PROCESS CONTROL TRAINING—SIMULATORS ARE ONLY HALF THE STORY

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ABSTRACT

With reference to greenfield plant projects, using process simulators similar to the designed plant Human Machine Interface (HMI) or Distributed Control System (DCS) has become common practice. These simulators represent a "virtual plant" based on process modeling of the circuit chemistry and thermodynamics, and on the physical nature of the plant, including equipment, valves, piping, etc. The virtual plant allows trainees to troubleshoot problems, optimize process variables, react to alarms, etc., all based on the process simulation model.

Performance Associates' experience is that this complex simulator training is valuable, but only after more in-depth training on the process and control logic. To truly optimize a process plant, prior to simulator training, the control room operators must have detailed knowledge of the following:

- Process objective of each process system, comprising a group of unit operations.
- Process objective of each unit operation.
- Process chemistry and the variables affecting it.
- Important characteristics of each unit operation, the variables affecting it, and the impact on downstream unit operations.
- Plant control loops, interlocks, and alarms.
- Safety issues related to the process and control schemes.
- Operating procedures for start-up and shutdown under various scenarios, as well as important operator tasks.

Additionally, trainees must be intimately familiar with the applicable fundamental scientific concepts, such as pressure, temperature, heat exchangers, electricity, PID control logic, combustion, etc. With this fundamental and plant-specific foundation, the process simulator can be fully exploited for training.

INTRODUCTION

It is common practice in the metallurgical process industry to develop a process simulator for training plant operators prior to plant start-up. These simulators generally have a DCS interface similar to the DCS interface the operator will see and use in the actual plant. Process graphics, controller face plates, and motor start-stop controls are all positioned as they are on the actual DCS. A mathematical model of the process provides the necessary information to the DCS front end so the simulator will act as it does in the actual process.

Performance Associates International, Inc., specializes in developing plant start-up training programs for new metallurgical process plants. Therefore, we are familiar with the approach taken by various mining companies to prepare operators for start-up. In this capacity, we have observed that some companies use the simulator as the primary training tool for their operators. While the simulator is a valuable tool, we have found that simulator training is more effective after more basic fundamental and plant-specific training has been conducted.

TRAINING PYRAMID

Performance Associates visualizes process training in the form of a pyramid consisting of basic, intermediate, and advanced levels. Refer to Figure 1.

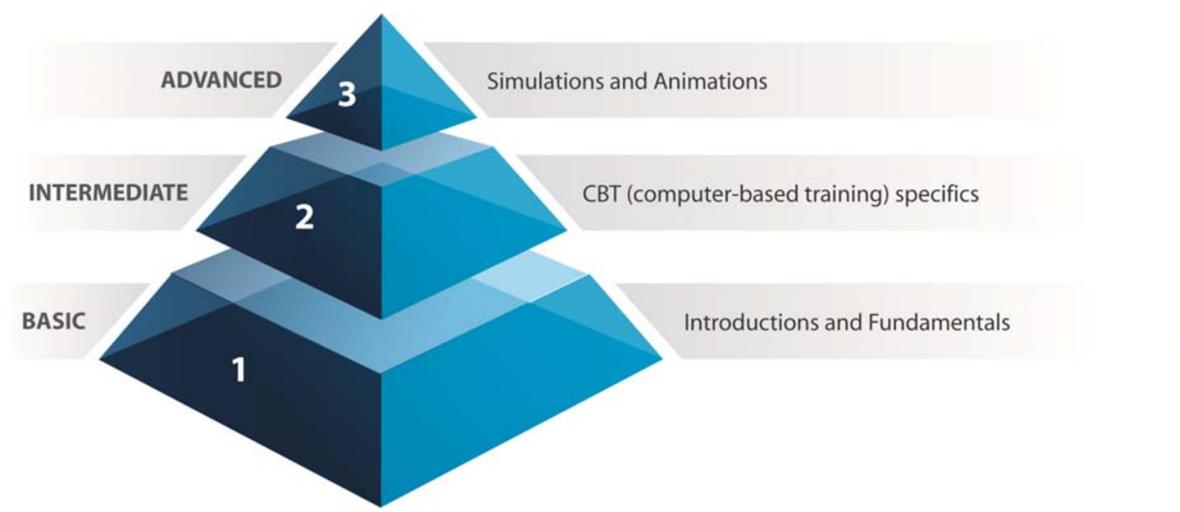

Figure 1– The training pyramid

Basic Training

The theoretical foundation for training is the basic level of the pyramid—the introductions and fundamentals. This training includes applicable scientific principles, such as pressure and pressure measurement, temperature and heat exchangers, acids and bases, solutions and solution concentration, slurries and slurry density, etc. It also includes the basics of process unit operations, such as crushing and conveying, grinding, pumping, size classification, flotation, dewatering, sampling, furnaces, boilers, offgas, etc. The training on each process unit operation includes topics covering the objective, applicable scientific principle of operation, equipment components and general design, and key characteristics and variables. The basic training provides the foundation for the intermediate, or plant-specific training. Ideally, the basic training is computer-based training (CBT) where trainees can interact with the training material via a computer; CBT facilitates the use of animations and videos with voice-over narration to support the theoretical material. Figure 2 illustrates one of the pages from a lesson on the fundamentals of flotation technology.

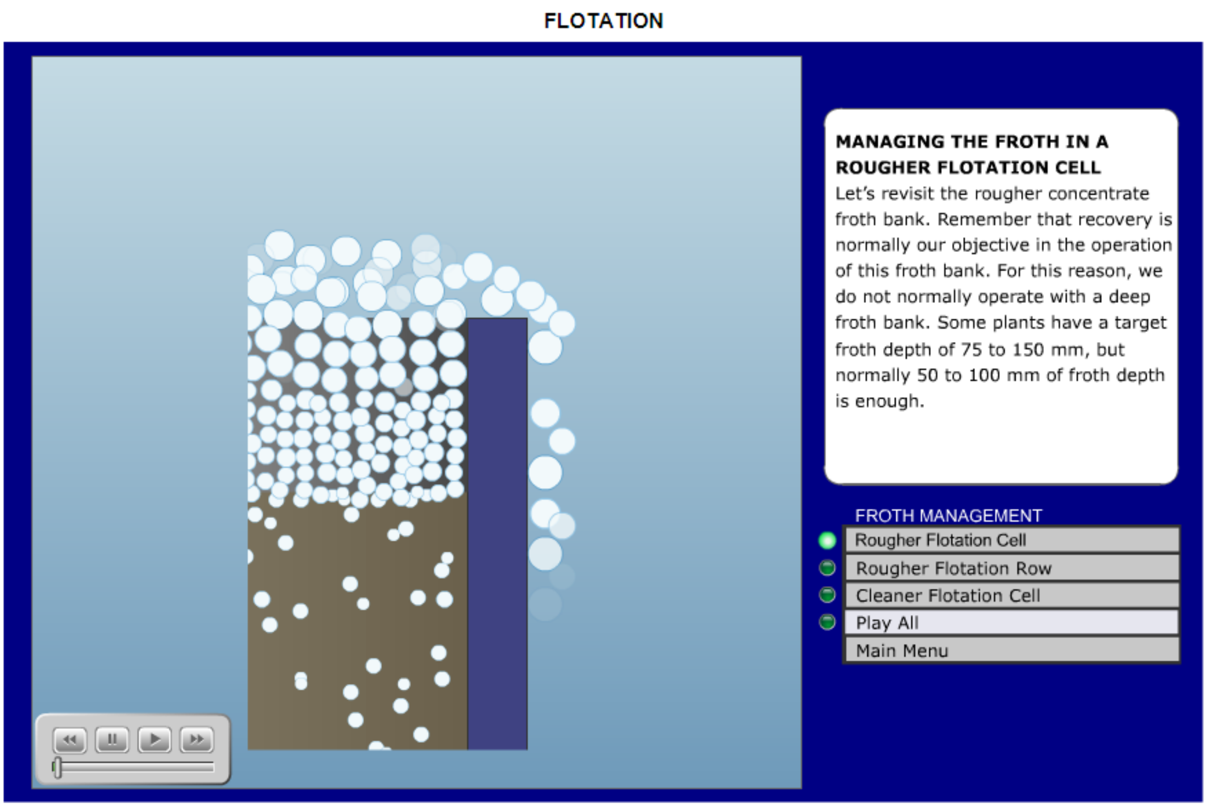

Figure 2– Screen shot of one of the pages in a basic training module on froth management in flotation

The basic training is general in nature and is not meant to be specific to any particular plant. This allows new hires to be trained in the basics before piping and instrument drawings (P&IDs) and process flow diagrams (PFDs) are completed for a new plant. We are also aware of several cases where companies preparing to start new plants have used the basic training as a screening device to make the final selection of new hires and to identify the most appropriate position in which to assign selected new hires. This approach provides an effective methodology to eliminate personnel who interview well but later prove difficult to train.

Intermediate Training

Intermediate training focuses on the plant-specific process. This training is specific to the owner's process and includes the following topics:

- Safety training associated with the specific process, including safe job procedures.
- Process description covering the actual circuits, equipment, and chemistry associated with the new process.
- Each control loop associated with the specific process, including the process variable targets and controller set points. Refer to Figure 3 for an example of a control loop.
- Plant-specific safety and process interlock logic.
- Plant-specific alarms and suggested alarm responses.
- Plant-specific start-up and shutdown procedures under various conditions.
- Other plant-specific standard operating procedures, such as taking samples, measuring the crusher gap, optimizing flotation cell performance, etc.
- Process troubleshooting.

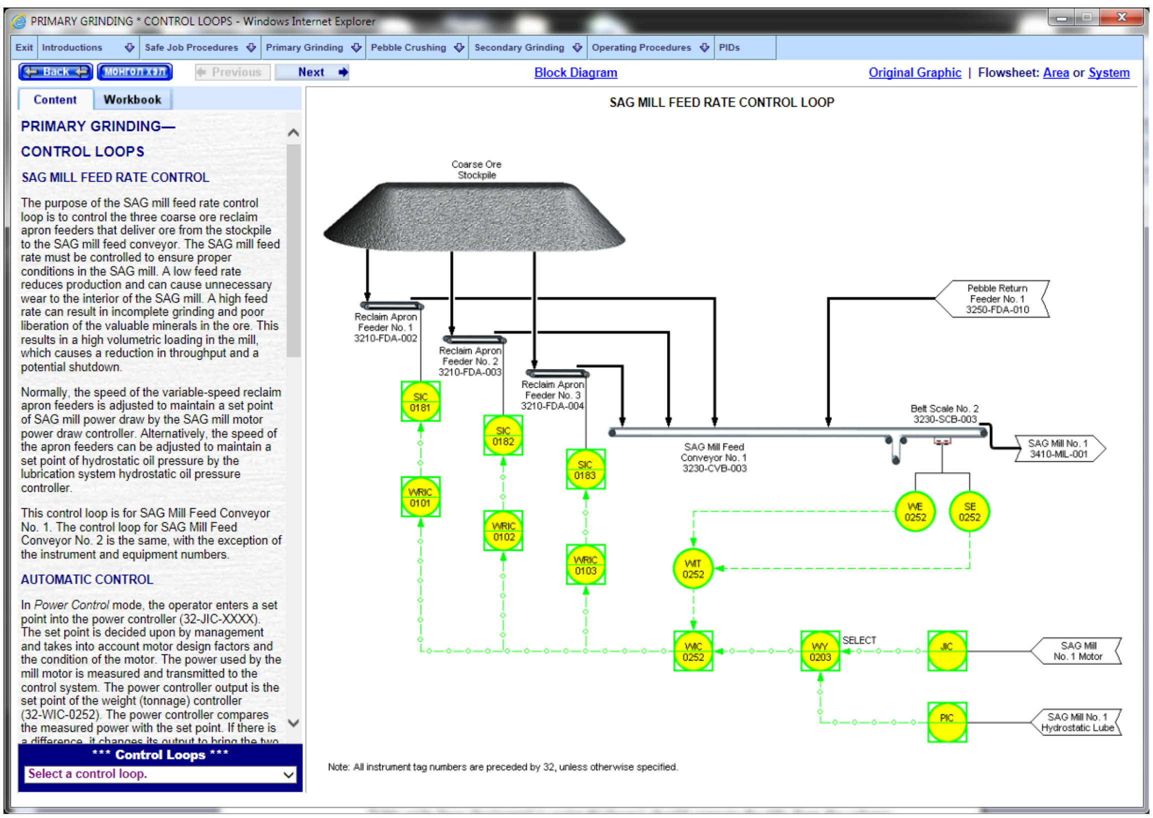

Figure 3– Screen shot of one of the control loops in a plant-specific intermediate CBT module

The intermediate training builds on the basic training by applying the fundamentals of unit operations to the exact equipment and circuits used in the trainee's plant. This includes using the same tag numbers and process flows.

At the end of each intermediate training module, simulation drills are conducted where the training instructor writes down hypothetical problems, each on one piece of paper. The class is then divided into two or more teams. The instructor selects one of the problems previously written. The instructor then describes a symptom to one of the teams that the control room operator would see based on the problem. The selected team discusses the applicable issues relating to the problem and then tells the instructor what the control room operator should do first in order to troubleshoot the problem.

For example, the instructor might say that the field operator in the semiautogenous grinding (SAG) mill area has just reported that the mill discharge slurry appears to be very thick (high slurry density). The target slurry density is 68 percent solids, but the calculated discharge is running at about 75 percent solids and seems to be increasing. The team would then discuss the symptom of the problem and tell the instructor what they would do. For example, they will know from the earlier computer-based training that there is a ratio control loop that modulates process water flow rate into the SAG mill in proportion to the solids entering the mill. The trainee team might say that they would check the ratio controller and the output to the process water control valve. The instructor would then explain what they would see regarding the flow controller set point and output to the flow control valve. This back-and-forth process goes on until the team finds the answer. If a team is not able to solve the problem, one of the other teams can pitch in and try to help. Once the particular problem has been solved, the instructor can take out the original paper on which he or she wrote down the problem and show it with the answer to the class.

These types of simulation drills provide the following results:

- Make the training interesting and get the trainees directly involved.
- Allow the trainees to put into practice the information they have learned.
- Provide a template on how to think through problems and effectively troubleshoot them in a logical sequence.

Advanced Training

Advanced training combines the knowledge gained in the basic and intermediate training and provides the opportunity for each trainee to practice using a DCS simulator that mimics the actual plant process. High-end equipment and process animations can also be effectively used in the advanced training. An advantage of the advanced training is that process and instrument problems can be introduced into the DCS simulator, requiring the operator trainee to troubleshoot the problem using the actual instrumentation available in the real plant. By this time, the trainee has spent many hours in basic and intermediate training and is intimately familiar with the characteristics of the unit operations, chemical and/or physical changes to the feed, process variables, control loops, interlocks, alarms, and necessary operating procedures.

Thousands of manhours will have been spent by the CBT developer interpreting the engineering information, including PFDs, P&IDs, functional descriptions, logic diagrams, and equipment supplier manuals. The information obtained from these source documents will then be written into the CBT material at a level consistent with the education level and degree of industrial culture of the employee population. The information in the final CBT—the basic and intermediate training—represents the prerequisites for the advanced simulator training.

HYPOTHETICAL CASE STUDIES

The following case studies are meant to illustrate the requirement for a deeper level of knowledge regarding the plant and its processes than can normally be attained by having prospective operators study P&IDs and directly enter the DCS simulator training.

Case No. 1—Sump Level Control

Assume that a new operator uses a DCS simulator that is similar to the one in Figure 4.

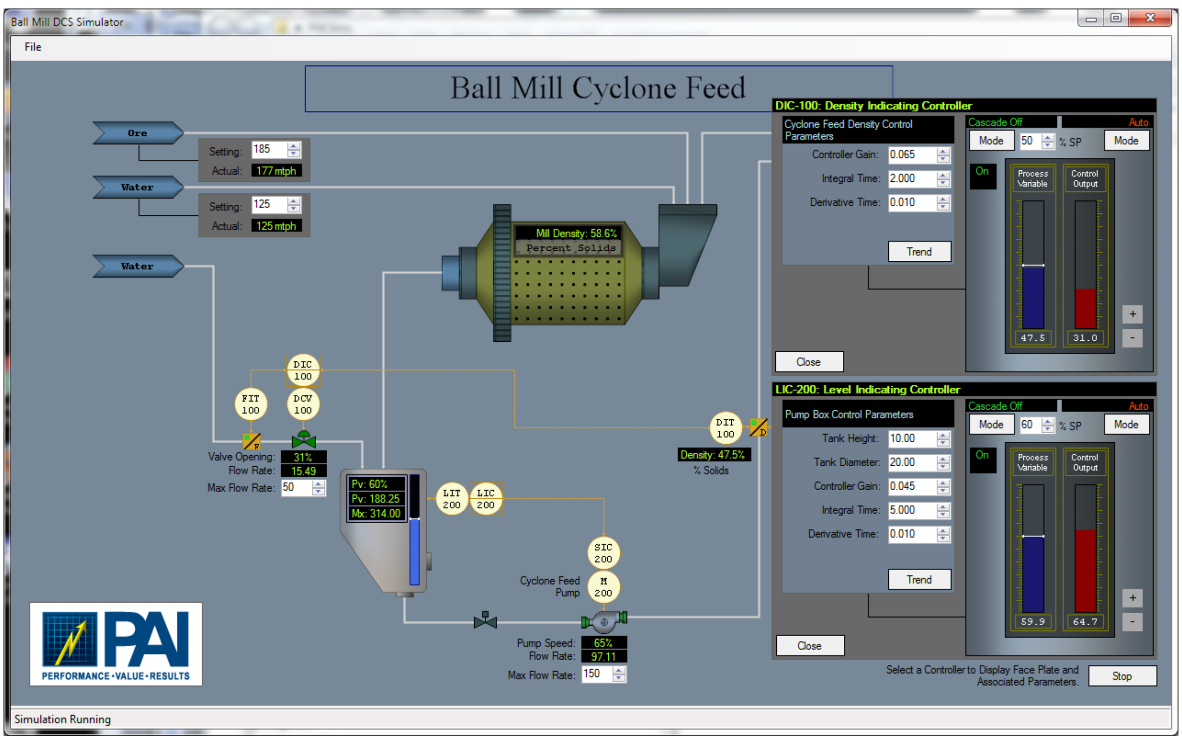

Figure 4– Screen shot of a DCS simulator screen with controllers for cyclone feed sump level control and cyclone feed density control

<u>The Scenario</u>

1. The cyclone feed sump level is being controlled effectively by varying the speed of the cyclone feed pump via the level indicating controller (LIC).

2. Over the next several simulated weeks (time can be speeded up in the simulator), the level is still being controlled by the level indicating controller, but over time, the controller output is trending higher.

3. After another several weeks, the controller output is nearing 90 percent to control the sump at the set point.

The Question

The question for the trainee is—"Why is the output trending higher over time in order to provide the same level of control?"

The Answer

The trainee, having been through basic and intermediate training, has learned that:

1. The cyclone feed pump is a slurry pump.

2. The level indicating controller output is acting on a variable-frequency pump motor controller. Increasing sump level above the set point causes the impeller to speed up, increasing discharge flow rate. Decreasing sump level below the set point causes the impeller to slow down, decreasing discharge flow rate.

3. The slurry being pumped to the cyclone is abrasive.

4. Output from the level indicating controller trending higher over time for the same level of control indicates that the speed of the pump impeller is also trending faster over time for the same level of control.

5. The pump impeller will wear because slurry is abrasive.

6. The most likely cause is that the pump impeller is gradually wearing, necessitating higher speeds for the same pumping discharge flow rate. The pump can then be inspected, and arrangements made to change the impeller.

This problem is similar to problems faced by control room operators in metallurgical plants. Having gone through the simulation drills in the intermediate training, this trainee has learned to methodically think through the symptoms and to rely on his or her knowledge of the unit operation in question, as well as the control logic, to come to the correct conclusion.

Case No. 2—Cleaner Column Cell Copper Concentrate Grade Problem

Assume that a new trainee operator is faced with determining the cause of low concentrate grade from Cleaner Column Cell No. 1. The applicable washwater control loop is shown in Figure 5.

The Scenario

1. The column cell washwater flow rate is controlled by a raw water flow indicating controller with an operator-entered set point flow rate. Output from the controller operates a flow control valve in the water line.

2. The concentrate grade is lower than normal only for Cleaner Column Cell No. 1. Grade is normal for the other three column cells.

3. The washwater flow rate, airflow rate, and froth depth for all four column cells appear to be about the same.

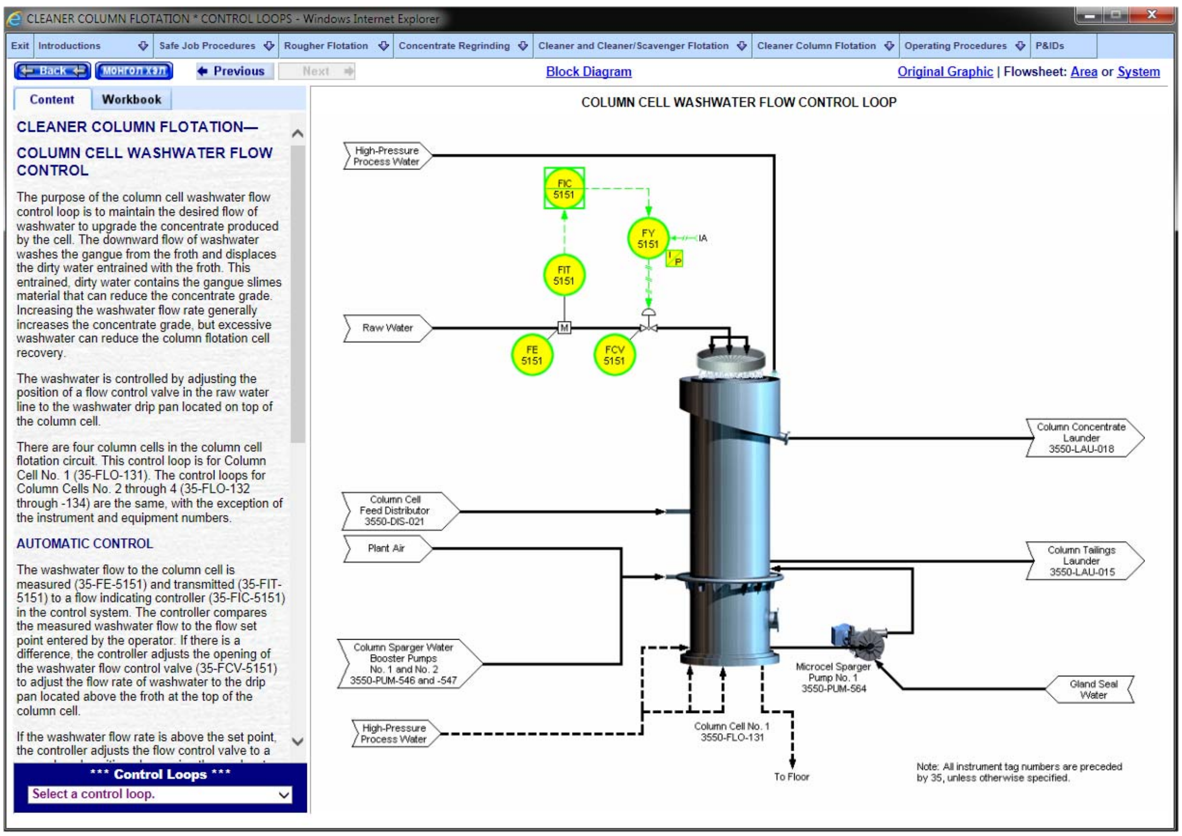

Figure 5– Screen shot illustrating the Cleaner Column Cell No. 1 washwater flow control loop

The Question

The question for the trainee is—“Why is the concentrate grade from the first column cell lower than the target and also lower than that from the other three column cells?”

The Answer

The trainee, having been through basic and intermediate training, has learned that:

1. Washwater is added to the column cell to wash entrained gangue from the froth as it rises toward the top of the column. This stabilizes the froth and improves the concentrate grade. The amount of water added results in a net downward flow of liquid through the column.
2. Raising the set point above the target washwater flow rate does not improve the concentrate grade, but, as shown in Figure 6, results in degraded recovery. Furthermore, the normal set point flow rate for the other three column cells results in the target concentrate grade.

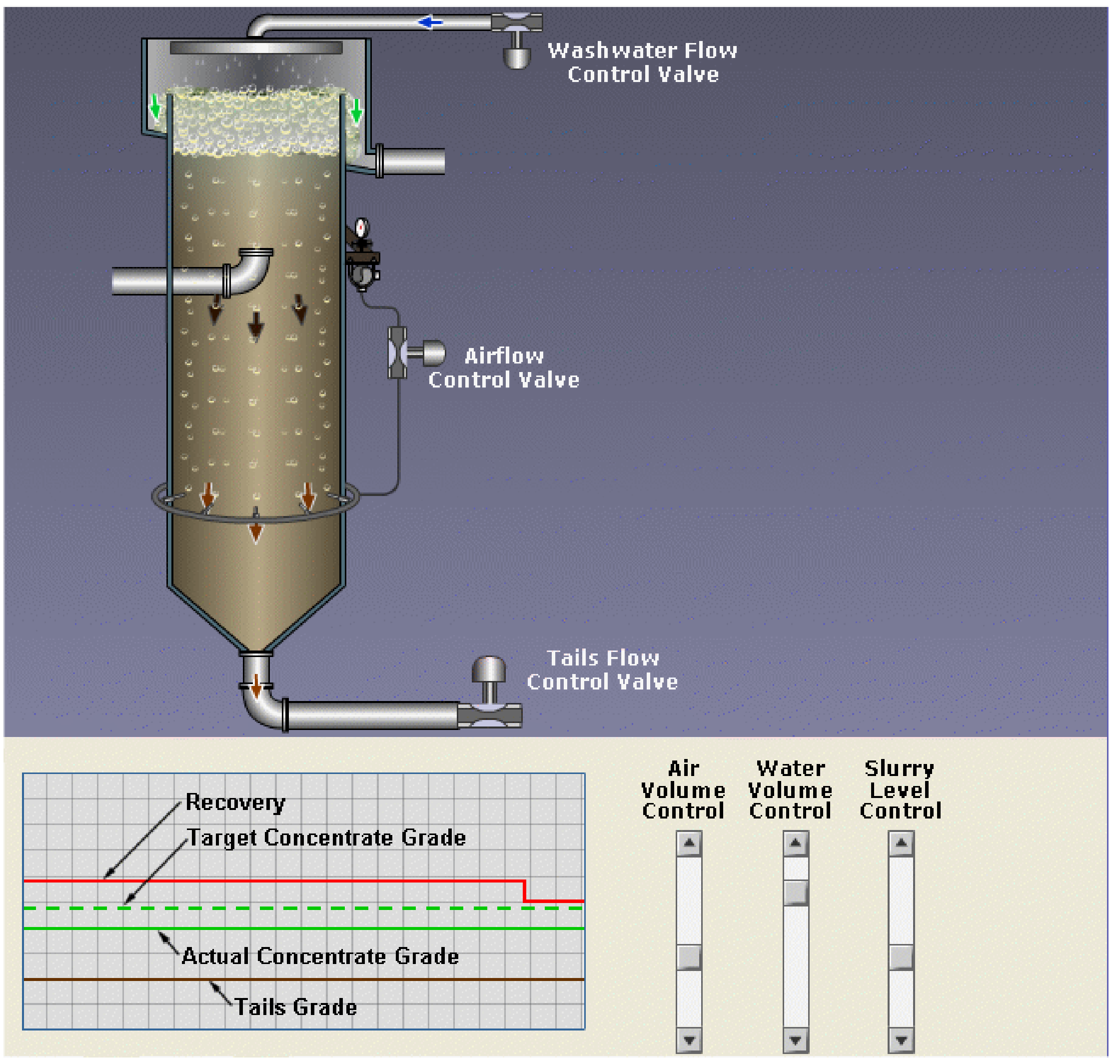

Figure 6– Screen shot of an animation of a cleaner column flotation cell from a basic computer-based training module; note the high water volume set point and the degraded recovery on the trend

3. There is no difference in the airflow rate and froth depth for any of the cells, and the washwater flow rate is the same for all four cells.
4. The trainee knows that the significant variable is the washwater flow rate, as it is designed to wash gangue out of the froth. The trainee also knows that the washwater is metered into a distribution tray above the top of the column. The distribution tray covers the cross section of the column and has holes drilled in the bottom to allow an even distribution of the washwater. The water percolates through the holes in the tray and drips into the rising column of froth in the column flotation cell.
5. The trainee decides that the problem revolves around the flow of water from the distribution tray onto the froth. The subsequent inspection shows that some of the holes in the distribution plate are blocked, resulting in channeling and an inadequate distribution of washwater.

As in the first hypothetical case, this operator has learned to methodically work through the problem, relying on his or her training in the fundamentals of column flotation cells, as well as the operator's knowledge of the applicable control loops. In this case, the DCS and instrumentation were doing all that was asked. It was the hardware comprising the flotation cell that was the problem. This required that the operator be intimately familiar with the unit operation and its principle of operation.

CONCLUSION

High-end DCS simulators are an effective tool for training operators of metallurgical process plants. They can make the transition from the simulator to the actual plant control system much easier than in those cases where they are not used. However, for effective start-ups, it is critical to understand that this tool is the culmination of a much deeper training program. It is only through providing the basics and intermediate plant-specific training that trainees can get the most out of the simulator training.

When getting ready for a plant start-up, preparations must begin early, and training should consider the *Training Pyramid*—operators must learn the fundamentals and process specifics before commencing simulator training.