Metropolitan Water Reclamation District of Greater Chicago

WELCOME

TO THE MAY EDITION

OF THE 2019

M&R SEMINAR SERIES

BEFORE WE BEGIN

- SAFETY PRECAUTIONS
  - PLEASE FOLLOW EXIT SIGN IN CASE OF EMERGENCY EVACUATION
  - AUTOMATED EXTERNAL DEFIBRILLATOR (AED) LOCATED OUTSIDE
- PLEASE SILENCE CELL PHONES OR SMART PHONES
- QUESTION AND ANSWER SESSION WILL FOLLOW PRESENTATION
- PLEASE FILL EVALUATION FORM
- SEMINAR SLIDES WILL BE POSTED ON MWRD WEBSITE (www. MWRD.org: Home Page ⇒ Reports ⇒ M&R Data and Reports ⇒ M&R Seminar Series ⇒ 2019 Seminar Series)
- STREAM VIDEO WILL BE AVAILABLE ON MWRD WEBSITE (www.MWRD.org: Home Page ⇒ MWRDGC RSS Feeds)

Wendy Anderson, P.E.

Ms. Wendy Anderson is a Professional Engineer in the State of Colorado with a B.S. & M.S. in Civil Engineering from Colorado State University in Fort Collins.

Wendy is currently a Senior Engineer at Metro Wastewater Reclamation District in Denver advising the Operations Director and Superintendent on wastewater process unit operations at a 140 MGD wastewater treatment plant. Wendy oversees a 6 MW combined heat and power generation facility and is a project manager of energy-related projects.

Wendy is a Class A Wastewater Operator in Colorado and a Certified Energy Manager.

Taking Ammonia-Based Aeration Control to the Next Level

Real World Experience and Lessons Learned

METRO WASTEWATER RECLAMATION DISTRICT

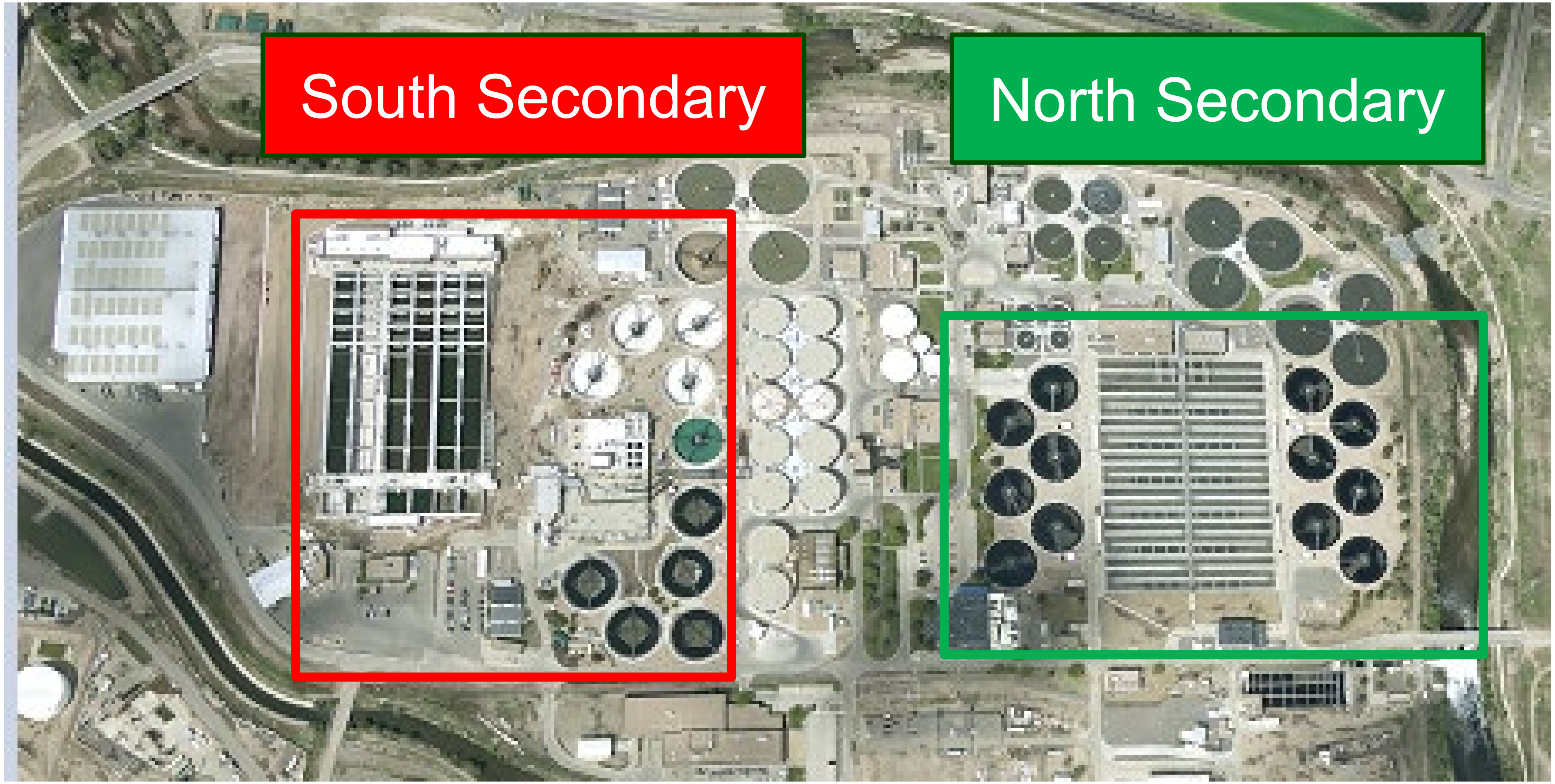
Robert W. Hite Facility
Denver, Colorado

Agenda

1) MWRD - Denver
2) Ammonia-based aeration control at MWRD-Denver
3) Feedback control system testing
4) Comparison of feed-forward versus feedback controls
5) Control system selection
6) Relate this to Stickney's ABAC system?

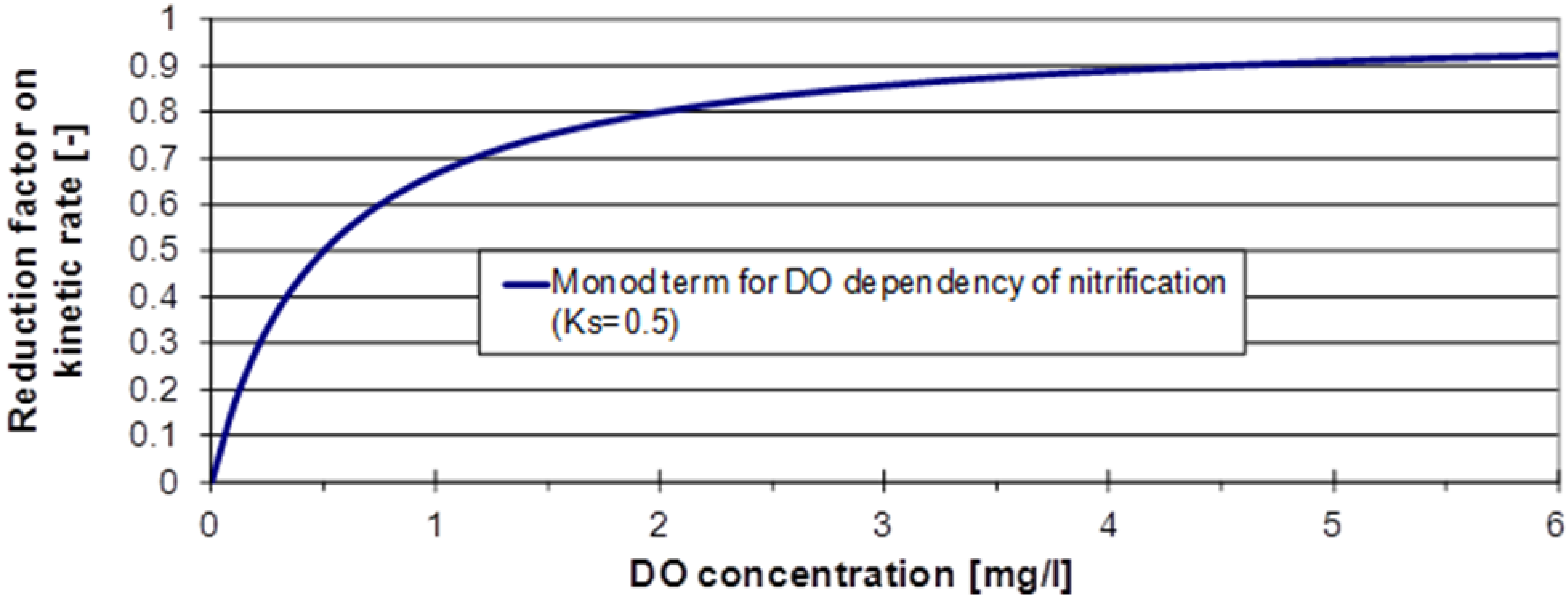
Robert W. Hite Treatment Facility

Two Secondary Treatment Areas



Why ammonia-based aeration control (ABAC)?

- Reducing energy consumption



Testing and Application of ABAC

Pilot-testing two feedback systems

*1) **Direct** ABAC*
*2) **Cascade** ABAC*

Later:

Full-scale use of two aeration control systems:

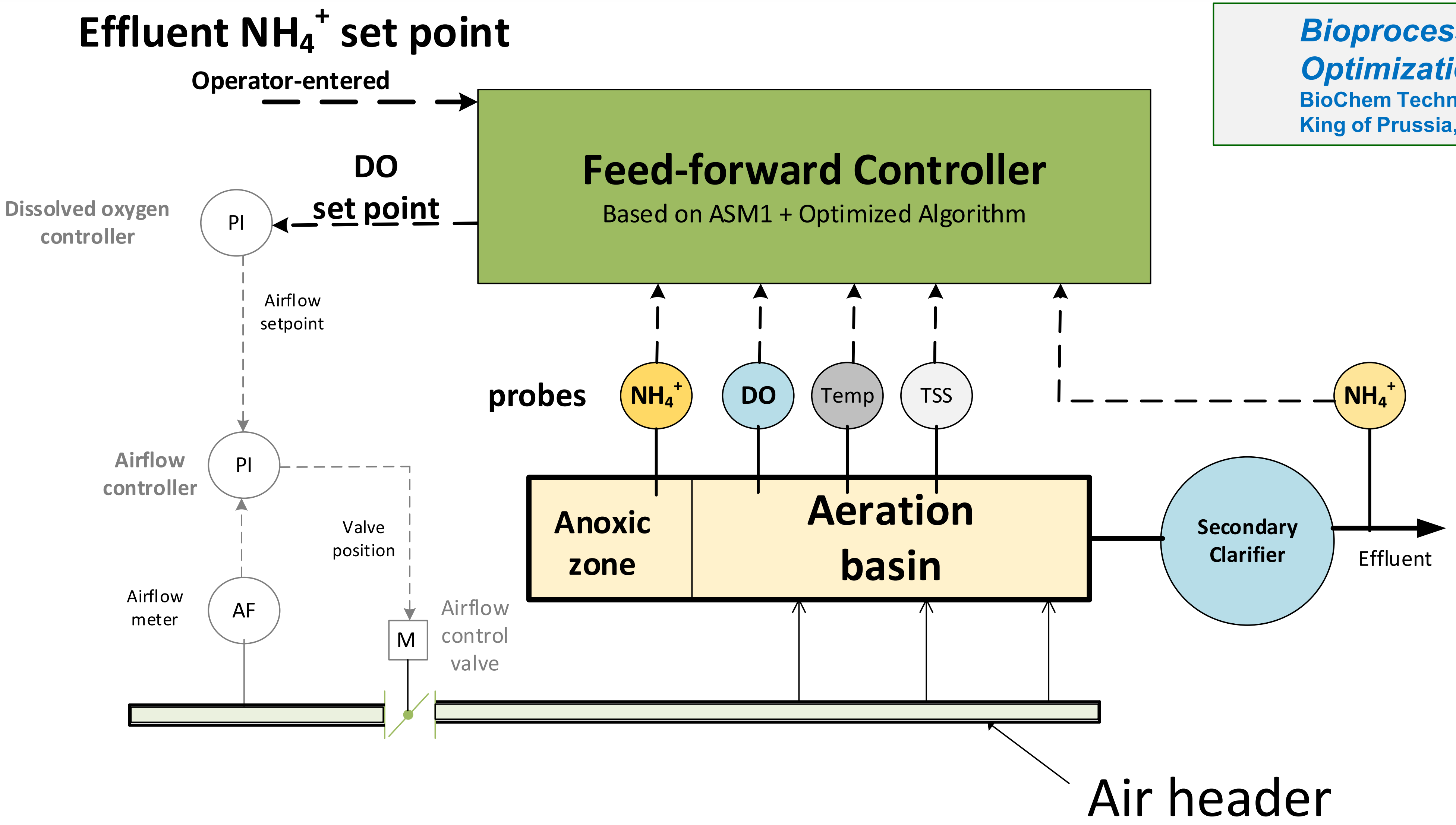
*1) **Cascade** (feedback) ABAC*
*2) **Feed-forward** ABAC*

A Little Background

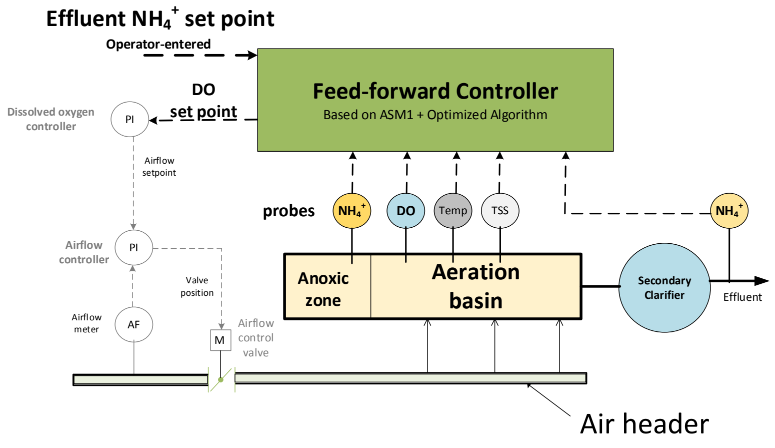
What's the difference between feed-forward and feedback ammonia-based aeration control?

Feed-forward ABAC (BIOS™) – North Secondary

Bioprocess Intelligent Optimization System (BIOS™),
BioChem Technology, Incorporated, King of Prussia, PA



Feed-forward ABAC (ASM1) – North Secondary



Ammonia removal rate, $\left(\frac{\frac{mg}{L}NH_3}{hr * g_{MLSS}}\right)$=

$$-\left(f_{NH}+\frac{1}{Y_A}\right)\mu_A\cdot\frac{S_{NH}}{K_{NH}+S_{NH}}\cdot\frac{S_{DO}}{K_{DO_A}+S_{DO}}\cdot X_A+k_a\cdot S_{ND}\cdot X_H-f_{NH}\cdot\mu_H\cdot\frac{S_S}{K_S+S_S}\cdot\frac{S_{DO}}{K_{DO_H}+S_{DO}}\cdot X_H$$

Autotrophic Uptake | Nitrification | Ammonification | Heterotrophic Uptake

$$-\left(f_{NH}+\frac{1}{Y_A}\right)\mu_A\cdot\frac{S_{NH}}{K_{NH}+S_{NH}}\cdot\frac{S_{DO}}{K_{DO_A}+S_{DO}}\cdot X_A+k_a\cdot S_{ND}\cdot X_H-f_{NH}\cdot\mu_H\cdot\frac{S_S}{K_S+S_S}\cdot\frac{S_{DO}}{K_{DO_H}+S_{DO}}\cdot X_H$$

Insignificant | Modified to use measurable variables | Incorporated into measured NH_4 adjustment

$$SARR\cdot\frac{S_{NH}}{K_{NH}+S_{NH}}\cdot\frac{S_{DO}}{K_{DO_A}+S_{DO}}\cdot X_{MLSS}$$

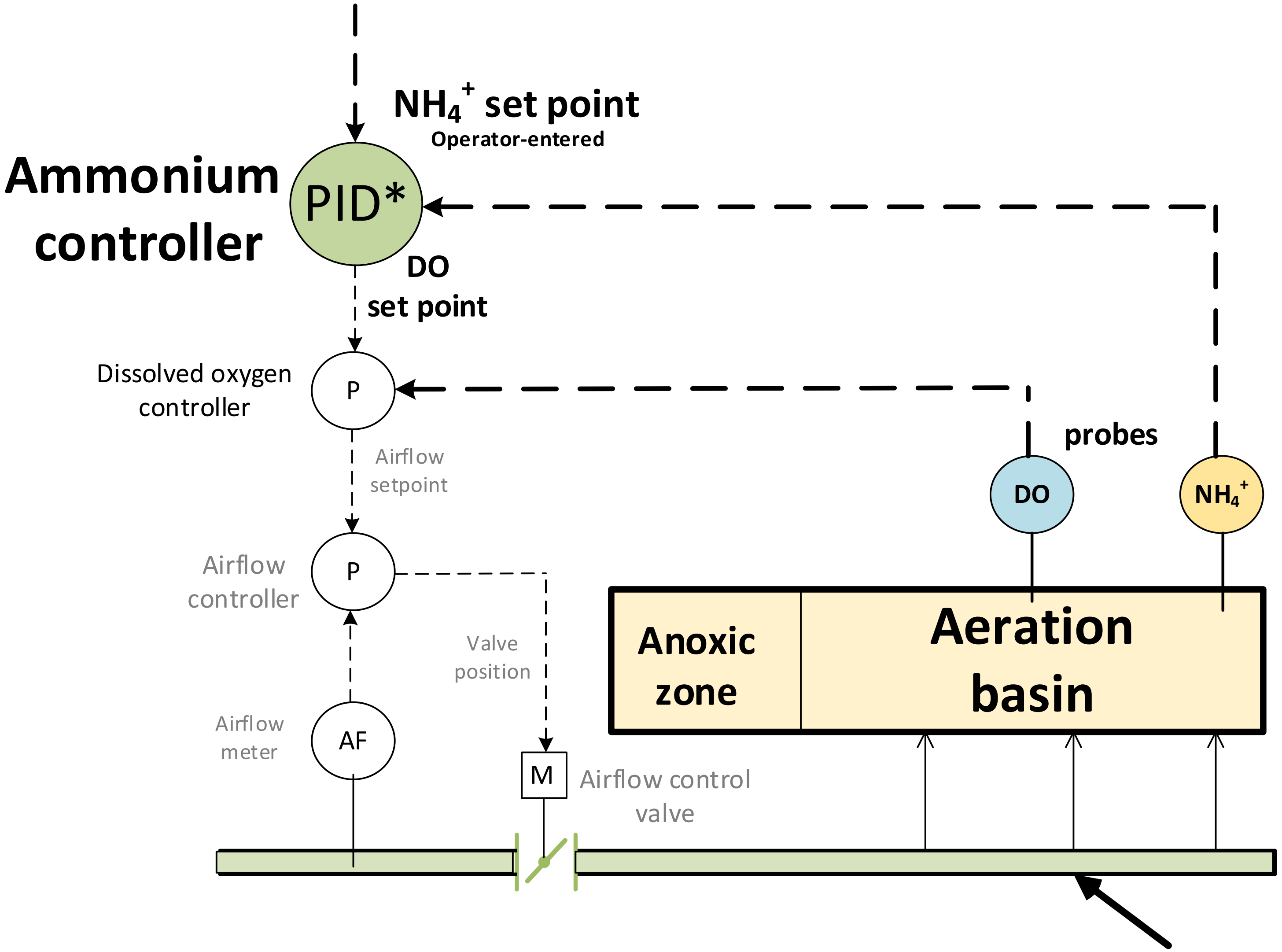
Specific Ammonia Removal Rate (mg NH4 removed per g of TSS)

Mixed Liquor Suspended Solids (g of TSS)

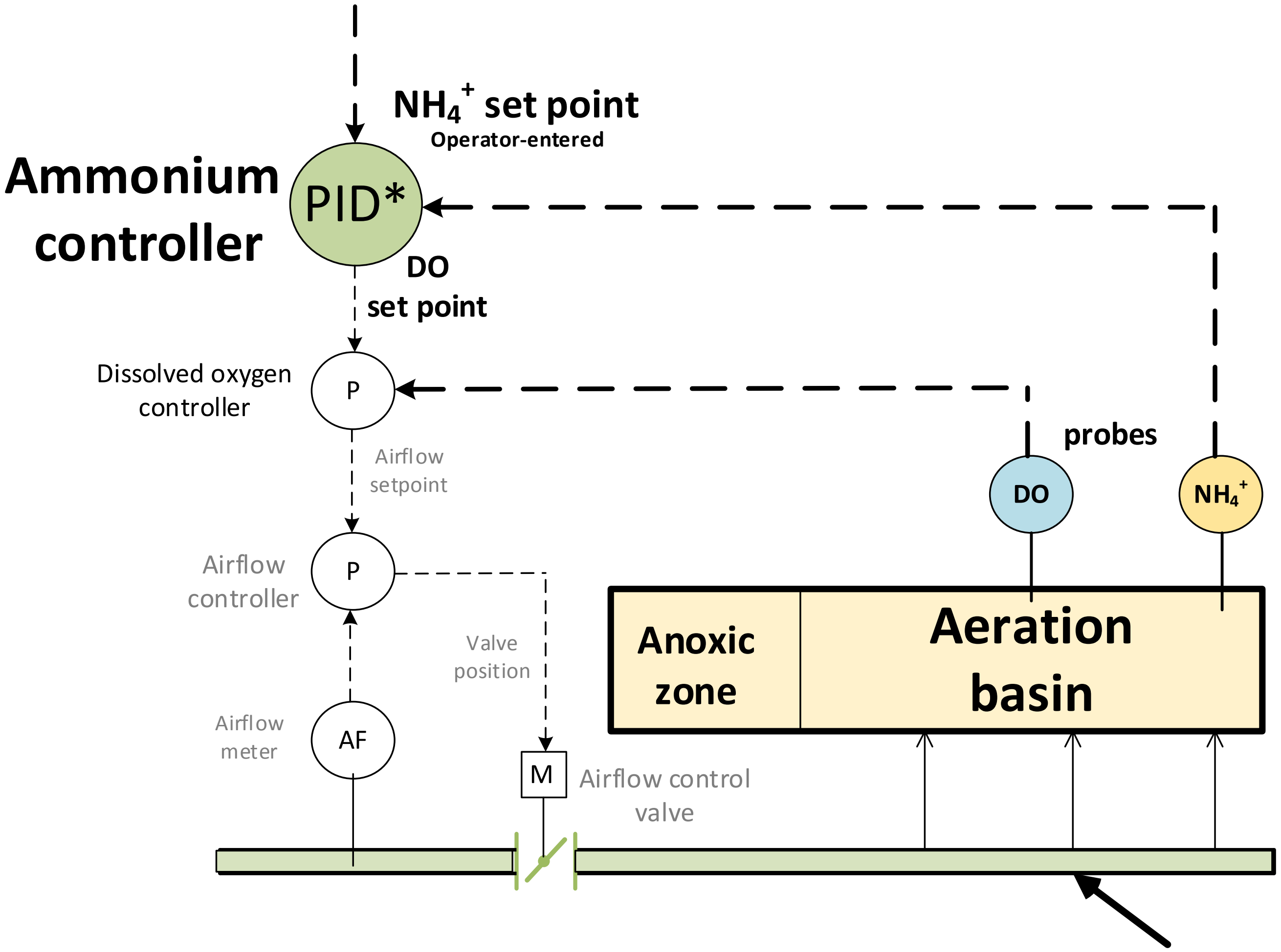
Drawbacks

1) Complicated (?)
2) Proprietary
3) Needs lots of analyzers/probes

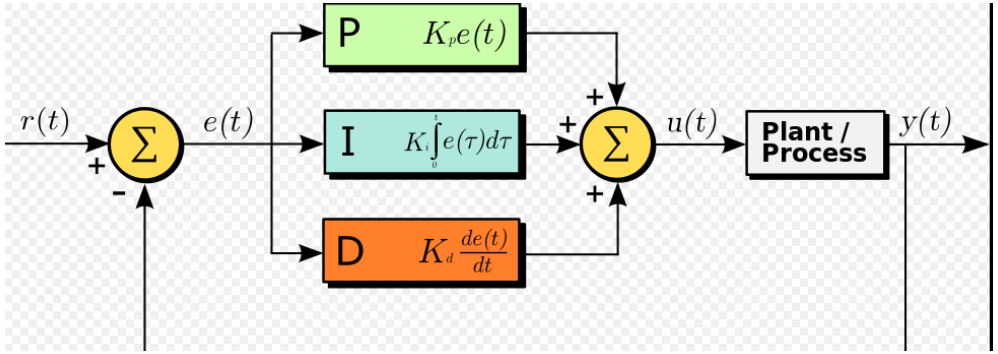
Feedback (PID) ABAC – South Secondary



Feedback ABAC (PID) – South Secondary



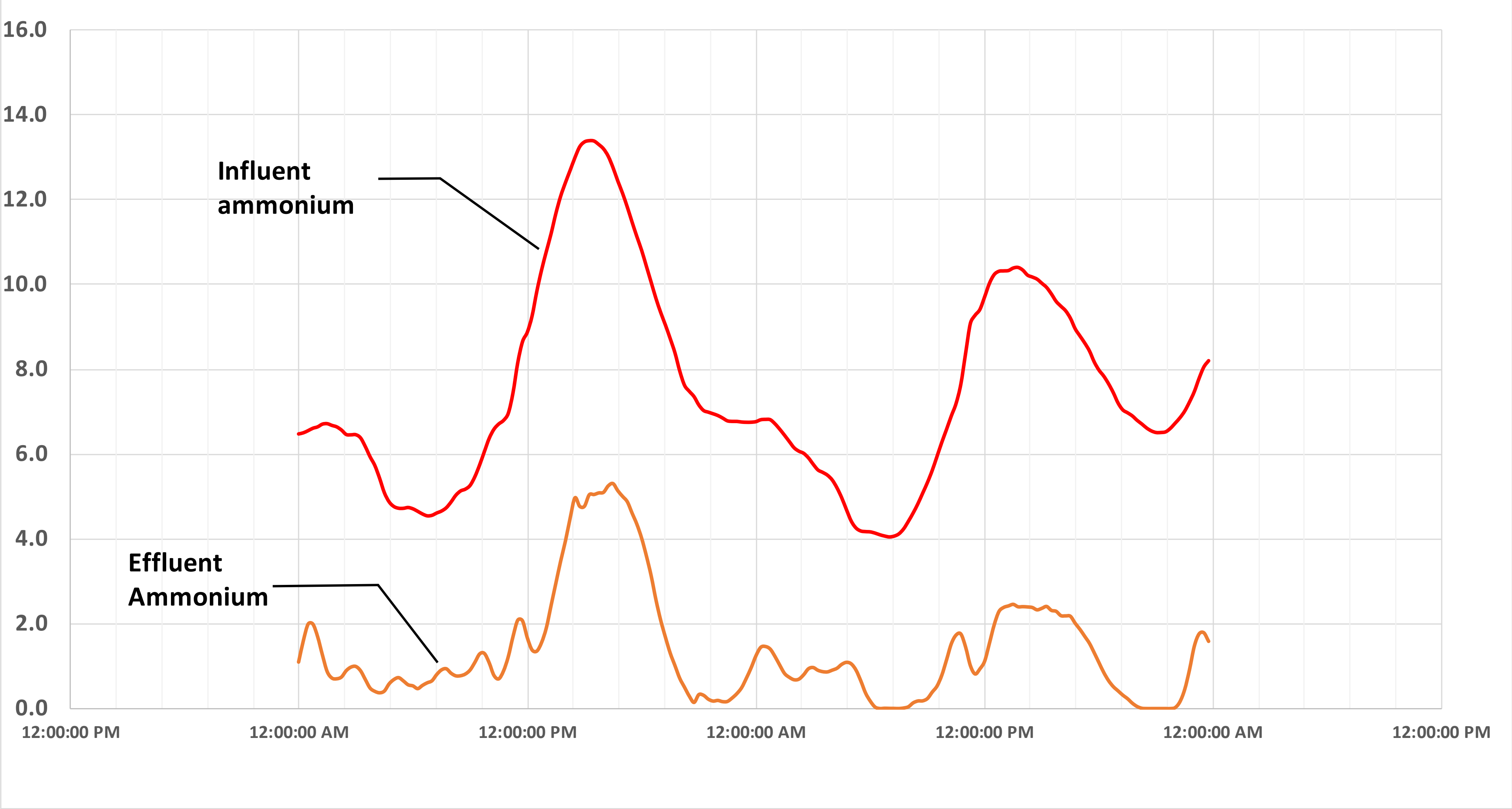
$$u(t) = K_{\mathrm{p}} e(t) + K_{\mathrm{i}} \int_0^t e(t')\,dt' + K_{\mathrm{d}} \frac{de(t)}{dt},$$



Drawbacks

1) Complicated (?)
2) Reactive/time lag
3) Oscillations
4) Seasonal adjustments

MWRD Denver - Ammonia Loading Profile



Testing of Feedback ABAC

<u>Pilot-testing two feedback systems</u>

1) ***Direct*** *ABAC*

2) ***Cascade*** *ABAC*

Goals for PID ABAC Demonstration Test

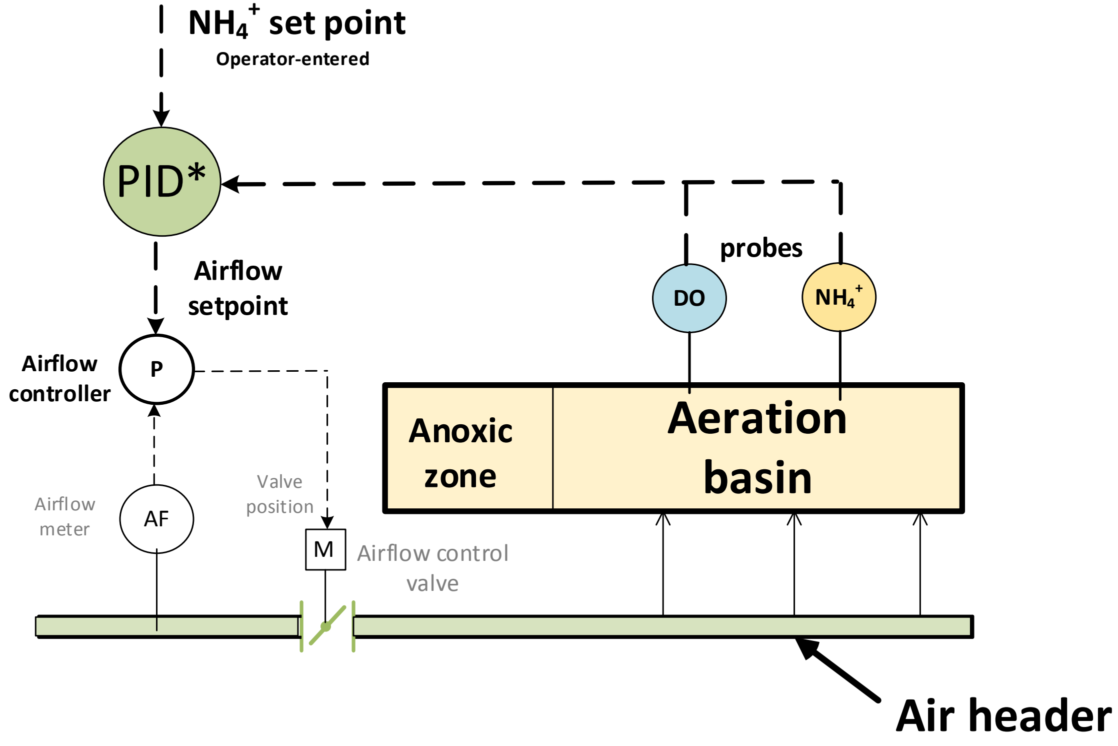
- Implementable by District staff
- No reduction in nitrogen removal efficiency (at as good as DO control)
- Reduce power consumption

Feedback (Direct) ABAC

NH_4 set point → ~~DO set point~~ → Airflow set point → Valve Position

Features:

- Simple – control airflow directly from ammonia measurement
- Has been applied successfully at a number of facilities.
- Limits on DO and airflow can be applied in the logic.
- Improved energy efficiency over DO control

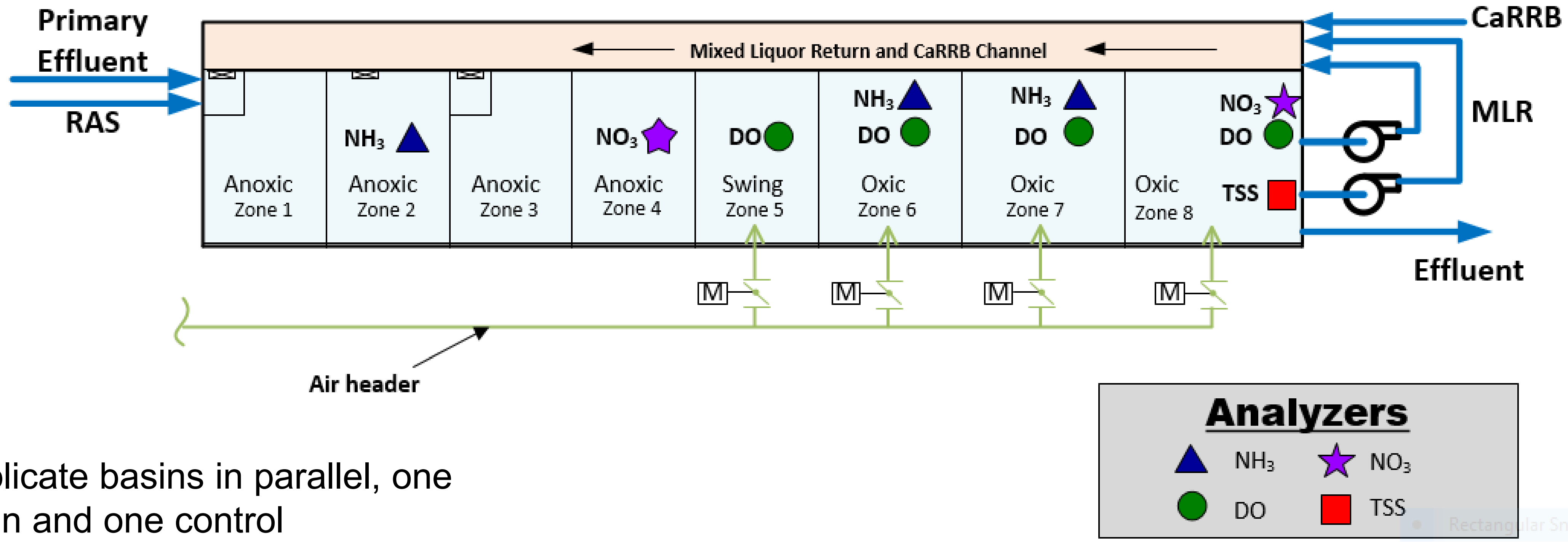


*Proportional integral derivative

Direct ABAC Instrumentation

South Secondary

6 Parallel Basins – Modified Ludzack Ettinger process



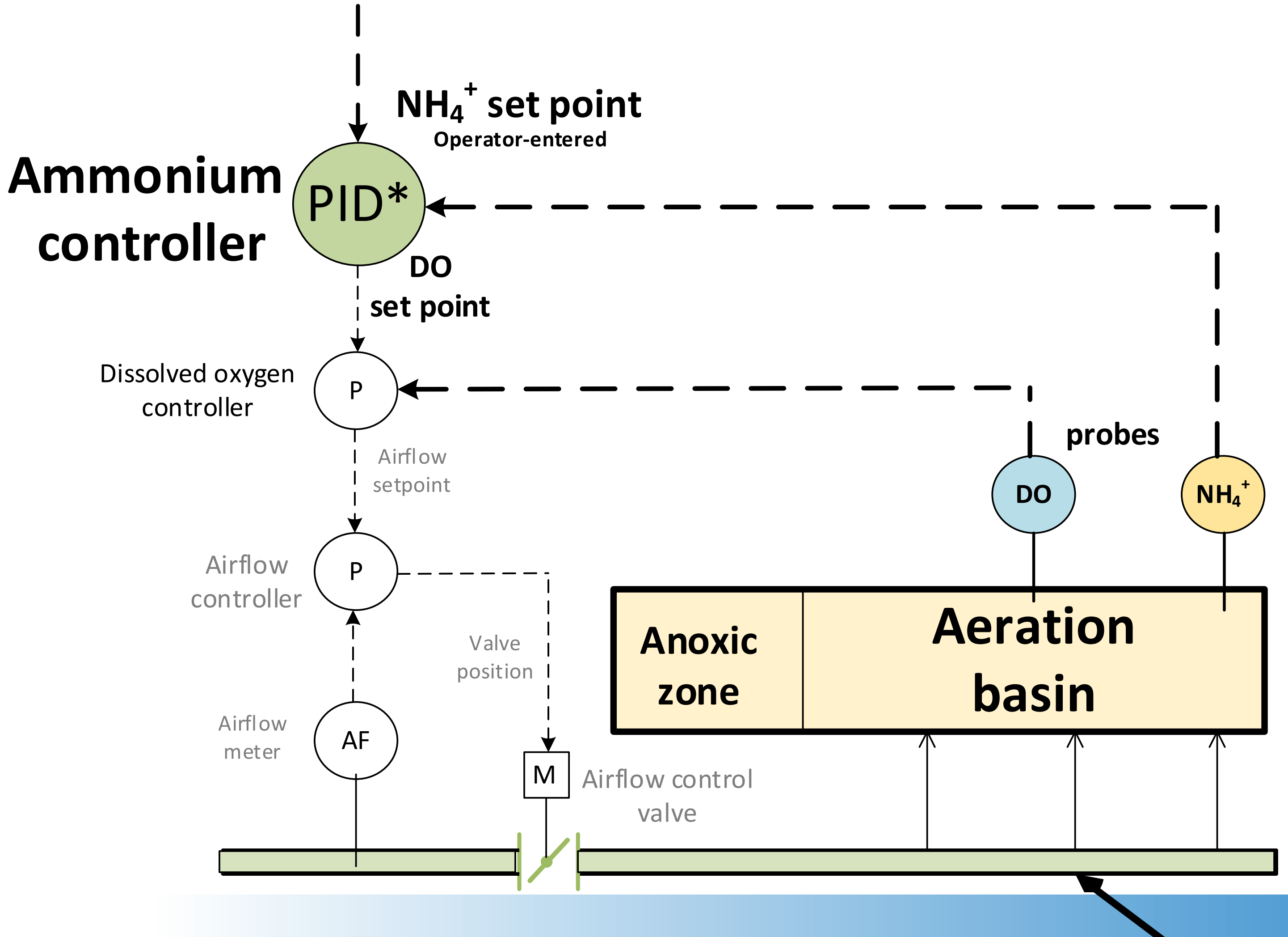
Two duplicate basins in parallel, one test basin and one control

Results from Direct Control

- Testing period – 3 months
- Average 10% decrease in airflow compared with DO control
- Too much oscillation/instability – DO would vary too rapidly
  - Rise and fall to undesirable levels
  - Control valves moving frequently
  - Preferred to have slower ammonia control manipulate the set point of the faster DO control (cascade control)
    - Simplifies control system tuning
  - No fail safe condition if the controller or analyzer fails – difficult to establish

Feedback (Cascade) ABAC – South Secondary

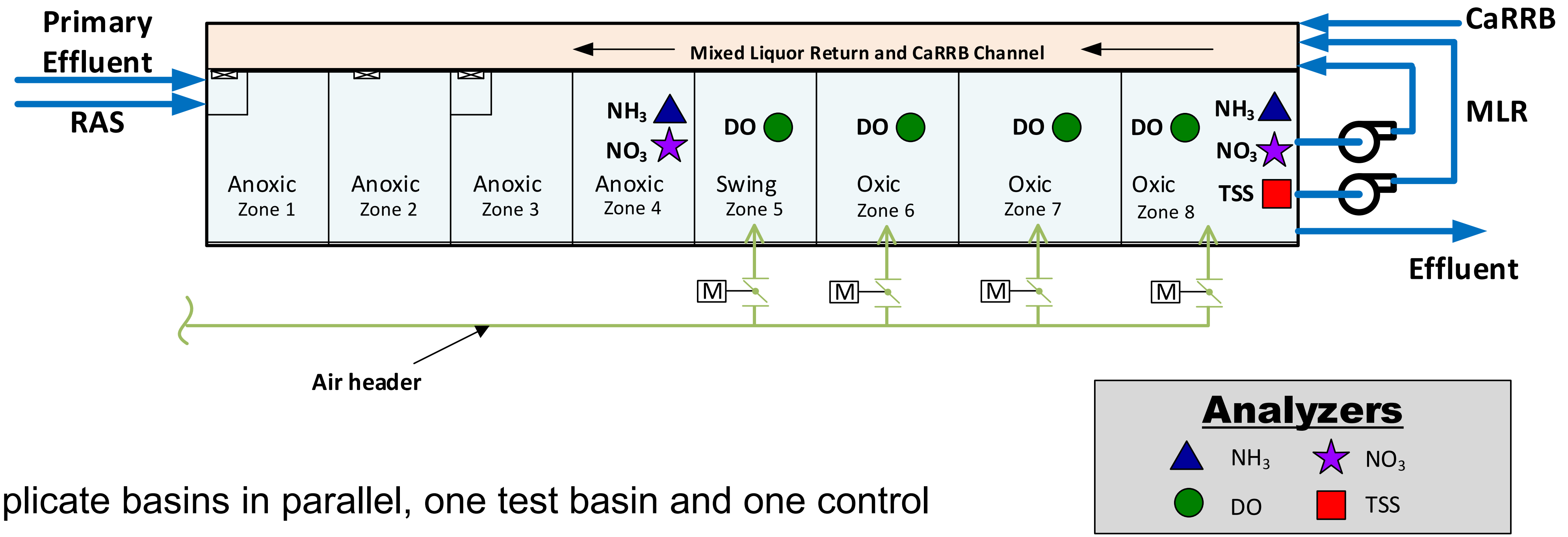
NH_4 set point → DO set point → Airflow set point → Valve Position



Cascade ABAC Instrumentation

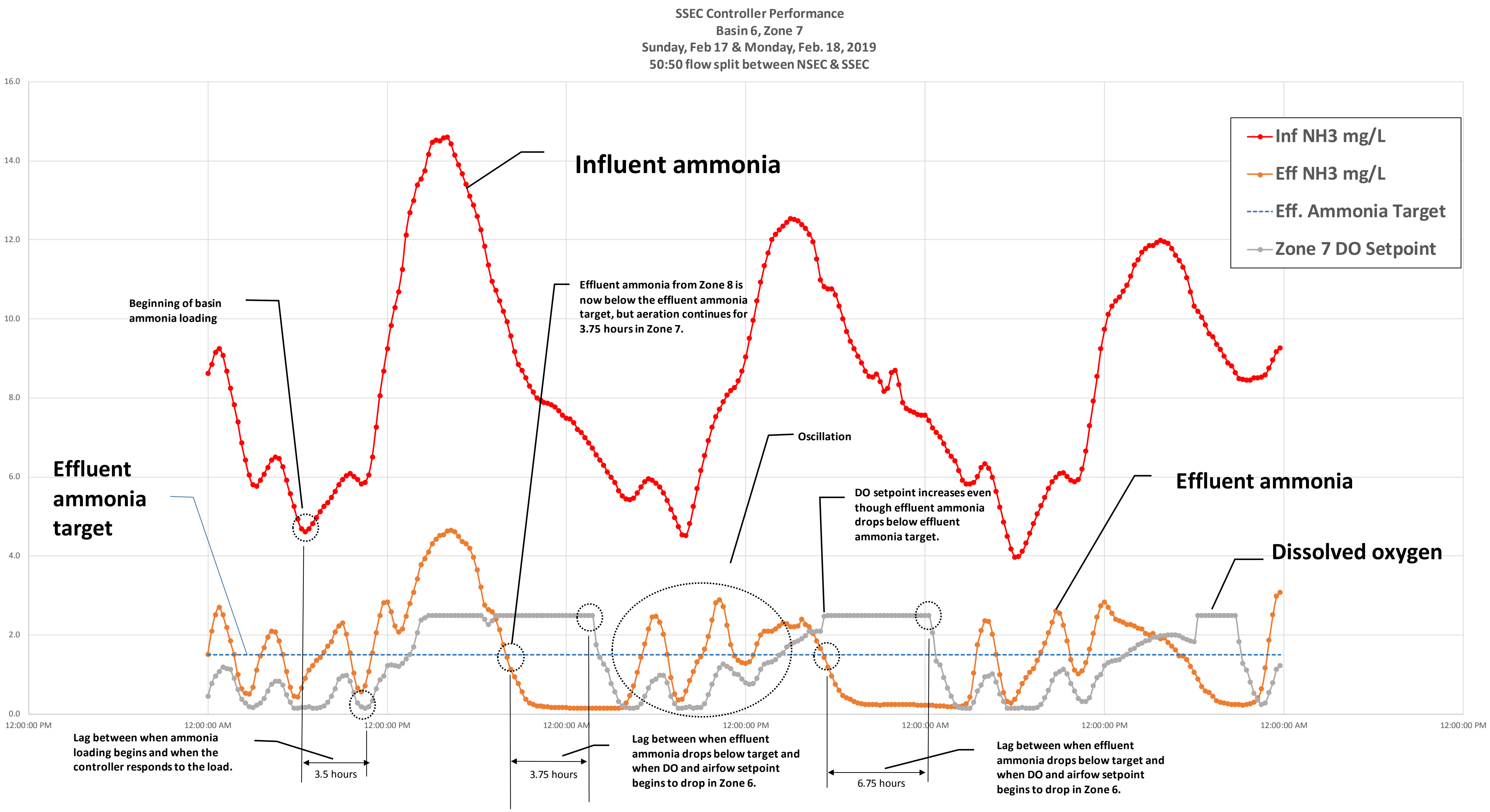
South Secondary

6 Parallel Basins – Modified Ludzack Ettinger process

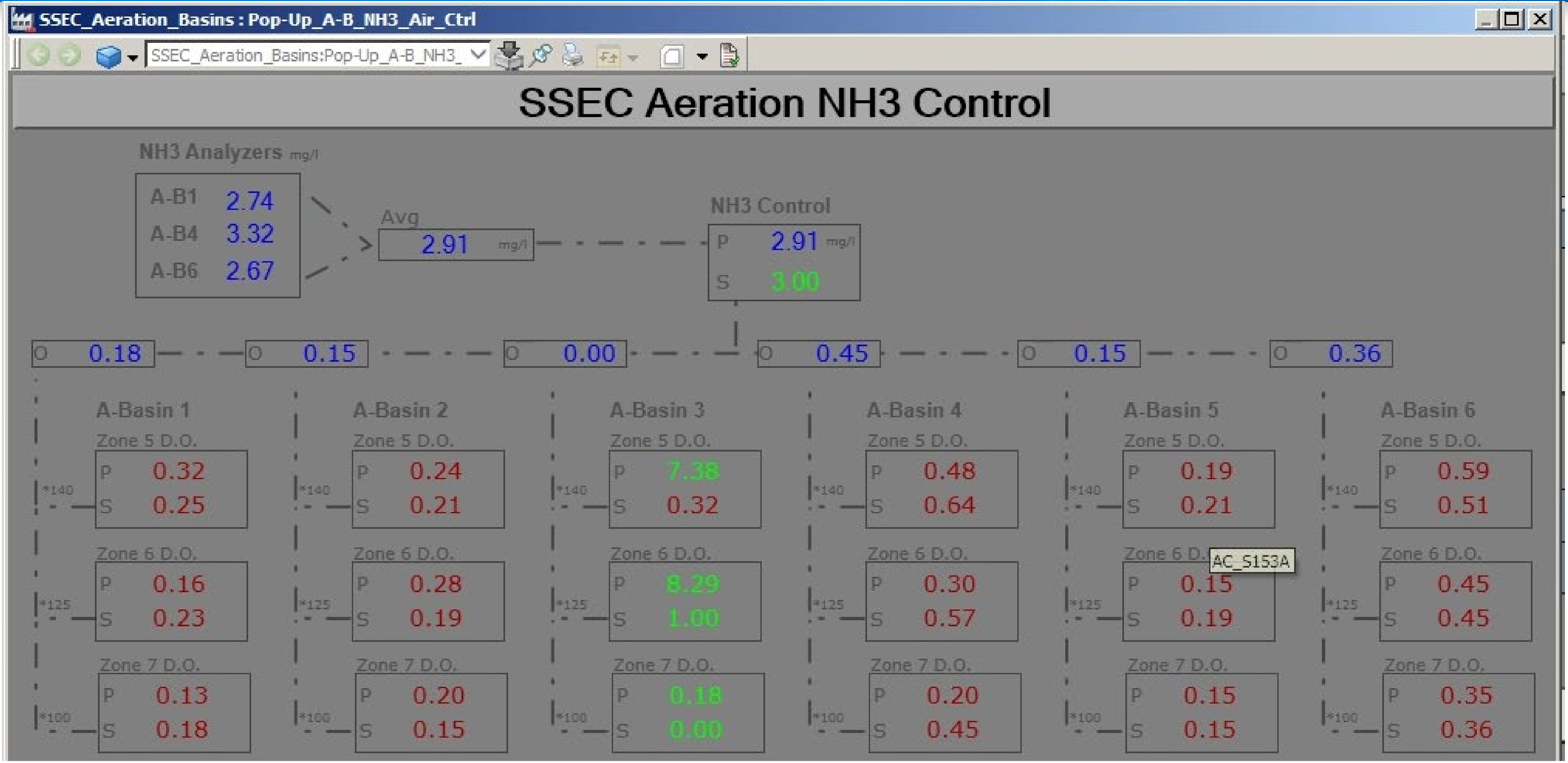


Two duplicate basins in parallel, one test basin and one control

Findings - Feedback Cascade ABAC



SCADA Control Panel



Compare: Direct versus Cascade Feedback Control

OK

- Direct Control - too much oscillation/instability – DO would vary rapidly
  - Rise and fall to undesirable levels; control valves moving frequently

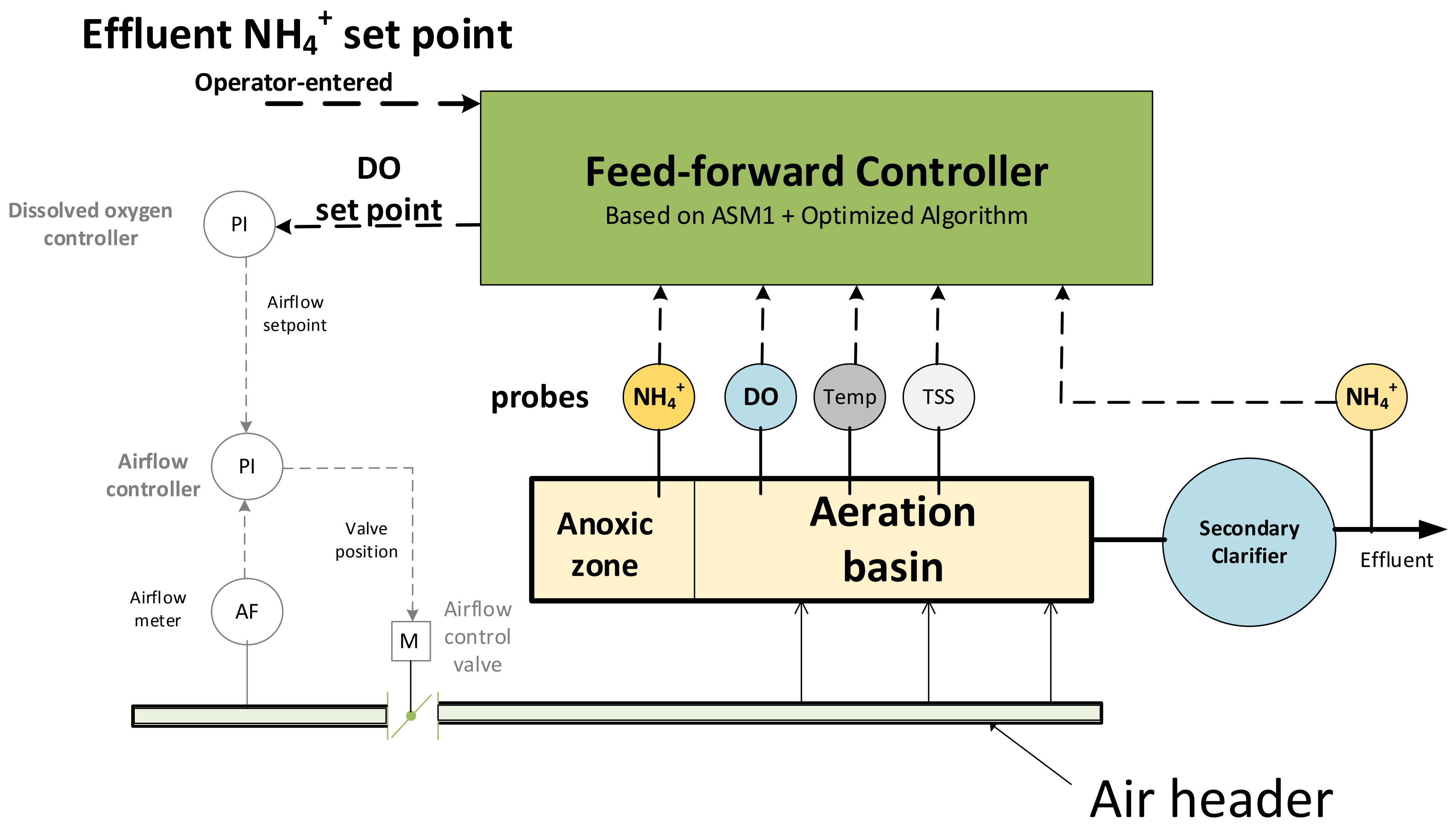
Better

- Cascade control – NH_3 concentration dictates DO set point, keeping DO concentration from varying rapidly
  - This simplifies PID control system tuning
- DO controller is the fail safe for an cascade feedback failure;
  - Fail safe system for a direct controller is more difficult to develop.

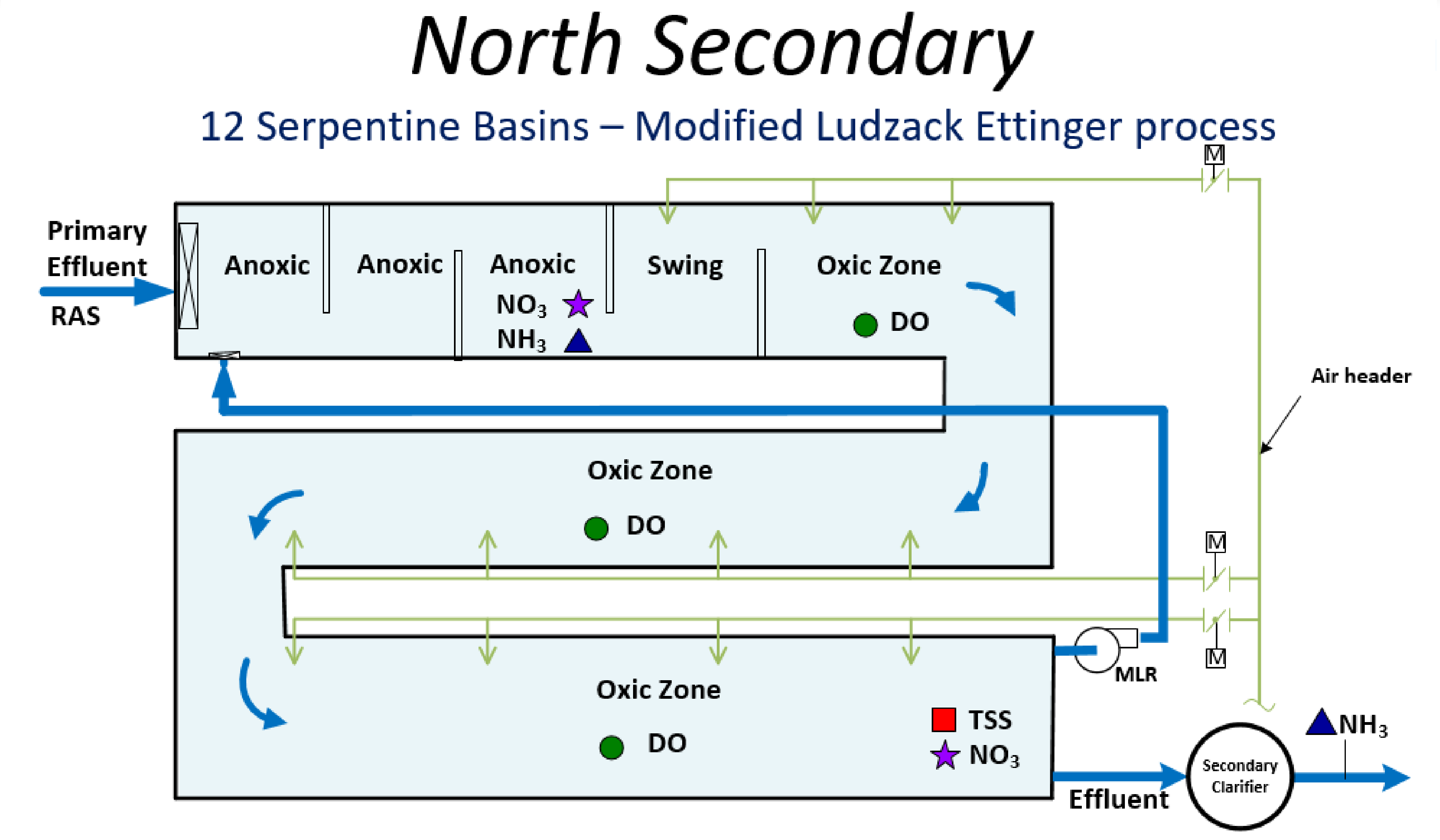
Effective use of the feedback cascade controller

- Need more steady-state conditions for PID controller
- Need to activate extra aerated volume (i.e. swing zone) when peak load is anticipated
  - Might use additional ammonia probe or program swing zone activation for a specific time of the day
- Tuning to minimize windup and oscillation
- ISE probe can be unstable at low NH_3 concentrations
  - Colorimetric NH_3 analyzer may not sample frequently enough
- Periodic adjustment of tuning constants (every four months?)
  - Not a “smart” controller; requires intensive and frequent(?) tuning

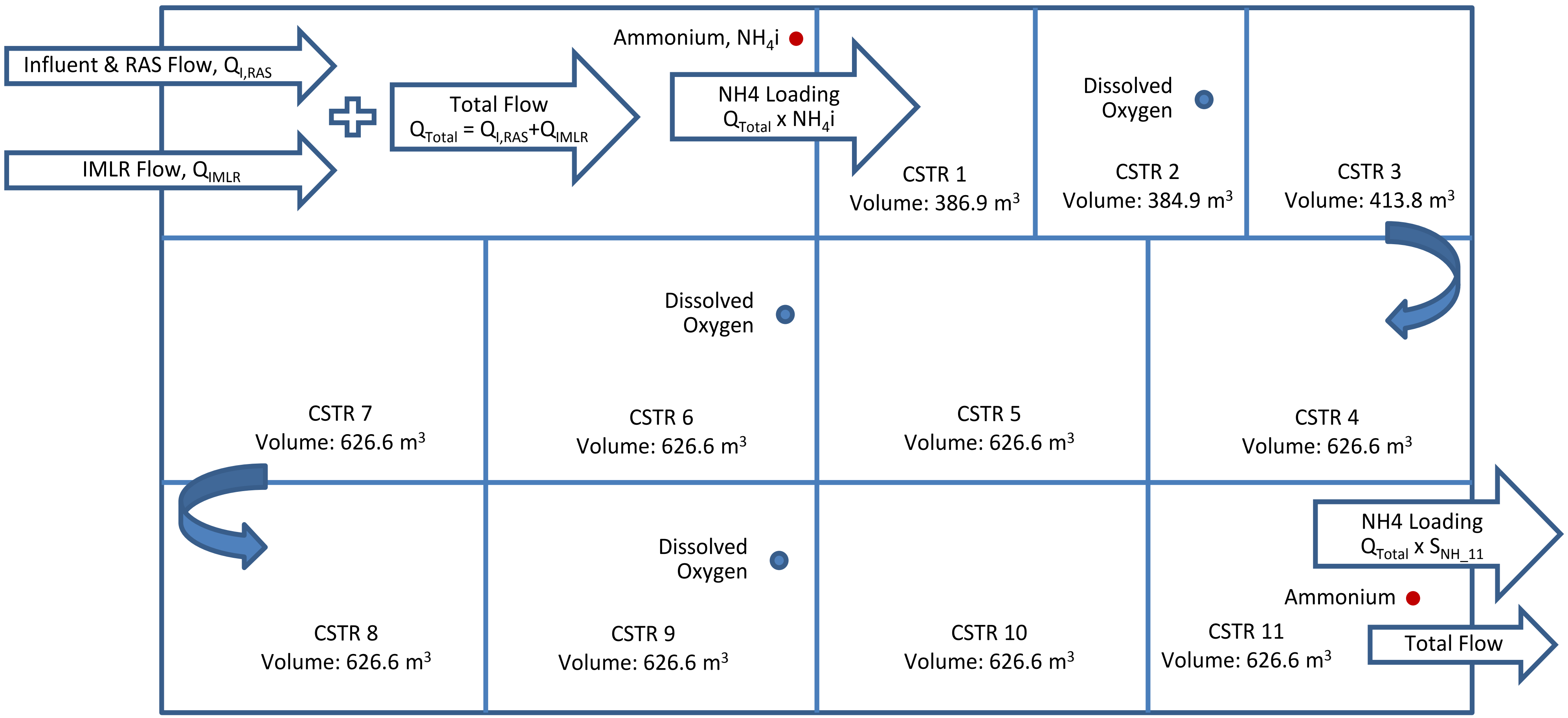
Feed-forward ABAC (BIOS™) – North Secondary



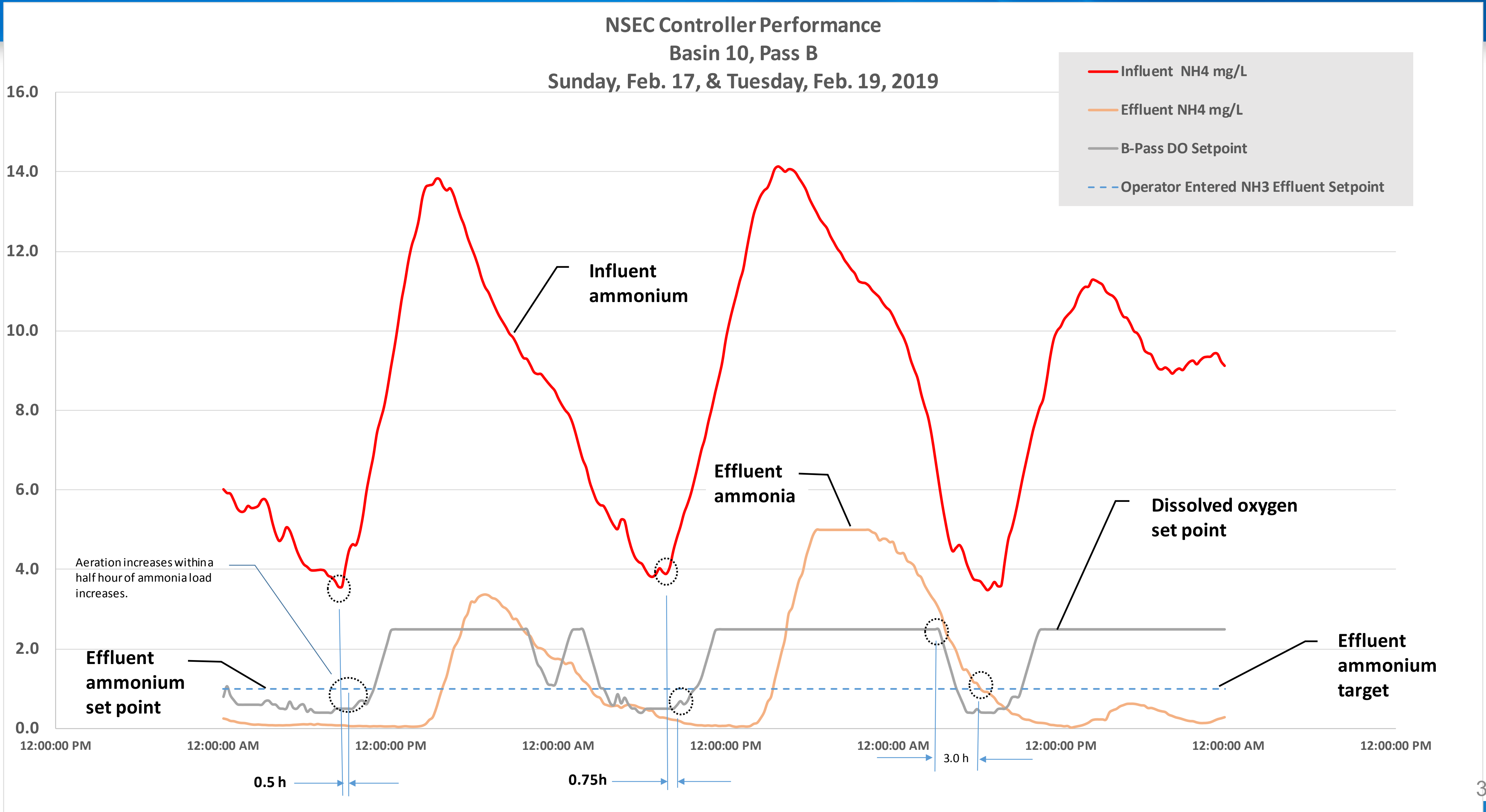
Feed-forward ABAC Instrumentation



Virtual Zone Control – DO Profiles



Feed-Forward Control



Features: Feed-forward Auto Tuning

- The BIOS software includes the ability to automatically update the specific ammonia removal rate – every 24 hours.
- BIOS compares the predicted effluent NH3 to the measured
  - The specific ammonia removal rate is adjusted to align these values (10%).

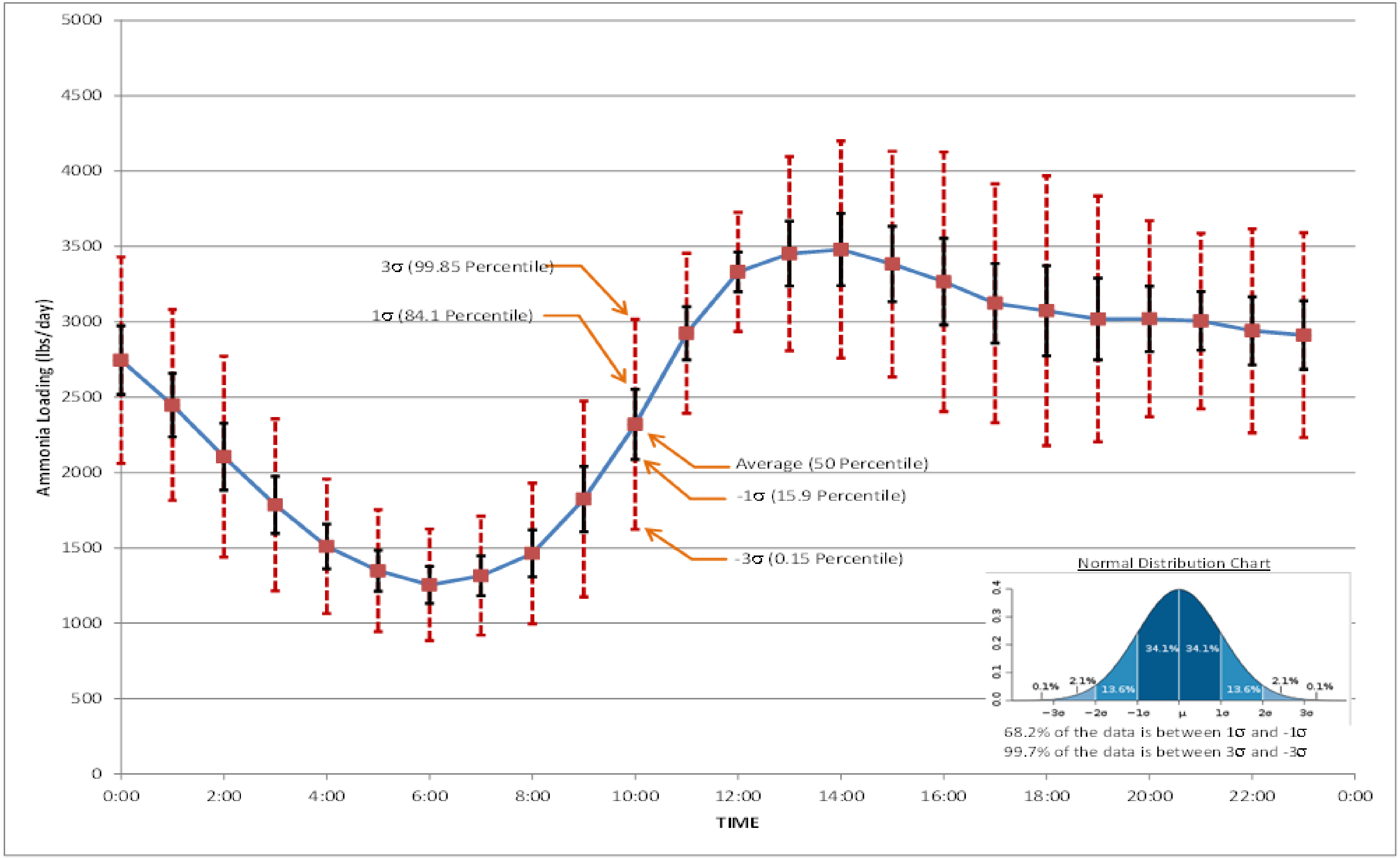
Ammonia removal rate, $\left(\frac{\frac{mg}{L}NH_3}{hr*g_{MLSS}}\right)$=

$$SARR \cdot \frac{S_{NH}}{K_{NH} + S_{NH}} \cdot \frac{S_{DO}}{K_{DO_A} + S_{DO}} \cdot X_{MLSS}$$

Specific Ammonia Removal Rate
(mg NH4 removed per g of TSS)

Mixed Liquor Suspended Solids
(g of TSS)

Features: Analyzer Fault Detection



Final Controller Comparison

Feature	*Feedback*	*Feed-forward*
Transport lag	Can be significant	Minimal
Oscillation	Can be significant	Acceptable level
Proprietary software	No	Yes
Instrumentation	Two analyzers	Five analyzers
Tuning	Recommended periodically	Self-tuning
Failsafe	DO controller	Archived NH3 load data
DO prediction accuracy	Acceptable	Acceptable

Aeration Control at MWRD – Going Forward

- Both systems are saving money (10% - 20% over DO control alone)
- Ammonia control not always superior to DO control
- Future upgrade – which controller will we settle on?
  - MWRD diurnal peaks are probably too large for PID control;
    - Too much lag time
    - Instability (oscillation) equals system inefficiency
  - Feed-forward: no lag, no oscillation, self-tuning capability
    - No of required analyzers for feed-forward was not a drawback
- Future Upgrades the NSEC
  - Probably standardize on the feed-forward system
  - Maybe look at integrated package that include blower controls
  - Design whole aeration system in conjunction with the control system

Thank you

METRO WASTEWATER RECLAMATION DISTRICT

Robert W. Hite Facility
Denver, Colorado

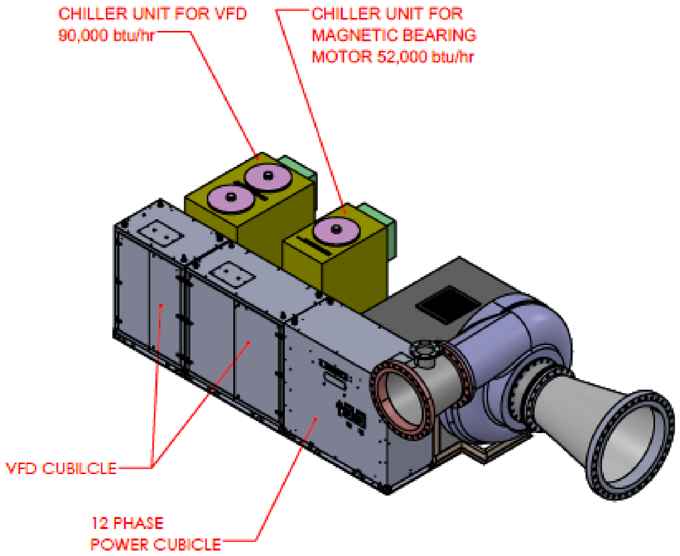
Wendy Anderson
wanderson@mwrd.dst.co.us

Direct-Drive Turbo Blower Demonstration

- Blower manufactured by APG-Neuros
- Largest direct-drive turbo blower available on the market
  - 1 MW (1,340 HP), 23,000 scfm
- First full-scale demonstration of this blower
- Frictionless shaft rotation with magnetic bearing system

1MW permanent magnet synchronous motor

1MW VFD and power panel assembly



Typical Aeration Tank at Stickney