



# DO/Nmaster™ White Paper

Precise aeration control for energy-efficient, low dissolved oxygen nutrient removal

## Summary

Aeration is the largest single energy use at most activated sludge plants. Operating the aerobic zones at low dissolved oxygen (DO) reduces that energy while maintaining nitrogen removal, but only if DO, airflow and ammonia are controlled precisely. Conventional PID control cannot provide that precision. DO/Nmaster, a machine-learning based real-time control system, replaces PID control and has been proven at full scale: at the City of Chico, a 2018 control project built around DO/Nmaster reduced aeration energy per pound of oxygen demand by 47.6%, verified under a PG&E program; at the Pomona Water Reclamation Plant of the Los Angeles County Sanitation Districts, after replacement of the blowers had reduced blower energy by 34%, lowering DO with DO/Nmaster and SRTmaster added a further 30%, in a demonstration funded by the U.S. Department of Energy.

## 1. Why aeration control matters

The long-standing practice of holding aerobic-zone DO at or above 2 mg/L is mostly a safety margin against losing nitrification, not a biological requirement. Rising energy costs, carbon reduction goals and tighter nutrient limits are moving plants to lower DO. At low DO, nitrogen is increasingly removed by simultaneous nitrification and denitrification inside the aerated zones. The margin, however, is narrow: ammonia removal is highly sensitive to very small changes in operating DO. At the Pomona Water Reclamation Plant, reducing the average DO by only 0.03 mg/L doubled the effluent ammonia concentration. Low DO operation is therefore as much a control problem as a process problem.

## 2. Why conventional control falls short

1. **Non-linear control elements.** Butterfly valves and blower vanes are non-linear: a change of two to three degrees in valve opening can double the airflow. PID control applies a fixed linear formula and cannot follow this behavior accurately.
2. **Interacting loops.** Each valve and blower loop traditionally operates independently. The loops interfere with one another, causing valve and blower hunting and unstable airflow.
3. **Slow measurement.** An actuator can move several degrees in a second; airflow meters must respond as fast as the airflow changes.
4. **Wasted pressure.** Control must keep valves as open as possible, so that blower energy is not spent overcoming the headloss of partially closed valves.

At Pomona, under DO setpoints varied between 0.5 and 2 mg/L, the average DO control error was 0.20 mg/L (20%) with tuned PID control.

### 3. The DO/Nmaster approach

DO/Nmaster replaces the PID loops with control that learns from the plant's own operating data. It consists of:

- **A data filtration database.** All incoming and outgoing data is filtered and stored. Every reading is checked before it is used. Faulty readings are detected and not acted on, and operators are alerted.
- **Machine-learning control modules.** For each aeration grid, the modules calculate setpoints for airflow, DO and valve position. The loops can operate independently or as one coordinated aeration control structure, with the blowers following the airflow demand of the grids.
- **Ammonia-based aeration control.** Ammonia can be made the master control parameter, with DO setpoints calculated from it, and the DO profile along each tank is adjusted to use no more air than the process needs.
- **Operator interface and historian.** Operators set setpoints and control limits and review custom charts.
- **Standard communication.** DO/Nmaster runs on a Windows-based computer and exchanges data

with the plant SCADA system using the standard OPC protocol. The existing PLCs or DCS continue to operate the valves and blowers.

### 4. Instruments

Precise control needs instruments that are fast and accurate enough. At Pomona, the airflow meters had a time constant of 0.18 seconds, and the modulating actuators, designed for continuous process control, had a position accuracy of 0.1%. DO and ammonia analyzers complete the measurement set. These instruments can be bought from any supplier. Ekster & Associates sells no hardware, but provides recommended performance specifications.

### 5. Field results

#### Airflow.

At Pomona, the average airflow control error was 0.75% and the median 0.25%, with butterfly valves. This is comparable to linear-characteristic valves. At the City of Chico, machine-learning valve models have controlled airflow since 2019 with a median error of 2.9%.

### **Dissolved oxygen.**

At Pomona, the average DO control error was 0.06 mg/L (6%) with DO/Nmaster, against 0.20 mg/L (20%) with tuned PID control under the same conditions.

### **Energy.**

At the City of Chico (12 MGD design), a 2018 control project built around DO/Nmaster (DO/Nmaster; 15 automated valves; 15 airflow meters; 3 ammonia meters; DO meters increased from 6 to 15; centrate storage with night-time injection; improved blower sequencing), with the existing blowers and diffusers, reduced aeration energy per pound of oxygen demand by 47.6%, saving 1,198,692 kWh per year, as verified under PG&E's California Wastewater Process Optimization Program. At Pomona (15 MGD), aeration energy fell from 1,300 to 550 kWh per million gallons of influent (kWh/MG). Replacing 50-year-old centrifugal blowers with high-efficiency blowers reduced blower energy by 34%; lowering the DO setpoints with DO/Nmaster and SRTmaster added a further 30%.

### **Nitrogen.**

At Pomona, total inorganic nitrogen removal averaged about 84% both before and after the transition to low DO, and ammonia was controlled precisely enough to reduce, or eliminate, the aqueous ammonia added for chloramination.

### **Reliability.**

DO/Nmaster has been in service at Chico since 2018, and at Pomona since the U.S. Department of Energy demonstration.

## **6. Operator authority**

DO/Nmaster acts automatically, but operators keep authority over the process. They can override the system at any time and set the setpoints and limits within which it operates. Faulty sensor readings are detected and not acted on, and operators are alerted to abnormal sensor and actuator behavior.

## **7. DO/Nmaster and SRTmaster together**

Low DO operation depends on a stable biomass. SRTmaster holds the sludge age close to its target; at Pomona the average SRT control error was 0.13 days, less than 2%. The two systems share one architecture and operate together.

## **8. Next step**

A free plant assessment estimates the saving for a specific plant. Send one year of operating data and energy bills. You will receive a written estimate of savings in kWh and dollars, the assumptions behind it, any changes required before installation, and a fixed price. If your plant is already operating efficiently, the estimate will say so.

## References

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