WWOA 2013
Advances In Control Strategies

October 2013

Outline

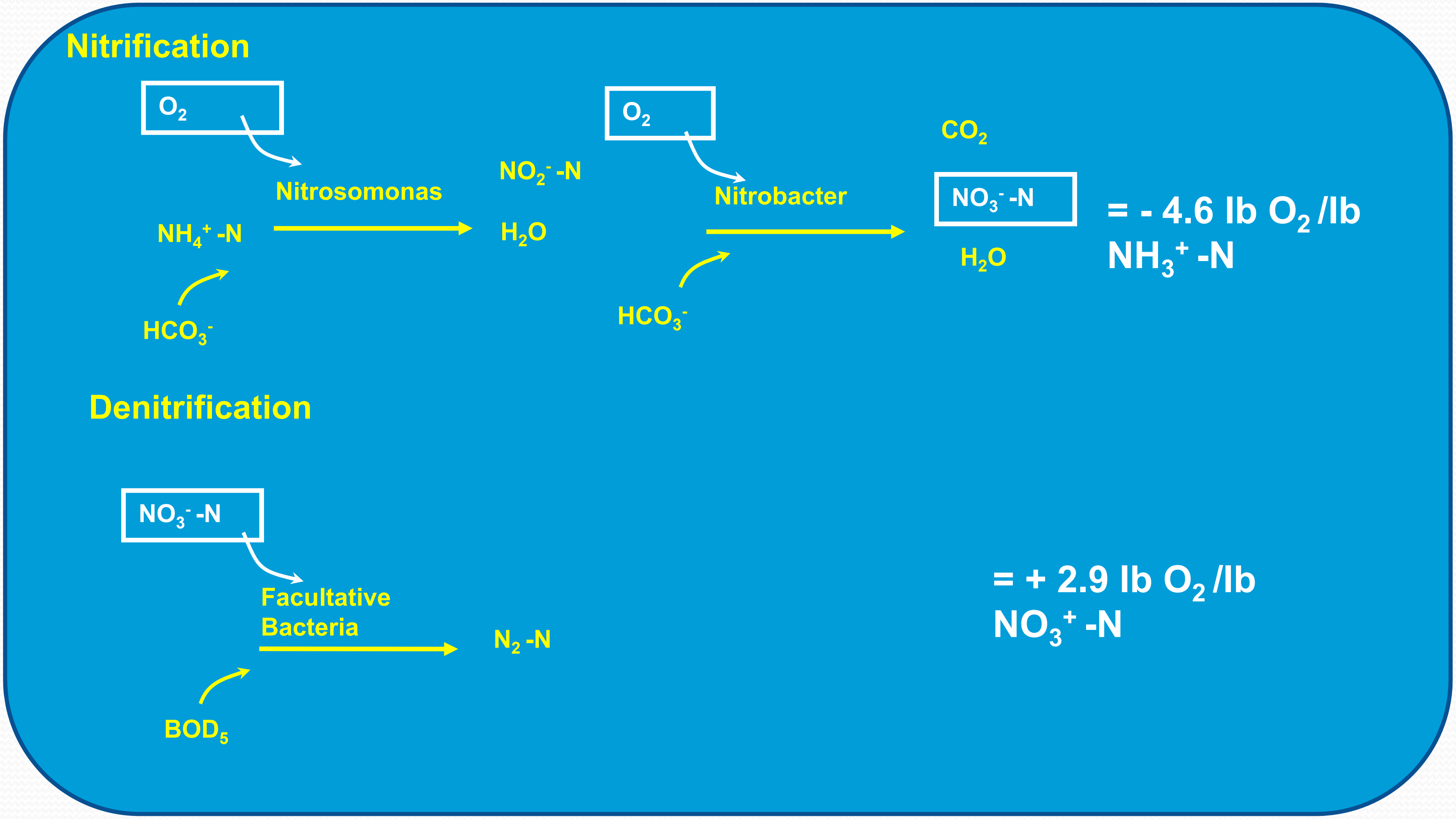
- Review of the Process Basics.
- Advances in Measurement Technology
- Advances in Control Technology
- Tighter Discharge Limits
- Cost Reduction (Chemical and Energy)
- Control Considerations
  - Control Fundamentals
  - Control Opportunities

Process Basics

Process Fundamentals

- Special Focus On
  - Nitrification – Biological removal of ammonia
  - Denitrification – Biological removal of nitrate/nitrite
  - Biological Phosphorus Removal
  - Chemical Phosphorus Removal
- Other Processes
  - BOD Removal
  - Disinfenction

Nitrification and Denitrification



Nitrification

O_2

Nitrosomonas

NH_4^+ -N

HCO_3^-

NO_2^- -N

H_2O

O_2

Nitrobacter

HCO_3^-

CO_2

NO_3^- -N

H_2O

= - 4.6 lb O_2 /lb NH_3^+ -N

Denitrification

NO_3^- -N

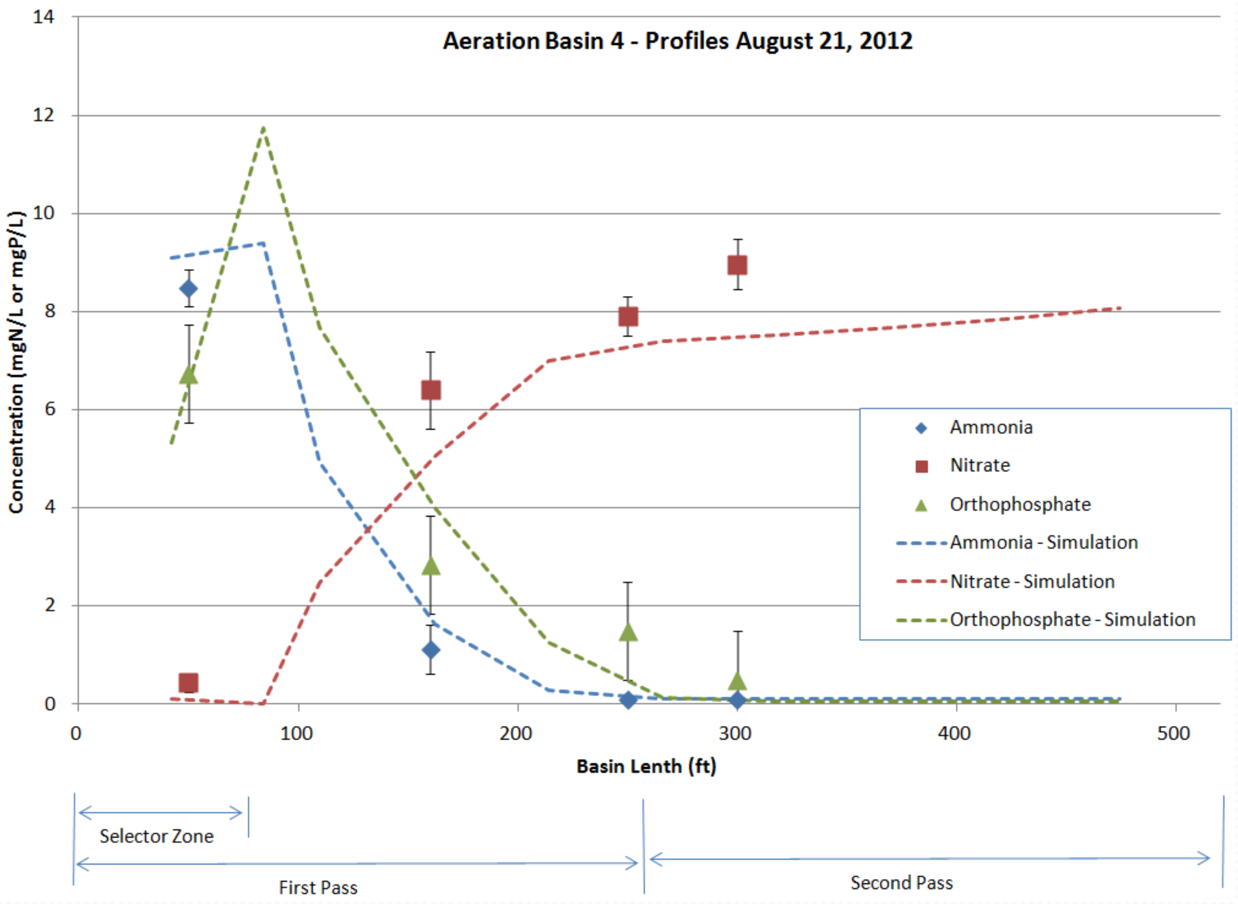
Facultative Bacteria

BOD_5

N_2 -N

= + 2.9 lb O_2 /lb NO_3^+ -N

Plug Flow Nitrification Trend



Advances in Measurement Technology

- Online Analyzers
  - Lower Capital Cost
  - More Reliable with Less Maintenance
  - Lower Consumable Costs
  - Better Accuracy

Parameters

**Limited Range and Application*

Available Parameters

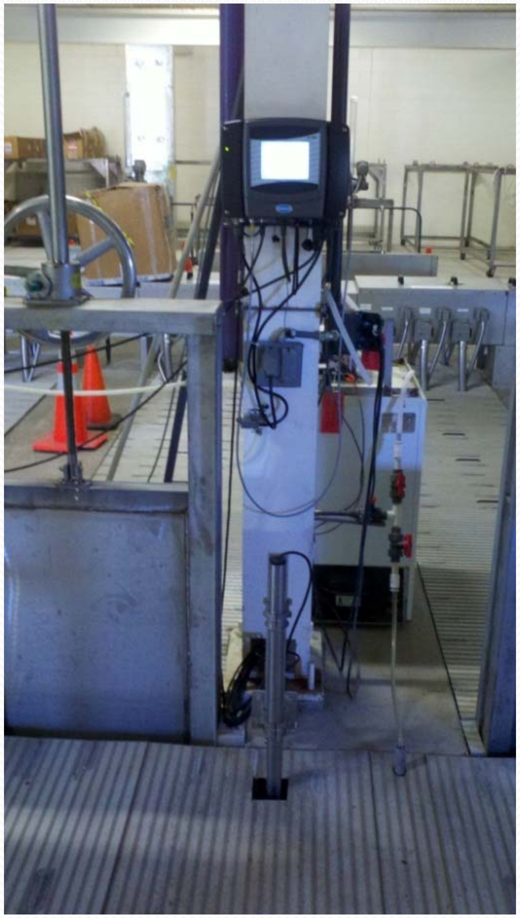
Parameters

ASA Pub #	**Parameter**	ChemScan	MODERNWATER
41	Ammonia, Free	X	
163	Ammonia, Total	X	
	Antimony		X
158	Aquatic Humic Substances (AHS)	X	
	Arsenic		X
136	Barium	X	
	Cadmium		X
162	Chloramine	X	
49	Chlorine, Free	X	
121	Chlorinie, Total	X	
133	Chrome VI	X	X
	Cobalt		X
39	COD	X	
52	Color, Aparent	X	
125	Color, True	X	
66	Copper	X	X
159	Dissolved Organic Carbon (DOC)	X	
	Gold		X
85	Hardness, Total	X	
160	Humic Matter	X	
166	Iodine	X	
141	Iron, Ferric	X	
43	Iron, Ferrous	X	
129	Iron, Total	X	X
	Lead		X
134	Manganese	X	X
	Mercury, Dissolved		X
123	Molybdate	X	X
122	Monochloramine	X	
68	Natural Organic Matter (NOM)	X	
	Nickel	X	X
56	Nitrate	X	
57	Nitrite	X	
130	Nitrogen, Total	X	
124	Nitrogen, Total Oxidized	X	
	Nutrients, Multiple	X	
	Organic Acids	X	
157	Ozone, Dissolved	X	
	Palladium		X
42	Percent Transmittance	X	
40	Phosphate, ortho	X	
132	Phosphate, poly	X	
131	Phosphorous, Total	X	
149	Polymers, Synthetic	X	
69	Potassium Permanaganate	X	
	Selenium		X
144	Silica	X	
	Silver		X
167	Solids Correlation	X	
127	Specific Absorbance	X	
128	Spectrum Matching	X	
135	Sulfate	X	
168	Sulfite, Dechlorination	X	
161	Tannin	X	
	Tellurium		X
	Thallium		X
	Tin		X
126	TOC	X	
	Toxicity, Specific Metals		X
120	Triazole	X	
67	Turbidity*	X	
	Zinc		X

*Limited Range and Application

Highlighted In-Stream Technologies

- Ammonia
- Nitrate
- Ortho-Phosphate
- Oxidation Reduction Potential (ORP)



History of Control Technology

- Programmable Logic Controllers (PLC)
  - Developed for GM in the 1970s.
  - Meant as Relay Replacement Units (Digital)
  - Originally Analog was expensive and cumbersome.
- HMI Software
  - Follow the Development of PLC by about 10 years.
  - Quickly caught up with current technology.
- Distributed Control Systems (DCS) was cost prohibitive except in the largest facilities.

Advances in Control Technology

- PLC Hardware
  - Analog Modules are less expensive.
  - Analog Modules have enough resolution to handle Process Control Applications
  - Processor have the memory and speed to handle Process Control.
- PLC Software
  - Data Structure to Support Process Control Application.
  - Additional Languages to support Process Control.
- PLC Manufactures are determined to serve this market

Tighter Discharge Limits

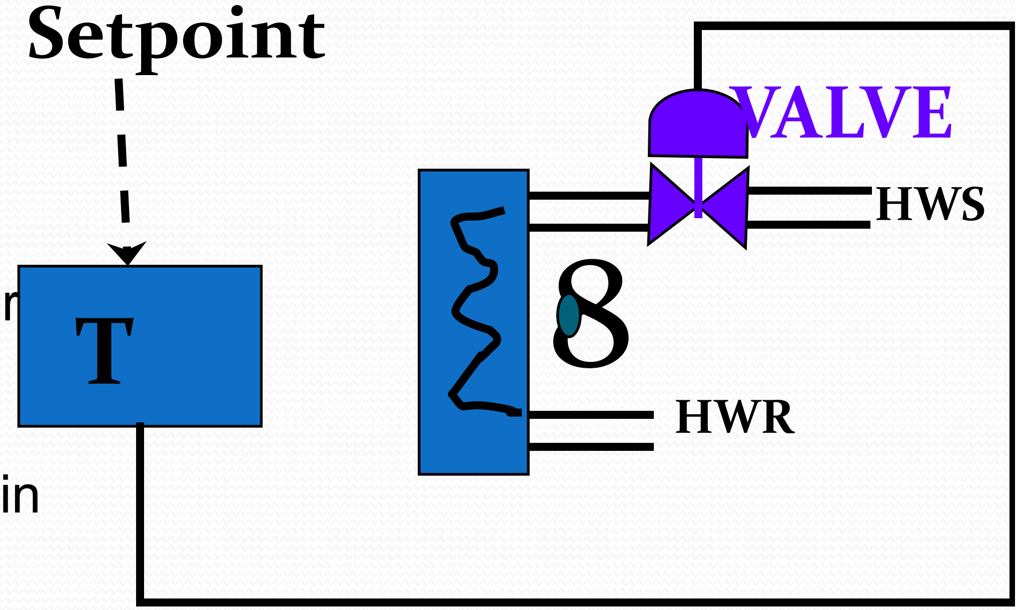
- EPA and DNR Continue to Dictate Tighter Limits on Phosphorus.
- “The DNR estimates up to 163 municipal plants may need new filtration systems that could run a total of $300 million to $1.13 billion.”
- Very little point in belaboring this issue.

Cost Reduction

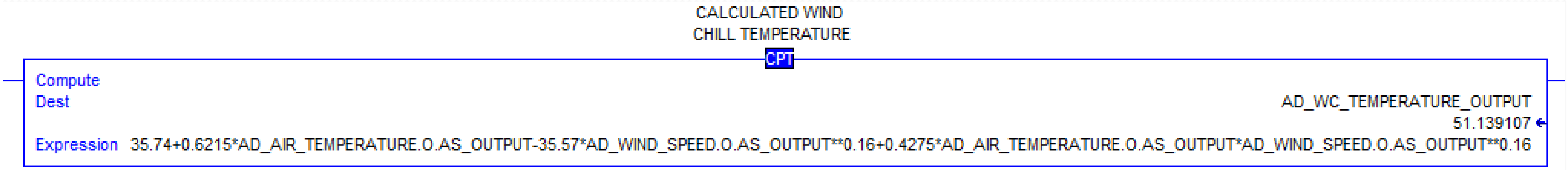
- It is oblivious if there was a magic money tree it is gone.
- Energy savings has always made sense when cost effective.
- Lowering Chemical Costs makes sense.
- Lowering Chemical Usage minimizes the chemical byproduct effects on waterways

Control Fundamentals

- To Control a Parameter it Must be Measured.
- To Control a Parameter there must be a Controllable Device. (VFD, Valve, Gate Position, etc)
- More Information is always better then less.
- Math and Algorithm Capabilities in PLCs are unlimited. (Add, Sub, Mult, Divide, Square Root, All Trig Function, Log, Ln and Compute)



Algorithm Example



```
CALCULATED WIND
CHILL TEMPERATURE
CPT
Compute
Dest        AD_WC_TEMPERATURE_OUTPUT
            51.139107
Expression  35.74+0.6215*AD_AIR_TEMPERATURE.O.AS_OUTPUT-35.57*AD_WIND_SPEED.O.AS_OUTPUT**0.16+0.4275*AD_AIR_TEMPERATURE.O.AS_OUTPUT*AD_WIND_SPEED.O.AS_OUTPUT**0.16
```

Control Opportunities

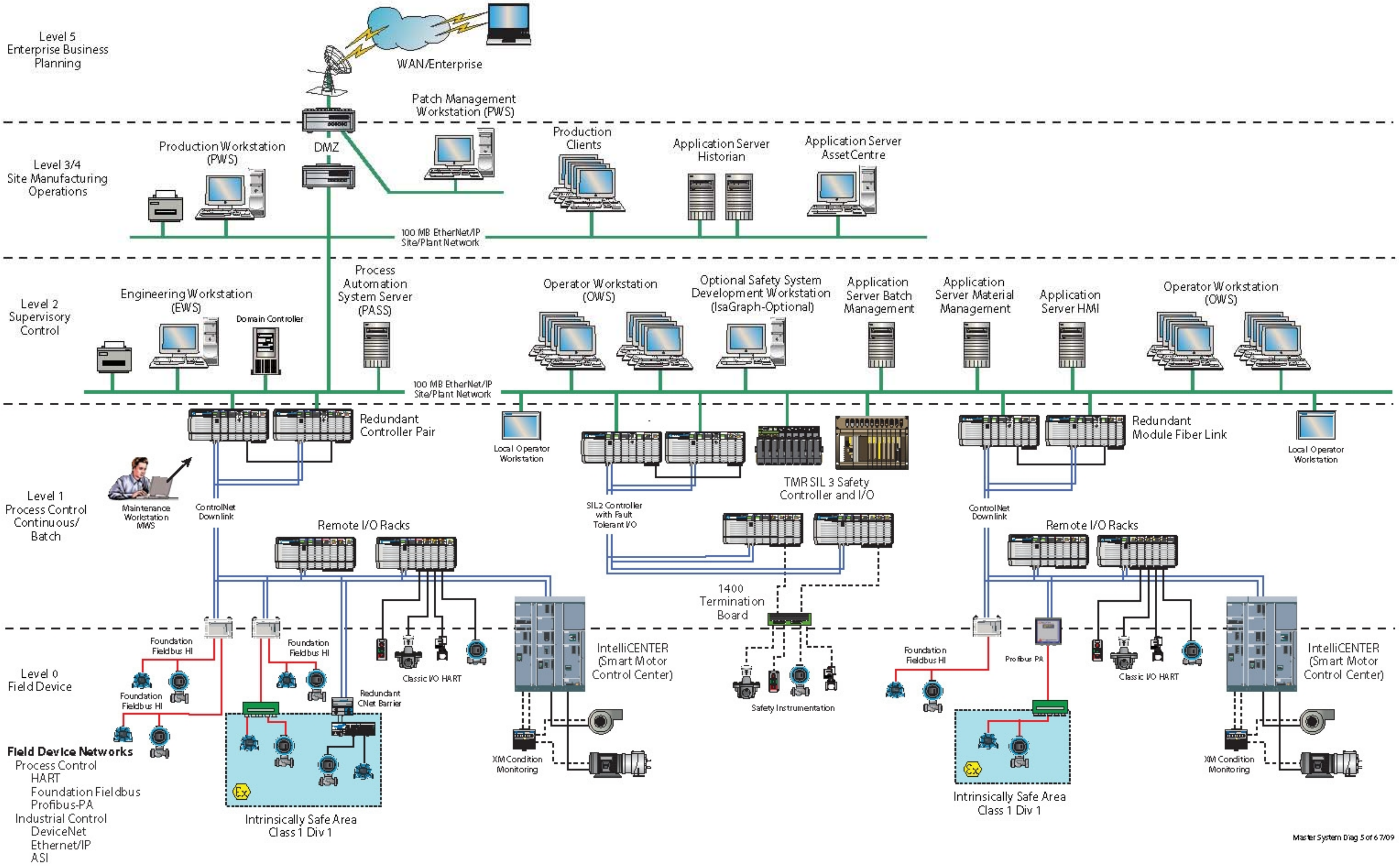
Overview of Process Control Systems

- Field Instrumentation
- Control Devices (usually PLCs)
- Human Machine Interface (Hardware and Software)
- Process Historians
- Reporting Systems

Rockwell Automation

Process Control Multi Server/Multi Client System

PlantPAx
Process Automation System



Field Device Networks
- Process Control
  - HART
  - Foundation Fieldbus
  - Profibus-PA
- Industrial Control
  - DeviceNet
  - Ethernet/IP
  - ASI

Master System Diag 5 of 6 7/09

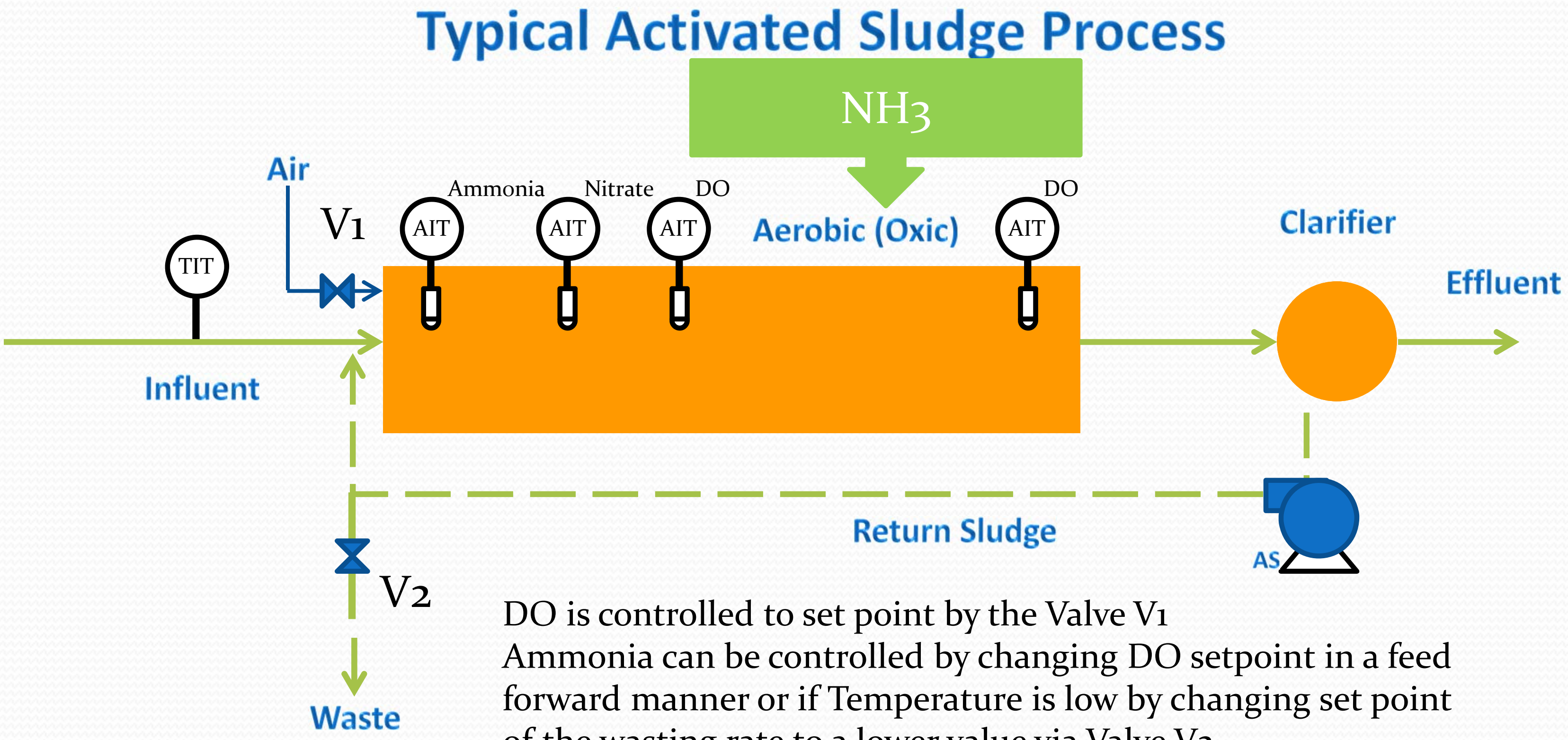
Data, Information, Knowledge and ***Control***

- Data – Your daily log sheets
- Information – Charting or Trending the log sheets
- Knowledge - Seeing patterns that answers the How questions
- Control - Implementing Systems to Control what we now have Knowledge of.

Key

Nitrification – Ammonia Removal	NH3
Denitrification – Nitrate Removal	NO3
BPR – Biological P Removal	P_{BPR}
CPR – Chemical P Removal	P_{CPR}

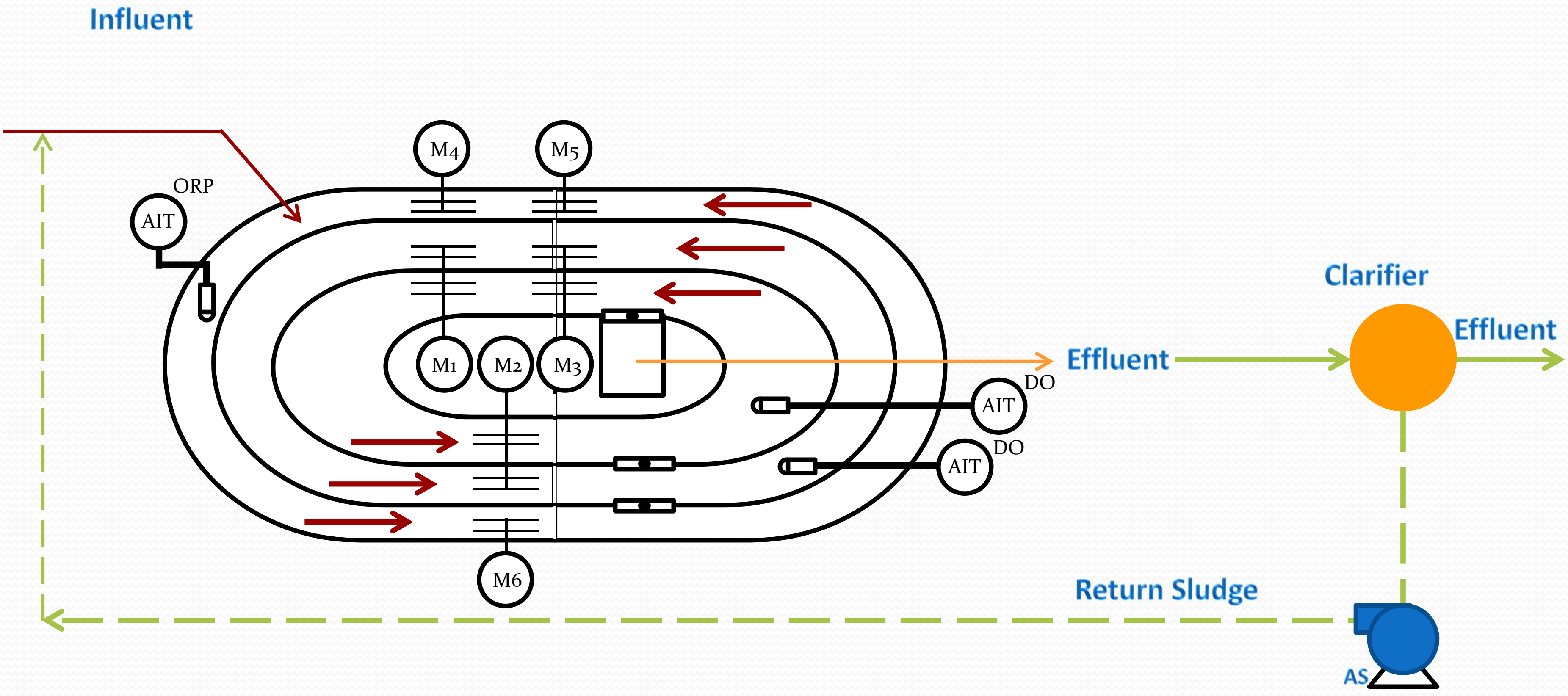
Plug Flow Process with Nitrification



DO is controlled to set point by the Valve V1
Ammonia can be controlled by changing DO setpoint in a feed forward manner or if Temperature is low by changing set point of the wasting rate to a lower value via Valve V2

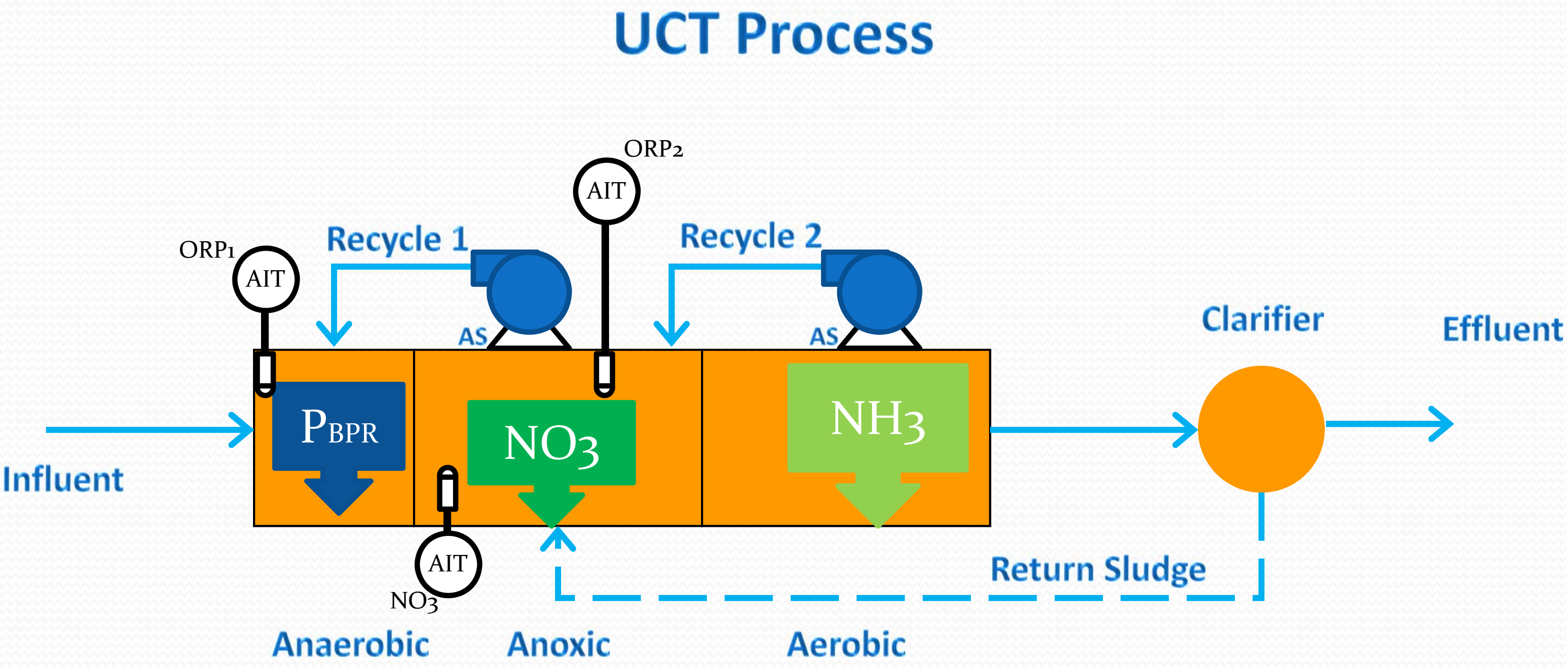
Simple BPR Process

Simple BPR Process
(A/O Process)



DO controlled by changing the speed of Aerator Motor M1,2,3
ORP controlled by changing the speed of Aerator M4,5,6
ORP could be affected by the return rate.

BPR Process



ORP1 can be controlled by changing the speed of Recycle Pump 1
ORP2 can be controlled by changing the speed of Recycle Pump 2
Nitrate can be controlled by changing Recycle Pump 2 Rate with
the nitrate being the master variable in this zone.

The Phosphorus Calculation

- By measuring the mg/l of Phosphorus and the Total Influent Flow to the Plant, the Total Phosphorus entering the plant can be determined:

  Total P (lb/day) = Phosphorus mg/l * Plant Flow MGD * 8.34

- Calculate the pounds of Fe required by the equation (based on 1:1 molar ratio):

  Fe Req'd (lb/day) = Total P (lb/day) *1 mole P/31 lbs P*
  1 mole Fe/1 mole P *55.85 lb P/1 mole Fe

The Final Calculation

- Include Nullification Ratio of Fe to Phosphorus

  1.6 Moles Fe/1 Mole Phosphorus (Typical range 1.6-2 in an activated sludge plant)

  Fe Req'd (adjusted) (lb/day) = 1.6 * Fe Req'd (lb/day)

- Final Calculation to Determine $FeCL_3$ Flow Rate:

  $FECL_3$ Flow Rate (gpd) = Fe Req'd (adjusted) (lb/day)
  *162 lb $FeCl_3$/55.85 lb Fe * 1 lb solution/ 35% solution
  * 1 gallon / (8.34 * SG)

  $FeCl_3$ Solution per hour = Flow Rate (gpd)/24

The Cost Savings

- Flow Pace Only vs. Phosphorus Calculation
- Plant under normal conditions 12 MGD and 7 mg/l P
- Flow rate in a Rain Event goes to 30 MGD at 2.8 mg/l. Gallons of Solution goes to 158 gallons per hour but should be only 67 gallons per hour. Cost per hour lost is $113.
- Night time flows go to 6 MGD and Phosphorus goes to 5 mg/l. Flow rate of Solution goes to 31 gallons per hour but should go to 23 gallons per hour. Cost per hour lost is $10.

Questions?