A Holistic Approach to Plant Control Provides Process Improvement and Energy Savings

Tilo Stahl
BioChem Technology Inc.
King of Prussia, PA

BIOCHEM TECHNOLOGY, INC.

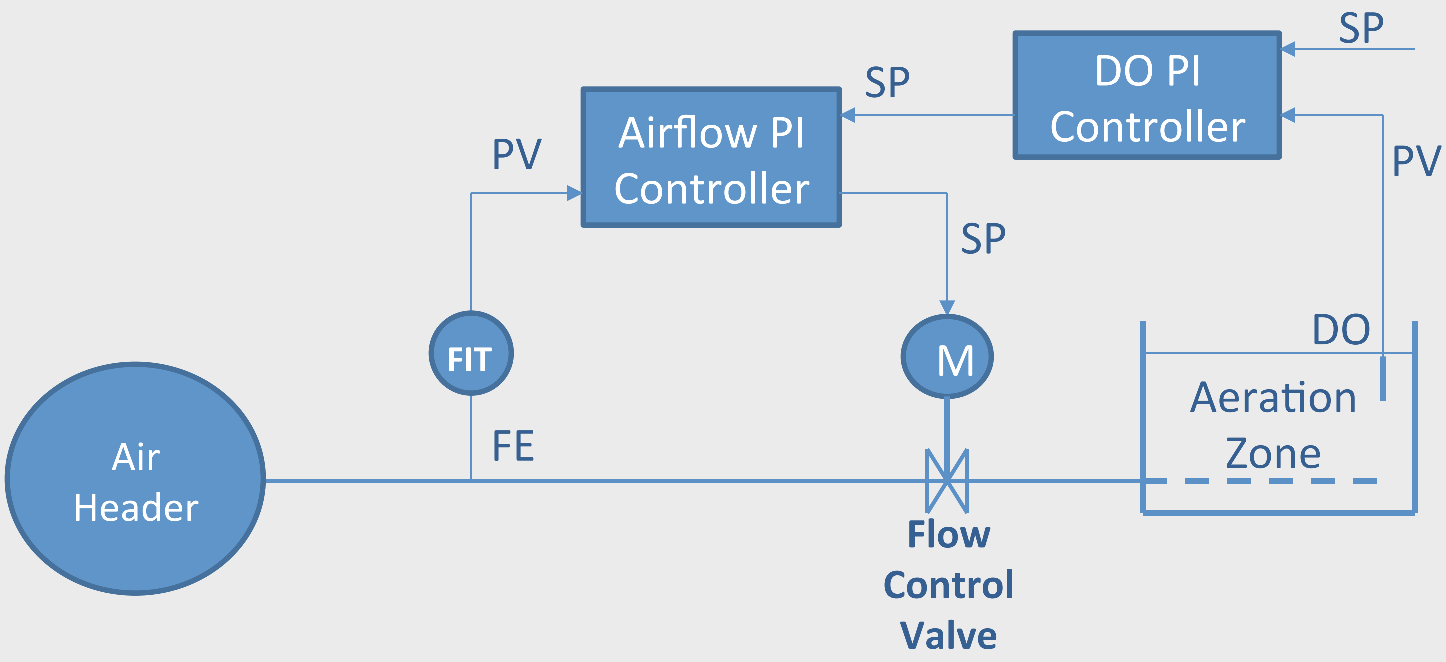
Holistic:

“Relating to or concerned with complete systems rather than individual parts”

(www.Merrian-Webster.com)

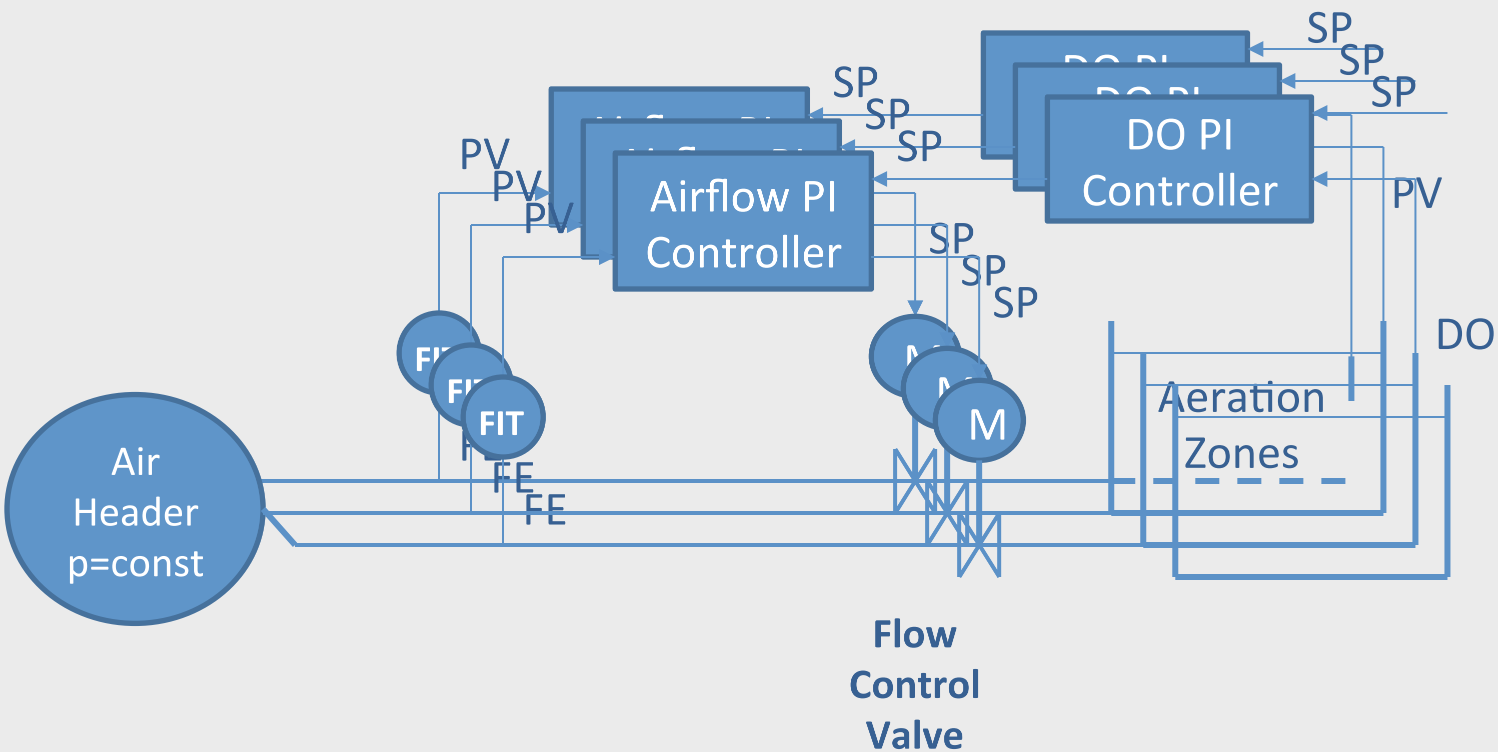
Secondary Treatment Control Systems

- **Aeration control** – typically independent cascaded PI loops for each zone



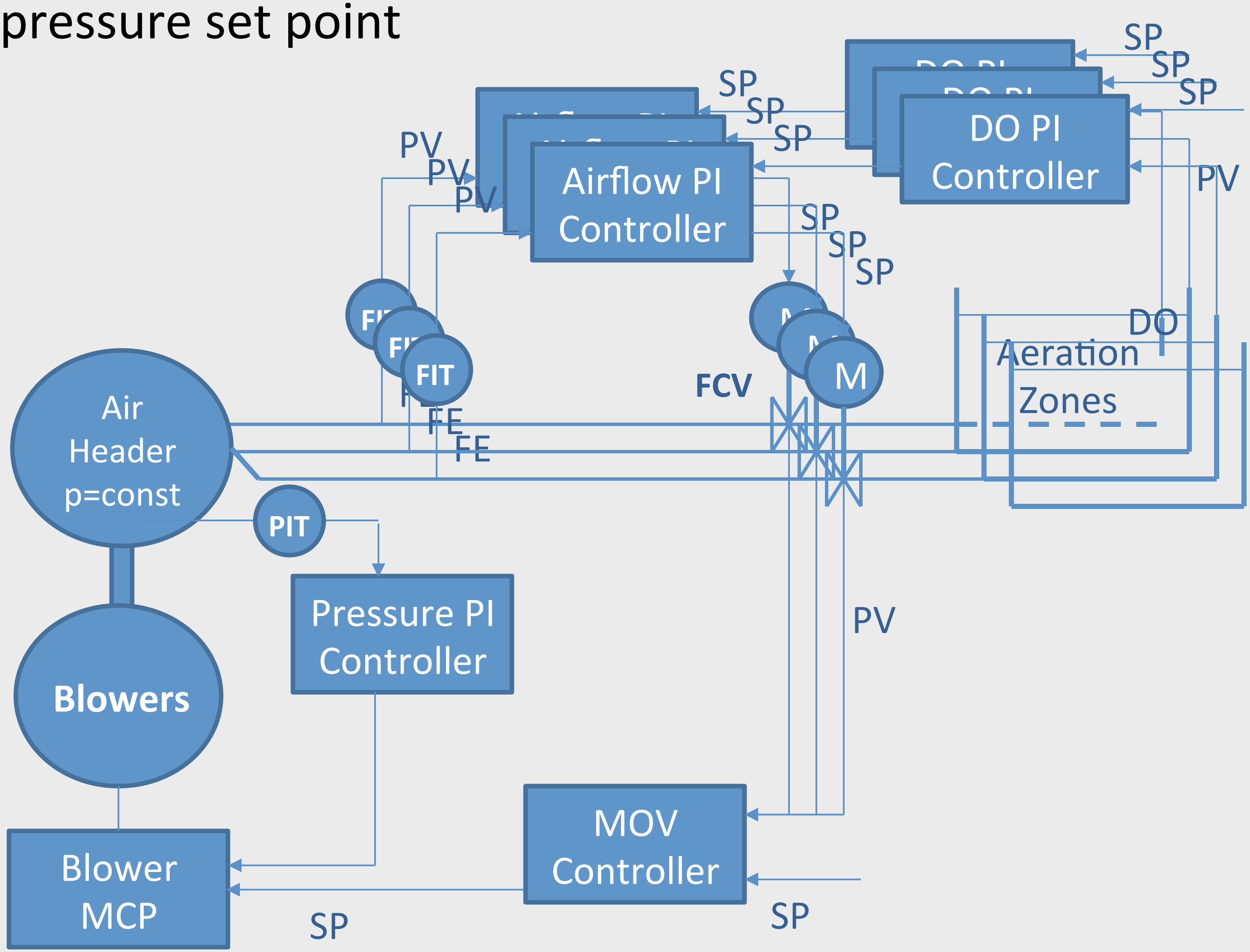
Secondary Treatment Control Systems

- **Aeration control** – typically independent cascaded PI loops for each zone and blowers controlled on pressure
  ⇨ all sorts of interactions



Secondary Treatment Control Systems

- **Most-Open-Valve** – cascading PI feedback from valve position to pressure set point



Secondary Treatment Control Systems

- **Ammonia control** – PI feedback of blower settings or DO set points based on effluent NH4
- **Nitrate recycle flow rate** – typically fixed ratio (200 to 400%) of influent flow
- **Carbon addition** – typically flow based
- **Swing zone control** – typically manual, seasonal
- **Waste rate** – manual

⇨ **NOT holistic control**

Case Study: City of Lebanon (PA) WWTP

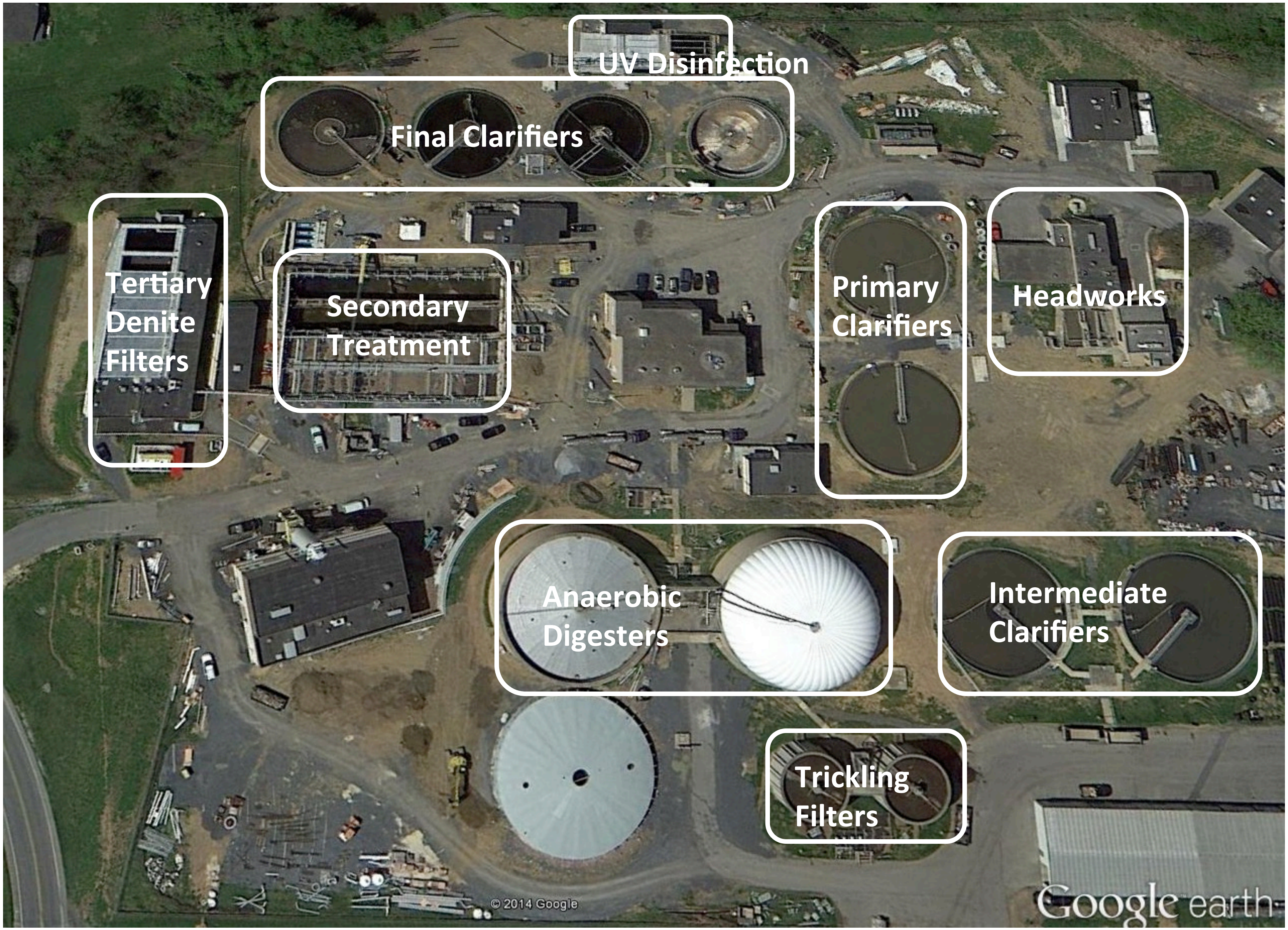
Situation

- Chesapeake Watershed
- Average Daily Flow of 6 MGD
- Design Capacity 8 MGD, Wet Weather 34 MGD
- Nitrogen TMDL is 146,000 lbs p.a.
- (equiv. to TN 8mg/l at current ADF)
- BNR Upgrade in 2010 to 2014
- Landlocked

Upgrade Objectives

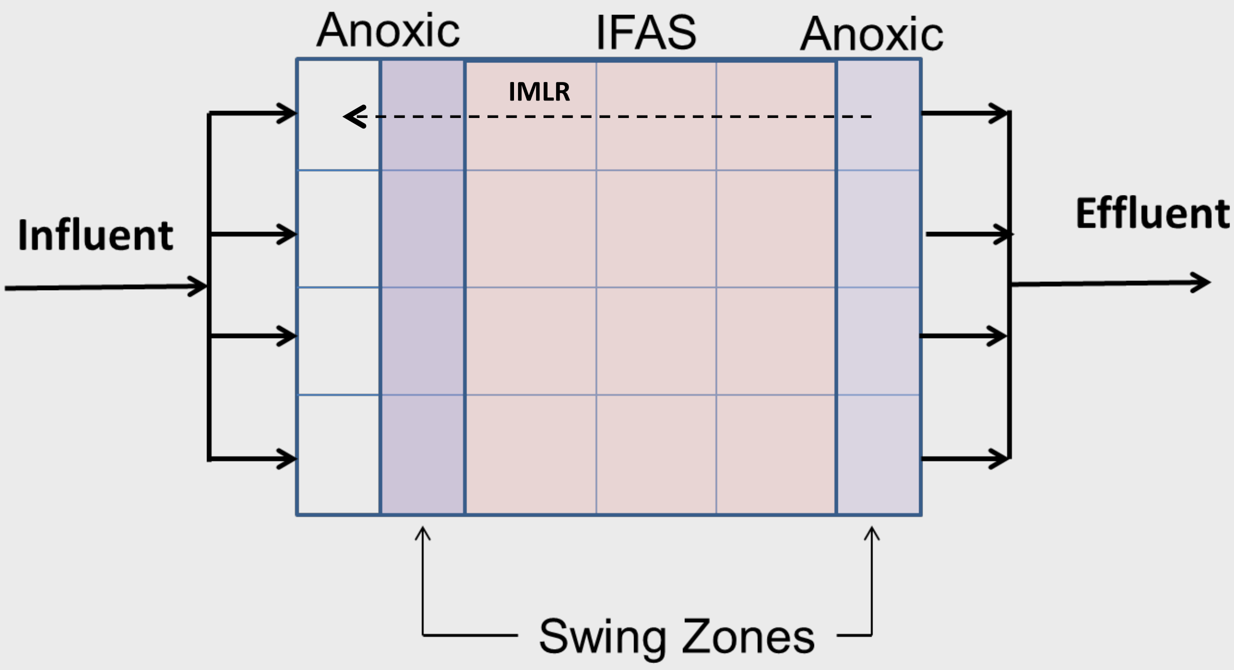
- Upgrade to Nutrient Removal
- … in the same footprint
- … and save energy

City of Lebanon (PA) WWTP Layout



Secondary Treatment Design Features

- Four 200 HP single stage centrifugal blowers
- Four process trains, each with:
  - One anoxic zone for denitrification
  - Two swing zones with fine bubble diffusers
  - Three IFAS zones with coarse bubble diffusers
  - Internal mixed liquor (nitrate) recycle
- Trickling filter bypass for carbon addition

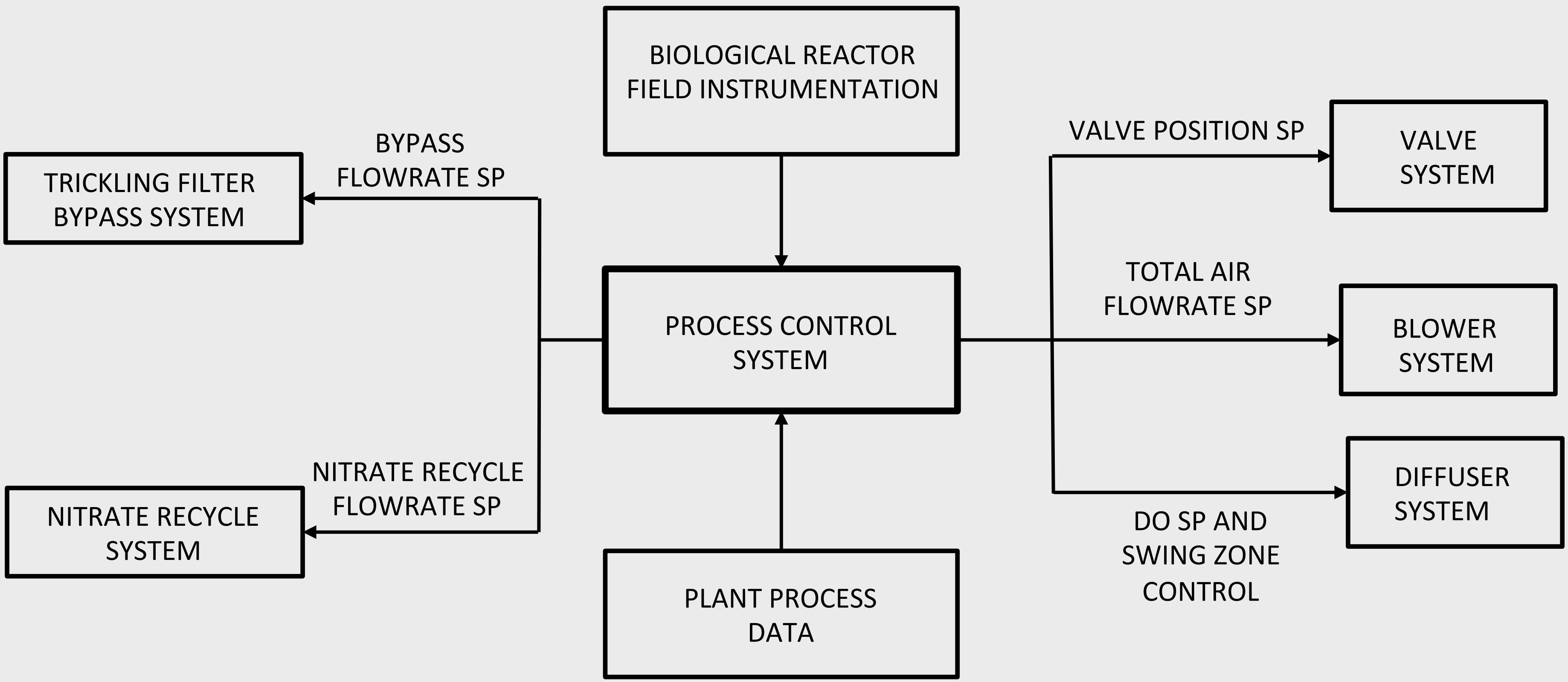


Lebanon Control Objective

Optimally utilize the plant capacity to meet effluent permit requirements with the lowest possible energy and chemical consumption and without system disruptions

- Switch swing zones on/off based on aerobic demand
- Determine optimal DO set point in each zone
- Maintain DO set points in IFAS zones and swing zones
- Control blowers to meet total demand
- Control air flow to each zone
- Minimize aeration system pressure using most-open-valve logic
- Control mixed liquor recycle to manage denitrification
- Control trickling filter bypass to provide carbon in anoxic zones as needed
- Control SRT

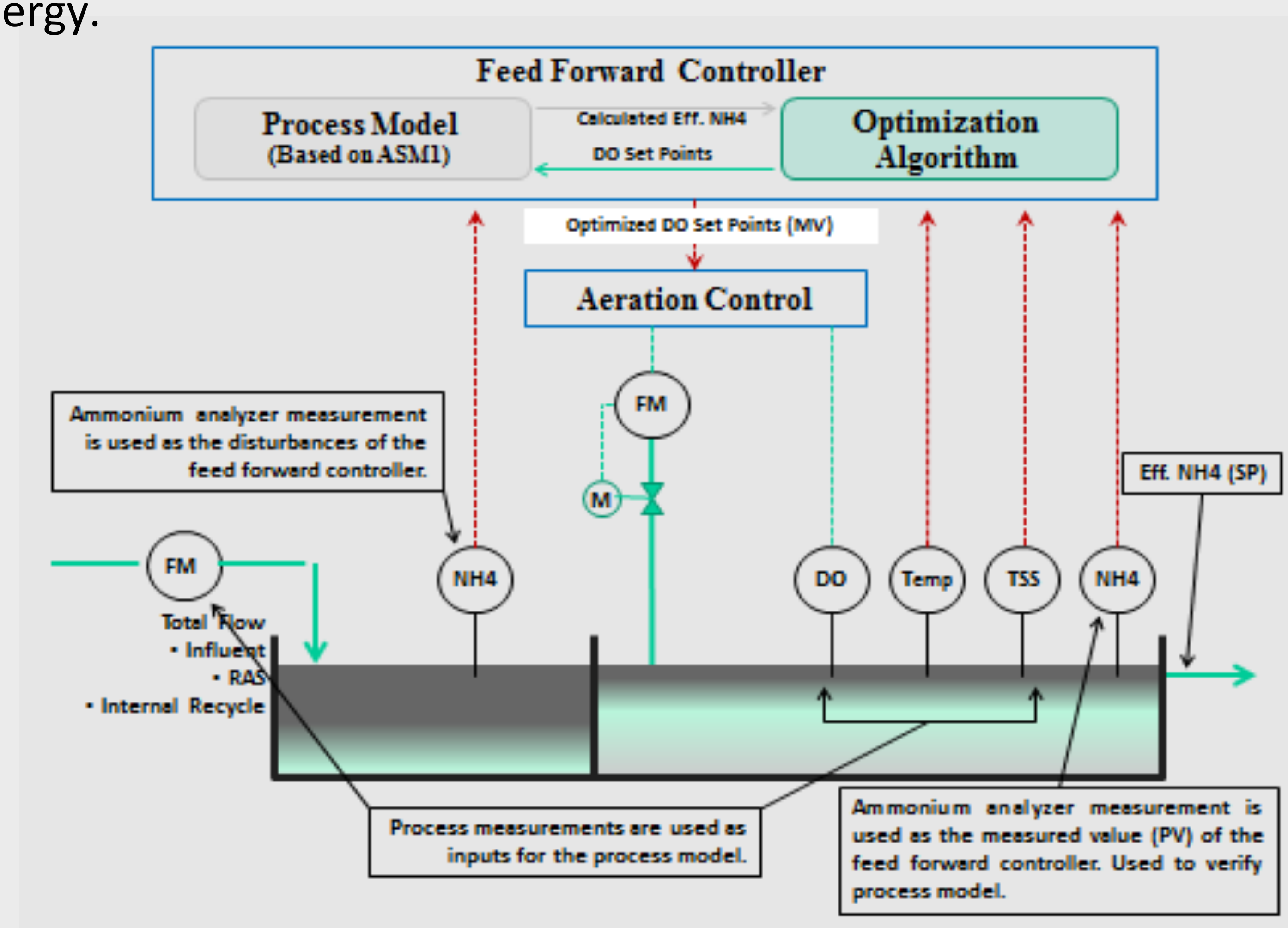
Lebanon Control Architecture



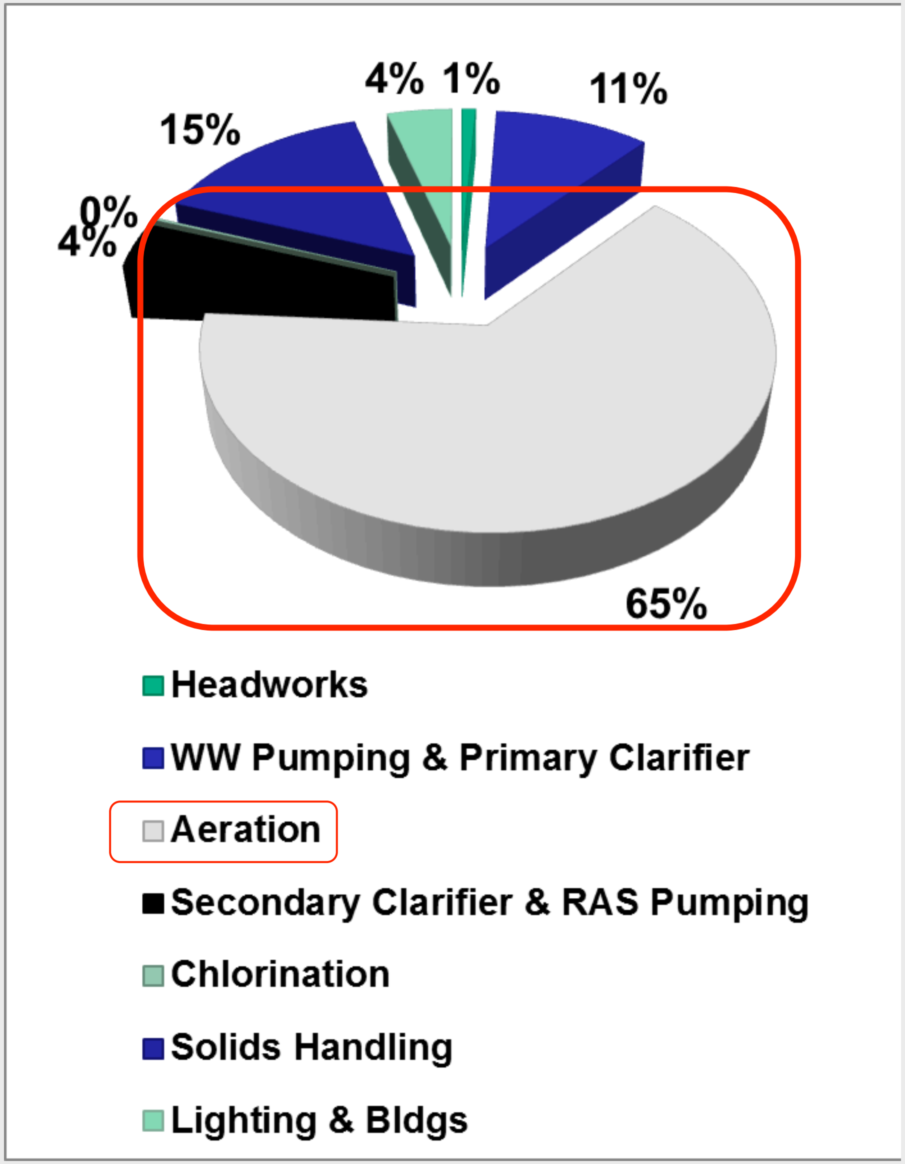
Core Control Components: "Ammonia" Control

The BIOS controller uses a feed-forward control model, process data and ammonia loading to calculate • overall aerobic capacity requirements • individual DO set points • ideal nitrate recycle flow rate • trickling filter bypass rate.

The goal is to achieve the required total nitrogen removal rate with minimum aeration energy.



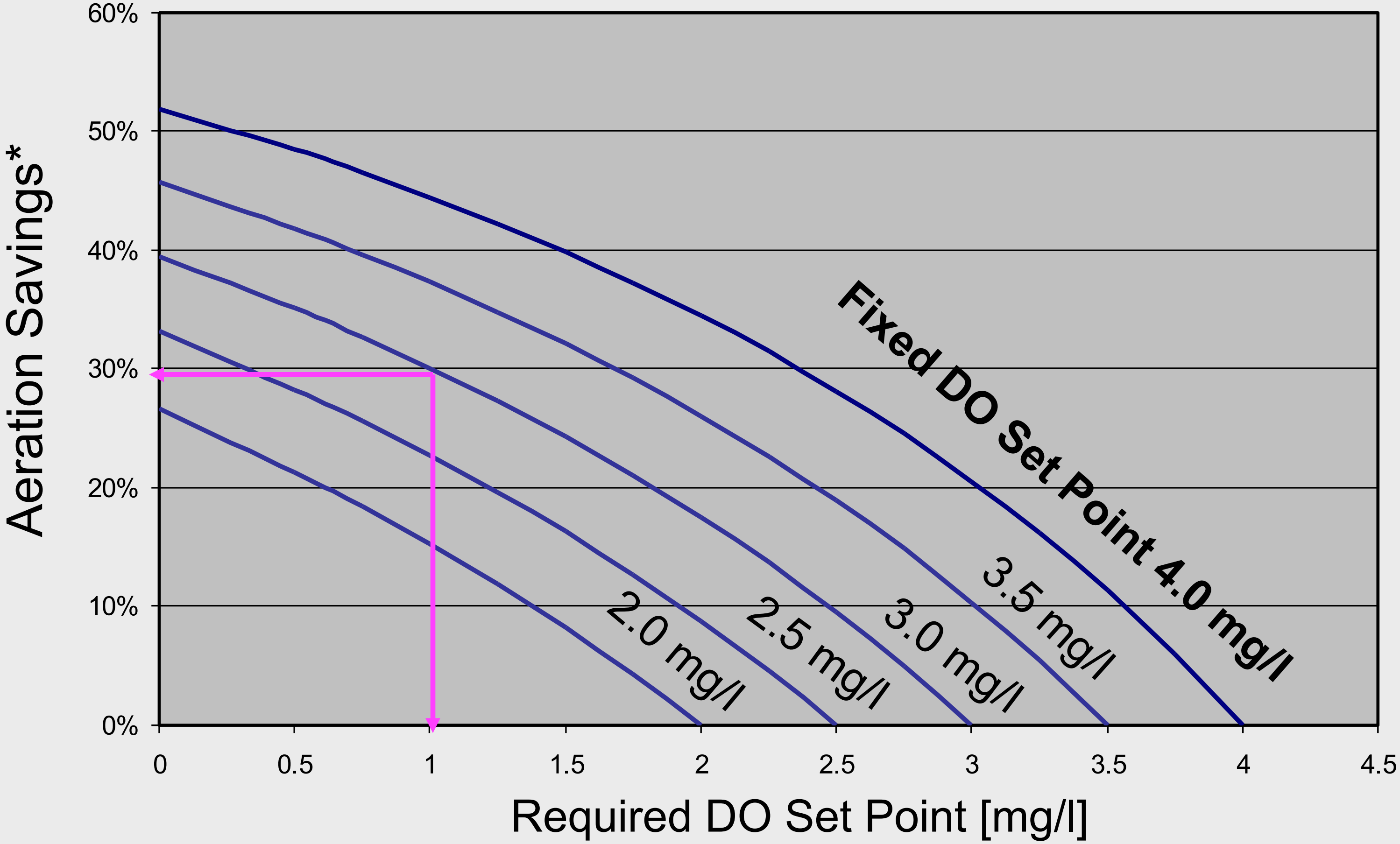
Energy in WWTPs



Data from WEF MOP 32 (2009)

Airflow Reduction as Function of DO

OTE = k*SOTE*$(C_s - C)/C_s$

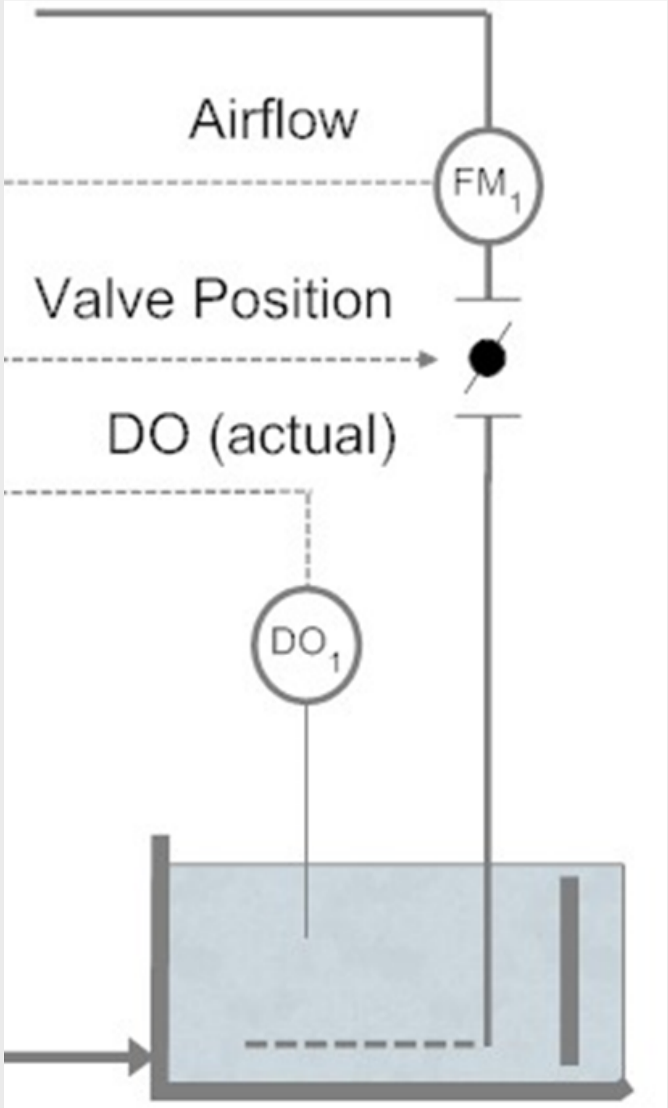


* Assuming constant oxygen demand

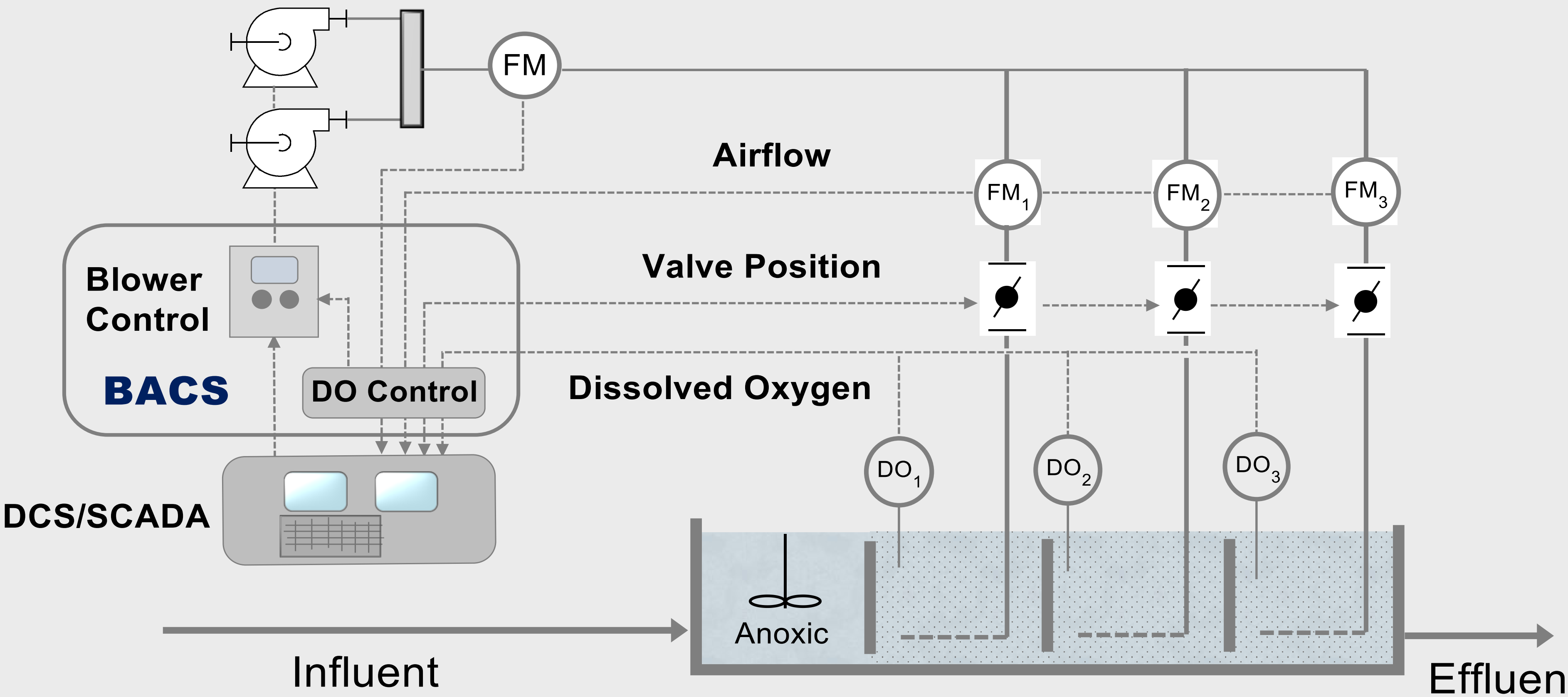
Core Control Components: Aeration Control

The BACS controller calculates:

- changes in OUR based on air flow and dissolved oxygen
- required change in airflow in each zone
- total airflow in all zones
- valve position in each zone
- MOV to minimize system pressure

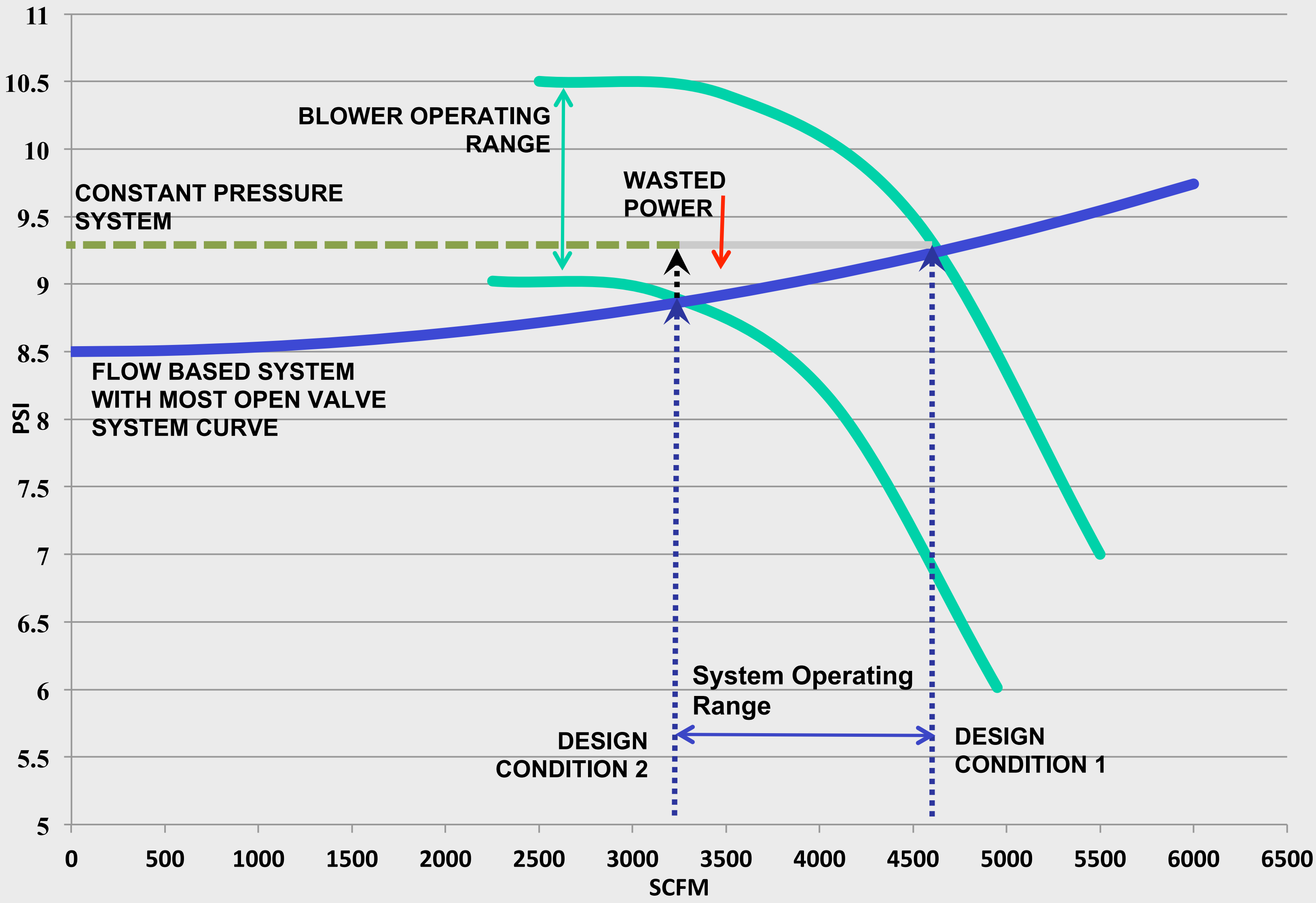


Bioprocess Aeration Control System



BACS Most-Open-Valve Performance

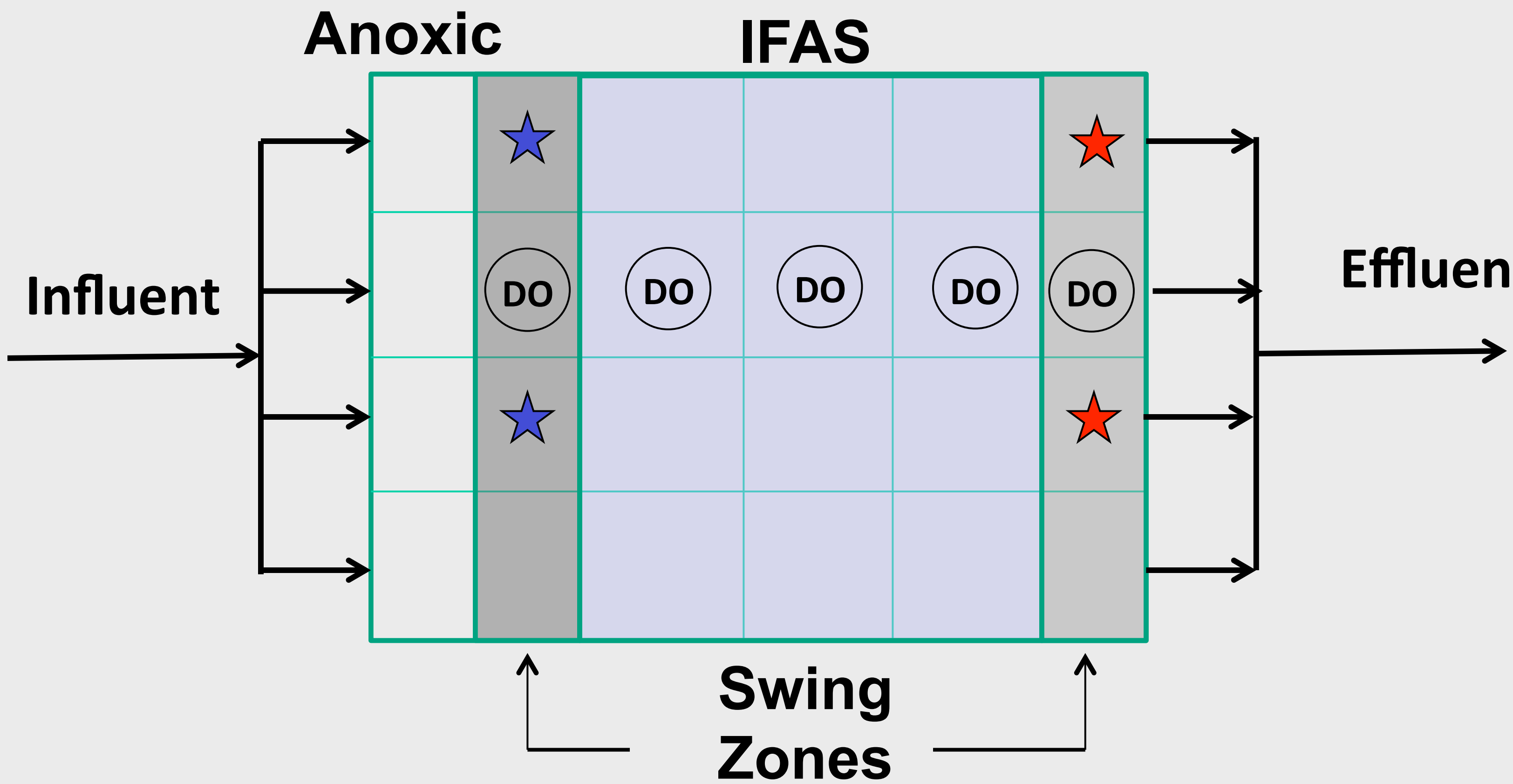
average 5% energy savings vs. constant pressure



Summary of Control Sequence

1. Aerate swing zone under high oxygen demand conditions
2. Determine required DO set point in each aeration zone (within process constraints e.g. minimum IFAS aeration)
3. Determine MOV location (IFAS zone when swing zones are not aerated, swing zone when aerated)
4. Control blowers to meet total calculated oxygen demand
5. Position valves in each zone to meet localized oxygen demand
6. Control nitrate recycle rate to maximize denitrification
7. Control trickling filter bypass to provide carbon as need in anoxic zones

Secondary Treatment Instrumentation



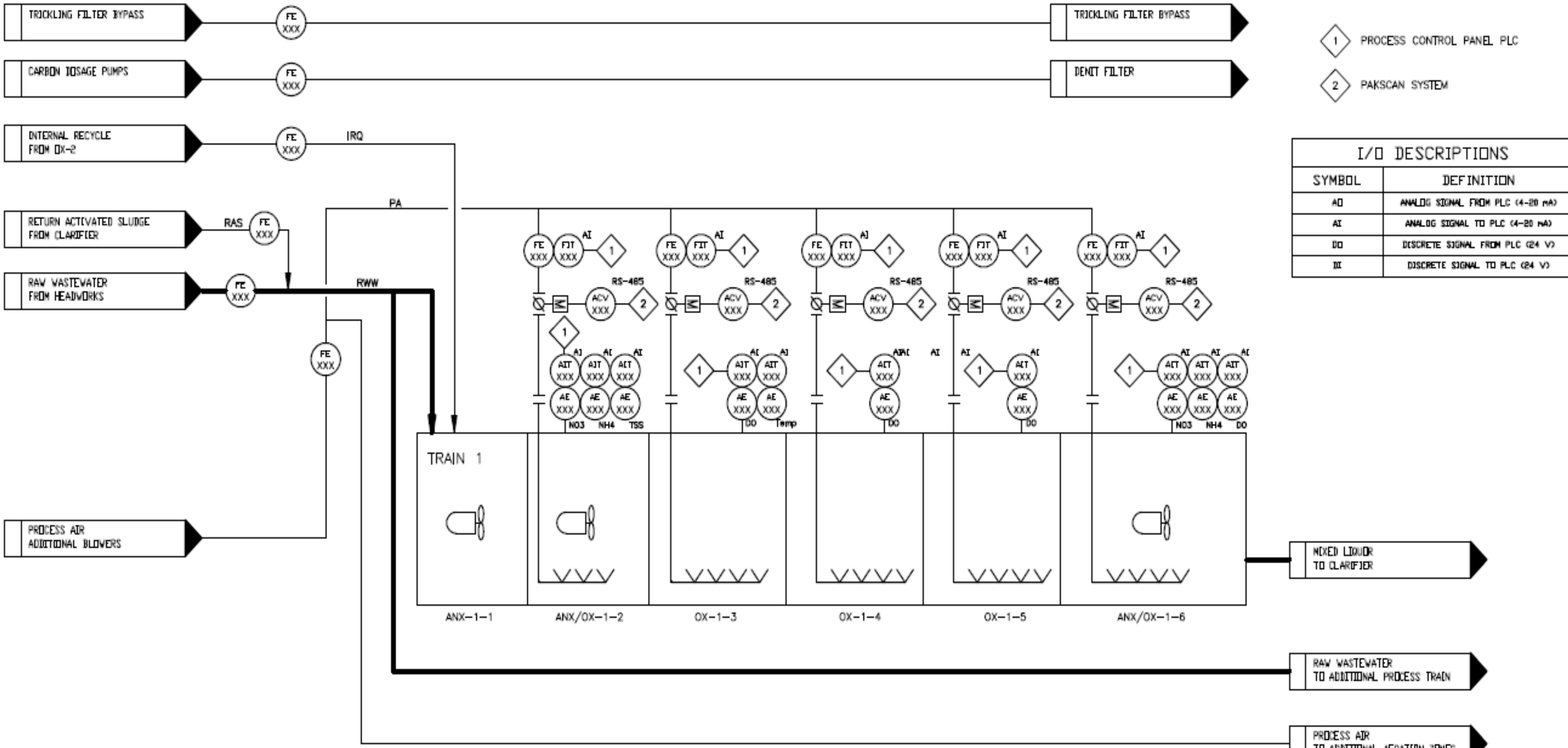
★ NH4/NO3/TSS (blue star)

★ NH4/NO3/pH (red star)

DO + AFM + FCV in all IFAS and swing zones

Totals:	NH4	4	DO	20
	NO3	4	AFM	20
	TSS	2	FCV	20
	pH	2		

Secondary Treatment P&ID

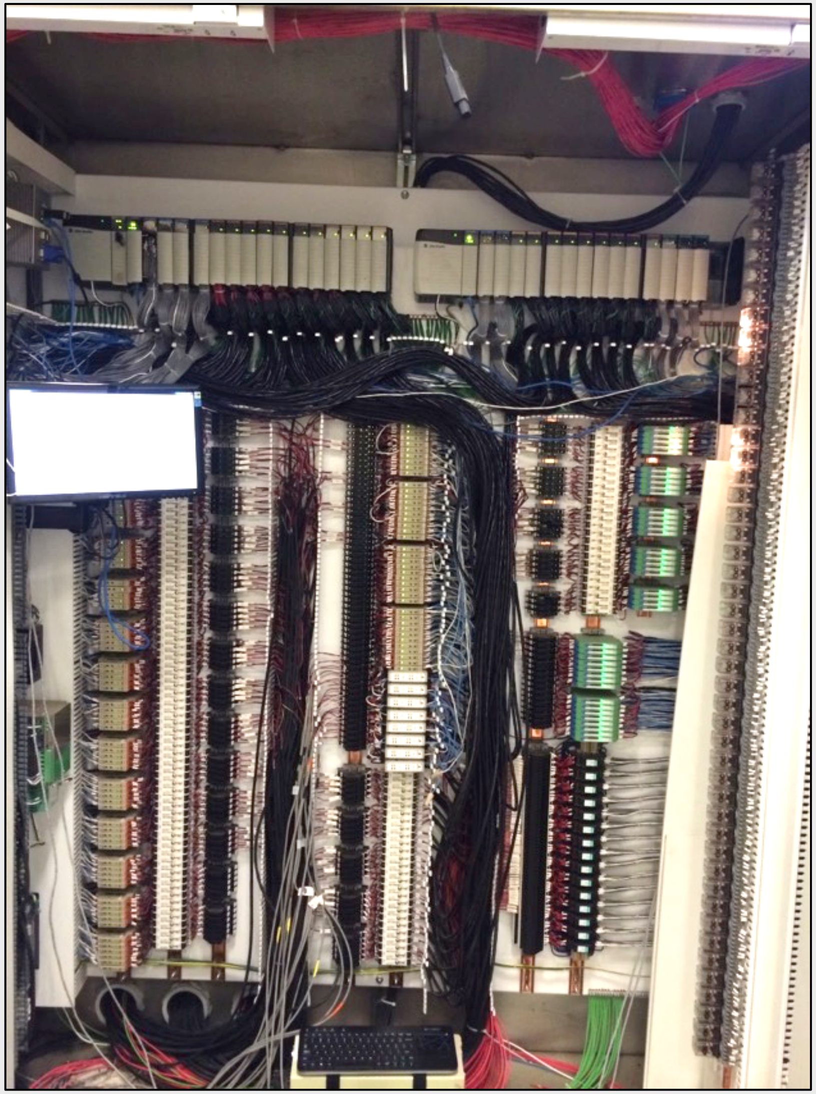


I/O DESCRIPTIONS

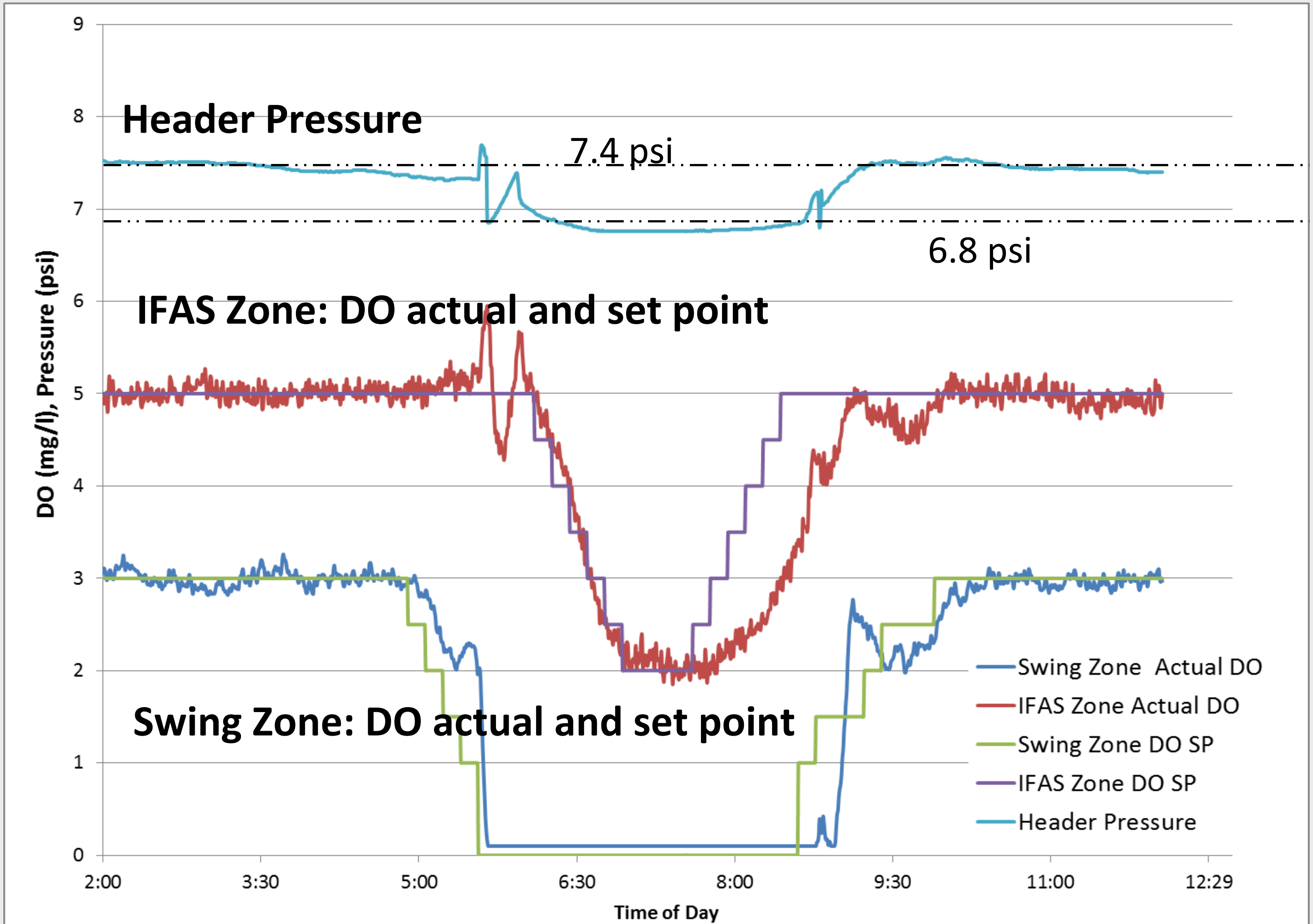
SYMBOL	DEFINITION
AO	ANALOG SIGNAL FROM PLC (4-20 mA)
AI	ANALOG SIGNAL TO PLC (4-20 mA)
DO	DISCRETE SIGNAL FROM PLC (24 V)
DI	DISCRETE SIGNAL TO PLC (24 V)

NOTE: TRAIN 1 AND 3 ARE CONSIDERED THE CONTROL TRAINS AND ARE IDENTICAL. TRAIN 2 AND 4 DO NOT HAVE THE NH4, NO3, TSS, AND TEMP SENSORS.

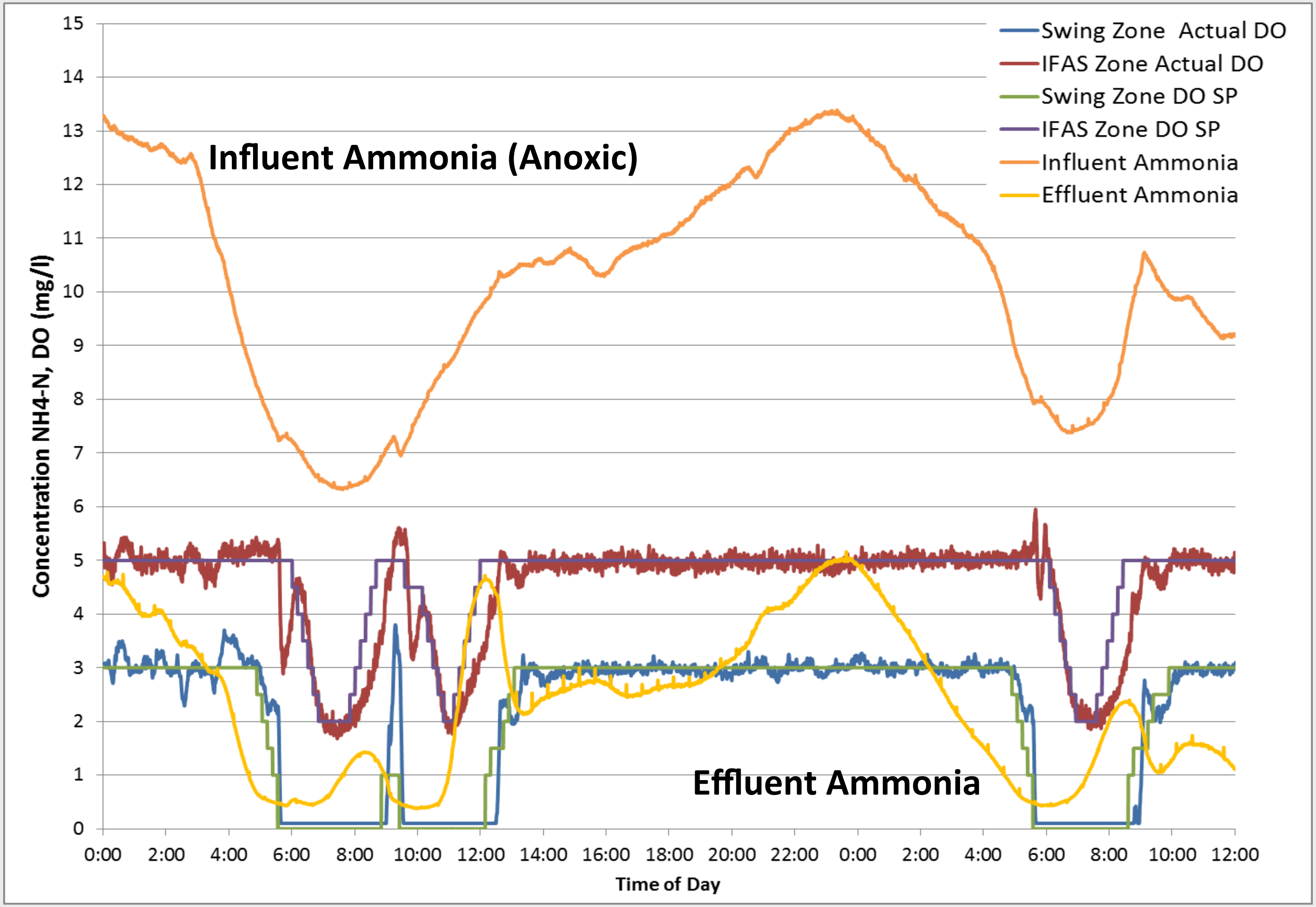
View of Control Panel



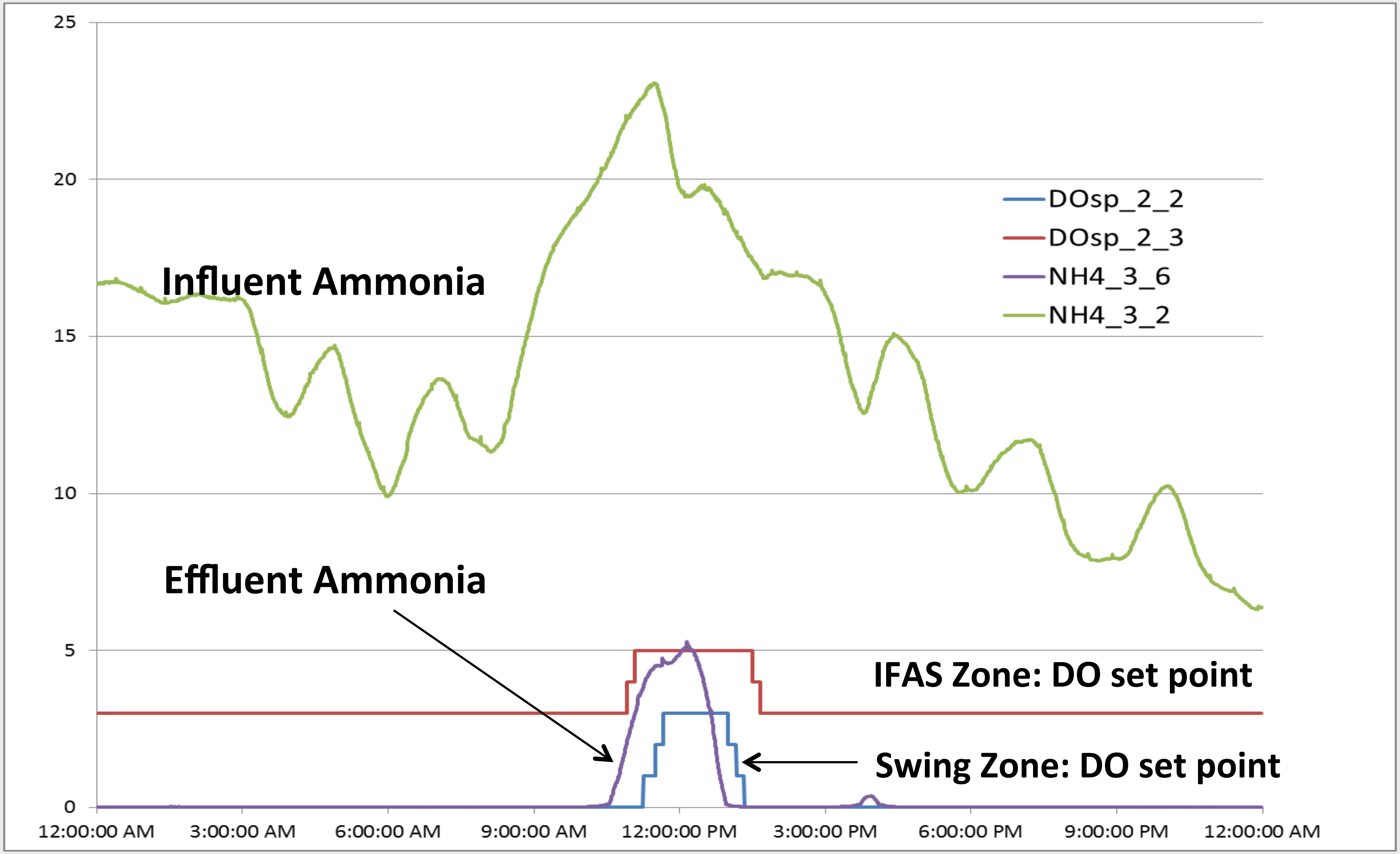
Results: Aeration Control



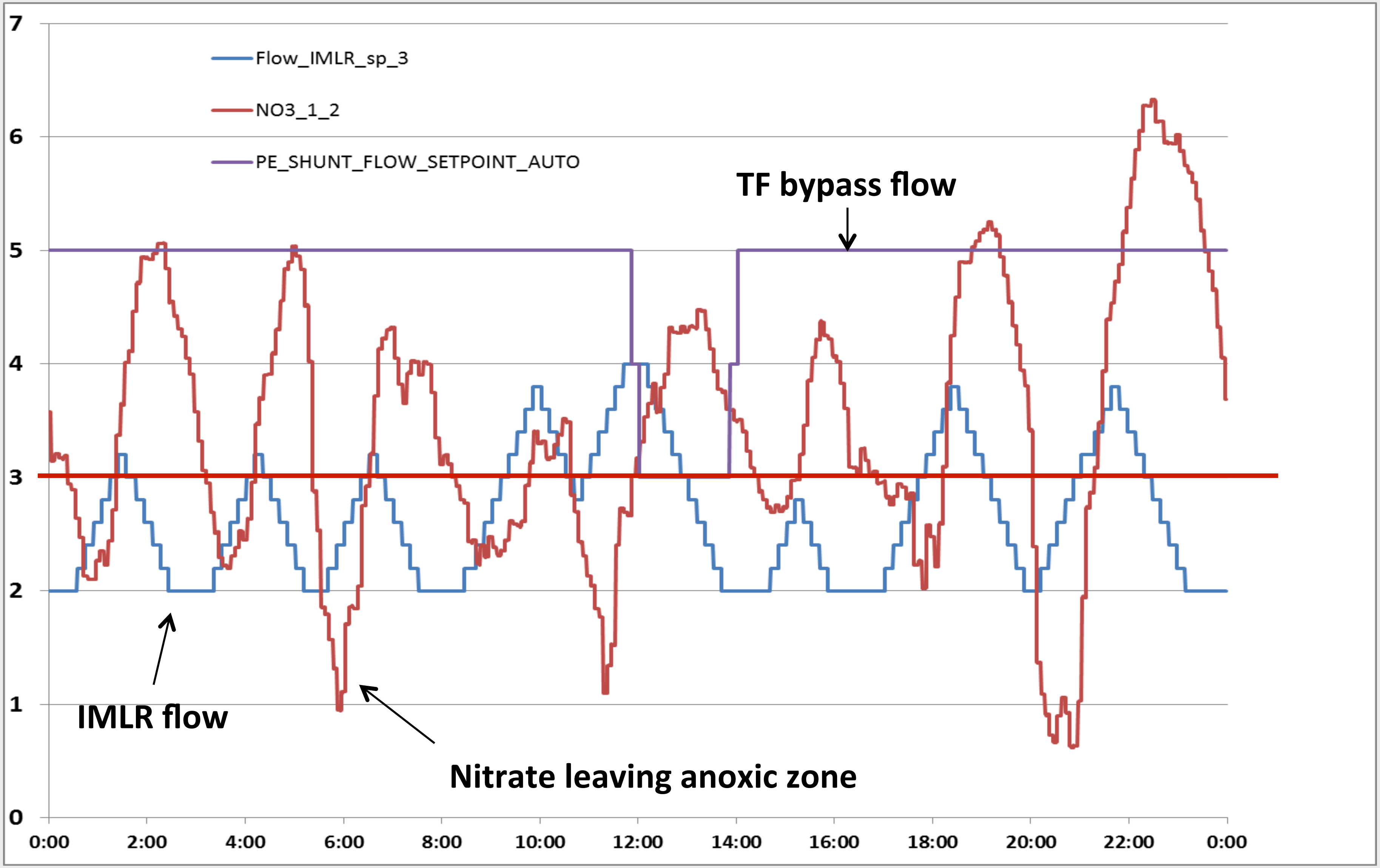
Results: Ammonia Control



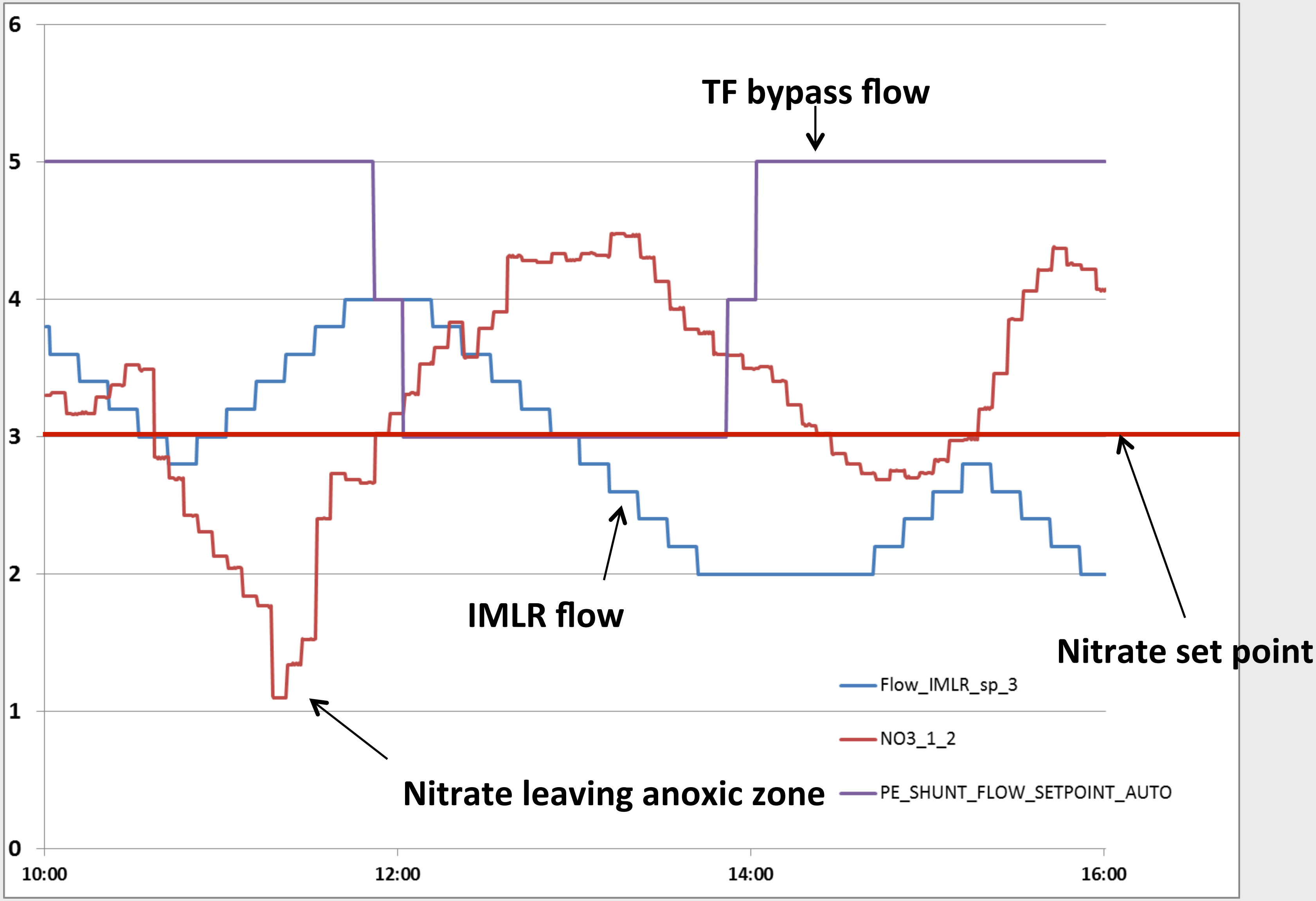
Results: Ammonia Control



Results: Denitrification Control



Results: Denitrification Control



Summary

- Aeration control, ammonia control and denitrification control in one integrated control package
- Combination swing zones and IFAS zones aerated based on aerobic capacity requirements
- Flow-based Blower control
- MOV control on combined coarse and fine bubble diffusers on common air header
- Denitrification control through active control of mixed liquor recycle and carbon shunt

⇨ **Holistic control based on comprehensive and detailed process understanding and monitoring**

Results: Energy Savings

- DO set point control (ammonia control) saves approx. 15% of aeration energy
- MOV control saves approx. 4% of aeration energy
- Nitrate recycle pumping minimized to reduce pump energy
- The plant consistently meets permit.

Acknowledgements

- Frank DiScuillo – Lebanon City Authority WWTP Superintendent
- Fred Updegraff – VP Gannett Fleming
- Steven Kestel – BioChem Technology
- Greg Duffy – Biochem Technology
- Matt Gray – Keystone Engineering Group (fmr. BioChem)

Thank You

Questions????

Contact:

tstahl@biochemtech.com