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GPI West Monroe digester optimization project

Valmet Inc. and Graphic Packaging Intl. (GPI) collaborated on continuous digester optimization projects that included three digesters in West Monroe, Louisiana. Graphic Packaging is one of the world's largest manufacturers of folding cartons, unbleached paperboard, coated recycled board, microwave packaging and machinery. The West Monroe facility manufactures combined folding carton for use in beverage and other product packaging.

Kraft pulp digester operation plays a critical role in the whole pulp mill economy. Furthermore, high and steady pulp quality results in additional bottom line profits for the paper mill. The key to pulp production and quality optimization is to ensure selective delignification, which can be accomplished by precise and strategic management and control of optimum cooking conditions. Accurate and reliable pulp quality measurements are essential elements of an advanced control package.

Continuous cooking alkali profile management has become an increasingly important factor to maintain quality targets. Information about the cooking liquor composition within the process can be utilized to determine the alkali profile in the digester and to optimize the addition of cooking chemicals into the process. Cooking liquor measurements give indirect information about the extent of the cooking degree. Typical variation of the white liquor strength is generally 5 %, or greater after production breaks. If this variation is not measured and controlled, it will have a significant effect on cooking conditions and pulp quality. Kappa and residual alkali measurements provide an accurate estimate of pulp yield and with enhanced control of delignification and alkali profile, the mill can increase pulp yield while maintaining steady blow Kappa level.

Before advanced control implementation West Monroe had a high degree of Kappa variability and a lower than optimum average Kappa. The aim was to reduce Kappa variation, stabilize operation, and increase the yield and paper mill runnability. The strategy was to incorporate a MPC (Model Predictive Control) based APC (Advanced Process Control) package with all three digesters in conjunction with Kappa and alkali analyzers, and new chip level gauges.

This paper presents improved results achieved at the GPI West Monroe mill. Digester blow Kappa variations were reduced by more than 50%. The reduced Kappa variation has been sustained for more than a year.

Target

Cooking is a highly interactive process and practically all the major control loops are coupled (1). At the same time, there are a lot of different disturbances present – wood age, density, chip size, white liquor concentration, etc. (Figure 1). The control package discussed in this article works at upper control level and calculates optimal set points for base level controls. Base level controls (like interlockings and speed controls) are in the mill DCS system.

Disturbance source	Effect	Detected by
Chip size	Alkali impregnation	**Residual**, density, kappa
Chip age	Moisture +impregnation	Density
Wood species	Reaction rate	Density, moisture, **residual**
Chip decay	Na consumption	**Residual**
What part of trunk	Kappa	Moisture, density
Chip moisture	Alkali + liquor to wood	Moisture, residual
Bark content	Na consumption	**Residual**
Chip source	Impregnation rate	**Residual**
White liquor Effective Alkali	Alkali to wood ratio	**Residual**
Liquor/Wood ratio	Reaction rate + movement	Moisture, residual
White liquor sulfidity	Reaction rate	**Residual**
Residual	Effective alkali +lignin condensation	**Residual**

Figure 1. Effect of Different Process Variables On Cooking.

Project targets

- Optimal Average Kappa Level
- Reduced Kappa Variability
- Cooking Chemical Savings
- Steam Savings
- More Production from Same Wood
- Better Paper mill runnability
- Zero incident project

The goal was to find and maintain optimum cooking conditions throughout the digester to ensure selective delignification and to simultaneously optimize pulp quality and production costs. To achieve this, reliable pulp quality measurements that provide accurate real-time information were added. Figure 2 shows the implemented control structure.

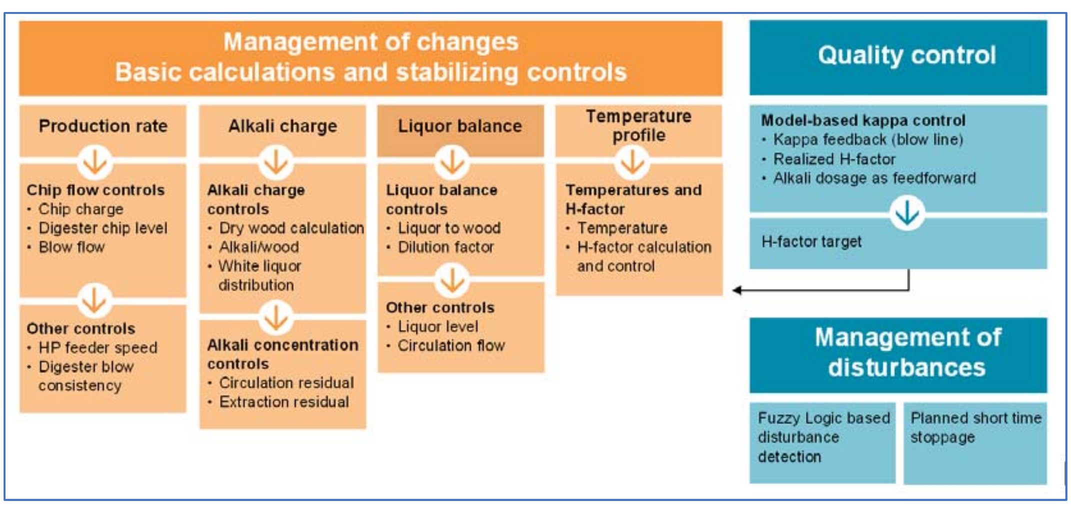


Figure 2. Implemented Control Structure.

Project implementation

Before the project, the entire process area was reviewed, including instrumentation, regulatory controls, lab testing, and other process operating conditions. Process data analyses was part of the study. The purpose of this review was to identify opportunities and establish an economical payback guarantee. Also, the new analyzer's performance and uptime were guaranteed.

Analyzers commissioning was the first part of actual project implementation. The control system installation and start up was followed by the tuning period. The tuning started with base tuning and hands-on operator training at site. The base tuning period was followed by the process stabilization, data and experience collection phase. During this phase process performance follow up was made remotely and actual mill visits were done as needed.

Process optimization is the primary method that delivers project savings. Advanced controls reduce quality variability and stabilize the process, which allows the process to be moved closer to economic optimum compared with baseline.

One key for success on this type of project are the operators, an extremely important step was to complete enough training prior to system implementation. Figure 3 outlines the performance solution delivery process.

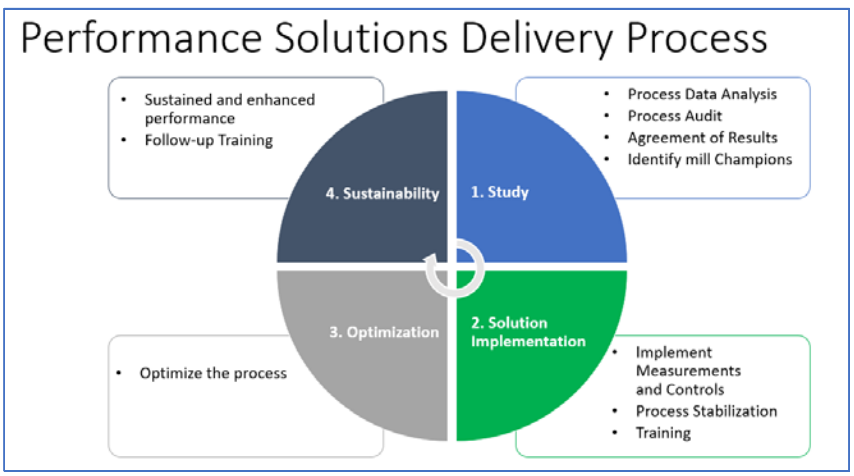


Figure 3. Delivery Process.

New measurements

The project included not only controls, but also special measurements including Kappa analyzer to measure blow Kappa numbers, white liquor/REA alkali analyzer and chip level measurements. Measuring and controlling the amount of residual lignin in the pulp after digester stabilizes fiberline unit operations and produces a consistent downstream product. This improved stability can be leveraged to manage the target kappa number to increase yield, thereby increasing productivity or reducing wood use.

Digester alkali profile management is an important factor for digester optimization projects. Alkali profile is measured by an automatic on-line titrator based on the SCAN-N 33:94 laboratory standard. Both white liquor strength and residual alkali levels are measured.

Pulp quality (Kappa) control

H-factor represents the effects of cooking time and temperature as a single variable. Total H-factor is a sum of zones' H-factors. MPC based Kappa control display is presented in Figure 4.

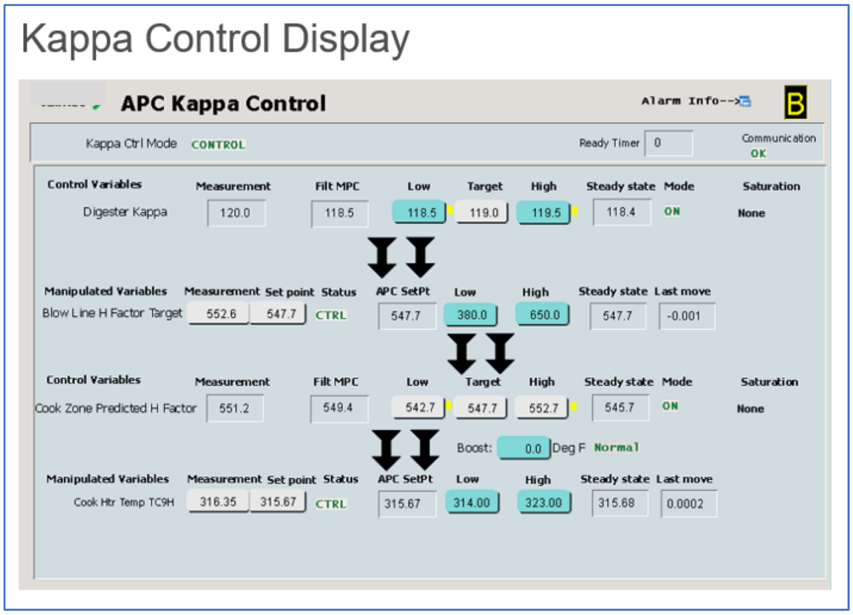


Figure 4. Kappa Control Display Example.

Chips residence times in the digester are calculated based on digester geometry and packing profile. In residence time calculation, information of customer, equipment supplier, and possible tracer measurements are utilized. Kappa feedback control eliminates process long-term disturbances like changes in chip quality.

As a result of optimization project, the overall blow Kappa standard deviation was decreased about 40% compared to base line (Figure 5). Based on steadier blow Kappa, it was possible to increase the digester A blow Kappa target by 7 units (Figure 5). This means higher pulp yield and increased production, especially since the mill is producing unbleached pulp. Figure 5 shows that the results have been getting better after the actual project due to the continuous application performance management (APM).

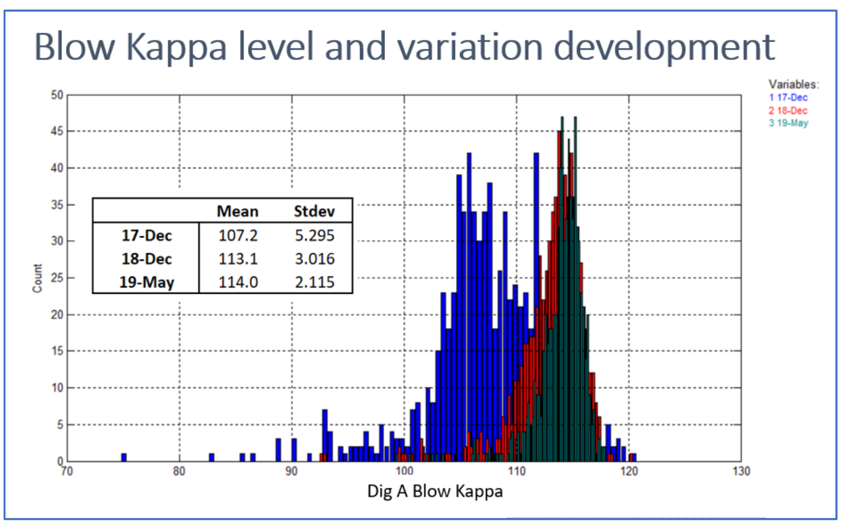
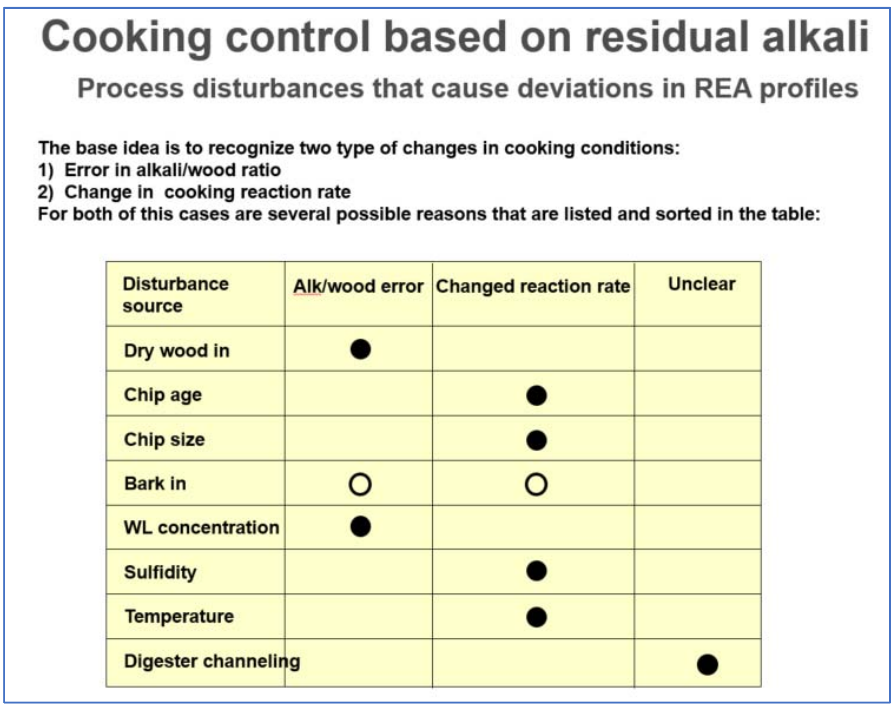


Figure 5. Blow Kappa Development. H-Factor and Kappa Feedback Controls are Applying MPC Control Algorithm.

During the optimization phase of project, a relationship between production rate and H-factor was noticed. The linear relationship was indicating that the H-factor MV target was too high at high production rates, and too low at low production rates. There was also a linear relationship between production rate and residual effective alkali in both the lo-solids and main extractions. This relationship debunks the theory that the H-factor model was incorrect and suggests that the assumption of 100% chip meter packing degree at all rpms was wrong and was the reason for a miscalculation of the production rate, and consequently the alkali dosage controls and zone delays. The solution to this was to add a chip meter filling degree table to the application, which assumes less than 100% pocket filling at higher rpms. Production rate compensation to the calculated H-factor controls was included to limit the linear relationship between production and H-factor at constant Kappa.

Alkali profiling

Along with modern cooking processes, alkali profile management has become an increasingly important factor. The information about the cooking liquor composition within the process can be utilised in the profiling of cooking chemicals into the process (1). Cooking liquor measurements give indirect information about the changes in cooking conditions (Figure 6).


Cooking control based on residual alkali

Process disturbances that cause deviations in REA profiles

The base idea is to recognize two type of changes in cooking conditions:
1) Error in alkali/wood ratio
2) Change in cooking reaction rate
For both of this cases are several possible reasons that are listed and sorted in the table:

Disturbance source	Alk/wood error	Changed reaction rate	Unclear
Dry wood in	●		
Chip age		●	
Chip size		●	
Bark in	○	○	
WL concentration	●		
Sulfidity		●	
Temperature		●	
Digester channeling			●

Figure 6. Process disturbances that cause deviations in REA profiles.

When the amount of chips, moisture and cooking liquor strength is known the desired white liquor flow rate can be exactly calculated (2). Total alkali/wood ratio target is given in recipe. Momentary total alkali/wood ratio is calculated based on dry wood flow, momentary total white liquor flows and related white liquor and black liquor concentrations. White liquor and black liquor concentrations are measured with automatic alkali analyzer. Alkali/wood ratio is automatically corrected based on residual alkali measurements. Maximum correction is limited with recipe value. Changes of white liquor concentration are automatically taken into account in the white liquor total flow. Residual alkali level before and after the project are presented in Figure 7.

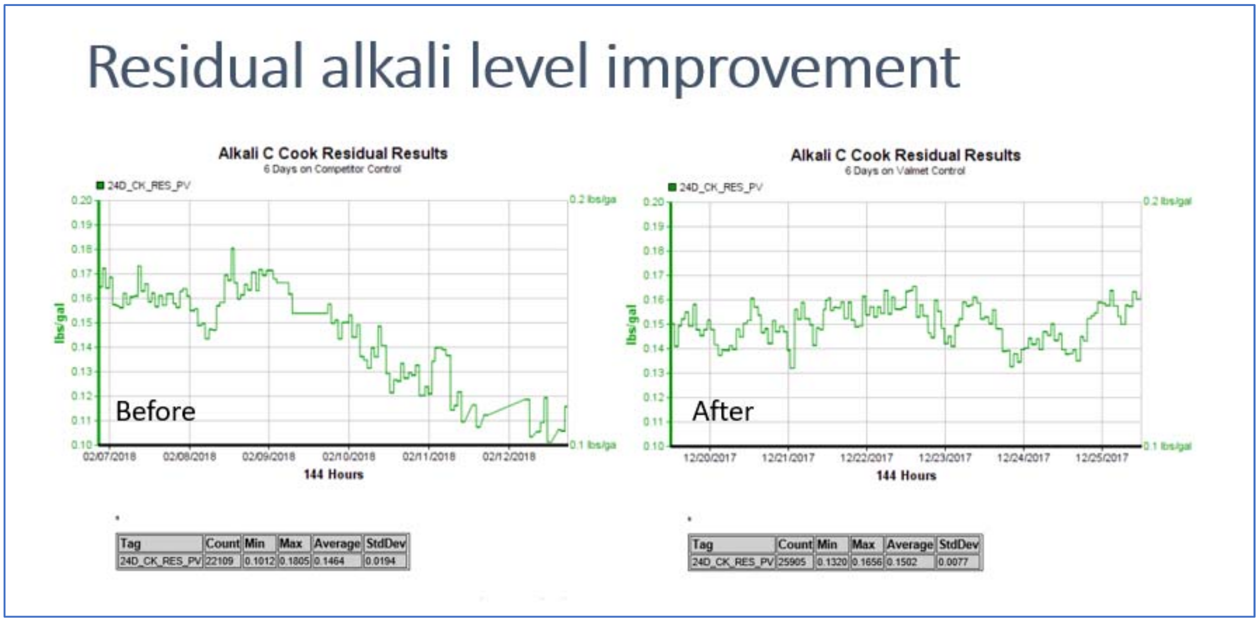


Figure 7. REA Before and After the Project.

Alkali level and profile has proven to have a clear affect on cooking yield (3). Figure 8 shows the relationship between residual alkali, H-Factor and blow Kappa number.

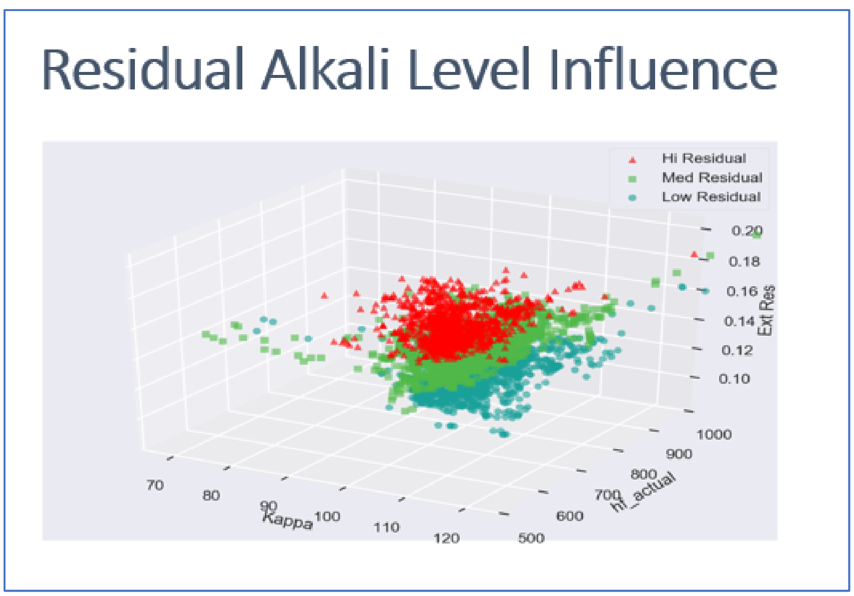


Figure 8. REA vs. H-Factor and Kappa.

In the same way as quality control for kappa, the alkali profiling control is applying the MPC algorithm.

Management of changes

The changes in production rate, pulp grade and/or wood species managed through the whole process. They are simple to start and follow from a “Management of Changes” display. The system makes automatic setpoint changes at the proper time and at the given rate. The idea is to free operators from routine duties to allow them to concentrate on more demanding tasks such as coordination of actions, and to tasks that need intelligent decisions. Due to management of changes some production increase is achieved because the amount of off-grade pulp is minimized. Another advantage is that the change management application decreases human errors. The process parameters are changed automatically at the right time to their new target values.

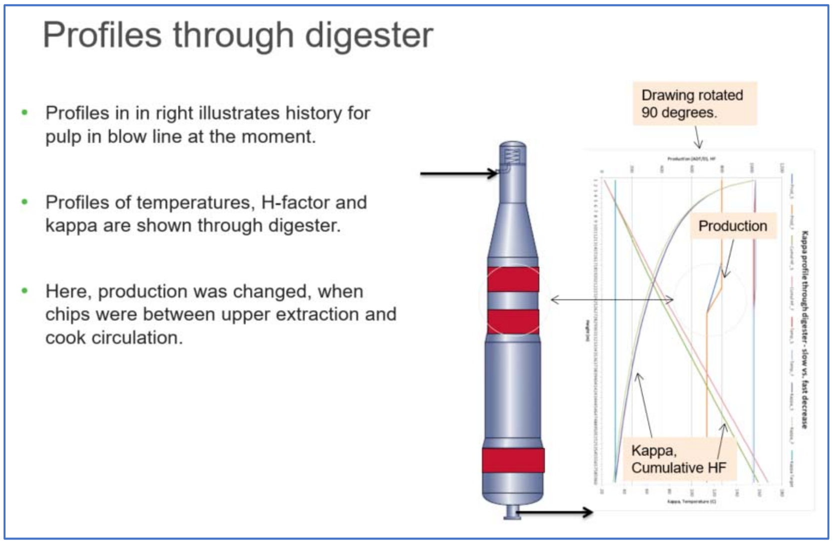


Figure 9. Digester Profiles.

Liquor to wood ratio control

Liquid coming to the digester consists of water in chips, black liquor, white liquor and condensed steam. Liquor to wood ratio is controlled in the top of the digester and between extractions. Liquor balance controls are based on digester liquor balance and liquor/wood ratios in different zones. The principle of control is shown in Figure 10.

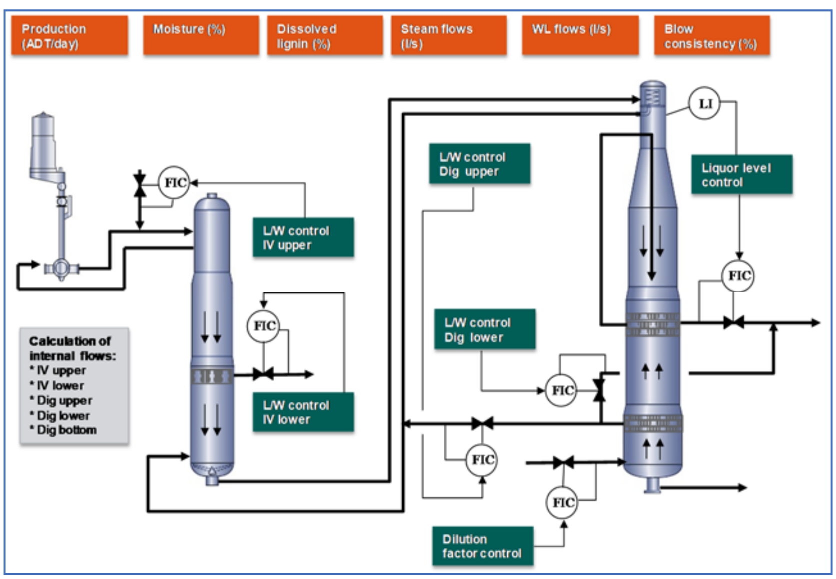


Figure 10. Principle of Liquor Balance Controls In Dual Vessel Process.

Dilution factor is the ratio between downwards flowing pulp and upwards flowing washing liquor. Control affects the amount and/or distribution of total washing liquor pumped to the bottom of the digester.

Application Performance Manager (APM) is a suite of tools used to monitor, evaluate, and troubleshoot the performance of optimization solution. The analyzers performance monitoring is included to APM functionality.

APM includes:

- Web trends and displays
- Automated graphical reports
- Automated email alerts

Training

During the theory training the general targets, functions and controls of the optimization were studied step by step. The essential structure of the programs were learned. The purpose was to teach an overview of optimization to the operating and maintenance personnel.

After the theory training the hands-on system operating training was done in the control room during the normal operation of the mill. Special attention was paid to the content of the operating windows and their utilization in the practical process operation.

Technical engineers, shift and relief supervisors and other management personnel were also trained in a formalized classroom environment.

Summary

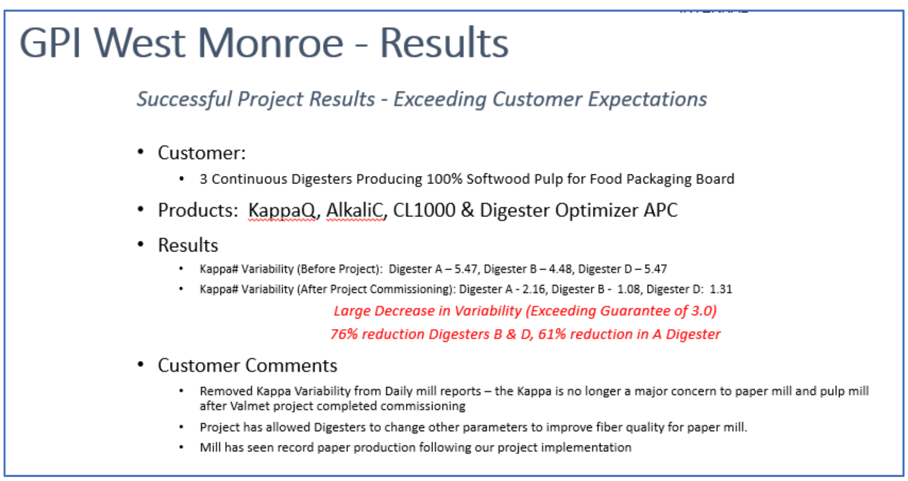


Figure 11. Project Results.

Automated titration based on-line measurement and optical Kappa measurement provides quality measurements for operators and optimization purposes. All this is combined with sophisticated optimization control algorithms. As a result, Kappa and residual alkali level standard deviation reduction was achieved (Figure 11.). This resulted in chemical savings and better yield in digester. Based on an increased Kappa target, the mill can justify 20 incremental tons/day *vs*. the 6 ton/day project goal. Other significant savings are realized from better runnability, and the mill has seen a record production following the project implementation.

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3. Riika Rautiainen, Raimo Alén, Influence of cooking conditions on the properties of first-thinning scots pine (pinus sylvestrís) kraft pulp. Cellulose Chemistry and Technology. 43(7):281-286 · July 2009

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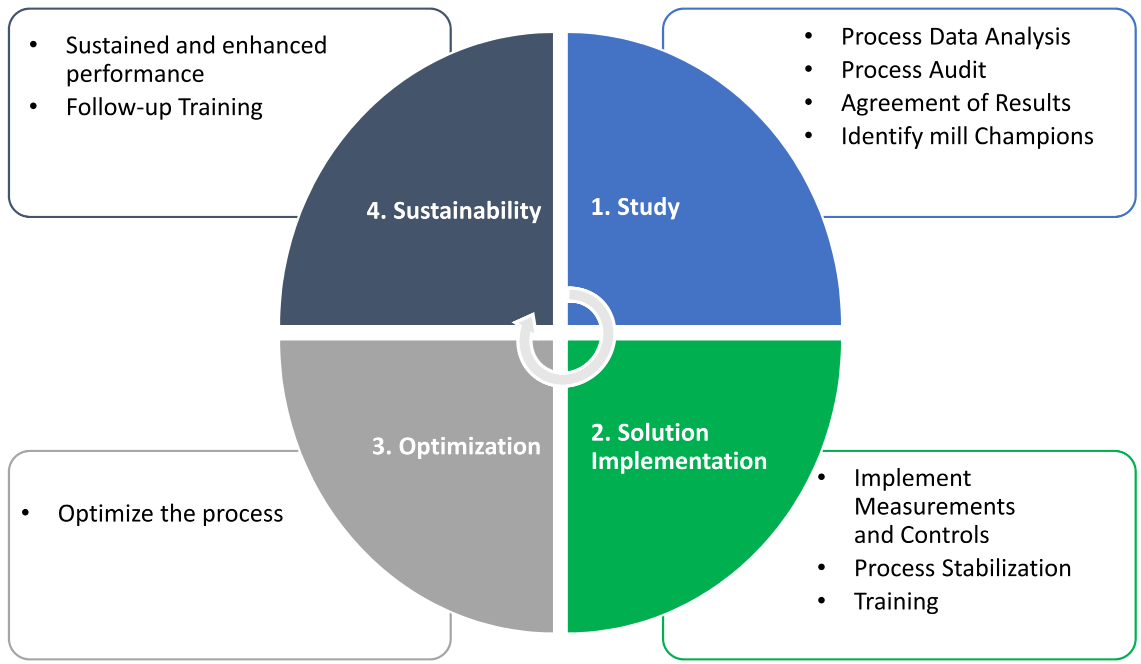
Performance Solutions Delivery Process



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Effect of process variables on cooking

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Chip age	Moisture +impregnation	Density
Wood species	Reaction rate	Density, moisture, **residual**
Chip decay	Na consumption	**Residual**
What part of trunk	Kappa	Moisture, density
Chip moisture	Alkali + liquor to wood	Moisture, residual
Bark content	Na consumption	**Residual**
Chip source	Impregnation rate	**Residual**
White liquor Effective Alkali	Alkali to wood ratio	**Residual**
Liquor/Wood ratio	Reaction rate + movement	Moisture, residual
White liquor sulfidity	Reaction rate	**Residual**
Residual	Effective alkali +lignin condensation	**Residual**

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Chip age		●	
Chip size		●	
Bark in	○	○	
WL concentration	●		
Sulfidity		●	
Temperature		●	
Digester channeling			●

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Implemented Solution Components

Management of changes
Basic calculations and stabilizing controls

Production rate

Chip flow controls
- Chip charge
- Improve vessel and digester chip level
- Blow flow

Other controls
- HP feeder speed
- Digester blow consistency

Alkali charge

Alkali charge controls
- Dry wood calculation
- Alkali/wood
- White liquor distribution

Alkali concentration controls
- Circulation residual
- Extraction residual

Liquor balance

Liquor balance controls
- Liquor to wood
- Dilution factor

Other controls
- Liquor level
- Circulation flow

Temperature profile

Temperatures and H-factor
- Temperature
- H-factor calculation and control

Quality control

Model-based kappa control
- Kappa feedback (blow line)
- Realized H-factor
- Alkali dosage as feedforward

H-factor target

Management of disturbances

Fuzzy Logic based disturbance detection

Planned short time stoppage

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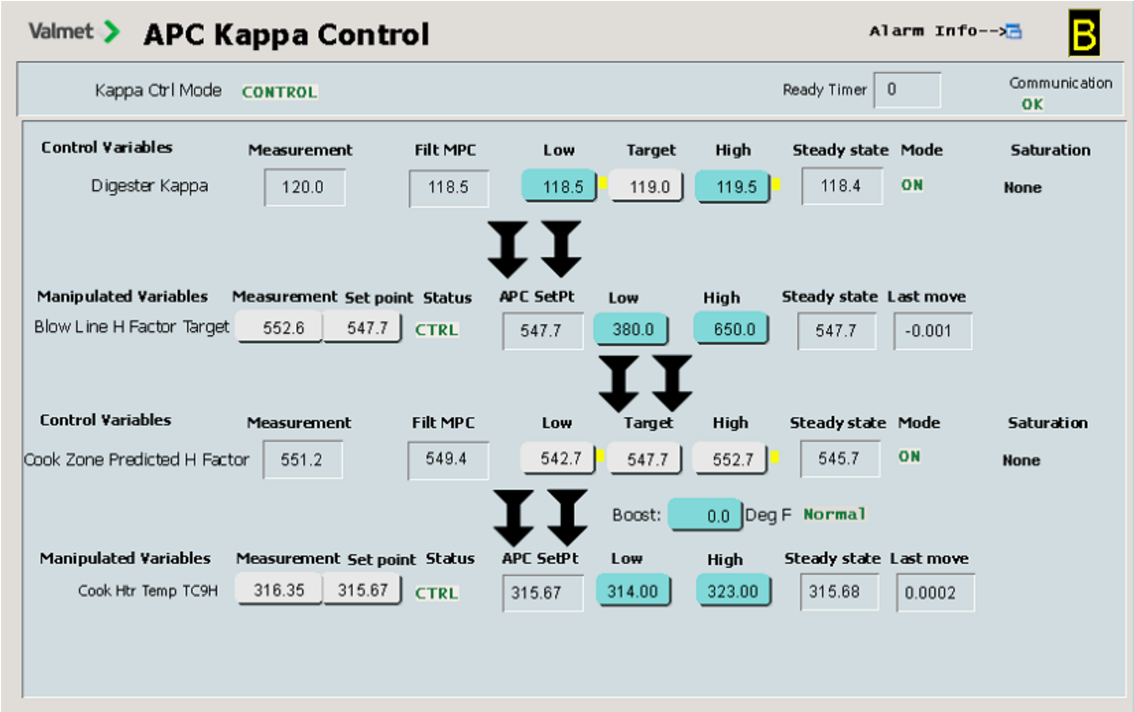
Kappa Control Display Example



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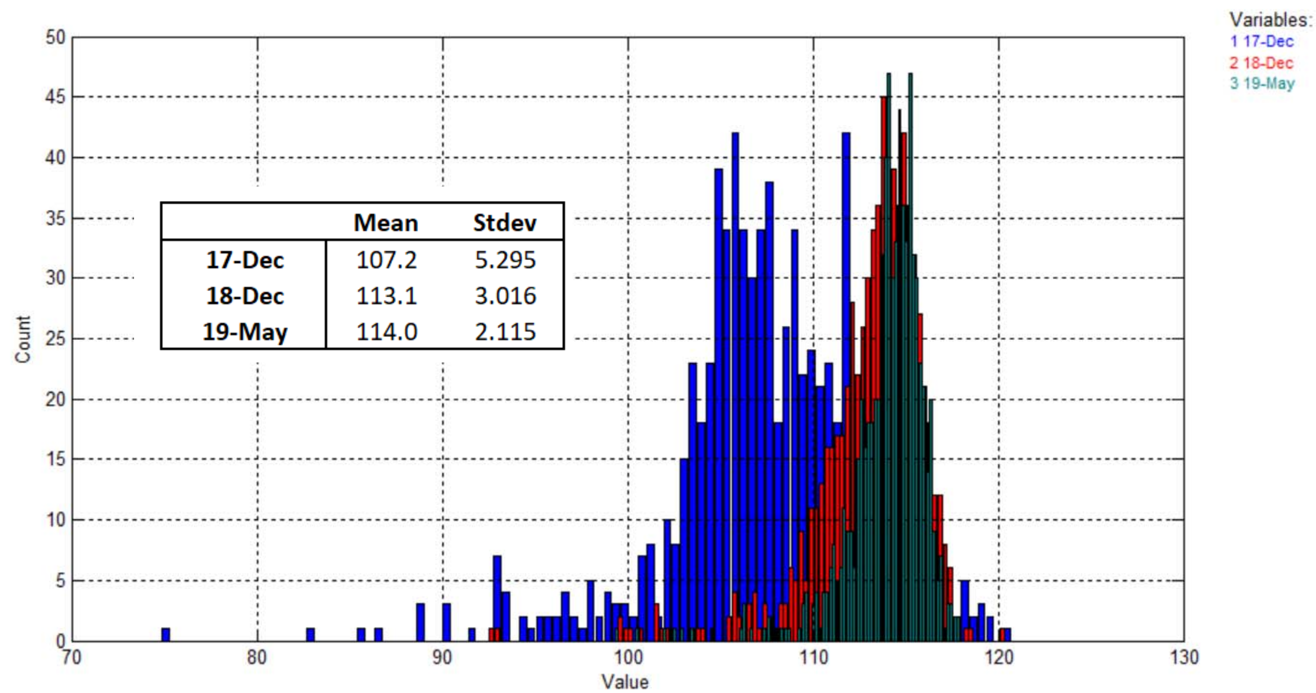
Blow Kappa level and variation development



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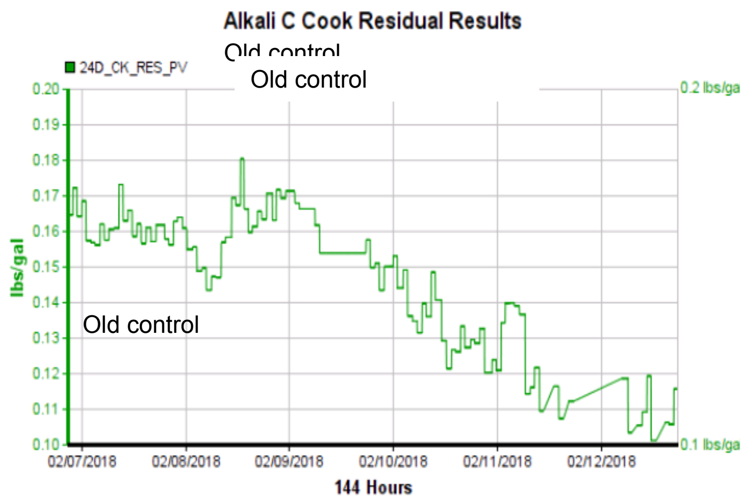
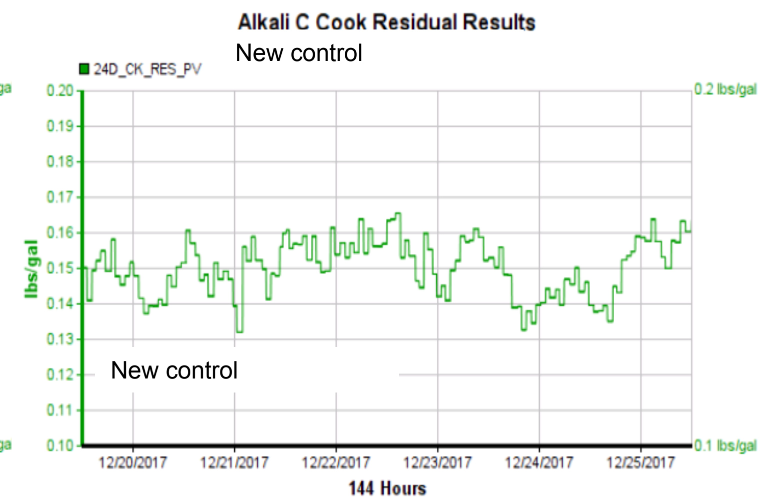
Residual alkali level improvement



Tag	Count	Min	Max	Average	StdDev
24D_CK_RES_PV	22109	0.1012	0.1805	0.1464	0.0194



Tag	Count	Min	Max	Average	StdDev
24D_CK_RES_PV	25905	0.1320	0.1656	0.1502	0.0077

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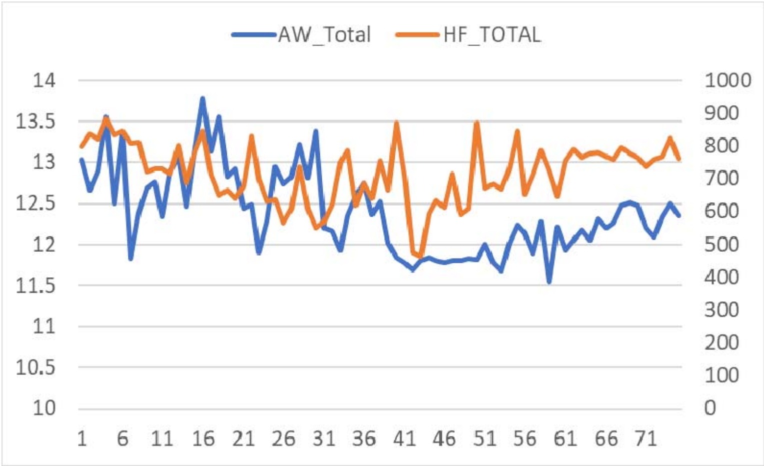
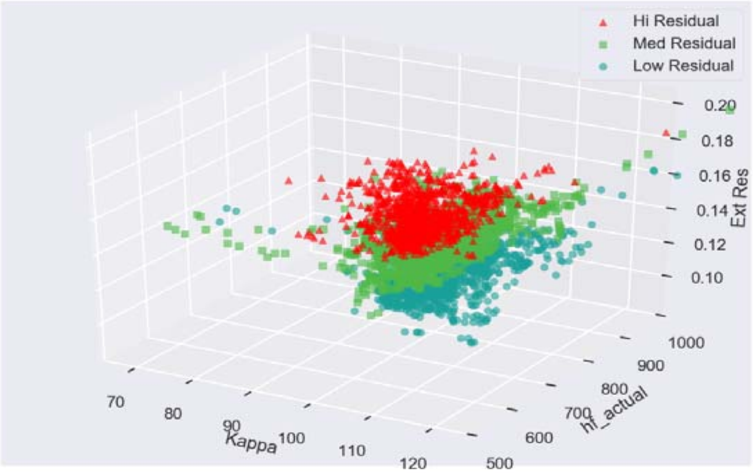
Residual Alkali Level Influence





-3.047	kappa per %EA
-0.328	%EA per Kappa

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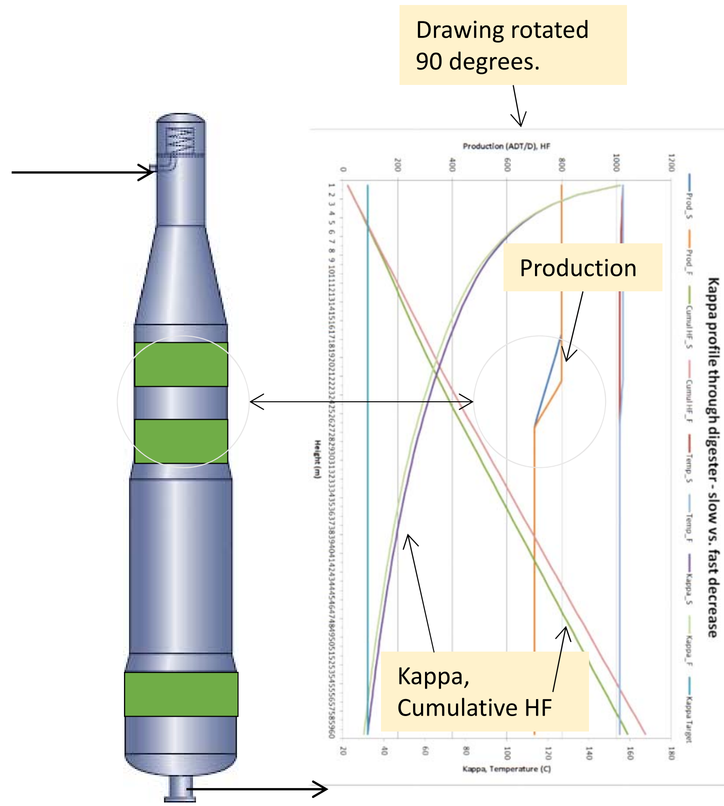
Profiles through digester

-Profile on the right illustrates history for pulp in blow line at the moment.

-Profiles of temperatures, H-factor and kappa are shown through digester.

-Here, production was changed, when chips were between upper extraction and cook circulation.



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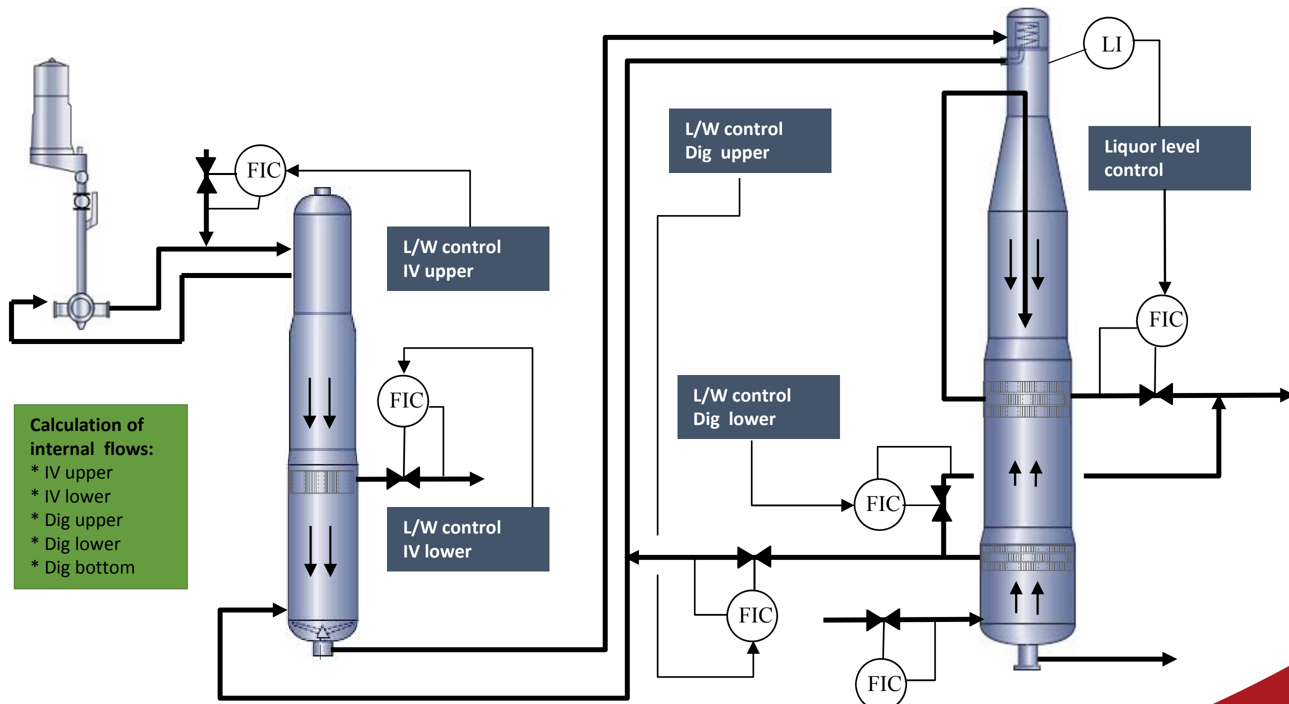
Liquor balance controls

Dual vessel

Production (ADT/day) | Moisture (%) | Dissolved lignin (%) | Steam flows (l/s) | WL flows (l/s) | Blow consistency (%)



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GPI West Monroe – Results

- Project Results

Customer:

3 continuous digesters producing 100% softwood pulp for food packaging board

Products: KappaQ, AlkaliC, CL1000 & Digester Optimizer APC

Results:

Kappa# variability (before project): Digester A 5.47, Digester B 4.48, Digester D 5.47

Kappa# Variability (after project commissioning): Digester A – 2.16, Digester B – 1.08, Digester D: 1.31

Large decrease in variability (exceeding guarantee of 3.0)

76% reduction Digesters B & D, 61% reduction in A Digester

Customer Comments:

Decrease in Kappa variability has removed the major pulp quality concern to paper mill.

Project has allowed digesters to change other parameters to improve fiber quality for paper mill.

Mill has seen record paper production following our project implementation