EXPERIENCE WITH ADVANCED PROCESS CONTROL AT THE CHEVRON PHOSPHATE FERTILIZER PLANT

1989 AIChE CLEARWATER CONVENTION

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ABSTRACT: THE ROCK SPRINGS PHOSPHATE FERTILIZER PLANT IS A 200,000 TONS P205 PER YEAR FACILITY EQUIPPED WITH ELECTRONIC AND COMPUTER PROCESS CONTROL EQUIPMENT. BASIC SETUP AND OPERATION OF THIS EQUIPMENT IS DESCRIBED. THE CONCEPTS OF COMMAND EVALUATOR SYSTEM, SUPERVISORY CONTROL AND ADVANCED CONTROL STRATEGIES ARE REVIEWED. APPLICATIONS OF ADVANCED PROCESS COMPUTER CONTROL FOR REACTOR SULFATE CONTROL AND GRANULATION PLANT SLUDGE FEED CONTROL ARE DISCUSSED.

Chevron Rock Springs Fertilizer Plant

Chevron has operated a 400,000 product tons per year phosphate fertilizer plant in Rock Springs, Wyoming since 1986. The plant uses sulfur recovered at Chevron's Carter Creek, Wyoming gas plant and phosphate rock mined in Vernal, Utah and shipped as slurry through a 95 mile pipeline.

A Badger Engineering designed phosphoric acid plant processes the rock along with sulfuric acid produced in a Lurgi five-pass, double absorption sulfuric acid plant. Products include merchant acid, super acid, 11-52-0, 18-46-0 and 16-20-0.

The basics of the plant's primary process control system are described in this paper. Use of this control system for advanced process management is presented.

Rock Springs Process Control

The Rock Springs plant uses a distributed control system for basic process regulation (Figure 1). A mini-computer based monitoring with supervisory set-point control system is used with the instrumentation. Each control room has 3 work-stations which allow the operators to monitor critical portions of the plant, make process adjustments, initiate motor start/stop commands and instigate advanced control functions.

Taylor MOD-30 single-loop controllers are used in each control room. These stand-alone controllers provide individual loop control along with auxiliary analogue input. Each controller is capable of communicating with other instruments and with the process control computer. The plant can be controlled from either the individual faceplates or through work-stations. The attractiveness of this configuration is that system integrity is assured upon failure of the process computer since each loop is separate. Any computer driven advanced control or monitoring function will cease operation.

Supervisory Setpoint Control System

As supplied by Taylor Instruments, the computer system is capable of basic process control monitoring with trending and process graphics. We developed a supervisory system that provides a safe and reliable interface between the operators, the advanced control program and the distributed control equipment. The supervisory system allows the control system to change the state of operation if any integrity check fails. Operator interaction with the supervisory system is limited to simple ON/OFF commands and data entry. The system decides the eventual control state and informs the operator. Understandable and safe operation is assured by keeping operator interactions simple and consistent.

The supervisory system provides the engineer with a systematic method for integrity checking, eliminating the need for hard-coding these functions in a multitude of program locations. An engineer relatively inexperienced in computer process control is better able to understand previously written programs and to write new programs safely. He also has the capability of tuning and changing critical constants and parameters on-line. Additionally, the system allows the engineer to monitor the performance of the supervisory system and individual programs.

The kernel of the supervisory system is the command evaluator. The command evaluator is a systematic way of controlling simple or complicated control functions based engineering values, computer programs, operator input values, multiple process measurements and system status. The operator has only two commands available to control an individual supervisory strategy (Figure 2). If he wants to use the program he enters **ON** (or **AUTO**); if he doesn't want to use the program he enters **OFF** (or **MAN**). The command evaluator then determines if it will allow the desired state. The process that the command evaluator uses is a series of logic checks to insure that the status of all involved parameters, instruments, signals, etc. are correct.

The status of the command is displayed on the operator's console. The display is designed to always keep the operator informed about the current operability of a particular scheme. The operator has five states to monitor for any given strategy:

ON The supervisory program is functioning fully with no errors detected.

OFF The supervisory program is turned off and has no apparent errors.

CONDitional The operator has requested **ON** but there is something not allowing the system to control the appropriate valve or motor, etc. A common condition causing a **COND** status is a slave controller is in manual. Upon clearing check, the command will change from **COND** to **ON.**

FAIL Fail means that something critical to the safe operation of the supervisory system is not functioning. Perhaps a measurement is in error or out of range, perhaps an instrument has failed or gone off-scan, maybe the engineer has attempted to write a program with a division by zero, or perhaps the program read information from storage incorrectly. Any control to the field will be turned off if this condition occurs.

FOFF Fail**OFF** occurs whenever a strategy has failed and the conditions that caused that failure have cleared. If the operator wants to resume using the strategy he must turn the command back ON.

Several mixes of instrument, instrument-to-instrument and computer to instrument control schemes are possible (Figure 3). This provides the engineer with maximum flexibility while maintaining system consistency.

Advanced Computer Process Control

The supervisory system is used to perform advanced control strategies. An advanced control strategy is defined as any scheme which provides control separate from base level control. The distributed control instruments are only capable of uncomplicated single loop control. An advanced control scheme could run single loop control if desired, but its real intent is to provide the operator with a tool to make complex process changes based on multiple inputs and frequent calculations.

Our objectives for any advanced control scheme are: 1. standardizing plant operation by attempting to bring all operators up to the skill level of the best operator and 2. providing operators with process help by making the complex and tedious calculations used for process control. For instance, a nomogram can be programmed to calculate solids content in reactor slurry given filtrate and slurry specific gravities. Or, $\%P_2O_5$ based on temperature and pressure in the evaporators can be calculated.

I will present two examples of advanced control strategies used at the Rock Springs facility. Each case uses a computer program to calculate one or more process variables based on inputs from several sources. The computer system controls setpoints in one or more slave controllers. The supervisory system uses the command evaluator to control the computer's access to the process control equipment (suppresses setpoint moves if needed).

Phosphoric Acid Reactor Sulfate Control

Sulfate control in a phosphoric acid reactor is traditionally a difficult problem for control. The problem is inconsistent manual measurements, long lag times and seat-of-the-pants adjustments cause unpredictable and inconsistent control response. On-line sulfate measurement with closed loop control has been attempted with varying success. Our approach is to maintain periodic manual sulfate sampling and analysis, enter the results in the computer and allow the computer to adjust feed flows. The strategy is designed to first control the P_2O_5 rate to the reactor and then control the sulfate level.

The first step uses a combination of field measurements and engineering constants to calculate the P_2O_5 flow to the reactor (Figure 4). This calculated value is the process measurement for the master controller which adjusts the setpoint of the rock slurry feed slave controllers. Any change to the master controller setpoint (in TPH P_2O_5) is used to feed forward a new setpoint to the sulfuric acid controller as well as make the correct adjustment to the slave controllers. The command evaluator checks integrity and may preempt any computer generated field move.

The second step will function only if the first step is activated (Figure 5). This function begins with a new operator entry of free sulfate analysis. A relative sulfuric acid setpoint change is calculated and sent to the slave controller. The program accounts for previous control changes, previous measurements and present control region. "Adaptive" gain and reset are utilized to help minimize perturbations caused by inaccurate analysis. Reset windup is prevented by accounting for valve limitations and lack of response. Various "tuning" constant entries allow the process engineer to adapt the program to changing conditions.

In early 1988 we ran the sulfate control program for about two months. Figure 6 and 7 show the results of the test run. Two conclusions can be drawn from these data: 1. the strategy showed an immediate and marked improvement over previous experience and 2. field equipment malfunction can destroy acceptance of an advanced control strategy. Operator distrust resulted from operational problems in the density/flow meter which in turn caused erroneous calculated values and less than rational control moves. Recovery of operator acceptance has still not fully occurred.

Granulation Sludge Mix System

Another advanced control strategy we have installed and are presently using is a system to batch mix granulation feed sludge mixes (Figure 8). Pressures to minimize over-formulation while consuming priority sludges drove this project. The strategy is designed to be completed in three phases:

1. Volumetric mixing of super acid sludge, cold/hot 52% clarifier underflows and filter feed. We assume that consistent mixes can be made because the feed sludges do not vary appreciably.

2. Construction of chemically consistent batches based on analyses of individual feed sludges.

3. Integration of 1 and 2 into the existing grade and over-formulation advanced control system.

So far, only the first design objective has been completed and is functioning. The programming, equipment specification, and instrumentation integration effort was considerable. Again, we discovered that correctly functioning field equipment (in this case flow meters, level meters, computer-to-computer communication and discrete I/O) is necessary for acceptance of advanced control schemes.

Operation of the system requires the granulation operator to select which "recipe" is appropriate for the granular grade. The computer then calculates either the maximum volume of mix based on available feeds or the percent feed availability based on current mix tank volume. Once the selected mix constraints are met, the operator is allowed to activate the mixing system. After activation, the granulation operator notifies the phosphoric acid operator to prepare lines and start the correct pumps (up to three at once). The mix system monitors each component, alerts the phosphoric acid operator that it is about to stop a particular pump and then stops the appropriate pump (the audible and visual alarms give the operator opportunity to service lines after the pump is stopped). There is an override mode that allows the operator make "custom" mixes if the situation dictates.

Conclusions

Experience at the Rock Springs plant has shown that process computer based advanced control strategies are accepted and useful operator tools. We have shown that safe and reliable control of phosphoric acid reactor sulfate and batch granulation sludge mixes are practical.

Several observations were made during the implementation of these and other advanced control strategies:

1. Reliable and reasonably accurate field instrumentation is critical to correct operation and ultimate operator acceptance.

2. Operator training in all aspects of the control system, the supervisory system and individual advanced control schemes is crucial.

3. Engineering and management buy-in and "championing" are sometimes necessary.

4. Initiation of advanced control strategies close to start-up of a new plant (especially a grass-roots plant) is very difficult because operators, engineers and management are all struggling to understand their new plant. Although early success is possible, better knowledge of plant operational quirks would make for better strategy development and a higher degree of acceptance and success.

FIGURE 1

PROCESS CONTROL SYSTEM

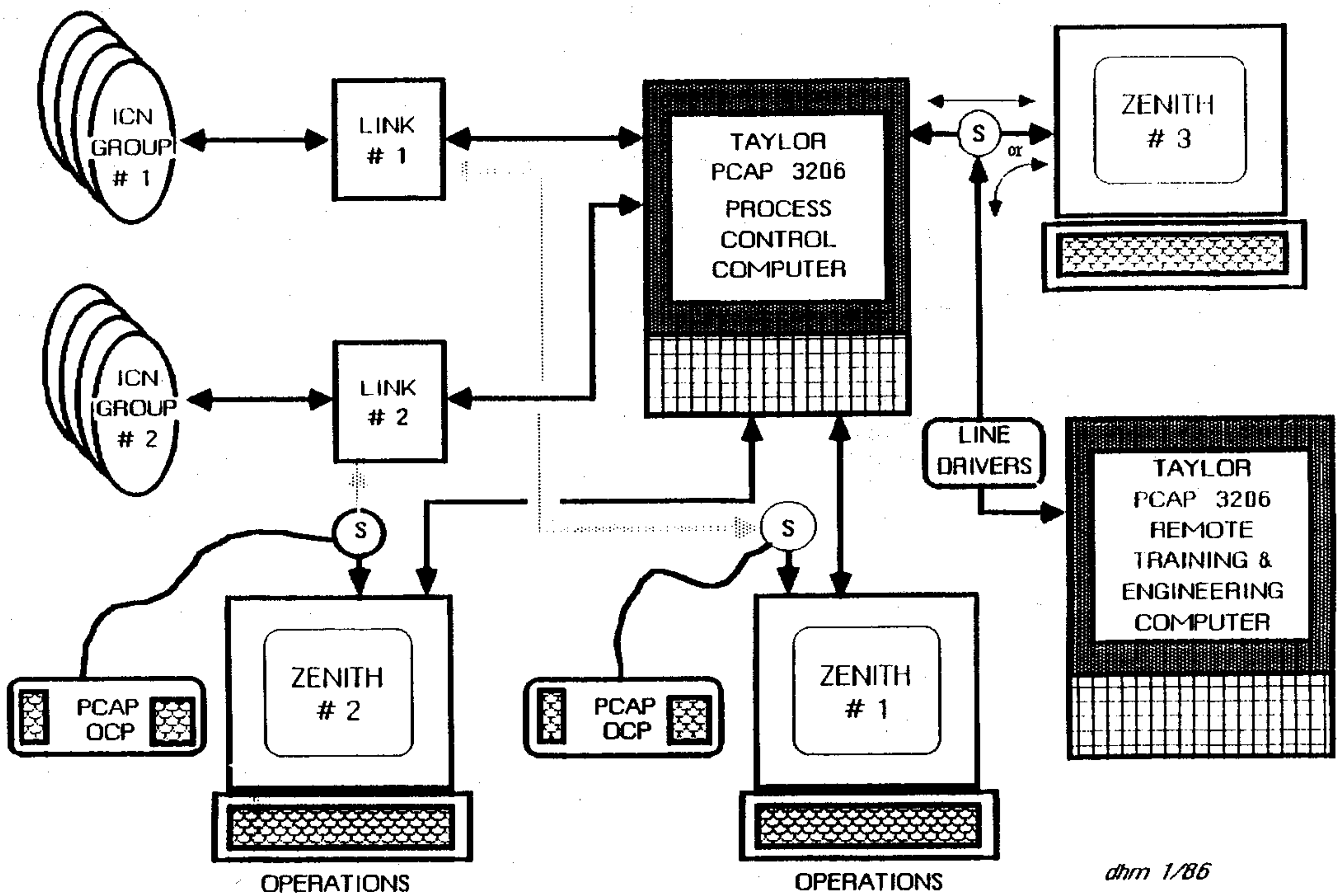

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FIGURE 2

Command State Transitions

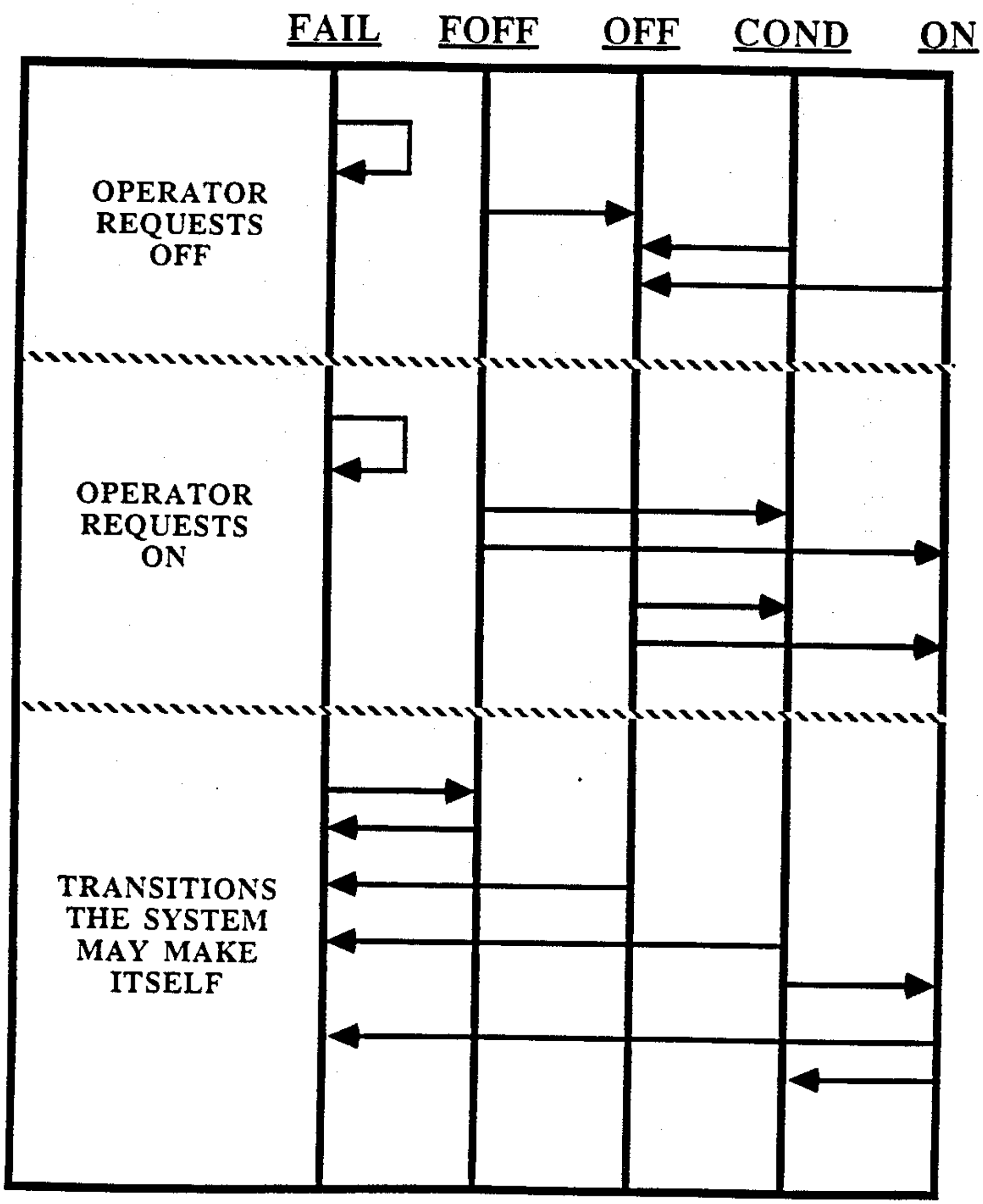

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FIGURE 3

Mixed Supervisory Command Pathways

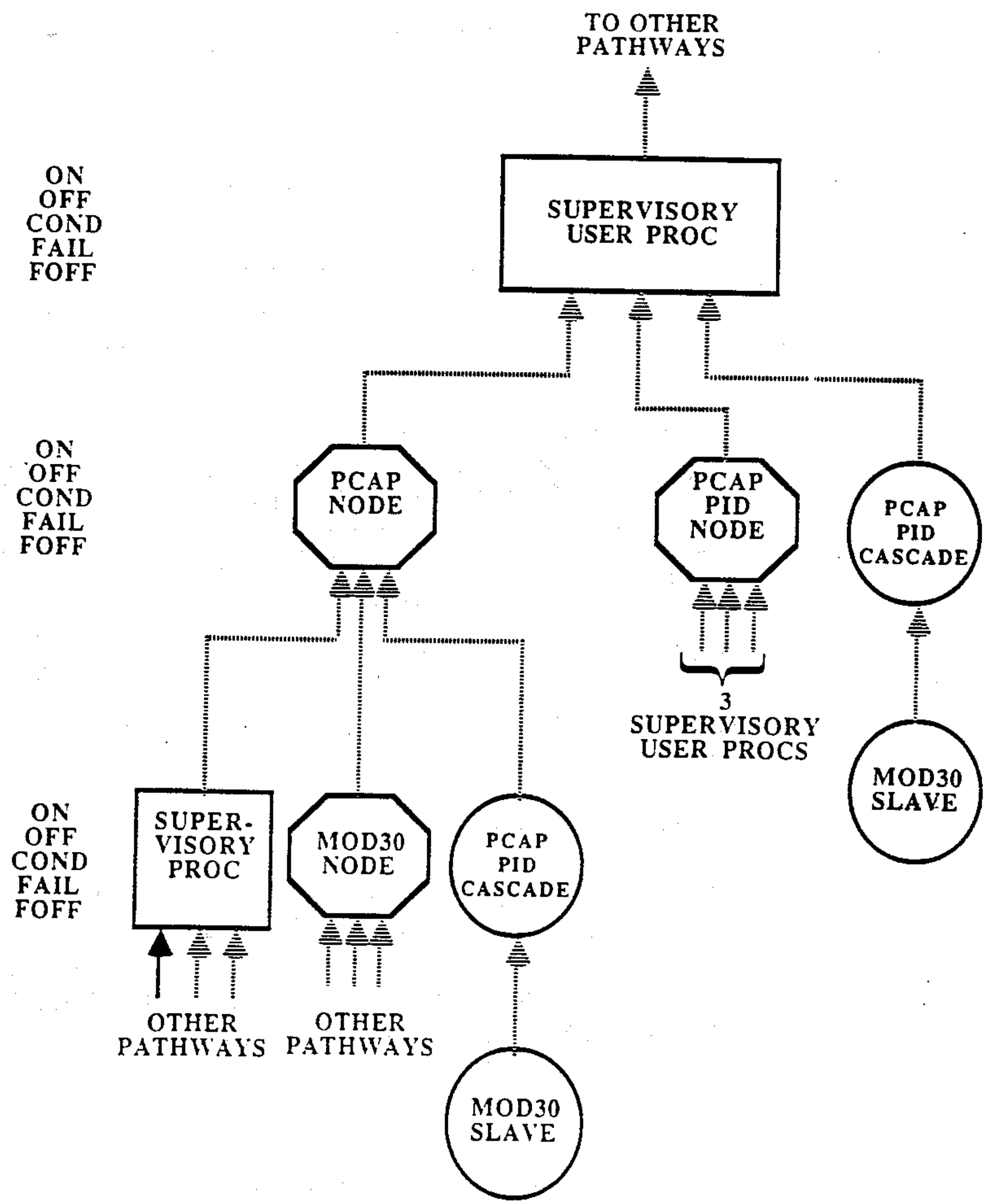

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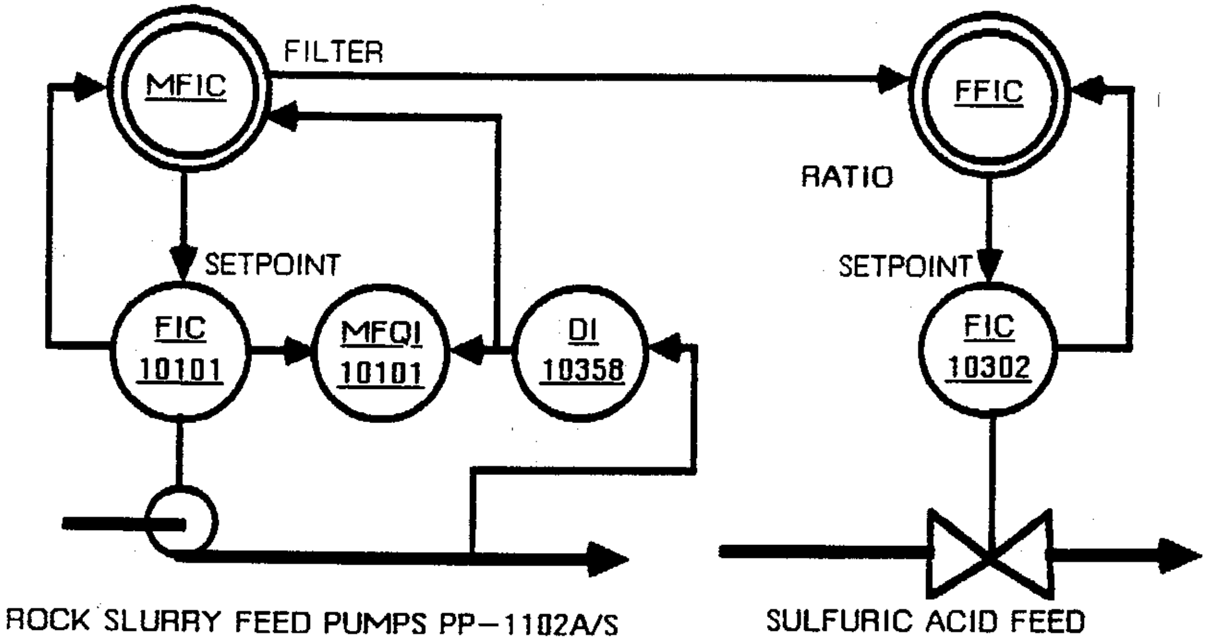
FIGURE 4

REACTOR FEED CONTROL



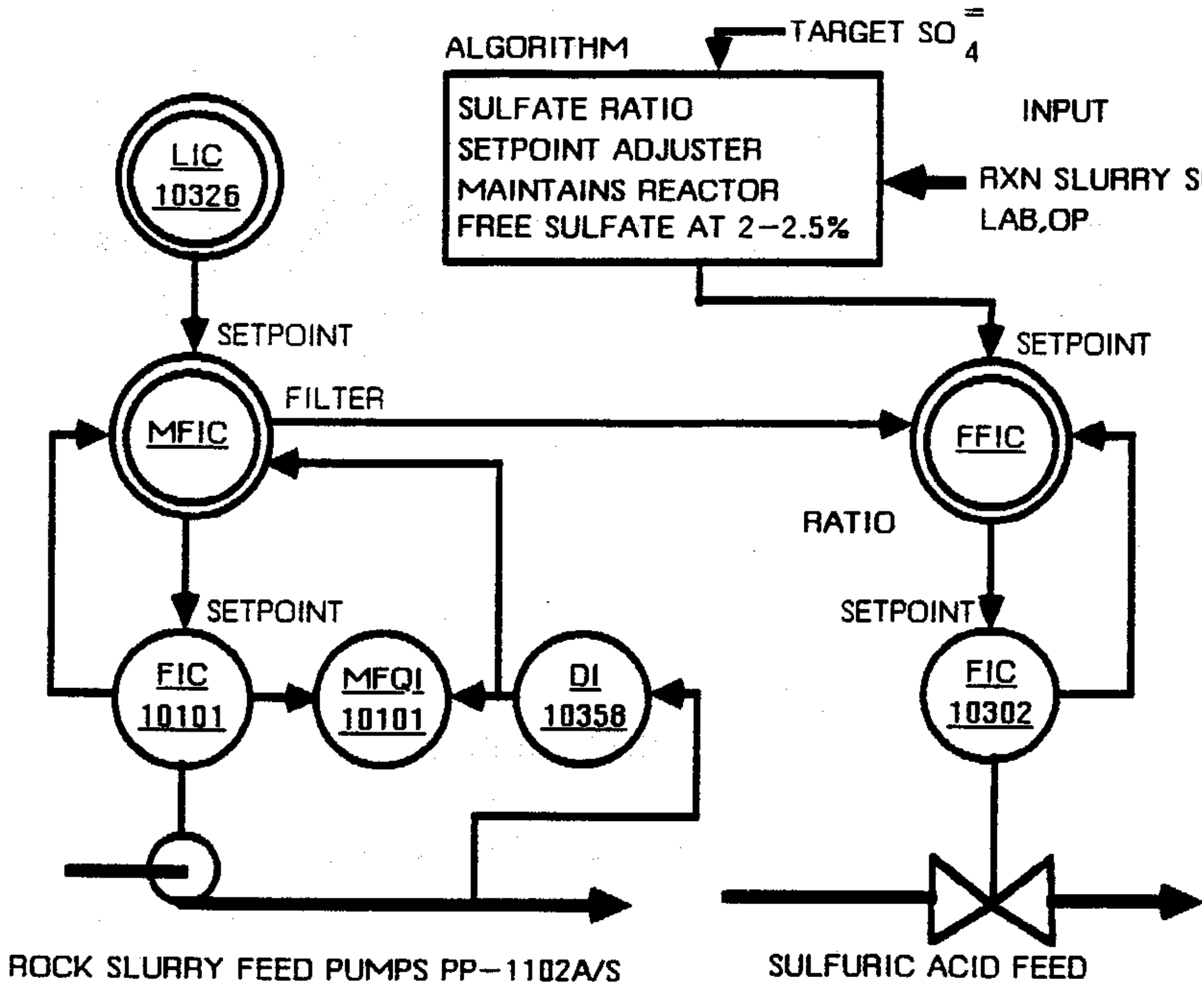
1. MANUAL OR AUTOMATIC CONTROL MOD30

2. COMPUTER CALCULATES MASS FLOW RATE AND RESETS ROCK SLURRY SLURRY CONTROLLER FIC–10101 SETPOINT

3. SULFURIC ACID CONTROLLER FIC–10302 SETPOINT RESET TO MAINTAIN CONSTANT RATIO TO ROCK FEED MASS FLOW

FIGURE 5

REACTOR FEED & SULFATE CONTROL



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4. ROCK SLURRY MASS FLOW RATE SETPOINT ADJUSTED BY FILTER FEED TANK LEVEL PCAP CONTROLLER

5. SULFURIC ACID TO ROCK RATIO ADJUSTED BY COMPUTER TO MAINTAIN 2.0 TO 2.5 % FREE SULFATE IN REACTOR SLURRY

FIGURE 6

REACTOR SULFATE CONTROL

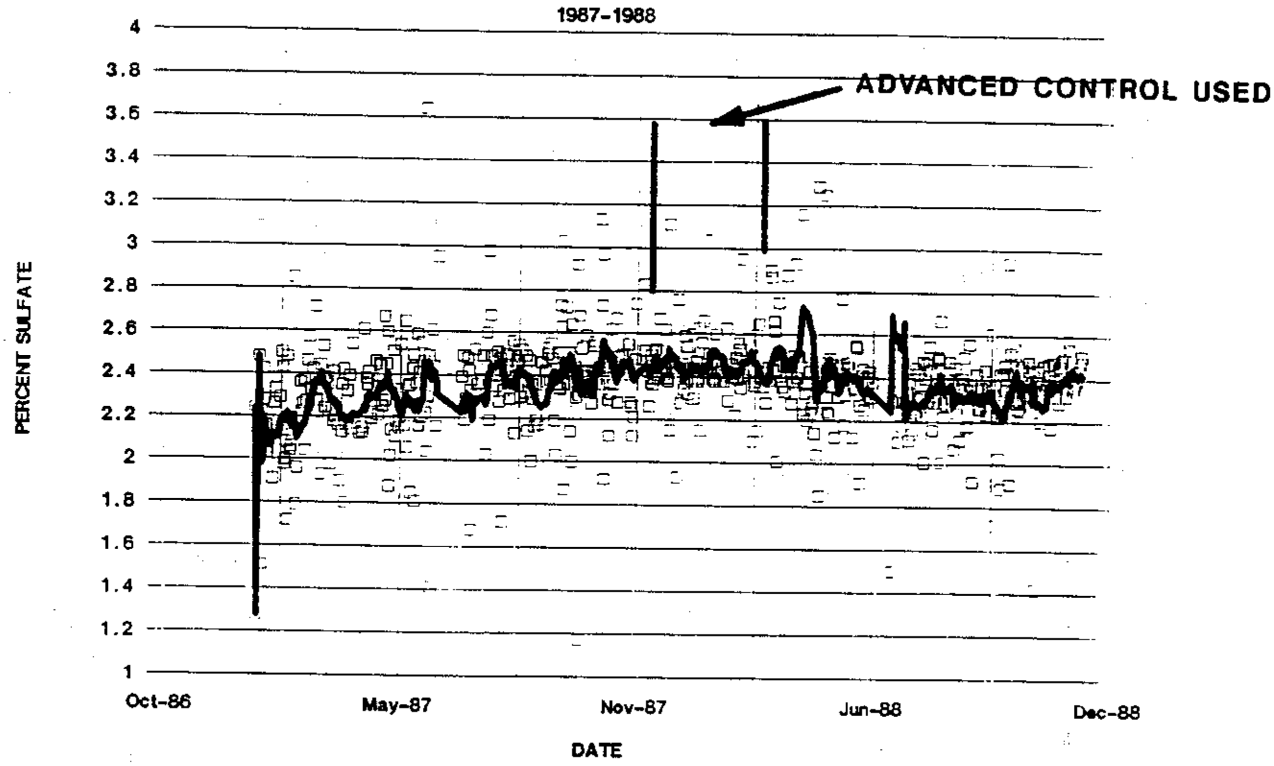

FIGURE 7

REACTOR SULFATE CONTROL

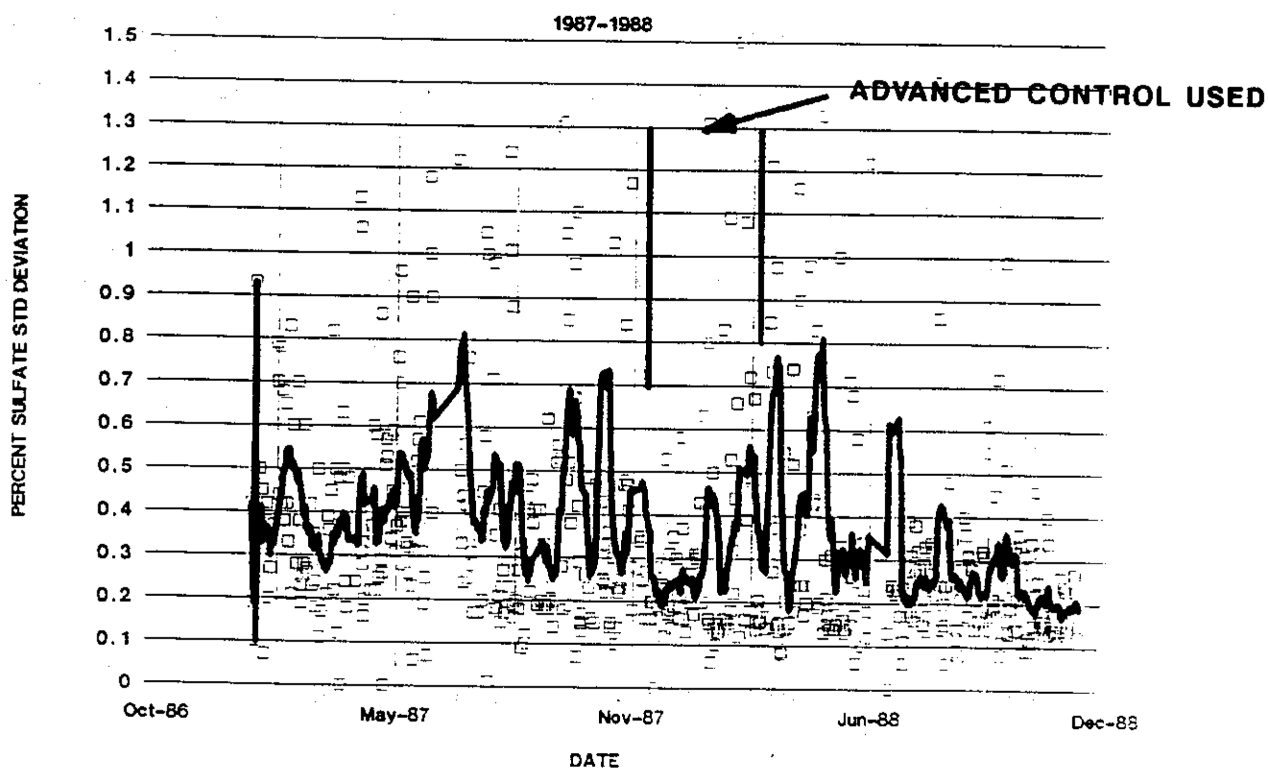

FIGURE 8

SLUDGE BATCH MIX