

Integration of process simulation with millwide information and control

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The potential benefits of integration are significant, and the costs are relatively minor.

Process simulation programs, both steady state and dynamic, have been used extensively by the industry for design, troubleshooting, removing bottlenecks, and process balancing. Because of their sophisticated formats, these tools have remained in the domain of the research lab or MIS shop. Therefore they are used sporadically—when the need arises.

Simulation programs have not migrated to the mill floor where they would have the most impact on day-to-day operations. Downward migration has been nonexistent, because the benefits of a process model are not apparent unless the process simulation program is part of a distributed control system (DCS) package or a millwide system.

Two factors have hindered the use of stand-alone simulation programs at the mill level: the need to build and maintain a detailed mill model, and the difficulty in working with the simulation programs on an infrequent basis.

With the introduction of a millwide information and control system (I/C), the DCS is seen as one part of the integrated information management of the mill. The systems are now available to easily migrate the simulation program into the mill environment. The major deterrents to their use by mill personnel can be removed by the careful design of process schematics and windows and by a commitment to develop the mill model as part of the millwide installation.

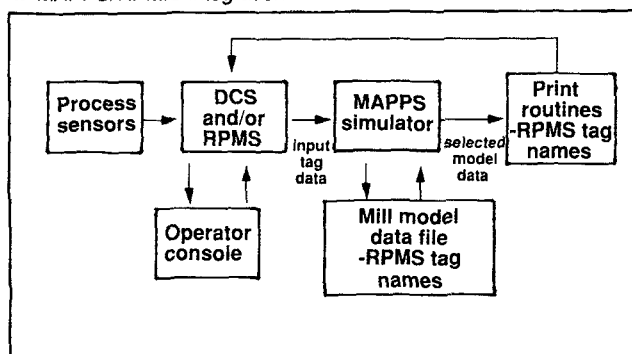
Millwide information systems embrace a variety of techniques

Millwide system technologies have been extensively discussed and often maligned, but there now appears to be a growing acceptance of the concept by the industry. Major benefits from millwide information management, discussed by Perkins, Fadum and many others (1, 2), are listed below.

- Product scheduling

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1. MAPPS/RPMIS integration



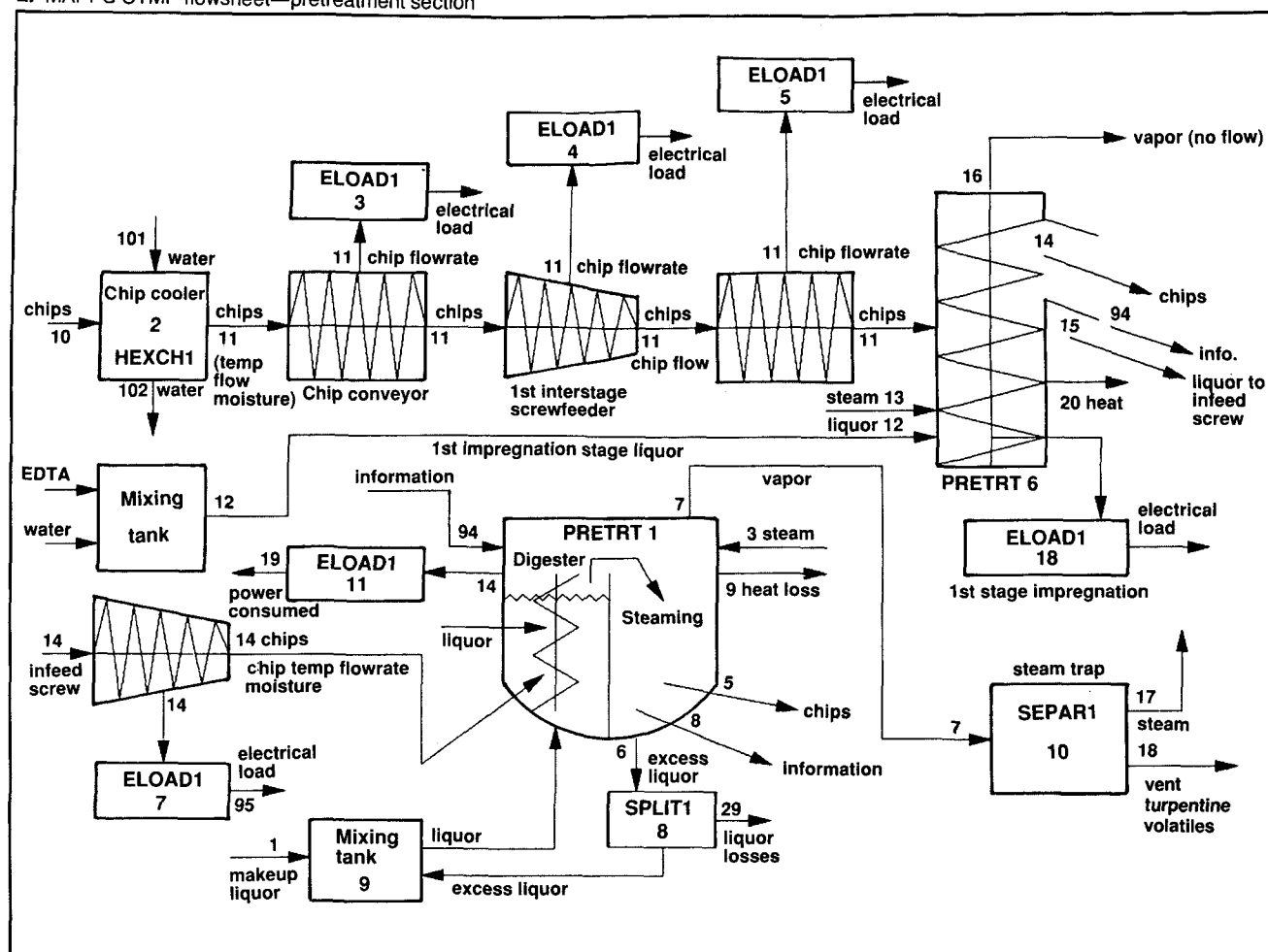
- Inventory control
- Product tracking
- Decision support
- Quality management
- Energy management
- Shop floor control
- Production monitoring.

Although many different systems may still be termed "millwide," an I/C system should combine under a single architecture the process control system, historical database, and business office and management computer systems. The system should be accessible through a single data window as advocated by Clark and McMordie (3).

New types of information available through integration

An integrated system should also include tools for production management, such as trim optimization and production scheduling as suggested by Perkins. The millwide system is the ideal environment for a host of productivity tools, many of which are not yet available or are currently used in isolation. Migration of a process simulator into the millwide system would provide the three important new types of information not generally available to mill operations and management:

2. MAPPS CTMP flowsheet—pretreatment section



1. Mass and energy balanced reconciled process data (RedD) returned to the historical database.
2. Information not currently available through the limited numbers and types of sensors—referred to later as inferential information (InFI). This information also points to new sensor applications.
3. Optimized setpoints available to the DCS (OSP).

Data reconciliation

RedD data is commonly analyzed off-line and is frequently used to schedule boilouts in evaporator systems. In an integrated system, RedD could provide evidence of failed or out-of-calibration sensors and continuous data on process energy and mass flows. Data reconciliation is accomplished by using a linear or quadratic programming optimization program to minimize a specially-defined objective function between the model output (predictions) and the measurements. The optimization is normally subject to a variety of constraints and bounds. However, the key constraints enter naturally through the laws of mass and energy and (possibly) momentum conservation, which form the basis for the process models. Other constraints may involve physical or design limits. At the optimum, the reconciled model values will approximate the measured values.

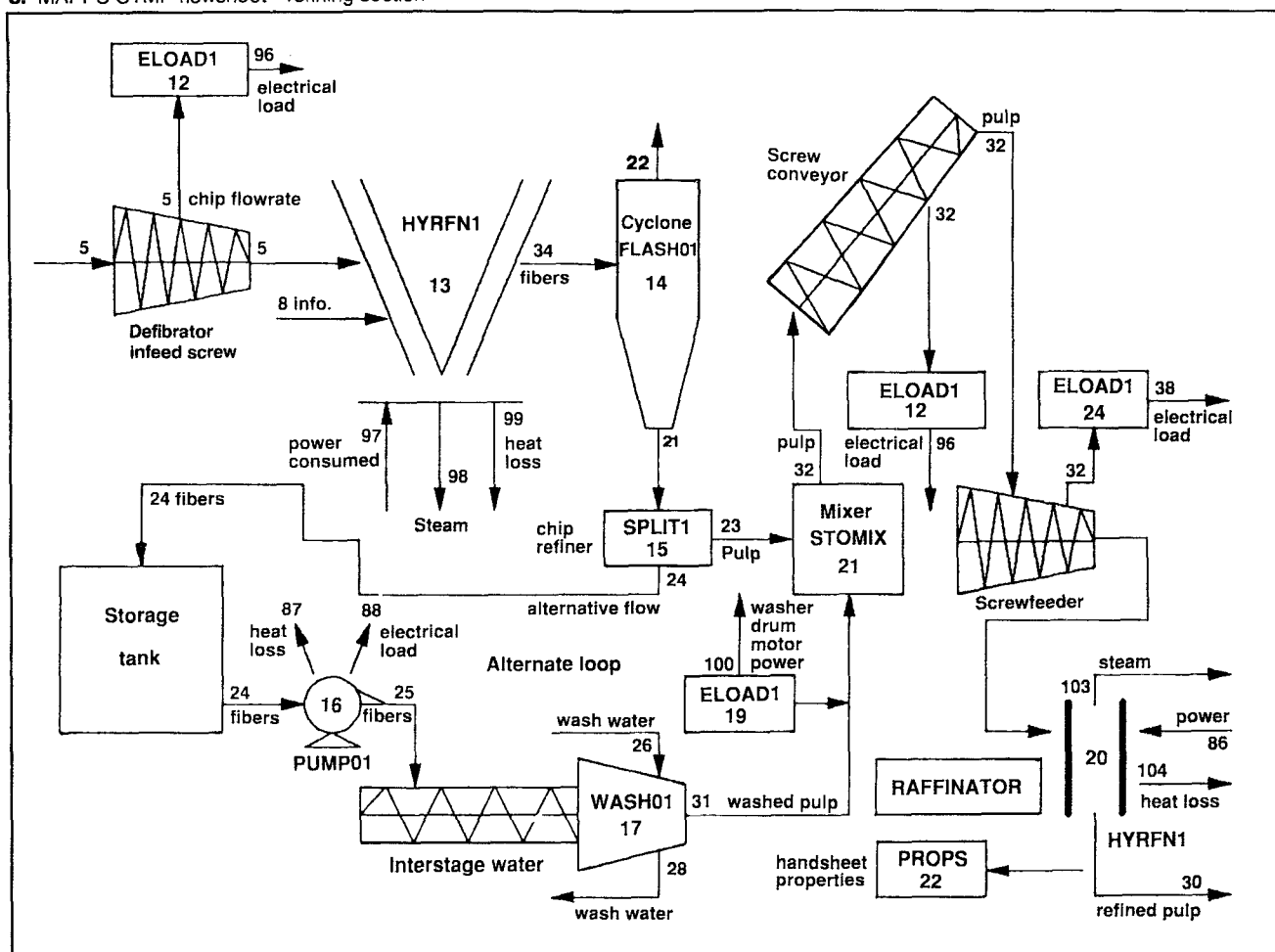
Significant residual deviations indicate possible sensor problems, a problem in setting up the optimization problem, or an improperly structured model.

End-use performance + mass and energy

InFI data can take on a variety of forms and serve a variety of uses. Unlike other simulation programs, Modular Analysis of Pulp and Paper Systems (MAPPS) handles not only the usual mass and energy flows but also the difficult-to-measure pulp quality and paper property variables called performance attributes (PATs). The variables form the basis for more sophisticated and predictive process models for refiners, screening and cleaning, forming, pressing, and calendering, to name a few, making it possible to simulate many of the subtle effects in pulping and papermaking (4-6). In this enhanced simulation environment, the application engineer can develop more realistic and predictive millwide process models. These more sophisticated models can be used to develop and test advanced control strategies based on inferential or model-reference control and setpoint optimization techniques.

General information such as product properties and pulp quality—e.g., fiber freeness, fiber length and width distributions, optical and tensile properties—generated by

3. MAPPS CTMP flowsheet—refining section



the process blocks can be presented as supervisory information. Product and handsheet properties at strategic locations could be predicted from property models and also made available. This information can be combined with related operating data computed by the process models. For example, consistencies and freeness throughout stock prep, drainage, basis weight, moisture and retention profiles, sheet moistures and caliper throughout the press section, sheet brightness, scattering, and absorption through the papermaking process could be related to pulp and paper properties in these areas. These data could be presented along with related process data, such as refiner loadings, machine speeds, press loadings, and dryer steam consumption.

Advanced control

InfI data could also provide a basis for more advanced control algorithms such as feed forward, inferential, and model reference control. Implementation of these advanced control strategies would depend on the cost vs. benefit. Feedforward control would require an accurate model as well as measurements of the process inputs. Model accuracy and precision must be assured through detailed validation studies prior to the development of the

systems. To assume continued model accuracy, on-line self-tuning algorithms would be essential for full-mill model reference control.

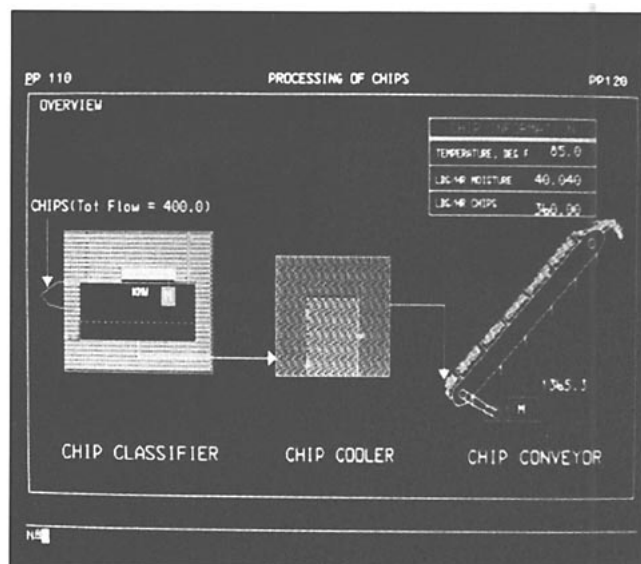
Perhaps a more feasible approach would be inferential control based on new or revised feedback control loops using InfI data. Model reference control as discussed by Stephanopolous (7) could be used to adaptively tune existing or modified controllers. Although the full-mill model, which is able to show interactions across the process, would be preferable for control, portions of the mill could be modeled, integrated directly into the DCS, and used to augment local control loops.

Setpoint optimization

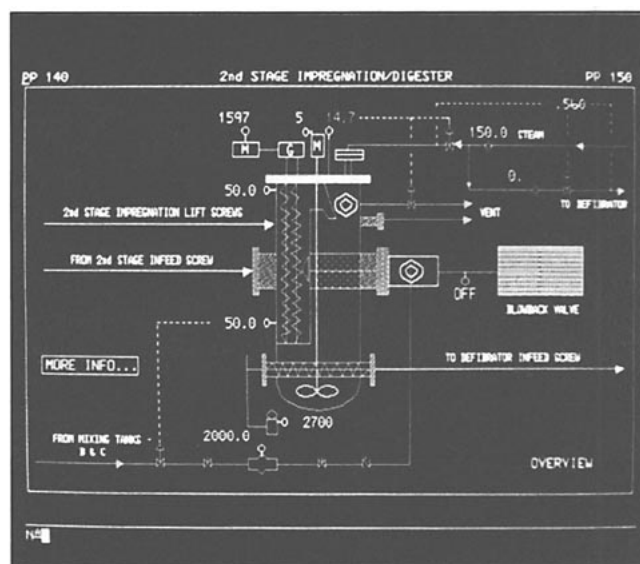
Combinations of RedD and InfI along with cost and production data could be used to form an overall management goal objective function. This constrained optimization problem, when run along with the mill model simulation, would yield values of optimal process inputs. Many of these inputs would represent setpoints for key process control loops. These optimal setpoints would be made available to the DCS or provided at the supervisory level.

The entire system could be implemented in stages with supervisory level information as the first major milestone, followed by evaluation of the model over a period of time.

5. Chip feed/cooler schematic



7. Second pretreatment (digester) schematic



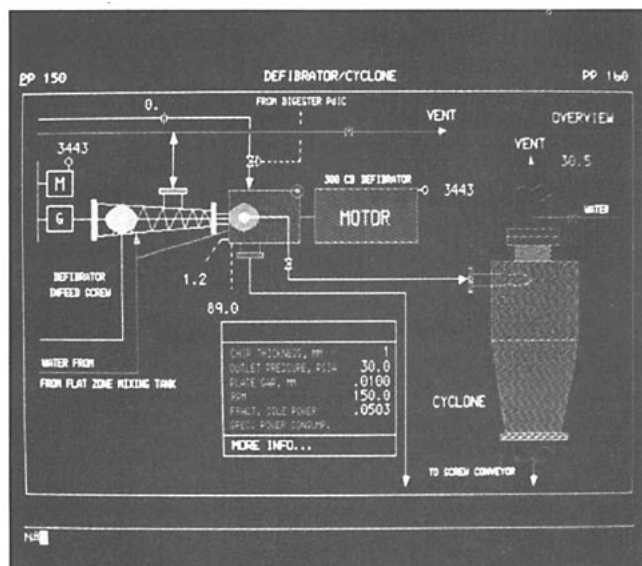
other “slave” programs such as schedulers, discrete-event simulators for shop floor management, and operator trainers, thus enhancing the value of all subsystems.

A demonstration platform for millwide simulation

A cooperative venture with members from both educational institutions and industry is in the formative stages in Atlanta. Among the many diverse goals of the venture are the development of new chemithermomechanical pulp (CTMP) technology, demonstration of energy-saving techniques, process modeling, better understanding of the effects of pretreatment on refining, and last but not least, demonstration of an integrated information and model-based simulation system. The CTMP pilot plant, based on Sprout-Bauer refiner technology, was provided to Georgia Institute of Technology by Mead Corp. Process control

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8. Primary refiner (defibrator) schematic



technology was provided by ABB/Combustion Engineering in the form of a Taylor Model 300 DCS.

A real-time database and advanced control system called RPMIS, provided by IBM, was installed. It communicates with the DCS as shown in Fig. 1. The MAPPS process simulation program developed by the Institute of Paper Science and Technology (IPST) was integrated into RPMIS so as to run as a "slave" directly with the DCS through touch screens or through separate RPMIS monitors. Through the process schematics, developed through the schematic building facility of RPMIS, the operator can view selected tag information generated by MAPPS as well as test the effects of changing process inputs, whether or not the process is in operation.

System architecture

Process sensor data are passed to the Mod 300 system and on to RPMIS, which logs the historical data. These data are defined by tag names which are commonly understood across both the DCS and RPMIS. Without the simulation program and process model, that would be the end of the story as far as control and information processing is concerned. However, with the pilot model the current values of the RPMIS tags are passed to MAPPS as input information.

The current level of sensor data is not enough to completely define the simulation model. Other input data are provided directly through RPMIS or are currently hard-wired into the data file. MAPPS communicates with RPMIS through the RPMIS tag names. The level of integration is rather shallow, as will be explained later. Each time MAPPS is scheduled to run, it is booted up and run as a batch program. When MAPPS reads and interprets the flat input data file containing the pilot model, the RPMIS tags are parsed as input data. As these tags are interpreted, the current tag values are read in. This is the input side of the interface. As the simulator is run to convergence, a specially modified print block is run. This block identifies all the MAPPS variables

of interest to RPMIS. These data are gathered by the model and passed as arguments to the RPMIS tags through standard subroutine calls. This output side of the interface passes data back out to RPMIS each time MAPPS is run.

In this way a large variety of additional (Infl) data are passed back to RPMIS which are now available to the operator through process schematics screens. These data include electrical loads, moisture and temperature profiles in the chips before and after pretreatment, fiber length distributions and freeness development, handsheet properties, power consumption in the refiner, and fiber consistencies throughout the process.

Interfacing to the model

Another advantage of the integrated system over the use of a stand-alone simulation program is the added ease of use of the system for the occasional user such as the mill operator. The entire window on the mill model is viewed through the process schematics which are designed to the operator's specifications. Both inputs to the model and outputs from the model are passed through the process schematics or background screens, which may contain figures or tables of related data. It is the simplified and specific nature of this interface which removes one of the deterrents to the use of a simulation tool at the mill level, making the model and simulator transparent to the operator.

Resource requirements for integration

The integration effort was relatively straightforward and required only a few days to modify the programs. Model development was, of course, more involved, requiring several days to "build" the data file and tune the model. Building the graphical interface and coding the tags within RPMIS also took about four days. For an integrated mill, one would expect that this effort could take considerably longer. However, this process could be broken down into individual process areas with each requiring two to three weeks' time.

The relatively shallow integration results in an inherently slower run time and degraded performance, meaning that not all simulation results will be available in real time. A deeper level of integration will require modifications to the simulation program to make the code "reentrant." Other modifications to increase speed are to reduce the use of menu files, reduce I/O, and continually update the current data file. It is hoped that these modifications will be portable to other millwide systems. The key implementation issue remains the development of the mill model to the degree of detail required by mill operators and engineering.

A specific application—the CTMP pilot process

The MAPPS process schematics representing the CTMP pilot system are shown in Figs. 2 and 3. Each block represents basically one physical operation in the process. Figure 2 shows the general flow of chips through the chip cooler, conveyors, interstage screw feeders, and pretreatment vessels. Figure 3 shows the flow of chips or fibers through the infeed screws, and refiners (defibrator and raffinator) with an alternate path through interstage

washing. Blocks labeled "ELOAD" compute the electrical power consumed for each of the attached blocks.

The pilot process consists of a screw feeder/conveyor system into each of the two impregnation vessels. Compression during feeding and decompression in the impregnation stages causes the chips to break down into a wide variety of shapes, from toothpicks to fines. In the first impregnation stage, the fibers absorb a solution of EDTA in water. The second and more important impregnation stage consists of an alkaline pulping liquor impregnation followed by a pressurized steam impregnation.

During impregnation, the chips absorb moisture into the lumens and cell walls, causing them to soften and lose volatile and extractable components. Transport into the cell lumens is primarily via Darcy's Law, while transport into the cell walls is through diffusion subject to thermal and chemical equilibrium. Moisture can also enter the fibers through vapor phase diffusion in the steaming section.

Steaming also heats the chips, which also contributes to softening. Energy transport is primarily by conduction but also may occur through sensible heat from liquid impregnation. Thermal softening occurs as the temperature of various portions of the chips reach and exceed the glass transition temperature, which is a function of the chemical composition and thermal properties of the cell wall as well as the presence of thermal softening agents such as water.

The extent of thermal softening then affects the energy required for fiber-fiber separation in the refiner. Ideally, separation will occur predominantly in the S-2 layer, creating large surface areas and improved bonding. Portions of the chips heated above the glass transition temperature will separate prematurely at the middle lamella. Fibers will then be coated with lignin, with low surface area and poor bonding potential. MAPPS models of pretreatment and refining are designed to take these and other interactions such as fiber swelling and surface area development into account.

Several of the RPMIS process schematics referred to earlier are shown in Figs. 4-8. Touching the overview schematic, Fig. 4, will select one of the detailed schematics. Input data to MAPPS, such as total chip flow, and output information from MAPPS, such as electrical loads, are shown in Fig. 5. Touching the screen on input data brings up a menu from which input data can be changed.

Control loops are set up to maintain specified liquor levels in each impregnation vessel, as shown in Figs. 6 and 7. MAPPS computes the quantity of liquor absorbed or entrained by the chips. Comparison of the computed and measured liquor flows is one means of adjusting and testing the transport process models used to simulate pretreatment.

Input information required for the refiner models, such as chip thickness, plate gap, rpm, etc., may be passed directly to MAPPS as shown in Fig. 8, while other background information is available by pressing "MORE INFO." This generates additional screens showing fiber length distribution bar charts and fiber and handsheet properties.

The CTMP pilot system provides an excellent opportunity to demonstrate advances in process modeling developed at IPST as well as the enhancements to the information system available through process simulation.

In the future, the system will be expanded to include

an optimization program which performs a variety of functions including data reconciliation, model tuning, and setpoint optimization. The latter will be provided as information and as a guide to operators.

Conclusions

The work to date has demonstrated the feasibility of integrating a process simulation program with a millwide data management system. The potential benefits of such an integration are significant and the costs are relatively minor. The key bottlenecks remain justification of the millwide system and the effort involved in developing a mill model to meet the specific needs of mill operations and management. The long-range goal of achieving productivity gains through process simulation may be at hand. □

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CORRECTION

Incorrect trademark name given in the *Focus on Predictive Maintenance*

On p. 37 of *Focus on Predictive Maintenance*, the name for Chevron's DELO® product line was incorrectly given as DELCO® in two instances.

Focus on Predictive Maintenance was a supplement to the August issue of *Tappi Journal*.

Tappi Journal regrets any inconvenience due to this error. □