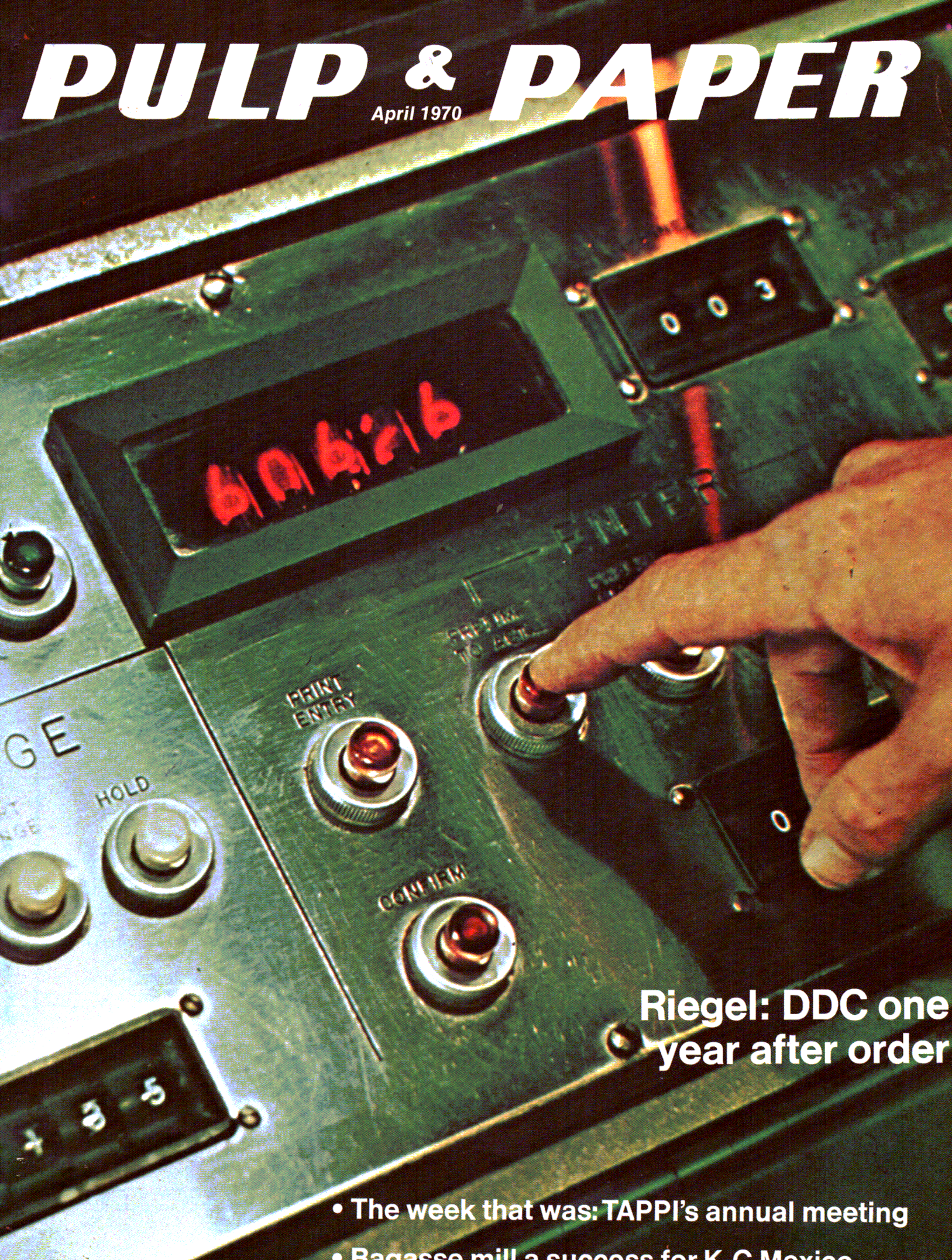
PULP & PAPER

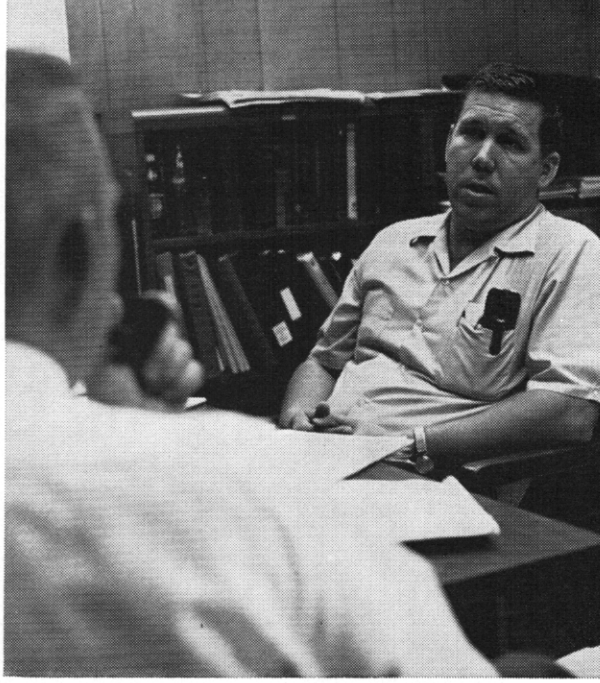
April 1970



Riegel: DDC one year after order

- The week that was: TAPPI's annual meeting
- Bagasse mill a success for K-C Mexico

Goal: Computer control from 1 year of order Result: DDC on time!



Mark Massey Jr.,
Riegel's Control Systems Supervisor, discusses some hardware considerations.

Riegel Paper Corp. and equipment supplier meet tight computer program at North Carolina operation. Direct digital control of paper machine and bleach plant is giving rapid return on investment.

☐ Successful completion of grade changes under automatic digital process control marked the first anniversary of the start of an ambitious joint project involving Riegel Paper's Carolina operations at Riegelwood, N.C., and Industrial Nucleonics Corp., Columbus, Ohio.

A major goal of the project was to put a paper machine and a bleach plant under computer control within 12 months from date of placing the order. Meeting this tight schedule required a unique approach involving separate, but concurrent system development and programming effort by the two companies.

Besides the unusually fast attainment of on-control status, other unique features of the project include new automatic control algorithms, extensive training of operators, new concepts in operator/system communications, and a flexible, effective management information system.

Riegel no newcomer to computer control

Riegel is no newcomer to computer control, having decided in 1964 to adopt this approach gradually on several of its machines at Milford, N.J.

Plans were laid at the Carolina operation, also, resulting in an examination of new control methods and their applicability to operations there. Feasibility studies indicated that computer control for the bleach plant and paper machines would yield more than enough economic return to justify the project. In the case of the bleach plant, improved control techniques were expected to optimize the use of chemicals. The paper machine applications could anticipate savings from reduction of off-quality paper as well as economic advantage due to increased production rate.

The go-ahead was given late in 1968. Riegel's Carolina operation formed a three-man Control Systems Group, consisting of a supervisor, a process engineer, and a programmer/analyst. As the project workload grew, the group expanded to six members with the addition of another process engineer, a programmer, and a technician.

In addition to the bleach plant, one paper machine, No. 15 (the Carolina Belle), was selected for control. The newer No. 18 machine (the Carolina Queen) went on stream in 1967 and took over most of the light weight bleached board production at the mill. This gave No. 15 the heavy weight orders. Because of this, No. 15 ran dryer-limited much of the time and offered more economic potential for computer control.

A lot of capability seen needed

Riegel's Control Systems Group surveyed the entire project and developed realistic performance requirements, consistent with the economic return guidelines indicated by the earlier feasibility studies. As the scope of the project became better defined, it was clear that considerable computation capability would be required to handle the several mill areas scheduled for application of control. Based on a comparative analysis of suitable units available at the time, an IBM 1800 computer was placed on order.

The Riegel group carried the economic analysis through to the point of specifying the control objectives required to obtain those economics, and the key instrumentation required. Detailed instrument and operator station specifications were drawn up for the bleach plant.

Industrial Nucleonics had already been in contact with Riegel concerning new methods of paper machine control

1. Riegel progress report.

Milestone	Date	Time	Comment
1. Purchase order received	9-16-68	4 months	System designed and manufactured
2. Engineering specifications	10-14-68		
3. A. Electronics and operator stations	12-1-68		
B. External cabling design for total system			
4. Computer (IBM 1800) arrived and operational	1-3-69	3 months	System assembled, programmed and tested
5. Interface with IN hardware completed and checked out	2-7-69		
6. Hardware control and display programs completed	2-28-69		
7. Control algorithms completed	3-15-69		
8. Formal operator training began	3-26-69		
9. All programs completed and checked out	4-11-69		
10. Computer and system shipped	4-12-69	64 days	System operational on computer control
11. Installation started	4-14-69		
12. Wet press system operational	5-12-69		
13. Size press BW and moisture and computer on line	5-14-69		
14. Bleach plant hourly and shift logging system operative	5-18-69		
15. Formal operator training completed	5-31-69		
16. First basis weight control	6-12-69		
17. First moisture control	6-16-69		
18. Basis weight and moisture control turned over to mill personnel	7-3-69	17 days	BW and moisture control in routine use
19. Headbox control started	7-3-69	3 months	All control and information systems in operation
20. First control function in bleach plant turned over to operators	7-3-69		
21. Start reel gauge installation	7-9-69		
22. Complete reel gauge installation (all readouts operational)	7-11-69		
23. First grade change	7-30-69		
24. First speed change	7-30-69		
25. Inaugurate daily information summaries on bleaching operations	8-8-69		
26. Headbox control turned over to mill personnel	8-21-69		
27. Speed change turned over to mill personnel	9-8-69		
28. Grade change turned over to production	9-30-69		

and Riegel had worked with the supplier since 1956 when the first AccuRay® basis weight control system was installed at the Warren Glen, N.J., mill. The Milford, N.J., mill received a system in 1959, and since that time, additional basis weight control and AccuRay Moistron* moisture measurement systems have been installed on both machines at Riegelwood.

In 1964 IN had formed an Industrial Systems Research and Development Division around a nucleus of four advanced-degree systems design and control specialists. Utilizing a hybrid computer facility, unique and sophisticated algorithms for paper machine control were developed. A model reference control algorithm was created which, when coupled with a new headbox control system, allowed an automatic grade change program to be included.

Early discussions evolved the concept of a shared-program approach to the use of a computer in process control, in which the user "assigns" a major segment of the overall project to a hardware and/or software supplier, completing the remainder with his own in-house staff. This held the promise of reducing the time required, because each team would be working on its own portion simultaneously. But it also posed the potential problem of coordination and cooperation between two independent organizations working separately on the same overall system—a problem which never materialized.

Project initiated in the fall of 1968

The Riegel/IN joint project began on September 16, 1968 (see time table, Figure 1). It was agreed that the bleach plant would be the responsibility of Riegel, for systems design, control, and information readout programming. IN was to be responsible for the paper machine system control and information system programming, manufacture of the basis weight and moisture measurement systems and integrating the computer with them. The IBM 1800 would be delivered to IN's Columbus, Ohio, plant for that purpose.

During the early stages, a number of planning meetings were held at Riegelwood and at Columbus. These sessions resulted in a tailored control package for No. 15 machine, and the establishment of the necessary guidelines for merging the bleach plant and paper machine systems after delivery to Riegelwood. Important details, such as the technique for handling digital and analog input and output, naming of sub-routines, ground rules for sharing of core space and assignment of program priorities also were decided at this time.

Further planning at Riegelwood dealt with the need for new instrumentation and hardware to interface it with the computer, both on the paper machine and in the bleach plant. Taylor Instruments supplied most of this and handled the installation contract.

Control system checked out before shipment

For their portion of the project, IN assigned a project manager to coordinate all of the activities required to insure meeting the tight time schedule. Engineering and programming specifications were prepared for the basis weight and moisture measurement systems. Operator stations were designed, cable schedules determined, and all of the IN-supplied hardware manufactured.

The computer was delivered to Columbus on schedule and was operational by January 3, 1969. By February 28, 1969, the computer had been integrated with the measuring systems, and the entire hardware package checked out. When the integrated system was shipped to Riegelwood on April 12, IN had completed a thorough test of the entire system, including simulation tests of most of the controls, and had designed a management information collection and readout system to provide key cost and quality data.

Operator training was extensive, thorough

Early in the design phase, IN had assigned a project systems engineer to participate in system development; he ultimately played a key role in the successful installation, startup, and integration of IN's portion of the system at Riegelwood. During the final checkout period in Columbus, this man, in cooperation with Riegel process control personnel, began formal training of the machine operators who would use the equipment.

The purposes were:

1. To include machine operators as integral parts of the project.
2. To develop confidence among the operators by giving them knowledge in advance as to what the system was intended to do and how it would help them.
3. To minimize startup time and maximize economic return at the earliest possible date by conducting the training operation before shipment instead of after installation.

The paper machine crews were sent to Columbus for training sessions covering both theoretical aspects and practical details of hardware operations. Topics included were:

New measurements and actuators, system operation, communicating with the system and theory of control loops.

The practical sessions were aided by a program whereby the actual operator stations, control panels, and typewriter output devices which would be installed on the machine were placed on operating status. Operators could call up setpoints, variables, a limited number of reports and messages, and, in essence, "fly" the system themselves.

Also, Riegel and IN had developed a detailed training manual while the system was being assembled. This served as a guide during all the training, and continues as an operator reference for on-line operation.

When formal training ended, each machine crew member had ten hours of classroom instruction, plus several hours of practical sessions on the system itself.

Bleach plant operator training was conducted at the mill, beginning shortly after the first portion of that system became usable. This, too, was intentionally very thorough in recognition of the importance of the operator to the success of the system.

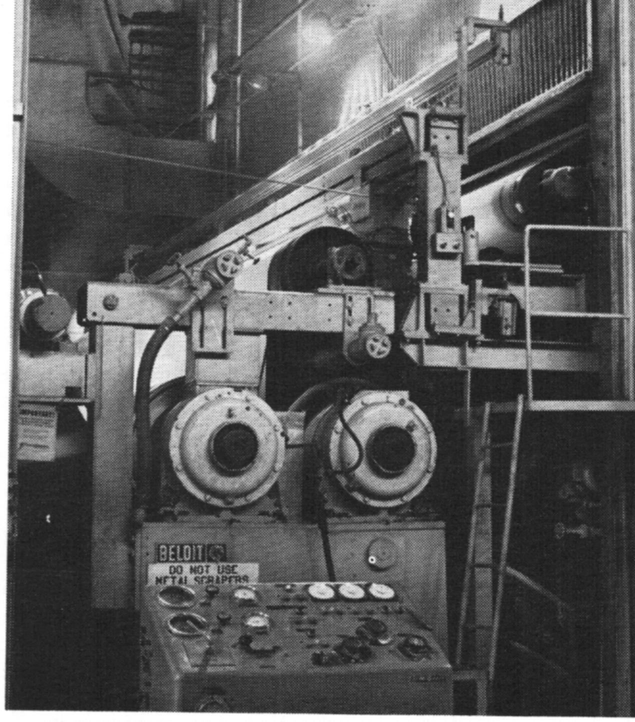
Paper machine system startup

Just over two months from start of installation, the paper machine had basis weight and moisture on computer control. Seventeen days later it was turned over to the operators. By July 30, an automatic grade change had been made.

As each of the control loops came on line, members of the team from Riegel and IN scheduled themselves around the clock to be on hand to answer questions, provide guidance and observe operation. Only after everyone was satisfied that no major problems existed was a loop given to the operators without team assistance.

The new reel basis weight and moisture sensors were the last of the measurements to be installed (July 11, 1969). This was done purposely and on schedule after the size press control system was in full operation. The operators were accustomed to running the machine on weight control from the existing analog AccuRay® system at the reel, and did not want this removed until the new control operating from the measuring units installed ahead of the size press had been proven.

All on-machine modifications were coordinated with



Basis weight and moisture measurement
location just ahead of size press.

wire changes, and no machine downtime was required by any part of the entire project.

The remaining controls were turned over to the machine crews as they were checked out: coordinated headbox control, August 21; automatic speed change, September 8; and grade change, September 30, 1969.

Bleach plant system—more smooth integration

The computer-instrumentation interface was completed and checked out shortly after arrival of the computer at Riegelwood, and the process control group began testing programs involved in the bleach plant information system. This package included the programs for outputting hourly and shift logs, demand logs, instrument status logs and the programs required to handle a complete operator's console.

As with the paper machine, the bleach plant station allows the operator to input necessary control targets and manual test data, to make requests for several kinds of reports that appear on the message typewriter, and to display key process variables on digital Nixie readouts.

By mid-May, the hourly and shift logs were functioning and the training of bleach plant operators began. Simultaneously, the closed loop control function for the hardwood chlorination stage was readied for checkout, and on July 3 this loop was turned over to the trained operators.

Attention was then concentrated on development of a management information system which would facilitate supervision of the bleaching operation. Operator training was continued as this aspect of the system developed, and by mid-September the bleach plant operators and pulp mill supervision had abandoned the previous hand logging and information system in favor of the new computer system.

Operator/system communications

The operator's stations at the paper machine are designed to make it easy for the operator and the computer to communicate. One console is located at the wet end and another at the dry end of the machine. Each provides process information displays and alarms, scanning unit traversing controls, and computer communications. A message typewriter is associated with each console. Annunciator color bars indicate control status and process variables that are in or out of limits. Plotters provide trend and profile information of the weight and moisture measurements. The operator may select either the composite, computed from the last ten actual profiles, or the latest single scan information. Example composite profiles are shown in Figure 2.

The wet end operator's station (Figure 3) contains one set of operating controls. Large Nixie displays provide easily readable information on basis weight, moisture and speed, while indicator lights alert the operator to system outages or operating status. A Nixie display and thumbwheel switches at this station allow the operator or control engineer to call up many of the 3,000 variables in the common portion of core memory for observation.

The message typewriter explains control status or responses to error conditions from a library of 95 plain language messages. Typical examples:

"The difference between the front side and the back side slice openings is excessive."

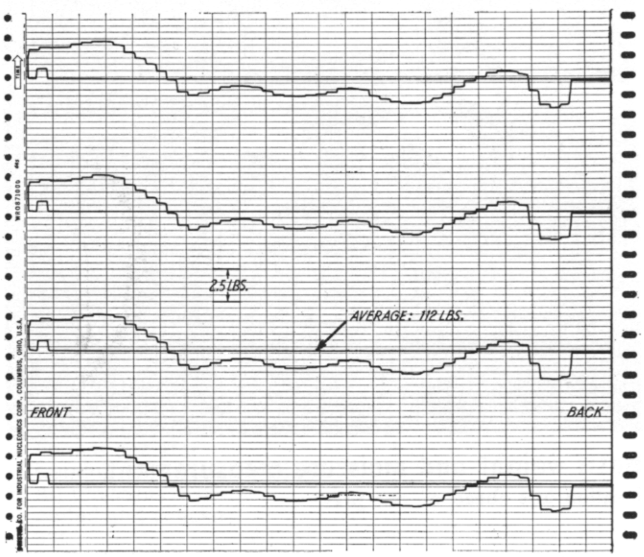
"An excessive stream flow error was detected. The headbox control is on manual."

"A fourth or main section pressure controller status switch is on manual. The moisture control has been put on manual."

The several reports that are available can be called from the operator's station also. One of these, called a Reel/Roll Summary, provides key quality information on each reel taken off the machine. The computer calculates basis weight and moisture average for the entire reel, plus 95% confidence band on those averages expressed as "Hi" and "Lo." In addition, the computer segments the total reel by sets and five equal width cross machine positions. These segments approximate actual rolls produced in the winder, and the same measure of average and statistical variability is calculated as is done for the entire reel. Riegel has been utilizing the Reel/Roll Summary in its quality control program since November, 1969. It has received wide acceptance from the shift personnel who perform the quality control function.

In addition, the computer prepares a shift summary report and a grade summary report which organize the production data to enable management and supervision to compare actual performance against standards.

For the Carolina Belle, a 236-inch coated bleached

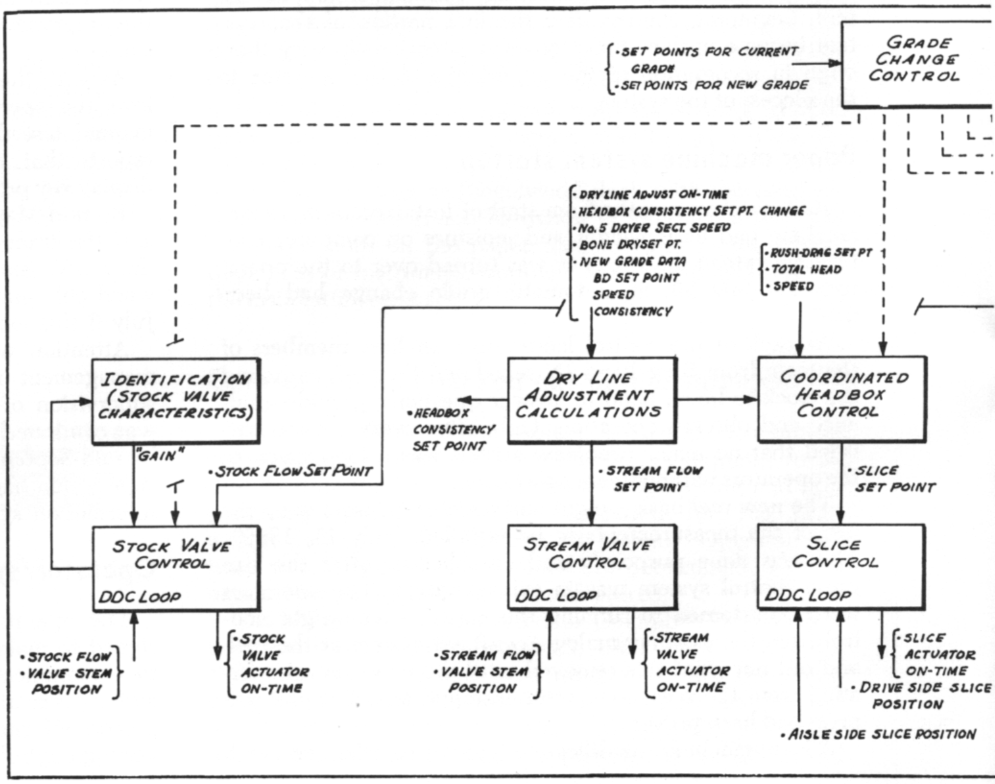


2. Composite profiles of size press

bone dry weight taken from plotter at wet end operator station. Computer program divides profile into segments which are averaged over last 10 scans to remove machine direction weight variations. Note repeatability of true profile.

3. Wet end operator station,

showing (top to bottom): color bar annunciator units, large digital displays, trend and x-y plotters, system operating controls, including smaller digital displays for calling up key variables. Effective two-way communication between operator and system has been given major emphasis from program beginning.



board machine, basis weight is measured after the third wet press, ahead of the size press and at the reel.

The wet press moisture reading is computed, since the total wet press weight, size press moisture and basis weight are known continuously. The ability to determine moisture profiles as well as long-term average values after the wet presses has provided an additional operating and engineering tool which is being used for optimizing water removal.

The paper machine control strategy is multivariable control of six basic loops of which four are direct digital control. Figure 4 shows how the combination of loops permits non-interacting control of basis weight and moisture, coordinated headbox control and grade change control. Grade changes are defined as basis weight and/or speed changes on the machine.

Because the paper machine has an inherently long transport lag, it is desirable to dynamically compensate for this in order to control more frequently and improve process uniformity. This system uses a model reference technique to distinguish between changes caused by past control actions and new errors from disturbances or changing conditions in the process. A deviation from target is interpreted as an error which is fed to the controller and to a linear mathematical model of the process. At the end of the next sampling interval, if a difference exists between the model and the process, a new error is identified and an appropriate control action on the process is again made. This technique permits full-gain control response without waiting for the transport time to elapse.

The basis weight control changes the position of the thick stock valve. A feature of this part of the system permits periodic identification of changes in backlash or flow characteristics of the valve. If changes have occurred, the control constants are adjusted automatically by a routine in the computer.

Headbox control automatically adjusts the slice position to maintain the desired spouting velocity. Working in coordination with this is the dry line control which modulates the stream flow valve to maintain the dry line at the proper point on the wire, based on a simplified operator interface with the computer.

The control loops working together form grade change control. This provides coordinated adjustment of fiber, moisture, speed, rush/drag, and stream flow from the current grade set points to the desired new grade values. Variable changes plotted against time during an actual grade change are shown in Figure 5.

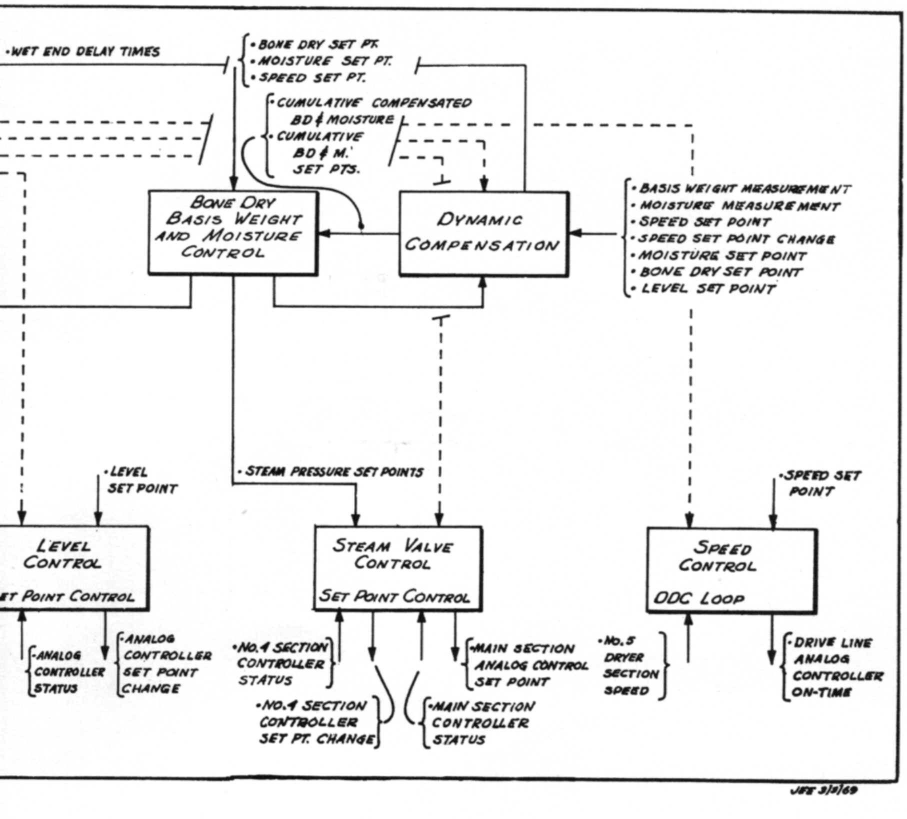
Elaborate safeguards have been built into the system to protect against operator or computer error. Extensive checking routines assure that control actions called for are not beyond the capability of the process.

Results of the system

Riegel's early feasibility studies had pinpointed areas of potential economic return from a project such as this. The company's appraisal indicates that the system will meet economic expectations. Key factors in achieving economic results will be:

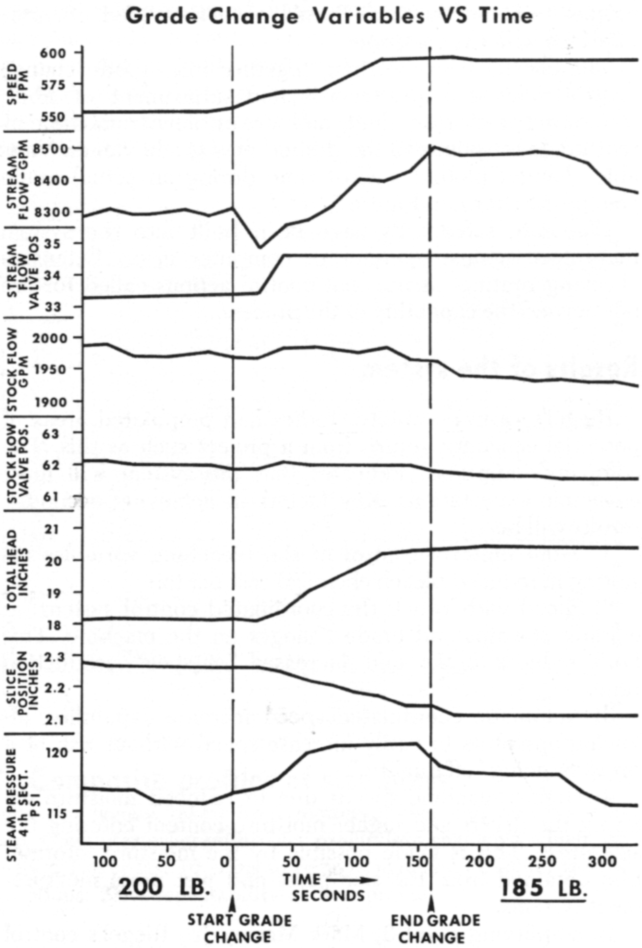
1. More uniform control of the bleaching variables resulting in reduced bleach chemical cost per ton.
2. Speed with which the coordinated control system facilitates startups and grade changes on the machine. This both reduces broke and increases "on-spec" production time.
3. Automatic coordinated speed increase capability, allowing operators to easily increase speed without risk of a break or going "off quality."
4. Higher machine speeds due to reduced moisture entering the dryers and higher moisture content entering the size press. This is made possible by the moisture information obtained from the size press and wet press measurement systems.

In amplifying point 3, Mark Massey Jr., Riegel's control systems supervisor, says: "The computerized control functions, the information system, and the alarm messages remove much of the risk that the papermaker knows is inherently there when numerous operating changes are made on the machine. By proving to him that small changes in



4. Block diagram

showing combination of DDC and supervisory control loops used to carry out the paper machine control strategy.



5. Plot of values assumed by key variables during automatic grade change.

production rate can be performed via computer control without risking a break or going 'off quality,' he will use this new tool to maximize his production rate consistent with current drying conditions on the machine."

What of the future?

The installation now stands as an on-line, working, automatic control and information system. While some work continues in control of "fine tuning" and in the content and format of some of the reports, the main emphasis is toward more utilization by production supervision and management. The goal is for the system to become the basic data source for production management's economic decisions, and the major means, in conjunction with operators and their supervision, for carrying out these decisions. Thus the system's effectiveness is being expanded into the realm of higher management, and toward greater economic return.

Furthermore, Riegel expects its customers to benefit from continuing improvement in product quality and uniformity resulting from the control system. Stabilization of variables on the machine, plus management's expanded ability to exert overall control over its manufacturing facilities, will enable the company to be even more responsive to customer requirements—in an age of ever-tightening quality tolerances.

The wisdom of Riegel's decision to approach a major process control project on a cooperative, shared-computer basis has been amply demonstrated. The primary goal of getting on line quickly, Riegel feels, was well justified, and has enhanced a rapid return on the investment. ☐