Aeration System Improvements with a 5-Year Payback

Scott Phipps
Wastewater Treatment Aeration Timeline

• 1970’s
  – Major infrastructure investment
  – “Quick and cheap” solutions
    • Coarse bubble diffusers & PD/MS blowers

• 1980’s
  – Construction and operation of WWTP
  – Introduction of fine bubble diffusers

• 1990’s
  – Widespread adaptation of fine bubble diffusers
    • Blower inefficiencies (higher pressures & operational gaps)
  – Introduction and implementation of controls
    • Further Blower inefficiencies

• 2000’s
  – Stricter nutrient limits (NH₃-N and TN)
  – Blowers reaching end of useful life
  – Advancement of blower technologies & controls
Energy Management

“The Perfect Storm”

- Energy costs are rising
- Rising treatment regulations
- Economy influence
- Social and environmental influences
  - CO₂ Emissions
  - Air Quality
- Federal and local government energy policies
  - Renewable energy portfolio standards
  - Grants and funding for “green” projects
Electricity Escalation
Midwest U.S. – 1985 through 2012

1985–2000 ~ 0.7%
2001–2006 ~ 1.7%
2007–2012 ~ 5.2%
Water Quality Requirements & Impacts

**Secondary Treatment**

- Activated Sludge with advanced treatment and nitrification: 1,900 kWh/MG
- Activated Sludge with advanced treatment, no nitrification: 1,600 kWh/MG
- Activated Sludge with no advanced treatment or nitrification: 1,400 kWh/MG
- No Activated Sludge: 1,000 kWh/MG

Average is 1,800 kWh/MG
Energy Consumption in W/WW Industry

- W/WW 3% of the nation's energy use (Source: EPA)
- W/WW loads typically largest energy user for municipal utilities
- Operating budgets stagnant or declining
  - More automation (lower personnel $)
  - Reduce energy

![Pie chart showing energy consumption in W/WW Industry]

- Personnel: 45%
- Energy: 30%
- Solids Disposal: 10%
- Maintenance: 3%
- Chemicals: 4%
- Other: 8%
Yesterday’s Thinking
“Energy = Electrical Power”

Potential Energy
- Denitrification
- Primary clarifier enhancement
- Primary sludge fermentation

Energy Sinks
- Aeration improvements
- High efficiency motors
- Pump VFD
- Reduce chemical use

Energy Harvesting
- Anaerobic digestion
- Gas recovery
- Nutrient recovery
- Co-gen
- Heat recovery
What is an Aeration System?
Aeration System
Most Energy Efficient Operation

• Three systems must work together
• Environmental & operational conditions control frequency in M.E.E triangle
• Improvements to one +/- impacts other two “circles”
Aeration System Evaluation
Step–by–Step Checklist

1. Blower curve conversion & efficiency
   – Design vs. operating pressure
   – Mechanical vs. electrical efficiency
2. Data analysis
   – Raw + PC performance + recycles
3. Oxygen transfer (diffuser) evaluation
   – Alpha, fouling factor ($\alpha \cdot F$)
4. Aeration demands
   – Daily, weekly, and monthly variations
5. Seasonal analysis
   – Winter, summer and transitional time periods
6. Present worth & LCC
# Case Study #1

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Case Study #1</th>
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<tbody>
<tr>
<td>Location</td>
<td>Kentucky</td>
</tr>
<tr>
<td>Treatment Configuration</td>
<td>Conventional Nitrifying Activated Sludge</td>
</tr>
<tr>
<td>Existing Blowers</td>
<td>3,000 hp Multi-Stage (w/ Vanes)</td>
</tr>
<tr>
<td>Capacity</td>
<td>20,000 – 40,000 scfm (2) 10,000 – 20,000 scfm (1)</td>
</tr>
<tr>
<td>Minimum Mixing</td>
<td>5,400 scfm</td>
</tr>
<tr>
<td>Diffuser</td>
<td>Tube</td>
</tr>
<tr>
<td>Purpose</td>
<td>Smaller blower motor failed. Get smaller blower operational?</td>
</tr>
</tbody>
</table>
Case Study #1
Aeration Tank Influent Loads

![Graph showing influent loadings for CBOD and TKN over different design points. The graph illustrates the minimum, average, and maximum day loads for each parameter.](image-url)
Case Study #1
\( \alpha F \) Determination

![Graph showing the relationship between \( \alpha \) and \( F \).]

- **Expected \( \alpha F \) - Factor Operating Envelope**
- **Alpha (\( \alpha \)) Range**
- **F-Factor Range**
Case Study #1
Impact of $\alpha F$ on Oxygen Transfer Capacity

- $\alpha F = 0.45$
- $\alpha F = 0.35$
Case Study #1
AOR vs. Air Flow ($\alpha F = 0.35$)
Case Study #1
Air Flow Projections ($\alpha F = 0.35$)
Case Study #1
Summary of Evaluation

Operating Blower #3 provides 33% savings compared to Blowers #1 or #2 based upon current air demand.

<table>
<thead>
<tr>
<th>Functioning Blowers</th>
<th>Duty Blower</th>
<th>α F</th>
<th>TOTAL (kW-hr/yr)</th>
<th>ANNUAL ELECTRICAL COST</th>
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</thead>
<tbody>
<tr>
<td>Blowers 1 &amp; 2</td>
<td>1 or 2</td>
<td>0.35</td>
<td>9,680,000</td>
<td>$570,000</td>
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<tr>
<td>Blowers 1, 2 &amp; 3</td>
<td>3</td>
<td>0.35</td>
<td>6,460,000</td>
<td>$380,000</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$190,000</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Potential Savings with Conservative α F</td>
<td>$190,000</td>
</tr>
<tr>
<td>Blowers 1 &amp; 2</td>
<td>1 or 2</td>
<td>0.45</td>
<td>9,270,000</td>
<td>$550,000</td>
</tr>
<tr>
<td>Blowers 1, 2 &amp; 3</td>
<td>3</td>
<td>0.45</td>
<td>4,930,000</td>
<td>$290,000</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Potential Savings with Aggressive α F</td>
<td>$260,000</td>
</tr>
</tbody>
</table>

- Assumptions:
  - Electrical = $0.059 /kW-hr
  - D.O. = 2.0 mg/l
  - Six aeration tanks in operation
  - Blower 1 or 2 required to operate ~ 10% annually
### Case Study #2

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<tr>
<th>Criteria</th>
<th>Case Study #2</th>
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<tr>
<td>Location</td>
<td>Ohio</td>
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<tr>
<td>Treatment Configuration</td>
<td>Tricking Filters + Nitrification Activated Sludge</td>
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<tr>
<td>Existing Blowers</td>
<td>1,500 hp Single-Stage Gear</td>
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<tr>
<td>Capacity</td>
<td>20,000 – 44,000 scfm (4)</td>
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<tr>
<td>Minimum Mixing</td>
<td>12,000 scfm</td>
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<td>Diffuser</td>
<td>Ceramic Disc</td>
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<tr>
<td>Purpose</td>
<td>Turndown, over aeration.</td>
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<td></td>
<td>More efficient system?</td>
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Case Study #2
Trickling Filter + Nitrification Activated Sludge

<table>
<thead>
<tr>
<th>Criteria</th>
<th>T.F. Effluent</th>
<th>Dewatering</th>
<th>Total</th>
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<tbody>
<tr>
<td>Flow</td>
<td>37.0 mgd</td>
<td>0.3 mgd</td>
<td>37.3 mgd</td>
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<tr>
<td>BOD5</td>
<td>12,700 lb/d  (41 mg/l)</td>
<td>Negligible</td>
<td>12,700 lb/d</td>
</tr>
<tr>
<td>TKN</td>
<td>7,100 lb/d  (23 mg/l)</td>
<td>270 lb/hr</td>
<td>9,200 lb/d</td>
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</tbody>
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Case Study #2
Loading Design Points – AOR

![Graph showing Actual Oxygen Requirement (AOR) vs Loading Design Point]

- Total AOR
- TKN AOR
- BOD AOR
Case Study #2
α F Determination

α F Curves for Diffusers

- Alpha (α) Range
- Expected α F - Factor Operating Envelope
- F-Factor Range

Average Basin Alpha (α)

Fouling Factor of Diffuser (F)
Case Study #2
Impact of $\alpha F$ on Oxygen Transfer Capacity

![Graph showing the impact of $\alpha F$ on oxygen transfer capacity.](image_url)
Case Study #2
AOR vs. Air Flow ($\alpha F = 0.6$)
Case Study #2
Aeration Blower Evaluation

• Three types of blowers
  – Magnetic bearing
  – Air bearing
  – Oil bearing
  – Base loading multi-stage

• Seven configurations evaluated
  – 5,000 – 12,000 scfm blower capacities
  – 250 – 600 hp
  – Average KW power demand ~ 460 KW (vs. 950 KW current)
  – Average electrical demand ~ 4,030 MW/yr (vs. 8,300 MW/yr)
Case Study #2
Net Present Worth and Payback

Best Case: 5 – 6 years
Worst Case: 12 – 13 years
Case Study #2

Project Status

- Design completed in March 2014
  - Significant electrical upgrades
  - Pre-selected blower manufacturer
- Bid in April 2014
  - Pre-negotiated blower equipment and services
  - Engineer’s OPCC ~ $2.73 million
  - Bid ~ $2.56 million
- Awarded in July 2014
- Substantial completion in 4Q 2015
Summary

• Aeration system evaluation
  – Impacts of dewatering
  – $\alpha F$ selection
  – Impacts of mixing

• Evaluate entire system
  – Control setpoints (i.e. DO, ORP, NH$_3$-N)
  – Oxygen transfer (i.e. diffusers)

• Blower payback difficult a majority of the time
  – Typically, need to change two system components
Questions