Using on-line computer simulation for rapid displacement heating control system checkout

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A new rapid displacement heating simulation was used to debug a distributed control system. The authors believe it has already taken weeks off the actual time that will be needed for startup.

The rapid displacement heating (RDH) technique of pulping offers a number of advantages over conventional batch cooking (*1*, *2*). Reports of a 60–75% decrease in steam consumption and an increase in fiber strength have caught the attention of mills considering expanding or retrofitting their pulping lines. The RDH system is more complex than a set of conventional batch digesters, and therefore requires a more complex control system. The increased operational complexity is due to the closely coupled nature of the process, and the increased tankage due to segregated hot liquors. Since the full-scale implementation of this technology to the industry is relatively new, the optimum method of operation is still being sought.

We describe the use of a simulation running on a microcomputer to assist in the design and checkout phase of a distributed control system (DCS) for a six-digester RDH system from Beloit Corp. This simulation was constructed for Willamette Industries to assist in the checkout of the ABB Master control system. While actual startup has not occurred, we estimate that many weeks of on-site checkout time have already been saved.

RDH process

The RDH method of pulping involves pulping liquors of increasing temperature and alkalinity through the digester to heat the chips and prepare them for cooking. When the cooking phase is complete, the hot black liquor is displaced by washer filtrate. As the hot black liquor leaves the digester, it passes through a heat exchanger, heating the incoming white liquor which, in turn, is charged to another digester. It is this exchange that creates the energy savings as well as adds to the complexity of control. After the chips are cooled, they are either displaced from the reactor by compressed air or are simply pumped out. The alkalinity profiling which occurs in the precook steps, along with the cold blow, are the primary factors leading to increased fiber strength (*3*). The exchanging of hot black liquor with incoming white liquor leads to the increased thermal efficiency.

Control system checkout overview

Figure 1 illustrates how the various components of the system were connected. A model running on a microcomputer provided simulated process values to the control programs via an RS-232 serial interface. The ABB control programs were modified such that the output values were made available to the EXCOM communications package, which transferred these values to the MasterPiece serial port. These valve positions and motor commands were read by the simulation running on the microcomputer, and the appropriate process values, as well as the status of limit switches, were returned to the control system. Using this technique allowed the control system to operate exactly as if it were connected to the actual RDH process.

The model

The simulation included all phases of the RDH digester. **Figure 2** illustrates the major steps a single RDH digester undergoes in a full cooking cycle: (a) the digester is filled with chips, (b) cool black liquor (170°F) is circulated through the digester, (c) the digester is pressurized and hotter black liquor (290°F) is introduced to the chips, (d) hot black liquor at cooking temperature (340°F) is pumped to the digester, (e) white liquor mixed with some black liquor at cooking temperature is finally introduced to the digester, (f) liquor within the reactor is recirculated to

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insure an even temperature and concentration profile (steam may be injected to achieve cooking temperature), (g) after cooking is complete, washer filtrate (170°F) is used to displace the hot cooking liquor, and (h) once cooled, the chips are pumped to the blow tank.

As liquors enter the digester, displaced liquors are sent to appropriate tanks based on their temperatures. Because the hot liquor tanks are maintained at pressures up to 90 psig and the cool liquor tanks are at atmospheric pressure, switching of destination tanks challenged flow and digester pressure controllers.

A temperature profile through the digester was constantly calculated so that the control system could perform the proper outlet flow switching. Because of the drastic swings in outlet pressure, modeling the proper hydraulic behavior of the system became important. Actual pump curves and control valve coefficients were used to calculate system pressures. In addition to all the analog process values being simulated, the model also returned appropriate signals for limit switches on valves and contacters for motors. The ability to simulate the failure of those limit switches and contacters was included. All the signals—digital, analog, limit switches, etc.—are necessary to properly evaluate the DCS logic, as they all interact in the proper control of the actual process.

The control system

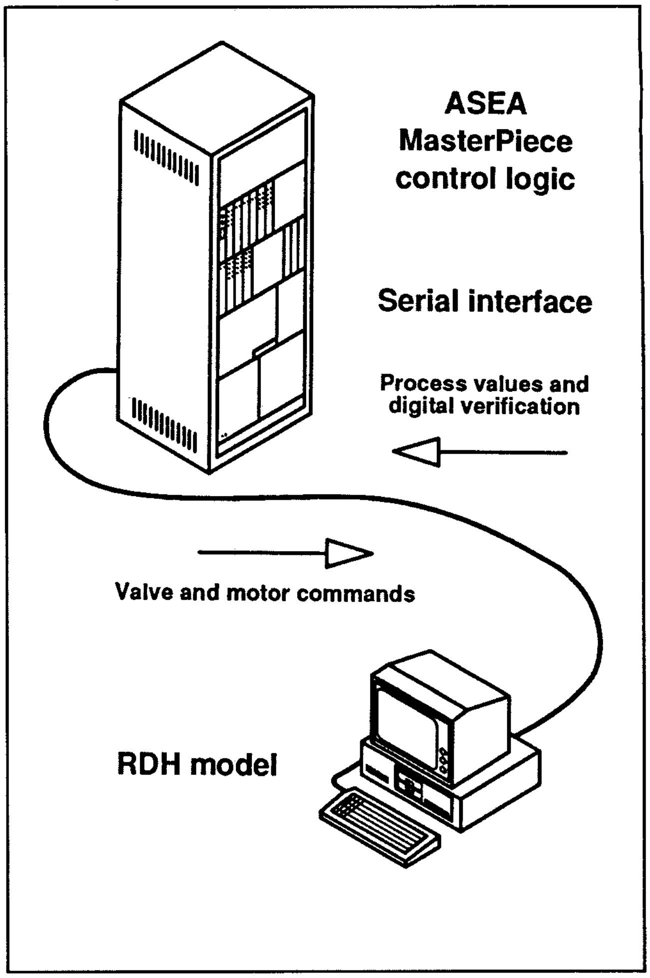
The RDH process involves controlling and interlocking 44 valves and 8 motors for the operation of a single digester and the tank farm. All of this interlock logic, as well as the controllers for the analog loops, was programmed into the ABB MasterPiece system. The only modification to the control programs to allow the simulation to be used was to reassign loop inputs and outputs from hardware addresses to data exchange files.

The linkup

The control system and the model running on an IBM Model 70 were connected by an RS-232 serial link running at 19,200 baud. On the control side, the communications were handled by a standard ABB package called EXCOM. EXCOM withdrew valve command data from the data exchange file and sent them to the microcomputer via the serial link. A subroutine in the model program received those commands and transferred them to data arrays for use by the model. After the simulation was run the procedure was reversed, the microcomputer returned process values to the control system, and the cycle continued.

Each cycle involved exchanging a total of 64 analog signals and 96 boolean values. The analog values were bundled into data sets which contained up to 24 values and were sent and received by a single command. The digital signals were condensed such that 32 digital signals were transmitted in a single hexadecimal value. This value was then broken up and decoded by the communications subroutine in the model.

1. Control system checkout overview



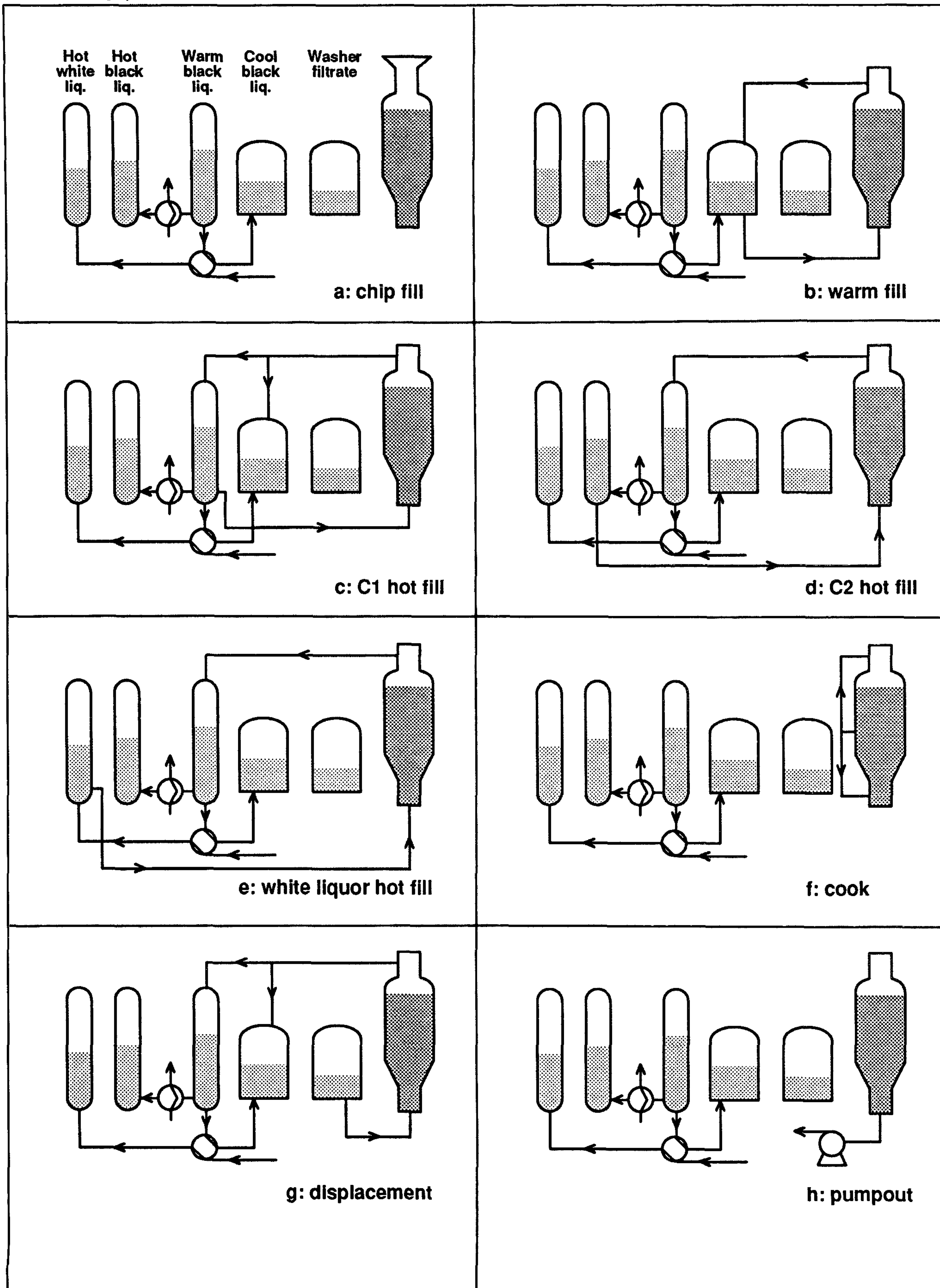
Checkout using simulation

The checkout of the control system was done in two phases. In Phase 1, the simulation was used to debug the control programs in the DCS. After Phase 1, the mill personnel recognized that this was an excellent tool for performing the Factory Acceptance Test for the RDH control system. This second phase of testing involved not so much finding programming errors as studying the operation and philosophy of the control system.

The Phase 1 work was an iterative process. We found that the model as initially presented was lacking in certain areas. As difficulties were detected and resolved on one side of the system, weaknesses on the other side were detected. Sometimes control programs are tested by "closing the loop" within that program or by using other programs running on the same hardware. Because the model in this case was physically separate from the control software and because one individual was in charge of that software and another was attending to the model, we were one step closer to the actual operation. This led to a more thorough and realistic checkout.

Phase 1 was productive. Bugs were found and resolved. Interlocks were tested; sometimes there were too many, sometimes not enough. At one point, conflicting logic requirements would not allow the digester sequence to proceed under any circumstances. This logic was modified.

2. RDH cooking cycle



A control strategy which had been proposed involving pressure override on a flow controller was found to be unstable, regardless of controller settings. Because of the simulation, a new strategy was employed which worked without problems.

Most of the issues resolved during simulation drive check-out would not have been addressed until actual startup.

Phase 2 work involved more testing and receiving input from mill personnel. At this point, the programming errors had been eliminated. By using the simulation, mill people were able to observe the modeled process and actually use the control system. In doing this, they came up with a number of suggestions concerning how to better present the data to the operator, as well as changes concerning safety and basic operation of the unit. In a normal test using manual switches and potentiometers, none of these issues could have been examined. The mill people were pleased at the opportunity to experiment with this new system before the chips and liquor started flowing.

Conclusions

The RDH system presents a unique control challenge in that it combines the analog loops normally found in a DCS with digital and interlock logic traditionally found in programmable logic controllers. Both of these functions were combined in the ABB MasterPiece system. A detailed simulation was used to test and evaluate that control system. In retrospect, it is hard for us to envision how this system could have been properly tested by any other means. The uses of the simulation are far from over, as the mill intends to use it for training of the RDH operators. With this training experience, and the control system checkout accomplished to date, there is little doubt that the startup of the RDH digesters will be safer and shorter than it would have been without the use of simulation.□

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