Aeration Systems
25 Years of Experience

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Outline

• Aeration system types
• Terminology
• Mechanical (surface) aerators
• Combined (jets and turbines)
• Diffused aeration
  – Coarse
  – Fine pore
    • Ceramic
    • Plastic
    • Membranes
Terminology

• Efficiency
  – Standard oxygen transfer efficiency (SOTE) (percent oxygen transferred)
  – Standard oxygen transfer rate (SOTR) (mass transferred per unit time)
  – Standard aeration efficiency (SAE) (mass transferred per unit time per unit power)
Terminology Cont

- SOTE - percent
- SOTR – lb O2/hr or kg O2/hr
- SAE – lb O2/hp-hr or kg O2/kW-hr
- All above at standard conditions (e.g. 20°C, clean water, etc.)
- OTE, OTR, AE – at process conditions
Standard and Process Conditions

- Adjustment formulas based upon driving force, temperature, barometric pressure, water quality, saturation concentration, etc.
- Driving force and water quality the most significant
- Driving force = \((\text{DO}_S - \text{DO})/\text{DO}_S\)
- Water quality – alpha factor, 0 to 1!
- Total correction can result in process water transfer of only 30 to 80% of clean water transfer
Mechanical Aerators

• Two types
  – High speed (900-1200 RPM)
  – Low speed (30-80 RPM)

• Operate at the surface
• Modest efficiency
• High heat loss
• Mist, spray
• Often simple to install, especially high speed
• Higher alpha factors (0.6 to 0.9) depending upon energy density
High Speed Surface Aerator
(Axial Pumping)

Motor

Splash Guard

Impeller

Float

Water Level

Water Flow

Bell or funnel
Specifications

• 1 to 75 hp (1 to 56 kW)
• Up to 2.2 lb O2/hp-hr (1.3 kg O2/kW-hr)
• 900 to 1200 rpm motors, no gear box
• Floc shearing potential
• Misting and drift potential
• Quick installation, quick delivery
• 8 ft (2.5 m) depth without draft tubes
High Speed - Out of Service

- **Motor (1 – 75 hp)**
- **Splash guard, directs water flow**
- **Float**
- **Bell, acts as a funnel.**
High Speed – Out of Service
For Sale !!!!
Specifications

- 5 to 150 hp (112 kW), rarely greater, but possible
- 3 to 3.5 lb O2/hp-hr (1.8-2.2 kg O2/kW-hr)
- ~40 to 80 RPM impellers
- Depths to 15 ft (3.5 m) without draft tubes or lower impellers
- Usually pier mounted, but occasionally mounted on floats
- Long lead time for purchase and installation
- Misting and drift potential
- Little potential for floc shear
- Lower impellers and draft tubes for operation at greater depth
- New impeller designs
Flow Pattern

Motor/Gear Box

Never uniform DO!

Number = DO
During Construction

Pitch bladed turbine with lower impeller

3 to 10% power used for lower impeller
In Service

Low speed

High speed
In Service
Maintenance
Floating
HPO-AS Application
Slow Speed Horizontal

• Used in oxidation ditches
• Much less frequently used in the US
• Used to impart a linear velocity as well as aerate
• Efficiencies similar to slow speed vertical aerators
Trade Show
In Service (Off) – Oxidation Ditch
In Service – Oxidation Ditch
Combined Types

- **Turbines** – using mechanical energy to make fine bubbles from a coarse orifice
  - Sparged
  - Down draft
- **Jets** – air and water flowing through a venturi creates fine bubbles without a small orifice
- **Alpha factors** similar to fine bubble diffusers, as opposed to mechanical aerators (0.3 to 0.6)
Turbines

- Energy efficiency to 3 lb/hp-hr (1.8 kg O2/kW-hr)
- Very large power input possible (> 200 hp mixers (150 kW))
- Gear boxes (~ 100 to 400 RPM)
- Much less frequently used today
- Fewer in-tank maintenance problems
Sparged Turbine

Requires two “primer movers”

Depths to 10 m or more

Very large OTR can be obtained in a small volume

Used more in industry than for wastewater treatment
Down Draft Turbine

Requires two “primer movers”

Depths to 5 m or more

Lower blower horsepower due to shallow diffuser depth
Down Draft Turbine

Impeller and sparge ring

Draft Tube
Down Draft Turbine

- Motor/Gear
- Support Columns
- Impeller
- Draft Tube
Jets Flow Diagram

Air supply from a blower

Mixed Liquor Pump

Water

Air
Nozzle and Piping

Air Supply

Mixed Liquor Supply

Nozzle
Jet Nozzle
FiberGlas Jet

- Air Supply
- Nozzle
- Mixed Liquor Supply
New, Novel Designs
Diffused – Coarse Bubble

- Low maintenance, low efficiency
- 1 % /ft or (3%/m) SOTE
- 2.0-3.0 SAE (1.2 – 1.8 kg O2/kW-hr)
- Large orifices – 0.25 in (60 mm)
- Handles large air flow and high OTRs for many industrial applications
- Phased out in most municipal applications in favor of more efficient fine pore systems
- Alpha in the 0.6 to 0.8 range
Floor Coverage

- Spiral roll – least efficient but great mixing (0.3 to 0.5 % SOTE/ft)
- Cross roll and “ridge and furrow”
- Full floor coverage – most efficient
- Odd arrangements often work well
- Depth limited by blower restrictions
Spiral Roll – Empty Tank

Cut off valve under the deck for each arm

Swing Arms, with knee joint

Spargers
Retracted Swing Arm

Knee Joint

Sparger

Cut off valve
Swing Arm With Spargers
Spargers
Coarse Bubble – D24
Cross Roll System
Full Floor Coverage

- Kenics static tube
- Cells
- Air Header
Fine Pore Diffusers

- Ceramic plates – original custom build systems
- Ceramic domes – imported from England, technology ruined in the US
- Ceramic discs – pioneered by Sanitaire
- Ceramic tubes – old and new versions
- Membrane discs – sometimes interchangeable with discs
- Membrane tubes – many manufacturers
- Plastic tubes and discs – some special uses
- Panels – proprietary geometry
Fine Pore Diffusers

- Usually implemented with full floor coverage
- Quiescent systems – low turbulence and low fluid velocities
- Suitable for low to medium rate systems
- Requires routine cleaning
- Highest efficiency of all the systems, so far! 8.0 SAE (4.8 kg O2/kW-hr)
- Best system to minimize VOC release
Fine Pore Plates

Developed and used by many large US cities, in custom, site-specific designs.
Plastic Plates – An Old Idea With New Materials
Ceramic Domes
Domes On Air Headers
Ceramic Disc Diffusers
Membrane Discs
Other Discs

Plastic Sintered Disc

EPDM Disc
Mini Panel
Empty Tank With Discs
Saran Wrap Tubes
Five Different Tubes

- EPDM
- PVC
- Ceramic
- EPDM
- Plastic
PearlComb Plastic

Sintered Tube
One Manufacturer’s Offerings
Diffusers in Lagoons

Air Lateral

Hoses provide support and deliver air

Up to six standard membrane diffusers

Parkson Biolac

Float

Aertec, EDI

Air Lateral

Nylon rope and anchor

Reef Diffusers

Membrane tube diffusers
Special Geometries
Off-gas testing in progress with portable hood
Diffuser Details

3/4 in NPT Connector

Flap Valve to prevent water entry into the piping system

Punch Pattern
Panel Diffuser

~ 4 m
Mesner Panels
Surface Aerator Problems

• High speed
  – Freezing
  – Impeller wear
  – Bearing failure

• Low speed
  – Gear box failures
  – Structural failures
  – Surging, oscillation, unstable conditions
  – Impeller or hub failure
Impeller Damage
Structural Failure of a Float Arm
Structural Failure of an Aerator Float Arm

Stress Crack

Repaired crack with a welded plate
Diffused Aerator Problems

• Coarse bubble
  – Piping failure
  – Corrosion
  – Leaks

• Fine pore
  – Fouling (biological)
  – Scaling (chemical)
  – Leaks into the piping system that foul diffusers
  – Back pressure build up
  – Material failures (membrane problems)
  – Piping failures
  – Leaks
Material Failures

• Hardening of the membrane from leaching of membrane components, resulting in increased pressure drop and reduced efficiency

• Softening of the membrane due to absorption of wastewater constituents, resulting in membrane expansion, increased pressure drop and reduced efficiency

• Change in pore size due to aging
Fouling and Scaling

• Fouling – biological growth on diffuser surfaces, coalescing bubbles, increasing pressure drop
• Scaling – precipitation of minerals (calcium carbonate, silica)
• Fouling from the inside due leaks into the piping system
Tank With Partial Cleaning From Hosing
Diffuser Coated With Bioslime
Liquid Acid Cleaning
HCl Gas Cleaning

HCl Gas is introduced into the air headers and flows through the diffusers, dissolving salts.
Experimental Setup
### Some Energy Approximations*

<table>
<thead>
<tr>
<th>Aerator Type</th>
<th>SAE lbO₂/hp-h (kgO₂/kW-h)</th>
<th>Low SRT AE at 2 mg/L DO</th>
<th>High SRT AE At 2 mg/L DO</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Speed</td>
<td>1.5–2.2 (0.9–1.3)</td>
<td>0.7–1.4</td>
<td>(0.4–0.8)</td>
</tr>
<tr>
<td>Low Speed</td>
<td>2.5–3.5 (1.5–2.1)</td>
<td>1.2–2.5</td>
<td>(0.7–1.5)</td>
</tr>
<tr>
<td>Turbine</td>
<td>2-3 (1.2-1.8)</td>
<td>0.6-0.9</td>
<td>(0.4-0.6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.9-1.4</td>
<td>(0.6-0.8)</td>
</tr>
<tr>
<td>Coarse Bubble</td>
<td>1-2.5 (0.6 –1.5)</td>
<td>0.5 – 1.2</td>
<td>(0.3-0.7)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.6–1.6</td>
<td>(0.4-0.9)</td>
</tr>
<tr>
<td>Fine Pore</td>
<td>6–8 (3.6–4.8)</td>
<td>1.2-1.6</td>
<td>3.3-4.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.7–1.0)</td>
<td>(2–2.6)</td>
</tr>
</tbody>
</table>

*Use at your own peril!
Final Thoughts

• Engineers have a wide range of options for aeration

• Mechanical aerators
  – High speed – simple quick solution, usually not best on any specific parameter
  – Low speed - expensive but can be relatively efficient, good mixing
  – Both have high cooling rates and high VOC stripping rates. Not recommended for cold applications
  – Good for lagoons
Final Thoughts

• Coarse bubble diffusers
  – Low maintenance
  – Low efficiency
  – Never a good energy conserving solution but often the maintenance free solution

• Fine pore (bubble)
  – Best energy conservation
  – High maintenance
  – Commit to clean or do not purchase

• Design standards exist to assist manufacturers, designers and owners