Fan System Optimization

Overview

Sponsored By:
Institution of Engineers Singapore

Presented By
Ron Wroblewski, PE
What is Efficiency?

\[ \eta = \frac{\text{output}}{\text{input}} \quad \text{or} \quad \eta = \frac{\text{Useful Output}}{\text{Energy Input}} \]

Efficiency is the portion of energy you paid for that is actually doing the work.
What is Deficiency?

Deficiency is the energy working against you.

- Heat,
- Vibration, and
- Noise

\[
\text{deficiency} = 1 - \eta
\]
Damper Locations

Rolling Mill Reheat Furnace Example
Optimization Benefits

Financial
Corporate
Production
Maintenance
Safety
Environmental
Societal

Time Magazine April 5, 2004
Characteristics of Fan Systems

Tough

Enduring

They will suffer years of abuse quietly, because of their resilient nature.

To the untrained eye, the inefficient fan and the efficient fan look the same.

The conditions that cause them to work inefficiently are everyday occurrences.
Measuring Fan Systems ISO 5802

• Very specialized skill
• Not taught at university
• Skills and techniques needed to measure the performance of a fan system draw from
  — Calculus
  — Fluid dynamics
  — Thermodynamics and
  — Psychrometrics
Measuring Fan Systems ISO 5802

- Flow is difficult to measure.

- Because the air in the duct has mass and momentum, the flow is:
  - Unsteady
  - Pulsing
  - Uneven

- Affected by twists, turns, contractions and expansions in the ductwork
Variable Frequency Drives

- Price has been decreasing
- Reliability has been increasing
- Becoming much more common
- Not a panacea
- Is there variation in the load?
- Not suited for constant loads
- Helps reduce mechanical maintenance
- Can cause electrical power quality problems
Other Optimization Strategies

1. Replace belts and pulleys to slow down the fan
2. Replace the impeller with more efficient model
3. Replace fan with more efficient model
4. Convert to belt drive
5. Use Variable Inlet Vanes
6. Streamline airflow and reduce friction at key choke points
Other FSO Strategies

**Advantages:**
- Often lower cost than VFDs
- Solutions more deeply rooted in the system

**Disadvantages**
- Not as sexy
- Requires training, knowledge and hard work
- May require measuring the fan performance
- Requires the boss to fund a FSO study
FSO Tools and Training – US DOE

- Fan System Assessment Tool (FSAT) Software:
  - Free from US DOE
  - Basic fan online training on US DOE website
  - Loads of publications available for download
    - Efficiency guides
    - Tip sheets
    - Case studies
FSO tools and training - Productive Energy

In-Person Training

• Introductory to advanced level
• ½ day to 5 day duration
• Measuring equipment available
• Classroom demo for measurement lab
• On-site measurement of fan systems
• Remote coaching
FSO online training – productiveenergy.com

- Informal cooperation with AMCA International
- 6 modules already online
  - Motors intro
  - Psychrometrics
  - Heat Recovery*
  - Simplified affinity laws
  - Fan controls
  - Measuring fan performance
- 4 modules under development or upgrade
- Total of 15 modules planned
Case Study – Malting

Expansion of a malthouse

- Germination beds
- Spray pumps
- Heat Exchangers

4 fans serve the kiln

- Fluctuating conditions
- $P_t$ loss across new system, ~11 in/wg
- Space constraints
## Malting – Proposal Options

<table>
<thead>
<tr>
<th>Proposal #19107</th>
<th>730 SWSI = $30,030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q</td>
<td>150,000 ACFM</td>
</tr>
<tr>
<td>$P_s$</td>
<td>11 in/wg</td>
</tr>
<tr>
<td>$\rho$</td>
<td>0.072 lbs/ft$^3$</td>
</tr>
<tr>
<td>$N$</td>
<td>875 RPM</td>
</tr>
<tr>
<td>$HP$</td>
<td>387 BHP</td>
</tr>
<tr>
<td>$P_{s(\text{Max})}$</td>
<td>14 in/wg</td>
</tr>
<tr>
<td>$\eta$</td>
<td>67%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Proposal #19108</th>
<th>670 DWDI = $39,835</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q</td>
<td>150,000 ACFM</td>
</tr>
<tr>
<td>$P_s$</td>
<td>11 in/wg</td>
</tr>
<tr>
<td>$\rho$</td>
<td>0.072 lbs/ft$^3$</td>
</tr>
<tr>
<td>$N$</td>
<td>890 RPM</td>
</tr>
<tr>
<td>$HP$</td>
<td>379 BHP</td>
</tr>
<tr>
<td>$P_{s(\text{Max})}$</td>
<td>11.8 in/wg</td>
</tr>
<tr>
<td>$\eta$</td>
<td>68%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Proposal #19207</th>
<th>660 DWDI = $40,955</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q</td>
<td>150,000 ACFM</td>
</tr>
<tr>
<td>$P_s$</td>
<td>11 in/wg</td>
</tr>
<tr>
<td>$\rho$</td>
<td>0.072 lbs/ft$^3$</td>
</tr>
<tr>
<td>$N$</td>
<td>890 RPM</td>
</tr>
<tr>
<td>$HP$</td>
<td>359 BHP</td>
</tr>
<tr>
<td>$P_{s(\text{Max})}$</td>
<td>14.2 in/wg</td>
</tr>
<tr>
<td>$\eta$</td>
<td>72%</td>
</tr>
</tbody>
</table>
Malting – Analyses

![Graph showing airflow vs. static pressure for different proposals](image)

**Proposal #19107**
730 SWSI
Peak $P_s \approx 14$ inH2O

**Proposal #19108**
670 DWDI
Peak $P_s \approx 11.8$ inH2O

**Proposal #19207**
660 DWDI
Peak $P_s \approx 14.2$ inH2O

#19207, peak $P_s \approx 14.2$ inH2O

150000 CFM @ 11 inH2O
## Malting – Simple Payback

<table>
<thead>
<tr>
<th></th>
<th>Proposal #19107</th>
<th>Proposal #19207</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>BHP</td>
<td>387</td>
<td>359</td>
<td></td>
</tr>
<tr>
<td>Cumulative BHP</td>
<td>1,548</td>
<td>1,436</td>
<td></td>
</tr>
<tr>
<td>kW</td>
<td>1,154.8</td>
<td>1,071.3</td>
<td>83.6</td>
</tr>
<tr>
<td>kWh/yr, @8000 Hours</td>
<td>9,238,464</td>
<td>8,570,048</td>
<td>668,416</td>
</tr>
<tr>
<td>$/yr, @ $0.05/kWh</td>
<td>461,923</td>
<td>428,502</td>
<td>33,421</td>
</tr>
<tr>
<td>First Cost</td>
<td>$ 30,030</td>
<td>$ 40,955</td>
<td>$ 10,925</td>
</tr>
<tr>
<td>Cumulative First Cost</td>
<td>$ 120,120</td>
<td>$ 163,820</td>
<td>$ 43,700</td>
</tr>
</tbody>
</table>

**Simple Payback:** 16 months
Case Study – Coke Oven
Steel Mill – Coke Oven Baghouse Fan

670-683 Type R37A DIDW
Summary

- 2 @ 2000 hp
- Intermittent process cycles
- 13.8 kVa

- Savings $369 000 / year
- Cost $929 000
- Simple payback 2.5 year
Steel Mill

Hot Dip Plating Line
- 22 Fans
- Size 50 to 200 hp
- Damper controlled

Savings $883 000 /year
Cost $751 000
Simple payback 0.9 Years
Thank You!

Ronald G. Wroblewski, P.E.

PRODUCTIVE ENERGY SOLUTIONS

Madison, WI 53726
1 (608) 232-1861
www.productiveenergy.com
ron@productiveenergy.com