University of California, Los Angeles

Dissolved Oxygen Control – What to Expect and How to Avoid Pitfalls

Michael K. Stenstrom

Professor, Civil and Environmental Engineering Department

Outline

- Terminology
- Benefits of DO Control
- Typical Feed Back System in an Air Plant
- Turn Up and Turn Down Mechanisms
- Problems and Hunting
- High Purity Oxygen Applications
- Maintenance and Economics
- Conclusions

Energy Savings

- Maintaining “proper” DO can save significant energy at activated sludge plants, averaging as much as 30% of the power used for aeration
- Aerator power is often 50% of the plant’s total power
- Improper DO control systems can waste energy over uncontrolled cases and can cause accelerated equipment failure

Provide Adequate DO for Organisms

- DO requirement for organisms
  - Function of oxygen uptake – high uptake requires higher DO
  - See Jenkins et al for critical DO required as a function of F/M ratio
- Nitrification
  - Nitrification typically requires higher DO than carbon-only removal systems
  - Higher DO required for nitrification at marginal SRTs – at lower SRT, higher DO helps the reliability
- Conventional Wisdom:
  - 0.5 mg/L for carbon-only
  - 2.0 mg/L for nitrifying systems
  - Simultaneous nitrification/denitrification can occur with high uptake rates even at DO = 4.0 mg/L.

Case Histories

- Case histories show that 10 to 58% reduction in blower energy costs can be achieved with good DO control systems
- Effluent variability is reduced with good control, increased with poor control
  - Improved BOD and COD removals
  - Reduced SVI
  - More consistent nitrification

Issues for DO Control

- Probe calibration
  - Always required – no free lunch
  - Expect to calibrate at least weekly
  - If you don't commit to calibrate, don't bother to install a control system
  - It is cost effective to use DO and calibrate, yet it is often not performed, because it is too troublesome for the operators or staff
  - Designers need to facilitate probe calibration. Designs that require excessive time or skill to remove probes for calibration insure that calibration will not be performed.

Examples of Feed Back Control

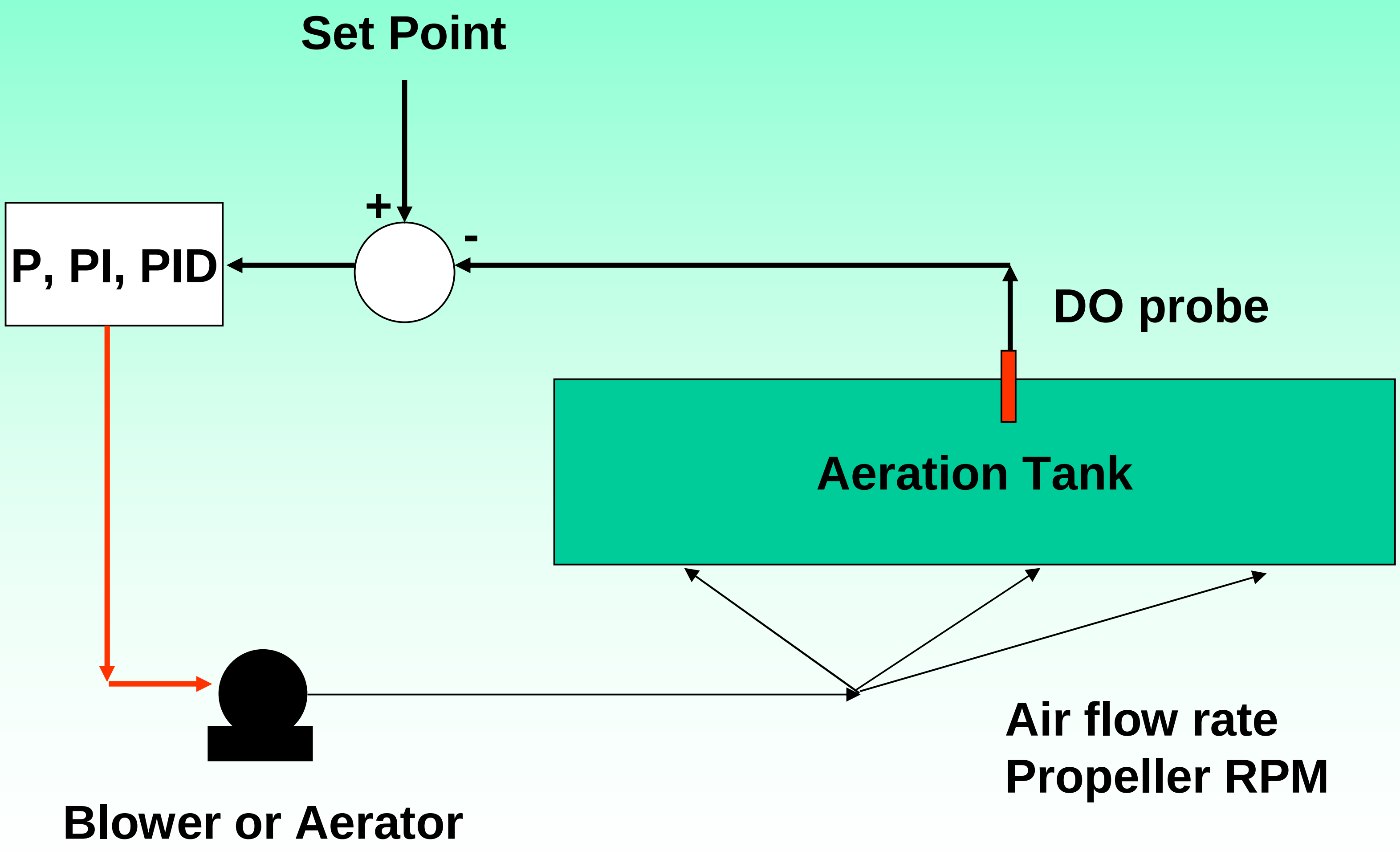
- An operator selects the desired DO concentration, called a set point
- A DO sensor measures the actual DO and an electronic circuit compares the two values and the difference is the error
- A controller manipulates a blower or aerator to adjust the aeration rate to change the measured DO to the set point

The relation between the error and the change in aeration rate is the function of the control law

The classic control laws are proportional to the error, or the integration of the error or the derivative of the error. Simple laws use on-off or differential gap (dead-band).

Control laws require tuning, meaning that the performance is a function of site-specific parameters that are dialed or programmed into a controller

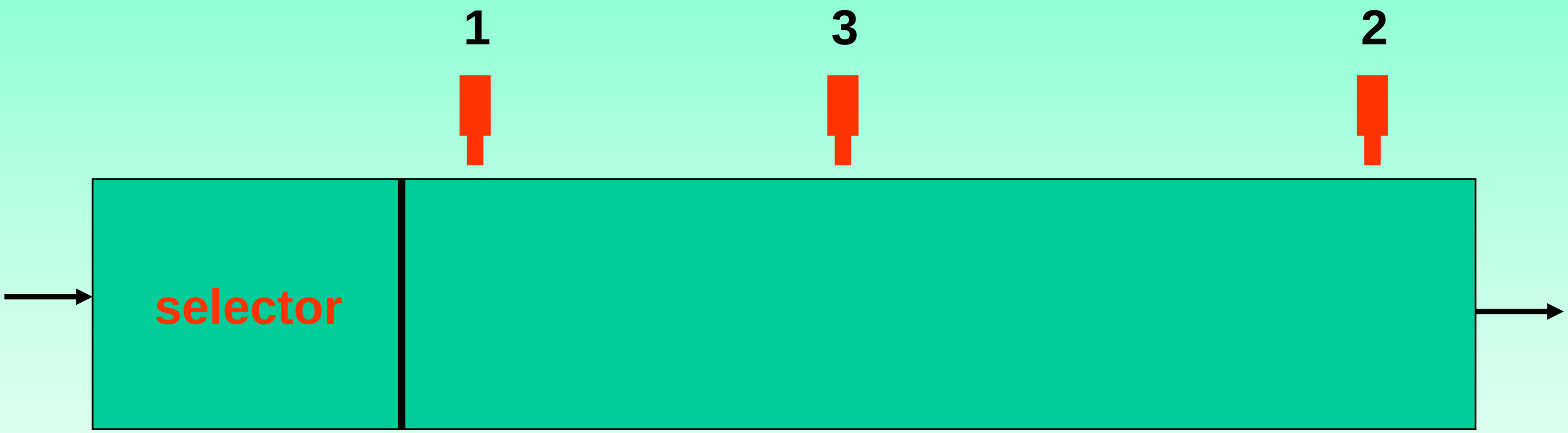
Diagram of a Controller



Difficulties

- The previous slide shows the difficulties:
  – A reliable DO signal must be obtained
  – The DO in the entire tank is manipulated, but there is usually only one DO probe.
  – Where to put it?
  – The blower or aerator must have “turn up” or “turn down” capabilities

Where to Monitor?



Location 1 – Generally results in excessive overall tank DO

Location 2 – Generally results in insufficient overall tank DO

Location 3 – Best compromise

Turn Up and Turn Down

- Depends on the device
  - Positive displacement (PD) blowers have constant flow rates
  - Centrifugal blowers operate best over a narrow range of pressures with some variability of flow, but often at reduced efficiency
  - Surface aerators usually operated a fixed speed

PD Blowers

- Usually for smaller plants
- Can be throttled on the suction with limited benefit
- Often used in combinations that provide discrete steps of air flow with dead band controllers
- Good candidates for variable frequency drives (VFDs)
- New VFDs are efficient and have largely solved the electrical noise problems

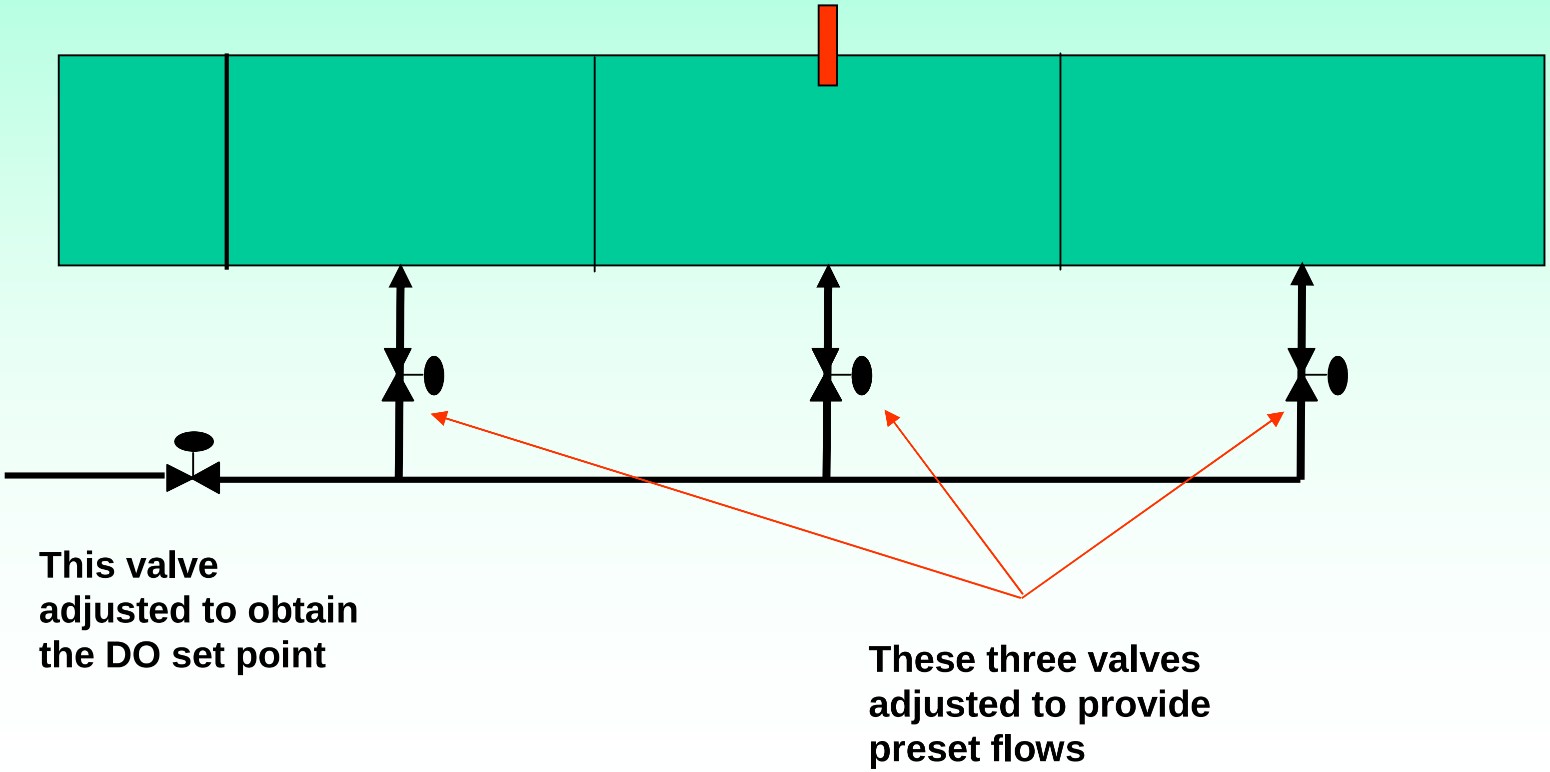
Centrifugal Blowers

- For medium and large plants
- Multi and single stage
- Larger models have inlet guide vanes that can adjust the curve to allow turn up or down within a range of pressures
- Newer models have both inlet guide vanes and outlet diffusers that extend this flexibility
- The use of vanes and diffusers usually requires a proprietary controller, and there are mixed stories of successes and problems
- Limited number of manufacturers
- Recently manufacturers have been providing VFDs for centrifugal blowers

Surface Aerators

- **High speed**
  - vary the number in service
- **Low speed**
  - Vary the number in service
  - Dual speed motors (900 or 1200 RPM)
  - Vary propeller submergence for certain types of propellers
  - VFD speed control

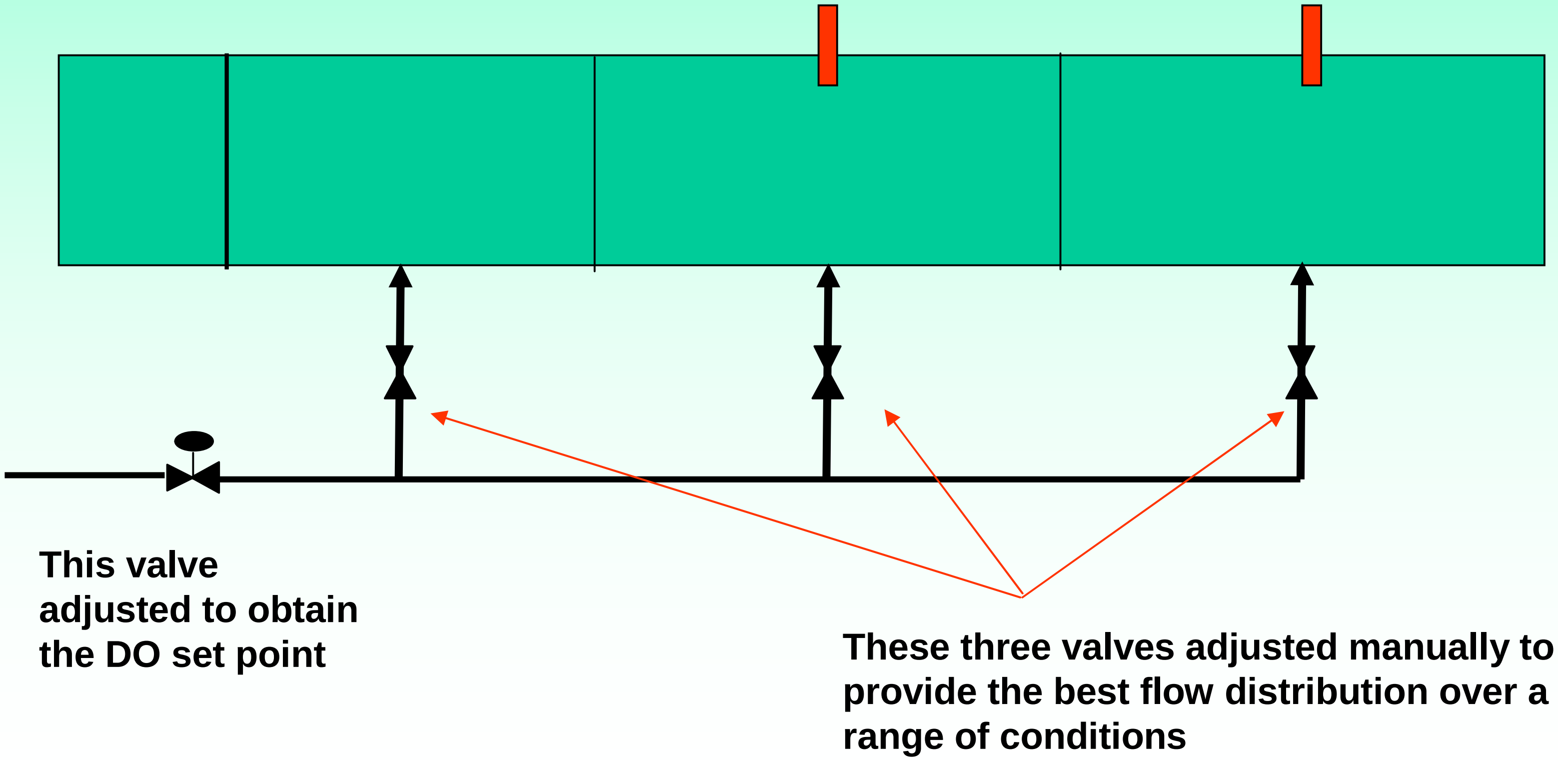
An Example Using Multiple Grids in a Plug Flow Tank



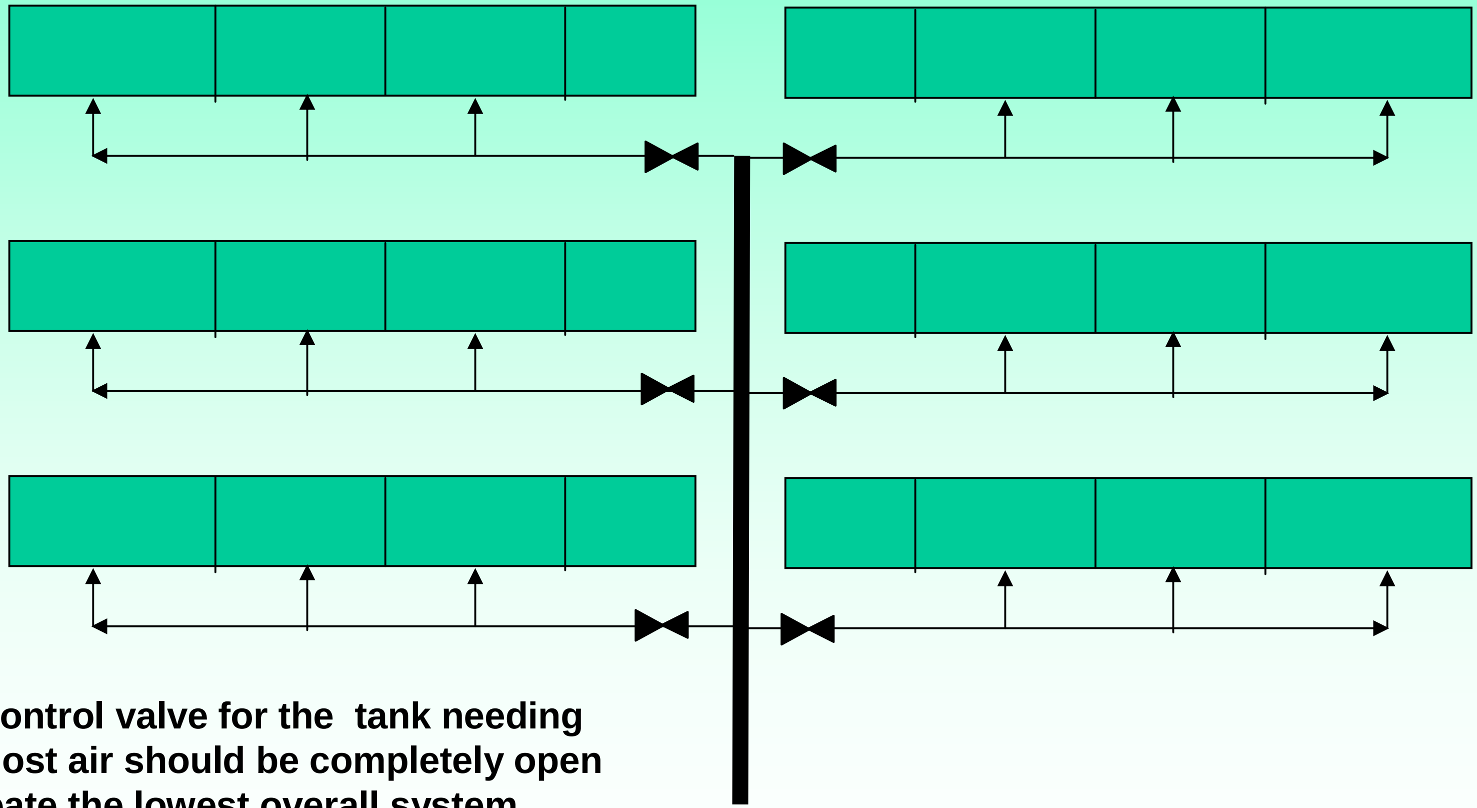
Problems

- Overly complex
- Four times the maintenance
- Hunting – smaller errors cause incorrect valve positioning with poor air distribution, and the controller constantly hunting for the set point
- Excessive ware
- Frustration
- Operators put the system into manual and energy is wasted

A Better way of Using Multiple Grids in a Plug Flow Tank



Multiple Tanks and the Open Valve Rule



The control valve for the tank needing the most air should be completely open to create the lowest overall system pressure

Control System Hunting with Multiple Tanks

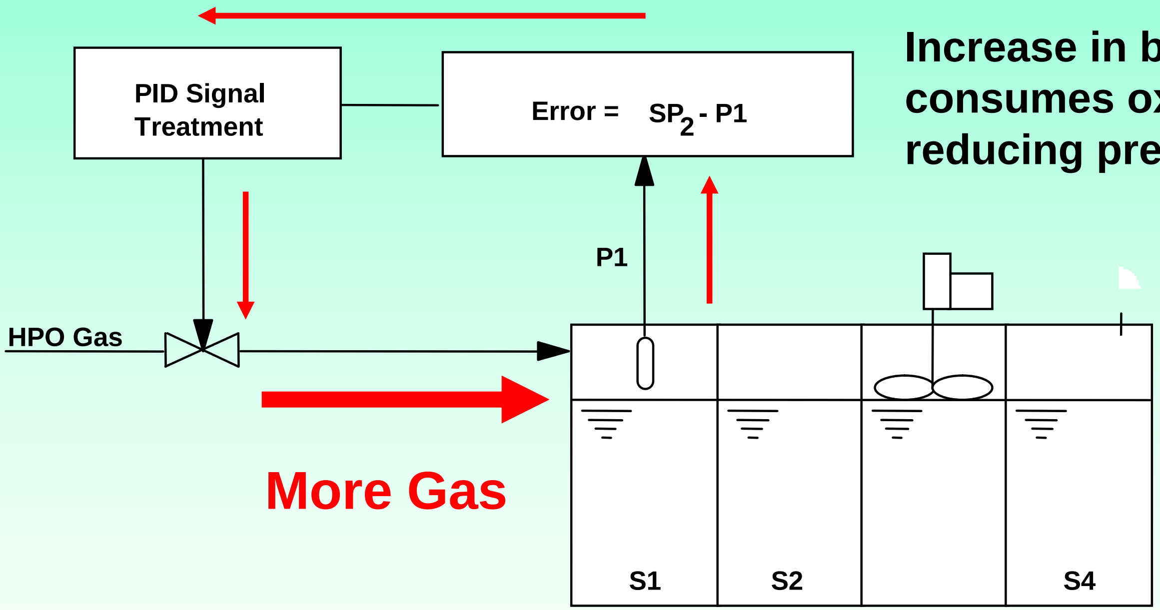
- An example of hunting
  - Tank 1 has low DO and the controller calls for more air by opening the valve
  - Tank 1 gets some air from increased blower output, but also robs air from other tanks
  - This causes another tank to need more air, and opens its valve, robbing more air from other tanks
  - Soon, multiple tanks are needing more air and an additional blower is turned on.
  - Next the DO rises in all tanks and one tank reduces air flow by closing its valve
  - The additional air is now directed to other tanks which soon have excessive DO
  - Additional valve closures occur and very soon there is excess air and a blower is shut down
  - This causes the air to decline to all tanks and a tank calls for more air and the process starts all over again

Cures for Control System Hunting with Multiple Tanks

- **Reduce gains so that more time is allowed for equilibration. This may cause more overshoot or undershoot but reduces the possibility of hunting**
- **Blowers with guide vanes and outlet diffusers have a better chance at avoiding this problem because they can better compensate for changes in system pressure**
- **Use limits on minimum and maximum air flow rates**

DO and Gas Purity Control in High Purity Oxygen (HPO) Activated Sludge Plants

Pressure Feedback to Increase HPO Gas Feed

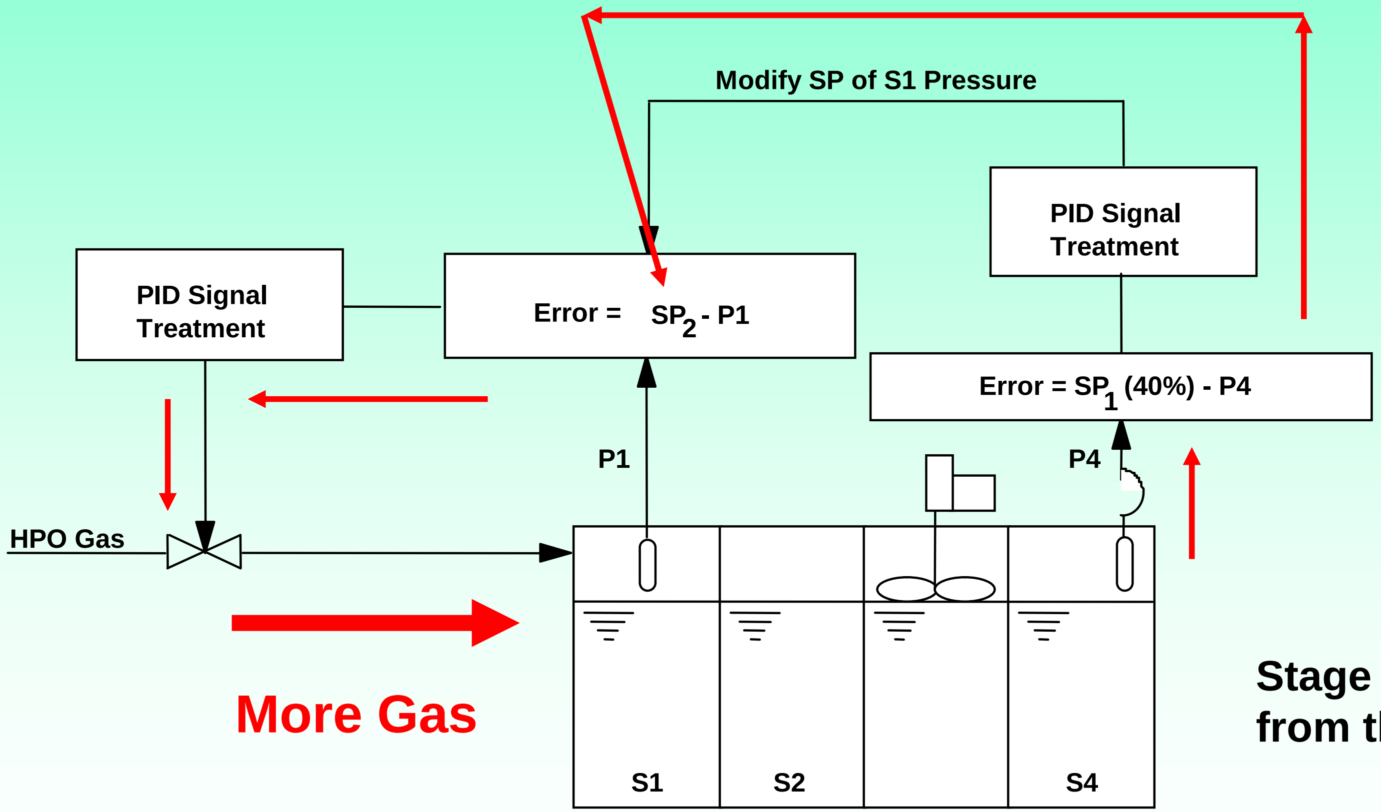


Increase in bioactivity consumes oxygen, reducing pressure.

Pressure Feedback Control

- Used at many plants without problems to regulate HPO gas flow. Saves energy and works well
- At other plants, it seems that a noisy signal prevents proper control, and operators revert to manual control, to stabilize the process but at extra energy cost

Stage 4 Purity Trim

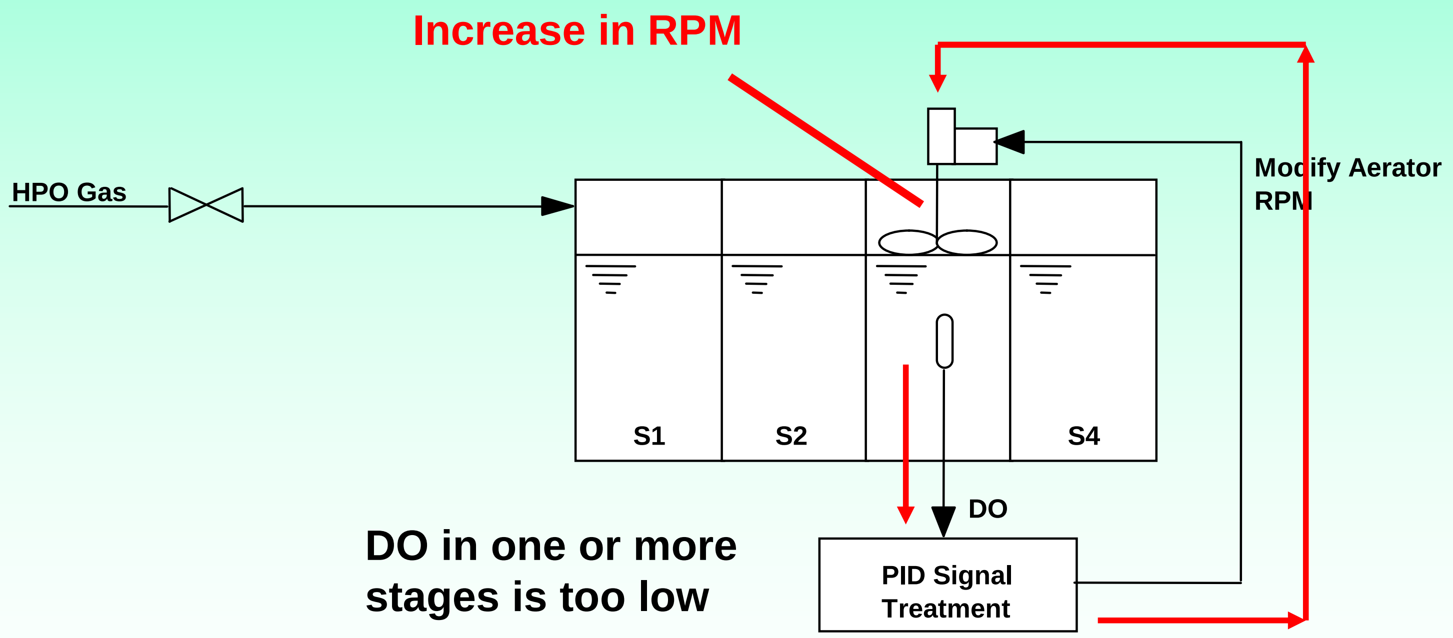


Stage 4 purity decreases from the desired set point

Stage 4 Purity Trim

- Not many plants use an automatic trim, but it works well and is a slowly responding signal. If gains are too high, then "hunting" and instability can occur
- Often, a "person" acts as the feedback control by manually adjusting the pressure set point

DO Control


Increase in RPM
HPO Gas
Modify Aerator RPM
S1
S2
S4
DO
PID Signal Treatment
DO in one or more stages is too low

DO Control

- The availability of variable frequency drives makes in much easier to control aerator RPM and DO
- Energy savings can be obtained at many plants by modifying stages 3 and 4
- DO control in Stage 1 is rarely needed

Questions????

www. seas . ucla . edu / stenstro

stenstro @ seas.ucla.edu