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Energy Efficient Fan and Dust Collection Systems

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Basics: Where are Significant Fan Loads?
Basics: Where Does Fan Energy Go?

- Energy Balance on Fan System Simplifies to:

\[
\text{Work}_{\text{fluid}} \ (\text{hp}) = \frac{\text{Flow} \ (\text{ft}^3/\text{min}) \times \text{PressureDrop} \ (\text{in}-\text{H}_2\text{O})}{6,356 \ (\text{ft}^3-\text{in}/\text{min}-\text{hp})}
\]

Power to Fan (kW) = \frac{\text{Work}_{\text{fluid}} \ (\text{hp}) \times 0.746 \ (\text{kW}/\text{hp})}{\text{Fan Efficiency} \times \text{Belt Efficiency} \times \text{Motor Efficiency}}
Overall Efficient Design Goal

- **Move Highest Possible Volume at Lowest Speed!**
  - Imagine blowing a deep breath out through two different straws…

1 CFM in

---

Deep Breath 1
1 CFM out
Fast velocity
Lots of work

Deep Breath 2
1 CFM out
Slow velocity
Little work
Fan Affinity Laws (if impeller size constant)

Volume flow rate varies in proportion to fan speed

\[
\frac{V_2 \text{ (CFM)}}{V_1 \text{ (CFM)}} = \frac{n_2 \text{ (RPM)}}{n_1 \text{ (RPM)}} \quad \Rightarrow \quad V_2 = V_1 \left(\frac{\text{RPM}_2}{\text{RPM}_1}\right)
\]

Small reduction in flow rate = large reduction in fluid work

\[
\frac{P_2 \text{ (kW)}}{P_1 \text{ (kW)}} = \left(\frac{n_2 \text{ (RPM)}}{n_1 \text{ (RPM)}}\right)^2 = \left(\frac{V_2 \text{ (CFM)}}{V_1 \text{ (CFM)}}\right)^3 \quad \Rightarrow \quad W_{f2} = W_{f1} \left(\frac{V_2}{V_1}\right)^3
\]

Thus, 50% reduction in flow = 88% reduction in work!
How to Efficiently Control Flow

- Efficiently Control Flow to Match Process Needs
- Methods to balance or vary flow
  - Bypass/relief damper – ZERO savings
  - Variable outlet damper – SOME savings
  - Variable inlet vanes – SLIGHTLY MORE savings
  - Varying rotational speed of fan – BIG savings

![Graph showing power and volume flow rate relationship for different control methods.](image-url)
Strive to Reduce End Use and Pressure

- Always Minimize Required End Usage or Demand First
  - Better focused air, shut off when not needed, seal leaks, routinely calibrate flow

- Minimize Pressure Drop in System: Imagine straw example is ductwork or process blower’s air path
  - Minimize bends, remove restrictions, use low pressure drop fittings and change filters
  - Friction loss through ductwork is inversely proportional to fifth power of diameter ($\text{DP}_{\text{headloss}} \sim C / D^5$)
Dust Collection or Material Transport

- Special Considerations: When Applying Lower Volume Flows and Velocities to Dust Collection or Material Transport System
  - Minimum flow velocities are required in system to carry debris or particulates
  - Reducing/varying flow can be done, but must be done through calculating flow profiles in ductwork system or through trial and error
  - Depending on particulate or debris Type: some systems use timed purge, where speed temporarily ramps up to 100%, after set period of time.

http://www.airhand.com/designing.aspx
Example #1: Optimized Dust Collection

- 750-hp of dust collection fan power
  - All on a VFD control
  - Specifically engineered to maintain minimum velocity to throw particulate
  - Additionally, all cleaned air is returned back to plant
    - Significantly reduces heating and cooling loads
    - Balances plant pressure

- Saves $140,000 /year in fan energy
- Saves $75,000 /year in HVAC energy
- This set-up is often not used because requires extra engineering and testing
Example #2: Optimized V-belts

<table>
<thead>
<tr>
<th>Synchronous V-Belts</th>
<th>Electrical Energy (kWh/year)</th>
<th>Electrical Demand (kW/mo)</th>
<th>Natural Gas (ccf/year)</th>
<th>CO2 Emissions (lbs/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Savings</td>
<td>259,082</td>
<td>36</td>
<td>0</td>
<td>637,341</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cost Savings ($/year)</th>
<th>Implementation ($)</th>
<th>Simple Payback (years)</th>
<th>Rate of Return (ROR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economics</td>
<td>$19,751</td>
<td>$5,400</td>
<td>0.3</td>
</tr>
</tbody>
</table>

- 6 125-hp blowers
- 3 75-hp blower

Example #3: IGV versus VFD Control

- Soap Manufacturer with a 600-hp Atlas Copco Blower
- Controlled with Inlet Guide Vanes to Vary Flows based on Process

<table>
<thead>
<tr>
<th></th>
<th>Electrical Energy (kWh/year)</th>
<th>Electrical Demand (kW)</th>
<th>CO2 Emissions (lbs/year)</th>
<th>Cost Savings ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Savings</td>
<td>295,394</td>
<td>564</td>
<td>718,271</td>
<td>$14,520</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Implementation Cost ($)</th>
<th>Simple Payback (years)</th>
<th>Rate of Return (ROR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economics</td>
<td>$47,123</td>
<td>3.2</td>
<td>30.8%</td>
</tr>
</tbody>
</table>
Example #4: Blower Controls

- 2 x 400-hp blower constant speed motors for quenching glass
  - replaced w/ efficient motors with VFDs
- Verified Savings: 509,429 kWh/year, 21.8 kW demand
  - about $50,000/year energy cost savings
  - $42,934 utility rebate
  - Savings Verified 3\textsuperscript{rd} Party: true power metering & production normalization
Example #5: HVLS Fans

- Large Soft Drink Manufacturer with Zero Air Conditioning
  - Multiple visits to plant in summer (one visit on 90F day) - always comfortable
- HVLS Fans throughout entire production floor (little to no crane systems)
- Savings result from higher acceptable cooling set-points + elimination of localized fans (some plants have 1000’s of ¼hp personalized fans)

http://www.megafans.co.uk/13.html
Example #6: VFD vs Damper

- 150 hp dust collector fan is oversized and dampered/throttled back to constant 60% flow
- Economical to un-throttle and slow with VFD
- Savings:
  - $36,000 /year
  - 450,000 kWh, 68 kW peak
  - $20,600 implementation ($15,000 post rebate)
  - Simple Payback: 5 months
Example #7: Optimize End Usage

- Very large facility with 4 very large boilers
  - 1,000 to 5,000 hp of combustion air fan + inducer fan at each boiler
  - Fans on variable speed drives
  - Operating around 4% excess combustion oxygen – only need to be around 1.5% to 2.0%

- Optimizing Air to Fuel Ratio saves $187,000 /year fan savings
  - Plus added $143,600 /year in fuel cost savings from better combustion

http://www.grc.nasa.gov/WWW/k-12/airplane/combst1.html
Example #8: Optimize Combustion Air

- 2 Kilns: each 800-hp exhaust fan + 200-hp blowers
- All fans on VFD controls set to maintain suction through kiln and air-to-fuel ratio
- Plant engineer suspected air-to-fuel ratio could be further optimized if cost effective (see table)
  - Fan savings only (fuel savings not included)
  - Results in both exhaust and supply fans being slowed

<table>
<thead>
<tr>
<th>Percent Flow Reduction</th>
<th>Power Savings kW</th>
<th>Energy Savings kWh/yr</th>
<th>Cost Savings ($/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1%</td>
<td>45</td>
<td>313,955</td>
<td>$23,547</td>
</tr>
<tr>
<td>2%</td>
<td>89</td>
<td>620,317</td>
<td>$46,524</td>
</tr>
<tr>
<td>3%</td>
<td>131</td>
<td>919,172</td>
<td>$68,938</td>
</tr>
<tr>
<td>4%</td>
<td>173</td>
<td>1,210,604</td>
<td>$90,795</td>
</tr>
<tr>
<td>5%</td>
<td>213</td>
<td>1,494,699</td>
<td>$112,102</td>
</tr>
<tr>
<td>6%</td>
<td>253</td>
<td>1,771,544</td>
<td>$132,866</td>
</tr>
<tr>
<td>7%</td>
<td>291</td>
<td>2,041,227</td>
<td>$153,092</td>
</tr>
<tr>
<td>8%</td>
<td>329</td>
<td>2,303,839</td>
<td>$172,788</td>
</tr>
<tr>
<td>9%</td>
<td>365</td>
<td>2,559,472</td>
<td>$191,960</td>
</tr>
<tr>
<td>10%</td>
<td>401</td>
<td>2,808,218</td>
<td>$210,616</td>
</tr>
</tbody>
</table>
Example #9: Seal Leaky System

- Same 2 Kilns exhaust through dust collector
- All fans on VFD controls set to maintain suction through kiln and air-to-fuel ratio
- Dust collection system seals were old and leaky. Could be repaired if cost effective (see table)
  - Fan savings achieved on exhaust fans as negative differential pressure is easier to maintain

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<tr>
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<th>Power Savings (kW)</th>
<th>Energy Savings (kWh/year)</th>
<th>Cost Savings ($/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1%</td>
<td>28</td>
<td>199,277</td>
<td>$14,946</td>
</tr>
<tr>
<td>2%</td>
<td>56</td>
<td>395,558</td>
<td>$29,667</td>
</tr>
<tr>
<td>3%</td>
<td>84</td>
<td>588,858</td>
<td>$44,164</td>
</tr>
<tr>
<td>4%</td>
<td>111</td>
<td>779,191</td>
<td>$58,439</td>
</tr>
<tr>
<td>5%</td>
<td>138</td>
<td>966,573</td>
<td>$72,493</td>
</tr>
</tbody>
</table>
Example #10: Small fans count too

- Egg Manufacturing Facility – Lots of chickens = lots of small fans
  - 1,600 ventilation fans at 1-hp each
    - Average 30% are on (2,700,000 kWh/yr)
    - All smooth v-belts
    - Changing to notched v-belts saves $5,400 /yr
  - 1,800 manure drying fans at ½-hp each
    - All on all hours (4,900,000 kWh/yr)
    - All standard efficiency motors
    - Increasing to “CEE Enhanced Premium Efficiency” motors saves $4,900 /yr

- Should such an opportunity have a “point of sale” type of incentive?
Questions?

Thanks for Listening!

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