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AN ADVANCED INFORMATION SYSTEM AS A FUNCTIONAL PART OF A NEWSPRINT MACHINE

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Synopsis The paper describes an information system applied to a newsprint machine as a functional addition to the operator's capabilities. Examples of its use by the operators are given.

The system was designed, as part of an initial machine installation, after the intensive study of the mode of operation of two generally similar machines. The objective was to retain the skilled operator as part of the control system, but to provide him with more information more conveniently displayed to enable better and faster decisions to be made. The stored program system permits the operator to manage the machine on an information by exception basis.

The system is a Bailey 754 with alarm monitoring data display and future arithmetic capability. There are 150 analog inputs, 200 contact closures, 26 speed and draw measurements and 15 integrations. Data acquisition is continuous providing data to the parallel programmed and independently operating subsystems.

Introduction

A PROGRAM for achieving centralised control of a modern newsprint machine was undertaken in 1965 by MacMillan Bloedel Ltd. The program as developed is based on a concept of process control improvement following the principles of systems engineering.

This concept applied to papermachine instrumentation was described in the paper *A systems approach to papermachine instrumentation*[1] and has

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Under the chairmanship of Dr D. B. Brewster formed the basis for the efforts at MacMillan Bloedel Ltd. Briefly, the approach follows the step-by-step program stated below—

1. Establish the ultimate objective and a program to achieve this objective in a logical, flexible and time acceptable program.

2. Carry out a systems analysis, dividing the system into appropriate subsystems based on—
(*a*) Parameters of production quality and production throughput
(*b*) Interdepartmental relationships
(*c*) Methods of supervision
(*d*) Economic factors of the process

3. Define the control problems as they become apparent from step *2* above. This will require investigation and evaluation of the specific process subsystems in so far as—
(*a*) What measurements are needed
(*b*) How are they to be measured
(*c*) What is being controlled
(*d*) What are the relationships between variables
(*e*) What effect does the individual control problem have on other parts of the whole process

4. Centralise supervision of first the process subsystems and, subsequently, the total system; automate this supervision when feasible and economical.

5. Develop and implement automatic management control as the need, the technology and economics dictate.

This approach may appear conservative and differs from the one many take today as a result of the availability of increased flexibility of process control computer hardware and software. In these instances, the process control computer is utilised for on-line control analysis, in addition to providing certain defined control actions. Whereas we recognise certain advantages to this latter approach such as familiarisation with the computer, use of the computer as a process learning tool and the forcing of discipline on operating and engineering procedures (when possible); we believe the step-by-step approach has greater long-term advantages, particularly for the situations in MacMillan Bloedel. This belief is strengthened when compared with published reports of the various applications within the industry. The advantages are—

1. The application of new techniques is kept within the realm of learning for existing personnel. Special skills are developed internally as anticipated, thus keeping the requirement for hiring hard-to-get skills to a minimum.

2. Full utilisation is made of present techniques and equipment when feasible. This is possible, since process control requirements are determined before a system is defined.

3. Process modifications are made as a result of process studies—before application of any advanced system. Consequently, any improvements resulting from the process modifications are known before application of the specified control system.
4. As process and control modifications are made, the program to meet our long-term objectives is reviewed and revised when appropriate. Thus, a 5-year plan permits realistic planning for capital investment and the staffing and training of personnel ultimately required for system application.
5. With the current dynamic state of the computer industry, we believe it prudent clearly to define objectives and requirements before committment is made to software and hardware. This is not because it is intended to await the availability of a greater performance-to-cost ratio, which, once the advantages of better control have been defined, could be an extremely costly procedure. The relative status of process operation, process investigation and advanced control system development is such as to permit leeway in choosing the time for involvement with more sophisticated systems.
6. If the number of complexity of processes making up the total process of an integrated pulp and paper mill be considered, it is seen that the computer capability and software complexity required to provide the desired control functions and systems analysis capability would be very large with comparably high capital investment. A number of computers appears a more practical solution. As an alternative to such an investment, we have chosen to develop a hybrid simulation facility, which will be used for study of all major areas of our integrated mills. In addition to the process and control studies, this facility will provide the means of gaining familiarity with basic software requirements, as well as a clearer understanding of real time demands. The simulation facility is proving our most valuable tool.
7. A step-by-step approach permits diversification of our personnel to a much greater degree. The systems employed to date have not required large team efforts from our central systems group and has thus permitted a carrying out of studies on several major process areas simultaneously. In addition to establishing process control requirements in areas that are interacting in the integrated mill, this approach has had the added advantage of developing the interest and the recognition of needs in the major areas of the mill (and all our mills) during the same time period. This is proving to be extremely valuable, as we all know a positive attitude toward process control improvement is imperative to the success of any system application.
8. Being freed from the added complexities of hardware and software and from the pressures of justifying an installation, it is possible for us during our systems and control analysis periods, to include the investigation and evaluation of special sensors for various critical measurements. Although we agree that the application of advanced control need not be held up by lack of certain measurements, it should be understood that these measurements might alter the control problems and most certainly would be desirable if available.

A study team surveyed the instrumentation and control system that were employed in the operation of two machines. The study team consisted of 7 full-time members, 4 part-time members and 7 corresponding members. The full-time members included 3 specialists; 1 experienced with on-machine instrumentation, 1 experienced with analog control applications in the paper industry and 1 knowledgeable in digital system technology.

The scope of the study included a systems analysis, as well as an analysis of control problems. Its objective was *operator-oriented* rather than *computer-oriented* and had the purpose of determining the instrument requirements for the centralised operation of the stock preparation and papermachine that would be installed in eighteen months.

The study consisted of the following activities—

1. 25 meetings with operating personnel on the No. 9 machine at Powell River and the No. 5 machine at Port Alberni for the purpose of defining instrumentation requirements for a modern newsprint machine.

2. On-machine studies to determine the instrument needs and included—

   1. Dry end measurements on the two machines studied.

   2. Head box total head measurements on both machines.

   3. Head box and wire pit consistencies and Mersey drainage tests for one machine.

The study also summarised the extent of instrumentation existing on the two machines, together with a layout of read-out stations in order to determine the requirements for and advantages of centralised information.

Instruments and procedures for accounting were also considered, as it is necessary to provide information for this function, as well as for operations.

The recommendations proposed a plan of action (Fig. 1), which started with what we knew and permitted expansion as time, manpower, experience and funds allowed. Each step provided a base for the next step, thus minimising the chance for loss of effort on the technical side and loss of confidence by operations as new techniques were learned by both parties.

The report included specific recommendations for the application of on-machine basis weight, moisture and caliper instruments; various analog control systems for stock proportioning and the papermachine; and the application of a digital information system to provide centralised data presentation on a 'management by exception basis' and which would provide the flexibility for expansion to include future performance monitoring and supervisory control. These recommendations took into account the current status of instrumentation technology within MacMillan Bloedel at that time, the staff and experience available for system application, the time and funds available for the new machine installation. Thus, the step-by-step approach (Fig. 1) was submitted as the recommended plan of action.

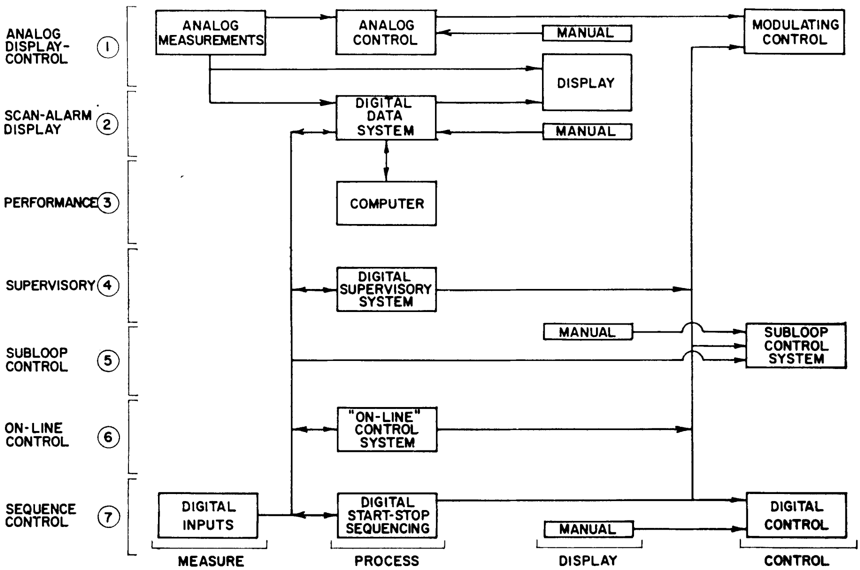


Fig. 1—Step-by-step approach to papermachine control submitted by the study team as the recommended plan of action

The digital information system recommended was to satisfy two major objectives—

1. To assist operating personnel in direct on-line action—
(*a*) To assist the operator in on-line monitoring of the process.
(*b*) To collect the display information to assist the operator in making decisions for on-line corrective actions.

2. To provide the means of gathering accurate, reliable data for on-line process analysis—
(*a*) To collect and record data for accounting and quality control purposes.
(*b*) To collect and provide records (printed or punched cards) to establish and implement long-range objectives. In order to implement long-range objectives, this system must be designed readily to accommodate future expansion.

These objectives defined the design criteria of the information system to meet the immediate as well as the long-range needs for achieving more efficient production, producing a uniform product and obtaining better utilisation of manpower.

Functional description of the information system applied to No. 10 papermachine

IN ACCORDANCE with the recommendations made by the study group, a multi-channel, parallel-stored program digital data acquisition system (a Bailey 754) was installed, which best met both the primary and secondary objectives. This system concept differs from the process control computer in that systems functions are performed by means of independent hardware subsystems rather than by timesharing a central processor.

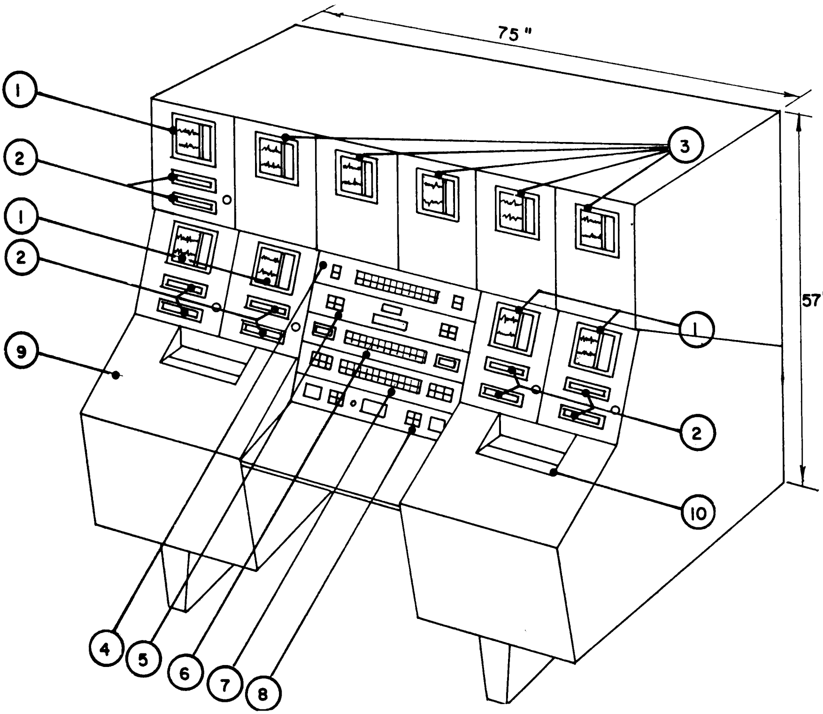


Fig. 2—Information system console: numbered arrows refer to—

1. Addressable analog recorders (red and blue pens)
2. Thumbwheel switches to select point address, zero suppression and range for each pen
3. Utility recorders (red and blue pens)
4. Back-lighted alarm annunciator buttons
5. Digital display lights select point number, input value of time
6. Back-lighted push-buttons to select display of common variables, thumbwheel switches to select variables not on push-buttons
7. Back-lighted push-buttons to select group review print outs
8. Thumbwheel switch and push-buttons for entering alarm limits and reviewing alarm status
9. Alarm printer
10. Utility printer

The particular advantages of this approach are—

1. Simplified programming—each subsystem has effectively continuous access to its own program. Thus, no executive routine is required and the programs are straightforward statements of sequential action or data.
2. The system reliability and, consequently, up-time is greater as failure of any one subsystem does not default the operation of other subsystems (with the exception, of course, of data acquisition).
3. System expansion capability and flexibility is extremely good—other subsystems such as the computer and control subsystems may be added to the present system with a minimum of system upset *if and when* required or desired.
4. This system required a minimum staff (one systems engineer) to implement. System programming did not require a trained programmer. (A two-year technical school graduate with no previous training or familiarity with the system modified, updated and documented the entire program in approximately four man-months.)

For our situation, the system described met the requirements for the plan of action dictated in Fig. 1.

Physically, the system operator's console (Fig. 2) is located in an air-conditioned control room (Fig. 3), with the stock preparation control console,

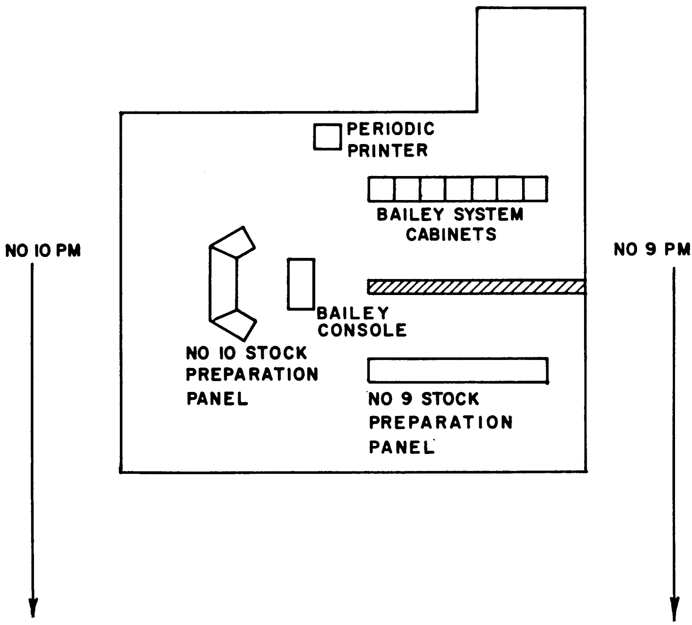


Fig. 3—Equipment located in the system information centre

approximately at the head box location for the No. 10 papermachine. This room also contains the stock proportioning panel for the No. 9 machine. The system cabinets are located in a room attached to the control centre.

The information system provides the following functions—

1. Data acquisition and storage for approximately 150 analog inputs. It also monitors approximately 20 integration inputs (pulse), 26 speed and draw measurements (binary coded decimal words) and up to 200 alarm contact inputs.
2. Alarm monitoring for all data inputs to the system. With the exception of adjustable alarm limits for all variables in data storage, this function has a hard-wired program. It reports new alarms, return to normals and alarm reviews on the alarm printer. Alarm reviews have time intervals select capabilities. A 20 window addressable annunciator located on the operators console is fed from the alarms monitor.
3. Periodic logging of selected variables as required. This subsystem has its own printer.
4. Value displaying in engineering units of any variable stored in data storage. Time may also be displayed by selection.
5. Analog trend recording for any variable as selected with up to 10 variables displayed at any one time. Each pen may be assigned to any variable.
6. Single point digital or analog trending of any selected variable.
7. Single-point digital or analog trending of historical data for any one of 100 programmed variables.
8. Group review, digital or analog trending of current data for any one of 20 programmed groups.
9. Group review, digital or analog trending of historical data as selected from one of 20 programmed groups. The historical interval may also be selected for up to 1 h.
10. Programmed data retrieval by tape punch.

The system is described more fully in Appendix 1.

Experience in using the system

IMPLEMENTATION of the system began in the autumn of 1967 with concentration on the first objective. This required working with the operators, developing procedures and demonstrating ways in which the information presented could be useful to the operators for on-line operations. One systems engineer was assigned full time to carry out this task.

Both the stock preparation people and the machine operators had undergone a training program before the systems arrived. For future installations, every effort will be made to secure time for 'hands on' training. Because all information pertaining to stock proportioning is available only through the system console, the stock proportioning personnel adapted to the use of the system very rapidly.

The machine tenders are not required to be in the control room and, since sufficient conventional instrumentation for operation is located around the papermachine, the machine tenders did not adapt as readily to the functional capabilities of the system. To achieve this goal, a systems engineer worked closely with the production superintendent in demonstrating the usefulness of the data presentation. The machine tender was then left to experiment for himself (which was found to be very important). Machine room personnel are now utilising the system to an effective degree.

To facilitate developing the procedures for the operators and as a basis for preliminary off-line analysis, a program of relatively simple but important process investigations was established. This programme is listed as Appendix 2 and consists of two types of project. The first type are those projects that could be undertaken by the systems engineer with only the information available from the system, production reports and other instrumentation. The other type of project required tests and other assistance from the mill technical department.

From October 1967 to June 1968, a record was kept of the situations in which the particular means of centralised information display assisted the operator in preventing improper operation or wastage. Appendix 3 lists a number of these situations and a summary is given below—

1. *Chest levels*—Whereas chest levels may be alarmed in the conventional manner, the fact that the alarm conditions are made apparent immediately to the stock preparation man and data presentation supports the alarm by appropriate information from which he can take proper corrective action has proven extremely valuable. Such action has prevented a number of incidences when chests might have overflowed or been pumped dry. In addition, with the variable alarm limits, the normal operating conditions can be altered to meet the current situation by approval of the appropriate supervisor.
2. *Stock consistencies*—Close monitoring of the consistency control loops has prevented a number of upsets to the machine. It should be pointed out here that 10 of the available 20 pens on the operator's console normally record stock consistencies and valve positions.

   For example, the mixed stock consistency transmitter appeared to shift its calibration. At this time, the dilution valve moved rapidly to a more open position. The problem was traced to the consistency regulator via the information system by noting that the basis weight did not change (on automatic control), but the mixed stock flow increased considerably. This situation had been previously noted on several occasions. On one of those earlier dates, the regulator dilution valve began creeping open, as shown in Fig. 4, at the same time as the mixed stock flow was being increased by the automatic basis weight control. Although the consistency indicated the same value, it must have been decreasing as indicated by the increasing mixed stock flow. The set point was raised by 2 per cent of chart and this brought the dilution valve and mixed stock flow down slightly, but they both remained higher than their previous values before the drift began. This indicates a shift in the mixed stock regulator set point by more than 2 per cent of chart.

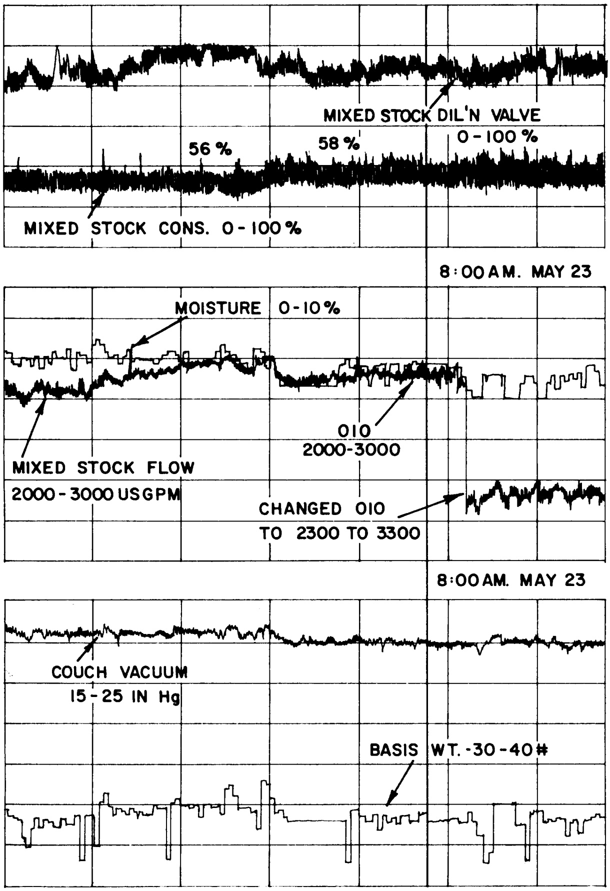


Fig. 4—Calibration drift in the mixed stock consistency regulator readily detected by means of the system analog recorders

At the second occurrence of the situation, a similar disturbance occurred, but this time it was much faster as shown in Fig. 5. Over a 1 h period, the set point was changed from 63 per cent to 70 per cent to 74 per cent to compensate for the drift in the instrument and to bring the dilution valve into a control range. Note that, during the time the set point was being raised, the mixed stock flow was increasing as well to maintain a constant basis weight. The instrument appeared to shift back as noted by the abrupt drop in the dilution valve position and the peak in basis weight. It finally stabilised at a set point of 5 per cent of chart higher than previously.

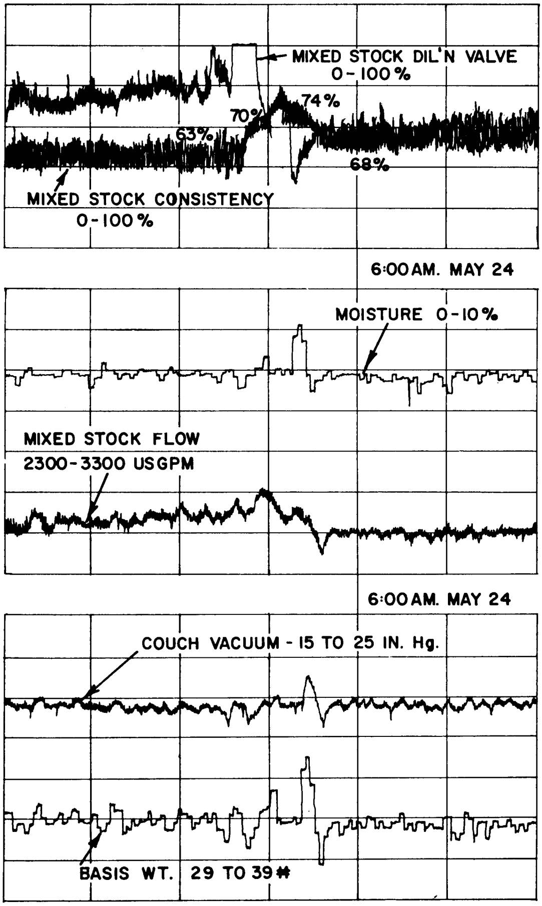


Fig. 5—System analog recorders readily detect a sudden calibration shift in the mixed stock consistency regulator and monitor the compensating set point changes made by the operator

3. *Stock flows* Alarm monitoring enabled immediate action to prevent off-specification paper on at least one occasion.
4. *Stock cleaning and de-aeration* During start-up, machine problems were analysed via the historical review function and it was found that the trouble

originated with a loose belt on the vacuum pump of the de-aerator. Other examples in this area were also resolved through use of process analysis by means of data presented from the historical review function.

5. *Head box* Monitoring of the head box variables saved machine down-time on several occasions.

Data from the information system was used to show that a small change in head box temperature will cause a significant change in head box total head. This relationship was studied using the digital trend facility on the utility printer. Fig. 6 is a record of this analysis. During this time, no adjustments were made at the head box, as attention was being concentrated on getting the sheet to the dryers and stacks. The jet-to-wire drag increased from 30 ft/min to 70 ft/min over this time period.

HEADBOX

TIME	HEAD BOX TOT HEAD	HI COUCH VAC	DRAW JET WIRE	FWD DR ROLL SPD	STRM FLOW VALV POSN	HEAD BOX LIQ LEVL	HEAD BOX TEMP	HOT WATR SHOW TEMP	B WT AS MADE O M	MIXD STOK FLOW
08:29	265.	20.09	0032	2289	39.9	14.4	069.	064.	31.8	2898
08:30	264.	20.29	0034	2288	39.9	14.8	069.	068.	31.8	2898
08:31	264.	20.70	0035	2287	39.9	14.7	069.	073.	31.8	2885
08:32	265.	20.90	0032	2288	39.9	14.7	069.	078.	31.8	2920
08:33	265.	20.91	0033	2288	39.9	14.7	070.	082.	31.8	2899
08:34	264.	21.02	0036	2288	39.9	14.9	070.	085.	31.8	2868
08:35	264.	21.10	0039	2289	39.9	14.9	070.	086.	31.8	2844
08:36	263.	20.81	0039	2287	39.8	14.9	071.	089.	31.8	2862
08:37	263.	20.82	0042	2288	39.8	14.9	071.	090.	31.8	2838
08:38	262.	20.81	0042	2288	39.9	14.8	071.	090.	31.8	2849
08:39	263.	20.72	0044	2288	39.9	14.8	072.	092.	31.8	2854
08:40	262.	20.68	0045	2286	40.0	14.8	072.	093.	31.8	2854
08:41	263.	20.93	0046	2287	39.8	14.9	072.	093.	31.8	2843
08:42	261.	20.81	0048	2288	39.9	14.8	073.	094.	31.8	2827
08:43	261.	20.84	0050	2287	39.9	14.9	073.	096.	31.8	2827
08:44	261.	21.10	0053	2286	39.9	15.0	073.	096.	31.8	2850
08:45	260.	21.22	0054	2287	39.8	14.9	073.	097.	31.8	2842
08:46	260.	21.27	0056	2287	39.9	14.9	074.	098.	31.8	2836
08:47	260.	21.25	0055	2286	39.9	14.9	074.	097.	31.8	2845
08:48	259.	21.21	0062	2287	39.9	14.7	074.	098.	31.8	2822
08:49	259.	21.57	0054	2285	39.4	14.9	075.	099.	31.8	2789
08:50	259.	21.22	0054	2286	39.0	14.9	075.	099.	31.8	2774
08:51	259.	21.09	0054	2286	39.0	14.9	075.	099.	31.8	2785
08:52	260.	21.04	0053	2286	39.0	15.0	075.	100.	31.8	2787
08:53	259.	20.97	0057	2287	38.9	14.9	076.	099.	31.8	2781
08:54	258.	20.93	0061	2287	39.0	15.1	076.	100.	31.8	2753
08:55	258.	21.04	0061	2285	39.0	15.2	076.	101.	31.8	2752
08:56	258.	20.99	0062	2285	39.0	15.2	076.	102.	31.8	2759
08:57	258.	20.79	0060	2286	39.0	15.1	077.	102.	31.8	2757
08:58	257.	20.70	0059	2287	39.0	15.2	077.	103.	31.8	2760
08:59	258.	20.83	0062	2286	39.0	15.2	077.	103.	31.8	2756
09:00	257.	20.64	0066	2287	39.0	15.1	077.	104.	31.8	2755
09:01	258.	20.55	0066	2285	39.0	15.1	077.	103.	31.8	2738
09:02	257.	20.44	0068	2285	39.0	15.1	078.	102.	31.8	2754
09:03	257.	20.18	0067	2287	39.0	15.2	078.	102.	31.8	2767
09:04	256.	20.01	0068	2285	39.0	15.1	078.	101.	31.8	2757
09:05	256.	20.12	0068	2285	39.0	15.2	078.	101.	31.8	2750

DECREASING TOTAL HEAD

INCREASING TEMPERATURE

Fig. 6—Head box temperature as an influence on head box total head

6. *Fourdrinier machine* In one instance, an alarm on the flat box header vacuum led to discovery of a leak on the end of one flat box. Adjustment of the end seal position by the operator corrected the problem.

7. *Press breaker stack loadings* The digital indication of press and breaker stock loadings appears to provide a superior method for setting these values.

8. *Dryer section* The No. 10 dryer steam system has been the subject of considerable analysis since start-up. An interesting example of a disturbance to the steam system is shown in Fig. 7(*a*) (Note the increase in sheet moisture). At this time, the main header pressure dropped to 14·0 lb/in^2, thus causing an increase in indicated steam flow (up to 135 500 lb/h) and a subsequent loss of individual dryer section pressures shown in Fig. 7(*b*). The dryer steam balances group review is also included as Fig. 7(*c*).

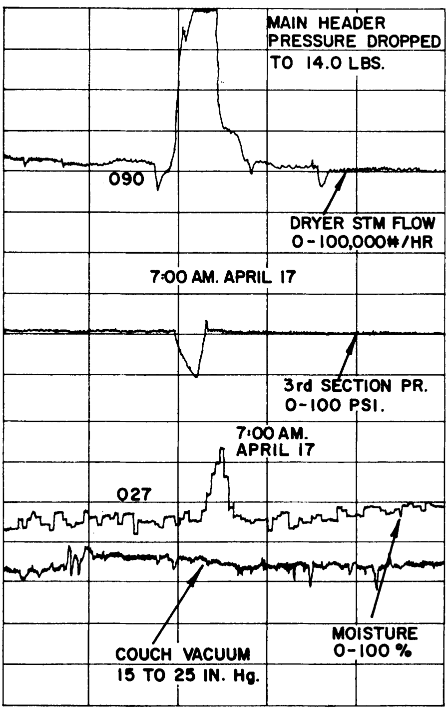


Fig. 7(a)—System analog recorders, used to monitor upsets in the dryer steam system, detect a sudden drop in the main header pressure resulting in a sudden rise in indicated steam flow and sheet moisture

STM SPLY

TIME	NO 1 DRYR PR	NO 1 DRYR DIFF PR	NO 2 DRYR PR	NO 2 DRYR DIFF PR	NO 3 DRYR PR	NO 3 DRYR DIFF PR	NO 4 DRYR PR	NO 4 DRYR DIFF PR	FELT DRYR STM PR	FELT DRYR DIFF PR
07:52	10.1	09.2	09.5	09.3	·20.7	09.9	06.9	09.0	25.8	09.2
07:11	09.8	09.2	09.5	09.3	20.7	09.6	06.7	08.9	26.0	09.1
07:12	09.7	08.9	09.4	09.4	20.7	09.3	06.7	09.0	25.7	09.2
07:13	09.7	08.9	09.3	08.9	20.6	08.8	06.7	08.8	25.6	09.1
07:14	09.6	08.4	09.3	08.6	20.6	08.7	06.6	08.9	25.3	09.1
07:15	09.5	09.0	09.4	08.6	20.6	08.7	06.6	08.9	25.3	09.1
07:16	09.5	09.0	09.4	08.7	20.7	08.0	06.7	08.9	25.3	09.1
07:17	09.6	09.0	09.3	08.7	20.6	07.0	06.6	08.8	25.2	09.1
07:18	09.6	09.1	09.3	08.5	20.6	06.1	06.6	08.7	25.0	09.1
07:19	09.6	09.1	09.4	08.1	20.7	05.5	06.6	08.7	24.9	09.1
07:20	09.6	09.2	09.4	07.8	20.6	05.1	06.7	08.7	24.9	09.2
07:21	09.6	09.1	09.4	06.4	18.7	03.4	06.5	08.0	22.9	08.9
07:22	09.6	09.0	09.5	05.8	16.9	03.3	06.6	07.5	21.4	08.9
07:23	09.5	09.1	09.5	05.5	15.8	03.3	06.8	07.2	20.4	08.8
07:24	09.6	09.1	09.5	05.3	15.1	03.4	06.7	07.1	19.6	08.8
07:25	09.5	09.1	09.5	05.2	14.5	03.4	06.7	07.0	19.1	08.4
07:26	09.4	09.0	09.5	05.0	13.9	03.4	06.7	07.1	18.5	08.2
07:27	09.1	08.8	09.5	04.8	13.4	03.4	06.7	07.0	17.9	08.1
07:28	08.7	08.5	09.4	04.6	12.7	03.2	06.7	07.1	17.1	08.1
07:29	09.0	09.0	09.1	04.4	12.0	03.2	06.7	07.3	16.4	07.6
07:30	09.3	09.2	08.8	04.3	11.4	03.1	06.7	07.5	15.8	06.7

DRYER MAIN HEADER PRESSURE DROPPED

DRYER SECTION PRESSURES DROPPING

Fig. 7(b)—Steam supply group reviews records the decreasing pressure in each of the individual dryer sections caused by the drop in the main header pressure

DRYR STM BAL

TIME	DRYR STM FLOW	THER STM FLOW DRYR	HEAT VENT STM FLOW		DRYR COND FLOW	DRYR COND TEMP	MOIS AS MADE O M	NO 4 DRYR DIFF PR	NO 4 DRYR SPD	DRYR MAIN HEAD PR
08:36	0620	282	123	000	054	190	07.4	09.0	2205	59.5
07:26	0996.	188	141.	099.	076.	189.	07.7	07.0	2208	18.4
07:27	1019.	186	143.	101.	071.	188.	07.7	07.0	2206	17.8
07:28	1057.	184	145.	105.	065.	188.	08.1	07.1	2206	17.1
07:29	1082.	180	146.	108.	068.	187.	08.2	07.3	2206	16.3
07:30	1098.	180	144.	109.	074.	186.	08.2	07.5	2207	15.8
07:31	1109.	178	146.	110.	073.	185.	08.6	07.6	2207	15.3
07:32	1120.	178	150.	112.	064.	185.	08.6	07.5	2206	15.0
07:33	1128.	177	151.	112.	073.	184.	08.6	07.3	2206	14.7
07:34	1141.	176	151.	114.	068.	183.	08.9	07.2	2207	14.3
07:35	1152.	176	157.	115.	067.	182.	08.9	07.1	2208	14.0
07:36	1212.	185	159.	121.	072.	182.	08.9	07.5	2207	14.9
07:37	1353.	206	175.	135.	069.	181.	08.9	08.8	2207	18.9
07:38	1355.	217	173.	135.	072.	181.	09.3	10.1	2207	22.0
07:39	1302.	225	169.	130.	069.	181.	09.3	10.7	2206	24.2
07:40	1185.	236	166.	118.	071.	182.	09.3	10.9	2207	27.7
07:41	1154.	241	169.	115.	075.	183.	08.6	11.1	2208	30.0
07:42	1128.	259	185.	112.	067.	184.	08.6	11.7	2207	35.5
07:43	0787.	286	173.	078.	074.	186.	08.6	12.1	2206	51.7
07:44	0738.	274	159.	073.	062.	187.	07.8	11.5	2207	52.3

RESULTING UPSETS IN DRYER STEAM SYSTEM

MAIN HEADER PRESSURE DROPPING

INDICATED STEAM FLOW RISING

SHEET MOISTURE RISING

Fig. 7(c)—Dryer steam balance group review records the drop in main header pressure and the subsequent upsets in steam and condensate flows and temperatures through the dryer steam system

9. *Utilisation by machine room personnel* The information system has been a valuable tool for analysis of machine conditions during normal or disturbed operating conditions, primarily because of the availability of a maximum amount of information in a central location. There are many examples to be cited when the system was used as a study tool—
   (*a*) Analysis of the steam system with and without press vacuum.
   (*b*) Analysis of relationship between couch vacuum and mixed stock consistency.
   (*c*) Analysis of start-up conditions compared with previous operating condition.
   (*d*) Lubrication system—start-up checks.
   (*e*) Analysis of variations in basis weight.
   (*f*) For providing data for analysis by the technical department.
   (*g*) For accounting functions.
   (*h*) General usage includes a check on changes to the machine by machine operators and controller loop tuning in the stock proportioning areas.

To summarise our experience in using the system to date, recapitulation of the results compared with the system objectives should be in order.

The first objective of this information system was to assist the operator in on-line action. This objective has been attained, as can be seen from the examples cited in the preceeding section. There is still further work to be done here, including—

1. Additional operator training.
2. Further implementation of a function termed the critical alarm (another operator tool).
3. Addition of an arithmetic unit for on-line performance monitoring.

The second objective was to 'provide the means of gathering accurate, reliable data for off-line process analysis'. This objective has been realised in part, as indicated by reference to Appendix 2 and some of the previous examples. Further work is required in this area—

1. Calibration of all input data.
2. Addition of certain important inputs.
3. Addition of computing capability in the system.

From the philosophy (which way to go in digital systems) mentioned at the outset of this report, it is very apparent to us that the system purchased was the correct choice for this project. Had the technical aspects of the equipment been more complex, the manpower available for the project would have been unquestionably insufficient, both in regard to numbers and training. This would most certainly have increased the implementation problems and reduced operator acceptance.

Practical consideration for the application of digital systems

THERE are a number of factors that one should plan to deal with when considering the application of any digital system—

1. Hardware and software malfunction.
2. Training of operation and maintenance personnel.
3. Appropriate programs of routine maintenance.
4. Related instrument reliability.
5. Process operating experience on the system team.

The objective, of course, is to hold any upset as a result of these factors to a minimum. It was considered that the application of a simplified system to perform the functions required was desirable. Resolving the problems caused by these factors during implementation convinced us that the right choice had been made.

Comments* relating to hardware malfunctions and software errors are intended to point out 'occupational hazards', which will undoubtedly occur—in varying degrees—in the application of any sophisticated system.

At the time, the system was considered ready for on-line use, the stock preparation operators were knowledgeable about the system and its functions, although the papermachine operators had not really begun to use it and therefore did not understand its function or its capabilities. Stock preparation operators were using the system to nearly its full capability relative to their job. Yet, since the system is probably 80 per cent oriented to the papermachine, it was being used at something like 15 per cent of its total capability. The figures quoted are qualitative only.

This situation remained basically unchanged for approximately 3 months, at which time the papermachine operators began to pick up knowledge and interest in the information system. The breakthrough at this point can be completely attributed to the Production Superintendent, Powell River Division, who made a considerable effort to train each of the No. 10 operators individually on the functions of the information system and how these functions can be utilised to assist machine operation. After this training period, papermachine operators have been utilising the information system to approximately the same degree as have the stock preparation operators.

It is appropriate at this time to discuss the variety of problems that occurred during the particular system implementation. This topic is often discussed relative to any system installation and most of the problems are

* These comments should not be misconstrued as being a complaint against the particular supplier. On the contrary, the support received from the firm producing and installing this system under the circumstances is to be commended.

well known, but the experiences on this system represent the first case of what will be a continued factor in the start-up and implementation of advanced systems by our systems engineering group—

1. One of the main roadblocks to a much faster and smoother implementation phase was the hardware malfunctions at start-up and the continued malfunctions during approximately the first six months of operation. Although the number of equipment problems was not excessive, the operation was not as smooth as would have been desired. The result is a common feeling of mistrust among the operators of the information system reliability. With this feeling prevalent, it is most difficult to instil enthusiasm for using the equipment, regardless of how obvious the benefits are. It is essentially the age-old story of the human quality of remembering the bad points about something and tending to let all the good points slip away.

   The only way to offset this difficulty is to ensure that advanced systems of this type are shipped with a minimum of hardware problems. This can be achieved only by a thorough factory inspection, which requires sufficient lead time properly to specify and design the system.

   Once installed, equipment of this type must be subjected to regular thorough maintainance (preventive maintenance) in order that hardware malfunctions are kept to an absolute minimum. On the system described, it was demonstrated time and again that small failures (for example, erroneous type-out of a single group review) reinforced the feeling in the operators' minds that the information system was unreliable. Preventive maintenance is extremely important to the continued reliable operation of peripheral equipment.

2. Software errors obviously contribute to the feeling of non-confidence among the operating personnel just as greatly as hardware malfunctions do so. Here again, the only way to prevent problems of this kind is to provide sufficient time for the equipment and software to be thoroughly inspected on the factory floor; with its inspection being monitored by a user representative, if at all possible.

3. Advanced system installation on a process must include primary instrument problems as part of the total system implementation. Experience with our application indicates that this type of problem can also adversely affect the reputation of the system in the eyes of the operators. In any mill that is production-oriented, instrument malfunctions are not necessarily corrected immediately. Problems of spare parts, maintenance scheduling, job priorities and 'brush fire' work often delay maintenance for long periods of time, thus creating erroneous system data. One solution to this problem is to assign an instrument mechanic to the project full-time for the duration of the implementation phase.

   Calibration is another factor that must be mentioned. It is mandatory that the demands on a instrument mechanic's time do not preclude his ensuring that all system inputs are in calibration.

4. A serious problem in the implementation phase of the system described was the lack of process understanding (papermaking) on behalf of the systems engineering group.* Intimate process operating knowledge is needed during system implementation. It is in sufficient to have a basic familiarity with the process, as this has little to do with the hour-to-hour or day-to-day operating situations. An important key to implementing this type of equipment is to be able to show the operators, in their own terms of reference, how they can utilise the information in a way that is beneficial to their operation of the machine within their job responsibility.

   There is no way around this problem. As previously mentioned, the implementation phase of this project was effectively at a standstill, until the production superintendent stepped in and personally trained the individual operators in the uses of this equipment.

5. Associated with the above problem is the fact that the No. 10 information system was not required by the papermachine personnel to run the machine *as machines had been run in the past*. This being the case, there is a natural reluctance on the part of the operators to go out of their way to learn something that is not a definite requirement of their job responsibility.

   Conversely, the stock preparation personnel were forced to use the system as it provides the only records and/or indications of chest levels, stock flows and stock consistencies.

   It is obvious that equipment that can be considered as redundant will tend to be ignored. Future systems of this type should be an integral part of the process operation, thus assuring a starting point, at least, for complete system implementation.†

6. A more general problem that is always related to a staff project is the staff-line relationship in a business organisation. Even though both line and staff play an important role in company plans, the line officials retain full authority and responsibility for execution of these plans, once they become a firm part of company policy.

   The line and staff relationship must be considered in a project such as an advanced control system implementation. It is essentially a staff project and must be carried out without line authority or responsibility. A direct result of this situation is an inefficient project. It will be our recommendation in the future that consideration be given to active line participation and responsibility in the project. This would provide the authority within the project group and result in improved implementation for both operations and maintenance.

7. Another important problem was the lack of and timing for operator training. The only operator training for the system was carried out 6 months before operation of the system. This was an extensive course given to the majority

* This knowledge was available, but at too high a level in the company to be directly utilised.

† Consideration was given to this in the design stage, but it was too radical a step for acceptance.

of the papermachine and stock preparation operators. The course effectiveness was reduced because—

(*a*) Too much time elapsed from the time the course was given to the start-up of the machine. Candid comments from the operators indicate that, despite the course being good and an understanding of the system being achieved, most of this was lost in the following months before the system was installed.

(*b*) Lectures were given without equipment present. It is difficult to teach material of this type without having the actual equipment available to provide immediate experience.

The training problem is compounded by the fact that the No. 10 papermachine is the senior machine and is subject to more frequent changes of crews. This means that new operators without the familiarisation course as background frequently operate the machine.

It is suggested that continued 'hands-on' training be considered for this type of equipment. Training should be given to both the normal operators and the relief operators and should include any instrumentation or control that is part of the system's entire scope—that is, the scanning basis weight, moisture, caliper systems.

8. When planning an advanced system installation, parallel installation of other new equipment must be considered for the effect it will have on the ability of the operators to learn the operation and the capabilities of all systems. Without a program of learning, too much can be forced upon the operators at any one time.

It is also worthy of note that operators will tend not to experiment with an advanced system when the 'system expert' is around. It is advantageous to the success of advanced system application to permit the operators free time to operate the system after appropriate instruction and direction has been given.

Conclusions

THE primary objectives of the No. 10 information system were—

1. To assist operating personnel in direct on-line action.
2. To provide the means for gathering accurate, reliable data for off-line process analysis.

In the first objective, the operating personnel believe that, with proper and continued attention to the system, a substantial 'assist' to papermaking is possible. For example—

(*a*) The system is used extensively by stock proportioning personnel for monitoring stock flow and chest level.

(*b*) Group trending on the utility printer has assisted in improving start-up procedures and for speeding up and slowing down by presenting the operator with related variables such as basis weight, vacuums and stream flow valve position.
(*c*) Historical review of groups of data such as stream flows assist in determining points of upset during normal operation and during speed trials.
(*d*) Accurate data (and trending of this data) on speeds, draws and press section loadings is an assist in determining when changes were or should be made.
(*e*) Speed variation analyses are readily made on the system's trend recorders.
(*f*) Alarm monitoring provides an important key to resolving upsets (or potential upsets) before the danger point.

In order to obtain the full benefit of the system, it is mandatory that the system be maintained in first-class working order. This can be accomplished only by means of a thorough preventive maintenance program. Such a program must include all peripheral equipment associated with the system.

Routine checks and calibration of instruments providing data to the system are necessary to ensure validity of data presented (and to be used for calculations). Those instruments such as the beta-gauge that require certain mechanical adjustment (such as changing of cables) must be kept in proper operating condition if the confidence of the operator is to be gained and maintained.

One of the primary considerations at the time of system purchase was the manpower required to implement and use the system effectively. In spite of the simplicity designed into this system, which we had intended would render even one full-time man unnecessary (and which is technically the case), the normal resistance to change from past practices by operating personnel and the shortage of technical personnel at Powell River have shown that, for full utilisation, one man is needed to support the system and act as liaison between the system and operations. This man becomes even more important when the computing function is added to the system, although this should be compared with the 2–4 men required on other reported process control computer applications.

The ultimate intent of the process analysis is to determine specific control requirements for the No. 10 papermachine and to develop from these requirements generalised control system recommendations for newsprint machines.

It was—and is—imperative that the above objectives be met within the staff capabilities available within the company for such effort and that the use of the system for off-line work will not interfere with on-line implementation. The type of system employed satisfied these requirements in that a step-by-step approach was feasible—each step to be accomplished by degrees of system implementation—and that the internal system programming was relatively simple. As a result, special programming talent was not required to implement and maintain the desired system functions.

Steps planned to be taken in the complete program include the addition of an arithmetic section for on-line calculation of performance indices and, should the results of these indices indicate the desirability, some degree of supervisory control. The system has demonstrated its capability to provide the input output (1/0) function for such expansion capability satisfactorily.

There are several factors to be considered should the aforementioned steps be approved and carried out—

1. Although special programming talent is not deemed necessary, a systems engineer must be employed by the division to work with the systems engineering department in the implementation of the computer and, subsequently, of the control. His responsibility would carry on, after the systems engineering department has completed its activities, providing the necessary supervision and liaison with appropriate mill departments to ensure future successful system operation. This man could be a young process engineer with suitable abilities and trained on the job for the position.
2. Plans must be made and action taken properly to calibrate all input measuring devices—both as components and as a system—before completion of the computer expansion. Subsequently, periodic checks will be required to ensure that accurate and reliable data is being fed to the computer. Success of the system depends on this requirement being fulfilled. Some leeway is possible in data accuracy when used only for display of instantaneous data, but the best accuracy possible is absolutely essential when data is to be processed and meaningful indices established.

Given the continued co-operation of all departments involved, there is considerable knowledge yet to be gained by the expanded implementation of No. 10 information system. With the knowledge gained, there is every reason to expect additional economic benefits—primarily, through improved uniformity of operation and as foundation information for design of future papermachines and control systems.

Reference

1. Mardon, J., Barrett, J. E. and Meheffey, W. H., 'A systems approach to papermachine instrumentation': *Appita*, 1965, **18** (6), xvii–xl

Appendix 1

THE 754 system functions are as follows—

1. *Data acquisition* The data acquisition subsystem existing in the No. 10 system has the capability to monitor 150 analog inputs at 15 points/s. It also monitors up to 20 integration inputs (pulse inputs), 26 BCD digital inputs (speed and draw) and up to 200 contact type inputs.

2. *Alarm monitoring* This subsystem monitors all analog and digital inputs at a rate of 3 000 points/s and compares their stored value against a programmed alarm limit. At the same rate, it also monitors the status of the external contact closure alarms. The status of both types of alarms is stored to allow a review at any time or at a set interval of 1 min, 5 min, 30 min or 60 min of the existing alarm conditions. New alarms, return to normal messages and alarm reviews are presented on the alarm printer. This alarm subsystem also has the capability for comparing all analog or digital values against a second set of alarm limits, designated questionable alarms. This final function of the alarm monitoring subsystem is to provide area annunciation on a 20 window annunciator. Each alarm condition can be programmed to alarm in any area.

3. *Periodic logging* The periodic log subsystem provides a print-out, automatically or at regular intervals, of the values of approximatly 125 system inputs. These values are typed on a preprinted log sheet consisting of two pages bonded together to give a 'roller towel' typewriter sheet.

4. *Value displaying* The value of any system input, high or low alarm limit and high or low questionable alarm limit can be displayed on a digital read-out on the system console. This display is 4 digits with decimal point and sign. The 20 most frequently used variables can be displayed directly by depressing a push-button engraved with their alphanumeric identifier.

   Time can be displayed on these same digit lights by depressing a momentary push-button.

5. *Analog trend recording* Five two-pen recorders are mounted on the console to provide for trend recording of any 10 selected system inputs. Any pen can record any system input at a desired zero suppression and chart range.

6. *Utility functions* A utility subsystem is included in the No. 10 information system. This subsystem consists of a further five two-pen recorders and a separate printer. The following functions are possible—
   (*a*) Single point digital print-out of any system input, high or low limit or questionable high or low limit.
   (*b*) Single point digital trend print-out of current data for any analog input. Trend interval can be 1 min, 5 min, 15 min, 30 min or 60 min.
   (*c*) Single point analog trend of current data on one pen of the analog recorders. This pen is identified by having the printer first type out the variable and one set of current data.
   (*d*) Single point digital trend of historical data for 100 selected digital or analog inputs collected over 1 h at 1 min intervals.
   (*e*) Single point analog trend of historical data for up to 100 analog or digital inputs collected over 1 h at 1 min intervals. This pen is identified by having the printer first type out the variable and one set of current data.

(*f*) Group review* digital trend of current data for anyone of a possible 20 logging groups on operator demand. The trend interval can be set at 1 min, 5 min, 15 min, 30 min or 60 min.

(*g*) Group review analog trend of current data for any one of a possible 20 logging groups on operator demand. The variable presented on the recorders are identified by having the printer first print out the group review with one set of current data.

(*h*) Group review digital trend of historical data at 1 min intervals for the previous 60 min on operator demand.

(*i*) Group review analog trend of historical data at 1 min intervals for the previous 60 min. The analog values are identified by having the printer first print out the group review with one set of current data.

7. *Tape punch* The No. 10 system has a paper tape punch available as an output device. This paper tape can be initiated automatically or on demand to record the values of up to 100 system inputs.

8. *Critical alarm review subsystem* This subsystem was set up so that an alarm condition on any variable could initiate, via programming, a group review analog trend of historical data for a selected group, automatically followed by an analog trend of current data for the same group. The operator has the ability to stop this review by—

(*a*) Stop utility push-button if the critical variable is no longer in alarm.

(*b*) Critical alarm disable keylock switch if the variable is still in alarm.

Some modifications to the system have been made that enhance its usefulness—

(*i*) The five utility recorders were given an alternate function. Those recorders may now be directly connected, through a push-button on the information system console, to the following permanent inputs—

Recorder 1 Red—Mixed stock consistency
Blue—Mixed stock dilution valve position
Recorder 2 Red—Groundwood consistency
Blue—Groundwood dilution valve position
Recorder 3 Red—Kraft consistency
Blue—Kraft dilution valve position
Recorder 4 Red—Broke consistency
Blue—Broke dilution valve position
Recorder 5 Red—High couch vacuum
Blue—(Not yet assigned)

If the push-button designated *enable recorders* is backlighted, these five recorders will be connected to the above variables. If this push-button is not backlighted, the recorders are then available for use with the utility subsystem as designed.

The reason this modification was made was to utilise these recorders. Previously, they were sitting idle 99 per cent of the time for the following reasons—

(*a*) If the recorders are being driven from the utility subsystem, the utility printer is tied up. Hence, display of current data in the analog trend format is impracticable, as the utility printer cannot be used.

* The system has been organised such that groups of 10 variables can be displayed together in the various formats

(*b*) The scaling of the analog recorders is unsatisfactory, hence they are very difficult to interpret. The scale is either 1:1 or 1:4 and this can be determined only by knowing beforehand what you expect to see on the recorder. Besides, because the one scale must accept both very large and very small signals, the resolution is very poor.

(*c*) The noise from the chart motors causes intermittent resetting of the system time. This is also a deterrent to their use.

(*d*) The chart speed switching from high to low was not fast enough and sometimes 15 min was required before the chart would move.

(*ii*) The compiler subsystem was modified to permit data collection at either 1, 2 or 3 min intervals, thus providing a 1, 2 or 3 h historical review. The sampling interval is changed via a thumbwheel switch in cabinet 8.

This feature provides a system memory that can be altered to suit a specific purpose—for example, long-term studies (up to 3 h) can be recorded through a historical review at the end of the study period.

(*iii*) The historical review capability in the utility subsystem was modified to allow the print-out to skip from 1 to 59 items of the oldest data. This feature allows any part of the historical record to be displayed without having to wait for all 60 readings to be typed out.

This feature is implemented by setting the number of readings to be skipped on the two righthand digits of the thumbwheel switch on the right side of the console. Once the group review is selected, the *historical review by-pass* push-button is depressed and the correct number of readings will be displayed.

(*iv*) The alarm subsystem was modified to provide an alarm dead band on all programmable alarm limits. The system as installed had two sets of alarms, one for standard process monitoring and one designated *questionable* to provide alarming for such things as instrument failure. Since the questionable alarms were not implemented and indications were that they would not be, it was decided to utilise this memory and hardware to provide an alarm dead band. Thus, the system now has an alarm limit and a return to normal limit and both must be programmed for each point alarmed. Return to normal limits are programmed as *questionable* alarm limits. The purpose in applying the dead band concept in digital system alarming is to eliminate annoying conditions when a process variable is oscillating around the alarm point and causing repeated print-outs of alarm and return to normal conditions.

(*v*) The critical alarm subsystem was modified to correct difficulties inherent in the original design. The main modification provided the facility for initiating a critical alarm group review only on a *new* alarm condition. This feature allows operator acknowledgement of the group review at any time after it has been initiated, regardless of whether the alarm condition still exists.

Appendix 2

Process implementation projects

These projects can be divided into two main types. The first type are those projects that can be undertaken by the systems engineer with only the information available from the system, production reports and other instrumentation. The second type of project involves work that must be done by the Powell River technical department.

The project descriptions to be given here are brief and merely serve to outline the objective of the work.

Type 1 projects

1. *Lost time analysis* The project objective will be to show how the data system can be used as an effective tool for lost time analysis and reporting.

An example of a lost time analysis for a one month period will be produced. The project will take into consideration the lost time reporting system already in use at Powell River and will determine where the data system can be of advantage.

2. *Head box variables correlation to basis weight* The objective is to determine any relationships between variations in the head box variables and basis weight (machine-direction).

   The basis weight gauge will be used in conjunction with the continuous monitoring of the head box variables.

3. *Heat and material balances over the dryer systems* The objective is to utilise the information available from the data system plus any other necessary information such as hood dry bulbs and fan amperage in order to calculate a heat and material balance over the dryer system.

4. *Relationship between dryer steam consumption, moisture and felt age* At fixed moisture levels, cross-plots between steam consumption and felt age will be made to determine a relationship between the two. All dryer felts will be taken into consideration.

5. *Relationship between average basis weight and mixed stock consistency* The objective will be to determine the relationship between average basis weight and mixed stock consistency for the No. 10 papermachine.

   The data will be collected at periods of constant mixed stock flow and machine speed.

6. *Relationship between suction box vacuum and amount of broke* This relationship will be defined for the No. 10 machine at times when the other factors influencing drainage are constant—that is, constant basis weight and groundwood freeness.

7. *Temperature of system as related to couch and flat box vacuum* Temperature will be plotted against these two vacuums to determine this relationship for No. 10 papermachine. Care must be taken to ensure that other influences such as groundwood freeness are relatively constant.

8. *Relationship between couch vacuum, flat box vacuum and moisture at the reel* The objective is to define the relationships between couch and flat box vacuums and reel moisture for the No. 10 papermachine.

   Data will be plotted for periods of steady dryer conditions.

9. *Felt tension versus steam consumption* With other related variables constant, a relationship between felt tension and steam consumption will be looked for.

10. *Felt age versus press vacuum for three presses* The objective is to determine what effect the felt age has on press vacuum. Data will be plotted for periods of two successive felts on the machine.

11. *Head box consistency as a function of dryer steam* At a fixed moisture and machine speed, the relationship between No. 10 head box consistency and the dryer steam consumption will be determined. This can be done directly using the manual test results.

12. *Basis weight valve position versus consistency* At different levels of machine speed, the curve showing basis weight valve position as a function of consistency will be determined.

13. *Speed change responses* Data will be gathered to determine the response of the process to a change in machine speed. Particular attention will be paid to basic weight and moisture.

Type 2 projects

1. *Calibration of consistency regulators* The objective here is to obtain data that can be used to define the absolute calibration of the regulators on the No. 10 stock preparation system, particularly kraft and groundwood stocks.

2. *Relationship between formation and total head* At a fixed drag on the wire, formation will be cross-plotted against machine total head (speed).

   Formation samples will be taken and run off in co-ordination with the mill technical department.

3. *Relationship between formation and drag* At fixed speeds, formation will be cross-plotted with drag to define the operating point at which the formation is the optimum.

   Formation samples will be run off in co-ordination with mill technical department. At the same time, the relationship between drag and CD & MD tearing strength will be evaluated.

4. *Press moisture profiles* A correlation between press moisture profiles and dry end basis weight and moisture profiles will be made in conjunction with the mill technical department.

   At the same time, the effect of differential loading on the presses will be evaluated.

5. *Effect of loading on the breaker stack* Caliper and smoothness variations at the dry end will be correlated with the breaker stack loading. Samples will will be taken at reel turn-ups by co-ordination with the mill technical department.

6. *Basis weight, moisture and smoothness with and without steam to the calender stack* The effect of steam in the calender stacks on these three variables will be determined. Samples will be taken at a reel turn-up for each of the two conditions.

7. *Effect of whitewater on formation*

8. *Suction box vacuum as a function of freeness* To correlate changes in groundwood freeness to suction box vacuum at stable machine conditions. Testing will be done by the mill technical department.

Appendix 3

Area	*Incident*
Chest levels	1. Machine chest level was alarmed at a high level condition on start-up and subsequent overflowing was prevented. 2. A similar situation occurred on start-up with the kraft stock chest. 3. The pump feeding the No. 10 kraft stock chest kicked out, thus causing the kraft stock chest level to fall. A system alarm alerted the operator and the pump was started again, but not before the level dropped to 3·2 ft. Without this early warning, the kraft stock flow to the machine chest would have been disturbed and the trial upset. 4. In another instance, a high alarm condition was noted on the high density groundwood storage. The operator was able to take action to prevent overflow and stock loss. 5. The power to the pumps feeding the No. 10 kraft stock chest and the dye head box was lost. A low level alarm on the kraft stock chest was recorded at 13.08 h, but the operator was not available. At 13.26 h, the dye head box emptied and a dye flow low alarm was initiated. This was picked up by the operator and steps were taken to remedy the situation. Although the operator was working on the dye flow, a kraft stock flow alarm was initiated at 13.41 h as the kraft stock chest had also emptied. At this point, all flows to the machine chest were shut off. The alarm monitoring system provided the warning to the operator and, had the first alarm condition (13.08 h) been acknowledged, the disturbance would probably have been less. Without the alarm system, the problem would have been far more severe.

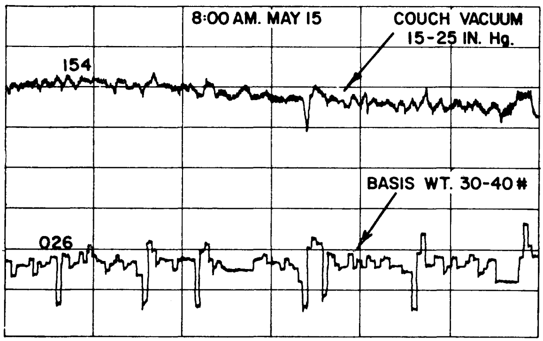
Area	*Incident*
	6. The stock preparation operator requested that the low level alarm on the kraft stock chest be raised to permit more time on occasions when the trouble occurs. He reported that a recent power cut-off on the kraft stock supply pumps had caused No. 9 machine to run out of stock while No. 10 machine was just keeping up. The limit was raised after discussion with stock preparation supervision. This example represents how the alarm monitoring system can be used and how the operating personnel have utilised it.
Stock consistencies	*1.* One start-up, a failure in the groundwood stock consistency controller was picked up immediately by the alarm subsystem. Action was taken to prevent a machine disturbance.
	2. The groundwood dilution water for groundwood consistency control was shut off when the groundwood mill was shut down. A high alarm on the groundwood dilution valve position was recorded at 12.32 h. At 12.42 h, the mixed stock consistency regulator was out of control as noted by a high alarm on the mixed stock dilution valve position (due to machine chest becoming heavy). At 12.48 h, the machine went down due to the increased consistency. Although operator action was not fast enough to prevent the machine from going down, the warning was available and alternative action could have been taken to prevent the downtime. For example, stock flows to the machine chest could have been shut off temporarily while the dilution water was returned.
	3. A similar problem occurred at a later date, when maintenance crews shut down the groundwood water pump not realising that it was being used for consistency control on No. 10 machine (the groundwood mill was down). The groundwood dilution valve position high alarm warned of the situation. The operator was able to get the dilution water back before the machine was put down. It was noted on this occasion that the mixed stock dilution valve position started to increase rapidly 5 min after the upset and went from 55 per cent open to 84 per cent open in the following 18 min. This indicates a 5 min dead time in the machine chest.
Stock flows	*1.* During start-up, the dye line plugged and flow was

Area	*Incident*
	cut off. The system alarm for low dye flow enabled immediate corrective action and prevented off-specification paper.
	2. The low limit on dye flow was removed by persons unknown. This was picked up by the operators and replaced at their request. This example points out that, once a system is installed, its additional features—above and beyond conventional instrumentation—come to be depended upon in the same fashion as other instruments.
Stock cleaning and de-aerator	1. A low alarm on the de-aerator vacuum warned the machine tender of trouble. Subsequent investigation pointed out a slipping belt on the vacuum pump. The vacuum did not drop more than 1 in Hg over the trouble period. Had the operator not been warned at this early stage, it is possible that the vacuum could have dropped further and upset the machine.
	2. An alarm condition in one of the supply pressures was picked up. Historical review of the centrifugal cleaner group indicated that a sump level was varying. Subsequent investigation showed a troublesome control valve, which was then repaired.
	3. An alarm on the tertiary cleaners supply pressure was initiated. Investigation via the centrifugal cleaners historical review pointed out a low secondary rejects sump level. This level could not be increased with the level control because of the control valve sticking. The instrument department was notified and and the condition rectified.
	4. An alarm on the secondary centrifugal cleaner supply pressure was recorded at 9.19 h. At the same time, a sharp drop in basis weight and couch vacuum occurred as shown in the analog record of Fig. 8. Investigation of the centrifugal cleaner group review as shown at the top of Fig. 8 showed that the primary rejects sump level had jumped from 35 to 96, whereas the secondary cleaners supply pressure apparently remained constant. It is assumed that, at the jump in sump level, a surge in light stock to the secondary cleaners was caused and this was the reason for the low couch vacuum and basis weight. The transient in the secondary supply pressure was likely very fast, hence a sustained offset in the secondary supply was not recorded over the 1 min interval sampled. The

Area	*Incident*
	low couch vacuum and low basis weight are also shown on the head box historical group review in Fig. 8. The machine tender, who had been analysing the problem on the charts in Fig. 8, investigated the cause of the sump level change and found that a cleaning man had turned the set point knob on the locally mounted level controller while cleaning it.

TIME	C-C PRIM SPLY PR	C-C SEC SPLY PR	DECU LATR VAC	C-C TERT SPLY PR	C-C TERT DSCH PR	C-C PRIM SUMP LEVL	C-C SEC SUMP LEVL	STRM FLOW VALV POSN
09:15	30.3	35.6	27.4	46.7	0.71	35.5	37.3	39.7
09:16	30.3	35.6	27.4	46.7	0.70	35.1	37.3	39.6
09:17	30.3	35.6	27.4	46.7	0.71	35.1	37.3	39.6
09:18	30.2	35.5	27.4	46.8	0.71	35.2	37.3	39.7
09:19	30.2	35.7	27.4	46.9	0.71	35.3	36.7	39.6
09:20	30.2	35.6	27.3	46.8	0.71	86.8	38.8	39.6
09:21	30.3	35.6	27.3	46.9	0.71	94.4	37.1	39.7

SUDDEN RISE IN SUMP LEVEL



TIME	HEAD BOX TOT HEAD	HI COUCH VAC	DRAW JET WIRE	FWD DR ROLL SPD	STRM FLOW VALV POSN	HEAD BOX LIQ LEVL	HEAD BOX TEMP	HOT WATR SHOW TEMP	B WT AS MADE O M	MIXD STOK FLOW
09:14	269.	20.87	0014	2290	39.7	15.1	089.	105.	31.8	2548
09:15	270.	20.77	0016	2291	39.7	15.0	089.	106.	31.8	2540
09:16	269.	20.87	0012	2291	39.6	15.0	089.	105.	31.7	2542
09:17	270.	20.90	0014	2291	39.6	15.1	089.	105.	31.7	2537
09:18	270.	20.80	0016	2289	39.7	15.1	089.	105.	31.7	2550
09:19	270.	20.83	0015	2291	39.6	15.1	089.	105.	31.6	2565
09:20	269.	20.84	0014	2290	39.6	15.1	090.	106.	31.6	2561
09:21	270.	20.45	0013	2290	39.7	15.1	089.	105.	31.6	2567
09:25	269.	20.90	0014	2291	39.6	15.1	089.	105.	30.6	2597
09:26	270.	21.03	0015	2291	39.7	14.9	089.	105.	30.6	2604
09:27	269.	21.07	0013	2298	39.6	15.1	089.	105.	30.6	2601
09:28	270.	21.13	0000	2291	39.7	15.1	089.	105.	32.1	2572

DROP IN COUCH VACUUM

DROP IN BASIS WEIGHT

Fig. 8—The centrifugal cleaner group review (top) records a sudden rise in sump level: the resulting surge of light stock to the head box causes a drop in couch vacuum and basis weight as indicated in the system analog record (centre) and the head box historical review (bottom)

Area	*Incident*
Head box	*1.* On several occasions, the head box level went into high alarm, owing to an inadequate air supply. On these occasions, the sheet on the wire became very wild, but the machine did not break down. The problem was corrected by supplementing the compressor air with enough mill air to provide a stable level control at the hornbostel. Had the problem not been noticed at an early stage, it is conceivable that prolonged operation in this state could have caused some down-time.
	2. On start-up, the information system was useful in recording deviations in the head box total head. At this time, when the head was generally constant because of a fixed machine speed, programmable limits were put on total head. This alarming procedure provided immediate corrective action and eliminated down-time.
	3. Several pens of the selectable trend recorders were put on the head box variables and the whitewater flow to the groundwood mill to determine if fluctuations in this whitewater flow are causing temperature upsets to the head box during normal operation. The trend recorders were set up recording the key variables over a period of several days in order to provide data for a correlation analysis.
	4. The jet-to-wire draw measurement is a useful variable to have displayed and recorded. Early calibration problems in the differential pressure sensor providing the measurement caused a considerable feeling of mistrust with the calculated reading, but this has since been overcome and the draw value is now reasonably accurate. This figure can be utilised by mill management and supervisory personnel to monitor the machine operation. For example, on one occasion, management personnel requested the 35 ft/min drag existing on the machine be reduced as part of an investigation of low tear values on the machine.
	5. On another date, the machine tender used the calculated draw value to set up the machine. This was the first recorded example of operator acceptance of and confidence in this variable.
Fourdrinier machine	*1.* On start-up, the flat box header vacuum kicked out, forcing the machine down. Subsequent analysis by

Area	*Incident*
	means of the utility subsystem historical review indicated that the flat box header vacuum had failed first.
Press and breaker stack loadings	*1.* The digital indication of press and breaker stack loadings appears to provide a superior method for setting up these values. It is possible to set up the nip pressure values exactly, using the information system, whereas it is very difficult to interpret the pressure gauges on the press and breaker stack consoles. Boss machine tenders have been using this information system facility for both setting up and recording loading values.
	2. On one occasion, a machine room supervisor had been able to solve the problem of a soft back edge on the reel by using the information system to analyse all those factors that can affect it. It was found that an uneven breaker stack loading had been the cause.
Dryer section	*1.* The No. 10 dryer steam system has been the subject of considerable analysis since start-up. It has been pointed out that the information system has been used for monitoring changes in dryer pressures and corresponding changes in steam flow. From this information, there is some evidence that the steam system is undersized and could be the cause of some paper breaks.
	2. In a technical department survey into the possible causes for poor drying over a specific operating period, the data recorded on the periodic log sheets was used to study the steam system operation.
Examples of use by supervisory personnel	*1.* On machine start-up, the basis weight valve had to be set 100 per cent open in order to obtain a 32 lb sheet at the start-up speed. At the previous shut-down, the basis weight valve had been only 80 per cent open at the same mixed stock consistency. After approximately 4 h operation, the mixed stock consistency appeared to rise and the basis weight valve had to be cut back to 80 per cent open. Stock preparation and machine room personnel analysed the problem via the information system. Based on later events, it appears that the mixed stock consistency regulator had drifted over the shut-down.
	2. On another date, the fourth dryer section speed was put on a trend recorder, owing to a recent problem of it slowing down. Later that day, the boss machine tender noticed the speed beginning to fall off again

Area	*Incident*
	and was able to correct the problem before the sheet broke down. Before the speed was brought back up again, the draw after the breaker stack was extremely slack.
	3. The pump feeding the wire pit kicked out. The result was a falling level and rising consistency in the wire pit, which led to an increased basis weight. Although an alarm was not recorded by the system, it would have been had there been a correct high limit on the basis weight value. The machine was producing a 30 lb sheet on this occasion and the 33·5 lb alarm limit for the 32 lb sheet had not been changed. The head box historical review in Fig. 9 shows the increasing couch vacuum and an increased basis weight at 16.06 h.

TIME	HEAD BOX TOT HEAD	HI COUCH VAC	DRAW JET WIRE	FWD DR ROLL SPD	STRM FLOW VALV POSN	HEAD BOX LIQ LEVL	HEAD BOX TEMP	HOT WATR SHOW TEMP	B WT AS MADE O M	MIXD STOK FLOW
16:11	257	21.53	0022	2234	42.4	15.2	086	104	29.6	2452
14:27	256.	20.83	0018	2235	42.3	15.1	085.	111.	29.0	2512
14:30	256.	20.81	0017	2235	42.4	15.1	085.	112.	29.0	2513
14:33	256.	20.76	0017	2235	42.4	15.2	085.	111.	29.0	2505
14:36	256.	20.78	0017	2234	42.3	15.3	085.	111.	29.0	2511
14:39	256.	20.68	0016	2235	42.4	15.1	086.	111.	29.0	2512
14:42	257.	20.68	0014	2235	42.5	15.2	086.	111.	29.0	2509
14:45	256.	20.58	0015	2234	42.4	15.2	086.	111.	29.0	2503
14:48	256.	20.72	0015	2234	42.5	15.1	086.	110.	29.0	2501
14:51	257.	20.40	0014	2235	42.5	15.3	086.	110.	29.0	2515
15:12	257.	20.47	0013	2233	42.5	15.2	086.	110.	28.9	2522
15:15	257.	20.73	0014	2234	42.5	15.0	086.	110.	29.0	2497
15:18	257.	20.50	0013	2234	42.4	15.1	086.	110.	28.9	2510
15:21	257.	20.53	0014	2235	42.5	15.2	086.	110.	28.6	2522
15:24	257.	20.62	0013	2234	42.5	15.2	086.	110.	29.0	2530
15:27	257.	20.79	0000	2235	42.4	15.2	086.	110.	29.0	2512
15:30	257.	20.63	0000	2234	42.4	15.2	086.	110.	29.2	2490
15:33	257.	20.71	0000	2236	42.5	15.2	086.	110.	29.0	2495
15:36	257.	20.61	0015	2235	42.5	15.1	086.	110.	29.0	2532
15:39	257.	20.80	0013	2236	42.5	15.2	086.	110.	29.1	2521
15:42	256.	20.65	0013	2235	42.5	15.0	086.	110.	29.0	2510
15:45	257.	20.79	0013	2235	42.5	15.2	086.	110.	29.0	2516
15:48	256.	20.69	0014	2235	42.5	15.1	086.	110.	29.1	2513
15:51	257.	20.83	0000	2233	42.5	15.1	086.	110.	29.0	2510
15:54	257.	20.80	0000	2235	42.5	15.2	086.	111.	29.1	2501
15:57	257.	20.89	0000	2234	42.5	15.1	086.	111.	29.1	2517
16:00	258.	21.31	0013	2235	42.4	15.2	086.	110.	29.1	2512
16:03	256.	21.63	0014	2235	42.5	15.1	086.	110.	29.1	2510
16:06	257.	21.61	0014	2234	42.4	15.2	086.	110.	29.9	2484
16:09	257.	21.76	0014	2235	42.5	15.1	086.	110.	29.9	2480

RISE IN COUCH VACUUM

DROP IN MIXED STOCK FLOW

RISE IN BASIS WEIGHT

Fig. 9—The head box historical review records a sudden rise in basis weight caused by a level drop and consistency rise in the wire pit following the kick-out of the Broughton pump; the subsequent rise in couch vacuum and drop in mixed stock flow are also recorded

Area	*Incident*
	4. The basis weight average increased rapidly for a short period of time. Coinciding with this increase were falling de-aerator levels and a de-aerator vacuum, which went from 25·6 in Hg to 25·4 in Hg. Also over this period, the mixed stock consistency was out of control with the dilution valve 100 per cent open. Yet, all input consistencies to the machine chest were well controlled and did not show any disturbance. No conclusion was drawn from the analysis other than questioning a possibility of poor mixing in the machine chest, which would show up in the sheet with the mixed stock regulator out of control.
	5. A low basis weight alarm was recorded at about 8.38 h. The head box historical group review is shown in Fig. 10. The machine tender picked up the alarm and subsequent checking showed that the knotter had kicked out, thus causing the wire pit consistency to drop.

HEADBOX

TIME	HEAD BOX TOT HEAD	HI COUCH VAC	DRAW JET WIRE	FWD DR ROLL SPD	STRM FLOW VALV POSN	HEAD BOX LIQ LEVL	HEAD BOX TEMP	HOT WATR SHOW TEMP	B WT AS MADE O M	MIXD STOK FLOW
08:58	271.	21.23	-0000	2286	39.0	14.3	098	-321	31.5	2685
08:32	272.	20.85	-0000	2285	39.1	14.-	098.	110.	31.5	2668
08:33	272	21.02	-0001	2286	39.1	14.2	098.	110.	31.5	2670
08:34	272.	20.75	0002	2288	39.1	14.2	098.	141.	31.5	2655
08:35	273.	20.27	0007	2286	39.1	14.2	098.	400.	31.9	2646
08:36	273.	19.97	0007	2287	39.1	14.1	098.	110.	31.9	2642
08:37	273.	19.91	0009	2286	39.1	14.3	098.	111.	31.9	2638
08:38	273.	19.86	0007	2286	39.1	14.2	098.	102.	29.2	2667
08:39	272.	19.90	0006	2285	39.2	14.2	098.	109.	29.2	2663
08:40	273.	19 90	0005	2286	39.1	14.3	098.	110.	29.2	2647
08:41	273.	19.82	0008	2286	39.1	14.3	098.	111.	28.7	2649
08:42	273.	19.86	-0006	2287	39.2	14.2	098.	108.	28.7	2680
08:43	273.	20.05	-0008	2287	39.1	14.1	098.	108.	28.7	2654
08:44	273.	19.98	-0008	2286	39.0	14.3	098.	110.	28.5	2632
08:45	272.	20.03	-0004	2287	39.1	14.2	098.	110.	28.5	2661
08:46	272.	19.93	-0005	2287	39.1	14.3	098.	109.	28.5	2652
08:47	273.	19.89	-0008	2286	39.1	14.3	098.	108.	28.5	2656
08:48	273.	20.02	-0008	2285	39.1	14.3	098.	107.	28.8	2765
08:49	274.	20.56	-0005	2286	39.1	14.4	098.	109.	28.8	2678
08:50	274.	20.34	-0007	2286	39.1	14.3	098.	109.	28.8	2659
08:51	273.	20.42	-0011	2287	39.1	14.3	098.	109.	29.5	2668
08:52	271.	20.75	-0000	2286	38.9	14.2	098.	109.	29.5	2662
08:53	272.	20.92	-0000	2286	39.0	14.2	098.	109.	29.5	2682
08:54	271.	20.95	-0000	2286	38.9	14.3	098.	109.	30.1	2671
08:56	271.	21.08	-0000	2287	39.0	14.3	098.	107.	30.1	2679
08:57	271.	21.11	0000	2286	38.9	14.3	098.	109.	31.5	2682

DROP IN COUCH VACUUM

DROP IN BASIS WEIGHT

Fig. 10—The head box historical review records a sudden drop in basis weight caused by a drop in wire pit consistency following the kick-out of the Jonsson knotter

Area	*Incident*
	6. During parts of the breaker stack moisture survey the information system was put on the 3 min compiler sample interval in order to compile experimental data for subsequent recall.
	7. The 3 h recall in the utility subsystem was used to analyse a speed up to 2 705 ft/min. Historical group reviews were used to gather data on all machine conditions over the speed-up period.
	8. During the implementation of the automatic basis weight control, the information system was utilised to monitor machine conditions—for example, the system was used to show the backlash in the basis weight valve.
	9. Since start-up, the integrated values on the eighth page of the periodic log sheet have been used by the statistics department for accounting purposes. These are primarily steam and condensate values.
	10. Lost time has been used for accounting, but reliability problems with the reel amperage contact have not allowed complete acceptance of this value. The problem is one of location for the reel amperage contact. Operating changes such as a new doctor or changed draw from the stacks to the reel can cause changed loads and an erroneous contact, which leads to an incorrect accumulation of lost time.
	11. The machine operators began using the on-machine instrumentation for slice adjustments based on the oven-dry basis weight profile.
	12. It was pointed out during a meeting that the head box and draw group reviews are useful in analysing machine speed-ups so that they can be done in a minimum time with a minimum disturbance.
	13. The information system can also be utilised by machine room supervisory personnel to check on changes made by machine operators—for example, on one occasion, historical information was used to question a machine tender on changes he had made to the head box.

Discussion

The Chairman First of all, I would like to raise a question. You have given a number of examples of data being used to substantiate the existence of some problem. One of these was the relationship between air pad temperature and total head. This relation (Boyle's law) is well known and I believe that one of your papers several years ago included this. I wonder why you did not install analog control of total head in anticipation that temperature and other disturbances would be present. By not doing this, did you not contravene your philosophy of proceeding one level at a time?

Mr J. Mardon The main problems in papermaking today are almost entirely psychological. Consequently, it is not enough to know yourself what has to be done, you have to convince everybody to go along with you. In fact, we are now starting systems of the kind you are describing. One has to remember that the fellows who run these big machines, especially on the west coast of N. America, have something to be proud of. They have large production records. The machines today are running at speeds of 2 800–3 000 ft/min and, when we were doing this work, they were running at 2 400–2 500 ft/min. There is a tremendous inertia and desire for people to stay with what they know about. What might seem obvious to us is not obvious to them and it has taken three—four years to install our first successful system. All that you need to have in these large companies is one successful system and you very rapidly spread it through the rest of the company. I warn you young men whom I see in front of me, however, that it is also true that all you need is one unsuccessful system and you are out on your ear.

Mr T. J. Boyle I came into the paper industry five years ago and it has taken me almost that length of time to realise fully how little the papermaker relies on recorded data of any kind. Your system seems to suggest that you have succeeded in gaining acceptance of rather elaborate presentations of tabulated data. What steps have you taken successfully to add the use of digital data to the much sound information already available to operators?

Mr Mardon These things take time. It is rather like going through the Suez Canal, now shut down. During my first passage on the way back from India, I was conscious that the captain was proceeding at exactly the right speed. Had he gone any faster, he would have sucked the banks of the canal in and all the water would have run out. This is the kind of pace that one has to try to maintain—as fast as you can, but not so fast that everything collapses around you.

In this particular case, two facets of our general philosophy are involved. First of all, the capably senior papermakers in this large company were employed in the study, on the basis of which the system was designed. Mr Chatwin (in my view, one of the best papermakers in the world) put his personal attention to the very point you are speaking about. We have had four fairly skilled papermakers involved therefore in persuading everybody that the digital record was satisfactory and it is mainly due to Mr Chatwin's very hard work and dedication that we were able to make this point. One of our difficulties was failure of peripherals and maintenance. We had to work over the system again. These malfunctions, because of inadequate maintenance organisation nearly wrought failure. Unlike other systems, ours had these troubles.

Dr H. Sandblom I recall a paper published several years ago by some people from I.C.I. Ltd., in which it was reported how easily the operators had switched over to use digital information. Everybody was, in fact, surprised to see how easily they had converted from the analog to the digital system. A further study showed that, even though the operators had had analog recordings to work from, they had apparently converted these to digital information.

Mr H. B. Carter My question may well be asked of Dr Sandblom. Our papermakers, I have found, like those in other mills, are completely oblivious to many written records even in circular chart form. We also have found that our papermakers have asked that we stop plotting moisture and basis weight profiles and give them the figures. Mr Mardon made a statement that he expects his system to enable him to upgrade the papermakers—does he mean that he cannot foresee any possibility of this system being controlled automatically, but that we will always have the machineman there? I interpret this as meaning that papermaking is still an art, in which case we are wasting our time in talking about automatic control.

Mr Mardon I advise asking Mr Staples about the architecture of this system, which he designed. We are all very proud of it. For machines under discussion, the machine tender should be maintained as part of the control loop. One of the dangers of putting the machines on to completely automatic control is that people who are running the process forget how to handle them in any other way. This particular system was carefully designed as explained and can in fact be regarded as a test bed. Our present work involves the installation of an arithmetic unit and checking out different things to see how much we may gain from various expansions and changes. For example, we have heard much about basis weight control by computer, but one of the necessary questions is that, if you have a fully functioning analog system, far better basis weight control can be obtained than by manual control. Is it worth the extra effort to put the basis weight control through the computer and get a very small additional improvement? It is very difficult to find out the answer to this, but, in the kind of equipment that we set up (this flying test bed), these and other things will all be investigated. We are taking things very slowly and in a very conservative manner.