Techniques for Determining Savings from Aeration Blowers

Tom Jenkins, P.E., JenTech Inc.
Keynote Speaker

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Techniques for Determining Savings from Aeration Blowers

Introduction
Blower & Vacuum Best Practices Magazine

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About the Speaker

Tom Jenkins, P.E.
JenTech Inc.

• President of JenTech Inc.

• Over 30 years of experience with aeration blowers and blower controls

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Determining Savings from Aeration Blowers

Thursday, April 25th, 2019
1:00 PM CDT
Thomas E. Jenkins
President, JenTech Inc.
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tom.jenkins.pe@gmail.com
Topics

- Utility Billing and Power Cost
- Determining Duty Cycles
- Life Cycle Cost Components
- Present Worth
- Simple Payback
Utility Billing & Power Cost

- Electric energy costs are complex
- They reflect utility costs for generation and distribution
- Very few operators or managers actually see electric bills
  - Even fewer understand them

- Work with your utility’s engineers!
  - They want to help you save energy
  - Conservation measures may be mandated by law or driven by need to avoid building new generation capacity
  - They can provide usage history, demand charts, rate details, etc.
Energy ≠ Power ≠ Electric cost

Energy cost usually consists of several components:

Time of Day Energy Consumption
- On-Peak 8:00 AM to 8:00 PM weekdays for typical WPPI customer (where it applies!)
  - 60 hours per week, 3,120 hours per year
- Off-Peak Weekends and Nighttime
  - 108 hours per week, 5,640 hours per year

Peak Demand Power = Average Power Consumption Over 15 Minutes During On-Peak time for the month

Power Factor – may be assessed against peak demand if PF < 85%

Using composite rate (average) can distort costs
Utility Billing & Power Cost

- Billing structures usually vary with the amount of power used
  - Small users may have only fixed rate energy charges
    - $0.07 per kWh US national average for industrial users
    - Source: U.S. Energy Information Administration, Form EIA-861M (formerly EIA-826), Monthly Electric Power Industry Report
  - Larger requirements may justify time of day billing
  - Very large users like a mid-size treatment plant will probably have demand charges in the billing structure
- The additional revenue must offset the cost to the utility for more expensive metering equipment
Utility Billing & Power Cost

- Simplified energy cost calculations
  - Method 1: Averages
    \[
    \text{$/Year} = \text{kW}_\text{ave} \cdot 8760 \text{ hours/} \text{year} \cdot \text{Average$/kWh}
    \]
  - Method 2: Actual Charges
    \[
    \text{OnPeak$/Year} = \text{kW}_\text{ave} \cdot 1.15 \cdot 3120 \text{ hours/} \text{year} \cdot \text{OnPeak$/kWh}
    \]
    \[
    \text{OffPeak$/Year} = \text{kW}_\text{ave} \cdot 0.85 \cdot 5640 \text{ hours/} \text{year} \cdot \text{OffPeak$/kWh}
    \]
    \[
    \text{Demand$/Year} = \text{kW}_\text{ave} \cdot 1.20 \cdot 12 \text{ months/} \text{year} \cdot \text{Demand$/kW}
    \]
    \[
    \text{Total$/Year} = \text{OnPeak$/Year} + \text{OffPeak$/Year} + \text{Demand$/Year}
    \]
Duty Cycles

- Duty cycle defines the blower loading as a function of time
- Duty cycle is determined by the process load
  - Assumes the aeration system is controlled so air delivered matches process demand
- The most significant impact on blower duty cycle is the diurnal load variation
Duty Cycles

- Ambient, inlet, and discharge conditions affect the power evaluation
- Trying to include all permutations is an exercise in futility
- DON’T just use design point conditions
  - These are worst case conditions and will not identify normal operation
  - These are typically based on 20-year population growth estimates
- Avoid extreme conditions
- Typically use average annual temperature (weather.com) or average of ASHRAE winter and summer design temperatures
- Use average humidity or 36% and 55 °F as default values
Duty Cycles

- Typical Diurnal Variations
  - 2:1 peak to minimum
  - Average Q During On-Peak Time = 115% of ADF
  - Average Q During Off-Peak Time = 85% of ADF
  - Peak Q (Demand Charge) = 120% of ADF
### Duty Cycles

<table>
<thead>
<tr>
<th>Hours</th>
<th>% of Time</th>
<th>% ADF</th>
<th>Time x ADF</th>
<th>Hours/Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>20.83%</td>
<td>70.00%</td>
<td>0.15</td>
<td>1825</td>
</tr>
<tr>
<td>3</td>
<td>12.50%</td>
<td>90.00%</td>
<td>0.11</td>
<td>1095</td>
</tr>
<tr>
<td>2</td>
<td>8.33%</td>
<td>100.00%</td>
<td>0.08</td>
<td>730</td>
</tr>
<tr>
<td>8</td>
<td>33.33%</td>
<td>107.50%</td>
<td>0.36</td>
<td>2920</td>
</tr>
<tr>
<td>6</td>
<td>25.00%</td>
<td>120.00%</td>
<td>0.30</td>
<td>2190</td>
</tr>
<tr>
<td>------</td>
<td>-----------</td>
<td>--------</td>
<td>------------</td>
<td>------------</td>
</tr>
<tr>
<td>24</td>
<td>100.00%</td>
<td>-------</td>
<td>1.00</td>
<td>8760</td>
</tr>
</tbody>
</table>

Five data points can accurately model the duty cycle for most municipal WRRFs.
Duty Cycles

Use estimated or reported power for each flow and pressure to determine daily power use. Use Wire-To-Air package power, use typical inlet conditions.

For four new blower and MOV controls, per manufacturer:

<table>
<thead>
<tr>
<th>Percent of Design Aeration Flow</th>
<th>Aeration SCFM</th>
<th>Misc. SCFM</th>
<th>Total SCFM</th>
<th>Disch. Press. psig</th>
<th>Qty. Blowers Running</th>
<th>SCFM per Blower</th>
<th>kW per Blower</th>
<th>Total Blower kW</th>
<th>Evaluation Factor (% Time)</th>
<th>Pro-Rated kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>70.0%</td>
<td>8,400</td>
<td>2,000</td>
<td>10,400</td>
<td>7.58</td>
<td>1</td>
<td>10,400</td>
<td>312.3</td>
<td>312.3</td>
<td>20.83%</td>
<td>65.1</td>
</tr>
<tr>
<td>90.0%</td>
<td>10,800</td>
<td>2,000</td>
<td>12,800</td>
<td>7.69</td>
<td>2</td>
<td>6,400</td>
<td>194.5</td>
<td>389.0</td>
<td>12.50%</td>
<td>48.6</td>
</tr>
<tr>
<td>100.0%</td>
<td>12,000</td>
<td>2,000</td>
<td>14,000</td>
<td>7.75</td>
<td>2</td>
<td>7,000</td>
<td>214.2</td>
<td>428.4</td>
<td>8.33%</td>
<td>35.7</td>
</tr>
<tr>
<td>107.5%</td>
<td>12,900</td>
<td>2,000</td>
<td>14,900</td>
<td>7.80</td>
<td>2</td>
<td>7,450</td>
<td>229.2</td>
<td>458.4</td>
<td>33.33%</td>
<td>152.8</td>
</tr>
<tr>
<td>120.0%</td>
<td>14,400</td>
<td>2,000</td>
<td>16,400</td>
<td>7.89</td>
<td>2</td>
<td>8,200</td>
<td>254.8</td>
<td>509.6</td>
<td>25.00%</td>
<td>127.4</td>
</tr>
</tbody>
</table>

|                   |               |            |            |                   |                     |                 |               | Total Evaluated kW: |                   |
|                   |               |            |            |                   |                     |                 |               | 429.6             |                   |
Life Cycle Cost Components

- **Initial Cost**
  - Capital expenditure: Capex
    - Equipment Cost
    - Installation Cost

- **Recurring Costs**
  - Operating expense: Opex (per year)
    - Energy
    - Repairs
    - Labor for operation
Life Cycle Cost Components

- Other Considerations
  - Interest expense
  - Inflation
  - Depreciation
  - Salvage value
Life Cycle Cost Components

- Establish Life of Asset
- Estimate Capex
  - Zero for existing asset
- Estimate Annual Opex
- Estimate Salvage Value

Life Cycle Cost = Capex + Opex x Life − Salvage Value
## Life Cycle Cost Components

Evaluate power for existing blower and controls (baseline), from manufacturer:

<table>
<thead>
<tr>
<th>Percent of Design Aeration Flow</th>
<th>Aeration SCFM</th>
<th>Misc. SCFM</th>
<th>Total SCFM</th>
<th>Disch. Press. psig</th>
<th>Qty. Blowers Running</th>
<th>SCFM per Blower</th>
<th>kW per Blower</th>
<th>Total Blower kW</th>
<th>Evaluation Factor (% Time)</th>
<th>Pro-Rated kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>70.0%</td>
<td>8,400</td>
<td>2,000</td>
<td>10,400</td>
<td>8.00</td>
<td>1</td>
<td>10,400</td>
<td>379.0</td>
<td>379.0</td>
<td>20.83%</td>
<td>78.9</td>
</tr>
<tr>
<td>90.0%</td>
<td>10,800</td>
<td>2,000</td>
<td>12,800</td>
<td>8.00</td>
<td>2</td>
<td>6,400</td>
<td>232.7</td>
<td>465.4</td>
<td>12.50%</td>
<td>58.2</td>
</tr>
<tr>
<td>100.0%</td>
<td>12,000</td>
<td>2,000</td>
<td>14,000</td>
<td>8.00</td>
<td>2</td>
<td>7,000</td>
<td>254.2</td>
<td>508.4</td>
<td>8.33%</td>
<td>42.3</td>
</tr>
<tr>
<td>107.5%</td>
<td>12,900</td>
<td>2,000</td>
<td>14,900</td>
<td>8.00</td>
<td>2</td>
<td>7,450</td>
<td>270.4</td>
<td>540.8</td>
<td>33.33%</td>
<td>180.2</td>
</tr>
<tr>
<td>120.0%</td>
<td>14,400</td>
<td>2,000</td>
<td>16,400</td>
<td>8.00</td>
<td>2</td>
<td>8,200</td>
<td>297.1</td>
<td>594.2</td>
<td>25.00%</td>
<td>148.6</td>
</tr>
</tbody>
</table>

**Total Evaluated kW:** 508.2
Estimate capital expense for four (4) new energy efficient blowers and MOV control upgrade. Assume installation cost = 20% of equipment cost.

<table>
<thead>
<tr>
<th></th>
<th>Blowers</th>
<th>Starters</th>
<th>Installation</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>New</strong></td>
<td>$1.65</td>
<td>$0.10</td>
<td>$0.33</td>
<td>$2.08</td>
</tr>
<tr>
<td><strong>Old</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Capex (Including Installation) Million $
Determine Composite Energy Rate from Bill:

<table>
<thead>
<tr>
<th>Charge</th>
<th>Usage</th>
<th>Rate</th>
<th>Cost</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service and Meter</td>
<td></td>
<td></td>
<td>$500</td>
<td>1%</td>
</tr>
<tr>
<td>On-Peak</td>
<td>224,866 kWh</td>
<td>$0.11</td>
<td>$24,735</td>
<td>35%</td>
</tr>
<tr>
<td>Off-Peak</td>
<td>299,170 kWh</td>
<td>$0.08</td>
<td>$23,934</td>
<td>34%</td>
</tr>
<tr>
<td>Demand</td>
<td>900 kW</td>
<td>$23.00</td>
<td>$20,700</td>
<td>30%</td>
</tr>
<tr>
<td>Total</td>
<td>524,036</td>
<td></td>
<td>$69,869</td>
<td></td>
</tr>
</tbody>
</table>

Composite Rate: $0.13 $/kWh
Life Cycle Cost Components

Estimate operating expense for energy

Method 1, composite energy cost and average power:

<table>
<thead>
<tr>
<th></th>
<th>Ave. kW</th>
<th>Annual Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>New</td>
<td>429.6</td>
<td>$501,800</td>
</tr>
<tr>
<td>Old</td>
<td>508.2</td>
<td>$593,600</td>
</tr>
<tr>
<td>Savings:</td>
<td>78.6</td>
<td>$91,800</td>
</tr>
</tbody>
</table>

Method 2, actual energy cost and power:

<table>
<thead>
<tr>
<th></th>
<th>Ave. kW</th>
<th>On-Peak</th>
<th>Off-Peak</th>
<th>Demand</th>
<th>Annual Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>New</td>
<td>429.6</td>
<td>$169,600</td>
<td>$164,800</td>
<td>$142,300</td>
<td>$476,700</td>
</tr>
<tr>
<td>Old</td>
<td>508.2</td>
<td>$200,600</td>
<td>$194,900</td>
<td>$168,300</td>
<td>$563,800</td>
</tr>
<tr>
<td>Savings:</td>
<td>78.6</td>
<td></td>
<td></td>
<td></td>
<td>$87,100</td>
</tr>
</tbody>
</table>

Labor and repair costs are considered negligible and equal for both alternates.
Present Worth Analysis

• A Common Method for Comparing Alternatives
• Typically Used for Projects with Long Lives
• Requires Assumptions on Interest Rates and Inflation
Present Worth Analysis

\[ r = \frac{\text{Rate}_{\text{Interest}} - \text{Rate}_{\text{Inflation}}}{1 + \text{Rate}_{\text{Inflation}}} \]

\[ \text{PWF} = \frac{(1 + r)^n - 1}{r \cdot (1 + r)^n} \]

\begin{align*}
\text{PWF} & \quad = \text{Present Worth Factor} \\
n & \quad = \text{number of years} \\
\end{align*}

\[ \text{NPW} = \text{PWF} \cdot \text{OpexSavings} - \text{CapexDifference} \]

\[ \text{NPW} \quad = \text{Net Present Worth} \]

Net Present Worth must be greater than zero to justify a project.
Simple Payback Analysis

- Simple to calculate and intuitive
- Shows how long it will take for Opex savings to offset Capex
- For Projects with short evaluation periods there is little difference between conclusions based on NPW or payback
- Requires fewer assumptions than NPW

$$\text{SimplePayback} = \frac{\text{CapexDifference}}{\text{AnnualOpexSavings}}$$
Example Analysis

- Replace all four existing blowers
- Assume 5% interest rate and 2% inflation
- Use 20 year evaluation period

\[ r = \frac{0.05 - 0.02}{1 + 0.02} = 0.0294 = 2.94\% \]

\[ \text{PWF} = \frac{(1 + 0.0294)^{20} - 1}{0.0294 \cdot (1 + 0.0294)^{20}} = 14.96 \]
Example Analysis

• Using Composite Power Cost:

\[ NPW = 14.96 \times 91,800 - 2,080,000 = -706,000 \]

\[ \text{SimplePayback} = \frac{2,080,000}{91,800/\text{year}} = 22.7 \text{year} \]

• Using Actual Power Cost:

\[ NPW = 14.96 \times 87,100 - 2,080,000 = -777,000 \]

\[ \text{SimplePayback} = \frac{2,080,000}{87,100/\text{year}} = 23.9 \text{year} \]

• The NPW is negative and the payback period exceeds system life. **The project is not justified!**
Example Analysis

- Reevaluate replacing only two Blowers.
- Using Composite Power Cost:

\[
\text{NPW} = 14.96 \cdot 91,800 - 1,040,000 = 333,000
\]

\[
\text{SimplePayback} = \frac{1,040,000}{91,800/\text{year}} = 11.3 \text{year}
\]

- Using Actual Power Cost:

\[
\text{NPW} = 14.96 \cdot 87,100 - 1,040,000 = 263,000
\]

\[
\text{SimplePayback} = \frac{1,040,000}{87,100/\text{year}} = 11.9 \text{year}
\]

- The reduced scale project is justified!
Thank You

Thomas E. Jenkins
President, JenTech Inc.
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About the Speaker

Stephen Horne
Kaeser Compressors, Inc.

- Blower Product Manager, Kaeser Compressors, Inc.
- Over 15 years experience with the design and function of blower systems in wastewater aeration applications
- Primary instructor for blower products and applications in Kaeser’s Factory Certified Training program
Case Study:
Savings from Aeration Blowers

Stephen Horne
Blower Product Manager
Kaeser Compressors Inc.
Background

• Small rural WWTP (400,000 gallons per day) with three aging blowers, originally installed in 1993.

• Additionally, current system included:
  • Manual throttle the air flow
  • No DO control
  • Blowers were at end of useful life
Repair or replace?

1. Hope and pray the first one would be enough until the upgrade
2. Repair one or two of the down centrifugal blowers (about $25,000 per unit)
3. Upgrade the blowers early
Air Demand Analysis - Objectives

• Site evaluation
• Analyze and verify current plant’s
  • Pressure
  • Flow
  • kW
  • Temperatures
• Report back to town how latest technologies for their existing profile can be applied
Energy Rebate

Securing Energy Rebates from Local Power Company

• Offer:
  o $0.07 per kWh reduction per kWh’s saved

• Requirements:
  o Pre- and post-installation energy measurements
  o Project must be complete by the end of 2018
  o Estimate savings must show simple ROI of 7 years or less
  o Final incentive based on post-installation energy measurements
Air Demand Analysis - Results

- Data recording from site revealed
  - 550 scfm
  - 7.5 psig
  - 32 kW

- This results in a specific performance of **4.27 kW/100 cfm**

- Blowers running fixed speed

- No feedback for Dissolved Oxygen Control
Current System

Assuming Discharge Pressure of 7.9 psig Per Original Design Conditions

<table>
<thead>
<tr>
<th>(2) 40 hp centrifugal blowers - No VFD or DO Control</th>
<th>ICFM</th>
<th>Operating Hours</th>
<th>Cost per kWh</th>
<th>kW/100 cfm</th>
<th>kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1212</td>
<td>8600</td>
<td>$0.07</td>
<td>4.27</td>
<td>445,480.00</td>
</tr>
</tbody>
</table>

Operating Cost $31,183.60 Per Year
Operating Cost $2,598.63 Per Month

Operating cost at a fixed 4.27 kW/100 cfm
DO Regulation Options for Dedicated Blowers

Fixed (On/Off)

VFD/PID

VFD/PID + (On/Off)
Proposed Solution 1: Fixed Speed Blowers

Assuming Discharge Pressure of 7.9 psig Per Original Design Conditions

<table>
<thead>
<tr>
<th>(2) 30 hp screw blowers without VFD and DO Control</th>
<th>ICFM</th>
<th>Operating Hours</th>
<th>Cost per kWh</th>
<th>kW/100 cfm</th>
<th>kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1362</td>
<td>6570</td>
<td>$0.07</td>
<td>3.20</td>
<td>286,452.00</td>
</tr>
</tbody>
</table>

Projected rebate of $0.07/kWh x 159,028 kWh = $11,132

Operating cost at a fixed 3.2 kW/100 cfm

Projected rebate of $0.07/kWh x 159,028 kWh = $11,132
Proposed Solution 2: Blower with DO Regulation PID

Assuming Discharge Pressure of 7.9 psig Per Original Design Conditions

<table>
<thead>
<tr>
<th>ICFM</th>
<th>Operating Hours</th>
<th>Cost per kWh</th>
<th>kW/100 cfm</th>
<th>kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>342</td>
<td>480</td>
<td>$0.07</td>
<td>3.92</td>
<td>6,432.00</td>
</tr>
<tr>
<td>598</td>
<td>2097</td>
<td></td>
<td>3.41</td>
<td>42,778.80</td>
</tr>
<tr>
<td>860</td>
<td>3447</td>
<td></td>
<td>3.23</td>
<td>95,826.60</td>
</tr>
<tr>
<td>1114</td>
<td>2097</td>
<td></td>
<td>3.18</td>
<td>74,233.80</td>
</tr>
<tr>
<td>1362</td>
<td>480</td>
<td></td>
<td>3.20</td>
<td>20,928.00</td>
</tr>
</tbody>
</table>

Operating Cost: $16,813.94 Per Year
kWh Reduction: 205,280.80 Total
Energy Savings: $14,369.66 Per Year
Energy Savings: $1,197.47 Per Month

Operating cost with variable kW/100 cfm, but reducing load to match demand

Projected rebate of $0.07/kWh x 205,280.81 kWh = $14,369
Project Implementation

Automated DO Controls

- 1 DO probe installed per basin
- Communicated directly with blower individual controllers on each machine

Machines

- 2 x 30 hp VFD screw blower
- Local machine controller
- Created a proportional integral differential loop (high/low shutoffs)
- Steady DO level
Result: Blower with DO Regulation (How did we do?)

2 x 30 hp VFD Screw Blowers → Avg. 3.04 kW/100 cfm

DAILY BLOWER AIR FLOW
320 – 600 cfm
Avg. 457 cfm

BLOWER POWER CONSUMPTION
9 - 22 kW
Avg. 14 kW

BASIN DISSOLVED OXYGEN
4 PPM
Techniques to Determine Energy Savings

Securing Energy Rebates from Local Power Company

• Results:
  o At a DO level of 4.0 ppm, the WWTP would save $18,298/year
    • Additional savings than originally estimated

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Cost</td>
<td>$112,000</td>
</tr>
<tr>
<td>Actual Rebate from Energy Company</td>
<td>$18,298</td>
</tr>
<tr>
<td>Actual Yearly Savings</td>
<td>$18,298</td>
</tr>
<tr>
<td>ROI</td>
<td>5.12</td>
</tr>
<tr>
<td>Savings over 20 years</td>
<td>$365,960</td>
</tr>
</tbody>
</table>
In Conclusion

- Explore all options when planning to replace or repair
  - Newer technologies are *significantly* more energy efficient
- Even for smaller treatment plants, advance controls and monitoring capabilities can make a big difference
- Take advantage of utility incentives to upgrades

For more information, visit: [www.us.kaeser.com/wwtp](http://www.us.kaeser.com/wwtp)
Techniques for Determining Savings from Aeration Blowers

Q&A

Please submit any questions through the Question Window on your GoToWebinar interface, directing them to Blower & Vacuum Best Practices Magazine. Our panelists will do their best to address your questions, and will follow up with you on anything that goes unanswered during this session.

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