Selecting the Right Fan
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
  - Inlet Vanes
Basic Fan 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 large HVAC and clean air industrial systems where energy savings are of prime importance
Backward Inclined - Flat Blade

• Backward inclined blades are single thickness or “flat”
• Efficiency is only slightly less than airfoil blade
• Same HVAC applications as airfoil blade
• Also for industrial applications where airfoil blade is not acceptable because of corrosive or erosive environment
Backward Inclined - Flat & Airfoil Blade

- High volume at moderate pressure
- High speed
- Non-overloading power characteristic
- Low abrasion resistance
- High efficiency
- Stable performance characteristic
- Low noise
- Generally clean air use
Forward Curved Blade

- Blades are curved forward in the direction of rotation
- Less efficient than Airfoil and Backward Inclined
- Requires the lowest speed of any centrifugal to move a given amount of air
- Used for low pressure HVAC systems
Forward Curved Blade

- Blades are curved forward in the direction of rotation
- Large volume at low pressure
- Slow speed
- Small size for a given volume
- Low to medium efficiency
- Must be properly applied to avoid unstable operation
- Clean air and high temperature applications
Radial Blade

- The blades are “radial” to the fan shaft
- Generally the least efficient of the centrifugal fans
- For material handling and moderate to high pressure industrial applications
Radial Blade

- Low volume at high pressure
- Large wheel diameter for a given volume - higher cost
- Material handling, self cleaning
- Medium efficiency
- Easy to maintain
- Rising HP characteristic
- Suitable for dirty airstream, high pressure, high temperature and corrosive applications
Radial Tip

- The blades are radial to the fan shaft at the outer extremity of the impeller, but gradually slope towards the direction of wheel rotation
- More efficient than the radial blade
- Designed to wear resistance in mildly erosive air streams
Inline Centrifugal Fan

- Cylindrical housing is similar to a vaneaxial 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 a centrifugal inline fan
- High volume advantages of axial fans
- Low sound, high efficiency advantages of tubular centrifugal fans
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
Propeller or Panel Fan

- One of the most basic fan designs
- For low pressure, high volume applications
- Designed for ventilation through a wall
- Also available in ring fan design
Propeller or Panel Fan

- Maximum efficiency is reached near free delivery
Panel Fan Installation
Tubeaxial Fan

- More efficient than the panel fan
- Cylindrical housing fits closely to outside diameter of blade tips
- For low to medium pressure ducted HVAC systems
- Used in low pressure industrial applications
Tubeaxial Fan

- Performance curve sometimes includes a dip to the left of peak pressure which should be avoided
Tubeaxial Fan – Spray Booth Application
Vaneaxial Fan

- Highest efficiency axial fan
- Cylindrical housing fits closely to outside diameter of blade tips
- The 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
Vaneaxial Fan Installation

VANEAXIAL FANS
Power Roof Ventilators

- Roof mounted exhaust ventilators. Available in centrifugal or axial wheel designs.
- Available in upblast damper design to discharge air away from the building.
- For low pressure exhaust systems of all building types.
Axial Roof Ventilator
Centrifugal Power Roof Ventilator
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 1 SWSI**
  - For belt drive (or direct) connection
  - Impeller overhung
  - Two bearings on base
  - Motor mounted beside fan, typically on a common base
Drive Arrangements For Centrifugal Fans

- **Arrangement 2 SWSI**
  - For belt drive or direct drive connection
  - Impeller overhung
  - Bearings in bracket supported by fan housing
  - Rarely used today
Drive Arrangements For Centrifugal Fans

- **Arrangement 3 SWSI**
  - 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
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
Drive Arrangements For Centrifugal Fans

- **Arrangement 4 SWSI**
  - For direct drive connection
  - Impeller overhung on prime mover shaft
  - No bearings on fan
  - Motor base mounted or integrally directly connected
Drive Arrangements For Centrifugal Fans

- 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
Drive Arrangements For Centrifugal Fans

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

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

- Arrangement 10 SWSI
  - For belt drive
  - Impeller overhung
  - Two bearings with motor mounted inside base
Drive Arrangements for Inline Fans

- Rotation of fans is determined by viewing the fan outlet end
- Specify horizontal or vertical mounting
- Fans can be supplied with support legs for horizontal floor mounting or horizontal clips for ceiling mounting. Vertical mounting clips are also available.
- Arrangement 9 belt drive motor positions
Motor Positions For Belt Drive Centrifugal Fans

- 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.
Fan 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
Fan 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
Fan Class of Construction

- AMCA designates minimum performance requirements for certain types of fans
- Construction standards are set based on pressure and outlet velocity
- Fan manufacturers use a variety of construction nomenclature
- In addition to performance limitations, fans have structural limitations
Centrifugal Fan Class Operating Limits

![Graph showing Centrifugal Fan Class Operating Limits](image)

**STATIC PRESSURE (SP) inches of water**

- **Class I**
  - Selection Zone: 2½” @ 3200
- **Class II**
  - Selection Zone: 5” @ 2300
  - Minimum Performance Class I
- **Class III**
  - Minimum Performance Class III
  - SELECTION ZONE
  - 8½” @ 3000
  - Fan is required to be physically capable of performing over this range.

**OUTLET VELOCITY (OV) feet per minute**

- **Ratings may be published in this LOWER RANGE.**
  - 2½” @ 3200
  - 4¼” @ 4175
- **Ratings may be published in this UPPER RANGE.**
  - 13⅛” @ 3780
  - 6⅜” @ 5260
Spark Resistant Construction

• Special construction used for applications where spark may ignite explosion
  • flammable or explosive gas or dust in airstream
• AMCA Standard 99-0401-86 has guidelines for spark resistant construction
  • 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
- Steps must also be taken to assure that the impeller, bearings, and shaft are adequately attached and/or restrained to prevent a lateral or axial shift in these components
Spark Resistant Construction - Type B

- The fan shall have a nonferrous impeller and nonferrous ring about the opening though which the shaft passes
- Ferrous hubs, shafts, and hardware are allowed provided construction is such that a shift of impeller or shaft will not permit two ferrous parts of the fan to rub or strike
- Steps must also be taken to assure that the impeller, bearings, and shaft are adequately attached and/or restrained to prevent a lateral or axial shift in these components
Spark Resistant Construction - 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
Why Special Materials are Used

- Corrosion resistance
- High temperature
- Spark resistance
- Abrasion and erosion resistance
Why Coatings Are Used

- Corrosion resistance
- Make fan easier to clean
- Aesthetics
- Safety (color marking)
Coating Selection

From Engineering Data Sheet ED-400

Table 4. Corrosion-Resistant Guide to Generic Coatings

<table>
<thead>
<tr>
<th>CORROSIVE</th>
<th>NO STEEL BLASTING</th>
<th>STEEL BLASTING</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>ASPHALT-UM</td>
<td>VINYL</td>
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<tr>
<td>NUMBER OF COATS</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>ACIDS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ACETIC</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>BORIC</td>
<td>E</td>
<td>G</td>
</tr>
<tr>
<td>CARBOLIC</td>
<td>F</td>
<td>U</td>
</tr>
<tr>
<td>CARBONSIC</td>
<td>F</td>
<td>G</td>
</tr>
<tr>
<td>CHROMIC</td>
<td>F</td>
<td>G</td>
</tr>
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<td>CITRIC</td>
<td>G</td>
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<tr>
<td>FLUOROBIC</td>
<td>X</td>
<td>G</td>
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<tr>
<td>FORMIC</td>
<td>F</td>
<td>G</td>
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<tr>
<td>HYDROBROMIC</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>HYDROCHLORIC</td>
<td>G</td>
<td>G</td>
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<tr>
<td>HYDROFLORIC</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>HYDROCHLOROUS</td>
<td>F</td>
<td>X</td>
</tr>
<tr>
<td>LACTIC</td>
<td>F</td>
<td>G</td>
</tr>
</tbody>
</table>
Motor Characteristics

- Horsepower
- Service Factor (Typically 15% or 1.15 SF)
- Frame Size (T-Frame, U-Frame)
- Speed (RPM - Rotations Per Minute)

<table>
<thead>
<tr>
<th>RPM - 60 Hertz</th>
<th>RPM - 50 Hertz</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Synchronous RPM</strong></td>
<td><strong>Actual RPM</strong></td>
</tr>
<tr>
<td>3600</td>
<td>3450</td>
</tr>
<tr>
<td>1800</td>
<td>1750</td>
</tr>
<tr>
<td>1200</td>
<td>1160</td>
</tr>
<tr>
<td>900</td>
<td>880</td>
</tr>
</tbody>
</table>
Motor Characteristics

- Enclosure:
  - Open Drip Proof (ODP)
  - Totally Enclosed (TEFC, TEAO)
  - 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
# Motor Characteristics – Exp. Motors

<table>
<thead>
<tr>
<th>Class</th>
<th>Group</th>
<th>Atmosphere</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>I (Gases)</td>
<td>A</td>
<td>Acetylene</td>
<td>Motor Not Available</td>
</tr>
<tr>
<td>I (Gases)</td>
<td>B</td>
<td>Hydrogen, Manufactured Gas</td>
<td>Motor Not Available</td>
</tr>
<tr>
<td>I (Gases)</td>
<td>C</td>
<td>Ethylether Vapor</td>
<td>Motor Available</td>
</tr>
<tr>
<td>I (Gases)</td>
<td>D</td>
<td>Gasoline, Petroleum, Naptha, Alcohol’s, Acetone, Lacquer Solvent, Natural Gas</td>
<td>Motor Available</td>
</tr>
<tr>
<td>II (Dust)</td>
<td>E</td>
<td>Metal Dust</td>
<td>Motor Available</td>
</tr>
<tr>
<td>II (Dust)</td>
<td>F</td>
<td>Carbon Black, Coal or Coke Dust</td>
<td>Motor Available</td>
</tr>
<tr>
<td>II (Dust)</td>
<td>G</td>
<td>Grain Dust</td>
<td>Motor Available</td>
</tr>
</tbody>
</table>
Motor Characteristics

- **Phase:**
  - Single (Normally Available up to 10 HP)
  - Three

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

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

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Easy to change fan speeds and performance</td>
<td>• Requires more maintenance</td>
</tr>
<tr>
<td>• Lower initial cost than direct drive</td>
<td>• More difficult to guard</td>
</tr>
<tr>
<td></td>
<td>• Belts create dust (clean room problem)</td>
</tr>
<tr>
<td></td>
<td>• Tougher to achieve tight balance</td>
</tr>
<tr>
<td></td>
<td>• Drive losses due to belt slippage</td>
</tr>
</tbody>
</table>
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.
Direct Drive: Advantages and Disadvantages

**Advantages**

- More compact
- Less maintenance
- No drive loss
- Easier to balance to low vibration levels

**Disadvantages**

- More difficult to make fan selections
- May require modified wheel
- Couplings can be difficult to align on Arrangement 7 or 8 fans
**Belt Drive – Final Comments**

- TCF does not recommend adjustable sheaves on fans with motors 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).
- TCF does not recommend two groove drives on fans with fractional HP motors.
  - Fan motor may not be able to start fan because of the two grooves.
Belt Drive – Final Comments

- Timing Belt Drives
  - TCF does not recommend the use of timing belt drives on fans.
    - Noise (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)
Nested Inlet Vanes

- Mechanical Volume Control Device
- Nested inlet vanes are built into the fan inlet cone
  - Saves space
  - Less expensive than external type
External Inlet Vanes

- External inlet vanes are bolted to the inlet flange of the fan.
- Use of external vanes should be considered for handling hostile environments since operating linkages are shielded from the airstream.
- External inlet vanes are available for high temperature construction.
Inlet Vane Curves

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

- Selecting the right fan involves considering and prioritizing many 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...
Flow and Pressure

- The required flow and pressure may control the style of fan used.

![Fan types - Range of duties diagram](image)
First Cost vs. Operating Cost

First Cost Considerations

- First cost should include the installation costs
- Unfortunately, some never look beyond this
- Make sure that all desired features are included when comparing costs

Operating Cost Considerations

- The ‘BHP’ (brake horsepower) of the fan will identify operating costs
- For variable volume systems, use BHP at part load
- Add losses for v-belt drives, inverters (VFD’s), and system effect losses
Expected Life, Durability, Reliability

- Difficult to quantify
- Compare materials of construction
- Use higher ‘class’ of construction
- Compare bearing life
- Lower speed operation is often more reliable
- Fans are often customized to improve reliability
Space Requirements

- Axial fans are usually smaller than centrifugal fans
- Forward curve fans are smaller than other centrifugal fans
- Radial bladed fans tend to be the largest fans
- Fan “arrangement” affects space
Simplicity of Installation

- Fan “arrangements” with motor mounted are easier to install
- Fan discharge position may simplify ductwork
- Use axial fan for straight through flow
High Temp and Severe Environments

- Bearings, v-belt drives, and motors may need protection and/or cooling
- High temperatures and corrosive environments may require special materials, and or coatings
- Need to know airstream conditions and ambient conditions
- Quantity and type of solids in the airstream can limit usable fan types
Variable Volume Requirements

- Methods of adjusting flow volume will vary with fan types.
- The ability to supply a variety of flow-pressure combinations with stable flow affects the fan type and fan size.
- Customize fan to optimize for variable volume requirements.

- Nested Inlet Vane
- External Inlet Vane
- VFD
- Outlet Damper
- 2 Speed Motors

- Parallel Fans
- Clutches
- Turbine Drive
- Adjustable Pitch Axial
- Controllable Pitch Axial
Sound Output

- Axial fans generate more noise than centrifugal fans
- Axial fan noise is in higher frequencies, which are easier to attenuate
- Forward curve noise is the most ‘pleasing’ and seldom generates noise problems
- Airfoil bladed centrifugals normally have the lowest sound output
Other Factors Affecting Fan Selection

- Ultra-low vibration requirements
- Low maintenance (fan inaccessible)
- Flow measurement devices
- Maximum (or minimum) outlet velocity
- Present and future performance needs
Thank you