Modernization of the UNOX-U Plant Instrumentation and Controls
Water and Sewer Authority of Cabarrus County
Rocky River Regional WWTP
Concord, North Carolina

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ABSTRACT: In the mid 1970s a two step oxygen activated sludge (OAS) nitrafication system was put on line at the Rocky River Plant of the Water and Sewer Authority of Cabarrus County in Concord, North Carolina. The system consisted of a 1st step for carbonaceous removal consisting of three trains with three stages each and a 2nd step for nitrogenous removal consisting of six trains with three stages each. The installed nameplate horsepower in the 1st step was 150, 75, and 60 and in the 2nd step was 40, 30, and 30. The oxygen supply was from a cryogenic distillation plant with a distillation column nominal capacity of 80 tons per day and a compressor capacity of 70 tons per day at 70^{O}F and 50% RH. The control system was manually set and implemented by analog pneumatic controllers. The design was based on the following influent conditions:

	1st STEP	2nd STEP
Flow, MGD	31.5	33.6
BOD_5, mg/l	250	28
COD / BOD_5	2.3	4.9
TSS, mg/l	100	85
NH_3-N, mg/l		15
TKN-N, mg/l		20
Alkalinity		300
Temperature	10-28^{O}C	

The plant operated successfully in this process mode for over twenty five years.

In the late 1990s Black & Veatch studied future options for the facility. A decision was made to retrofit the existing 2 Step process into a 1 Step process. The new system would have 12 similar trains. Designated oxygenators would then be retrofitted to 30 nameplate horsepower with new gearboxes. All analog pneumatic controllers would be converted to electronic

controllers. New electronic instrumentation would be provided. The oxygen activated sludge (OAS) system and cryogenic distillation oxygen production plant would be put on integrated direct digital control via PLCs. Control then would be automatic with manual inputs by the operators to adjust for changing influent load conditions. Consideration was given to potential future effluent requirements for total nitrogen control. Thus a criterion was set to maintain dissolved oxygen in the final oxygen activated sludge system stages of 2-4 mg/l. This would allow any future anoxic stages to be designed at a considerably reduced size; since last stage dissolved oxygen levels in OAS systems usually have dissolved oxygen levels upwards of 15-20 mg/l.

The new design was based on the following influent conditions:

	Minimum Month	Maximum Month	Peak Day
Flow, MGD	10	34	78.4
BOD_5, mg/l	80	151	32
TSS, mg/l	60	170	
TKN-N, mg/l	18	25.5	16
Alkalinity	100-400	100- 400	100-400
Temperature	16-28^{O}	16-28^{O}C	16-28^{O}C

The retrofit of oxygen dissolution equipment and instrumentation/controls was accomplished during the period of 2002-2003. There were some initial problems during the initial test period in matching the required oxygen transfer rates and mixing requirements to maintain K_{La}s necessary to attain a dissolved oxygen level of 2-4 mg/l; however the final performance test indicated good control of dissolved oxygen within the range specified. The automatic control system is running and while operator intervention is required when load changes occur it is functioning well. This is the first instance where both the oxygen dissolution and cryogenic distillation oxygen production subsystems have been integrated and put on automatic PLC control at any of the more than 75 such facilities installed.

KEYWORDS:

Digital Control; Automatic Control of Oxygen Production and Dissolution; Rocky River Plant, WSACC

INTRODUCTION

This paper illustrates that twenty year old wastewater systems need not be abandoned and replaced. It shows that older plants can be rejuvenated with modern control technology to provide cost effective operation. A description of the evaluation process, the original control system, the development of specifications and plans for the retrofit, and the design of the new control system are given. Details of the performance testing are illustrated.

FUTURE PLANNING FOR THE ROCKY RIVER REGIONAL WWTP

The Water and Sewer Authority of Cabarrus County was faced with a normal problem in a growing area. Their 24 MGD high purity oxygen activated sludge plant was nearing capacity. The liquid train portion of the existing plant consists of influent screening and pumping, four primary clarifiers, a first stage high purity oxygen basin consisting of three aeration trains with three cells per train, four first stage secondary clarifiers, an Archimedean screw type lift station to return all flow to the second stage, a second stage high purity oxygen basin consisting of six trains with three cells, per train, four second stage final clarifiers, disinfection, and discharge to the Rocky River. Black & Veatch was brought on board in a master planning effort to determine the most cost effective long term plan for expanding the WWTP.

The primary considerations in the master planning effort were cost effectiveness, efficient utilization of the available site, staged expansions to more than double the current flow, 34 MGD. All feasible options were considered, including conversion of the high purity oxygen process to diffused air. With the sunk cost of the existing cryogenic plant, and the concern that the clean air regulations may be leading toward controlling control of VOCs from aeration processes, it was both cost effective and desirable to stay with the high purity oxygen process. However much of the equipment was nearing the end of its useful life and spare parts were getting harder to find. So costs were included for updating the old pneumatic controllers at the cryogenic plant and high purity oxygen basins with solid state controllers and providing a more automated method for controlling dissolved oxygen in the basins.

The site area between the HPOAS basins and the river did not allow for addition of sufficient final clarifiers to meet the future flows required. This combined with the more efficient handling of flows since repumping to second stage could be avoided, was sufficient reason to convert the two stage operation to a single stage process. Immediately the number of final clarifiers currently available was doubled and expansion of the plant to 30 MGD could be achieved without constructing additional clarifiers. Also the mixing energy was greatly reduced when the influent loads were spread out rather than concentrated into the first stage. Still a good way to control the DO within each basin train was desired.

ORIGINAL CONTROL SYSTEM DESCRIPTION

The control for the oxygen plant (U plant) and the oxygen dissolution system (UNOX®) originally installed by the Union Carbide Linde Division was by means of local analog analyzers connected to a pneumatic control system. The control logic was embedded in the pneumatic system's controllers. This was standard instrumentation for that time period, the early 1970s. The primary parameter for control of the overall system and thus all subsystems was the pressure in the head space of the first stage of each oxygen activated sludge train. The set point for this was 2-3" of water gauge pressure. This control concept is based on the fact that the biomass in the reactor exerts a varying demand for oxygen dependent upon the carbonaceous and nitrogenous loads entering the plant. If the load increases the oxygen demand will increase as the biomass respires more. Oxygen will be taken from the gas space and the pressure will drop signaling a need for more oxygen production. If the load decreases, less oxygen will be taken from the gas space as the biomass slows its respiration. The pressure will increase as oxygen flows in and this will signal a need for less oxygen production. The pressure thus set the position of the oxygen feed valve for each train. At the Rocky River plant the first stage pressure control was tied back into the air control flow vanes of the three stage centrifugal air compressors feeding the cryogenic air separation plant. This was done from a pressure sensor in the main oxygen manifold. So that the capability for oxygen production control was available, however as with most U plants that control was never implemented in automatic mode.

At the Rocky River plant oxygen vent purity analyzers were provided to measure waste gas oxygen purity and provide an additional means of controlling oxygen production. The concept here is that the amount of oxygen utilized is reflected in the concentration of oxygen in the waste gas. Generally speaking 40-50% oxygen in the waste gas indicates 90% utilization; the exact oxygen purity is dependent on the waste strength. In addition the dissolved oxygen in the last stage of the reactor is directly correlateable to the oxygen purity in that stages gas space at a given waste load being processed. Thus another set point is available for oxygen production control. However because of the slow movement of oxygen thru the reactor stages this parameter has a very slow response time.

In addition to sensors and controllers for process control of the oxygen activated sludge reactors there were installed additional standard controls for safety purposes. These controls are commonly called LEL (lower explosive limit) controls. The sensors in this subsystem detect hydrocarbons in the reactor's gas space. If hydrocarbons are detected the controls actuate a series of actions and alarms. The first action is to dilute the reactor gas space with air until it reaches 21% oxygen when the hydrocarbons are detected at 25% of the LEL. The second action is to shut down the aerators if the hydrocarbons detected reach 50% of the LEL.

A cryogenic distillation plant with liquid oxygen backup provides oxygen. For the oxygen plant the controls were pneumatic, the standard of the day. An oxygen producing cryogenic distillation plant has the following subsystems for control purposes: air compressors, heat exchanger, turbine expander, and distillation columns. The air compressor has controls for flow, surge control, and the removal of waste heat. The reversing heat exchanger is not controlled but is monitored for temperature. The turbine expander has controls for flow, surging, and removal of heat generated. The distillation columns have minimal internal flow control, are monitored extensively for temperature, and have liquid oxygen export control. The liquid oxygen storage tanks have controls for vaporization to supplement or backup the cryogenic distillation plant. Cryogenic distillation plants have a very long life; operation at 50 years after installation is not uncommon. Both rotary subsystems (compressor and expander) also have a long life with spare parts available from the suppliers. The pneumatic controls of plants of this era must be maintained, repaired, and replaced on a regular basis. Unfortunately of the two original suppliers used at all plants Fisher and Foxboro one, Fisher, has discontinued the manufacture of its pneumatic controllers. Spare parts were getting harder and harder to acquire.

The control problems at the Rocky River plant centered on the original butterfly valves that were provided for gas flow control. Butterfly valves are not especially good as control valves to begin with. In addition at Rocky River for various reasons there were substantial changes over time that resulted in lower gas flows that exacerbated this control problem. As a consequence, as happens at many oxygen activated sludge plants, existing dissolved oxygen levels were above 10 mg/l and oxygen utilization was lower than 90%.

PLAN AND SPECIFICATION DEVELOPMENT

Based upon anticipated growth within the drainage area, it was decided that the initial project would expand the plant from 24 MGD to 34 MGD. This included more than 7 MGD from a single industry within the drainage basin. Based upon the blended industrial and domestic waste loading into the plant, the design process loadings are summarized below:

TABLE 1[1] Wastewater Flow

Parameter	1979 Design Basis	Current Industrial Allocation	Modified Industrial Allocation	Ultimate
Annual 24-hour Average, MGD	24	30	34	54
Maximum Month Daily Average, MGD	n/a	33	37.4	59.4
Peak Day, MGD	43.2	60	68	108
Peak Hour, MGD(1)	54.0	70	78	116

Based on plant data from 1994 and 1995, and cross checked based upon 1996 and 1997 data, influent wastewater characteristics are as follows on an annual average (AA) and maximum month (MM) basis and includes internal plant recycle flows:

TABLE 2[1] Influent Characteristics

	Existing		Design			
Parameter	17 MGD		30 MGD		34 MGD	
	AA	MM	AA	MM	AA	MM
BOD_5, mg/L	240	260	295	330	250	287
TSS, mg/L	340	450	324	428	358	467
TKN, mg/L	30	***37***	34	39	31	37
Temperature, °C	22	16/ 28	22	16/ 28	22	16/28
Alkalinity, mg/L	250	200	200	175	200	175

On the liquid process side, the expansion to 34 MGD included addition of fine screening and grit removal facilities and addition of three HPOAS trains adjacent to the existing first stage HPOAS basins. The project also included additions in the solids processing portion of the plant along with several plant upgrades such as standby diesel generator power and odor control scrubber and a plant wide PLC based plant monitoring and control system.

Unfortunately the major industrial contributor was forced to shut down near the end of design and plant flows quickly dropped from 18 MGD to 12 MGD. The expansion was no longer needed. However many of the process upgrades identified earlier were still desired. Therefore the project was divided into phases. The improvements to the High Purity Oxygen process were included in the first phase.

The master plan also concluded that denitritrifcation would be needed in the future for alkalinity recovery. Alkalinity entering the plant was adequate due to the large industrial contribution. However as the flows increased and the ratio of domestic to industrial flow became less, a means of recovering some alkalinity to avoid high cost of chemical supplementation was needed. Knowing that the high typical DO levels maintained in HPOAS basins would make alkalinity recovery via denitrification difficult, we searched for a way to maintain better control of DO in the third and final stage of the process. The RRWWTP staff had much experience with DO meters used in this environment and felt this was too unreliable and maintenance intensive to use for controlling the feed rate. Something new and innovative was needed. When we ran this by Lotepro, they suggested that there was a relationship between oxygen vent purity and DO in the basins. With this as a springboard, the operating concept was developed.

Speculative permit limits for the expanded facility were provided by the North Carolina Division of Water Quality. These limits are shown below.

TABLE 3[1] Future Limits

Parameter	Current		Expanded	
	Summer	Winter	Summer	Winter
$CBOD_5$, mg/L	17	25	10	20
TSS, mg/L	30	30	30	30
NH_3-N, mg/L	4	10	2	4
Fecal Coliform, #/100 mL	200	200	200	200
DO, mg/L	6	3	6	6
pH (SU)	6 - 9	6 - 9	6 - 9	6 - 9
Residual Chlorine, µg/L	- n/a -		20 - 25	

Specification Sections 11551 (High Purity Oxygen Dissolution Equipment), 11552 (Oxygen Production Equipment Control Modifications), 13500 (Plant Control System), 13510 (Computer

System Hardware), 13530 (Programmable Logic Controllers), 13550 (Software Control Block Descriptions), 13560 (Instrumentation), 13570 (Instrumentation), and 16050 (Electrical) and the Plans (Drawings P-1,3, 4, 5, 6, 7, 8, 9, and 10) defined the complete control system as to hardware, software, and functions. These Specifications Sections were developed by Black & Veatch in discussions with WSACC and vendors that had experience with oxygen production-oxygen dissolution systems; they were incorporated into the bid tender documents.

CONTROL SYSTEM DESIGN

It should be noted that the basic control logic of neither the oxygen dissolution or oxygen production subsystems was specified to be changed. The project consisted of retrofitting to replace obsolete or inadequate hardware, installing I to P devices, providing new control panels with PLCs, and writing the software programming to provide control.

One of the most important hardware changes specified was based on the need to provide rapid accurate control of gas flow. To satisfy this specification requirement, as illustrated in Figure 1, globe feed and ball vent valves were used. Historically all UNOX® and OASES® oxygen dissolution systems had been provided with butterfly valves to accomplish gas flow control.

FIGURE 1
Converted Oxygen Feed and Vent Control Subsystems
(note use of globe feed and ball vent valves)

The key elements in the new control system are the HBCP panel (high purity oxygen basin control panel) and the OPCP panel (oxygen production control panel) each of which contain redundant Allen Bradley PLC5 programmable controllers. The PLC5s perform all the real world I/O communications, computation functions, logic, and timing using Rockwell Software that incorporates copy written programs of Mixing and Mass Transfer Technologies LLC. The panels communicate with each other and the main control panel via fiber optic ether net. The HBCP is also connected to eight new gas analyzer panels, control valves, and control devices on the oxygen dissolution reactor train basins. The OPCP is connected to the air compressors, expander turbine, cold box, and LOX backup subsystems. There are local panels for each of the compressors and the LOX storage/vaporization subsystem. The HBCP is equipped with a single

Allen Bradley RAC 6181 local operator interface while the OPCP has two such devices. Each control panel LOI has several screens which are accessed by touching links. Each screen is composed of GRAPHICS, LABELS, INDICATORS, and CONTROLS components for performing various functions. Each panel also has an uninterruptible power supply (UPS). The panels are illustrated in Figure 2.

FIGURE 2
New Control Panels "U-Plant" (OPCP) and "UNOX" (HBCP)

Rockwell RS View 32 software was used for the screen graphics for the HBCP and OPCP. Rockwell Software Logix Panel Builder was used to for the screen graphics for the air compressor and LOX local panels.

SYSTEM HARDWARE AND SOFTWARE SUMMARY

The PLC/PC based system provided is capable of performing the following generalized functions:

1. Real time process control including PID control action, sequencing, etc.
2. Collection and storage of accurate, reliable operating information for current and historical use.
3. Assists plant-operating personnel by noting and communicating off-normal operating conditions and equipment failures.
4. Performs calculations based on automatically entered data.
5. Accumulates and stores equipment run-times for use in preventative maintenance.
6. Provides color graphic displays and summary data for use by the plant operating and supervisory personnel.

The system was designed so that all process control functions can be accomplished using the PLC. Control functions include start-stop, PID, automatic sequencing, flow integration and totalization, alarm / shutdown control, etc. All supervisory functions are accomplished at the PC via the MMI software package. Supervisory functions include database modifications, graphic display, historical data collection, set-point modifications, password entry, and alarm logging.

Security is provided by a user assignable password, multilevel protection system, which restricts access to specified system functions.

The system allows the operator to manually control (via touch screen entry) the status of valves, process flows, air compressors, etc. (i.e., on-off, open-close, set point values, etc.) when viewing the appropriate graphic screen on the L.O.I. Alarm annunciation is provided with the ability for separate and distinct annunciation of the individual operational areas. As installed, the control system will collect and store operating information, perform process control, monitor and report off normal conditions and equipment failures, perform plant process calculations, provide plant-operating displays, and provide pertinent data for preparation of reports. The system as supplied is configured to allow merging with a "Total Plant Control System" to be installed in a later phase of the Project.

CONSTRUCTION

As sustained treatment and continued effluent compliance were required during the time frame of construction both the installation and placing in immediate operation of specific equipment was critical.

Both influent wastewater hydraulic loading and carbon loadings were less than had been anticipated for reasons stated earlier herein, therefore considerable flexibility existed in upgrade of the activated sludge process, allowing a minimum of two each of the aeration trains to be off-line at a given time for modification. This also allowed the In-Situ testing of the new aerators without a reduction in plant capacity related to treatment. Subsequent to modification of a specific aeration train and all systems operation being verified, that train was placed in service freeing up a "sister" train for construction purposes.

It was imperative that the oxygen feed supply not be interrupted; therefore a "phased construction" approach was implemented related to the Air Separation Facility and its ancillary systems. To accomplish this, the main air separation plant was left in service during Phase I modifications of the sub-systems.

The liquid oxygen vaporization sub-system was removed from service in Phase I, the original system controls – field instrumentation – electrical was demolished. The new local control panel with its PLC was then set, new field instrumentation and electrical were installed, a detailed checkout/operational verification performed and the Site Acceptance Test completed.

As the original facility incorporated dual main process feed air compressors for the air separation process, modification of one of those machines occurred simultaneously with modification of the LOX sub-system during Phase I. This was comprised of demolition of the existing controls, modification of the existing local control panel to allow installation of the required PLC and associated I/O Rack, installation of new field instrumentation, a detailed checkout/operational verification performed and completion of the Site Acceptance Test.

Upon completion of Phase I, Phase II was immediately initiated with the LOX sub-system being placed in service as the primary oxygen feed supply and the main air separation plant being shut down and thawed to ambient temperature to allow construction to continue. Modifications included removal of the existing main control panel, installation of the new OPCP control panel, field instrumentation / electronic controls and associated electrical. The entire system was modified, system checked out with operation of all elements verified, plant cooled back down and successfully placed back in operation, utilizing the previously modified main air feed air compressor (Phase I), in eighteen (18) workdays.

Once back in operation the Site Acceptance Test was performed. Upon completion of the SAT Phase III was implemented whereby modifications to the second main feed air compressor were accomplished including the local control panel.

FIGURE 3
"U Plant" Controls After and Before Retrofit
(Note installed I to P device rack)

PERFORMANCE TESTING

Factory and Field Testing of the Control System

Specification Section 13500 part 3 item 3.01 defined the factory test for both hardware and software. This consisted of a seventy two hour test wherein the entire system's basic functions for all field I/O processing communications, alarm handling, operator display screens, alarm logging, and historical data storage for normal operating sequences and fault functions were tested by simulation. The results of the simulation were displayed on the display screens. The test was passed with no major glitches.

Following installation the Site Acceptance Test was conducted after all I/Os had been connected and verified. This consisted of thirty days operation wherein it was demonstrated that status, alarm, and process variable signals were valid and being updated appropriately. In addition it was verified that discrete and analog output signals from the control system were being correctly transmitted and implemented. Again the 30 day continuous test was passed with no major glitches.

Clean Water Testing of the Aerators

Specification Section 11551 required that eight 30 NHP surface aerators be provided in stages 2 and 3 in four of the existing reactor trains for the retrofit to a single stage system. Both the design and performance conditions that the aerators were to meet were defined. Of special interest were the performance conditions required for the aerators in the third stage of the reactor trains, which were a clean water test K_La of 3.44 @20^OC for oxygen transfer, a minimum 23 motor shaft horsepower for mixing, and the ability to hold a dissolved oxygen level between 2-4 while in actual operation under computer control for a weeks test period. The conditions posed a unique design problem in that the aerator's oxygen transfer rate needed to be low and yet enough horsepower had to be provided to attain adequate mixing. The solution chosen was to provide a classical 45^O Pitched Blade Turbine with a bottom impeller for mixing. The idea was to design an upper impeller to meet the low oxygen transfer and a lower impeller for mixing. It was found during preliminary testing that the combined pumping interaction between the two blades was not covered by existing correlations. After the testing of several unsuccessful impeller combinations the right impeller combination was found. As described in the field clean water test report [3] a 74" diameter upper 45^O pitched blade impeller with a 47" diameter lower 32^O pitched blade impeller successfully passed the initial performance tests. The K_La test data is illustrated in Table 4 and both the average and guarantee K_La values in Table 5.

TABLE 4 [3] K_La Measured and Calculated Values

Run	Emergence (in)	Liquid Temp. (C)	k_La_T (1/h)	k_La_{20} (1/h)
23	2.875	24.9	3.47	3.09
24	2.875	24.9	3.48	3.10
25	2.875	24.9	3.51	3.13
26	0.875	24.6	3.89	3.49
27	0.875	24.6	3.77	3.38
28	0.875	24.6	3.83	3.43
29	3.875	23.8	3.59	3.29
30	3.875	23.9	3.50	3.19
31	-0.125	23.9	3.75	3.42
32	0.625	24.0	3.73	3.39
33	1.875	24.0	3.88	3.53
34	1.875	23.9	3.65	3.33

TABLE 5 [3] Measured and Guaranteed K_La

Stage	Measured Average k_La_{20} (1/h)	Guaranteed k_La_{20} (1/h)	Ratio Measured to Guaranteed k_La (%)
2	3.105	3.09	100.49%
3	3.434	3.44	99.83%

The relationship between SOTR and Brake Horsepower is illustrated in Figure 3.

FIGURE 3 SOTR and Power Consumption

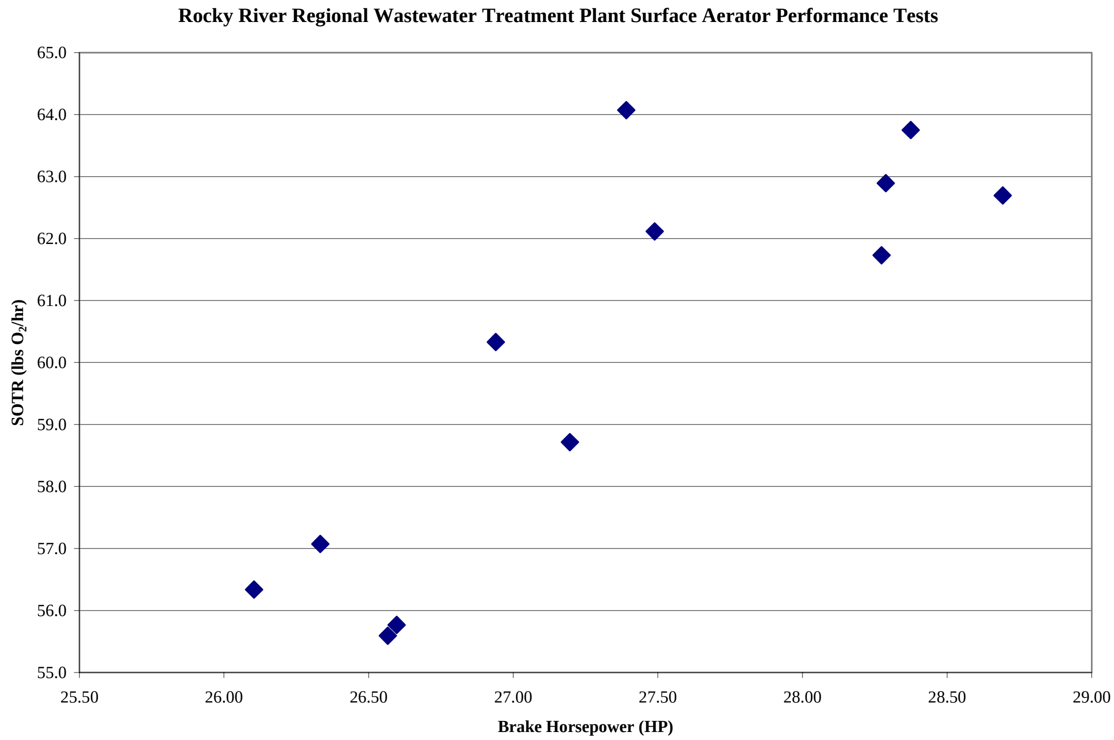


FIGURE 4
New Aerators

In Situ Testing for Dissolved Oxygen Control

The most important performance test condition, of course, was the one week test where the vent gas purity control bias was used to maintain the dissolved oxygen level between 2-4 mg/l. The results of this testing were reported in the aeration dissolved oxygen control field test [4]. Figure 5 shows the dissolved oxygen for each train based on all the instantaneous data taken. As can be seen from this figure there is a correlation between vent purity and dissolved oxygen. However that correlation is not “tight” and there are outlying measurements. This is caused by varying influent loads.

FIGURE 5
Dissolved Oxygen and Vent Gas Purity

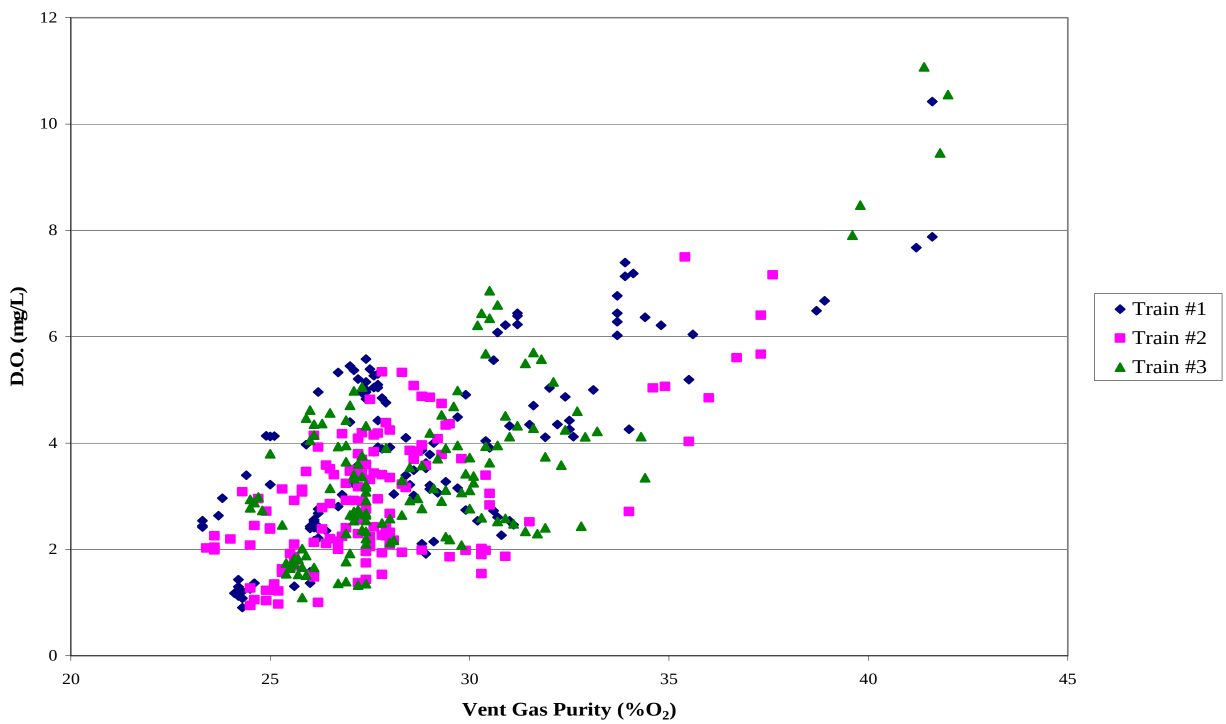


Figure 6 illustrates the daily average dissolved oxygen in basin five which consists of three reactor trains

FIGURE 6
DO, Daily Average Basin 5

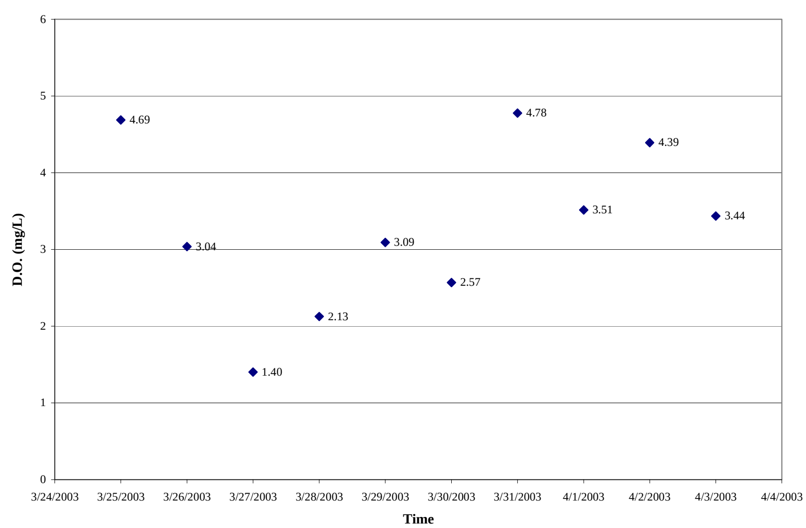
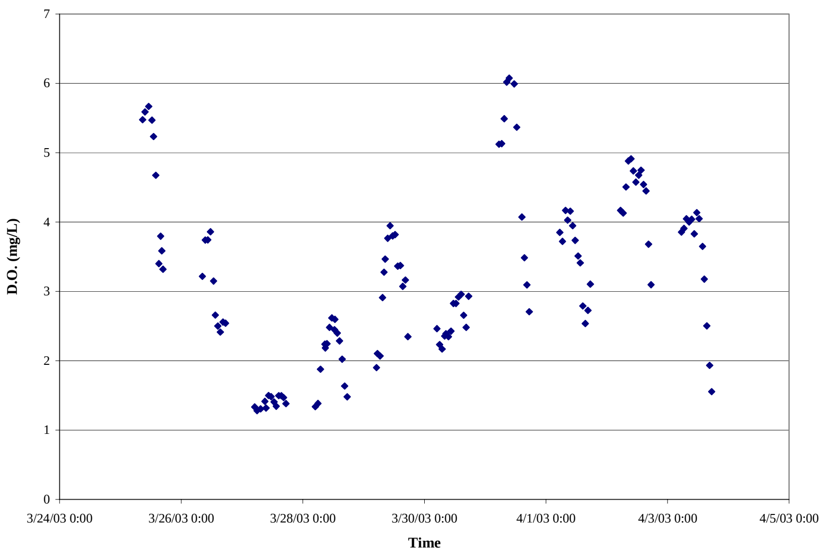


Figure 7 illustrates the hourly average dissolved oxygen measurements in basin five which consists of three reactor trains.

FIGURE 7
DO, Hourly Average Basin 5



Those who have operated UNOX® or OASES® systems can appreciate the remarkableness of the low dissolved oxygen levels resulting from the combination of the specially designed last stage impeller and operation under full integrated automatic control of both oxygen production and dissolution. Most UNOX and OASES systems have last stage dissolved oxygen levels between 10-20 mg/l; some systems have even higher levels.

The conditions of the test were not ideal. Several changes had occurred in the influent characteristics to the plant. The operating F/M (0.07-0.13) was significantly less than the design level (0.30). The BOD load varied considerably over the test period (11.8-36.7 lbs per 1000 ft^3). The flow rate also varied considerably over the course of a day (EG 6.81 to 19.04, 7.12 to 16.42 MGD).

CONTINUING OPERATION

The plant was commissioned in the spring of 2003 and has been in operation for over a year. The staff is satisfied with its operation. The data logging capability of the control system has reduced the paper work associated with monitoring the facility. There were initially minor problems in regard to the sampling system’s gas cleanup that required resolution. These involved incorrect connections for the heat tracing and also the filters used to clean up the gas. There were also problems when a thaw heater and electronic I/O control card failed as duplicity was not provided; from that experience it was learned that it would be better to directly connect the temperature sensors to electronic I/O cards rather than run those signals thru the preserved temperature recorder. Spare I/O cards are being purchased so they will be available in the future.

The operation and control of the oxygen production plant is reported to be substantially improved. This is witnessed by recent observations that product purity is continuously kept within 0.25% of its set point[5]. It is now known that operator intervention will be necessary to control the dissolved oxygen exiting the UNOX^{R} reactor trains within a range of 2-4 mg/l. This is because the continuously changing influent load changes the reactor trains oxygen uptake rapidly while the gas phase purity of the last stage changes very slowly. Single step treatment is used for 50% of the influent flow while two step treatment continues to be used for the other 50%. Now that phase 2 of the contract is nearing completion, and a previously uninstalled hydraulic flow meter has been installed, an additional mode of control can be evaluated- biasing for liquid flow control.

CONCLUSIONS

A novel control system for the oxygen production plant and UNOX® oxygen dissolution reactor trains has been implemented on full scale basis at WSACC's Rocky River Plant. It has been demonstrated that integrated control of both oxygen production and dissolution can be accomplished by means of PLC direct digital control.

The ability to run automatically at low dissolved oxygen levels has been proven. However operator intervention is necessary to keep the control within a select range. This is necessary to account for changing influent conditions by changing the vent purity set point.

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