Design and Operation of Advanced Aeration Control Systems

Session 10

Maureen D. Neville

January 22, 2018

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NEWEA – 2018 Annual Conference & Exhibit

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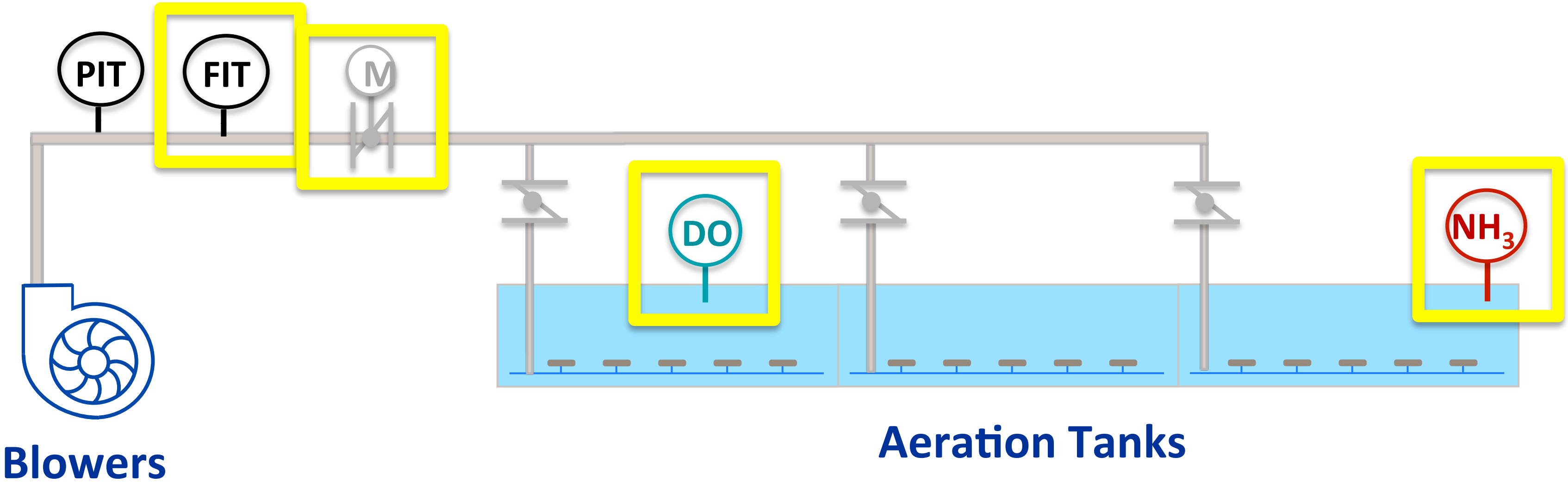
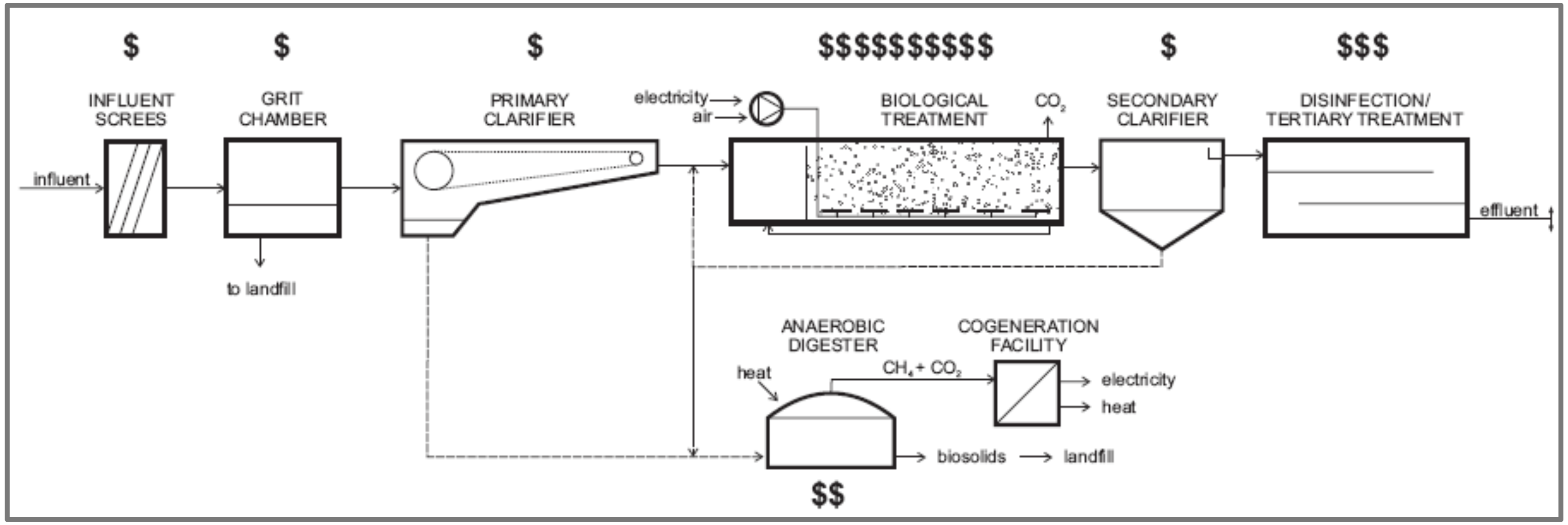
What is Advanced Aeration Control?

Use of <u>process sensors</u>, <u>automated control valves</u>, and <u>flow meters</u> to control blower output in an aeration system



Why Advanced Aeration Control?

- When permit limits dictate accurate control for optimal BNR operation
- When energy and other cost savings of advanced control can justify cost of control equipment



Source: Stenstrom and Rosso (2010) www.seas.ucla.edu/stenstro/Aeration.pdf

Outcomes from a Well-Designed Aeration Control System

1. Achieve process set point (DO typically) quickly and maintain set point under variable loading conditions

2. Maintain set points with as few actuator starts/stops as possible

3. Optimize energy use by minimizing air flow needed for process needs and by reducing pressure loss

Modulating Control Valve Comparison

Butterfly Valves (BFVs)

- The standard choice for MOV control in U.S.
- Not all BFVs are created equal….
- AWWA Type vs. High Performance Type

Diaphragm Control Valves

- <u>Iris Diaphragm Control Valve</u>
  - Six segments form central aperture, creating central flow axis
  - Hundreds of installations worldwide
  - 5 installations in the U.S.

Source: Egger Turo Pumps

- <u>Square Diaphragm Control Valve (SDCV)</u>
  - Sliding gate with square-shaped aperture
  - Falling flow axis
  - Installations worldwide dating back to early 2000s
  - 1 installation in the U.S.

Source: Binder Group

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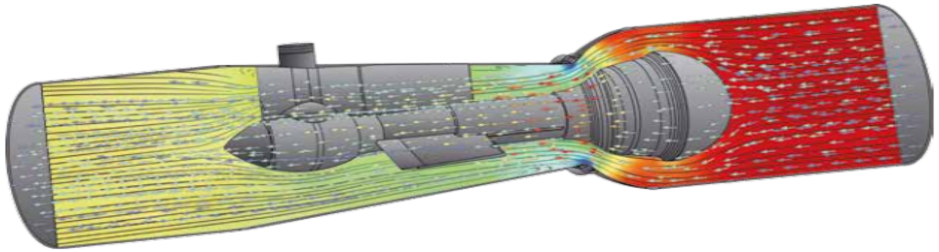
Jet Control Valves



Source: Binder Group

- Engineered for precise air flow control
  - Venturi-shaped valve body
  - Central control element (“bullet”) moves parallel to the flow
  - Annular orifice around control element

- 16 installations worldwide

- None installed to date in the U.S.

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Motor-Operated Actuators for MOV Applications

- Modulating duty = capable of up to 1,200 start/stops per hour
- Some valve manufacturers require a minimum positioning accuracy (±0.2%), which only some digital style actuators can achieve

Source: Rotork

Source: Limitorque

Source: Auma

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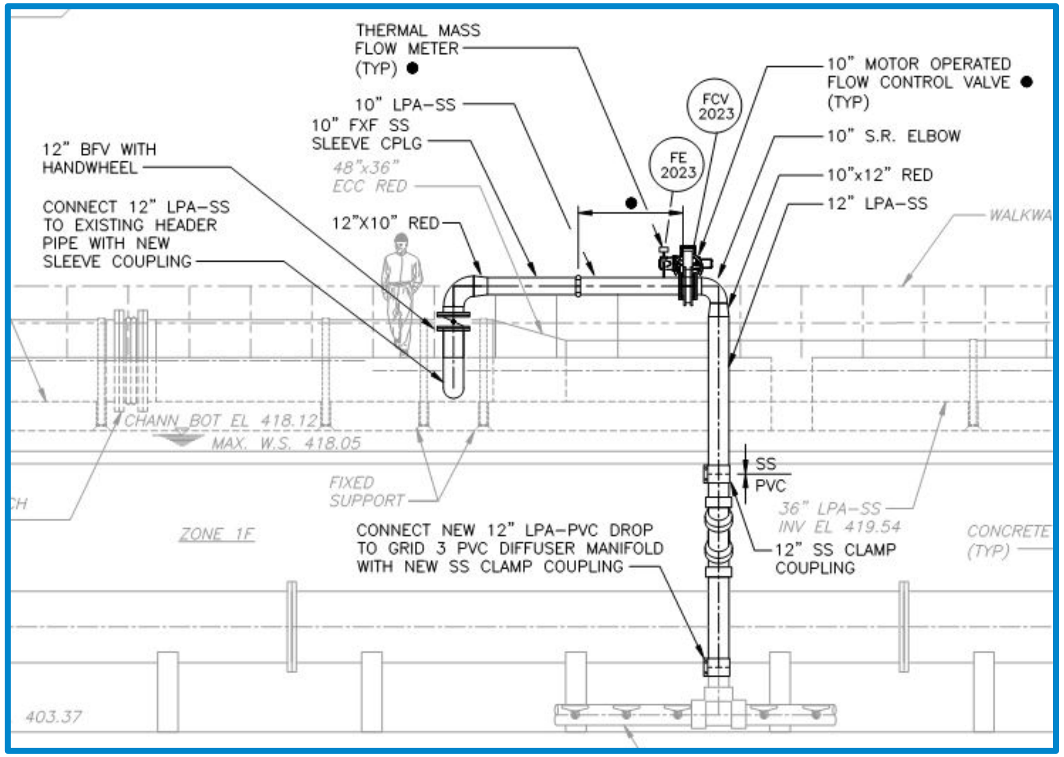
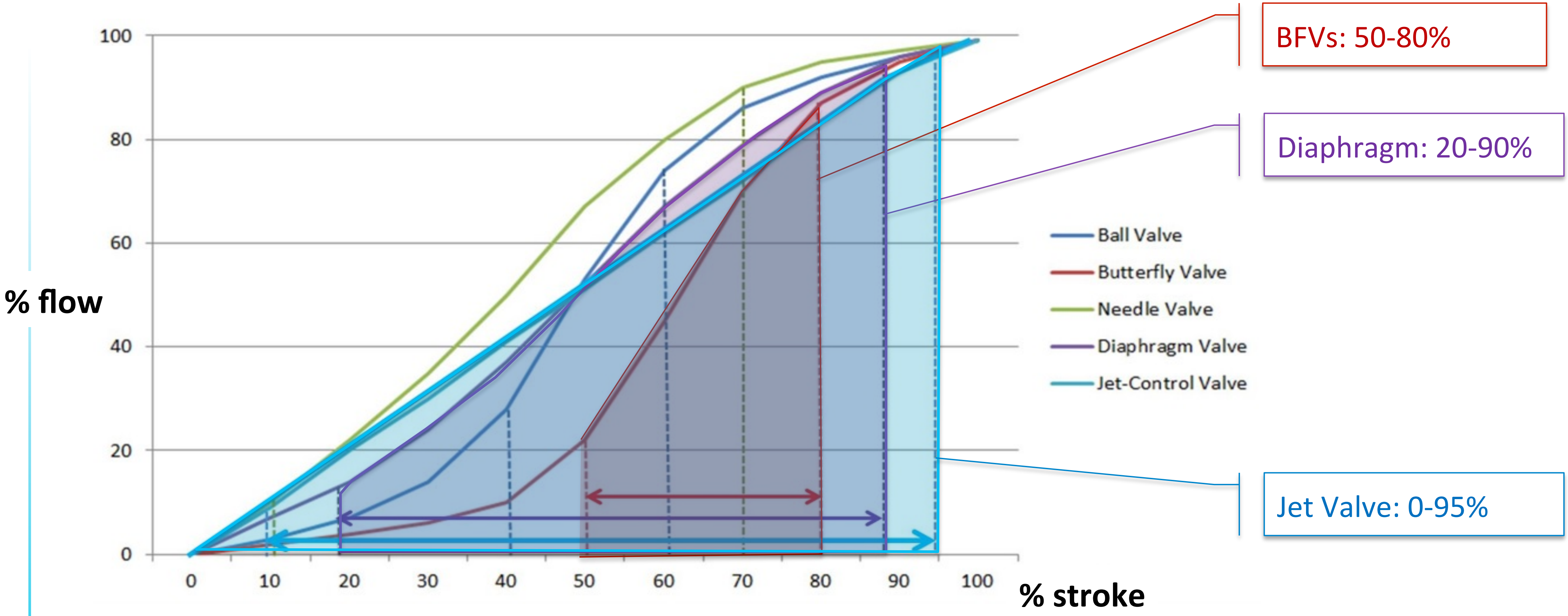
Factors to Consider for Valve Comparison

- Stable Range for Control
- Valve Size Selection + Flow Meter Installation
  - → Installed Cost
- Pressure Loss
  - → Operational Cost



Stable Range for Control



Source: The Binder Group

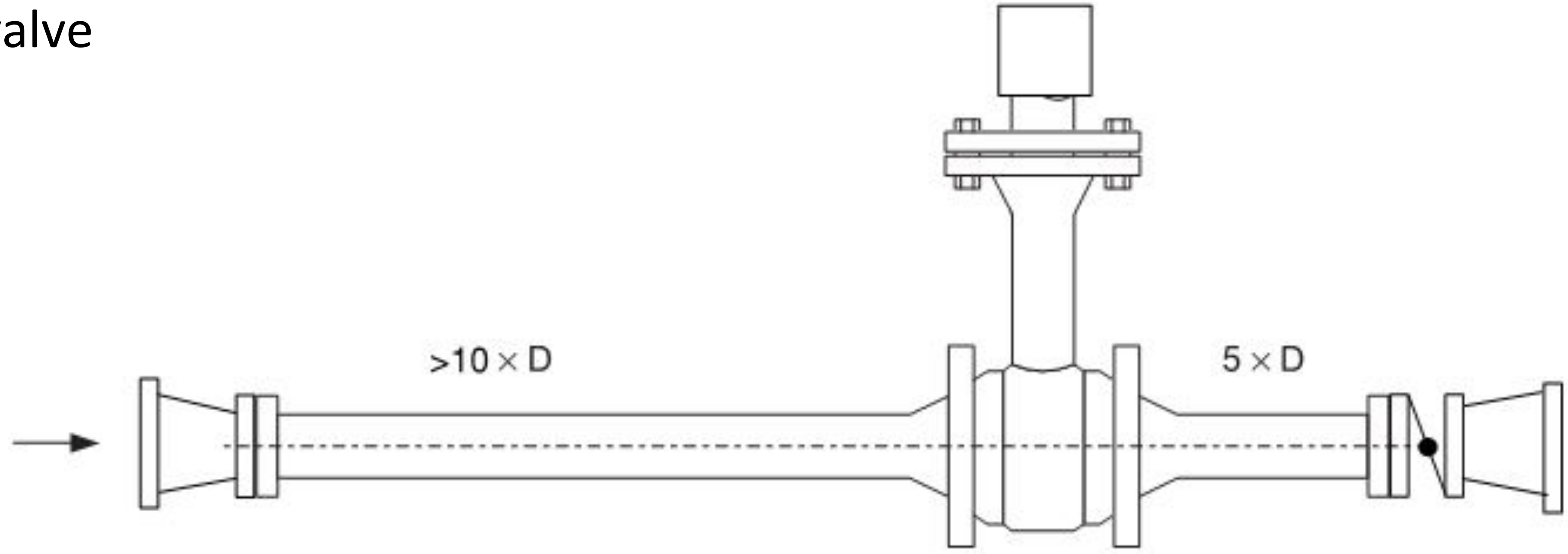
Valve Size Selections for Upper Blackstone Upgrade (28 Valves)

	Existing Pipe Size	DeZurik High Performance BFVs	Egger Iris Diaphragm Valves	Binder Square Diaphragm Valves	Binder Jet Control Valves
First Grid	**12-inch**	10-inch	10-inch	12-inch	12-inch
Middle 4 Grids	**8-inch**	5-inch	4-inch	6-inch	10-inch
Sixth Grid	**8-inch**	5-inch	5-inch	6-inch	10-inch
Seventh Grid	**8-inch**	5-inch	5-inch	8-inch	10-inch

Estimated Installed Cost: $1.3M $1.5M $1.7M $1.9M

Flow Meter Installation Requirements

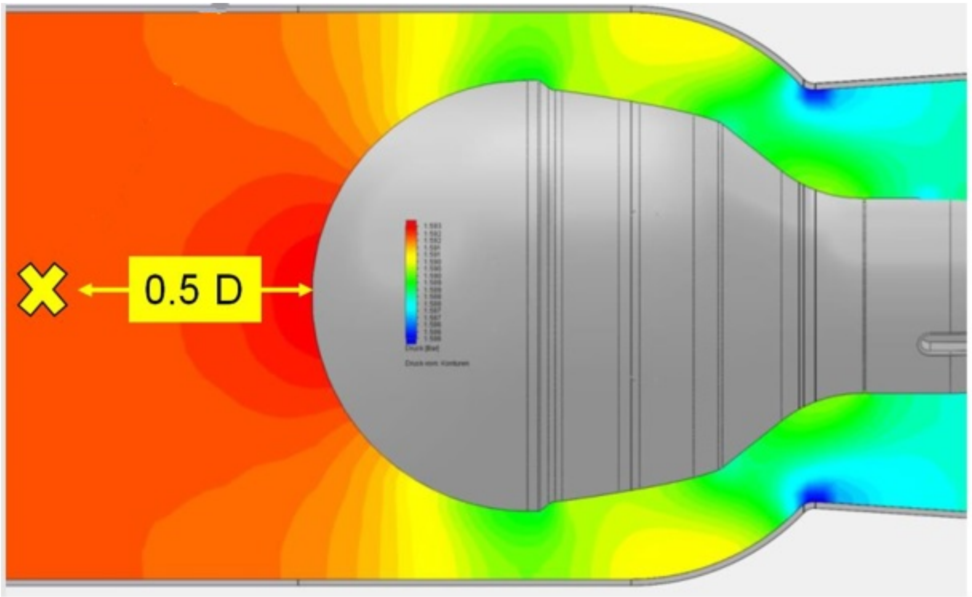
- Ideally…..
  - 10 straight pipe diameters upstream
  - 5 straight pipe diameters downstream before control valve



Flow Meter Installation Requirements

- Iris Diaphragm Valve
  - Can be installed only 1 pipe diameter downstream of thermal mass flow meter

- Jet Control Valve
  - Can be installed only 0.5 pipe diameter downstream of thermal mass flow meter



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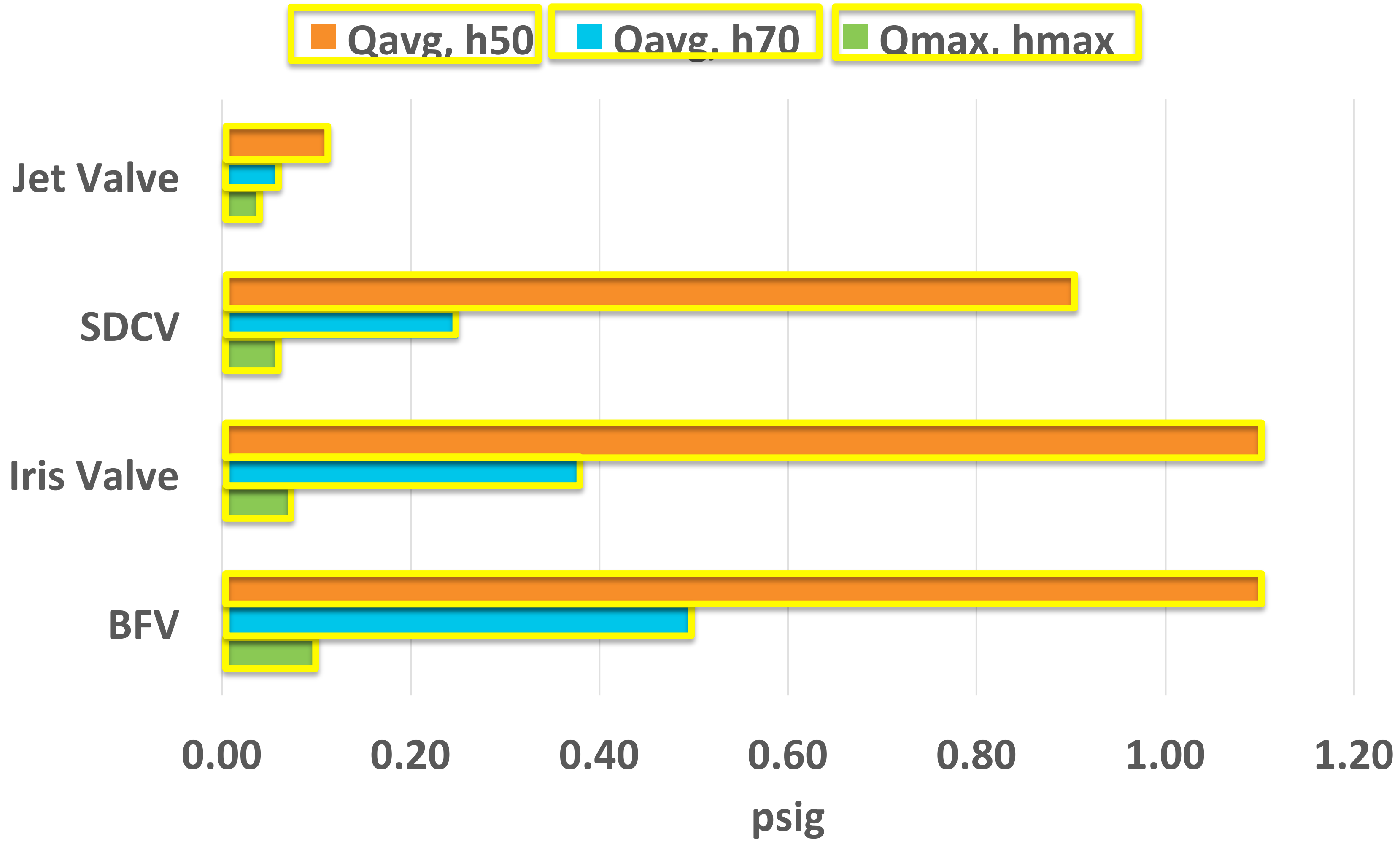
Pressure Loss Comparison at Various Valve Strokes



Est. Annual Cost Savings:

$34,000	$47,000	$87,000
$34,000	$34,000	$31,000
$26,000	$17,000	$9,000
$16,000	$8,000	$9,000

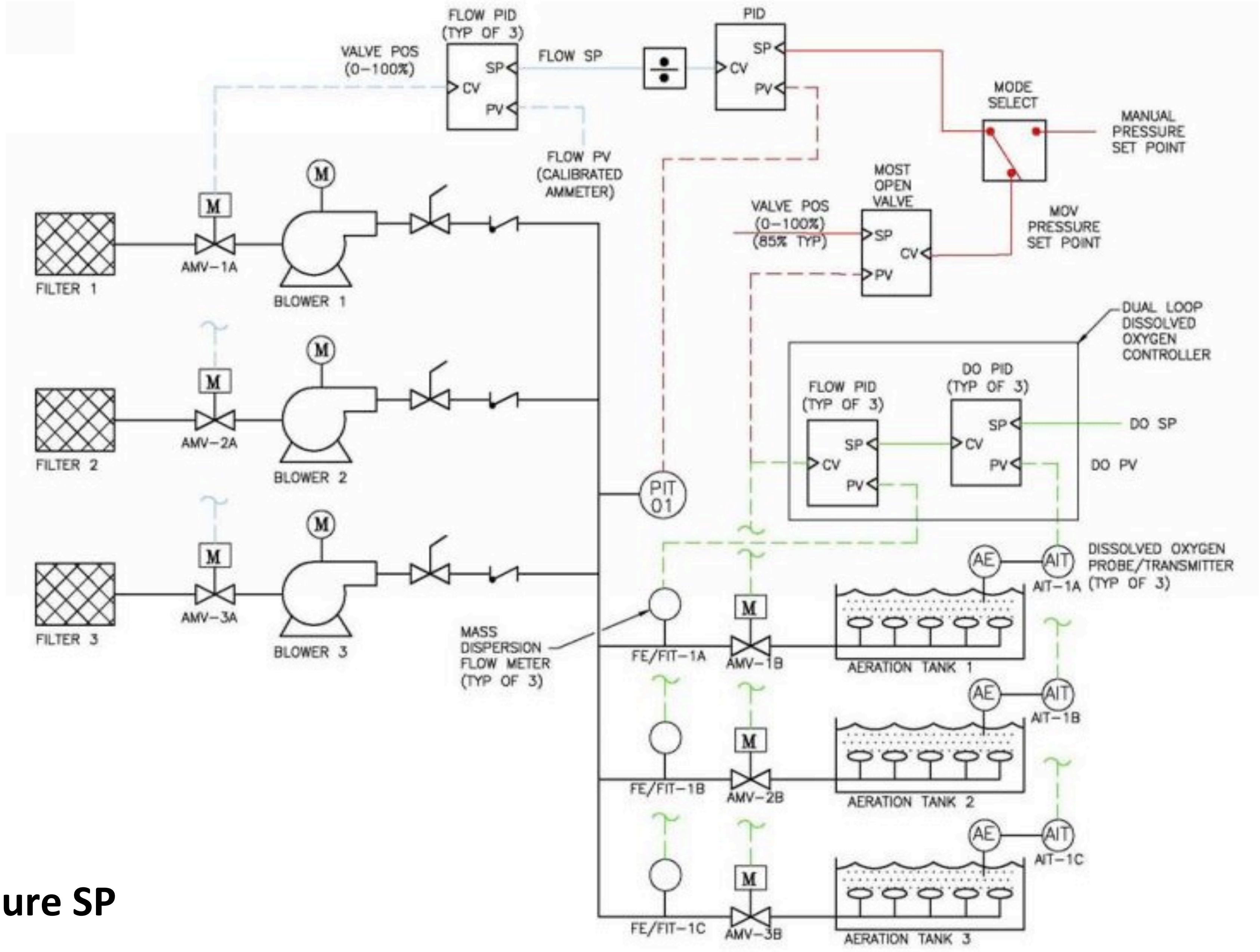
Most Open Valve Control Strategies for DO Control

Pressure-based MOV Control with DO PID Loops

1. **DO PID**
   →air flow SP

2. **Flow/valve PID**
   → valve position SP

3. **Blower pressure PID**
   → blower modulates to meet floating pressure SP



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Disadvantages of PID Loops

P = Proportional Term

Points system in the right direction to meet DO set point, assuming airflow is linearly related to DO concentration

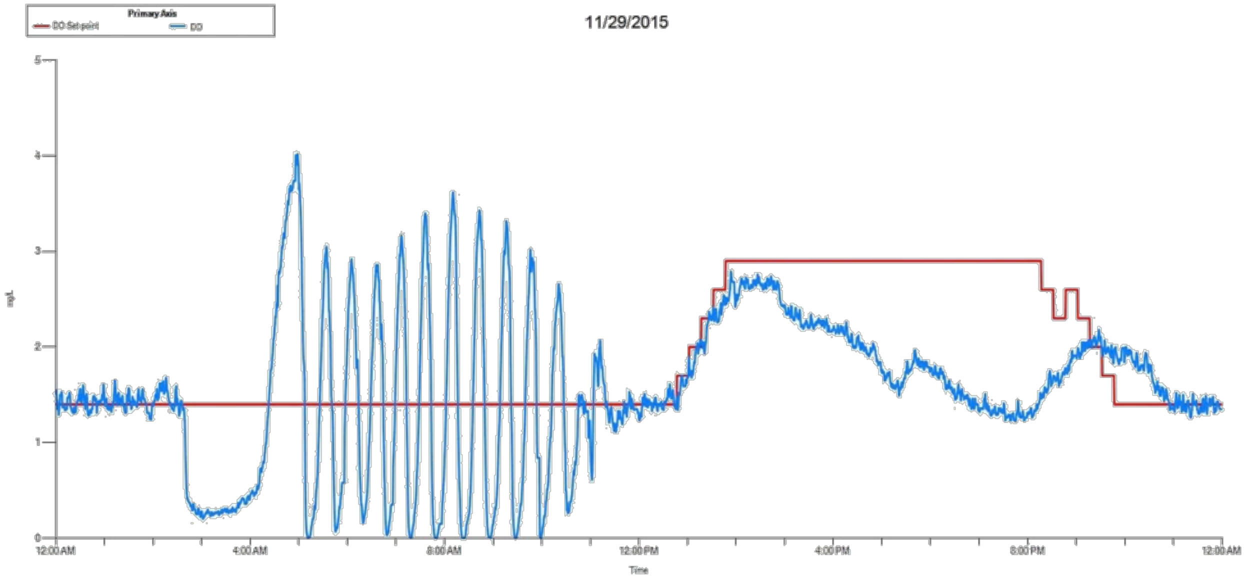
I = Integral Term

Forces system to balance time over versus under set point

D = Derivative Term

Applies some friction to the response, but in many cases not used

COMMON RESULTS:
→ Oscillation around set point
→ Poor response to diurnal range
→ Seasonal re-tuning needed



Source:
BioChem Technology

Flow-based MOV Strategies that Don't Use PIDs

Floating DO Control

- Uses a proprietary, nonlinear alternative to PID loops for valve and air flow control
- Operator-adjustable "response delays" to minimize oscillations

Predictive DO Control

- DO and valve control based on a wastewater process algorithm
- Calculates air flow based on real-time oxygen uptake rates (OUR)

Generally the blowers are also modulated to target air FLOW set point, although PRESSURE control could be used

Ammonia-Based Aeration Control (ABAC)

Ammonia Instrument Types

Type	Ion Selective Electrode Probes	Wet Chemistry Analyzers
Range	Nominally 0 – 1,000 mg/L N Typ calibrated around 1 – 20 mg/L N	Nominally 0.02 – 1,000 mg/L N Typ calibrated around 0.05 – 20 mg/L N
Accuracy	± 5% of mV signal + 0.2 mg/L	± 3% + 0.05 mg/L

Source: Upper Blackstone

Source: Hach Company

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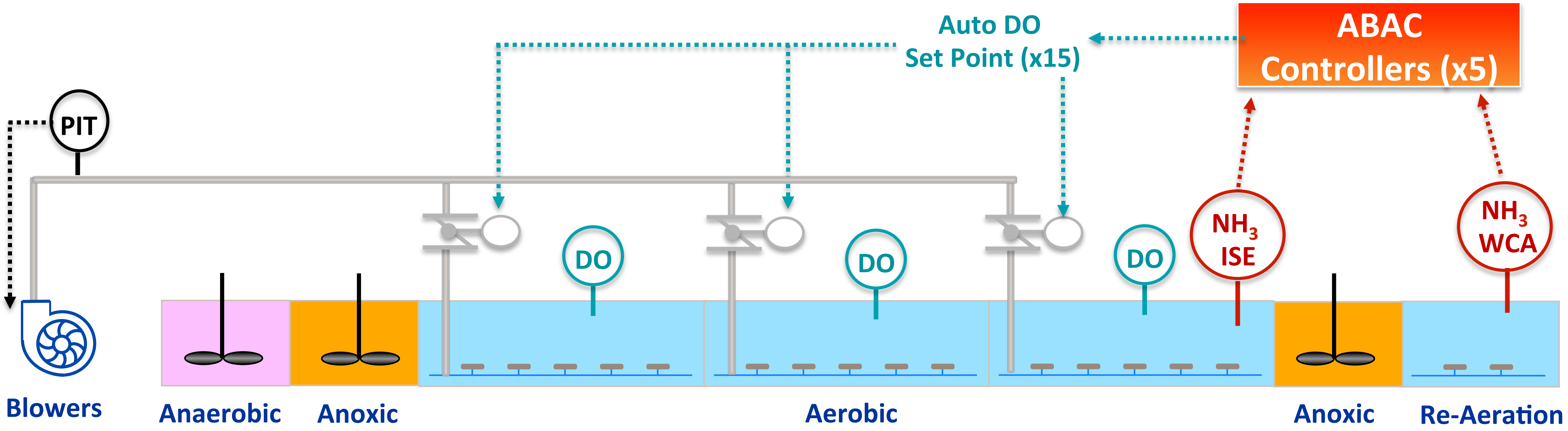
Ammonia Instruments for ABAC: Lessons Learned

	Ion Selective Electrode Probes	Wet Chemistry Analyzers
Low Ammonia	Often struggles in low ammonia environments (< 1 mg/L NH_4-N)	Better choice for locations with < 1 mg/L NH_4-N
Location	Most common in first half of tank (anaerobic/anoxic or head of aerobic) Mixed success for primary effluent (due to grease)	Most common at end of aerobic zone, secondary effluent, final effluent Mixed success in upstream locations (small tubing turns black)
Accuracy Checks	Require frequent accuracy checks and re-calibration	Accuracy checks recommended to identify when maintenance required on tubing or flow cells
O&M	Replacement cartridge heads can be costly if required multiple times/year	Reagent cost can be reduced by increasing time interval (balanced with process control needs)

ABAC Example 1: Nansemond WRRF (114 ML/d 5-stg Bardenpho) Suffolk, VA

ABAC Control Scheme	Ammonia Set Point	Ammonia Result
Ammonia PID controllers output Auto DO set points for each control zone	@ effluent = 3.5 mg/L	Typically 2.8 – 4.0 mg/L

- → 12% reduced energy
- → 47% reduced supplemental carbon
- → Reduced supplemental ammonia for chloramination



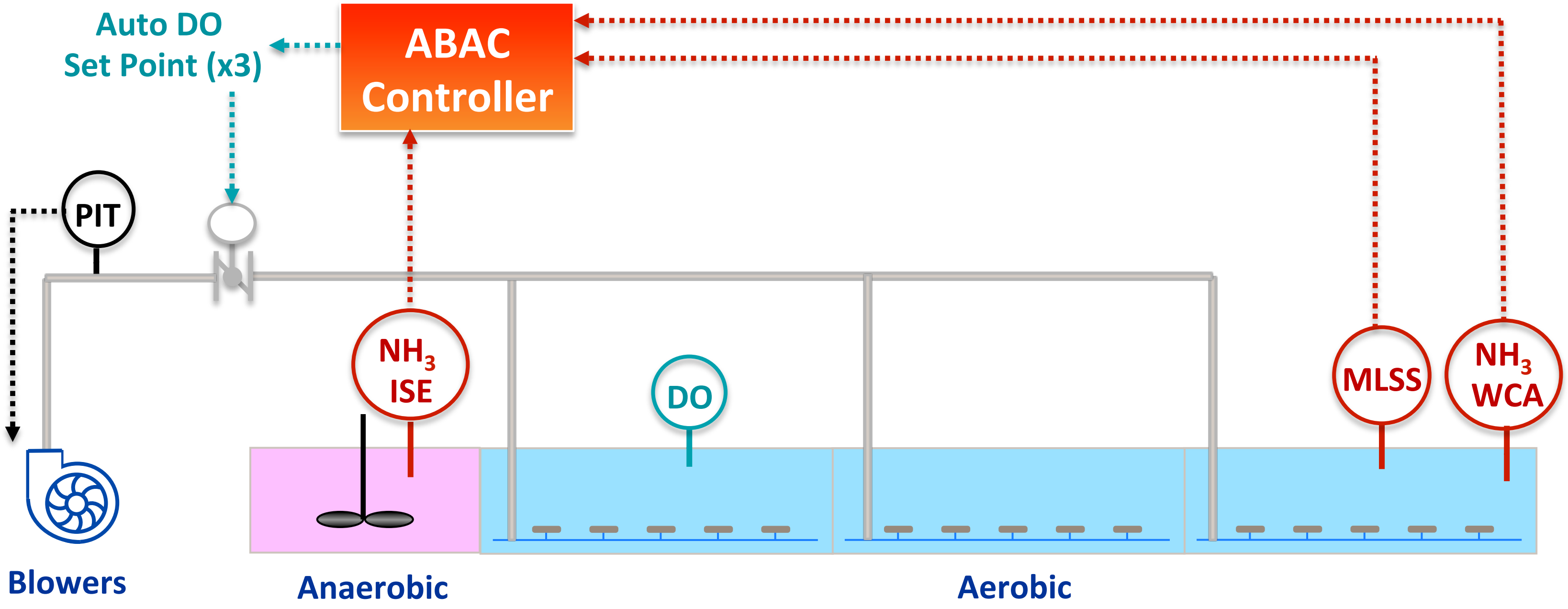
For more reading: Uprety et al, WEFTEC 2015

ABAC Example 2:

South Plant (87 ML/d A/O) Grand Rapids, MI

Control Scheme	Ammonia Set Point	Ammonia Result
Proprietary controller outputs Auto DO set point for each train	@ effluent = 4-5 mg/L	<1 mg/L due to blower turndown limitations

→ 15% reduced energy



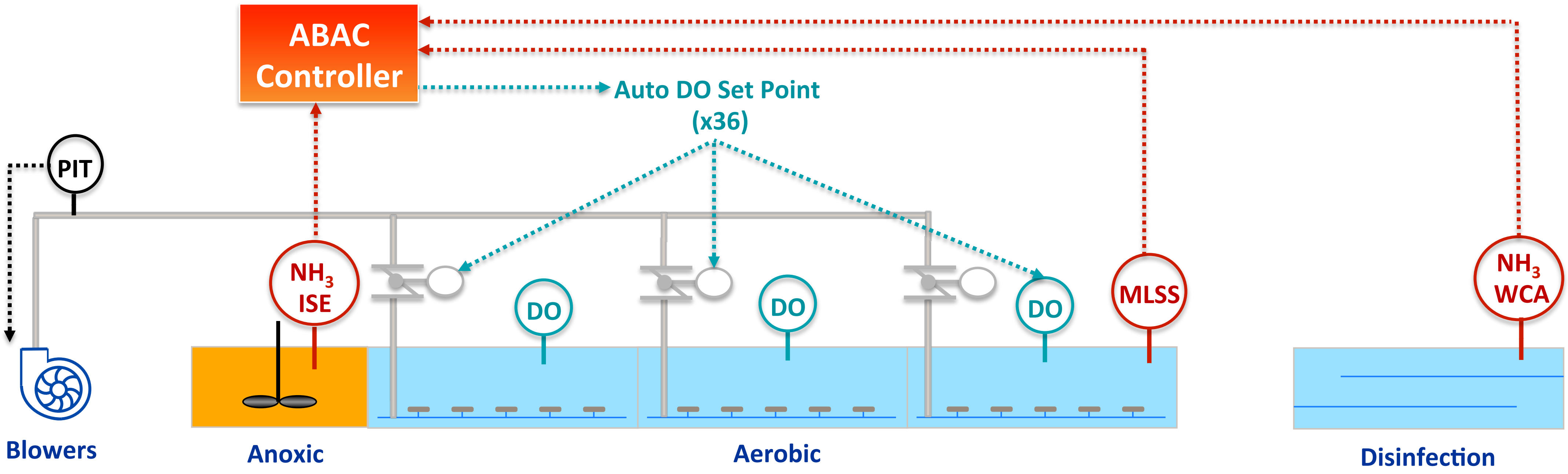
For more reading: Lunn et al, WEFTEC 2014

ABAC Ex 3: Robert W. Hite Treatment Facility (300 ML/d MLE)

Denver, CO

Control Scheme	Ammonia Set Point	Ammonia Result
Proprietary controller outputs Auto DO Set Point for each dropleg	@ effluent: 1.0 – 1.5 mg/L	~ 1 mg/L

→ 13% reduced energy

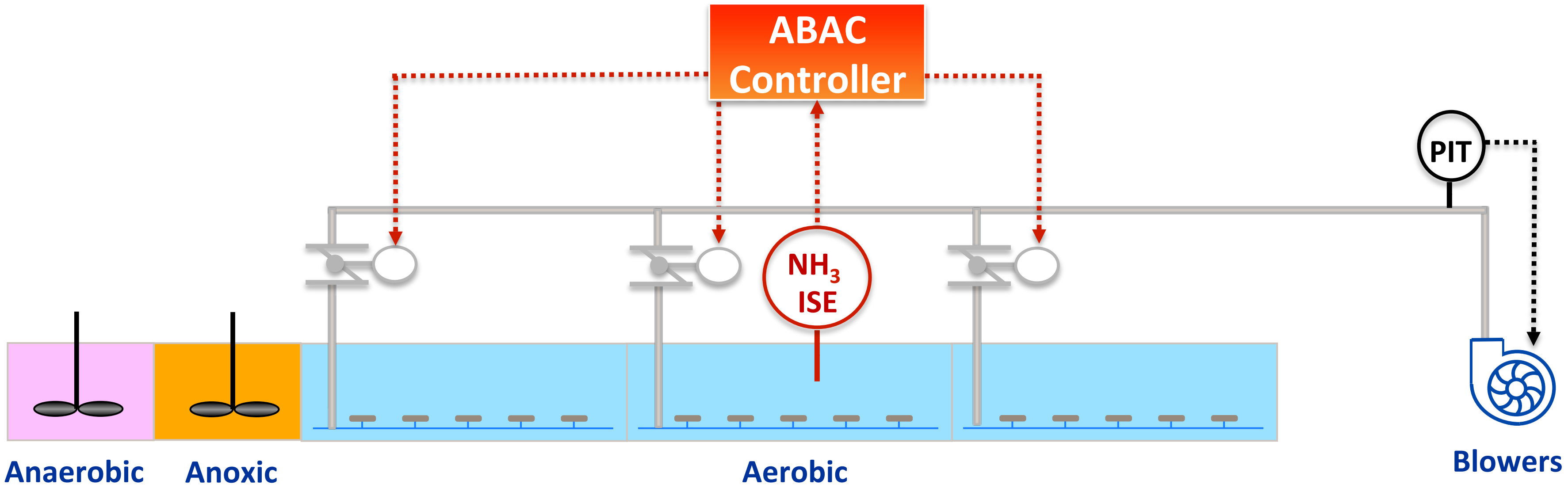


For more reading: Gray et al, WEFTEC 2012

ABAC Example 4: J.D. Phillips WRF (75 ML/d A^2/O) Colorado Springs, CO

Control Scheme	Ammonia Set Point	Effluent Ammonia
Ammonia controller directly modifies valve position (no DO control loops)	@ second aerobic grid: 3-4 mg/L	~ 1 mg/L during the daytime

- → 20% reduced energy
- → Improved detection of nitrification upsets
- → Lower shear on biofloc



For more reading: Lagrange et al, WEF Energy and Water Conference 2011

Conclusions

Recommendations for Designers and Operators

1. Define the desired outcomes (COST SAVINGS, TIGHTER PROCESS CONTROL)

2. Carefully define design criteria for valves and actuators

3. Pilot process sensors on a trial basis

4. Partner with experienced blower manufacturers and/or integrators who can deliver:
   - Tight control that maintains set points with minimal wear and tear on equipment
   - High level of service over time

Contact us!

Maureen Neville
CDM Smith
617-452-6292
NevilleMD@cdmsmith.com

Alex Doody
CDM Smith
512-652-5324
DoodyAT@cdmsmith.com

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