CAPITAL EXPENDITURES:
Big plans in Quebec
COMING IN JULY

MAINTENANCE: New techniques to overcome the problems of extreme environment maintenance

MAINTENANCE/REPAIR: Re-roofing Pacifica Papers

Journal of Pulp and Paper Science

44 Evaluating paper machine operation, Part II: Control and instrumentation, management issues — outsourcing and self-directed teams

Guidelines for successful co-operation with outstanding auditors:
D. Dumdie, Daishowa America; H. Cook, J. Mardon, A.G. Robertson, Omni Continental; A. Tkacz, Fletcher Challenge Canada; B. Davey, Norpac Controls; W.L. Adams, Adtech Consultants (T174)

58 Sulphur distribution during air gasification of kraft black liquor solids in a fluidized bed of TiO₂ particles

Total sulphur content of BRS increases as temperature rises:
L. Zeng, BC Research; A.R.P. van Heiningen, University of Maine (T188)

64 Improving data quality within an environmental management system

The author recommends a well-maintained program:
P.N. Riebel, P. Riebel & Associates (T194)

68 On-line supercalendering

New technology offers better printability at German mill:
C. Palm, Papierfabrik Gebr. Lang Papier; U. Gabbusch, Voith Sulzer Finishing (T198)

72 Stress-corrosion cracking of type 304L stainless steel in kraft recovery boiler environments

A mixture of sodium sulphide and sodium hydroxide induces cracking:
B. Prescott, P. Eng, D. Singbeil, Paprican (T202)
Evaluating paper machine operation, Part 2: Control and instrumentation, management issues — outsourcing and self-directed teams

Guidelines for successful co-operation with outside auditors

By D. Dumdie, G.A. Cook, A. Tkacz, B. Davey, W.L. Adams, J. Mardon and A.G. Robertson

An external audit team called in to evaluate a paper machine operation as a component of the larger paper mill system requires broad knowledge — papermaking and end-use principles and equipment, operations, control and instrumentation principles and equipment, and maintenance and management.

Part 1 of this work [1] described a method for evaluating the equipment and operational aspects of a paper machine operation. The material dealt with rules for paper machine operation, Lost Efficiency Analysis, and key information required for an evaluation. In the current paper, we extend the previous discussion, giving a level of detail appropriate for those who approve such evaluations, as well as those charged with assisting an audit team on-site.

We first review how an external audit team would approach the mill’s control and instrumentation. Section 2.1 considers evaluation issues for control strategies and control systems, Section 2.2 deals briefly with instrumentation issues, Section 2.3 discusses control and instrument maintenance, and Section 2.4 reviews the instrument department.

As some machine problems that appear to have technical causes may be related, in the end, to management issues, Section 3 addresses outsourcing and self-directed teams. For evaluating outsourcing’s role in machine efficiency and product quality, Section 3.1 discusses, and the appendix lists, contract terms for service suppliers (e.g. for on-machine gauging, papermaking chemicals and machine clothing). For evaluations in mills where self-directed teams are in place, Section 3.2 reviews the characteristics of such teams, and the potential disadvantages of such a management structure.

We restate here comments made in Part 1 concerning on-site evaluation time and the availability of critical information. The audit team’s job is to deliver a complete and authoritative report despite very limited on-site time. This requires that the mill make certain information available far enough in advance that the team can make preliminary evaluations. A well-run mill will be able to acquire and transmit the requested prior information, as it will be in routine use, and much of it will typically be available from computer databases.

Any requested information that is not made available beforehand will have to be acquired on-site by the audit team, and this will reduce the time available for other aspects of the job. The mill will also need to provide the inspecting team with a qualified and motivated person who is assigned to working full time to facilitate the inspection.

EVALUATING CONTROL

The function of control is to help manufacture a uniform product despite variations in raw materials and processes, equipment degradation and production or grade changes. Unplanned variations can be either random or systematic. Variations can also result from planned actions such as grade changes.

Audits of several thousand control loops at a 100 paper mills in North America reveal that up to 80% of installed loops do not reduce variability in the short term, while only 20% perform as intended and actually reduce such variability [2]. Of this 80% of under-performing loops, perhaps one-third underperform because of poor tuning, another third because of valve design and maintenance deficiencies and the remaining third because of control strategy or process design. While only a small proportion of control loops may be on critical process variables, these can be directly or indirectly affected by less critical variables.

A team engaged to evaluate control and instrumentation in a paper mill must determine where

G.A. COOK,
Omni Continental (1986) Ltd., West Vancouver, BC

A. TKACZ,
Fletcher Challenge Canada Ltd., Vancouver, BC

W.L. ADAMS,
Adtech Consultants, Inc., Powell, OH USA

J. MARDON,
Omni Continental (1986) Ltd., West Vancouver, BC [Now deceased]

D. DUMDIE,
Daishowa America Co. Ltd., Port Angeles, WA USA

B. DAVEY,
Norpac Controls, North Vancouver, BC

A.G. ROBERTSON,
Omni Continental (1986) Ltd., West Vancouver, BC
the control system improves and where it degrades machine efficiency, productivity and final product quality. The principles involved are relatively straightforward. In practice, however, checking how effectively they have been implemented and sustained, by conducting a control and instrumentation survey, involves many issues: Determining the validity of control objectives and methods; evaluating performance and tuning in critical control loops; checking field instruments for appropriateness and proper installation; reviewing maintenance procedures and practices; clarifying training for operations, engineering and maintenance personnel. Every component of a control loop can be important in achieving good variability control. In its work, the audit team must include everything from the furnish tanks and stock preparation at the wet end, through paper machine controls, to MD/CD and reel density profiles at the dry end.

The intent of a mill being ISO 9000 certified means that its products will meet the quality specifications that the mill claims for these products. However, the process work required for ISO certification aims to ensure that key process variables related to the quality specifications are both measured accurately and are documented. The certification does not, however, ensure that a mill is managing control issues in ways that ensure that its machine operation is efficient.

2.1. Evaluating control strategies and systems: The areas that the audit team will need to address in evaluating control strategies and systems are separated below into general control issues or strategies and systems issues that are more specific to particular process points.

2.1.1. Evaluating control strategies - control strategies: The audit team should first determine whether control objectives are consistent with production and operating requirements and should then evaluate control methods. For particular parts of the process, the team will first determine whether it is important to have good response to set-point change or to load change. This fundamental choice is often neglected during control design. When set-point change is more important, the type of closed-loop response desired must be chosen (i.e. response order, minimum Integrated Absolute Error (IAE), location of response poles, etc.). The control strategy (i.e. measured and manipulated variables, and the control law, which may be feedback, fixed or variable feedforward, model-based, etc.) can then be evaluated.

Often, process control strategies are designed using qualitative approaches like engineering experience or intuition based on training and experience. For example, consistency, pH, temperature and other blend-type controls can use simple feedback, cascade, feedforward, or even ratio control algorithms. The algorithm selected may not deliver the best solution for the desired objectives, and the approach leaves unanswered several questions that are frequently asked in process control. Which control method is best? Which is most cost effective? How should each method be evaluated for performance? Which should be used in a given application?

A more systematic approach to control strategy and tuning uses material and energy balance equations. This quantitative method has been successfully used to make significant improvements in reducing variability in difficult control problems [3] [4]. Advanced methods like fuzzy logic, multivariable predictive control and adaptive gain strategies can also offer significant improvements in controlling complex loops.

Not only are control objectives and the best strategies for achieving them rarely spelled out at the design stage, but they often evolve over time without the changes being adequately documented. As a result, there are often misunderstandings among different people working with a loop. For example, is a loop designed and operating for minimum variance, set-point tracking, within-range (e.g. some level control loops), low interaction with other variables, cascade control or good start-up characteristics?

The mill should have a control engineer who understands process dynamics, and troubleshoots and redesigns critical loops to suit process requirements.

The audit team should be familiar with the latest control strategy technology and should evaluate mill applications, making recommendations for improvement where appropriate. Documentation for control strategies for each loop should be checked. All loops that have some complexity or are critical for performance should have strategies and tuning methods clearly defined.

- Evaluating control strategies - loop tuning: The audit team should check that specific loops are being tuned relative to clearly defined and appropriate control objectives (e.g. min/max, rise time, overshoot, actuator energy, offset from set-point, disturbance rejection...). Tuning techniques encountered may include: Intuition; Zeigler-Nichols, which is essentially oscillatory; minimum IAE; Lambda tuning, which is preferable for set-point change [5]. The main audit concerns are to ensure that there is sufficient understanding of how to select appropriate methods, and that methods are used consistently.

When control tuning is changed, both parameter changes and the reasons for the changes should be logged so that a story can be built and captured for future reference. As tuning changes are often made to compensate for other deficiencies, the tuning log should be monitored carefully in order to uncover more fundamental issues that would otherwise remain unresolved.

When loop operating modes are not at their highest level, reasons for this should either be known or under investigation. The audit team should determine whether operators consider that key loops perform well, and if not, why not. If the mill has a regular program for assessing the dynamic performance of control loops, the team should evaluate this program and may use it when auditing critical loops during the survey.

Finally, if the mill uses statistical control charts to establish controllability and accuracy limits, or if an analysis of process variability (e.g. an EnTech survey) has been done and is available, these will also be most useful during the paper machine audit.

Evaluating control strategies - information and control systems: A mill’s information and control systems will include three functional layers - management information system (MIS), process data system (PDS) and distributed control system (DCS). The primary role of the DCS is to handle the dynamic process control portion of total plant control. It accepts process-variable inputs from field transmitters, and as well as from advanced control and production control packages residing in the PDS and MIS, and provides a window into the PDS for operators.

The PDS is the database for trends and historical data, statistical evaluation, reports and advanced control strategies, and typically provides a window into all of this information for managers, supervisors, engineers and lab personnel. The MIS integrates business management information (scheduling, accounting, etc.) with the plant management and process information available from the PDS and DCS. Advanced analysis, modeling and simulation, predictive control and optimization routines can be resident in one layer or in a combination of layers. All of the above functions are enabled by standards such as Foundation Fieldbus, OPC (OLE for Process Control), and fast, cost-effective, standard computing platforms.

When different groups manage and maintain the MIS, PDS and DCS, they can have different priorities for what the systems are intended to do. It is important to ensure that the groups communicate well, so that the systems complement each other effectively.

There are two key evaluation areas for the process information and control systems, Table I. First, the system must be easy for operators to use, with needed information organized and readily found. Second, a procedure must be in place to ensure that the system will be maintained and updated so that it accurately represents what is in the mill.

In Part 1 [1] on-machine diagnostics were not specifically discussed in detail. Effective diagnostics require not only an on-machine diagnostic system with built-in analysis capabilities but also that operators are trained to use the system for diagnosis. With a modern system, operators should need little input from specialists to do diagnostic analysis; analysis capabilities should be readily accessible.
TABLE I. Issues in evaluating the process information and control systems.

<table>
<thead>
<tr>
<th>System presentation</th>
<th>Access to data</th>
<th>Data presentation</th>
<th>Alarms/Warnings</th>
<th>Detailed information</th>
<th>Pulp mill</th>
<th>Crew information</th>
<th>Diagnostics</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Have the systems and processes been represented by clear and logical flow diagrams that operators can easily follow?</td>
<td>• Is information clear and well organized?</td>
<td>• With the old round charts, one could walk along the control panel and get an at-a-glance picture of upset time and causes. Today, while more information is often available, it can be difficult to interpret in order to identify, understand and respond to a machine problem. Lack of awareness of a problem at a particular process point means that the right questions will not be asked. Data must not just be presented as simple tables which operators do not have time to analyze. How does the system handle this?</td>
<td>• How are important events and deviations brought to the attention of the operators?</td>
<td>• To what extent are data from individual loops filtered so that they show only part of the true variation? Are anti-aliasing filters fitted, and are they understood?</td>
<td>• To what degree is pulp mill information, e.g. kappa number, or chemical consumption in the bleach plant, shown in the paper mill?</td>
<td>• As crews rotate, the current crew must put together recent and current historical information, including conditions requiring extra attention by the next crew. How does the system make this easier (e.g. during a shift, can an operator accumulate a ‘handover’ report as he goes along, or can he call one up automatically)?</td>
<td>• Does the system include an on-line diagnostics package for identifying and exploring system causes and effects, and for fast troubleshooting? Are operators trained to use the PDS/DCS for diagnostics as well as for process control information? What staff, with what training, is involved in system diagnostics?</td>
</tr>
</tbody>
</table>
TABLE I. Issues in evaluating the process information and control systems.

<table>
<thead>
<tr>
<th>Type</th>
<th>Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Historical data</td>
<td>• How easy is it to review historical test data over longer time scales, e.g. six months? Can simple histograms showing the data spread be called up on demand? Is there provision for the Technical Superintendent to review and report on changes or the stability of each test data item over, say three-month or six-month periods?</td>
</tr>
<tr>
<td></td>
<td>• How far back in time can trends be traced without data degradation? How does the system handle the need to correct historical data for downtime and the associated upset system time, i.e. for running in upset conditions? What are the criteria for selecting 'valid' long term data to be stored?</td>
</tr>
<tr>
<td>On-machine gauging</td>
<td>• Other than basis weight, moisture and caliper sensors, what on-machine sensors are there, and what use is made of them?</td>
</tr>
<tr>
<td></td>
<td>• Do the operators and Instrument department personnel understand the importance of data box size?</td>
</tr>
<tr>
<td></td>
<td>• Do mill personnel understanding the difference between the true variation and that displayed on the operator console?</td>
</tr>
<tr>
<td>Off-line data</td>
<td>• Does the system have the possibility of feeding in Scanpro and water removal information and trending it for the life of a felt?</td>
</tr>
<tr>
<td></td>
<td>• To what degree does the system accommodate routine testing? If such data are still entered manually, how are they entered and displayed? If the mill has an off-line tester (e.g. LW Autobase or Valmet PaperLab), the same question applies.</td>
</tr>
<tr>
<td></td>
<td>• How are non-routine tests put into the system?</td>
</tr>
<tr>
<td></td>
<td>• What provision is there in the system for identifying whether data from non-routine tests have been checked by follow-up discussions?</td>
</tr>
<tr>
<td></td>
<td>• How are system CD profiles (e.g. moisture, basis weight, fibre alignment, strength tests, etc.) from off-line testing (e.g. TAPIO) entered into the system? Is the comparison of on-line and off-line profiles known accurately? Is the effect of box size on on-line profiles understood, and is the actual box size used known?</td>
</tr>
<tr>
<td>On-machine defect measurement</td>
<td>• What sensors have been installed for on-line defect detection? What are the accuracies of these sensors, and how frequently are they calibrated?</td>
</tr>
<tr>
<td></td>
<td>• How is the information from these sensors made available to and used by operations personnel?</td>
</tr>
<tr>
<td>Lost time</td>
<td>• How does the system handle lost time data? Is it compiled on daily, weekly and monthly bases in a form suitable for further analysis?</td>
</tr>
<tr>
<td>Maintenance</td>
<td>• Can maintenance information flow in both directions; i.e. machine-to-maintenance and vice versa?</td>
</tr>
<tr>
<td></td>
<td>• Can the six-month running ratio of breakdown lost time to planned maintenance lost time be graphed?</td>
</tr>
<tr>
<td></td>
<td>• Can trades man-hours for maintaining specific equipment items over longer periods (e.g. annual) be obtained? This will help to identify items that make excessive demands of the maintenance crew during breakdowns and planned shutdowns, to the detriment of the maintenance backlog list. For example, a line shaft drive on a speeded-up machine may make such a demand on tradesmen resources that other key jobs do not get done, or planned shutdown down times may have to be regularly and significantly extended.</td>
</tr>
<tr>
<td></td>
<td>• If breakdown events are properly coded, can breakdown events over a six-month period be brought forth to show, for example, all pumps and piping failures, by machine or mill area? Repeated failures of the same units are easily recognized and action is usually taken. However, it is not uncommon to find, for example, more pump and piping failures related to one machine and its approach system, but no repeat failures for individual units.</td>
</tr>
<tr>
<td>Cost accounting</td>
<td>• What cost accounting data are available? Examples include cost of steam per kg paper; felt cost versus steam cost per tonne, through the life of each felt; cost of added fresh water; and cost of heat and fibre loss from whitewater discharge.</td>
</tr>
<tr>
<td>Accuracy</td>
<td>• What procedures ensure that the system will be maintained so that it accurately represents the equipment that is in the mill, and so that data acquired are accurate?</td>
</tr>
</tbody>
</table>

— Evaluating control strategies — robustness: The audit team should observe and test critical loops like the furnish blend system for robustness; i.e. for proper operation under a range of operating conditions. If the system is well engineered and maintained, loops will perform adequately over the entire range of paper machine operating conditions (speeds, blend ratios, etc.). But this may not be the case. For example, with simple feedback control alone, loops for consistency and for heat exchanger temperature can become unstable as they are turned down. A 50% reduction of a furnish component in a blend can destabilize a consistency loop and this can then upset the entire machine as the dry-stock blending algorithm then changes flow rates of the other furnishes to compensate.

— Evaluating control strategies — noise: As noise from primary sensing elements can be a problem in some loops critical to paper machine operation, the audit will include a noise analysis for such loops. For example, if a stock flow measurement is used in closed loop control, noise should be minimized by the primary element being either an AC magnetic flow tube or a pulsed DC element with ceramic electrodes. Some consistency transmitters can inject noise corresponding to >0.15% consistency into the control loop, from where it can propagate out into the process. For example, in controlling thick-stock flow to the silo, the combination of flow and consistency noise can easily cause basis weight
Improved by using a variable-speed drive as the final control element. Such a drive exhibits no stiction, backlash or hysteresis and, if properly sized and tuned, offers excellent dynamic response, high resolution and wide turndown.

Smart field devices are now available with built-in diagnostics that alert maintenance personnel to degradation in device performance. Smart valves provide position deviation alerts and actual valve positions so that operators have better information when analyzing process problems. Complementing this, software products now permit detailed, integrated tracking of the ongoing performance of process equipment and the effectiveness of the maintenance program.

### 2.1.2. Evaluating control systems

The audit team will consider control issues for at a wide range of loop types and locations in the process, Tables II and III.

#### Evaluating control systems  process design:
Designing a process for good control is as important as the control design itself; both are required for optimum results. The audit team will survey the entire process looking for potential design problems that could interfere with good control. [7] For example:

- Dilution water supply design is important to some processes (e.g., stuff box consistency). Constant header pressure is needed and is best achieved by using a dedicated pump. If water is to be supplied to more than one destination, a larger pump that runs on the flat part of its total head curve is appropriate. All too often, while the initial design is adequate, with time, supply headers are tapped into to meet other demands, and this gradually runs the pump down its curve. This results in an undersized pump for the required load and control interactions then becomes a problem.

- The design of furnish storage tanks and chests is important to both stock mixing/blending and to stock consistency control. Tank and chest size/shape must be matched to adequately sized agitators and motors. Properly designed internal fillets also help with mixing and can eliminate dead zones. Properly sized storage gives appropriate residence times which can improve process dynamics and control. The audit team can easily test for adequate storage design by observing the exiting variability.

- Proper line sizing is essential for many processes. Small lines can ensure turbulent flow for good mixing. Larger lines are needed for the laminar flow required by some primary elements. Line sizing and length are also important to many control loops as the line process deadtime. While, in principle, the shorter the deadtime, the better the control (e.g., pH, chemical dosage, consistency, etc.), in practice there may be limited opportunities for reducing dead-time (e.g., sensor location). When a loop's dead-time is significant relative to the time constant, a dead-time compensator like the Smith predictor should be used. Recycle lines can sometimes be used to maintain a constant main-line flow and control loop deadtime. This can stabilize process dynamics and so reduce the need for tuning manufacture. It can also help to keep flow-sensitive sensors in calibration (e.g., for consistency).

#### Evaluating control systems wet-end blend systems:
The wet-end blend system includes the unit operations responsible for combining and mixing pulp furnish components and additives in the machine's stock preparation area. The audit team will determine whether correct principles are being followed for consistency control, stock proportioning [8, 9] and stock sampling [10].

Furnish blend control combines consistency control at the storage tank and pulp stream flow (ratio) control [Dundie 1988]. Typically in the paper mill, several different pulp grades are blended to produce a desired paper grade. Good paper quality requires that this blend remain uniform; to this end, the consistency of each pulp must also remain constant. Moreover, different paper grades may require significantly different blend ratios for each pulp component. Given this, different consistency control loops will typically operate at significantly different volumetric flows (loads) when different paper grades are made. It is not uncommon for an individual pulp stream in the paper mill to experience large load changes with turn-downs of 4:1 or more. Since the consistency control process is not linear with load, tuning loops in a paper mill that has conventional regulatory controls can be a full-time effort where many machines make many different grades.

In addition, the controls that blend multiple pulp streams together, after each individual stream has been controlled for consistency, must deliver the final mixture in constant proportion on a dry fibre basis and not on a volumetric ratio basis. Consequently, changes in individual pulp consistencies will upset the dry fibre blend. This will require a change in volumetric flow which, in turn, will upset the consistency loop. Because consistency and flow interact, the overall stock blending control problem is non-linear and multi-variable.

The audit team will review with mill control personnel how this complex control problem is addressed. To ensure good quality, it is important that the mill does not simplify the control system by assuming that consistency is always constant. Control technology that is easily understood and implemented is available to handle stock blending.

The audit team will also check that additives like clay, starch, polymers and dyes are appropriately blended using dosage control (i.e., additive amount per dry ton of furnish) at appropriate wet-end locations.

### Evaluating control systems savell:
When not controlled properly, the savell can be the most disruptive unit operation in the wet end. In a typical paper mill, the savell operation blends fines from the...
**TABLE II. Issues in evaluating control and instrumentation by loop type.**

**Flow**
- Magnetic flowmeters to be used for pulp stock and some additive applications, differential pressure (DP) head devices to be used for steam and condensate flow, and Coriolis meters to be used for dye flow.
- All flow loops to use proportional plus integral (PI) control action, with tuning to provide a fast first-order response with little or no overshoot.
- All primary elements installed as per manufacturer’s recommendations (straight pipe runs upstream and downstream, fluid velocity and turndown within proper range, etc.)

**Consistency**
- Rotating shear type primary elements to be used for critical applications, such as stuff box and blend consistency.
- Blade or other less costly primary elements to be used for less critical applications, such as consistency to saveall.
- All consistency loops to use PI control action, with tuning to provide fast non-oscillatory response with minimal overshoot.
- All primary elements to be installed following manufacturer’s recommendations (straight pipe runs upstream and downstream, proper pulp velocity ranges), etc.
- Adequate in-line mixing of pulp and dilution water.
- Adequate stock chest design and agitation.
- Adequate stilling section upstream of rotating primary elements to ensure near laminar flow.
- Properly sized final control elements.
- Control loop piping design to ensure that worse-case deadtime does not exceed 10 sec (5 sec or less is preferred).
- Dilution water to be supplied at pump suction to prevent control loop interaction, and dilution injection velocity to be less than 1.2 m/sec (4 ft/sec) to enhance pump mixing.
- Control variability to be within ±1% of setpoint.
- For mixing zones in HD consistency storage tanks, agitation, power and fillet design to be adequate, and residence time to be a minimum of 20-30 min.

**Pressure/Differential pressure**
- Primary elements for stock pressures (cleaners, screens, etc.) to be flush-mounted diaphragm type to avoid plugging.
- Transmitters for non-stock process fluids (steam, water, etc.) to be simple DP type.
- All pressure loops to use PI control action and to have properly sized and maintained valves.

**Level**
- Sensors for furnish chests to be flush mount diaphragm type with water purge.
- All level loops to use PI control action and to have properly sized valves.
- Tuning is to accommodate stable control and to allow surge where appropriate.

**Temperature**
- Primary elements to be RTD for most applications.
- Thin-walled thermowells or no thermowells, and thin-walled primary elements for critical applications requiring tight control, i.e. less than ±0.25°C (0.5°F), e.g. breast roll and apron lip shower temperatures.
- All temperature loops to use PID control action with properly sized valves to provide fast non-oscillatory response with minimal overshoot.

**pH**
- Primary elements to have temperature compensation.
- PI control with properly sized valves and pH curve characterization if needed.

**Vacuum**
- Any standard primary element, using PI control with a properly sized final control element.

**General**
- All control valves to be properly sized for applications, and to meet EnTech specifications [6].
- No corresponding performance specifications are available for final control elements that are not valves.
- The DCS sampling rate to be checked. The 1-Hz sampling rate that is standard on most DCS’s should be suitable for all but the fastest loops.

wire pit with a portion of the virgin furnish, which is itself a blend. This mixture is then combined with the remainder of virgin furnish in a blend chest before being pumped to the machine chest. Because fines have a significant effect on pulp freeness, poor saveall operation can cause a highly variable freeness and drainage rate on the paper machine. This directly translates into variability problems in MD retention, weight, moisture and caliper. Moreover, stable MD profiles are required for the machine control system to deliver good, stable CD profiles.

Given this, the saveall, and the chests upstream and downstream of it, must operate without variability to ensure that a homogeneous pulp mixture is delivered to the paper machine. All flow, consistency and level control loops must quickly reach steady state after start-up and then must flat-line during normal set-point and load-change operations. Because so many interacting control loops must all operate in a stable fashion, loop tuning is critical. The saveall system must not be tuned by individual loops (flow, consistency, etc.) but as a single entity using dynamic decoupling for interacting loops.

The audit team will check for acceptable saveall operation by observing all trends associated with the saveall during start-up and steady-state operation. Lab testing of machine chest stock is also a rea-
TABLE III. Issues in evaluating surveying control and instrumentation by process location.

**Stock blending**
- Must be capable of blending all virgin furnishes on a dry fibre basis with stable proportioning and blend/machine chest level control under all paper machine operating conditions.
- Tests to be conducted during survey include flow/consistency interaction during setpoint changes in blend and consistency, and response of all furnish flows and blend ratios during load changes (setpoint changes in blend or machine chest level).
- Test also to demonstrate blend and machine chest tuning that permits surge without oscillation (moderate gain with small integral).
- Above changes not to upset saveall stability in any way.

**Additives blend**
- Additives to be dosed in proportion to fibre mass flow and able to handle setpoint and load changes quickly and without oscillation or significant overshoot.

**Blend and machine chest consistency**
- Survey to evaluate consistency response curves for load and setpoint changes at the blend and machine chests.
- Steady state control to be within ± 1.0% of setpoint (2-sigma).

**WW header pressure control**
- Test to ensure low pressure variability in all critical wet end consistency control loop dilution headers.
- Dedicated or oversized pumps running on the flat part of the total head pump curve may be necessary to avoid control loop interaction and dilution pressure variability.

**Saveall**
- Saveall system to reach steady state (levels, consistencies, and flows) in reasonable time following machine start-up, and to remain stable during normal operation (machine speed changes; set-point changes in wet end blend, level, consistency, and flow loops). This tests tuning of the overall saveall system, as opposed to individual loops.

**Cleaners**
- Audit to test both cleaner pressure and consistency stability.
- Proper tuning of both primary cleaner acceptor pressure and cleaner stand pipe levels is critical to cleaner operation, which affects machine total head and MD basis weight variability, and consequently CD basis weight variability.

**Total head (rush/drag)**
- Survey to evaluate response curve of on-line step change in rush/drag.
- Final control element (fan pump speed, valve, or other) to be evaluated for resolution, repeatability, stick/tension, deadzone, etc.

**Headbox temperature controls**
- Slice lip and apron lip shower temperature setpoints to be same as headbox temperature.
- Short term variability to be less than ±0.15°C (0.3°F) of the temperature setpoint to avoid apron distortion and CD/MD weight variability.
- Observe temperature trends at high resolution, checking for stability.
- Shower pressures are also important, as they affect on heat exchange and temperature control.

**MD basis weight**
- Thick stock flow to the silo at steady-state to deviate no more than 0.25% from setpoint.
- Either an AC flow tube or a pulsed DC unit with ceramic electrodes to be used to minimize flow measurement noise.
- Basis weight valve to be in good working order, with a resolution greater than 300-400 repeatable steps with minimal sticktion, backlash, and hysteresis, i.e. it should be capable of controlling BW to better than 0.25%.
- If flow loop used, tuning must be such as to eliminate all overshoot and flow oscillations with setpoint and load changes.

**MD moisture**
- Audit to evaluate steam and condensate system’s effectiveness for evacuating dryer cans and quickly reaching steady state operation.
- Stable header pressures for all steam sections.
- System response and recovery to be evaluated during and after machine breaks.
- Stable pressures, separator levels and blowthrough flows to be audited.
- MD moisture variability measurements by the paper machine control system to be reasonable for the grades produced.

**Controlled-crown roll pressure control**
- Audit to evaluate breaker stack and/or calendar stack swim roll oil pressure trends.
- Oil pressure variability for two-color printing is less critical than four-color printing and to be less than 0.1 psi (0.7 kPa) for four-color printing.
- Trend pressure at high resolution with no filtering.

A reasonable approach for evaluating uniform saveall and blend system operation.

---

Evaluating control systems—apron/breast roll shower temperatures: The apron lip and breast roll shower temperatures must be controlled to either stock temperature or to stock temperature plus 1 to 1.5°C (2 to 2.5°F). Poor control here will distort the lip which will affect basis weight, moisture and caliper in both the machine and cross directions; if variation is extreme, it can cause wet-end breaks. Good control is especially important for web performance in demanding press rooms. With a properly designed heat exchanger and control
**TABLE IV. Issues in evaluating instrumentation.**

**Equipment and suppliers**
- Are the types and models of equipment in use recognized as being of good design, accurate and reliable?
- Are there reasonable constraints on the number of models and suppliers in the mill? Too much variety increases support burden for personnel and spares. Some degree of standardization focuses efforts.
- How often is instrumentation checked for accuracy and stability?

**Long-term improvements**
- Is there a considered upgrade program? Often changes are made on an ad hoc basis, which complicates subsequent support.
- Are steps taken to identify instruments and applications that demand more than normal attention?
- Are causes of failure routinely identified and recorded?
- Are failures analyzed to see if better materials, alternative models or suppliers, change of location, etc. would reduce failure rates?
- Are preventative/predictive maintenance plans matched to applications to produce optimum long-term performance?
- How are newly available or alternative instruments evaluated? Often this is done too casually — instruments are put into a difficult situation and left to see if they survive. They are not adequately monitored, and conclusions drawn are not firmly grounded. As a consequence, opportunities are missed and errors made. This is neither useful for progress nor fair to suppliers.

**TABLE V. Issues in evaluating control system / instrument maintenance.**

**Planned vs. breakdown**
- What percentage of technicians' workloads are planned, preventative/predictive maintenance?
- What are figures for —
  - lost production time due to instrument/control problems?
  - average time to respond to emergencies?
  - percentage completion of preplanned work in shuts?

**Specified**
- Are there specific instructions that set out routines and tests to be done in servicing certain classes of instruments (e.g. consistency meters, control valves, scanning sensors, etc.)?
- Standard instructions should clearly indicate calibration requirements and features to be inspected. They should not be so bureaucratic as to stifle innovation, but should serve mainly as check lists and indicators of expected results.

**Manuals**
- Are maintenance manuals complete, well organized and readily accessible? It is good to have a direct reference to the required manuals shown on an instrument's specification record. Often supplier literature covers many similar models, and the multiple choices can lead to errors when such literature is consulted in situations where action must be taken quickly.

**Spare parts inventory**
- Has the inventory been looked at from the standpoint of risk analysis, or is it based on supplier recommendations?
  - Risk analysis will consider factors like likelihood of failure in actual applications, the severity of impact of a failure on production or safety, the possibility of alternative stop-gaps, number of items in use, etc.
- Are the spare parts indexes organized for rapid identification? Well-organized documentation will be important in time-critical circumstances.
- How often are the spare parts in stock checked against the list of available parts? For example, if this is tracked well, the spare parts inventory can be kept at a minimum; if it is not, missing spares could be overlooked until they are suddenly needed.

**Operator satisfaction**
- How satisfied are operators with instrument maintenance services?

**Work order**
- How does the work order system work?
- Is the number of work orders outstanding routinely and readily available.
- How is outstanding work flagged?
- Is a list of jobs available if the PM goes down on an unscheduled basis?
- Is the work order system used to produce an analysis of what isn’t completed, for the next shut?
- Does the system include a list of people, phone numbers, etc. for maintenance activities?

System, temperatures can be maintained to within ±0.15°C (0.3°F). The audit team should observe high resolution, unfiltered temperature trends for these two showers.

— Evaluating control systems — MD and CD controls: MD moisture control — which involves steaming the dryers, evacuating condensate and ventilating the hoods — is complex and can have many problems. Evaluating the MD moisture systems involves observing trend data for steam, condensate and ventilation and comparing these to trend data for paper moisture. All loops should run at steady state and should quickly recover from upset conditions during and after breaks.

Variability in MD basis weight is also influenced by many paper machine variables, all of which can be evaluated for stability and control. A partial list of these variables includes thick-stock flow to the silo, machine chest or stuff box consistency, headbox total head, breast roll and apron lip shower temperatures, polymer/retention aid system...
### TABLE VI. Issues in evaluating the instrument department.

<table>
<thead>
<tr>
<th>Category</th>
<th>Questions</th>
</tr>
</thead>
</table>
| Staffing level            | • What is the staffing level of the department?  
                         | • What is the ratio of trades personnel to instrument units?              |
| Training level            | • How many hours of training per technician are there in an average year?  
                         | • What is the level of training of Instrument department employees, and is there a training plan?  
                         | • What courses have the instrument department personnel taken to keep up to date with control and instrumentation developments?  
                         | • What training is organized when new equipment is introduced?           |
|                           | • What follow-up steps have been taken (e.g. ISA, EnTech courses)?     |
|                           | • Are one or more copies of the TAPPI Process Control reference book available [7]? If so, how many persons have read and understood it? If, as is common, this book does exist in a mill but a large number of employees have not understood it, what steps are being taken to train the employees? |
| Documentation             | • Are training records kept?                                             |
|                           | • Are ISA training manuals used?                                         |
|                           | • Are instrument department records readily available?                   |
|                           | • Are instrument calibration records readily available, e.g. consistency transmitters and flowmeters used in stock proportioning? |
|                           | • What time efficiency is lost due to control and instrumentation?       |
|                           | • Are instrumentation failures analyzed, and are there disproportionately high failure rates for certain instrument types? |
|                           | • What deficiencies have been identified and what are the plans for dealing with them? |
|                           | • Is relevant documentation available relating to the effectiveness of the instrumentation and control systems? |
|                           | • For documentation, a wide range of formats will be found, both paper-based and electronic. It is important that they be meaningful and accessible, complete, organized and up-to-date. The audit team should check for: |

- P&I diagrams
- Instrument specifications
- Supplier maintenance manuals
- Spare parts lists
- Control strategies and loop tuning procedures and records
- Installation standards
- Safety procedures
- Failure analyses
- Planned maintenance routines
- Calibration procedures and records

| Recruiting                | • What factors are considered for new instrumentation/control employees?  
                         | • What are relative weightings of education, technical training, apprenticeship, experience, seniority, and other factors. |
| Test equipment            | • What is the quality and availability of test equipment?               |
| Outside help              | • Are outside contractors, suppliers used for any services? What written contracts are in place? |
| (See also Section 3.1)    | • What arrangements have been made for back-up support by suppliers?   |
|                           | • For outside contractors used for maintenance, training, parts refurbishing, do contracts specify response times, performance standards and warranties? |
| Work practices            | • Are multi-craft or flex-craft work practices in operation?           |
| Communications            | • How good are channels of communication between –                    |
|                           | • members of the maintenance and operations departments? Shift and day workers?  
                         | • Is reporting adequate to ensure follow-through?                       |
|                           | • Are marginal cases noted that may be symptomatic of more severe approaching situations? |
| Associations              | • Is participation in technical and professional associations encouraged (e.g. ISA, CPPA, TAPPI)? |
|                           | • How many employees are members of the ISA?                          |

A number of issues prevent defining what CD variability is typical, acceptable or expected for a given type of paper machine. For example:

- The width and resolution of raw measurement data boxes varies with the supplier and sensor technology.
- Sensor electronics, including the sampling and averaging methods and rates, vary with the supplier and the sensor technology and almost always provide some type of hardware filtering that affects the variability calculation. Supplier control software typically has several types and degrees of software filtering capabilities for both MD and CD profiles.
- Procedures for mapping data collected at the frame into control and display data boxes vary with the supplier and the mapping procedure affects variability calculations.
- The statistical methods used for calculat-
ing long- and short-term (low- and high-frequency) variabilities vary with the supplier.

Given the above, CD and MD profiles are best evaluated by observing unfiltered profiles from the highest resolution sampling (number of data boxes) available from the supplier.

It is difficult to assess paper quality adequately from a statistical (2-sigma) analysis of CD or MD profiles. More information is available if profiles for individual reels are converted into waterfall or topographical descriptions and the mill then compares profiles and CD locations on the machines and mills then compare with problem areas in the press room [11].

As almost all dry-end measurement systems interpret MD variability as CD variability, a stable MD profile (particularly short term) is necessary for achieving good control. As for CD profile control, the audit team should observe MD profiles that have been collected using the control system's maximum sampling rate without data filtering. This should be done using single-point gauge operation for at least six different points that are spaced evenly across the web.

The evaluation team should also determine the adequacy of MD/CD control loop tuning and MD and CD profile filtering. Given profile stability problems under specific operating conditions, mill personnel may detune loops and may impose excessive filtering on profiles. Detuned controls may perform well at near-steady-state conditions but poorly during upset. Excessive MD and CD profile filtering can create the illusion of stability by giving profile displays that appear flat, while degrading paper quality by actually adding variability to the profiles. When filtering is increased over time, it is common to compensate for the stability consequences by progressively detuning loops. The analysis cycle of filtering and detuning can result in a gradual degradation in product quality. The audit team can quickly test for this problem by making filtering/tuning changes and observing the results during steady-state and upset conditions such as a paper break or start-up.

**2.2. Evaluating instrumentation:** The audit team will evaluate instrumentation in several contexts. Table IV lists some direct instrumentation issues. As the team will include instrumentation in surveying control issues on the basis of either loop type or by process stage, Tables I and II include numerous references to instruments. The team will also address instrument issues in assessing maintenance, which is discussed in the next section.

**2.3. Evaluating instrument/control maintenance:** The audit team will evaluate a wide range of technical, administrative and managerial factors in control system and instrument maintenance, Table V.

Using the term “unit” to mean a transmitter, controller, valve or similar item, typical responsibilities would be 200 to 600 services by a technician. This number has increased significantly over the years as technology has improved. Pneumatic analog instruments require more maintenance than electronic analog which typically require a greater effort than single-loop digital. The DCS is more reliable and easily maintained than any of them.

The emerging Fieldbus/HART technology will make immediate on-line information available to operations to facilitate predictive maintenance, monitor operating performance, and troubleshoot process problems on-line. Given profile stability problems under specific operating conditions, mill personnel may detune loops and may impose excessive filtering on profiles. Detuned controls may perform well at near-steady-state conditions but poorly during upset. Excessive MD and CD profile filtering can create the illusion of stability by giving profile displays that appear flat, while degrading paper quality by actually adding variability to the profiles. When filtering is increased over time, it is common to compensate for the stability consequences by progressively detuning loops. The analysis cycle of filtering and detuning can result in a gradual degradation in product quality. The audit team can quickly test for this problem by making filtering/tuning changes and observing the results during steady-state and upset conditions such as a paper break or start-up.

---

**3.1. Evaluating outsourcing and single-sourcing:** It has become increasingly common for a pulp and paper mill to transfer a substantial part of key operations to a single external supplier. Typical examples are maintaining control systems, chemical systems and paper machine clothing. The intent is to reduce fixed costs by eliminating permanent mill positions. The idea is that, in consideration of all the mill’s requirements in a service area being provided by that single supplier, the supplier will provide full support for the area (e.g., monitoring the use and efficacy of papermaking chemicals). The practice, such arrangements can have complications and must be carefully managed. Two main areas of concern are actual cost-effectiveness and in-house expertise.

The supplier needs to provide skilled people, and these are paid essentially the same as the people who were previously in the mill doing the job. The supplier needs to make a profit, and so charges out his people to the mill at up to twice the salary the mill would have paid them as mill employees. At the same time, the supplier’s employee, recognizing that he or she is not directly employed by the mill, must provide a product or service that creates value for both the mill and the employer.

When a mill has its own people looking after a key operational or service area, the body of expertise that develops can be properly documented, there is more ownership of the area, the people who are supporting the service are available to train others and the knowledge is retained in-house.

A contractual arrangement should govern the business and commercial relationship between the mill and the outsourced or single-source service provider.
Autonomy and responsibility

- A self-directed team operates with the concept of joint ownership and responsibility for the total goals of the organization.
- Team member shares responsibility for the team’s performance and effectiveness.
- A team is held accountable on many different fronts.
- Team decisions are by consensus.

Hiring, firing, training, performance

- A team may be allowed to hire and fire members.
- A team may be responsible for training its members.
- A team’s members will eventually become competent in a variety of skills and roles, as jobs are required to be rotated.

Team dynamics

- Individuals and teams are required to give and receive frequent feedback. Feedback is not a ‘performance appraisal’, but a group process to identify opportunities for improvement and sustain positive performance and behaviour.
- Team-building aims to improve problem-solving ability among team members by working through the tasks and interpersonal issues that impede a team’s functioning. The team-building process will be an ongoing activity in which each team member participates as both a learner and teacher.

TABLE VII. Potential weaknesses in self-directed teams that may be related to problems in machine operations.

<table>
<thead>
<tr>
<th>Issue</th>
<th>Potential weakness</th>
</tr>
</thead>
</table>
| Autonomy and responsibility | - Shared responsibilities tend to be set up without sufficient clear ownership of particular tasks by particular team members.  
- When everyone is responsible, no-one may take responsibility. Individuals who abuse the system and do not conduct themselves professionally, including team managers, must be recognized and dealt with quickly.  
- Despite a team’s level of autonomy, its members must accept and respond positively to decisions by and directives from management that they may disagree with. The team must also respond to needs for immediate action (e.g. arising from another team’s focus area).  
- Teams may take too long to make decisions.  
- A team manager is a ‘coach’ who ‘advises’ — but tends to have responsibility without authority.  
- For any given item (e.g. BW variation), the standards or targets to which managers and teams are working must be identical.  
| Hiring, firing, training, performance | - A team may choose new members for the wrong reasons.  
- The level of technical knowledge of team members can deteriorate without this being evident to management, who are not closely enough in touch.  
| Team dynamics | - Nonparticipation is unacceptable, but is difficult to deal with.  
- It is very difficult to prevent the competitiveness and ambition of a few group members from coming to dominate a group’s dynamics after a few years.  
- Conflict is inevitable, and must be dealt with quickly. If warring cliques develop, they will force people to choose sides, and this will seriously weaken the organization.  

such a contract exists, frequently it has been prepared by those responsible for purchasing and reviewed by the appropriate legal authority and the mill’s operational personnel then have to live with the results. Such contracts often do not clearly specify the duties of the supplier under different circumstances and frequently appear designed to promote the exclusivity of the particular supplier.

As a result, it is not uncommon to find that an outsourced mill, having transferred control over its key operational areas to an outside organization, has less flexibility and fewer options. These constraints develop because the mill gradually has less internal knowledge and the arrangement under which it is operating grants exclusivity to the supplier and, as a consequence, the mill’s operators have become demotivated. It is important to validate the supplier’s record before agreeing to an exclusive contract and terms that ensure that key issues are addressed must be present in outsourcing or single-sourcing contracts (Appendix 1).

3.2. Evaluating self-directed teams: Certain problems in a machine operation may not have a technical origin but instead may have their roots in management strategies. Recently, self-directed teams (SDTs) have become more common in paper mills and associated supplier industries. It is not uncommon to find that an SDT-based paper mill has a relatively low efficiency. When an audit team evaluates a machine operation in an SDT-based mill, the team will examine carefully how the SDTs contribute to efficiency. As guidelines for this part of an audit, we clarify what makes a team self-directed, outline the phases in the development of SDTs and suggest potential weaknesses in how SDTs function in a machine operation.

- Evaluating self-directed teams — characteristics of self-directed teams: Teams, in which individuals sublimate their personal egos for the good of the group and which act within a hierarchy of managerial authority, are well known to be capable of performing effectively, particularly when team members are free to express their opinions and make suggestions. What distinguishes a modern SDT from traditional teams is its high level of autonomy which effectively takes it outside the hierarchy.

In a mill, an SDT is a group of people who are responsible for a specific area of operations. Such a group operates with the concept of joint ownership and responsibility for the total goals of the organization but, typically, without having clearly identified which team member is responsible for particular tasks. This implies that each team member is equally responsible for the team’s performance and effectiveness. A team is trained to make its own decisions by consensus and is held accountable on many different fronts, e.g. product quality and cost, customer satisfaction, human resource issues, safety, productivity, troubleshooting and maintenance, self-management, communication and co-operation with other teams.
Team members, individually or in small groups, handle a range of social and technical issues including meetings, safety, conflict, justice, performance and career planning. A team may be responsible for hiring, firing and training its members. Team members are paid according to their acquired knowledge, demonstrated skills and positive performance rather than by job titles or seniority. Typically, skill ratings and tasks replace job descriptions. As jobs are required to be rotated, a team member will eventually become competent in a variety of skills and roles. As part of team building and performance management, team members are required to give and receive frequent feedback. Each team member is expected to be a self-starter.

Each team has a manager, leader or coordinator, whose role is to coach or, for a mature team, to advise. For operational areas that do not require a full-time leader, the role is handled by a designated team member. The manager provides leadership, especially in the area of following management directives, and ensures that the team has the necessary resources to maintain day-to-day operations. The manager's role is that of a regular team member who maintains an overview of team activities and helps the team to look at the problems it needs to solve in relation to the work it is doing.

The manager must have the social skills necessary to serve as an effective leader while acting as and being seen to be a fully-functioning team member. He/she is responsible for developing the team members to the point that they understand mill-wide results and how their performance affects these results. He/she brings outside help or resources into the team to improve their all effectiveness, ensures that team meetings are effectively planned and conducted and ensures that records and events are documented. He/she ensures that the company's philosophy is applied consistently in handling team conflict and development.

In principle, SDTs will co-operate to operate the mill and will deal with and resolve all special cases. Management will manage the business and plan for and execute changes to reduce common-cause variations. This can be a very productive system if developed and nurtured properly.

--- Evaluating self-directed teams ---

- Phases in SDT development: While it can be expected that different teams will develop at different speeds, an organization could take several years to develop to maturity. Because of this time scale, the weaknesses that can develop (as noted below) and the difficulty of reversing the effects of an SDT structure, it is important to understand the phases in SDT development, and the characteristic associated behaviors:

1. Start-up or supervisory phase. Management supervises in defining start-up and learning-curve responsibilities and boundaries for teams.

2. Participation or teaching phase. Management teaches. Team members recognize their responsibilities and the emphasis on communication, training, and co-operative goal setting.

3. Team-building or developing phase. Management offers support. Team members work to understand a team's purpose and role in the total functioning of the organization; teams work more effectively with other teams and team members develop and earn more decision-making abilities.

4. Mature or boundary management phase. Management advises and protects team boundaries against external disturbances and unreasonable demands. Team members develop some autonomy over their own activities in achieving the team's goals, have access to the information they need to solve the team's problems and are more involved in the decision-making processes that affect their team's responsibilities.

--- Evaluating self-directed teams ---

- Potential weaknesses in SDT-based mills: Table VII suggests the weaknesses that can develop in an SDT-based mill, which can result in low machine efficiency or product quality. The key areas relate to the autonomy and responsibility, technical performance, and internal team dynamics or functioning.

An SDT organizational structure requires much more time and energy to maintain than a traditional structure, and is much harder to manage.

Participating in an SDT can be difficult for many who come from a more traditional mill background, who tend to experience conflict with the basic team requirements.

If teams are set up to save costs by reducing staff, this will lead to overwork for the staff who remain and the extra effort required will not be sustainable in the long term.

An important point for considering efforts to improve operational efficiency is that the effects of a management system permeate all levels of the organization. The effects of an SDT-type structure cannot be quickly or easily reversed when management attempts to move away from such teams.

CONCLUSIONS

For an external team to effectively audit and report on the control and instrumentation issues of a paper machine operation as a component in a paper mill operation, the team will need to address a wide range of interconnected issues. As its on-site time is typically very limited, the team will need to be well organized, well prepared and clear about its aims.

To complement previous material describing a method for evaluating the equipment and operational aspects of a paper machine, a framework for evaluating the machine's control and instrumentation was described. Issues discussed include: Control strategies and loop tuning; process information systems; final control elements; control systems at particular process locations; instrumentation; instrument maintenance; as well as personnel, training and documentation in the instrumentation department.

As some machine problems that appear to have technical causes actually arise from management strategies, framework works were given for evaluating outsourcing and self-directed teams. The intent behind outsourcing and single-sourcing was compared with potential complications. As the risks to the mill increase if such supplier/mill relationships are not governed by appropriate contract terms, terms were listed that should ensure that key issues are addressed. Characteristics of self-directed teams were described, as were phases in their development. Potential weaknesses in how such teams function in paper mills, which could affect machine operations, were outlined, considering autonomy and responsibility, technical performance and internal team dynamics.

ACKNOWLEDGEMENTS

We gratefully acknowledge G.P. Chinn for general discussions on the material covered in this paper, Gunnar Mardon (BIM Chemi Canada, North Vancouver, BC) for material on supplier contracts and Patrick Tessier (ISAC Technologies, Calgary, AB) for discussions on control systems.

DEDICATION

This work is dedicated to George Harmon, who, while at the Bailey Meter Co., taught the most senior authors the elements of system engineering; and to Bill Bialkowski, who has committed his technical life to improving the practice of process control in the pulp and paper industry.

LITERATURE


APPENDIX: OUTSOURCING

In examining areas serviced under outsourcing or single-sourcing contracts, the audit team would look for provisions similar to the following in a mill's contracts with service suppliers. The selection of such consideration is based on the importance of the work and the benefits expected from the supplier. The following considerations that, with modifications appropriate to specific service areas, can be expected to apply rather generally to technical outsourcing contracts. We follow this with comments specific to contracts for on-machine gauging, machine clothing and papermaking chemicals which illustrate how the general principles might be modified for specific cases. As all three examples relate to the heart of the technology in a papermaking business, it is important for each side that nothing is overlooked in contracts.

The mill and supplier, jointly, should clearly define in detail what is included in the service under contract and the responsibilities of each party. The contract should clearly differentiate between those things the mill undertakes to do and those things for which the supplier is responsible. Both parties need to minimize cost and risk, and the mill needs to identify how critical field processes will be addressed.

General contract specifications - personnel: Where the contract is of such a nature that an employee of the supplier is permanently resident at the mill, the following conditions should apply.

1. The mill should have the right to accept or refuse the supplier's candidate representative, subject to mutually acceptable criteria. Criteria would include, for example, the candidate's formal training and when it occurred, courses taken subsequently and currently, membership in professional societies, mill experience (with references), papers published and individual reports written by the candidate (made available on a confidential basis), and individuals trained by the candidate in particular situations.

2. Once a supplier's representative has been accepted by the mill, the supplier may not change, transfer or terminate the representative without the mill personnel being advised in advance and agreeing to the replacement. For such changes, required transition periods should be specified prior to the incumbent's departure. Temporary relief replacements (for holidays, courses, absences beyond a specified maximum period, etc.) must be identified ahead of time and must also be acceptable to the mill.

3. The duties of, and amount of time that the supplier's representative(s) will put in, including time in the mill, should be clearly defined.

4. The on-site engineer must have a level of papermaking knowledge determined by the mill and must agree to obtain certifications specified by the mill.

5. The supplier's representative should have a specified annual training program that has been approved by the mill. Both the representative and the mill should sign off on the training program once it is complete. The mill should have the right to submit the supplier's representative to an oral examination after he/she returns from a course.

6. The mill should provide an individual whose primary duty is to understand the current situation in the technical area serviced by the supplier. The supplier should ensure that this individual is fully informed with all aspects of the mill's technology and performance in the area served by the supplier.

General contract specifications - records: Consider the following:

1. All measurements made should be reported on an interim basis and these reports should have a full commentary.

2. The supplier's representative should be responsible for maintaining the service program records.

3. The mill should support the supplier in obtaining documentation and training for all installed equipment.

General contract specifications - technical considerations: Technical considerations

1. The supplier should bring to the mill's attention all technical advances made by the supplier that are relevant to the service area and should provide the mill with a quotation for implementing such advances within 60 days of such advances being disclosed by the supplier to others in the industry.

2. Additional equipment should be supplied only when the mill has agreed in writing what will be installed and when.

3. The supplier should maintain an accurate knowledge of the best performance for the mill's types of machines and grades and should regularly compare the performance of the customer's machines with what is considered satisfactory industrial performance.

4. Security clauses, including a confidentiality agreement, with substantial penalties, should protect the know-how and intellectual property of the mill.

5. If the mill has a problem whose solution lies in the technical area served by the supplier and the supplier does not solve the problem to the mill's satisfaction within a specified time, then the mill should have the right to engage a different supplier. In such a case, the mill should be free to observe normal commercial confidentiality with regard to the technical material supplied by the alternate supplier.

6. Equipment performance standards should be set, with penalties and rewards depending on actual performance.

General contract specifications - communications: Consider the following procedures:

1. The supplier should train the appropriate mill operations personnel (e.g. down to at least the level of the machine tender) on the equipment and materials supplied, at a frequency determined by the mill. Training should cover all shifts, sessions should be at predetermined intervals and presentations should be documented. Presentations should deal with operating and maintaining equipment, mill performance in the area, the actual construction or nature of the specific material and equipment that the mill is using and the advantages of and the reasons for choosing a particular material or design.

2. Where something is found lacking, or operational problems are identified within the area of responsibility or its associated equipment, the supplier's representative should point these out to the appropriate mill representative, not only at the time of the initial observation, but regularly if the problem or condition persists.

3. The supplier's representative should maintain a log book that is similar in concept to the programming log of a computer supplier. All relevant changes and facts, including whose intellectual property any development is, should be recorded in this log book, and entries should be promptly signed and dated. The log book should be reviewed at predetermined times agreed upon by representatives of both the supplier and the mill and signed off as correct.

4. Once a year, for each service area, the mill should have the right to employ an outside consultant, who would legally qualify as an expert in the field concerned, who will audit the current service level and its effectiveness. If the service supplier fails to pass this audit, the contract may be terminated and/or appropriate penalties levied.

5. The supplier should schedule a meeting with mill management every six months to review key performance factors such as equipment uptime, number of failures, SQC records, parts use etc., along with recommendations and opportunities.

6. The supplier should provide copies of all relevant documentation (e.g. technical bulletins, published papers, brochures, etc.) when necessary and should ensure that the documentation reaches all appropriate levels in the mill. The supplier should be responsible for communicating any such documentation to mill supervision and senior operators through appropriate means, including formal and informal presentations.

General contract specifications - termination of contract: Consider the following reason: Failure of the supplier to satisfactorily fulfill the duties described above may be cause for terminating the contract.

Examples of specific contract provisions - on-machine gauging system: In order that supplier contracts ensure that basic technical/economic principles are addressed in sufficient detail for this gauging system, the general terms given above might be modified or extended by terms such as the following.

Examples of specific contract provisions - technical considerations: This is an example of a contract provision:

1. The mapping should not change under similar conditions of operation and should be checked regularly by the supplier and mill representatives together.
SQC can be used to determine an appropriate frequency. The mapping should be checked against changes in headbox flow and jet-to-wire speed difference.

2. A readout should be available of data boxes which are in use for different conditions, and of the control range used (which would indicate if CD control is being usefully applied across its full range). If the system is damped, for example, by averaging five or six boxes, the ratio of basis weight variation (peak-to-peak range) which is obtained with the smallest possible box size to that used should be shown.

3. The contribution of MD variability to CD variability should be shown. MD variations that are being aliased into the CD profiles (possibly causing CD controls to react to non-existent perturbations) should be identified.

4. The exact calibration procedure for basis weight and moisture should be specified.

5. How head is calculated should be described clearly. Calculations should include the dynamic head (added to the static head) and any head loss due to a sheet package (subtracted from total head).

6. In the calculation of jet speed, allowance should be made for the slice contraction coefficient (as provided by headbox manufacturer).

7. The supplier should guarantee the improvement over manual control for the headbox in question as well as the CD range obtainable with the smallest boxes.

8. The levelness of the apron, the accuracy of the slice beam and the maximum allowable backlash in the slice screws for the above guarantees to hold should be stated.

9. The supplier should state the MD variability detectable, both in frequency and percentage of true amplitude, when the gauge is on single point, for the system under consideration. The method of checking this statement should be given (e.g. using the Tapio profiler or the Norwegian PFI Mass gauge).

10. Single-point tests should be done at regular intervals determined by the mill (e.g. once a month) and additionally whenever the mill requests it.

Machine clothing: Supplier contracts should ensure that basic technical/economic principles in selecting and managing machine clothing are addressed in sufficient detail. Such principles include: clothing construction; the effects of clothing on efficiency in forming, pressing and drying; requirements for ongoing programs for monitoring clothing performance in different machine sections; the true costs of clothing as part of the paper machine system (e.g. Mardon and Larson 1994).

Papermaking chemicals: For papermaking chemicals, outsourcing has the potential to compromise the machine operation more seriously than for other services. Frequently, once a mill has transferred control over its chemistry, the loss of internal mill knowledge in chemical use and performance and the exclusivity of the outsourcing contract, result in mill personnel becoming reluctant to try to change the chemical program.

Résumé: La présente communication s'ajoute à la description précédente d'une méthode d'évaluation du matériel et des aspects opérationnels d'une usine papetière. Elle discute d'abord des secteurs à consi'dérer lors de l'évaluation du contrôle et des instruments : conception du contrôle, matériel, stratégies, réglage, entretien, documentation, formation et organisation du service de l'instrumentation. Ensuite, certains problèmes de machine, dont les causes semblent techni- ques, sont en réalité le fait de problèmes de gestion. La communication discute des formules de vérification pour l'implication et les équipes autonomes.

Abstract: This paper complements an earlier description of a method for evaluating the equipment and operational aspects of a paper machine operation.

First, it discusses areas to address when evaluating control and instrumentation. These include control design: equipment; strategies; tuning; maintenance; documentation; training and organization specific in the instrumentation department.

Second, as some machine problems, whose causes are apparently technical, actually arise from management issues, the paper discusses audit frameworks for outsourcing and self-directed teams.


Keywords: MANAGEMENT, PAPER MILLS, PAPER MACHINES, EVALUATION, CONTROL, SYSTEMS, INSTRUMENTATION, OPERATIONS RESEARCH