Paper Machine Process Control Optimization

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ABSTRACT

In the paper making process, the process variations can be classified into three categories.

1. *Machine Direction variation*
2. *Cross Direction variation*
3. *Random variation*

The paper quality is measured in two dimensions: the machine direction and cross machine direction. The measurement of the primary paper parameters (basis weight, moisture, ash etc.,) and good control of these in machine direction considerably improves the paper quality. This has been effectively proven by comparing the variations in these parameters with and without a "Quality Control System".

It is important to realize at this juncture that the control of these parameters only is not enough as they are influenced by a host of other parameters. This paper highlights some of the important influencing parameters and the controlling strategy for them. The paper further describes some process design aspects of approach flow, stock preparation and steam and condensate system aiming a substantial enhancement in the quality of paper.

There is another dimension to the way in which a process parameter is controlled. The process parameters normally have variations at different frequencies. The paper also describes the method for analyzing the variability that exists at a particular frequency or period. It is important to realize that not all of these frequencies can be controlled by a controller. The frequencies beyond the controllers' controllability need process troubleshooting. Paper discusses some of the sources for these variations and the elimination methods subsequently.

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PROCESS CONTROL

A controller's ability to control a process parameter depends on the variation of the parameter. The variations can be classified into slow drifting, medium drifting and fast drifting variations. A controller can control only upto its "cut-off" period. The cut-off period for a closed loop without deadtime depends on its closed loop time constant and for a closed loop with deadtime depends on closed loop time constant, process deadtime and sample rate. ABB Bangalore has the software tools to obtain the "Time Series Analysis" from which the variations can be analyzed. The time series analysis provides excellent means of troubleshooting process and/or controller problems. Then a controller's optimum performance can be achieved.

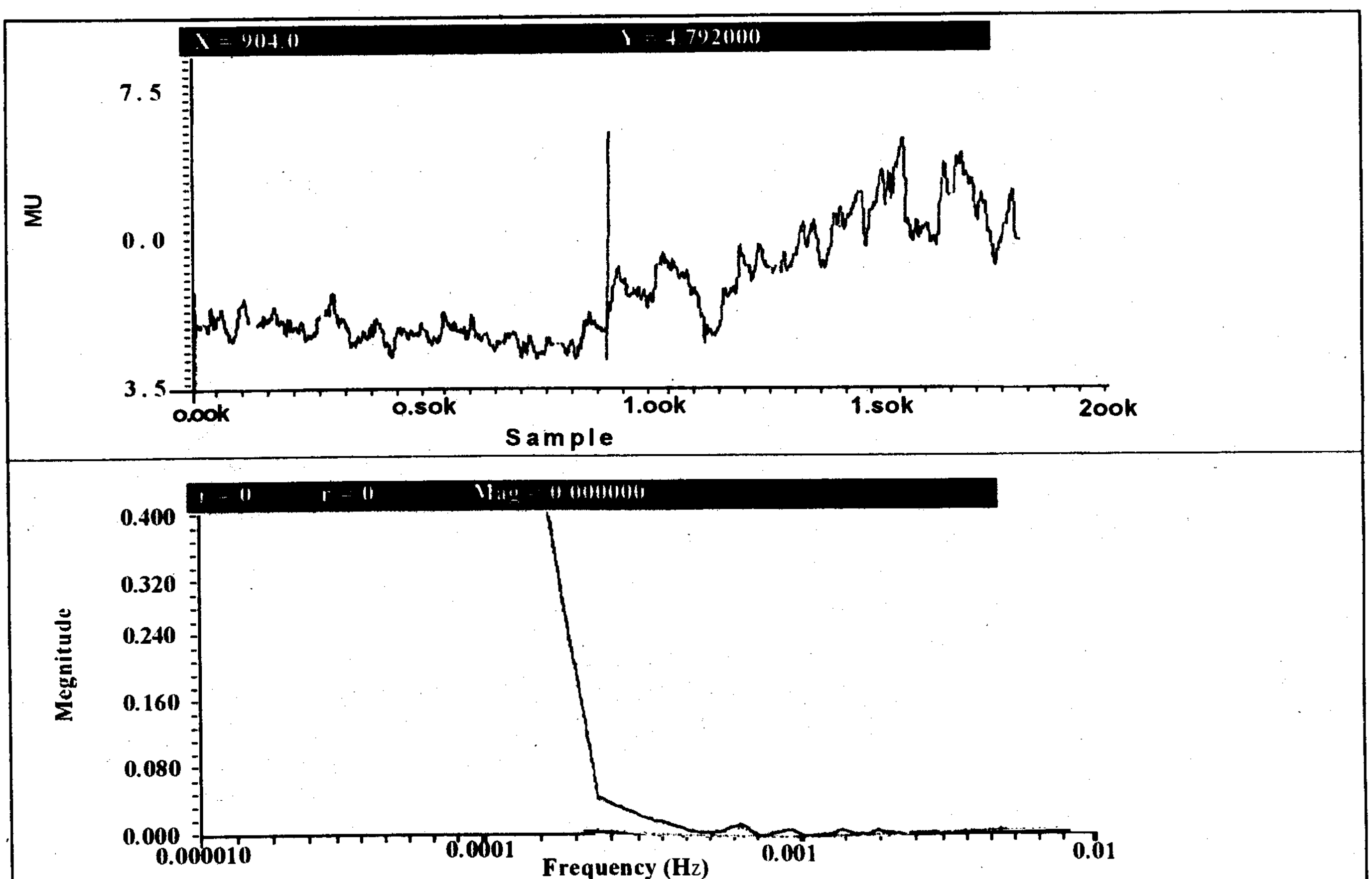
The tool plots the variations in time domain and frequency domain (power spectrum). The power spectrum plot shows the variability at a particular frequency. The time series and power spectrum of moisture of paper made on one of our customer's machine is illustrated below : (note : the plot is Off-Control when the controller is in Manual).

The Power spectrum of this time series indicates that most of the variability occurs rather slowly and it tends to flatten towards the right. The point where the power spectrum flattens out is called corner period.

Variability that is slower than the corner period is what can be controlled (to the left of the corner period) and variability that is faster than the corner period (to the right) is high frequency variations which is usually beyond the controller's cut-off period and one should not attempt to tune the controller. These high frequency/short term variations are to be corrected by troubleshooting the process. Some of the sources of these variations and the methods for elimination of these variations are covered in this paper appropriately.

STOCK PREPARATION

One of the prime requisites for making good quality paper is to have uniform and consistent quality stock to the paper machine. "Good Input to



the machine = Good Output from the machine". This section addresses some of the key parameters and the control strategy for these parameters when adopted can result in uniform furnish to the paper machine.

Control loops

1. Consistency & flow control in each street
2. Blend Chest level (measurement)
3. Machine chest level
4. Ratio & Proportioning control
5. Refiner control

Control Strategy

- Consistency Control

The following are the recommendations to achieve good consistency control.

a) The consistency transmitter should be chosen depending on application; one of the criteria for consideration of the transmitter being the accuracy. Better the accuracy, better the control resolution.

b) The dilution water pressure should be kept constant. The dilution valve should be sized so that the pressure drop across the dilution valve is 30 to 60% of the total available pressure drop.

c) Transportation lag between the consistency transmitter and the dilution valve should not be greater than 10 seconds.

d) The conventional consistency controls have following drawbacks :

: control loop interaction between furnish flow and consistency

: variable process gain due to changes in furnish flow

This can be illustrated as follows :

$F_I + F_D = F_F$

$F_I C_I + F_D C_D = F_F C_F$ where

$F_I C_I$ are flow & consistency before dilution

$F_D C_D$ are flow & consistency of dilution water

$F_F C_F$ are flow & consistency after dilution

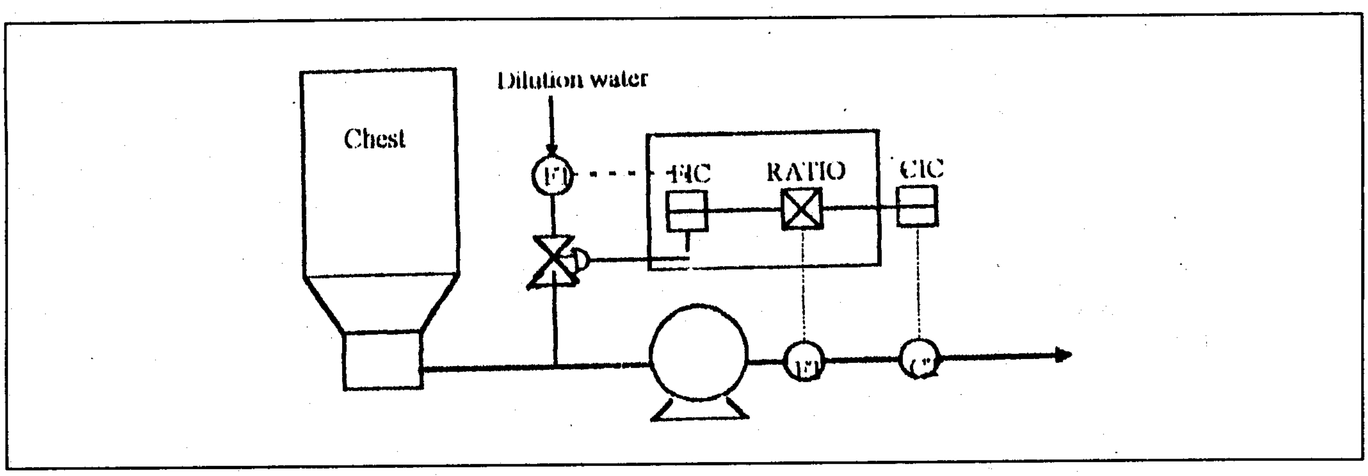
$C_F = C_I + F_D/F_F \quad (C_D - C_I)$

From this it is evident that the consistency is dependent on furnish flow.

Process Gain= $d\, C_F/d\, F_D = C_D - C_I/F_F = -C_I/F_F$ -(as dilution consistency is negligible)

From the above, it is evident that the process gain and thereby the control loop gain varies inversely with furnish flow. Therefore change in furnish flow can cause severe stability problems in consistency control loop.

The above problem can be solved by rationing the dilution flow to the furnish flow as illustrated in the diagram below.



Stock Blending

It is recommended to blend the stock on dry weight basis although conventional practice is based on volumetric flow. It is necessary to have consistency and flow transmitters in each stock street including the broke in order to calculate the dry weight in each street. The consistency control is to be designed as explained above.

The blend chest level controller output is taken as the reference and based on the ratio set for each of the stock dry weights, the flow in the respective stock is controlled.

The dyes, chemicals and fillers' flows are rationed with respect to the thick stock flow.

Refiner Control

The variables to be controlled in the refiner is the horse power per ton of dry stock. In order to achieve this, a consistency and flow transmitter is necessary at the inlet of the refiner for calculating the dry weight fibre. The final control element is the refiner loading motor, The secondary control is the refiner load control achieved by controlling the speed.

APPROACH FLOW

In this section, we discuss not only the controls but also some of the design aspects which affect the controls.

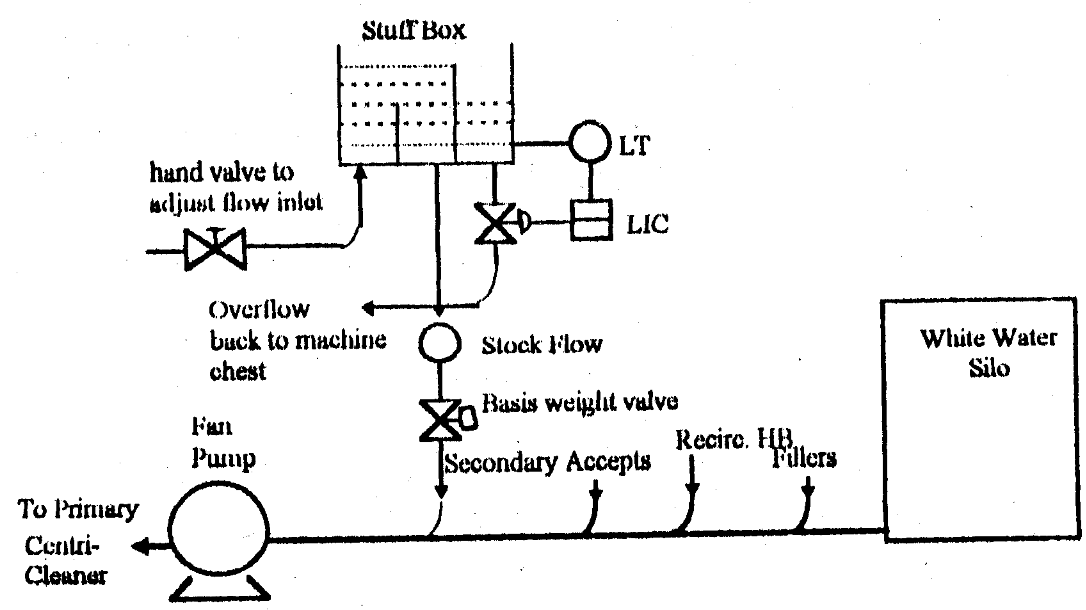
Stuff Box & Fan Pump

The stuff regulating box should be properly designed and the recommended design is illustrated in the diagram below.

The manual valve at the inlet to the stuff box is for adjusting the inlet flow. The level control of the stuff box overflow section controls the recirculation to the machine chest. This is required to maintain the uniformity of refining (control refiner).

The stuff box should be located at a minimum elevation of 6 metres from the centre of the fan pump.

It is recommended not to add any chemicals (like alum, rosin etc.,) as these additions can cause turbulence in the mag flow meter resulting in very noisy stock flow measurement.



The basis weight valve should be located 2 to 3 metres below the silo level.

Piping at fan pump suction

Proper piping at fan pump suction is very important to avoid Machine Direction basis weight variations. Some of the considerations are :

- The thick stock line from the stuff box should be close to the fan pump suction. This is to ensure proper mixing in the fan pump.
- Other secondary lines on the suction line can be added further away from the fan pump suction as shown in the diagram above.
- The piping from the stuff box to the fan pump should not be unnecessarily long and bends should be avoided.
- Fan pump suction line should have an eccentric reducer to avoid air entrapment.
- Any two lines at the fan pump suction should not diametrically oppose each other as the pressure fluctuation in one of the lines causes back pressure in the opposing line.
- Any air in the system has to be removed for better MD basis weight control. In high speed machines, it is a common practice to have deculator. It is recommended to ensure level control in the overflow section of the deculator. In low/medium speed machines, stand pipe may be used. The centricleaner and pressure screen bleed is fed to the standpipe and deaerated stock is fed to the next stage of centricleaners.
- Water cascading from the fourdrinier white water tray to the silo should be avoided as it would result in air entrapment and consequently high frequency MD basis weight variation. The water cascading can be avoided by "channeling" the fourdrinier white water to the silo.

Cleaner reject pit level control is achieved by controlling the dilution water valve. This is important as any head variation in the reject pit leads to MD basis weight variation.

Screen reject pit level control: the reject of each screen to be collected in separate tanks with level control (same as cleaner reject tank control mentioned above).

Headbox

The main parameters to be controlled in the headbox are liquid level and total head. The total head should be controlled tightly as it has a great influence on short term MD basis weight variations. In addition, the jet/wire ratio has to be maintained even during wire speed changes to avoid paper breaks at speed changes.

The liquid level control is usually achieved by controlling the air pad. The total head control can be either by having a mid - ranging arrangement between the stream flow valve and the recirculation valve or by fan pump speed control. (the recirculation valve should be sized for a maximum of 20% of the total flow to the headbox).

The jet/wire ratio is cascaded with the total head and any changes in wire speed is fed forward to the total head controller in order maintain the jet/wire ratio.

For the headbox and fourdrinier parameters affecting the basis weight variations (MD and CD) following measures need to be taken.

- The pressure drop across the tapered manifold has to be balanced to avoid CD basis weight variations.
- The slice lip opening should be uniform and the slice lip polished to avoid CD basis weight varation. Any warping in the slice lip is to be corrected.
- The clearance between the rectifier roll and the headbox wall should be uniform across the headbox pond.
- Any rectifier roll speed change leads to change in the process model of the CD basis weight which causes CD variation.
- Deckle straps should be adjusted properly on the fourdrinier. Any improper positioning of the deckle board causes cross flows at the edges and thus bad CD profile.

- Any change in fourdrinier table like forming board repositioning, foil angle changes and alignment of foils, change in design of foils etc., causes change in process model for the CD basis weight.

Other Wet End parameters to be controlled

Couch Pit

The couch pit is designed to repulp fourdrinier trims during normal operation and repulp whole wet end sheet during sheet break. This kind of operation causes large changes in consistency between normal run and sheet break. To overcome this, a "swing type" couch pit is to be used in conjunction with one of the following instrumentation and control schemes.

a) 2 nos. pumps (one larger capacity and another smaller capacity pump) with 2 nos. solenoid valves.

   During normal operation, the smaller pump pumps the thin stock to the saveall through the thin stock line and valve. (the higher capacity pump and the valve in the thick stock line to be shut during the normal run).

   During wet end sheet break, the higher capacity pump pumps the thick stock to the broke chest via the thick stock line and valve. (the smaller capacity pump and the valve in the thin stock line to be shut during a wet end break).

   The consistency in the couch pit is controlled by regulating the dilution water.

   Both the pumps are on couch pit level control.

b) A single pump with a 3 way valve arrangement:

   During normal operation, the 3 way valve operates to allow the thin stock to flow to the saveall and during the wet end break the 3 way valve operates to allow thick stock flow to go to the broke chest. If the couch pit consistency or the level is low, the 3 way operates to allow for recirculation to the couch pit.

   The couch pit consistency and level are controlled as in the above case.

Dry End Pulper

The dry end pulper is designed to repulp all the dry broke (trimmings from rewinder, finishing house broke and machine breaks at dry end). The consistency and level control of the dry end pulper is very important. Typical instrumentation and control circuit is explained below. A chute shower is operated during the dry end break. The dry end pulper consistency is to be measured and the level to be controlled by means of 2 control valves (one is the discharge valve to the broke chest and the other is a recirculation valve back to the pulper). If the consistency and the level in the pulper is normal, the discharge valve to the broke chest opens and the recirculation valve closes. If level is low and the consistency is normal or low, the recirculation valve opens and the discharge valve closes.

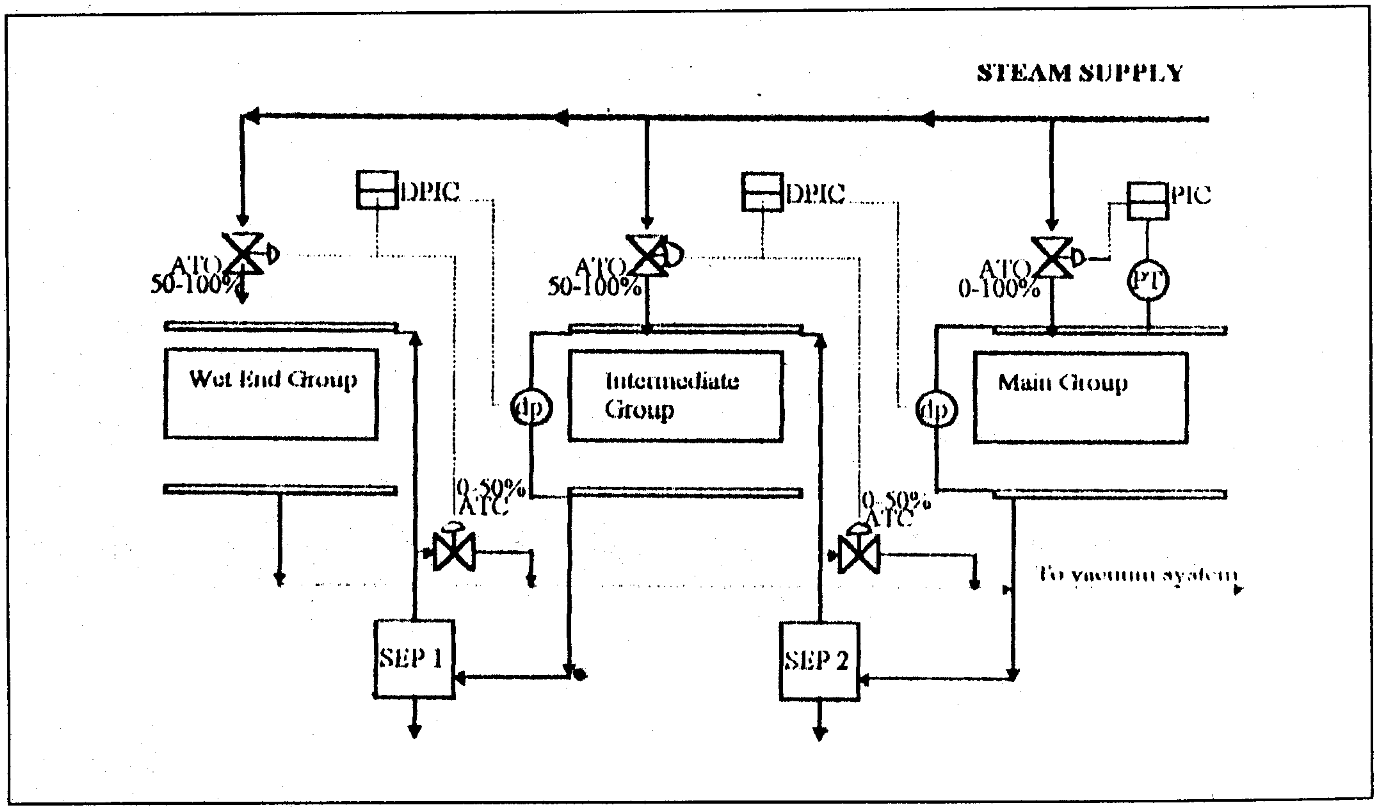
Steam & Condensate system

It is important to have proper heat balance in the steam and condensate system to get good quality paper on the machine. Although there are several steam and condensate system designs, the basic requirements for proper functioning of the steam and condensate system is illustrated below which is a "3 stage cascade system".

In a cascade system, the blow through steam from one section is reused in the previous section. In the example above, the blow through steam from the main dryer group is used in the intermediate group and the blow through from the intermediate group is used in the wet end group. The overall drying rate and thereby the moisture is controlled by pressure control in the main dryer group. The pressure in the intermediate group depends on the differential pressure set on the main dryer group and the pressure in the wet end group is dependent on the differential pressure set in the intermediate group.

The following need to be considered :

- Pressure control
- Differential Pressure control
- Condensate level control



- Pressure and Differential pressure control at Sheet Break
- Choice of siphon based on the condensate behaviour and siphon clearance
- Dryer configuration (conventional or Unirun)

Differential Pressure Control

The DP control is achieved by a split range valve arrangement. The valve in the flash steam dump to the surface condenser is Air to close and the make up valve is Air to open. The operating range for the valves being 0-50% and 50-100% respectively. It is to be noted that the range selection of the valve operation is based on the heat balance of the dryers system. The operation principle is explained below :

If the DP in the main group increases, the live steam valve at the inlet of the intermediate group opens. This creates a back pressure in Separator 2 and therefore restores the DP in the main dryer group.

If the DP in the main group decreases, the valve that vents off excess steam to the low pressure vacuum line and condenser opens thus restoring the DP.

Pressure & Differential Pressure Control at Sheet Break

When the machine is running with sheet on the dryers, the condensing load is of a certain magnitude and the steam supply to the machine is controlled to meet the demand. Pressures and DP's are stable.

At sheet break, the sheet is no longer in contact with the dryers and therefore the condensing load drastically reduces. However, the steam is still flowing in the system in the same quantities as when the sheet was on the machine. As a result there is more steam in the system than is actually required.

This causes imbalance in the system as pressures will rise and DP's will be lost. This causes rapid increase in temperatures in the dryers and condensate will remain in the dryers as sufficient DP is not available to remove the condensate.

Normally a system not fitted with blow down valves and vacuum system takes a long time to cool down to a temperature where the sheet can be replaced without further breakages and removal of the accumulated condensate takes a long time. This causes increase in down time and difficulty in controlling moisture.

To overcome the above undesirable problems, it is necessary to reduce the steam supply to the main group at sheet break to a lower preset value. However the DP is maintained at the same value prior to the sheet break thus ensuring effective drainage of the condensate from the dryers. When the sheet is rethreaded, the steam pressure in the main group is restored to the original value prior to the sheet break.

Surface Condenser : when the system operates at low pressures, it is essential to maintain the recommended vacuum in the surface condenser in order to maintain the required DP in the wet end group. It is recommended to avoid sub cooling type of surface condenser. Water logging in the surface condenser should be avoided. This problem can be resolved by installing a vacuum receiver. A temperature control loop is to be incorporated at the surface condenser.

Choice of siphon based on the condensate behaviour and siphon clearance

The selection of siphon should be so as to optimize the following :

- maximize dryer shell temperature to achieve the maximum drying rate
- minimize the dryer shell temperature deviation to achieve a flat moisture profile
- proper condensate extraction to prevent flooding

Siphon clearance should be adjusted periodically. When blow through steam rate increases, there is a possibility of the siphon tips being eroded. This makes the clearance between the dryer shell and the siphon tip to get enlarged which causes flooding of the dryer can and improper moisture control. The percentage of blow through is to be maintained as per the design and machine speed.

Unirun Screen :

In application where the unirun screens are used, the following key considerations are to be taken into account for proper moisture control.

- As the sheet is not in contact with the bottom cylinders directly and is in contact with the screen, the heat transfer to the sheet is poor. Hence the blow through steam is more from the bottom cylinders than the top cylinders. In a system where separate steam and condensate system is not available for the top and bottom dryers, the high blow through steam from the bottom cylinders could reduce the available DP in the top cylinders and consequently the top cylinders would be flooded. Therefore it is recommended to install separate steam and condensate system for the top and bottom dryers.

Conclusion

Maximum benefits of an online process control system can be accrued by through process survey and optimizing control performance. Should process modification be necessary, it is worthwhile to consider the investment as it goes a long way in improving the quality of the product. Even a good Online Process Control System cannot cover the process deficiency if it exists.