Selecting the Correct Fan

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Outline

• Fan Types
  – Applications
  – Performance Characteristics

• Fan Construction
  – Drive Arrangements
  – Fan Rotation and Discharge
  – Fan Class of Construction
  – Spark Resistant Construction
  – Special Coatings and Materials

• Fan Selection Considerations
  – Motors
  – V-belt Drives
  – Air Volume Control
Basic Fan / Wheel Types

• **Centrifugal**
  – Backward Inclined Airfoil-blade
  – Backward Inclined Flat-blade
  – Forward Curved Blade
  – Radial Blade
  – Radial Tip

• **Axial**
  – Propeller / Panel Fan
  – Tubeaxial
  – Vaneaxial

• **Special Designs**
  – Power Roof Ventilators
  – Tubular Inline Centrifugal
  – Mixed Flow
Backward Inclined – Airfoil Blade

- Name is derived from the “airfoil” shape of blades
- Developed to provide high efficiency
- Used on larger HVAC and clean air industrial systems where energy savings is key
- Not well suited for dirty airstreams, can have balance issues
Backward Inclined – Flat Blade

- Backward inclined blades are single thickness or “flat”
- Efficiency and FRPM are slightly less than airfoil blade
- The most widely used wheel design
- Used for applications where airfoil blade is not acceptable due to dirty, hot, corrosive or erosive airstream
Backward Inclined – Flat & Airfoil

- Stable performance characteristic
- Non-overloading power curve
- High volume at moderate pressure
- Low abrasion resistance
- High efficiency
- Low noise
Forward Curved Blade

- Blades are curved forward in the direction of rotation
- Less efficient than airfoil or flat blade designs
- Requires the lowest speed of any centrifugal to move a given amount of air
- Used for low pressure HVAC systems
Forward Curved Blade

- OVERLOADING power curve
- Must be properly applied to avoid unstable operation
- Clean air and high temperature applications
- Higher volume at low pressure
- Small size for a given volume
Selecting for Overloading HP

8600 cfm @ 1.8 in wc (4.84 BHP)
10000 cfm @ 1.5 in wc (5.97 BHP)
Radial Blade

- Blades are flat and “radial” to the fan shaft
- Generally the least efficient of the centrifugal fans
- Material handling and moderate to high pressure industrial applications
Radial Blade

- OVERLOADING power curve
- Material handling, self cleaning
- Suitable for dirty airstream, high pressure, high temperature and corrosive applications
- Low volume at high pressure
- Moderate efficiency
- Easy to maintain
Radial Tip

- Similar to backward inclined near the hub, but gradually slope towards the direction of wheel rotation ending in a radial direction at the blade tip
- More efficient than the true radial blade
- Designed for wear resistance in mildly erosive air streams
Common Propeller Types

- Adjustable / fixed pitch cast aluminum
- Stamped / extruded aluminum
- Fabricated / die formed steel
- Polymer / composite
- Almost limitless number of configurations
Propeller or Panel Fan

- One of the most basic fan designs
- Low pressure, high volume applications
- Designed for ventilation through a wall
- Ring fan design offers slightly higher pressure
Propeller or Panel Fan

Propeller panel fans are best utilized near free air
Tubeaxial Fan

- More efficient than the panel fan
- Cylindrical housing fits closely to outside diameter of blade tips
- Low to medium pressure ducted industrial and commercial HVAC systems
Tubeaxial Fan

Performance curve sometimes includes a dip to the left of peak pressure which should be avoided.
Vaneaxial Fan

- Highest efficiency propeller axial fan
- Cylindrical housing fits very closely to outside diameter of blade tips
- Straightening vanes allow for greater efficiency and pressure capabilities
- For medium to high pressure HVAC systems
Vaneaxial Fan

- More compact than centrifugal fans of same duty
- Aerodynamic stall causes the performance curve to dip to the left of peak pressure which should be avoided
Specialized Adaptations

- Spun aluminum fans for roof mounted exhaust applications
- Upblast or downblast configurations
- Available with or without discharge dampers
- Can utilize centrifugal wheels, props or mixed flow impellers
Plenum/Plug Fan

- Offers tremendous flexibility for inlet and discharge in a AHU application
- Works better than a housed centrifugal for high flows and low SP
- Wall clearance rules must be followed to avoid significant system effect losses
Inline Centrifugal Fan

- Wheel is generally an airfoil or backward inclined type
- Housing does not fit close to outer diameter of wheel
- For low and medium pressure HVAC systems or industrial applications when an inline housing is geometrically more convenient than a centrifugal configuration
Mixed Flow Fan

- Cylindrical housing is similar to an inline centrifugal
- High volume advantages of axial propeller
- Low sound, high efficiency advantages of tubular centrifugal
The required flow and pressure may control the style of fan used:

- **Centrifugal**
- **Axial**
Fan Construction

- Drive Arrangements
- Fan Rotation and Discharge
- Fan Class of Construction
- Spark Resistant Construction
- Special Coatings and Materials
Drive Arrangements for Centrifugal Fans

Arrangement 10 SWSI

- Belt drive
- Impeller overhung
- Two bearings with motor mounted inside base
Drive Arrangements for Centrifugal Fans

Arrangement 9 SWSI
- Belt drive
- Impeller overhung
- Two bearings with motor mounted outside base
Drive Arrangements for Centrifugal Fans

Arrangement 1 SWSI

- Belt drive
- Impeller overhung
- Two bearings on base
- Motor mounted beside fan, typically on a common base
Drive Arrangements for Centrifugal Fans

Arrangement 4 SWSI

- Direct drive
- Impeller overhung on prime mover shaft
- No fan shaft / bearings
- Motor base mounted or integrally directly connected
Drive Arrangements for Centrifugal Fans

Arrangement 8 SWSI
- Direct drive
- Arrangement 1 plus extended base for motor
- Motor coupled to fan shaft
Drive Arrangements for Centrifugal Fans

Arrangement 3 SWSI

- Belt drive
- One bearing on each side supported by fan housing
- Motor mounted off the fan, typically on a common base
Drive Arrangements for Centrifugal Fans

Arrangement 3 DWDI
- For belt drive (or direct) connection
- One bearing on each side and supported by fan housing
- Motor mounted beside fan, typically on a common base
Arrangement 7 SWSI
- For direct drive connection
- Arrangement 3 plus base for motor
- Motor coupled to fan shaft
Drive Arrangements for Centrifugal Fans

Arrangement 7 DWDI

- For direct drive connection
- Arrangement 3 plus base for motor
- Motor coupled to fan shaft
Motor Positions for Inline Fans

- Rotation of impeller is determined from outlet end
- Horizontal or vertical mounting
- Hanging or floor/base mounting
- Belt driven motor positions are determined from outlet end
Motor Positions for Belt Drive Centrifugal Fans

Location of motor is determined by facing the drive side of fan and designating the motor position by letter W, X, Y or Z.
Rotation & Discharge Positions

Clockwise rotation as viewed from drive end

- Up Blast
- Top Angular Up
- Top Horizontal
- Top Angular Down
- Down Blast
- Bottom Angular Down
- Bottom Horizontal
- Bottom Angular Up
Rotation & Discharge Positions

Counter-clockwise rotation viewed from drive end

- Up Blast
- Top Angular Up
- Top Horizontal
- Top Angular Down
- Down Blast
- Bottom Angular Down
- Bottom Horizontal
- Bottom Angular Up
AMCA designates minimum performance requirements for certain types of fans to determine fan class:

1) Backward Inclined, SWSI and DWDI
2) Backward Inclined airfoil, SWSI and DWDI
3) Forward Curved, SWSI and DWDI
4) Inline Centrifugal

Construction standards are set based on pressure and outlet velocity (not volume and wheel size).

Fan manufacturers use a variety of construction nomenclature (level, duty, numerical, etc.).

In addition to performance limitations, fans have structural limitations.
Centrifugal Fan
Minimum Performance Points

Selecting The Correct Fan
Spark Resistant Construction

Special construction used for applications where a spark may ignite explosion
  – flammable or explosive gas or dust in airstream

AMCA Standard 99-0401 has guidelines for spark resistant construction with three levels
  • Type A
  • Type B
  • Type C
Spark Resistant Construction

- Type A
  - All parts of the fan in contact with the air or gas being handled shall be made of nonferrous material

- Type B
  - The fan shall have a nonferrous impeller and nonferrous ring about the opening though which the shaft passes

- Type C
  - The fan shall be so constructed that a shift of the impeller or shaft will not permit two ferrous parts of the fan to rub or strike
Special Materials / Coatings

- Abrasion and erosion resistance
- Easier to clean
- Corrosion resistance
- High temperature
- Spark resistance
- Aesthetics
- Safety (OSHA Yellow)
## Coating Selection

Table 4. Corrosion-Resistant Guide to Generic Coatings

<table>
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<th>Corrosive</th>
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<th>Steel Blasting</th>
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<td>Epoxy</td>
<td>Air Dried Phenolic</td>
<td>Synthetic Resin</td>
<td>Heavy Vinyl</td>
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<td>U</td>
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<td>E</td>
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<td>E</td>
<td>E</td>
<td>G</td>
<td>E</td>
<td>E</td>
</tr>
</tbody>
</table>
Motor Characteristics

- Power (HP, kW)
- Service Factor (Typically 15% or 1.15 SF)
  - Reverts to 1.0 when used with a frequency drive
- Physical Size in T-Frame or U-Frame (Automotive)
- Rotational Speed (RPM - Revolutions Per Minute)

### Typical Motor Speeds (RPM)

<table>
<thead>
<tr>
<th># of Poles</th>
<th>60 Hz Power</th>
<th>50 Hz Power</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Synchronous</td>
<td>Under Load</td>
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<tr>
<td>2</td>
<td>3600</td>
<td>3500</td>
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<tr>
<td>4</td>
<td>1800</td>
<td>1770</td>
</tr>
<tr>
<td>6</td>
<td>1200</td>
<td>1170</td>
</tr>
<tr>
<td>8</td>
<td>900</td>
<td>870</td>
</tr>
</tbody>
</table>
Motor Characteristics

Enclosure:

- Open Drip Proof (ODP)
- Totally Enclosed (TEFC, TEAO, TENV)
- Severe Duty (Mill & Chem., Hostile Duty, Dirty Duty...)

Explosion Proof

- Division I = Explosive agent present under normal operating conditions
- Division II = Explosive agent only present under abnormal operating conditions
- Class – Defines types of hazardous materials (gases/dusts/fibers)
- Group – Defines the relative degree of hazard for each type of hazardous material
# Typical EXP Motor Classifications

<table>
<thead>
<tr>
<th>Class</th>
<th>Group</th>
<th>Atmosphere</th>
<th>Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>I (Gases)</td>
<td>A</td>
<td>Acetylene</td>
<td>No</td>
</tr>
<tr>
<td>I (Gases)</td>
<td>B</td>
<td>Hydrogen, Manufactured Gas</td>
<td>No</td>
</tr>
<tr>
<td>I (Gases)</td>
<td>C</td>
<td>Ethylether Vapor</td>
<td>Yes</td>
</tr>
<tr>
<td>I (Gases)</td>
<td>D</td>
<td>Gasoline, Petroleum, Naptha, Alcohol’s, Acetone, Lacquer Solvent, Natural Gas</td>
<td>Yes</td>
</tr>
<tr>
<td>II (Dust)</td>
<td>E</td>
<td>Metal Dust</td>
<td>Yes</td>
</tr>
<tr>
<td>II (Dust)</td>
<td>F</td>
<td>Carbon Black, Coal or Coke Dust</td>
<td>Yes</td>
</tr>
<tr>
<td>II (Dust)</td>
<td>G</td>
<td>Grain Dust</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Phase:
  Single (Normally used on fans up to 3HP)
  Three

Voltage 3-Phase:
  200, 208, 230, 460 standard in US
  575 in Canada
  190, 380, 415, 440 International (50 HZ)

Voltage 1-Phase:
  115, 230 standard in US & Canada
  110, 220 International (50 HZ)
Motor Efficiency

  - Standard efficiency (1HP and above)
- EISA (Energy Independence and Securities Act of 2007)
  - Effective December 19, 2010
  - EPAct efficiency eliminated (1HP and above)
  - Motors manufactured for use in the US must meet the minimum efficiencies listed in NEMA MG 1, Table 12-12
Direct Driven

Disadvantages
• More difficult to make fan selections
• May require modified wheel
• Couplings can be difficult to align on Arrangement 7 or 8 fans

Advantages
• More compact
• Less maintenance
• No drive loss
• Easier to balance to low vibration levels
V-Belt Drives

Economical Means of Transferring Power from Motor Shaft to Fan Shaft

- Motor Sheave – Fixed or Adjustable Pitch
- Fan Sheave
- Belts
V-Belt Drives

**Disadvantages**
- Requires more maintenance
- More difficult to guard
- Belts create dust (clean room problem)
- Tougher to achieve tight balance
- Drive losses due to belt slippage

**Advantages**
- Easy to change fan speeds and performance
- Easy to make fan selection

*Selecting The Correct Fan*
Estimated Belt Drive Loss

- Higher belt speeds tend to have higher losses than lower belt speeds at the same horsepower.
- Drive losses are based on the conventional v-belt which has been the “work horse” of the drive industry for several decades.
- Typically, an additional 5% to 7% should be added to fan BHP for sizing motors.

![Graph showing drive losses vs motor power output](Image)
Timing Belt Drives

Not recommend for use on fans by most fan manufacturers

- Noise (up to 13 dBA louder than V-Belt drives)
- Alignment is critical
- No slip characteristic is hard on motors
- Increased vibration
- Cost (2-3 times more expensive than V-Belt drives)
Belt Drive – Final Comments

Adjustable sheaves not recommended for drives over 10 HP
• Cost – Adjustable sheaves are 2-3 times more expensive than fixed sheaves.
• Adjustable sheaves use set screws to lock in pitch diameters and set screws can vibrate loose.
• Belt life is shorter on adjustable pitch drives (belt rides higher or lower in sheave).

Dual groove drives not recommended with fractional HP motors
• Motor may not be able to start fan because of the additional resistance from the extra belts.
Available methods of adjusting volume will vary with fan type

Is near constant pressure a requirement?

Technology is rapidly changing the preferred options for these applications

- Controllable pitch axial
- Two-speed motors
- Dampers, outlet or inlet vanes
- Multiple fans in parallel
- Single phase motor speed controllers
- Variable Frequency Drive (VFD)
- Electronically Commutated Motor (ECM)
Inlet Vanes

- External vanes (bolt to inlet flange) increase overall fan dimensions, but generally use external linkage allowing for a wider range of applications.
- Internal vanes are more compact (and generally less expensive), but may not be suitable for extremely high temperature or corrosive airstreams.
Inlet Vane Curves

<table>
<thead>
<tr>
<th>% Open</th>
<th>BHP</th>
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</thead>
<tbody>
<tr>
<td>100</td>
<td>32.13</td>
</tr>
<tr>
<td>75</td>
<td>27.00</td>
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<tr>
<td>50</td>
<td>21.00</td>
</tr>
<tr>
<td>25</td>
<td>16.00</td>
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</table>
Selecting the Correct Fan

- Selecting the correct fan involves considering and prioritizing variables
  - Application
  - Performance (flow and pressure)
  - First Cost of Fan
  - Operating Costs
  - Life, Durability & Reliability
  - Space Requirements
  - Simplicity of Installation
  - High Temperatures and Severe Environments
  - Variable Volume Requirements
  - Sound Output
  - Etc...
Questions?

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