Introduction to Fan Systems
Background

• Critical for process support & human health.
  – shop ventilation
  – material handling
  – boiler applications

• In the manufacturing sector, fans use about 78.7 billion kWh of energy per year.
  – represents 15% of electricity used by motors

• In the commercial sector, electricity needed to operate fan motors composes a large portion of the energy costs for space conditioning.
Fan Types

- **Centrifugal fans** use a rotating impeller to increase velocity of an airstream. Air moves from the impeller hub to blade tips, gaining kinetic energy.
  - Generate high pressures.
  - Frequently used in
    - “dirty” airstreams (high moisture & particulates),
    - material handling applications,
    - higher temperatures.

- **Axial fans** move an airstream along the axis of the fan. Air is pressurized by the aerodynamic lift generated by the fan blades, like a propeller & an airplane wing.
  - Used in “clean air,” low-pressure, high-volume applications.
  - Less rotating mass, more compact than centrifugal fans of comparable capacity.
  - Higher rotational speeds, noisier than in-line centrifugal fans of the same capacity.
Fan Selection

- Starts with a basic knowledge of system operating requirements and conditions such as
  - Airflow rates
  - Temperatures
  - Pressures
  - Airstream properties
  - System layout
- Other considerations, such as
  - Cost
  - Efficiency
  - Operating life
  - Maintenance
  - Speed
  - Material type
  - Space constraints
  - Drive arrangements
  - Range of operating conditions
• High level of uncertainty associated with predicting system airflow and pressure requirements.
  – Tendency to *increase* the specified size of a fan/motor assembly, protection against being responsible for inadequate system performance.

• Oversized fan/motor assembly creates a different set of operating problems, including
  – Inefficient, more costly fan operation
  – Excess airflow noise, pipe/duct vibrations
  – Poor reliability

• ‘Systems Approach’ in fan selection process will yield a quieter, more efficient & more reliable system.

• Sourcebook available to help designers and operators improve fan system performance through better fan selection and improved operating and maintenance practices.
Fan System Assessment Tool

- Use the Fan System Assessment Tool (FSAT) to help quantify the potential benefits of optimizing fan system configurations that serve industrial processes.
  - Requires only basic (?) information about your fans and the motors that drive them.

- Calculate the amount of energy used by your fan system
- Determine system efficiency
- Quantify the savings potential of an upgraded system
- This tool DOES NOT tell the user how to improve the system. But it does provide a means of prioritizing energy improvement opportunities.
CSU IAC Case Study Example Plant 582: A Beverage Container Manufacturer

- Manufacturer of beverage containers
- Plant area: 336,000 ft²
- 100,000,000 kW annual energy consumption - about 11 MW peak demand
- Annual electricity costs: $4.6 million/yr
- Estimated 10,000 hp of motors
- Two 30 hp combustion air fans on each of three units – one backup per unit
• Twin City Fan (Type BCS-SWSI, Model 270BCS) backward curved single-width/single inlet (SWSI) high volume/pressure fan

• 30 hp Siemens premium efficiency motor rated at 93.0%, rated speed of 1,794 rpm, and a measured current of 35 A at 460 V

• At full load, the motor power is \( 30 \text{ hp} \times 0.746 \text{ kW/hp} \div 93.0\% = 24.1 \text{ kW} \).
CSU IAC Case Study Example Plant 582: Combustion Fan Operating Conditions

- Static pressure at fan outlet: 3.4 in. H$_2$O
- Dry bulb temperature: 79.7°F at inlet & 82.5°F at outlet
- Wet bulb temperature: 66°F at inlet & 67°F at outlet
- A venturi-type flowmeter was installed downstream of (just above) the combustion air fan.
- Flow typically varies from about 6,000 cfm to 6,667 cfm.
- Flow (from flowmeter): about 6,333 cfm.
- Motor amp load: about 19 amps.
So What’s The Big Deal?

• One 30 hp fan out of 10,000 hp!!!
• Fan runs 100% of time (8,760 h/yr)
• Plant personnel suggested that despite their protestations, the fan was oversized when designed

Let’s see if this is a big deal
**FSAT Inputs**

**Fan and motor inputs:**
- Fan style: CENTRIFUGAL - Backward Curved (SISW)
- Diameter: 27.00 in
- Fan configuration: Fixed
- Motor nameplate hp: 30
- Motor nameplate rpm: 1780
- Nameplate Full Load Amps: 35.0
- Motor efficiency class: Energy efficient
- Nominal motor voltage, volts: 480

**Operating parameters:**
- Operating fraction: 1.000
- Electricity cost, cents/kwhr: 8.30

**Electrical power or current and drive inputs:**
- Current: 10.0 A
- Measured voltage, volts: 480
- Drive type: Belt drive

**System inputs:**
- Measured flow rate, cfm: 8387
- Measured fan static pressure, in H2O: 3.40

**Gas property inputs:**
- Gas density, lbm/cu.ft: 0.0800
- Gas compressibility: 1.000
### Calculated Results:

<table>
<thead>
<tr>
<th></th>
<th>Existing fan, motor</th>
<th>Existing fan, EE motor</th>
<th>Optimal fan, EE motor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fan efficiency, %</td>
<td>25.9</td>
<td>25.9</td>
<td>80.3</td>
</tr>
<tr>
<td>Motor rated hp</td>
<td>30</td>
<td>30</td>
<td>7.5</td>
</tr>
<tr>
<td>Motor shaft power, hp</td>
<td>13.8</td>
<td>13.8</td>
<td>4.5</td>
</tr>
<tr>
<td>Motor efficiency, %</td>
<td>92.8</td>
<td>92.8</td>
<td>90.2</td>
</tr>
<tr>
<td>Motor power factor, %</td>
<td>73.3</td>
<td>73.3</td>
<td>73.6</td>
</tr>
<tr>
<td>Motor current, amps</td>
<td>19.0</td>
<td>19.0</td>
<td>6.4</td>
</tr>
<tr>
<td>Electric power, kW</td>
<td>11.1</td>
<td>11.1</td>
<td>3.7</td>
</tr>
<tr>
<td>Annual energy, MWhr</td>
<td>97.2</td>
<td>97.2</td>
<td>32.8</td>
</tr>
<tr>
<td>Annual cost, $1,000</td>
<td>6.1</td>
<td>6.1</td>
<td>2.1</td>
</tr>
<tr>
<td>Annual savings, $1,000</td>
<td>0.0</td>
<td>0.0</td>
<td>4.1</td>
</tr>
</tbody>
</table>

### Optimization rating
- Optimization rating: 33.7
- Size margin (%): 15

### Additional Information
- Fluid hp: 3.4
- Existing W-G eff: 22.9
- Optimal W-G eff: 89.0

**FSAT Results**
Several Options Considered

- Resheave the fan to reduce flow
- Get a new, smaller fan
- Add a variable speed drive
Resheaved Fan Curve

TWIN CITY FAN AND BLOWER PERFORMANCE CURVE

- **CFM**: 5,367
- **SP**: 3.4 in wg
- **RPM**: 1,140
- **BHP**: 4.46
- **Outlet Velocity**: 1.757
- **Density**: 0.019

Corrections for:
- Compressibility
- % width 0%
- Altitude 5,500
- Temperature 80°F

<table>
<thead>
<tr>
<th>Noise Level</th>
<th>Decibel</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>91</td>
</tr>
<tr>
<td>2</td>
<td>84</td>
</tr>
<tr>
<td>3</td>
<td>80</td>
</tr>
<tr>
<td>4</td>
<td>84</td>
</tr>
<tr>
<td>5</td>
<td>82</td>
</tr>
<tr>
<td>6</td>
<td>76</td>
</tr>
<tr>
<td>7</td>
<td>66</td>
</tr>
</tbody>
</table>

*1/182000 10.04*
Resheave the fan – cheapest option
(plus, this was suggested by fan mfg)
Savings: 64,700 kWh/yr and 7.5 kW-mo.
Total energy and demand savings: $4,080/yr
Estimated installed cost: $500
Simple payback: 1.5 months