Integrated Paper Machine Control: Past, Present, and Future

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Presented to
TAPPI '88 Engineer ng Conference
Ch cago, I linois
September 19 22, 1988

Technical Paper

TP88-26

Bailey Controls
Babcock & Wilcox, a McDermott company

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INTEGRATED PAPER MACHINE CONTROL - PAST, PRESENT, FUTURE

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ABSTRACT

The paper-making processes has undergone many changes over the years. In the past we had operators who were skilled in the art' and "feel" of papermaking. Today, with sophisticated Distributed Control Systems we see a true integration of paper machine control. The traditional regulatory control, advanced control, motor start/stop, scanning sensors, drives and roll-tracking, are now integrated into a "single window' environment. Tomorrow will bring revolutionary systems such as non-scanning sensors and expert systems using the latest artificial intelligence techniques to allow the total mill to be operated in a strategic process management manner.

INTRODUCTION

Papermaking is no longer just an art, but a sophisticated process involving many different disciplines and control systems.

Past - The Paper Industry has evolved from the old M 40 roundchart recorder/controller of the 50 s & 60's to the IBM 1800's, and mini-computer control systems of the 70 s.

Present - With todays rapidly changing technology, Distributed Control systems with Multi-function controllers have the power of yesterdays main frame computers, or large panel board systems. With a single window' an operator can, with one or two keystrokes, startup and control his Paper Machine with increasing sophistication.

Future - Tomorrow we will see complete non-scanning sensors to measure and control high frequency disturbances. In addition, we will be able to track the total final product quality information back through the complete Pulping & Paper Making process.

PAST

In the first half of the 1900's Papermaking was considered an operating art. There was little instrumentation other than a few scattered indicators, gauges and recorders. Most paper machines were designed to run at speeds of less than 1000 feet per minute and trimmed less than 150 inches with manual regulations of the process and of the machine drive and components. Product testing was entirely off-line

Early Paper Machine Gauges

In the early 1950's some of the early gauging companies included Tracerlab, Industrial Nucleonics, Isotope Products and Curtiss Wright.

The early Basis Weight gauges were mounted on simple C Frames that often measured at a single point across the machine. To overcome the possibility of measuring at either an unrepresentative heavy or light spot across the machine, the measuring area was 14 inches in the cross-direction (CD) by two inches in the machine direction (MD). An averaging of the short term machine direction variations was achieved by using a fairly long, one to three minute response time. The gauge would respond to long term MD trends in Basis Weight but was incapable of responding to short term MD variations. In addition, due to the short C. Frame, it could not be used for cross direction profiling. [1]

Shortly after the Basis Weight gauges were introduced came the moisture gauge, both conductivity and RF types were used. The two sensors were then mounted together on a "O-Frame' to scan across the entire web. Later in the sixties came the on-line Caliper & Formation sensors. A typical Weight & Moisture direct reading system with automatic control cost between $70-$80K.

Often the acceptance of the gauging system by the people who were using the equipment, was predicated on the clarity and accuracy of the information presentation. Early in the on machine sensor history, direct reading scales and wide strip chart recorders were first justified to management as an operating record which could be easily interpreted by operators for control purposes and by management personnel for economic justification studies.

This conventional approach to recording the machine direction averages had the advantages of high readability, ready trend detection, and was unambiguous as a final product record. Little attention was paid to profile records from which the operator was expected to make a trend analysis and presumably take corrective action. Often the profile information was presented in such a way as to be used as a rough indication of the overall profile but of little use for fine adjustment.

The X Y recorder was an ideal solution. Basically, the X Y recorder was a modification of a standard single pen recording system but provided a means of plotting one variable as a function of another, i.e., vertical axis accepted a measured variable, and the horizontal axis represented the simultaneous position of the measuring gauge. As a historical note, the X Y recording system was originated by Noel Obenshain of Westvaco back in 1955 [2]. Typical recorder displays are shown in Figures 1 & 2.

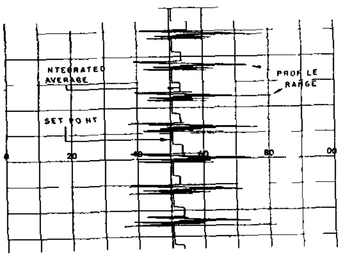

Fig. 1 Strip Chart Recorder Display

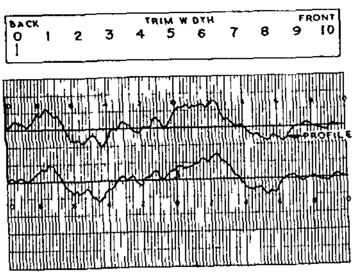

Fig 2 X Y Recorder Display

With the profile information available and with increased emphasis on the abilities to set the slice accurately, the slice lips were changed to include micrometer readouts, and motorized control was added enabling individual adjustments. This was the start of todays automatic CD Control.

In 1957 J Franklin of Bowaters commented that before papermaking can be termed a truly automatic process, each step on the machine must be measurable and controlled, not only longitudinally, but laterally. In this field the Papermaker & Process Control Engineer meet in designing an existing future [3].

Early Regulatory Control

In the period up to 1960 analog pneumatic control was almost exclusively used. Controls were direct connected using circular chart recorders with pressure & temperature capillaries. Then there was a major conversion to transmitting systems. With pneumatic transmitters, measurements were converted to pneumatic signals of a fixed range which were transmitted to a receiver located in a control center. Controllers in the control center then computed (pneumatically) the appropriate control actions which were again transmitted back to the field located regulating devices such as valves, drives and others. With transmission based systems, there was a considerable reduction of installed control system costs.

Paper Machines were being instrumented using groups of instrument control centers rather than scattered instrumentation. Operating instrument control centers were beginning to be designed for Stock Blending, Paper Machine Wet End, Press Section, and Dryer Sections. Many control centers had attractive color graphic layouts of their control process [4].

Early Computer Control

There were two types of early computer control system. First, the large main frame (IBM 1800) types used to automate or control the complete Papermaking process. Second, we had the small mini computer (32K), Packaged Control System supplied by the various gauging companies.

With both of these types of computer control systems came the first use of CRT displays and typewriter printers Operator interfaces became much more extensive with modern keyboards, video displays and customized printed reports These systems represented a combination of supervisory & direct digital control Many control loops had analog back up controllers function as digital-to analog converters in the computer mode and could be switched either automatically or manually

As experience with these systems grew, operator acceptance increased It was found that when a computer was added to the system the increase in uniformity was usually not spectacular. The reason for this is that the two main points with a computer were its speed of operation and its memory With a Dry End beta gauge controlling the stock valve, the computers speed and memory were of little value However, if the computer was used with flow and consistency data gathered at the headbox, the computer had the ability to predict what the basis weight would be at the reel. In this feed forward type of control the computer excelled and substantial improvements in short term control uniformity could be achieved.

As process control computers became more popular in the mid 1970's, there was a technological shift away from the pneumatic control panels and we found the all electronic system. Computers and application packages were becoming available at lower initial cost. We also found that the new solid state electronic transmitters offered better accuracy, repeatability and dependability while reducing maintenance. Microprocessor based systems are now available which encompass all elements of control including those previously handled by separate programmable logic controllers and analog system in a single product line.

The results and acceptance of these early Paper Machine Computer Control systems have been well documented. In most cases these systems, some installed two decades ago, are just now being replaced with the next generation of control; the microprocessor based Distributed Control System.

PRESENT

Distributed Control Systems

With todays microprocessor technology the role of the Distributed Control System has expanded from one of replacing analog instrumentation to having the potential in both size and function to be the backbone of the Millwide Control System . We have seen Distributed Control Systems fully distributing the measurement and control functions that previously were accomplished in larger single computer systems.

A modern Distributed Control System (DCS) must have the architecture to properly partition the control function narrow enough so that a single point of failure does not require a total system shutdown. It must offer technological transparency to allow today s systems to be compatible with tomorrows technology The vendor must strive to keep his product contemporary to sustain new business, but must also continue to provide parts and service for the installed life of the products

Todays systems require an open system' architecture where communications are possible both horizontally and vertically at all levels

Module to Module

Module to Foreign Device

Process Unit to Process Unit

System to System

System to Computer

Recently multifunction controllers (MFC s) have been introduced with more power and flexibility than ever before 32 bit microprocessor, full redundancy multi-tasking, over 280K bytes of memory.

One of the most difficult historical problems, both for control vendors and users, has been control system obsolescence. Both vendors and users are driven by the apparently diametrically opposed needs to have the benefits of the latest technology while avoiding the cost and production interruptions associated with periodic total replacement of instrumentation systems . [5]

Several of today's systems have the ability to provide direct access to configuration data through the use of a Personal Computer or Engineering Work Station

Configuration is referred to in todays DCS as the programming" of the control logic This is primarily done in SAMA language function codes. (See Figures 3 & 4). This allows the Control Engineer the ability to see the process through a glass box rather than the "black box of software extensive system of yesterday. The Engineering Work Station (EWS) provides configuration, tuning and documentation support to the Engineering & Maintenance personnel Configurations may be generated off line without affecting control or interfering with the process operators. The new or revised configurations can be stored on diskettes and/or directly downloaded to the DCS. Using the Computer Assisted Drawing (CAD) software, configuration loop/logic drawings are generated concurrently with the configuration design, providing a powerful and accurate documentation standard [6]

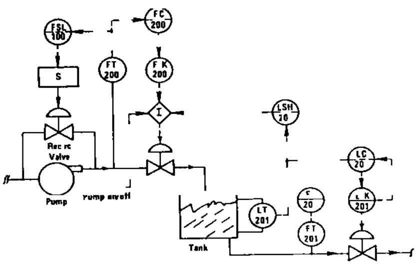

Figure 3· Level Control P&ID

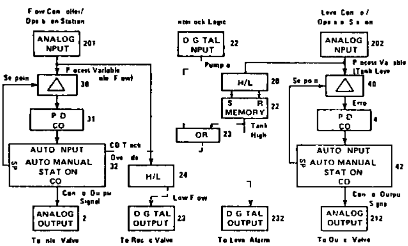

Fig 4 Level Control SAMA (Function Code) Logic

Systems Integration

An objective of todays DCS is to provide one integrated system capable of handling all process control functions formerly handled by several system (PLC s, controllers, computers, etc). A modern system must be capable of easily and cost effectively integrating the following control functions

Basic Regulatory Loops

Motor Start Stop Controls

Interlocking & Sequential Functions

Advanced/Multi Variable Control Strategies

Complex Mathematical Process Models for Optimization

It has been the writers experience that PLC s are used with interfaces to the DCS only where they presently exist before modernization, where there are separate instrument/electrical maintenance jurisdictions, or when there is a very high concentrated number of digital I/O. In normal Paper Machine modernizations, motor start/stop functions are totally integrated into the DCS When using either DCS s or PLC s, scan time should be kept in mind especially where quick control speed is critical

Interfacing DCS s to other foreign devices, i e , Gauging Systems, Drive Systems, Roll Finishing Systems, etc , is usually accomplished by using an RS 232C serial interface These interfaces are usually fairly straight forward using standard protocol. In some cases the user friendliness of two devices becomes political at which time the end user needs to clarify which vendor is responsible for what. See Figure 5

	GENERAL PURPOSE COMPUTER	DEDICATED TURNKEY COMPUTER	DISTRIBUTED CONTROL SYSTEM	PROGRAMMABLE LOGIC CONTROLLER
MIS	■■■■	■■	■■■	■
DATA HIGHWAY/ COMPUTER NETWORKS	■	■■	■■■■	■■■
OPERATOR CONSOLE	■	■■■	■■■■	■■
ADVANCED CONTROL	■■	■■■■	■■■■	■
REGULATORY CONTROL	■■	■■■	■■■■	■
DISCRETE/LOGIC CONTROL	■■	■	■■■	■■■■
SENSOR/ANALYZER INTERFACE	■■	■■■■	■■■	■
ANALOG I/O	■	■■	■■■■	■■■
DISCRETE I/O	■	■■	■■■	■■■■

■ INCAPABLE WORST
■■ MODERATE CAPABILITY
■■■ GOOD/ACCEPTABLE
■■■■ OUTSTANDING BEST

Fig 5 Millwide Control System Selection Guide

Advanced control within a DCS has increased as its technology offered more computing power and flexibility True single window systems are now beginning to appear. This concept or consolidation will allow the operator to view his complete paper machine process in just one type of window or CRT display This also improves the maintenance of the overall operation as the number of computer systems or boxes is reduced into one standard design

Examples of advanced control strategies that have been accomplished in todays Distributed Control Systems in the Paper Machine areas are

. Couch Vacuum/Refiner Control

. Consistency Control (Feed forward)

. White Water Smoothing

Group Start/Stop Sequences

Cold Start

Headbox Controls -

Total Head & Level

Jet/Wire Ratio

Remote Slice Control

Angle of Impingement

- Point of Impingement

- Headbox Flow, Consistency Machine Retention

Slice Rectifier Roll Speed

Steam & Condensate

Dryer Pressure Letdown Thermocompressor

Machine Speed & Draw

MD Basis Weight & Moisture Control

CD Basis Weight, Moisture, Caliper

Coordinated Grade Change

Alarm Management

Profile Display

Figures 6, 7, 8, 9, 10 show examples

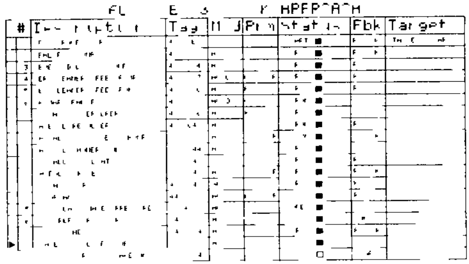

Fig 6 Group Start up Graphic

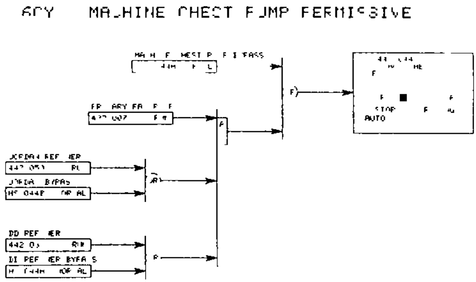

Fig 7 DCS Graphic Help Page

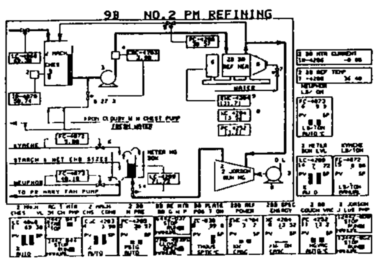

Fig 8 DCS Process Overview Graphic

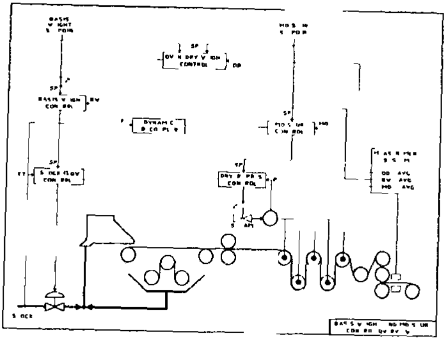

Fig 9 Basis Weight & Moisture

COORDINATED GRADE CHANGE TABLE F20A

	DESCRIPTION		MODE	PV	SP	STAR D		ED T		BYPASS
A	NEUPHOR	0	AUTO C	4 70	5 00	839	3	90	6	B PASS
B	DB REF SPEC ENERGY	02	CASC	24 6	24 .	3	32	3 1	62	BYPASS
C	STOCK FLOW	03	CASC	78	783	606	33	606	63	BYPASS
D	WIRE SPEED	04	AUTO/C	6 9	624	845	34	624	64	BYPASS
	DRAW PROFILE NO					0 00	35	0 00	65	BYPASS
G	VERTICAL SLICE	06	CASC	0 32	0 94					
G	HORIZONTAL SL CE	07	COTR C	0 2	0 2	0 1	37	0	67	BYPASS
F	JET / WIRE RAT O	08	AU O C	00	00	00	38	00	68	B PASS
G	HEADBOX FLOW	09	AUTO C	8975	9000	9300	39	9300	69	B PASS
	REDUCING STM PRESS	0	AU O C	0 0	00 0	95 0	40	95 0	0	BYPASS
J	04 5 DRYER PRESSURE	1	AUTO C	5 0	5 0	25 0	4	25 0		B PASS
J	04 5 DRYER D FF PRES	2	CASC	6 99	7 00	5 50	42	5 50	2	NORMAL
	ST SECT ON PRESSURE	3	CASC	4 2	4 3	70 0	43	70 0	3	NORMAL
K	ST SECT ON DIFF PR	4	CASC	6 90	7 00	7 00	44	7 00	74	NORMAL
L	2ND SECT ON PRESSURE	5	CASC	63 3	64 0	9 0	45	97 0	5	B PASS
M	TOP AFT DRYER PRESS	6	CASC	2 8	. 6	38 9	46	39 9	6	B PASS
N	BOT AFT DRYER PR RAT	7	AUTO C	90 0	90 0	90 0	47	90 0		B PASS
N	BOT AFT DRYER PRESS	8	AUTO C	27 0	27 0					
O	5 2S PRESS MO STURE	9	AU O/C	84	79	75	49	75	79	BYPASS
B	COUCH VACUUM	20	AUTO C	5	5	2 0	50	2 0	80	B PASS
P	BASIS WEIGHT	2	AU O/C	33 4	33 2	33 0	5	33 0	8	B PASS
Q	REEL MO STURE	22	AUTO C	3 62	3 69	4 00	52	4 00	82	BYPASS
S	POINT OF IMP NGEMENT			9 55		0 00		9 56		
S	ANGLE OF IMP NGEMENT			4 43		0 00		4 4		
T	APRON BLADE									

GRADE CHANGE

V	PROGRAM SELECT	GRADE
W	GRADE SELECT	46
X	PRECHECK	NO
Y	GO BUTTON	NO
Z	MANUAL CHANGE	OFF
U	STORE	OFF
	ACT VE GRADE	46
	T ME REMA N NG	72

SPEED CHANGE

V	PROGRAM SELECT	GRADE
	ED SPEED	
X	PRECHECK	NO
Y	GO BUTTON	NO

AGC 000
GRADE SELEC OR
00 00
46 000
1 000
TARGET

Fig 10 Coordinated Grade Change Table Graphic

Operator Interfaces

Todays operator consoles with high resolution CRT touch screen displays are a far cry from yesterdays strip chart, nixie tube readings Modern systems offer tag or point capabilities of over 20,000 They have the ability to provide sophisticated trending and logging features which allow the operator to retrieve operating data from several months past Displays are easily designed and configured with free format display hierarchy All displays have the capability of being customized by the operator With graphic capabilities of several thousand pages the DCS can truly be a window into the process

Alarm Management

With the ability of todays systems to control the complete process from one console containing many thousand control points, the issue of process alarms needs to be addressed How many times have operator consoles been observed with flashing unacknowledged alarms? Systems now have multi level alarm management capabilities and event alarm suppression Why, when during a sheet break, have numerous flow and rate alarms going off when this is a completely normal condition when that event (sheet break) occurs? Why not have these points have new alarm limits set when certain events occur? Most systems have dedicated panels or graphic pages devoted just for alarm annunciation This allows the operator with minimal key strokes to identify the alarm and take corrective action A challenge exists to both the systems designers and mill operations to engineer alarm management into the system correctly so we can eliminate the necessity of operators monitoring (or ignoring) meaningless alarms

Statistical Process Control (SPC)

In the last several years the application of statistical process control (SPC) has became a prime issue in this industry. Increased resource costs and global competition have fostered the spread of the computerized Statistical Quality Control SQC) techniques and Statistical Process Control (SPC) procedures from discrete manufacturing operations to continuous processing operations Advances in technology have allowed these statistical operations to be performed or accomplished on line in the DCS [7]

FUTURE

As Chris Liakos wrote, Someone once said, if he knew he had been living in an era , he would have paid more attention to what was going on around him at the time [8] The next era is here so we must pay attention. We have heard and seen the start of millwide systems. These systems will continue to evolve and allow optimization of all individual mill process units and the coordination of each area to one total mill operating plan In doing so, mill management will have real, on line control of production, rates, material, inventories and schedules

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Areas that will have a major impact on the next era are

- Non scanning Paper Machine Sensors
- Process Optimization
- Expert Systems
- Strategic Process Management

Non Scanning Paper Machine Sensor

As this paper reflects, paper machine gauging systems have been with us for over a quarter of a century. Even though there have been six generations of sensor development, the technique of scanning the sheet has changed very little. We are beginning to see various non scanning individual sensors. When development of the full complement of the basic measurements is accomplished, (weight, moisture, caliper) then high frequency, minute measurements can provide a new dimension in paper machine control.

Process Optimization

Process optimization is one of the main goals of a millwide system. It can be utilized to minimize mill operating costs by actively supervising the various production departments within the mill, including the paper machine. The major economic benefits are in the area of increased production and reduced operating cost.

By maximizing production, a grade target structure can be entered into the system and it will determine optimal inventory targets and coordinate production rates for all operating departments. This results in reducing operational disturbances, improving optimal production planning, quality control, energy production coordination and energy management.

Expert Systems

The uses of Expert Systems and Artificial Intelligence is increasing at a high rate. Expert Systems are rapidly moving out of the off line environment and into on line process control applications, usually integrated with today a distributed control system.

The field of Expert Systems can be defined as the branch of Artificial Intelligence that attempts to model and retrieve human knowledge about objective concepts, facts and their relationships.

An example of an Expert System for the paper machine area is to optimize the furnish blend and operating parameters for the development of new paper grades by efficiently reviewing and selecting bits of previous production strategy which lend themselves to meeting customer specifications.

The era of large stand alone computers running Expert Systems is over. Expert Systems will be embedded in process control systems in multiple distributed modules. These distributed Expert Systems will be available and cost effective for a large number of applications at a minimum cost to the user [10]

Strategic Process Management

With our todays increased global competition in our industry, the need to focus on improving profitability and quality will require us to look at a higher level of control. Strategic Process Management. This represents the top of the control hierarchy and may be the objective of mill management. With the utilization of the full power of modern distributed control systems this is capable of achievement

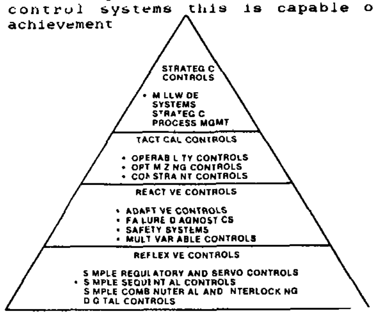

Figure 11 The Control Hierarchy

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The key objective to a plant wide strategic process management system should be to automate process operations as much as practical, and present information critical for control cost analysis of current and future operations. Further it should also provide a communication system for implementing operational plans

It is evident that significant cost savings can be achieved through coordination of the complex production, quality, energy and maintenance functions of an integrated mill This forms the essence of Strategic Process Management. The synergistic benefit of properly integrated and coordinated controls yields a whole (total mill wide control), which is greater than some of its component parts (unit optimizations). [11]

CONCLUSION

Paper Machine Control has changed considerably over the last three decades. We have seen it change from total manual control to a cumbersome main frame computer control to todays user friendly system using the latest microprocessor technology. Tomorrow we will see total plant wide optimization, and we will continue to evolve through the many changes and operations characteristic of a natural progression

REFERENCES

1 Hazlewood, E., Beta Gauge on Machine Application in Papermaking, Vance Publishing, NY, (1974), P. 2.

2. Smith, Bruce, Scanning Basis Weight & Moisture Gage Systems on Paper Machines, TAPPI Vol 43, No 3, (March 1960), P. 226 234

3 Franklin, J N , TAPPI Vol 40, No 7, (1957), P 171A 175A.

4. Keyes, M.A. and Johnson, R K , and Scheib, T J., Computerized Control Evolves in Pulp & Paper Industry, Southern Pulp & Paper (February 1981).

5. Keyes, M.A. TAPPI Vol 67, No 2 (February 1984), P. 56 57

6 Foster, W.P & Lowen, Brad A Fully Integrated Control System Installed on a Fine Paper Machine, presented paper NY Canadian PIMA Conference, (September 1987) Ottawa, Ontario

7. Bailey Network 90 Application Guide AG 0000 911-10, Distributed Control System Tools for On Line Statistical Process Control (SPC) Bailey Controls Company, Wickliffe, Ohio (1988)

8 Liakos, C , TAPPI, Vol. 77, No. 7 (July 1983), P. 8.

9 Keyes, M A., Strategic Process Management ..A Key to Paper Industry Global Competitiveness and Profitability in the 1990's, Bailey Controls Company, Wickliffe, Ohio Technical Paper TP88 7.

10.Lukas, M P and Keyes, M.A., The Evolution of Expert Systems For For Process Control, Technical Paper, Control Systems '88, Montreal, Quebec

11.Yorke, G and Enterline, L Strategic Management of a Pulp and Paper Complex, Technical Paper ISA '86, Houston, Texas

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