Evolution of Aeration Control Technology
Outline

- Why Control Aeration Equipment?
- Instruments Utilized
- Methods of Control
- Current Approach
- Control Technology
  - Large plants
  - Small plants
- Examples
Why Control Aeration Equipment?

- Energy Costs $$$$$$$$
- Typically 40-60% of WWTP Total Energy Usage
- Biological Control
  - Too Much Air - Poor Settling
  - Too Little Air - Dead Bugs, Poor Settling
- Controlled Aeration = Happy Bugs
Why Do Dissolved Oxygen Levels Vary?

- Diurnal Fluctuation in BOD and Ammonia Load
- Photosynthesis / Respiration effects
- Variable Sidestream Loads
- Variable Oxygen Uptake due to Seasonal Environmental Conditions (Temperature, etc.)
Instruments Utilized

- **Dissolved Oxygen Probes**
  - Historically Membrane Type
  - Prone To Erroneous Readings and Malfunctions
  - Frequent Recalibrations

- **Optical Multi-function Probes**
  - Can Monitor DO, ORP, Turbidity
  - Some Need Air Cleaning
  - Pipeline Mount Models
  - Wireless Models
Optical vs Steady State

Six sample concentrations measured seven times using membrane covered and optical sensors.

DO values correlate almost exactly even at low DO levels below 1 mg/L
Off Gas (Oxygen Uptake Rate)

- Off Gas or Uptake Rate Measurements
  - Monitors DO in Off-gas Rather than in Mixed Liquor (I.E. Respiration Rate)
  - Measures Biological Activity -- not just the Environmental Conditions
  - More Akin to a “Heart Rate Monitor”
Methods of Control

- **Mechanical Aeration**
  - Change Levels with Control Weir
  - Change Device Speed
  - Weir Can be Automated to Provide Some Control

- **Diffused Aeration**
  - Control Air Distribution within Tank
  - Diffuser Distribution / Density
  - Drop Throttling
  - Control Air Volume
    - Blower Inlet Throttling
    - Variable Speed Blowers
Mechanical Aeration

- Three Primary Types
  - Horizontal Brush Rotors / Oxidation Ditch
  - Vertical Rotors
  - Hybrids
Horizontal Mechanical Aeration

- Horizontal Brush Rotors / Oxidation Ditch
  - Change Levels with Control Weir
  - Limited Aeration Control and Operational Flexibility
  - Weir Can Be Automated to Provide Some Control
  - Rotors Can Work with Variable Speed (More Commonly with Belt Drive)
  - Oxygen Input Location is Concentrated
  - Limited Potential for Nutrient Removal
  - (Anaerobic/Anoxic/Oxic Zones)
Vertical Mechanical Aeration

- **Vertical Rotors**
  - Change Water Levels with Control Weir
  - Change Speed
  - Numerous Rotors Mean Numerous Variable Speed Devices
  - Some Potential for Nutrient Removal (Anaerobic/Anoxic/Oxic)
- Fixed Location of Oxygen Input Limits Control Potential
Hybrid Mechanical Aeration

- **Hybrids**
  - Surface Aerator/Mixers With Diffused Air
    - More Flexibility Than Surface Aeration Alone
    - Air Rate can be Varied
  - Submerged Draft Tube Mixer/Aerators With Diffused Air
    - More Efficient Mixing/Aeration with Down Flow Fluid Movement
    - Air Rate can be Varied
  - Submersible Aspirating Pump
    - Air Rate and Pumping Rate can be Varied
Diffused Aeration Control

- Most Common Means of Providing Oxygen in Reactors
- Full Floor Coverage Fine Bubble Diffusers
- Several Headers along Length of Reactors
Tiers of Air Distribution Control

- **1st Tier -- Diffuser Distribution within the Tank**
  - One Time Control (No Moving Parts)

- **2nd Tier -- Header Regulation along Length of Tank**
  - In Response to DO Meters within Header Zone

- **3rd Tier -- Header Regulation Between Tanks**
  - In Response To DO Meters within Tank (Or Averaged)
  - Use Most Open Valve Logic to Ensure at Least One Valve is Wide Open

- **4th Tier -- Blower Output Control**
  - Most Complex -- But Most Energy Savings Potential
1st Tier - Diffused Aeration Control

Diffuser Distribution Within Tank

- Match Oxygen Uptake Rate along Reactor
  - Measure Oxygen Uptake Rate with Off-Gas
  - Use Typical Exponential Distribution
  - Simple And Works Well
2nd and 3rd Tier - Header Regulation Between and Along Tanks

- Use Most-Open Valve Position Control
- Used to Minimize Blower System Pressure
- Maintains at Least One Tank / Header at its Maximum Open Position
Methods of Diffused Aeration Control

Diffuser Distribution Within Tank

- Dissolved Oxygen Probe
  - Measure Oxygen Uptake Rate with Off-Gas
  - Control Air Drop Valve(s)
- Oxygen Uptake Rate
  - Measure Oxygen Depletion in Off-Gas
  - Control Air Drop Valve(s)
4th Tier - Blower Output Control

- Use Blower Speed to Regulate Header Pressure in Response to Tank Demands
- Greatest and Most Effective Means to Control Output and Energy Consumption
Rotary Positive Blowers

- Variable Speed Control Works Well
- Good Turndown Range
- More Commonly Used for Biosolids Stabilization
- Least Efficient of Aeration Blowers
- Least Common
Multi Stage Centrifugal Blowers

- Workhorse of the Industry
- Inlet Valve Throttling
- Flat Curve - Lower Turndown Potential with Speed Changes than Other Blower Types
Single Stage Blowers

- Single Stage Centrifugal Blower
  - Inlet and Outlet Vanes (Dual Point) Control
  - Motorized Control or Vane Angle
  - Appropriate for Large Plants
  - Inlet Vanes (Shown Below)
Single Stage Blowers

- Single Stage Centrifugal Blower
  - Dual Point Control Vanes
  - Outlet Control Vanes Shown Below
  - More Efficient than Simple Butterfly Valve Control
Single Stage Blower
With Dual Point Control

Dual Point Control - Relative Efficiency Map

1960’s

Flow %

Head %

increased turndown

100
95
90
85
80
75
80
90
95
100
High Speed Turbo Blowers

- Use Single Stage Centrifugal Technology
- Most Are Single But Some Use Dual Point Controls
- Variable Speed Control Works Well
- Package Systems (Unit Responsibility)
- Some Use Inlet Air for Motor/Blower Cooling
- Air or Magnetic Bearings
- Approx. 7 Mfrs.
Blower Type Efficiency Comparison

Blower Technology Performance Comparison

- Variable Speed PD Blower
- Variable Speed Multi-Stage Blower
- Variable Speed Direct Drive Single-Stage
- Single-Stage Blower with Dual Point Control

![Graph showing efficiency comparison between different types of blowers based on mass flow rate. The graph plots relative wire power against mass flow rate.]
Integrated Controls
Turbo Blower Package Controls

- Packages Blower Control for Plants Using Single or Multiple Blowers (Single Source Responsibility)
  - Essentially “Plug And Play”
  - Provide DO Signal for Control and Blower Controls are Internal
  - Multiple Blowers can be Accommodated
  - Ideal for Smaller Plants
- Benefits
  - Approximately 40-50% Aeration Power Savings and 25-30% Overall Plant Power Savings
Turbo Blower Distributed Controls

- Multiple Blowers can be accommodated
- Use Most Open Valve Control
  - Minimize Blower Pressure
  - Provide DO Signal for Control and Blower Controls are Internal
- Benefits
  - Approximately 25-35% overall Plant Power Savings
Example Plant No. 1

- Replaced One Existing Multi-Stage Centrifugal Blower
  - Evaluation Suggested an Equivalent Blower Size Replacing One Blower Out of Five
  - Blower also Provides Re-aeration Air (Approximately 5% Of Total)
  - Plant has Two Sets of Tanks with Different Depths and thus Different Pressures

- Results
  - Approximately 25-35% Overall Plant Power Savings

![Graph showing energy usage over months from July to December, with data points for 2013 and 2014.]
Example Plant No. 2

- Replaced Existing Multi-Stage Blower
  - Equivalent Blower Size Utilized
  - Blower Control Software had some Initial Issues but now Resolved

- Results
  - Approximately 20-25% Overall Plant Power Savings
    (Based on Limited Experience)
Example Plant No. 3

- Replaced Existing Multi-Stage Centrifugal
  - Equivalent Blower Size Utilized (No Evaluation Performed)
  - Blower also Provides Re-aeration Air and Aerobic Digestion Air
  - Plant has Significant Seasonal Load Variations
  - DO Probe has been Problematic

- Results
  - Approximately 15% overall Plant Power Savings
Example Plant No. 4

- Replaced One Existing Single-stage Blower
- Already had Tapered Fine Bubble Aeration
- Partitioned Biological Reactors and Added Coarse Bubble Mix (Anoxic Zone) for Nutrient Removal
- Aeration Zone uses Two DO Probes - One Near End and One In Middle
- Uses Most-Open Valve / Pressure Control For Air Distribution Between Tanks

- Results
  - Approximately 10-15% Overall Savings
  - Approximately 5% from Power and 10% from Chemical
Example Plant No. 5

- Replaced Hybrid Mechanical Aeration with Single-stage Blowers
- Partitioned Biological Reactors and Added Submersible Eductor Mixing for in Anoxic Zone for Nutrient Removal
- Added Tapered Fine Bubble Aeration Grids
- Aeration Zone uses DO and Ammonia Probes – Ammonia Probes Now Used to Control DO Setpoint
- Uses Most-Open Valve / Pressure Control For Air Distribution Between Tanks

Results:
- Approximately 40 - 45% Overall Power Savings on Aeration
- An Additional 10-15% Power Savings by Using Ammonia Control
Conclusions

- Aeration Controls Save Energy $$$$$$$ and Optimize Process Performance
- Can Now More Easily Be implemented at Small Plants
- Higher Levels of Sophistication and Controls Can Increase Savings
Just Like Aeration Equipment – Fashions Evolve!
Acknowledgments

George Holzworth – City of Hastings
Bob Monroe – Gun Lake W&S Authority
Birt McKendree – City of Frankenmuth
Dave Monette – City of Warren
Mike Lunn – City of Grand Rapids
Randy Hamlett – Hamlett Environmental
Barry Simescu – Dubois Cooper
Jay Vermilye – Dubois Cooper
Thank You!.......Any Questions?

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