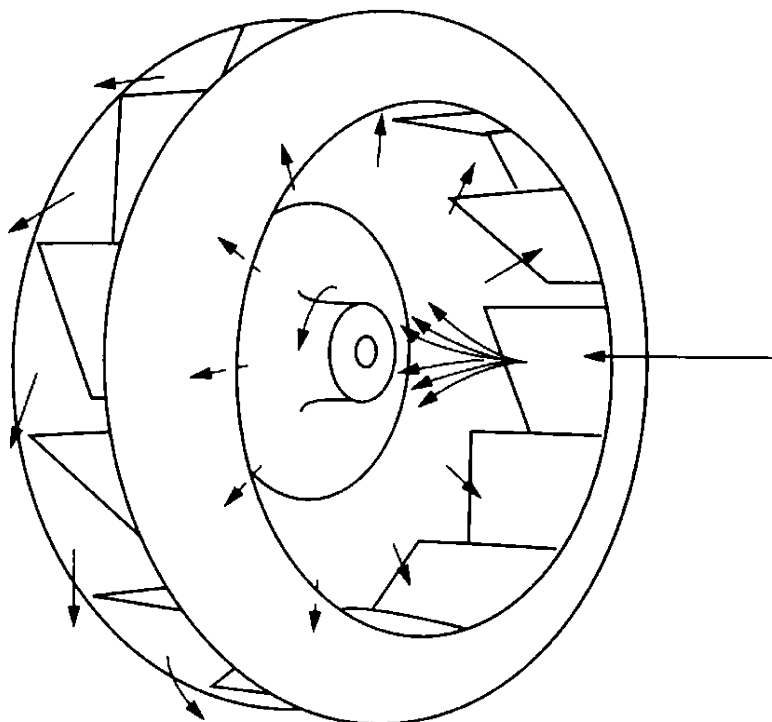


FIGURE 3.17 Centrifugal fan wheel, SISW, with BI blades welded to back plate and shroud.

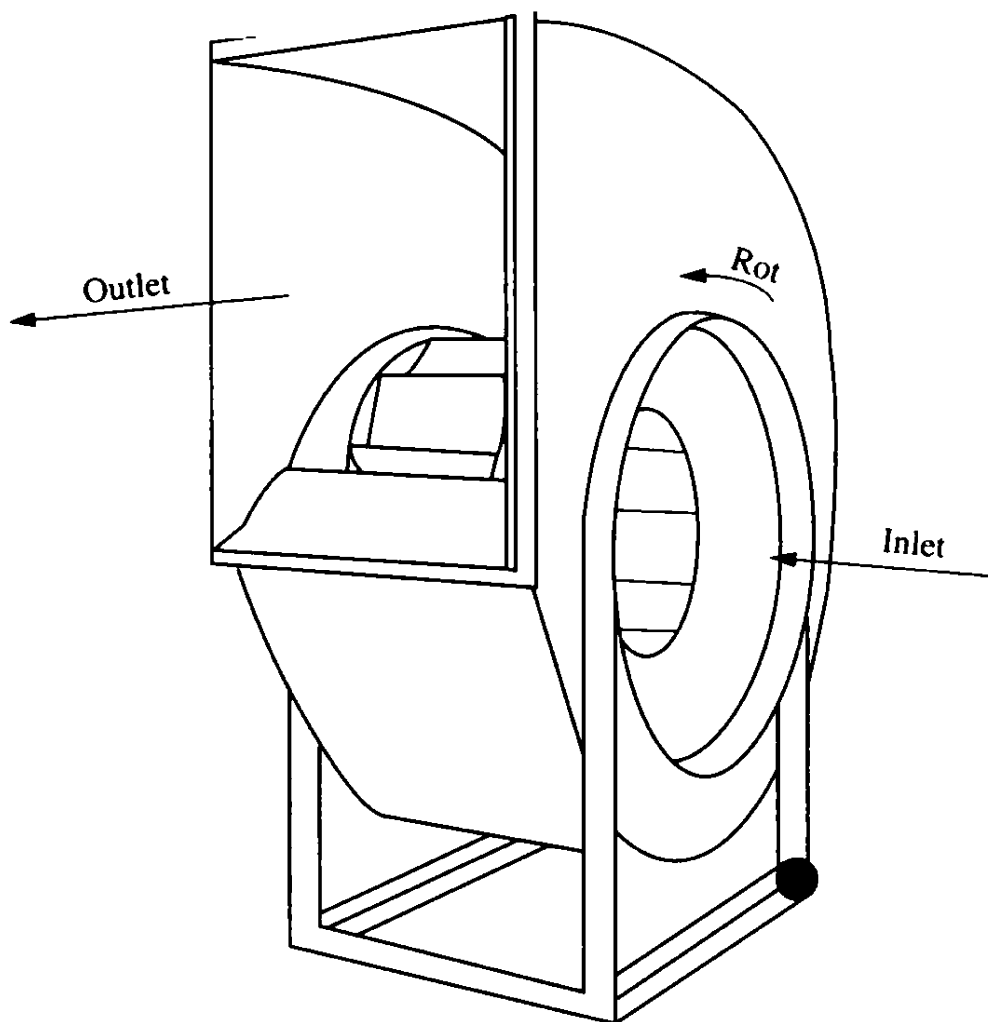


FIGURE 3.18 Angular view of centrifugal fan with BI wheel inside showing scroll housing, inlet side, and outlet side with cutoff all the way across housing width.

Centrifugal Fans with RT Blades

RT blades are curved, with good flow conditions at the leading edge. Only the blade tips are radial, as the term *radial-tip blades* indicates. Figure 3.20 shows a radial-tip centrifugal fan wheel. These RT wheels are used mainly in large sizes, with wheel diameters from 30 to 60 in, for industrial applications, often with severe conditions of high temperature and light concentrations of solids.

Centrifugal Fans with FC Blades

FC blades, as the name indicates, are curved forward, i.e., in the direction of the rotation. This results in very large blade angles and in flow rates that are much larger than those of any other centrifugal fan of the same size and speed. Figure 3.21 shows a typical SISW FC fan wheel, with many short blades and a flat shroud with a large inlet diameter for large flows. These fans are used in small furnaces, air conditioners, and electronic equipment, whenever compactness is more important than efficiency.

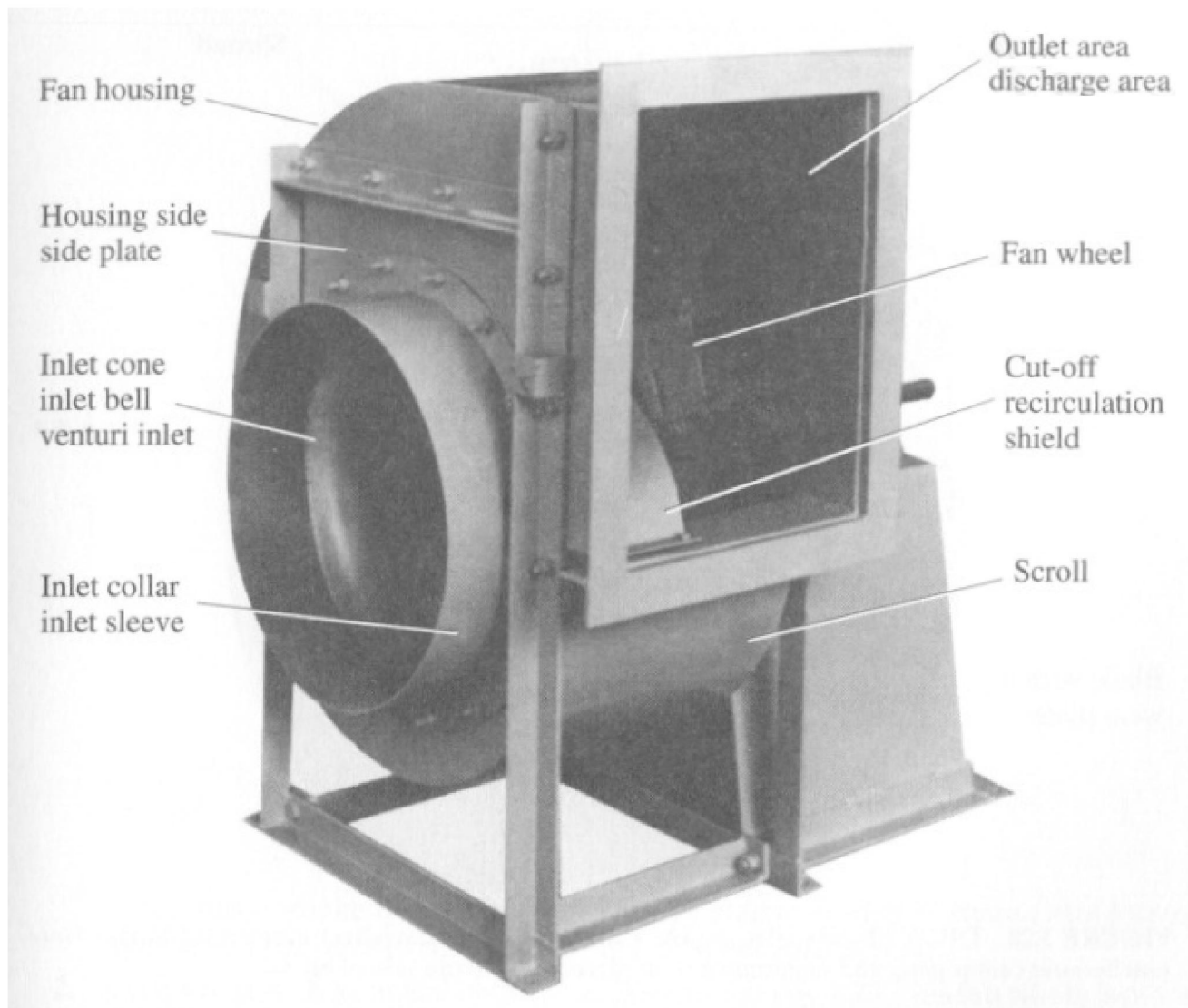


FIGURE 3.19 Angular view of centrifugal fan with BI wheel inside showing scroll housing, inlet side (inlet collar and inlet cone), and outlet side with recirculation shield opposite the inlet cone only. (Courtesy of General Resource Corporation, Hopkins, Minn.)

Centrifugal Fans with Radial Blades

Radial blades (RBs) are rugged and self-cleaning, but they have comparatively low efficiencies because of the nontangential flow conditions at the leading edge. Figure 3.22 shows an SISW RB fan wheel with a back plate but without a shroud. Sometimes even the back plate is omitted (open fan wheel), and reinforcement ribs are added for rigidity. These fans can handle not only corrosive fumes but even abrasive materials from grinding operations.

AXIAL-CENTRIFUGAL FANS

These fans are also called *tubular centrifugal fans*, *in-line centrifugal fans*, or *mixed-flow fans* (especially if the fan wheel has a conical back plate). The following two types of fan wheels are used in these fans:

1. A fan wheel with a flat back plate, as shown in Fig. 3.17, i.e., the same type as is used in a scroll housing. When used in an axial-centrifugal fan, however, the

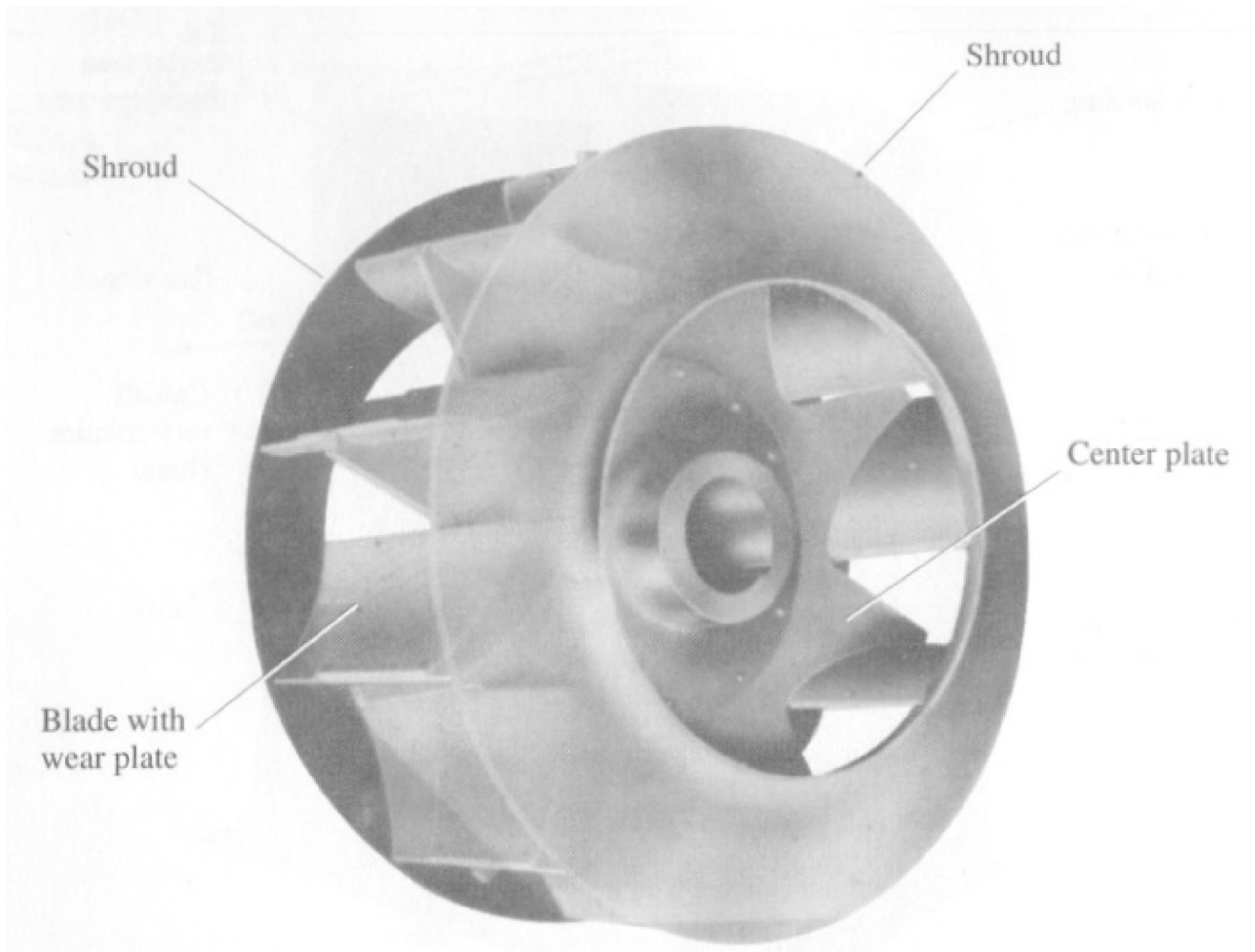


FIGURE 3.20 DIDW (double inlet, double width) centrifugal fan wheel with ten RT blades. Note notched-out center plate and replaceable wear plates on pressure side of blades.

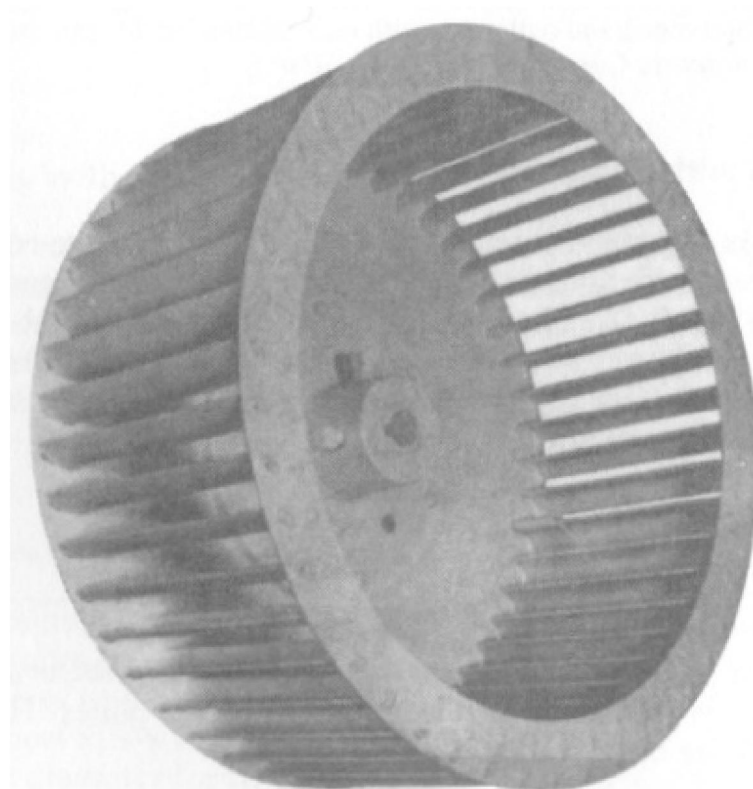


FIGURE 3.21 SISW centrifugal fan wheel with 52 FC blades fastened through corresponding slots in back plate and shroud.

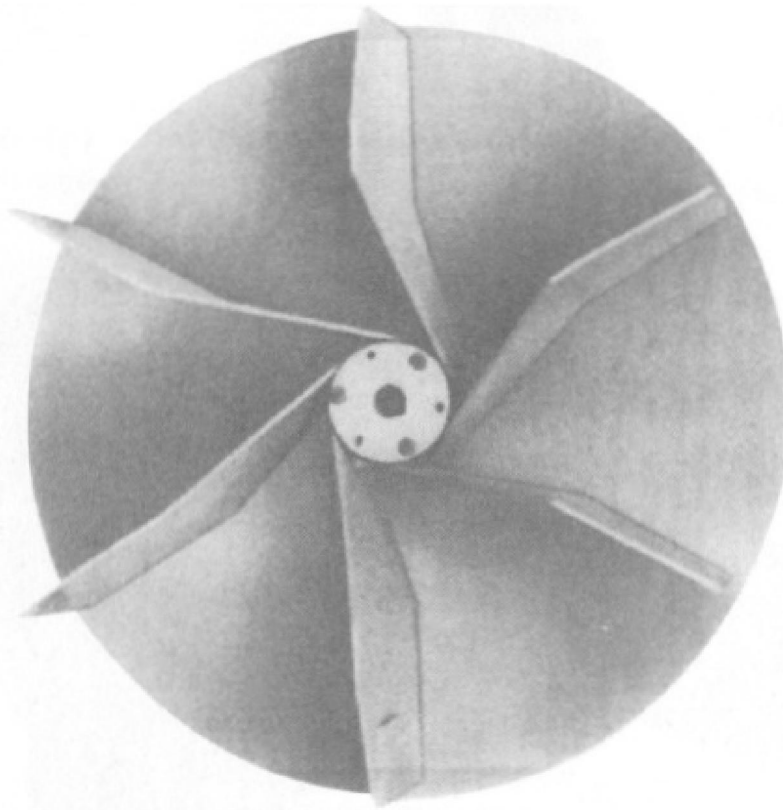


FIGURE 3.22 SISW centrifugal fan wheel with six radial blades welded to a back plate.

stream has to make two 90° turns, which, of course, results in some extra losses, especially if the diffuser ratio (housing i.d./wheel o.d.) is small.

2. A fan wheel with a conical back plate, as shown in Fig. 3.23. This fan wheel is more expensive to build, but the air stream here has to make only two 45° turns, a more efficient arrangement. In either case, the fan wheel usually has BI blades or occasionally AF or BC blades.

The following three types of housings are in common use in axial-centrifugal fans:

1. A cylindrical housing, as shown in Figs. 3.23 and 3.24.

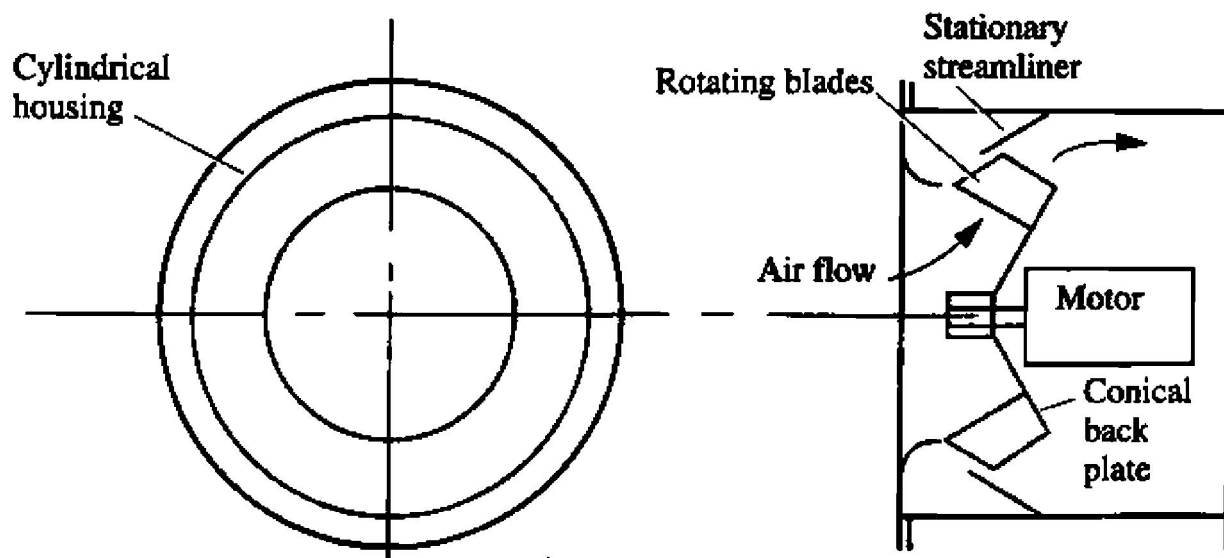


FIGURE 3.23 Mixed-flow fan showing direct motor drive, venturi inlet, fan wheel with conical back plate, and with a 45° diverging air stream discharging into a cylindrical housing.

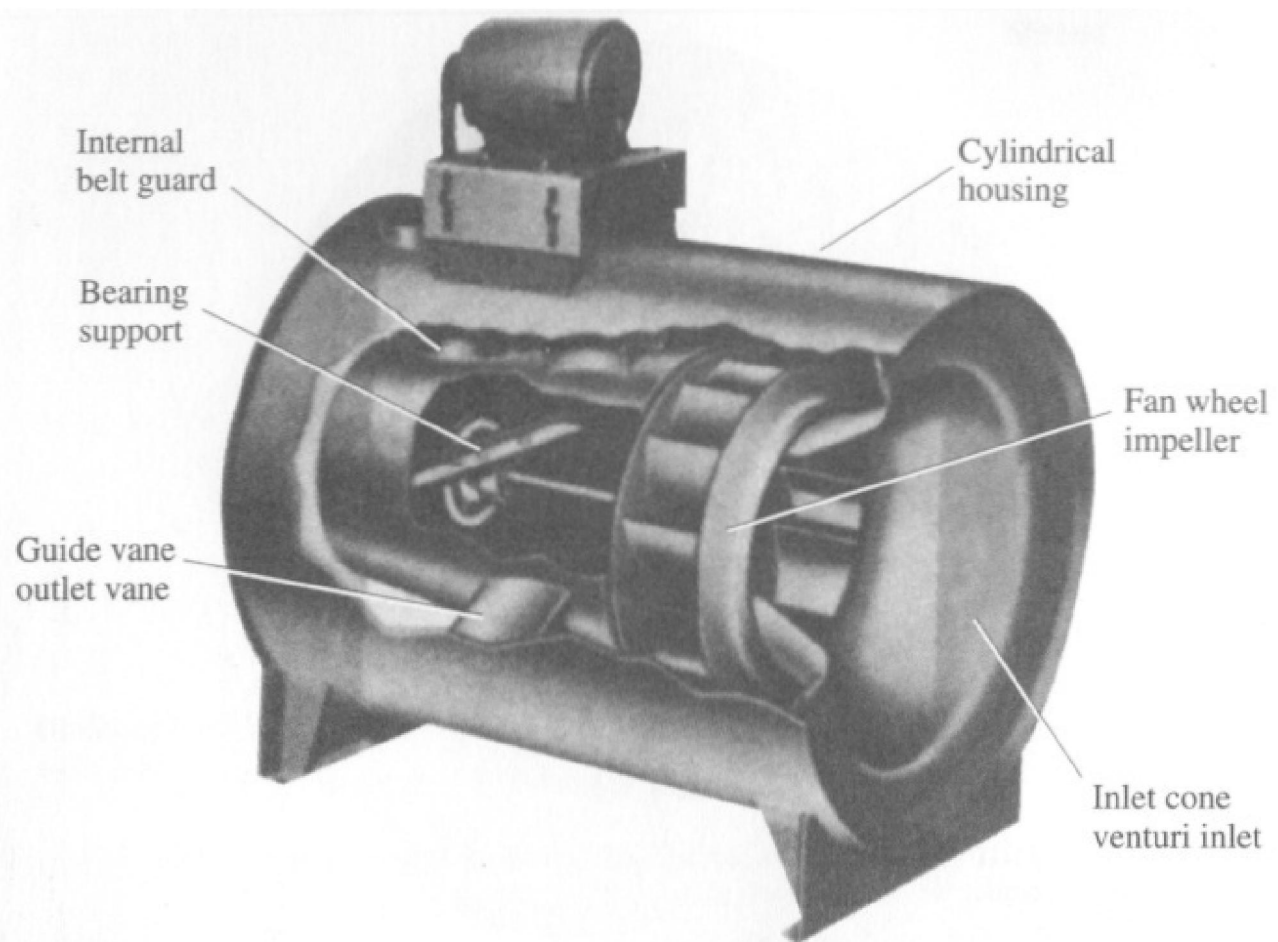


FIGURE 3.24 Axial-centrifugal fan showing belt drive from an outside motor, venturi inlet, fan wheel with flat back plate, and outlet guide vanes, all assembled in a cylindrical housing. (Courtesy of General Resource Corporation, Hopkins, Minn.)

2. A square housing, as shown in Fig. 3.25.
3. A barrel-shaped housing, as shown in Figs. 3.26 and 3.27.

Various wheel and housing combinations are possible. Figure 3.27 shows a special type of barrel-shaped housing which is covered by my U.S. patent no. 3,312,386. It has a separate chamber for the motor so that direct drive can be used, even if hot or corrosive gases are handled. This fan has the trade name Axcentrix Bifurcator, implying that the air stream is divided into two forks, flowing above and below the motor chamber but never coming into contact with the motor. The various types of axial-centrifugal fans will be discussed further in Chap. 9.

ROOF VENTILATORS

Figure 3.28 shows an exhaust roof ventilator with direct drive, a BI centrifugal fan wheel, and radial discharge using various spinnings. Various other models of roof ventilators are in common use. Some may have belt drive instead of direct drive, some may have axial fan wheels instead of centrifugal fan wheels, and some may be for upblast instead of radial discharge. While most models are for exhausting air from a building, some are for supplying air into a building. The various combinations of these features lead to ten different models, which will be illustrated and described in Chap. 10.

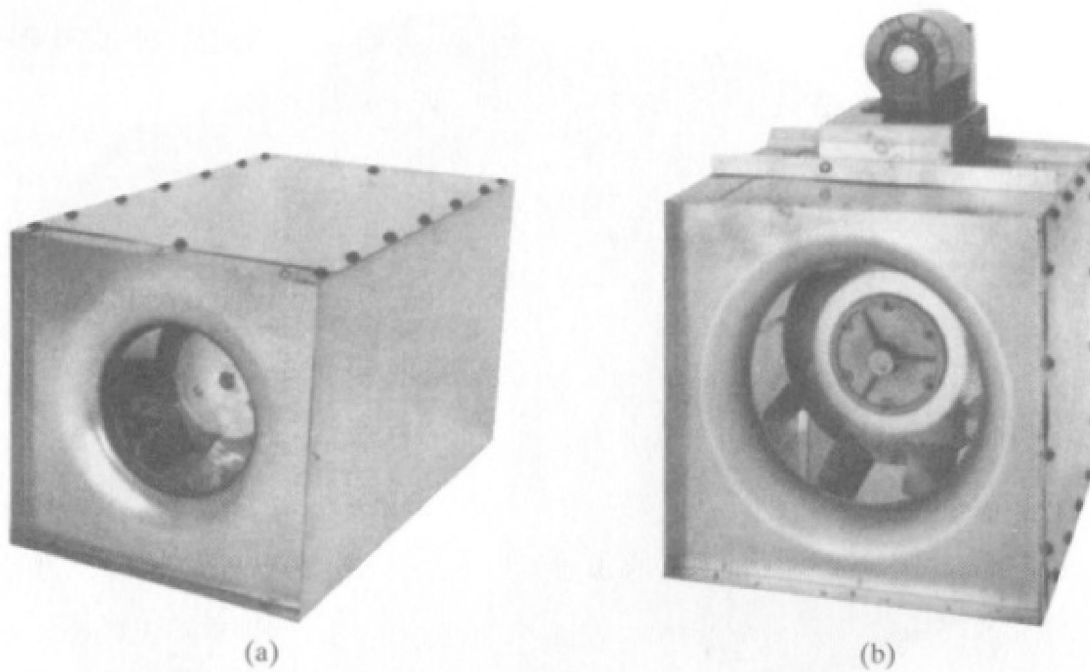


FIGURE 3.25 Mixed-flow fan in a square housing. Two models are shown, one for direct drive and one for belt drive. Both models have a venturi inlet, a fan wheel with a conical back plate, and an access door. The square housing results in lower cost and allows connection to either square or round ducts. (Courtesy of FloAire, Inc., Bensalem, PA.)

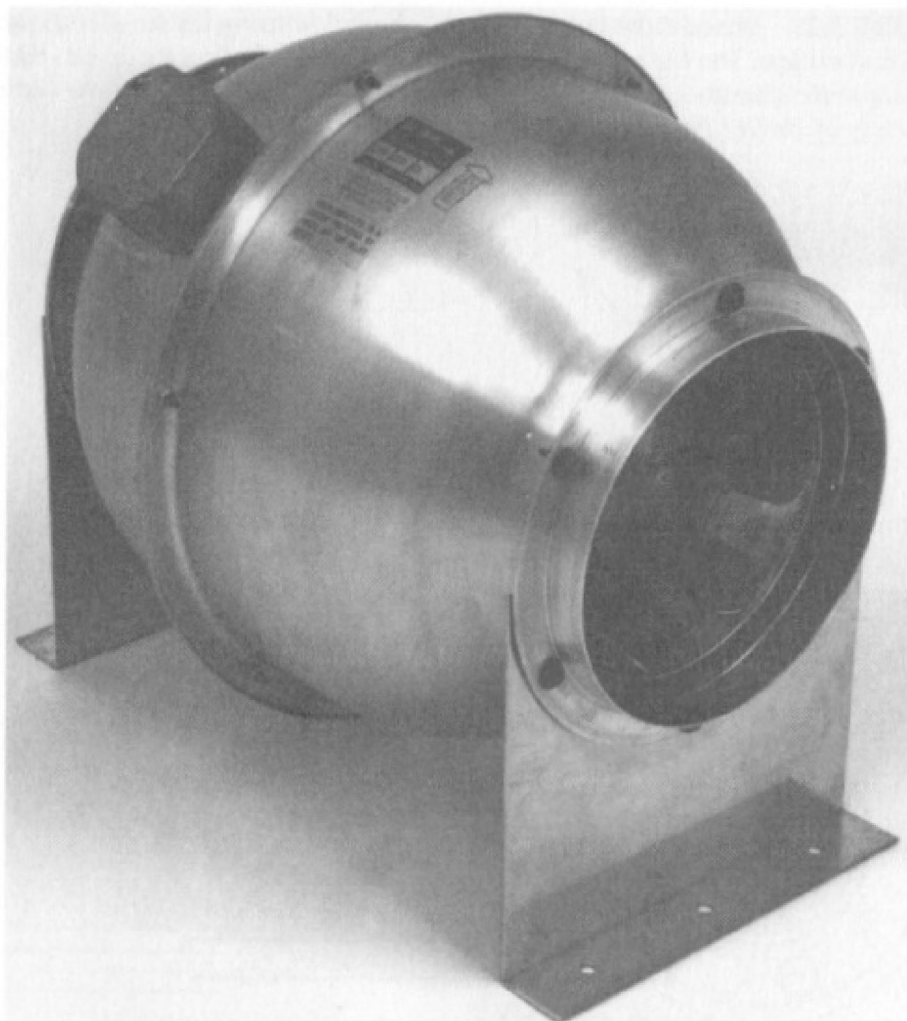


FIGURE 3.26 Mixed-flow fan with barrel-shaped spun housing for smaller diameters of inlet and outlet ducts. Direct drive. The fan wheel has a conical back plate. Outlet guide vanes (not shown) prevent excessive air spin at the small outlet diameter. (Courtesy of FloAire, Inc., Bensalem, Pa.)

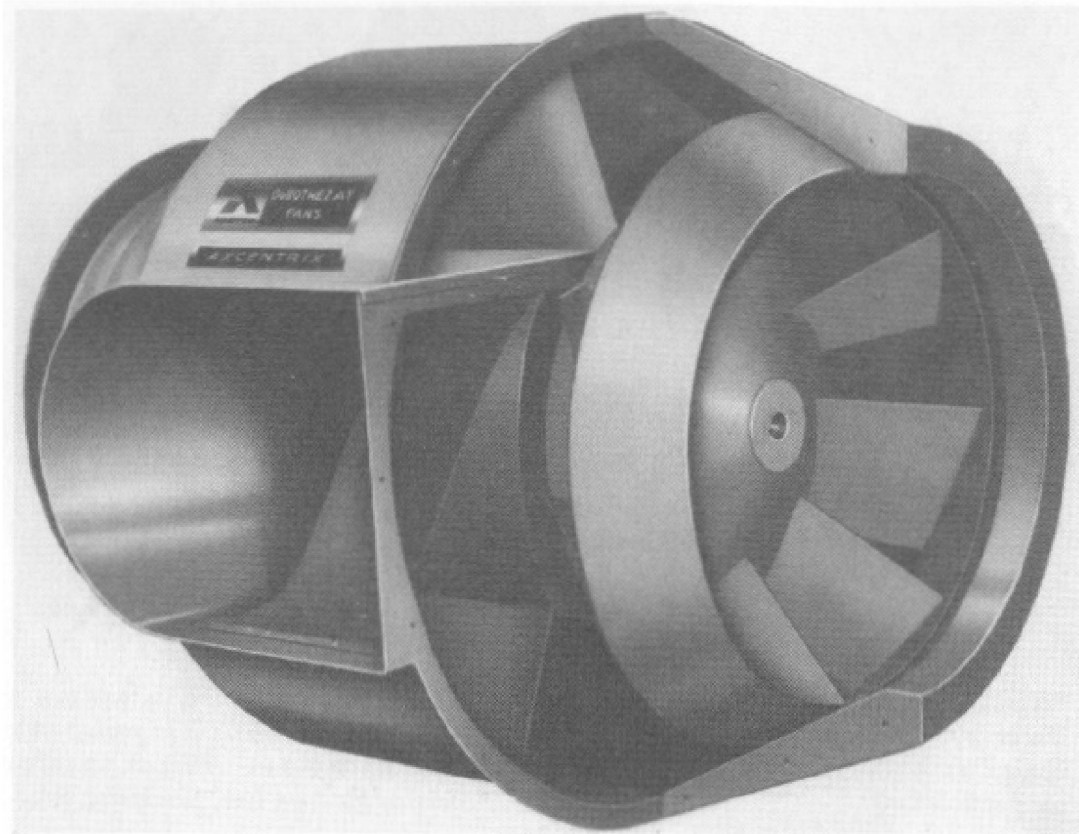


FIGURE 3.27 Mixed-flow fan with barrel-shaped housing for smaller diameters of inlets and outlets. The fan wheel with conical back plate is directly driven by a motor in a separate chamber. Outlet vanes (not shown) prevent excessive outlet spin. (Courtesy of Bayley Fan, Division of Lau Industries, Lebanon, Ind.)

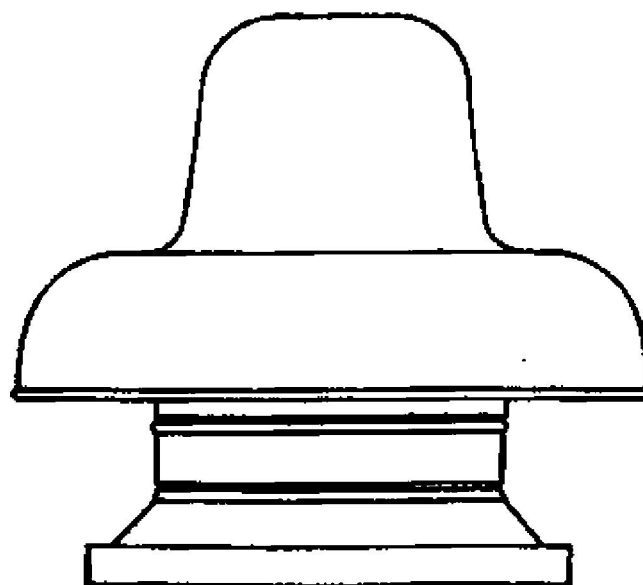


FIGURE 3.28 Schematic sketch of a centrifugal roof exhauster, direct drive, radial discharge, 15-in wheel diameter, 1 hp, 1725 rpm. (Courtesy of Flo-Aire, Inc., Cornwells Heights, Pa.)

CROSS-FLOW BLOWERS

A cross-flow blower is a unique type of centrifugal fan in which the airflow passes twice through a fan wheel with FC blading, first inward and then outward, as shown in Fig. 3.29. The main advantage of cross-flow blowers is that they can be made axially wider, in fact to any width desired. This makes them particularly suitable for certain applications such as air curtains, long and narrow heating or cooling coils, and dry blowers in a car wash. The flow pattern and principle of operation will be explained in Chap. 12.

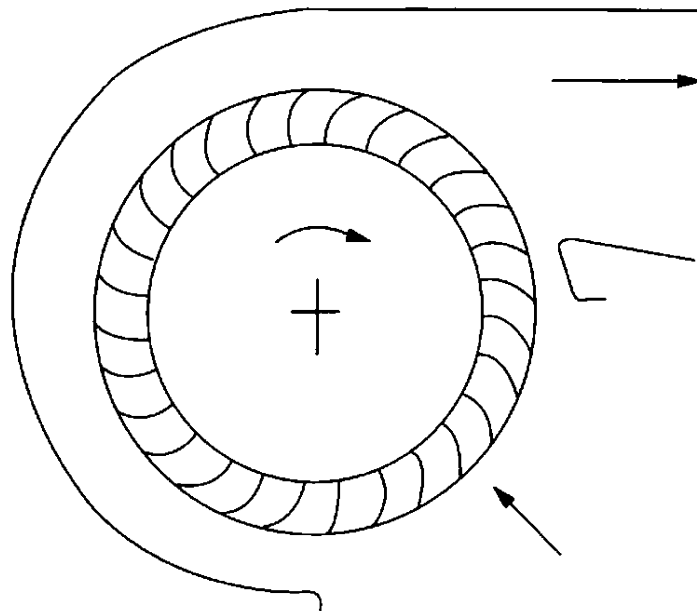


FIGURE 3.29 Cross-flow blower showing airflow passing twice through the rotating fan wheel.

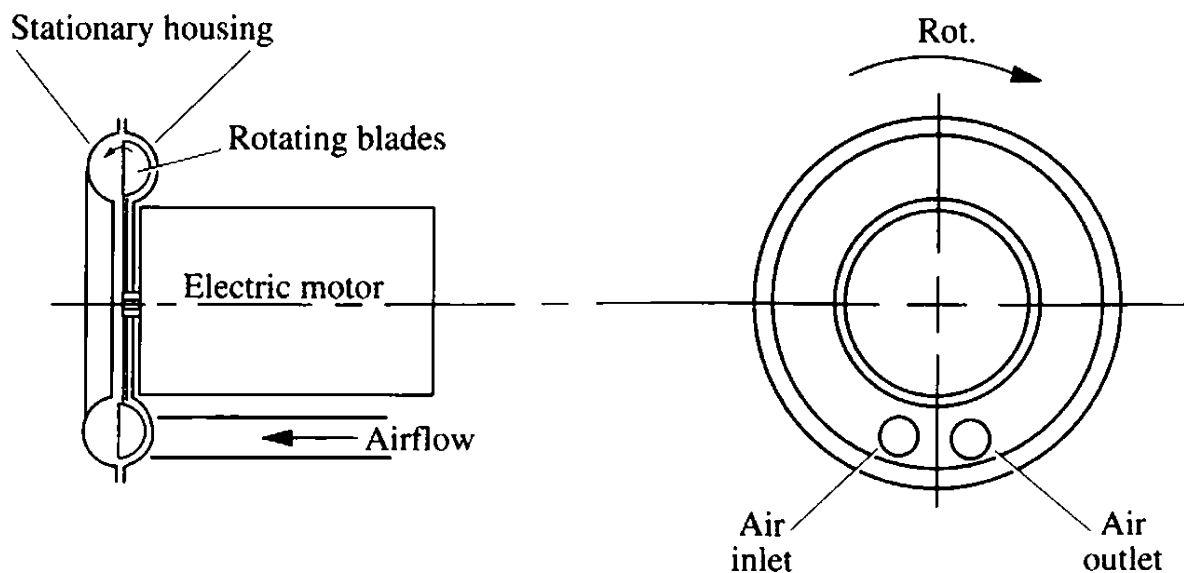


FIGURE 3.30 Vortex blower showing blades rotating in right half of the torus-shaped housing

VORTEX OR REGENERATIVE BLOWERS

The vortex or regenerative blower is another unique type of centrifugal fan. Here the airflow circles around in an annular, torus-shaped space, similar to the shape of a doughnut. On one side of the torus are rotating fan blades, throwing the air outward, as shown in Fig. 3.30. The airflow then is guided back inward by the other side of the torus so that it must reenter the inner portion of the rotating blades. This results in a complicated flow pattern that will be discussed in detail in Chap. 9.

CONCLUSION

From the preceding we note that there are many different types of fans. Nevertheless, only two basic operating principles are used in all these fans: deflection of airflow and centrifugal force.

In *axial-flow fans*, the operating principle is simply deflection of airflow. Here the pressure is produced exclusively by the lift of the airfoil or of the single-thickness sheet metal profile used for the cross sections of the blades. Since an airfoil has a better lift-drag ratio over a wider range of angles of attack than a single-thickness profile (see Chap. 2), airfoil blades will result in better efficiencies than single-thickness profiles.

In *centrifugal fans* (including mixed-flow, cross-flow, and vortex fans), the operating principle is a combination of airflow deflection plus centrifugal force. This results in the following two differences between the performances of axial-flow fans and centrifugal fans:

1. Centrifugal fans normally produce more static pressure than axial-flow fans of the same wheel diameter and the same running speed. (Axial-flow fans, on the other hand, have the advantages of greater compactness and of easier installation.)
2. Since in centrifugal fans the airfoil lift contributes only a small portion of the pressure produced (while most of it is produced by centrifugal action), the improvement in performance due to airfoil blades (over sheet metal blades) is not as pronounced in centrifugal fans as it is in axial-flow fans.