Integrating Control of Flocculant Delivery in a Phosphatic Clay Thickening Circuit

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ABSTRACT

Nalco Chemical Company and PCS Phosphate have formed a successful supplier/customer team effort that has resulted in major improvements in the operation of the clay thickening circuit at the Aurora, North Carolina concentrator. A Nalco OPTICUS® Automated Process Control System for thickener and flocculant control was installed in 1994. The paper will discuss in detail the development and refinement of the OPTICUS system over the past three years. The paper will survey the development and networking of process control for monitoring, controlling and operating four 325-foot Dorr-Oliver thickeners, three 80-foot high-rate Enviro-Clear thickeners and control links to the facility's clay/gypsum blending operation.

PCS Phosphate

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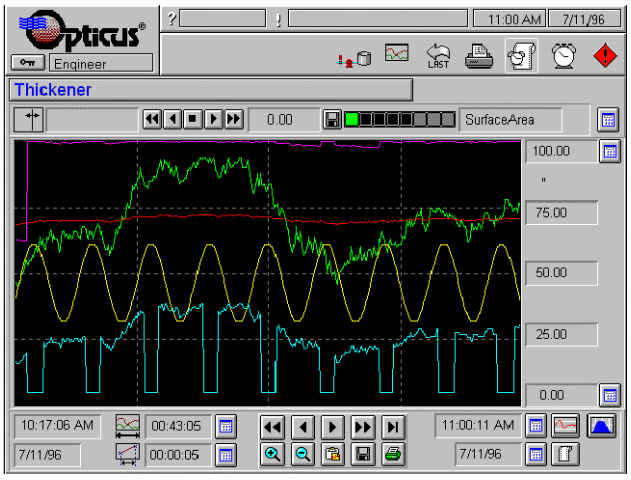
INTRODUCTION

Purpose: In 1980, the PCS Aurora Mill began operating a gypsum/clay blending circuit to develop a suitable material for land reclamation. Clay accounts for nearly twenty weight percent of all incoming ore from the mine and must be removed prior to the phosphate flotation process in the concentrator. Gypsum is a waste by-product generated during the production of phosphoric acid. Approximately 180,000 tons of clay and 665,000 tons of gypsum are blended each month in this circuit. The PCS blend circuit was a first for the phosphate industry and continues to be the only gypsum/clay blending circuit operation.

After years of testing, a gypsum/clay blending circuit was designed requiring clay solids content of nine to twelve percent. The increased clay solids were necessary to neutralize the acid remaining in the gypsum, to improve soil stability in the reclamation deposition site, to increase the efficiency of slurry pumping and to maintain the water balance in the mill. The four, 325-foot diameter, natural settling Dorr-Oliver clay thickeners that were installed as original equipment in 1966 to reclaim process water for the flotation process were not capable of achieving a solids content greater than six percent solids. Therefore, two Enviro-Clear thickeners were installed to achieve the density required for proper operation of the circuit. A third thickener was added in 1985 to accommodate an increase in clay resulting from a plant expansion.

Original Thickener Control Concept: The Enviro-Clear thickener circuit was designed to utilize flocculant to enhance the clay settling time and control the thickener clay bed level. A Modicon programmable logic controller (PLC) was installed to control the operation of the thickeners. Three control logic schemes were written for the thickeners. One was written for the PLC to regulate the flocculant delivery to maintain a set bed level in each thickener, a second to control the underflow solids, and a third to control the gypsum-to-clay ratio. A feed forward control that could adjust any of the previous three control methods by measuring the swings in the feed rate to the Enviro-Clear thickeners was also written. The only successful control scheme over the 14 years the PLC was used was the bed level control scheme. Individual single-loop controllers controlled all underflow and overflow pumps and all other ancillary equipment.

Original Flocculant Make-up System: The emulsion flocculant make-up system was installed as an independent control system at the reagent building. A complex array of relays and switches was utilized to make batches of emulsion flocculant. A separate and independent make-up system was installed for each thickener.



Opticus real-time trend graph

THE NALCO AND PCS TEAM EFFORT

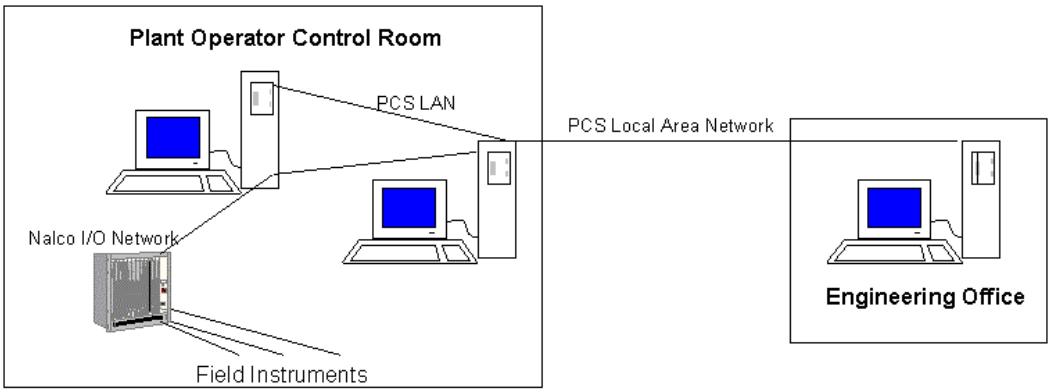
PCS Supplier Search: Throughout 1993 and 1994, PCS conducted an extensive test program to determine the most cost effective emulsion or dry polymer for the Enviro-Clear thickening circuit. The chemical supply philosophy at the time was to maintain multiple suppliers for each chemical used in the plant. Polymers from many chemical suppliers were screened in the lab and the most promising were selected for plant trials. During the testing phase, thickener control was poor and therefore it was difficult to make a fair assessment of each chemical. It was decided that the selection of the chemical supplier should include improvements in process control for the thickener circuit.

Teaming Evolution: A search for off-the-shelf thickener control systems was conducted without success. Each thickener manufacturer had control systems available, but none were robust enough for the complex requirements of the PCS circuit. Control system integrators and engineering firms were contacted to determine the cost of developing a control system for the clay thickening circuit. The search revealed that none of the contacted companies were experts in the thickener automation field. After considerable study, it was concluded that the Nalco OPTICUS® system was the control system best suited for implementation at PCS. The control system decision was based on overall cost effectiveness over a minimum time span of two years. Also, the chemical supply philosophy was changed to using a single supply source. The change in supplier philosophy paved the way to form a relationship with Nalco to supply both flocculant chemicals and a thickener control system.

With Nalco chosen as the supplier and the chemical program selected, focus turned to the thickener control system. The initial step for evaluation of an Opticus system was for Nalco and PCS to objectively evaluate the current flocculant delivery and control system. Next a list was made of the positive features of the system that needed to be maintained. Primary to these was to maintain real-time operator input into the control logic. The new Opticus system was not meant to replace experienced operators but to provide a tool for them to better control the thickeners. The new system would also need to have operator override capability so the operators could change to manual controls during abnormal plant conditions.

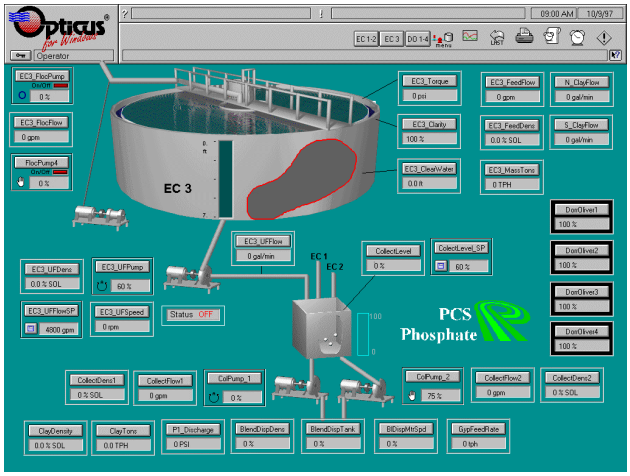
Next a list of design improvements to the PCS original system was made. Central to these was to include all operator feedback information and PLC input points on a common computer screen. This would allow the operator to see the entire circuit and make changes at only one location. Key to process improvement was development of new individual control schemes for each thickener that interacted with each other and the entire plant in an “expert” manner. This would involve incorporating years of engineering knowledge from Nalco, PCS engineering and operator experience. A re-evaluation and screening of plant sensors was also required. Nalco used several of their in-house developed sensors that were able to provide both feed forward signals as well as accurate mud depth readings. Once the system became operational, a major design improvement was to facilitate multiple operator terminals and make plant data available on the PCS corporate local area network (LAN).

Installation and start-up of the PCS Opticus system: was a major project that would change both the operation and culture of the plant. A project time line with achievable milestones was created. In 1994 Nalco was operating over 100 Opticus process control systems worldwide; these were based on an MS-DOS software program. Nalco was also prototyping new technology in a LAN-based Opticus for Windows control system at a West Coast U.S. plant. After evaluating the two systems verses requirements, it was decided that PCS would start up with the older MS-DOS based program and Nalco would continue development and incorporate design changes to the new Windows platform. In November 1994, the Opticus for MS-DOS system began thickener control at PCS. Drawbacks to the MS-DOS system were its limited number of inputs and control blocks (64 each), lack of a graphical interface, lack of network capability and lack of multiple terminal support.



Network configuration for Opticus computer and field I/O

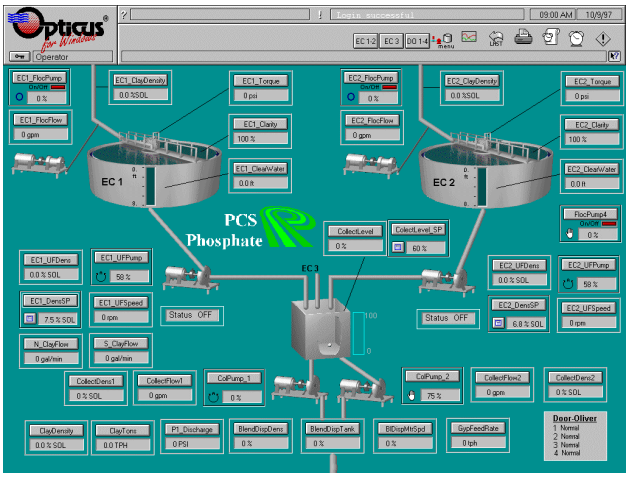
Opticus Development: Development of Nalco's Opticus for Windows 95 software was complete in March 1996. PCS became the first installation. The Opticus for Windows system consisted of three computers connected to the existing PCS LAN. Two of the computers were installed in the operator control room and one in the engineering office. All control strategies from the MS-DOS system were migrated then upgraded as needed.



Enviro-Clear 3 control/information screen

The control loops are run on the computer designated as "primary" in the control room. An adjacent computer designated as "standby" continually monitors the primary computer and automatically takes over operation of the control loops should the primary go down for any reason. During normal operation, loop parameters can be changed from any of the three computers completely transparent to the user. This is accomplished using client/server technology incorporated into Opticus. Historical data and reports are also available on any of the computer systems. It is very common for one operator to be making control changes to the circuit while a second operator reviews plant data collected from previous shifts. Having an operator console in the plant engineering office facilitates real-time data for engineering and management. It allows generation of daily reports without having to physically go to the plant or process manual log sheets. If necessary, the process engineer can even make control loop changes right from the office.

Over the first 18 months, it became evident that the Nalco/PCS team efort would be an ongoing process. Almost immediately after Opticus for Windows system was installed, a list of new requirements was generated. These included greater report and graphics capability as well as support for Windows NT. Nalco began development of Opticus 8.0 that would incorporate these requirements. The current time line calls for upgrade to Windows NT as soon as the plant computer network is upgraded. Opticus 8.0 with enhanced reporting is expected to be available for release first quarter 98.



Enviro-Clear 1-2 control/information screen

CONCLUSIONS

The Nalco PCS team effort has resulted in major plant improvements for the operation of both the Dorr-Oliver and Enviro-Clear thickening circuits.

Dorr-Oliver Circuit: No process data was available to the blend operator due to the distant location of these four thickeners. These thickeners were frequently overloaded, resulting in the discharge of clay into the clarified overflow water which in turn contaminated the phosphate flotation water supply. Real-time knowledge of Dorr-Oliver thickener conditions was made possible with the installation of the Opticus system. This was accomplished through the installation of clarity probes in each thickener and sending the clarity information signal back to the Opticus system via a radio transmission unit. The blend circuit operator can now utilize the clarity information to make proactive circuit changes and prevent thickener overload conditions that contaminate the flotation water source.

Enviro-Clear Circuit:

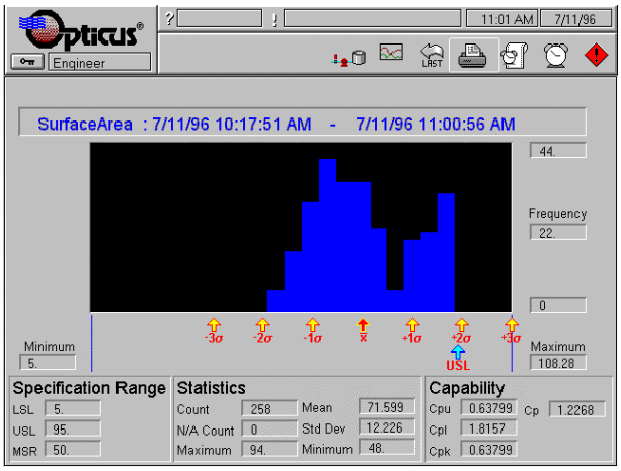
Reduction in Operating Costs - Field devices for measuring feed surface area, overflow clarity and depth of clear water above the flocculated clay interface were used in the control of flocculant. Previously the flocculant addition was adjusted to control the thickener mud depth. The new approach has been more efficient and has reduced flocculant consumption by 16 percent.

Improved Control - All primary control parameters and secondary monitoring parameters were incorporated into the Opticus operator interface for control of the process. The added functionality that the Opticus system provided resulted in considerable improvements in control of the processes. The built-in controllers provide all the requisite tools to tune, control, trend, and alarm any process variable. The use of alarms to warn the operator of deviation from process setpoint has reduced downtime and process upsets with a resulting increase in throughput of clay for treatment in the Enviro-Clear circuit.

Improved Direct Blending Capability - Steady control of underflow solids and improved pump control for delivery of thickened clay to the phosphoric acid plant improved the direct blend on-stream factor. Considerable savings are generated with each ton of gypsum that is eliminated from the gypsum stockpile inventory. Stockpiled inventories of gypsum require additional processing and operating cost in the operation of the blend circuit.

Ease of Operation - The Opticus system was utilized to consolidate multiple individual process variable controllers. Prior to the arrival of the Opticus system, circuit control was performed by using numerous single-loop controllers mounted in three separate control panels. The controllers were basic, with little functionality for process control. The majority of single loop controllers was used to control nine variable speed pumps that operated in the circuit. The Opticus system was used as a tool to graphically picture the entire circuit with the process equipment and associated controller together.

Job Quality Improvements - Only two operator interface screens were necessary to provide control of the entire circuit. The improved ease of operation has decreased manpower requirements, enabling the operator to focus attention on core operating needs. The blend operator assignment was transformed from a position of chaotic overload to an enviable position with considerable ease of control over the process.



SPC graphs

Data Management - Reporting functions were unavailable with the former PLC control system. The Opticus system has provided substantial data storage for trending, reporting and statistical process control. Process data can easily be retrieved and manipulated to review both exceptionally good and poor operating anomalies. This is a tool widely accepted by the operators and management to prevent recurring problems and to develop solutions to potential weaknesses in circuit control.

In summary, the Nalco/PCS partnership has resulted in major plant improvements at the PCS Aurora Mill. Started as a task oriented project, the supplier/user partnership has developed into an ongoing relationship between the two companies.