Energy Efficiency Evaluation for Process Aeration Blowers

2011 OWEA Annual Conference
June 22, 2011
Agenda

- New Way of Thinking about Energy Efficiency
- Aeration System Energy Considerations
- Introduction to M.E.E. Triangle
- Case Study for Energy Evaluation
  - Town of Greenwich, CT
    Grass Island WWTP
Wastewater Treatment
Today’s Buzzword – “Energy Efficiency”

“We’re going **GREEN**”

“This is the **monthly** power bill!”

“Greenhouse gases (GHG) – not from my plant”

“We are an energy [*neutral*] facility”

“I don’t know the size of my carbon footprint”
Wastewater Treatment
Different Thinking about “Energy”

<table>
<thead>
<tr>
<th>Yesterday’s Thinking</th>
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</thead>
<tbody>
<tr>
<td>Energy = Electrical Power</td>
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</table>

<table>
<thead>
<tr>
<th>Tomorrow’s Thinking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Influent Energy</td>
</tr>
<tr>
<td>Energy Sinks</td>
</tr>
<tr>
<td>Energy Extraction</td>
</tr>
</tbody>
</table>
Primary Treatment

Secondary Treatment

Disinfection

1° Clarifier → Activated Sludge → 2° Clarifier → Solids Handling

Aeration System

RAS

PS

WAS
Influent Energy
“It’s Free” – Use to Treatment’s Advantage

Primary Treatment

1° Clarifier

Secondary Treatment

Activated Sludge

Aeration System

2° Clarifier

Disinfection

Solids Handling

RAS

PS

WAS

PS

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Energy Sinks
Minimize Energy to Reduce Operating Costs

Primary Treatment

Secondary Treatment

Disinfection

1° Clarifier → Activated Sludge → RAS → 2° Clarifier → Solids Handling

Aeration System

RAS

WAS

PS
Energy Extraction
Energy Production > Energy Required

Primary Treatment

1° Clarifier → Activated Sludge → 2° Clarifier

Secondary Treatment

Aeration System

Disinfection

Solids Handling

RAS → PS

WAS
Tomorrow’s Thinking
Energy Management

Primary Treatment

1° Clarifier

Secondary Treatment

Activated Sludge

Aeration System

RAS

2° Clarifier

PS

Disinfection

Solids Handling

Solids Handling

WAS

PS
Aeration System
Wastewater Treatment Biggest Energy “Sink”

• Typically, 45 – 75% of total energy costs
• Why necessary?
  • Conversion of particulate to soluble material
  • Oxidation of soluble organic material (i.e. sCOD)
  • Nitrification
• Typical components
  • Oxygen control strategy
  • Oxygen transfer system (i.e. diffusers)
  • Air production (i.e. blowers, aerators, etc.)
Aeration System
Three Areas of Consideration

- O₂ Transfer
- Control Strategy
- Air Production
Aeration System
Major Design Considerations

- D.O. Meters
- Flow Measurement
- Flow Splitting
- Operational Philosophy

Control Strategy

O₂ Transfer

Air Production
Aeration System
Major Design Considerations

- Diffuser Style
- Bubble Size
- Tank Depth
- Operational Conditions

- \( \text{O}_2 \) Transfer

- Control Strategy
  - D.O. Meters
  - Flow Measurement
  - Flow Splitting
  - Operational Philosophy

- Air Production
Aeration System
Major Design Considerations

- Diffuser Style
- Bubble Size
- Tank Depth
- Operational Conditions

- D.O. Meters
- Flow Measurement
- Flow Splitting
- Operational Philosophy

- Type of Aeration
- Operational Conditions
- Environmental Conditions
- Operational Envelope

- O₂ Transfer

- Control Strategy

- Air Production
Aeration System
Most Energy Efficient (M.E.E.) Triangle

- Intersect of three components defines M.E.E. triangle
- Three components must work together
- Circle size controlled by efficiency of component
- “Larger Circle = More Efficient”
- Environmental & operational conditions control frequency in M.E.E triangle
- Improvements to one +/- impacts other two “circles”
Aeration System
Example for M.E.E. Triangle

- Control Strategy
- O₂ Transfer
- Air Production

M.E.E. – Most Energy Efficient

Control Strategy – Most advanced
O₂ Transfer -> 35% SOTE
Air Production – “Doesn’t match”
Aeration System
Air Production Sensitivity

- Air production is most sensitive to conditions and efficiency
- Control strategy – “Defined Efficiency”
- O₂ Transfer – “Partially Defined Efficiency”
  - Tank depth
  - Bubble size
  - Variables: Temp & Op. DO
- Air Production – “Variable Efficiency”
  - Type of equipment
  - Variable influent conditions
  - Diurnal conditions
  - Seasonal conditions
  - Environmental conditions

M.E.E. – Most Energy Efficient
Town of Greenwich, CT
Grass Island Wastewater Treatment Plant

- 12.5 mgd advanced WWTP
- Long Island Sound outfall
- Total nitrogen limit
- Modified Ludzak-Ettinger (MLE) configuration

Anoxic  Aerobic  MLE
Grass Island WWTP
Existing MLE Bioreactor Configuration

<table>
<thead>
<tr>
<th>Zone</th>
<th>Operation</th>
<th>Compartments</th>
<th>Diffuser Type &amp; Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Anoxic</td>
<td>5</td>
<td>Coarse bubble</td>
</tr>
<tr>
<td>2</td>
<td>Aerobic</td>
<td>2</td>
<td>Fine bubble – 750 diffusers</td>
</tr>
<tr>
<td>3</td>
<td>Aerobic</td>
<td>1</td>
<td>Fine bubble – 380 diffusers</td>
</tr>
<tr>
<td>4</td>
<td>Aerobic</td>
<td>1</td>
<td>Fine bubble – 205 diffusers</td>
</tr>
</tbody>
</table>
### Grass Island WWTP

#### Aeration System Components

<table>
<thead>
<tr>
<th>Component</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DO Control System</strong></td>
<td>Header Pressure Control&lt;br&gt;Multiple zone drop legs&lt;br&gt;DO control in 2 of 5 tanks</td>
</tr>
<tr>
<td><strong>O$_2$ Transfer System</strong></td>
<td>Ceramic Fine Bubble Diffusers&lt;br&gt;Submergence = 11 feet&lt;br&gt;SOTE = 22%</td>
</tr>
<tr>
<td><strong>Air Production System</strong></td>
<td>Single-Stage Centrifugal (Gear Driven)&lt;br&gt;Quantity: 3&lt;br&gt;Capacity: 10,000 ACFM&lt;br&gt;Discharge Pressure: 7.0 psig&lt;br&gt;Horsepower: 400 hp</td>
</tr>
</tbody>
</table>
Grass Island WWTP
Aeration System M.E.E. Triangle

M.E.E. – Most Energy Efficient

O₂ Transfer
Air Production
Control Strategy

Pressure Control
Ceramic Fine Bubble
1-Stage Cent.

Grass Island WWTP
## Grass Island WWTP
### Air Production System

### Design Criteria

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Design Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blower Style</td>
<td>Single-Stage Centrifugal</td>
</tr>
<tr>
<td>Quantity</td>
<td>3</td>
</tr>
<tr>
<td>Inlet Capacity</td>
<td>10,000 ACFM</td>
</tr>
<tr>
<td>Capacity Control</td>
<td>Inlet Guide Vanes</td>
</tr>
<tr>
<td>Inlet Temperature</td>
<td>100 °F</td>
</tr>
<tr>
<td>Inlet Relative Humidity</td>
<td>80%</td>
</tr>
<tr>
<td>Discharge Pressure</td>
<td>7.0 psig</td>
</tr>
<tr>
<td>Horsepower</td>
<td>400 hp</td>
</tr>
</tbody>
</table>

### Operational Criteria

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Operational Design Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barometric Pressure</td>
<td>14.4 – 15.1 psia</td>
</tr>
<tr>
<td>Inlet Air Temperature</td>
<td>0 – 100 °F</td>
</tr>
<tr>
<td>Relative Humidity</td>
<td>30 – 80%</td>
</tr>
<tr>
<td>Discharge Pressure</td>
<td>6.0 – 7.0 psig</td>
</tr>
<tr>
<td>Maximum Turndown</td>
<td>45% rated capacity</td>
</tr>
</tbody>
</table>
Grass Island WWTP
Air Production System Challenges

• Blower design criteria
  • Only one blower operates
  • Sized in ACFM at highest temp & R.H.
  • Single point capacity control (i.e. inlet guide vanes)
  • Only one blower is on standby power system

• Ancillary air demands
  • Vary with no. of units in service
  • Operating pressures vary among unit processes

• Insufficient blower turndown
  • Average blow-off ~ 1,000 scfm
  • Normal operation ~ 25% air vented
Grass Island WWTP
GPS-X Process Modeling Scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Description</th>
<th>Flow</th>
<th>Loadings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Current Condition</td>
<td>8.3 mgd</td>
<td>Past 3 years</td>
</tr>
<tr>
<td>2</td>
<td>Future Condition</td>
<td>10.0 mgd</td>
<td>20% increase over Current</td>
</tr>
<tr>
<td>3</td>
<td>Design Condition</td>
<td>12.5 mgd</td>
<td>50% increase over Current</td>
</tr>
</tbody>
</table>

- Influent diurnal flow patterns
- Primary effluent scenarios
  - Variable flow only
  - Variable flow and load
- Seasonal conditions
- Variable unit processes in services
Grass Island WWTP
Blower Operational Envelope

Operational Envelope

Design Max. Month

Current Avg. Annual

Current Winter Min. Hr

Percentile Plot

Total Air Demands (scfm)
Grass Island WWTP
Aeration Blower Design Criteria

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Design Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Units</td>
<td>3</td>
</tr>
<tr>
<td>Number of Units in Service</td>
<td>1 (Average Conditions)</td>
</tr>
<tr>
<td></td>
<td>2 (Peak Conditions)</td>
</tr>
<tr>
<td>Nominal Capacity</td>
<td>2,500 – 5,600 scfm</td>
</tr>
<tr>
<td>Capacity Turndown</td>
<td>45 – 100%</td>
</tr>
<tr>
<td>Discharge Pressure</td>
<td>7.0 psig</td>
</tr>
<tr>
<td>Horsepower</td>
<td>250 – 300 hp</td>
</tr>
</tbody>
</table>

- Alternatives
  - Multi-stage centrifugal (eliminated due to turndown)
  - Single-stage gear driven centrifugal
  - Single-stage direct drive centrifugal (i.e. “turbo” blowers)
Grass Island WWTP
Aeration Blower Alternatives

<table>
<thead>
<tr>
<th>Supplier</th>
<th>Drive</th>
<th>Point Control</th>
<th>Capacity Range</th>
<th>Horsepower</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Gear</td>
<td>Dual</td>
<td>2,500 – 5,600 scfm</td>
<td>250 hp</td>
</tr>
<tr>
<td>2</td>
<td>Direct</td>
<td>Single</td>
<td>3,100 – 5,700 scfm</td>
<td>300 hp</td>
</tr>
<tr>
<td>3</td>
<td>Direct</td>
<td>Single</td>
<td>3,150 – 5,650 scfm</td>
<td>300 hp</td>
</tr>
<tr>
<td>4</td>
<td>Direct</td>
<td>Single</td>
<td>3,200 – 5,600 scfm</td>
<td>300 hp</td>
</tr>
</tbody>
</table>

- Gear driven configuration met specified turndown
- Direct driven configurations required higher installed horsepower
- Evaluation to determine “wire-to-air” efficiency
  - Estimated efficiency among various components
  - Average ranged between 68 – 72% WAE
- LCC evaluations performed for electricity
  - Direct driven configurations marginally higher WAE
  - Required higher installed horsepower
Grass Island WWTP
Quantitative & Qualitative Evaluations

<table>
<thead>
<tr>
<th>Quantitative Evaluation</th>
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<tbody>
<tr>
<td><strong>LCC Criteria</strong></td>
</tr>
<tr>
<td>Capital Costs</td>
</tr>
<tr>
<td>Electrical Costs</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Qualitative Evaluation</th>
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<tbody>
<tr>
<td><strong>Qual. Criteria</strong></td>
</tr>
<tr>
<td>Technology Development</td>
</tr>
<tr>
<td>Footprint Requirements</td>
</tr>
<tr>
<td>Bearings</td>
</tr>
<tr>
<td>Capacity Control</td>
</tr>
<tr>
<td>Turndown Capability</td>
</tr>
<tr>
<td>Noise Level</td>
</tr>
<tr>
<td>Operator Familiarity</td>
</tr>
</tbody>
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Grass Island WWTP
Aeration System Recommendations

- Control Strategy
  - Maintain existing DO drop leg zones & header pressure control strategy
- Oxygen Transfer System
  - Optimize ceramic fine-bubble diffusers arrangement
- Air Production System
  - Three single-stage gear driven centrifugal blowers
  - 2,500 – 5,600 scfm/each
  - One or two units in service allows > 97% envelope operation
  - Sufficient turndown to eliminate “blow-off”
  - Power requirements permit two blower operation on standby generators
Grass Island WWTP
Aeration System M.E.E. Triangle

Existing System

New System
• New Way of Thinking about Energy Efficiency
• Aeration System Energy Considerations
• Introduction to M.E.E. Triangle
• Case Study for Energy Evaluation
  • Town of Greenwich, CT
  Grass Island WWTP
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