EXECUTIVE SUMMARY

Significant improvements in dryer section operation and energy efficiency have been achieved through the close integration of supervisory control and steam system design. Supervisory control of all system set points is used to optimize system operation and provide ease of use for the operators. Steam pressures, flows, and differentials are managed under all machine operating conditions including sheet breaks, tail threading, grade changes, and start-ups. The control system accomplishes this without the need for operator intervention. System designs can be simplified and a very wide operating pressure range is produced. Supervisory control assures that the dryer operation is consistent for different machine operating conditions and machine crews. This improved consistency results in better dryer section runnability by producing the same dryness curve as the sheet progresses through the dryer section.

The concept of an improved dryer control system is to utilize modern control capabilities to provide supervisory control over the steam control and dryer drainage system. There are many benefits that can be realized with this approach. Consistent dryer operation is produced over the entire machine operating range and for every machine operating crew. Drying conditions are controlled in a manner that produces consistent machine direction sheet moisture, constant draws, and improved runnability. Upsets such as sheet breaks, grade changes, and wash-ups are handled efficiently by the control system. This produces improved machine efficiency.

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Significant improvements in dryer section operation and energy efficiency have been achieved through the close integration of supervisory control and steam system design. Supervisory control of all system set points is used to optimize system operation and provide ease of use for the operators. Steam pressures, flows, and differentials are managed under all machine operating conditions including sheet breaks, tail threading, grade changes, and start-ups.

The control system accomplishes this without the need for operator intervention. System designs can be simplified and a very wide operating pressure range is produced. Supervisory control assures that the dryer operation is consistent for different machine operating conditions and machine crews. This improved consistency results in better dryer section runnability by producing the same dryness curve as the sheet progresses through the dryer section.

Different drying strategies can be used in the wet end “quality zone” to provide consistent sheet quality and runnability. Dryer pressures are varied according to a predefined set of pressure curves that ensures proper wet end sheet temperature graduation.

The operation of the dryer section is trouble free. The operating parameters are tightly controlled and controller limits are continuously set. This ensures that no dryer flooding or system problems can occur.

A wider range of operation can be achieved with supervisory control. The upper and lower operating limits of a system are difficult to maintain without continuous adjustment of the system. Operators are unable to make these fine adjustments to a traditionally controlled system.

The energy efficiency of the system is optimized. Establishing the proper system relationships and operating limits minimize venting and steam waste. Steam is conserved during upset and sheet off conditions.

Significant improvements in the ease of use of the system are achieved. There is little need for operator adjustment of the system. All system functions are driven from the moisture gage and the sheet break detectors. When adjustment is necessary, it is done using “Increase Drying / Decrease Drying” controls. The supervisory control manages all system set points based on the operator’s desire to increase or decrease drying on the machine.
Figure 1 shows a typical dryer drainage system for an LWC machine that utilizes a thermocompressor design. This system is considered to be a well-designed system by traditional standards. It incorporates thermocompressors for flexibility, blow-through flow control, individual control of wet end dryers, and flash steam recovery using a common collection tank. Control of the system would be through a DCS.

Within this system there are:

- 35 control valves
- 32 transmitters
- 12 pressure loops
- 3 flow loops
- 10 differential pressure loops
- 2 temperature loops
- 5 level loops

Even though most dryer drainage systems are controlled through a DCS, the control is typically single loop. The moisture gage would drive the pressure of the final steam group to control reel moisture. Generally, it is up to the operator to establish the system set points for the remaining sections. Occasionally, there are simple relationships programmed into the DCS to adjust pressures in some of the other sections based on the pressure of the moisture control group. It is up to the operator to adjust all differential pressure and blow-through flow settings, and monitor all other loops to ensure the operation and set point is correct.
The following is expected of the operator in managing the system.

- Adjust all system pressures as machine conditions change.
- Understand the operating limits of the system.
- Understand how the pressure changes affect the interactions within the system.
- Adjust differential pressures as machine conditions change. This requires knowledge of syphon characteristics.
- Manage pressures on grade changes.
- Turn dryer pressures and differential pressures down on sheet breaks. Pressure turndown is a common feature in many DCS systems however rarely are differential pressures adjusted. Pressure turndown is often done in a manner that creates instability in the system.
- Reset dryer pressures following a sheet break.
- Start the system up following a shutdown.
- Know when valves are not positioning correctly.
- Know when the system is not operating properly.

Because of the complexity, most of the above operator responsibilities are handled inconsistently. A significant factor in dryer operation is the preferences of different operating crews. Often a different set of operating set points are used for each operating crew. This leads to inconsistent dryer operation, which is difficult to optimize and improve.

IMPROVED DRYER CONTROL COMPONENTS

The following are the components of an improved dryer control system.

1. Utilize supervisory control to manage all system set points under all steady state, transitory, and upset conditions.
   - Supervisory control of all pressures using pressure curves to control the relationships between sections.
   - Establish system limits based on continuous analysis of pressure differences within the system.
   - Manage blow-through flows and differential pressures.
   - Provide sheet break turndown of pressure and differential pressure.
   - Manage grade changes using drying calculations to establish pressure ramps and steady state pressure set point.

2. Automatic start-up and shutdown of the system can be provided.
   - Start-up logic takes control of all valves and steam flows to control dryer warm-up following a shutdown.
   - Logic frees up the operators for other duties during the start-up and shutdown sequence.
   - The condensate return temperature dictates dryer warm-up rate.
3. The dryer operations are monitored to aid troubleshooting and assess system performance.
   - Incoming sheet moisture from the press section is continuously indicated based on an energy balance around the system.
   - The energy efficiency of the system is reported in terms of water evaporation and production rate.
   - Alarms are sent to the operators when the system is out-of-limits.

4. Condition of the field devices is continuously monitored.
   - The actual position of the valves is fed back to the control system. The actual position is compared to the controller output. The valve is characterized at start-up to establish the operating curve and deviations from this curve are “flagged”.
   - The integrity of the transmitter signal is continuously monitored.

IMPLEMENTATION OF SUPERVISORY CONTROL

There are two methods to implement a supervisory control system for the dryer section: a separate dryer drainage control system can be installed which is dedicated to the dryer section; or a Supervisory Computer can be added to interface to the DCS controllers.

Figure 2 shows the configuration of the dedicated dryer drainage control system. A controller is installed which is used exclusively for dryer system control. The workstation interfaces directly to the system controller. The supervisory and regulatory control logic is downloaded into the controller where it runs independent of the workstation.

The workstation is used as an interface to the controller. All the screens and interface to the system are configured into the Human Machine Interface running on the workstation. The dryer drainage workstation can be networked to an existing DCS. Depending on the DCS, it is possible to give the operators full view and control of the dryer drainage workstation screens from the DCS workstations.

Figure 3 shows the configuration with a dedicated supervisory control computer. Regulatory control functions for the dryer drainage system are done through the DCS controller. A direct communication link is made between the DCS controller and the Supervisory Computer. The Supervisory Computer reads and writes information to the DCS controller to adjust the system set points. In the event of a communications failure with the supervisory computer, the operators would remain in control of the system through the DCS, however, they would need to manually adjust system set points.
Figure 2: Separate dryer drainage control system with optional link to DCS.

Figure 3: Supervisory PC with existing DCS.
PRESSURE CURVES

The development of pressure curves is a key component of supervisory control of the dryer section. The pressure curves determine the relationship between the pressures used in the different steam groups. The pressure curves are developed using drying formulas, which keep the dryer temperature response linear with regard to drying capacity. Linear temperature response, not pressure response, is a key to good dryer and machine direction sheet moisture control. The linear temperature response provides the same sheet moisture control response whether the dryers are operating at high or low pressures.

The pressure curves are driven from the moisture control section of the dryer section. As the moisture control group pressure changes in response to a change in machine operating conditions, the steam pressures in all control groups change according to a set of pressure curves. The moisture control section is driven by the machine's moisture gage or can be manually set by the operators. If the operators choose to manually adjust pressures, they are only required to change the pressure in the moisture control group and all other pressures will be set accordingly by the supervisory control using the pressure curves. Normally, two buttons are provided: one for increasing drying and one for decreasing drying.

The pressure curves provide improved consistency and runnability. As machine operating conditions change, the dryer pressures are varied in the same manner each time and for each operating crew. The pressure curves are developed to keep the machine direction moisture constant at each section split down the dryer section. This regulates where the sheet shrinkage occurs and helps to keep the draws consistent as basis weight and speed changes occur.

The pressure curves are used to keep the system at the most energy efficient operating point. The system can be kept stable, without venting, over the entire operating range by closely regulating the dryer pressure relationships.

Normally, a number of sets of pressure curves are built into a supervisory control system. The operators can select the appropriate set of pressure curves. Typically an aggressive drying strategy would be used for heavier weight grades and a more passive drying strategy would be used for lightweight grades.

It is important that the pressure curves be adjustable by mill supervisory personnel. The relationships between the pressure groups can be fine-tuned by mill personnel to make the system produce the best dryer operation.
SYSTEM LIMITS (ANTI-FLOODING STRATEGY)

Supervisory control can be used to extend the operating range of many dryer drainage systems. To operate at the extreme low limits of a system requires frequent and careful adjustment of system pressures. Operators typically establish safe settings. Dryers are often valved out of service to produce dryer pressures that are sufficiently high to provide this safe operating point. Supervisory control can be used to make the many fine pressure adjustments which are needed to keep the dryers from flooding at very low pressures. This provides the ability to operate at very low pressures without having to valve dryers out of service. As an added safety feature, algorithms can be used which “look” at the pressure differences available in the system. Controller limits are continuously set to prevent the system from operating at pressures that will cause dryer flooding. As an example; if the vacuum level at the condenser is insufficient to provide good drainage, the lower pressure operating point of the system will be limited so that dryer flooding will not occur.

DIFFERENTIAL AND BLOW-THROUGH ADJUSTMENT

In a traditional dryer drainage system, operators typically establish differential pressure or blow-through flow settings that produce drainage under the worst operating condition. These settings are rarely changed. This means that they are not optimized for all other operating conditions. This leads to steam venting and inefficient system operation for much of the operating range.

The correct amount of blow-through steam depends on the syphon type, speed, operating pressure, and condensing load. Supervisory control can be used to adjust the differential pressure based on these machine operating parameters. The optimized differential and blow-through flow settings increase the efficiency of the system by reducing the steam venting and conserving thermocompressor motive steam use.
SHEET BREAK CONTROL

Most dryer drainage systems operate without problems during steady state operation. They may not have the best efficiency, but they do not create problems. However, it is during upsets such as sheet breaks that system problems frequently occur.

Some of the issues that need to be addressed during sheet breaks are:

- The dryer must be kept draining efficiently during a break. Many machines experience dryer loading on sheet breaks because the differential pressures do not follow the rapid changes in dryer pressures.
- The dryer pressures should be reduced to improve tail threading. The dryer surface temperature during a break should equal the surface temperature with the full sheet on. The amount of turndown will vary depending on the operating pressure.
- The dryer pressures need to be ramped down in a controlled fashion during a break to keep the system stable and to prevent flooding. Too often rapid changes in pressure create system problems.
- The blow-through steam flow needs to be optimized to prevent excessive steam waste during sheet breaks.
- The dryer pressures need to ramp up in pressure in a controlled manner once the tail has been established.
- The dryers must be capable of handling the high condensing loads that immediately occur once the sheet has been reestablished.
- Once the sheet has been reestablished, the drying conditions should be stable at the pre-break levels so that first quality moisture is achieved quickly.

Sheet breaks can be best handled using supervisory control strategy. The dryer ramp down and ramp up rates are regulated by the supervisory control system. The ramp rates are established to keep the system stable and the dryers draining during the break. The blow-through flows and differential pressures are also regulated to minimize the venting during breaks and to keep the vacuum condenser stable.

GRADE CHANGES

Grade change is another non-steady state condition that is typically not handled efficiently by traditional dryer drainage control systems. Grade change strategies vary considerably from mill to mill.

Dryer performance can be improved on grade changes by using the pressure curves to move the dryer pressure ahead of the moisture gage. Drying calculations can be used to anticipate the required dryer pressure change that will be required as the basis weight and speed are
AUTOMATIC SYSTEM START-UP AND SHUTDOWN

Start-up of the steam system is often an area that is inconsistently handled by operating personnel. The start-up time should be varied depending on how long the machine has been shutdown. If the shutdown has been short, then the warm-up time for the dryers is less, since the dryers will still be warm. If the shutdown has been long, then the time needed for warm-up will be significantly greater. Unfortunately it is impossible for the operators to know how fast to warm-up the dryers. If it is done too quickly, there is the potential for bearing failures due to temperature differences. If it is done too slowly, production is lost.

Supervisory logic can be used to take over complete control of the start-up and shutdown procedure. This relieves the operators from this responsibility, allowing them to perform other duties.

Logic is used to control the valve opening to regulate air bleed from the system, steam input to the system, and pressure ramp up. The temperature of the condensate being returned from the system is used to determine if the dryers have achieved stable temperatures. Once they have, the system begins to ramp up pressures.

PRESS MOISTURE INDICATION

The amount of energy used by the dryers is directly related to the amount of water being evaporated. Supervisory control provides a “tight” system where the energy flows and pressures are known. A complete energy balance around the system can be made with a few flow, temperature, and pressure measurements. This allows the total
energy use to be calculated which provides a direct indication of the amount of water that is being evaporated. The sheet moisture exiting the press section can be calculated knowing the amount of water being evaporated and the machine production conditions.

The on-line indication of sheet moisture leaving the press is a very useful tool in operating the paper machine.  
- Furnish changes can be identified. Identifying furnish changes will affect runnability and draws. Knowing that a furnish change has occurred allows the operators to anticipate the effects on machine operation.  
- Pressing efficiency changes and felt performance can be evaluated. This is useful in scheduling wash-ups and clothing changes.  
- Press felt break-in can be monitored to allow normal machine speeds as quickly as possible.  
- Drying efficiency changes and dryer problems can be identified. The dryer “U-factor” and drying rate is continuously calculated based on the evaporation rate. When changes occur, it is easy to determine if it is a dryer problem or the sheet moisture coming into the dryer section has changed.

**VALVE AND TRANSMITTER CONDITION MONITORING**

The steam control and dryer drainage system contains a large number of valves and transmitters. It is left up to the machine operators and instrument technicians to determine when valves are not positioning properly or a bad signal is coming from the transmitters.

Valve problems are the cause of many dryer drainage system control problems. If valves do not position as expected, then the system cannot be controlled properly. Poor loop tuning is often used to overcome valve problems.

“Smart” positioners on the valves can provide feedback of the actual valve position. Software can be incorporated into the supervisory control system to characterize the valves when the system is started up. The actual valve position is compared to the controller output and deviations from the characterized curve are flagged. The valve can be scheduled for maintenance when a poor performing valve is identified.
SYSTEM DESIGN

Supervisory control can be used with most traditional system designs provided the system is well designed and is in good condition. Both traditional cascade and thermocompressor systems can be made to operate in a more efficient, user-friendly manner.

One of the more recent developments is the integration of supervisory control with the system design. This changes the way systems can be designed. Less complicated, less costly to install, and more energy efficient system designs are possible.

Figure 4 shows a system design for an LWC machine when supervisory control is utilized. Some of the key system design features are:

- The system has a very wide operating range. Main group pressures from atmospheric pressures up to the maximum dryer rating are possible.
- Pumps from the individual separator stations are eliminated. The condensate can be returned back to the collection tank using pressure differences within the system. Supervisory control provides the assurance that the pressure differences always exist.
- The piping and installed cost of the system is reduced. There is less piping and the lengths are shorter.
- The vent valves to the condenser from the individual dryer groups are eliminated. On a break, the blow-through steam is vented through the system for maximum steam efficiency.
- Very deep vacuum levels are possible in the wet end dryers to control picking and runnability problems. Wet end dryer pressures of –7 psig are possible.
- Flash steam from the high temperature condensate is utilized in the wet end dryers. The condensate is returned back to the boiler house at a low temperature for maximum energy efficiency.
SUMMARY

The use of supervisory control to manage dryer operations has many advantages. The dryer operation is optimized for both the steady state and upset situations. Consistency of operation is achieved for all machine conditions and operating crews. Energy efficiency is improved by regulating system set points to match machine speeds and dryer pressures.

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