Air can be caused to move by natural forces, such as wind or differences in density (stack, or chimney, effect), or by mechanical forces. Natural forces (weather, for instance) are difficult to predict, let alone control, although density differences can be deliberately induced by manipulating temperatures.

Mechanical forces are obviously controllable, and hence better suited to the design process. The most common types of equipment available for moving gases (principally air), are:

- positive displacement devices which employ pistons, helixes, scrolls, intermeshing lobes, diaphragms, or the like, which sweep through a fixed volume, with very little clearance between the stationary and moving parts.

- devices with a rotating component called a wheel, impeller, or squirrel cage, which is noticeably smaller than the volume through which it rotates.

At one time, ASME considered the device to be a compressor if changed the density of the gas by more than 7%. This arbitrary demarcation is under review at present and the distinction between fans and compressors man change in the future. All of the abovementioned configurations are used for this purpose (compression).

Most ducted systems convey air where the density changes are usually less than 7%. They utilize the second category of devices listed above, which are referred to as fans or blowers.

The following material discusses some of the physical and operational characteristics of these devices.

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**BASIC FAN TYPES**

**CENTRIFUGAL**

Air enters the fan housing along the axis of rotation, and leaves perpendicular to the axis of rotation. Relative to the fan wheel, the air enters axially and leaves radially. Wheel types are determined by blade shape and number of blades. The most common types are:

1. **Forward-curved (F)** wheel: many short blades which are curved ("scooped") in the direction of wheel rotation. Sometimes called "squirrel cage" fan.

2. **Radial (R)** wheel: relatively few blades which are flat and which lie on a radius line of the wheel. Sometimes referred to as a "non-clog" or "materials-handling" wheel; frequently used in "dirty" air streams.

3. **Backwardly inclined (B or BI)** wheel: relatively few flat blades which are inclined backwards from a radius line in the direction of rotation.

4. **Backwardly curved (B or BC)** wheel: relatively few blades, inclined backwards from a radius line with slight curvature to the blade shape.

5. **Airfoil (A)** wheel: similar to BC wheel, except that the blade cross-section is an airfoil.

*Note: types 3, 4, and 5 above have very similar performance characteristics.*
AXIAL

Air enters and leaves the fan along the axis of rotation. Air leaving the wheel has a strong helical component of motion. Wheel configuration depends on blade shape (flat, curved, airfoil), number of blades, blade spacing (even or uneven), ratio of blade length to hub diameter, number of stages, and other special features. Fan type is determined by the nature of the housing surrounding the wheel.

- **Propeller** fan: no enclosing housing; may or may not include an inlet ring; usually includes a fan guard for safety.
- **Tubeaxial** fan: wheel is located in an enclosing tube, which acts as a safety guard and as a means of attaching inlet and/or outlet ductwork.
- **Vaneaxial** fan: similar to tubeaxial, except that a set of fixed blades is located immediately downstream of the wheel to convert the helical component of motion to an axial component (i.e. "unscrew" the air).

MIXED FLOW

Air enters and leaves axially, but there is a stronger component of radial (centrifugal) energy added than in the axial case. This type of fan is not commonly used in the HVAC/pollution industries. (However, mixed flow liquid pumps are not uncommon.)

CROSS FLOW

Air enters and leaves the wheel radially (similar to a turbine pump). Sometimes referred to as a tangential flow fan. Usually limited to type F wheel and small size.

Special designs have been developed which combine some of the desirable features of the so-called "pure" types of fan. For instance, a **TUBULAR CENTRIFUGAL** fan has a centrifugal wheel mounted inside a tubular casing, so that from external appearances the air enters and leaves the assembly in the axial direction. However, the fan performance characteristics are like a true centrifugal.

Similarly, several designs of roof-mounted **exhaust fans** combine centrifugal or axial wheels in special housings to achieve a particular result.

A recent variation is called a **PLUG FAN**. This arrangement used a centrifugal wheel where the inlet opening is separated from the discharge by a partition, but the conventional scroll, or housing, is not used. Therefore, the fan can be “plugged into” a housing which acts as a lowgrade housing around the wheel. This arrangement is used to save space in built-up systems which convey energy, but is not commonly used in mass-conveying systems.

Figures\(^1\) B-6 and B-7 in the Appendix show the major component parts for standard centrifugal and axial fans. Notice the drawings use “impeller” for “wheel”, and “housing” for “scroll”. Differences in terminology are common in the air-moving industry, and sometimes are geographic; that is, different parts of the country use different terminology.

\(^1\) AMCA Publication 201-90
### Table 1 Parameters to Consider for Proper Fan Selection

<table>
<thead>
<tr>
<th>Physical characteristics</th>
<th>(these do not depend on the operation of the fan)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Basic type (centrifugal, axial, etc.).</td>
<td></td>
</tr>
<tr>
<td>• Number of stages (axial).</td>
<td></td>
</tr>
<tr>
<td>• Wheel configuration (F, R, BI, A, etc.).</td>
<td></td>
</tr>
<tr>
<td>• Wheel width, number of inlets (centrifugal).</td>
<td></td>
</tr>
<tr>
<td>• Size; (some characteristic dimension, usually wheel diameter).</td>
<td></td>
</tr>
<tr>
<td>• Direction of discharge; direction of rotation.</td>
<td></td>
</tr>
<tr>
<td>• Bearing arrangement, motor position.</td>
<td></td>
</tr>
<tr>
<td>• Method of volume control.</td>
<td></td>
</tr>
<tr>
<td>• Materials of construction, weight.</td>
<td></td>
</tr>
<tr>
<td>• Special features (split casing, high temperature bearings, scroll access door, drain plug, volume control dampers, etc.)</td>
<td></td>
</tr>
<tr>
<td>• Cost to purchase, install, and maintain.</td>
<td></td>
</tr>
<tr>
<td>• Availability (if time is a factor, such as replacing a defunct fan).</td>
<td></td>
</tr>
<tr>
<td>• Other (including characteristics of the prime mover, if furnished by the fan vendor).</td>
<td></td>
</tr>
</tbody>
</table>

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### Operating Characteristics

- Fluid to be handled, fluid density, operating temperature.
- Volumetric flow rate (usually in standard CFM).
- Total pressure increase.
- Rotating speed (may include ways to vary speed, if furnished by the fan vendor).
- Mechanical efficiency, input power to fan shaft.
- Sound power level in eight octave bands
- Moment of inertia.
- Outlet velocity at design conditions.
- Operating characteristics of the prime mover, if furnished by the fan vendor.
- Cost to operate.
- Ambient conditions; fluid contaminants.

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### Description of Physical Characteristics.

**Type** and **wheel configuration** have been discussed in the previous section.

**Number of stages**: axial flow fans may have two or more wheels mounted in series on the same shaft. This obviously increases pressure rise across the fan for a given wheel diameter and volumetric flow rate.

**Wheel width**: a somewhat fixed ratio exists between wheel diameter and wheel width for fans which convey energy. The wheel diameter will be about twice the wheel width. This configuration is called **single width**, and is designed to have air enter the wheel from one side only, referred to as **single inlet**. This arrangement is abbreviated **SISW** or **SWSI**.
There are exceptions to the ratio. A fan designed to deliver air at a relatively high pressure rise for the flow rate will have a narrow wheel. Such a fan is sometimes called a pressure blower. One way to increase flow rate for a given pressure rise is to mount two single width single inlet wheels, one the mirror image of the other, back-to-back so that they share a common backplate (then referred to as a center plate), creating, in effect, two fans in parallel. This arrangement is called **double inlet double width (DIDW)** or **DWDI**. In the smallest wheels (10” diameter or less) the centerplate is sometimes omitted to save expense.

**Size** is generally expressed in terms of some characteristic dimension, the most obvious of which is wheel diameter, usually expressed to the nearest inch. Many manufacturers use the wheel diameter as the model number.

**Discharge direction**, for centrifugal fans, describes the position of the scroll relative to the horizontal plane. There are eight standard positions, as shown in the Appendix, for each of the two directions of rotation.

**Rotational direction**, (clockwise, **CW**, or counter-clockwise, **CCW**) is determined as follows:

- Single inlet - from the side opposite the air inlet.
- Double inlet - from where the prime mover (motor, turbine, etc.) inputs work to the shaft. If more than one prime mover is involved, the larger is taken as the reference.

For axial fans, discharge direction is field-determined, and rotational direction is left to the discretion of the fan manufacturer.

**Bearing arrangement** describes the relative position of the wheel, support bearings, and prime mover location. The industry standards are shown in the Appendix. Notice that some of the arrangements for SISW are not available for DIDW, and that some of the SISW arrangements locate the fan shaft bearings out of the airstream.

**Motor position** (centrifugal) relates the plan view of the motor and its shaft to the fan. This information is used by the fabricator of the base common to the fan and motor (Usually the fan manufacturer). Motor position for axial flow fans is usually determined by the bearing arrangement.

**Methods of volume control** can be categorized as follows:

- Alter the characteristic curve of the **system**, using manual or automatic dampers.
- Alter the performance characteristics of the **fan**.
- Alter the speed of the **prime mover**.
- Combination of the above.

Fan performance, for a given size and type, can be affected in these ways:

- Change rotational speed

  For direct drive, requires fluid coupling, gear train, or changing prime mover speed.

  For belt drive, requires some of the above, and/or variable pulley ratio drive.

  Cause the inlet air to pre-rotate, preferably in the direction of wheel rotation, which has the effect of making the air think the wheel has slowed down.
• Change the wheel performance characteristics

Axial fans can be obtained with adjustable pitch (manually changed and locked) or controllable pitch blades, which can be automatically changed as the fan operates.

Some centrifugal fan vendors offer a movable sleeve which inserts into the fan inlet opening, partially blocking the leading edge of the blades, in effect changing the active wheel width.

• Change the prime mover shaft speed

For electric motors, frequency inverters affect motor speed by varying the frequency of the power to the motor.

For turbine drives, the inlet fluid (steam, air, or combustion gases) can be throttled.

• Restrict flow into or out of the fan with adjustable dampers or ailerons. (Some engineers prefer to consider this as changing the system curve rather than the fan performance.)

Materials of construction are determined by either strength requirements (heavier duty construction for greater total pressure rise, corrosion potential in the gas stream, or need to mitigate the possibility of explosion caused by sparks.

Strength needs are expressed by class (Class I, Class II, etc.) and each class has a maximum allowable total pressure rise, Class I being the lightest.

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Operating characteristics

The fan industry typically displays fan capacity in either tabular or graphical (curves) form. Since gas flow rate is of primary concern, other performance data (pressure rise, shaft horsepower, efficiency, etc.) are expressed as a function of flow rate.

The most common way to describe fan performance is to compare total pressure rise to volumetric flow rate. Related data, such as shaft horsepower and fan efficiency can also be plotted as a function of flow rate. Flow rate is referenced to the fan inlet, so that density variations caused by pressure and temperature rise through the fan are not a factor.

Fan performance data are determined experimentally by the manufacturer for a given wheel type, size, and rotating speed. Rigorous test procedures have been developed by the Air Moving and Conditioning Association (AMCA) so that standardization of ratings can be achieved.

Normally, a fan will be tested from blocked off (sealed duct) to wide open (no duct) conditions for a given rpm. From which performance at other speeds can be calculated using a series of laws of affinity, called (in this case) “Fan Laws”.

These laws (discussed in detail in another handout) also allow calculating performance for other sizes of the same fan family, as long as geometric, kinetic, and fluidic similarity have been maintained.
Figure B-6 Terminology for Centrifugal Fan Components
Figure B-7  Terminology for Axial and Tubular Centrifugal Fans
TRANE CENTRIFUGAL FANS

AMCA STANDARD ARRANGEMENTS AND DISCHARGES

MOTOR POSITION, BELT DRIVE

Location of motor is determined by facing the drive side of fan and designating the motor positions by letters W, X, Y, or Z as the case may be.

ARRANGEMENTS OF DRIVE FOR CENTRIFUGAL FANS

The following tables illustrate designations for centrifugal operation adapted by the Air Movement and Control Association.

DESIGNATION FOR DIRECTION OF ROTATION AND DISCHARGE

Direction of Rotation is determined from drive side for either single or double width, or single or double inlet fans. (The driving side of a single inlet fan is considered to be the side opposite the inlet regardless of actual location of the drive.) For fan inverted for ceiling suspension, Direction of Rotation and Discharge is determined when fan is resting on floor.

Top Horizontal

Top Angular Up

Top Angular Down

Clockwise

Up Blast

Down Blast

Bottom Angular Up

Bottom Angular Down

Bottom Horizontal

Top Horizontal

Top Angular Down

Counter Clockwise

Down Blast

Up Blast

Bottom Angular Down

Bottom Angular Up
AMCA Publication 201-90

ARR. 1
For belt drive or direct connection. Impeller overhung. Two bearings located either upstream or downstream of impeller.

ARR. 3
For belt drive or direct connection. Impeller between bearings that are on internal supports. Drive through inlet.

ARR. 4
For direct connection. Impeller overhung on motor shaft. No bearings on fan. Motor on internal supports.

ARR. 7
For belt drive or direct connection. Arr. 3 plus common base for prime mover.

ARR. 8 (1 or 2 stage)
For belt drive or direct connection. Arr. 1 plus common base for prime mover.

ARR. 9 Motor on Casing
For belt drive. Impeller overhung. Two bearings on internal supports. Motor on casing or on integral base. Drive through belt fairing.

ARR. 9 Motor on Integral Base

NOTE: All fan orientations may be horizontal or vertical.

AMCA STANDARD 99-3404-83

DRIVE ARRANGEMENTS FOR AXIAL FANS WITH OR WITHOUT DIFFUSER AND INLET BOX

Figure 3-7