Fundamentals of Fans

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Vice President, Air Equipment Company

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Overview

- Fan Laws
- Fan Testing
- Different Fan Types
- Bearings
- Construction Requirements
- System Effects Video
These rules are only valid within a fixed system with no change in the aerodynamics or airflow characteristics of the system. For the purpose of this discussion, a system is the combination of ductwork, hoods, filters, grills, collectors, etc., through which air is distributed.

The first fan law relates the airflow rate to the fan rotational speed: Volume flow rate (CFM) is directly proportional to the fan rotational speed (RPM). If the fan RPM is increased, the fan will discharge a greater volume of air in exact proportion to the change in speed.
Fan Laws

- CFM = 10,000
- SP = 2"
- RPM = 1,000
- BHP = 10

- CFM = 12,000
- SP =
- RPM =
- BHP =
Fan Laws

- CFM = 10,000
- SP = 2"
- RPM = 1,000
- BHP = 10

- CFM = 12,000
- SP =
- RPM = 1,200
- BHP =
The second fan law relates the fan total pressure or fan static pressure to the fan rotational speed: Total or static pressure is proportional to the square of the fan rotational speed. If it is desired to increase the flow to 20,000 CFM without any physical change in the system, the required SP would be 4”
Fan Laws

- CFM = 10,000
- SP = 2"
- RPM = 1,000
- BHP = 10

- CFM = 12,000
- SP =
- RPM = 1,200
- BHP =
Fan Laws

- CFM = 10,000
- SP = 2”
- RPM = 1,000
- BHP = 10

- CFM = 12,000
- SP = 2.88”
- RPM = 1,200
- BHP =
Fan Laws

\[
\frac{BHP_{\text{new}}}{BHP_{\text{old}}} = \left(\frac{\text{RPM}_{\text{new}}}{\text{RPM}_{\text{old}}}\right)^3
\]

The third fan law relates the total or static air power (and the impeller power), to the fan rotational speed: Power, is proportional to the cube of the fan rotational speed.
Fan Laws

• CFM = 10,000
• SP = 2”
• RPM = 1,000
• BHP = 10

• CFM = 12,000
• SP = 2.88”
• RPM = 1,200
• BHP =
Fan Laws

- CFM = 10,000
- SP = 2
- RPM = 1,000
- BHP = 10

- CFM = 12,000
- SP = 2.88”
- RPM = 1,200
- BHP = 17.3
### Fan Testing

#### Duct Traverse Formats

<table>
<thead>
<tr>
<th>Duct Configuration</th>
<th>ASHRAE Handbook</th>
<th>Industrial Ventilation Manual</th>
<th>AMCA Publication 203</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rectangular</td>
<td>16 to 64 equal areas, maximum of 6 inches apart</td>
<td>16 to 64 equal areas, maximum of 6 inches apart</td>
<td>24 to 100 equal areas</td>
</tr>
<tr>
<td>Circular</td>
<td>20 equal concentric areas, along 2 diameters</td>
<td>6 to 12 (small duct), 10 to 20 (medium duct), 20 to 40 (large duct), equal concentric areas, along 2 diameters</td>
<td>24 to 48 equal concentric areas, along 3 diameters</td>
</tr>
</tbody>
</table>

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Since velocity in a duct is seldom uniform across any section, a traverse is usually made to determine average velocity. Velocity is lowest near the edges or corners, and greatest near center. Fig. 4 shows suggested Pitot tube locations for traversing round and rectangular ducts. To determine average velocity in the duct from the readings, average the calculated individual velocities or the square roots of the velocity heads. The number of traverse points should increase with increased duct sizes.
Fan Testing

-Calculating velocities and air volumes for airflow measuring and traverse probe stations

\[ \text{Air Velocity (FPM)} = 4005 \times \sqrt{\text{Velocity Pressure (in. wc)}} \]

\[ \text{Station Air Volume (CFM)} = \text{Air Velocity (FPM)} \times \text{Station Area (F}^2) \]
Different Fan Types

**Airfoil**

- **Impeller Design**
  - Highest efficiency of all fan designs. 9 to 16 blades of airfoil contour curved away from the direction of rotation. Air leaves the impeller at a velocity less than its tip speed and relatively deep blades provide for efficient expansion within the blade passages. This will be the highest speed of the fans.

- **Housing Design**
  - Scroll-type, designed to permit efficient conversion of velocity pressure to static pressure, thus permitting a high static efficiency. The clearance and alignment between wheel and inlet bell is very close in order to reach the max efficiency capability.

- **Performance Characteristics**
  - Highest efficiencies occur 50 to 65% of wide open volume. This is also the area of good pressure characteristics; the horse power curve reaches a maximum near the peak efficiency area and becomes lower towards free delivery, a self-limiting power characteristics.

- **Applications**
  - General heating, ventilating and air-conditioning systems. Used in large sizes for clean air industrial applications where power savings are significant.

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**Image Description**

- The image shows a graph with axes labeled 'PRESURE - HP' and 'EFFICIENCY' against 'VOLUME FLOW RATE'.
- The graph includes reference points labeled 'ME' and 'HP'.
Different Fan Types

AIRFOIL WHEEL
## Different Fan Types

### Backward-Inclined

**Impeller Design**
- Efficiency is only slightly less than that of airfoil fans. Backward-curved blades are slightly curved away from the direction of rotation and are single thickness.

**Housing Design**
- Scroll-type, designed to permit efficient conversion of velocity pressure to static pressure, thus permitting a high static efficiency. The clearance and alignment between wheel and inlet bell is very close in order to reach the max efficiency capability.

**Performance Characteristics**
- Peak efficiency is slightly lower than airfoil fan. Unstable left of peak pressure. Highest efficiencies occur 50 to 65% of wide open volume. This is also the area of good pressure characteristics. The horsepower curve reaches a max near the peak efficiency area.

**Applications**
- General heating, ventilating and air-conditioning systems. Also used in some industrial applications where the airfoil blade is not acceptable because of corrosive and/or erosion environment.

### Backward-Curved

![Graph](image)

### Table

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<th>Impeller Design</th>
<th>Housing Design</th>
<th>Performance Characteristics</th>
<th>Applications</th>
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<td>Efficiency is only slightly less than that of airfoil fans. Backward-curved blades are slightly curved away from the direction of rotation and are single thickness.</td>
<td>Scroll-type, designed to permit efficient conversion of velocity pressure to static pressure, thus permitting a high static efficiency. The clearance and alignment between wheel and inlet bell is very close in order to reach the max efficiency capability.</td>
<td>Peak efficiency is slightly lower than airfoil fan. Unstable left of peak pressure. Highest efficiencies occur 50 to 65% of wide open volume. This is also the area of good pressure characteristics. The horsepower curve reaches a max near the peak efficiency area.</td>
<td>General heating, ventilating and air-conditioning systems. Also used in some industrial applications where the airfoil blade is not acceptable because of corrosive and/or erosion environment.</td>
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Different Fan Types

Backward Inclined Wheel
Different Fan Types

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<td>-Simplest of all fans and least efficient. High mechanical strength and the wheel is easily repaired. Requires medium speed for a given point of rating.</td>
<td>-Scroll-type, usually the narrowest design of all fan designs because of required high velocity discharge. Dimensional requirements of this housing are more critical than for airfoil and backward-inclined blades.</td>
<td>-Higher pressure characteristics than the backward-inclined and airfoil fans. Power rises continually to free delivery.</td>
<td>-Used Primarily for material-handling applications in industrial plants. Wheel can be of rugged construction and is simple to repair in the field. Wheel can be coated for special materials. Not commonly found in HVAC applications.</td>
</tr>
</tbody>
</table>
Different Fan Types

RADIAL WHEEL

Open Sider Design  
With RIMS  
Radial Tip Forward Curved Heal
## Different Fan Types

### Forward Curved

**Impeller Design**
- Efficiency is less than backward-curved fans.
- Fabricated of lightweight and low cost construction.
- Has 24-64 shallow blades with both the heel and tip curved forward.
- Air leaves wheel at velocity greater than wheel tip speed.
- Wheel is the smallest of all fans and operates at lowest speed.

**Housing Design**
- Scroll is similar to other fan designs. The fit between the wheel and inlet is not as critical as on airfoil and backward-inclined bladed fans.
- Uses large cut-off sheet in housing.

**Performance Characteristics**
- Pressure curve is less steep than that of backward-curved bladed fans. There is a dip in pressure curve left of the peak pressure point and highest efficiency occurs to the right of peak pressure, 40-50% of wide open volume.
- Power curve rises continually toward free delivery.

**Applications**
- Used primarily in low-pressure heating, ventilating, and air-conditioning applications such as domestic furnaces, central station units, and packaged air-conditioning equipment from room air-conditioning units to roof top units.
Different Fan Types

Forward Curved Wheel
Different Fan Types

Plug Fan
(For oven or furnace recirculation)
Different Fan Types

Vane Axial
Bearing Types

- **Ball**
  - Single Row
  - Double Row

- **Spherical Roller**
  - Double Row

- **Cylindrical**
  - Single Row
# Bearing Failures

<table>
<thead>
<tr>
<th>Common Types of Failures</th>
<th>Common Causes of Failures</th>
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<tbody>
<tr>
<td>Overheating</td>
<td>Lubrication</td>
</tr>
<tr>
<td>Brinelling</td>
<td>Skidding-Light Loading</td>
</tr>
<tr>
<td>Fretting Corrosion</td>
<td>Loose Shaft Fit</td>
</tr>
<tr>
<td>Fatigue</td>
<td>Bent Shaft</td>
</tr>
<tr>
<td>Misalignment</td>
<td>Set Screws Loosened</td>
</tr>
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</table>

**Preventative Maintenance**

- Auto-Lubrication Device
- Vibration/Temperature Monitors
Fan Maintenance
### Rotation and Discharge

*Direction of rotation is determined by drive side of fan*

<table>
<thead>
<tr>
<th>Description</th>
<th>Clockwise Up Blast</th>
<th>Clockwise Top Angular Up</th>
<th>Clockwise Top Horizontal</th>
<th>Clockwise Top Angular Down</th>
</tr>
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<tbody>
<tr>
<td>AMCA STD</td>
<td>CW 360</td>
<td>CW 1-89</td>
<td>CW 90</td>
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<td>CW 271-359</td>
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### Rotation and Discharge

*Direction of rotation is determined by drive side of fan*

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To determine the location of the motor, face the drive side of the fan and pick the proper motor position designated by the letters W, X, Y, or Z as shown in the drawing to the left.
Drive Arrangements

ARR. 1 SWSI
For belt drive or direct drive. Impeller overhung, two bearings on base

ARR. 2 SWSI
For belt drive or direct drive. Impeller overhung. Bearings in bracket and supported by fan housing

ARR. 3 SWSI
For belt drive or direct drive. One bearing on each side and supported by fan housing.
Drive Arrangements

ARR. 3 DWDI
For belt drive or direct drive. One bearing on each side and supported by fan housing.

ARR. 4 SWSI
For direct drive. Impeller overhung on prime mover shaft. No bearings on fan. Prime mover base mounted or integrally directly connected.

ARR. 7 SWSI
For belt drive or direct drive. Arrangement 3 plus base for prime mover.
Drive Arrangements

ARR. 7 DWDI
For belt drive or direct drive. Arrangement 3 plus base for prime mover.

ARR. 8 SWSI
For belt drive or direct drive. Arrangement 1 plus extended base for prime mover.

ARR. 9 SWSI
For belt drive. Impeller overhung. Two bearings with prime mover outside base.

ARR. 10 SWSI
For belt drive. Impeller overhung. Two bearings with prime mover inside base.
QUESTIONS

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Please visit us at www.aecy.com

THANK YOU FOR YOUR TIME!