Press section water balance testing

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ABSTRACT: Monitoring and understanding press section parameters is essential to being able to establish best practices for optimal machine operating performance. Having equipment and methods in place to obtain accurate information regarding water removal in the press section (including dewatering through press nips and uhle boxes) allows for a means to establish optimal operational standards and pinpoint areas requiring improvements. Measurement of water removal through properly designed and installed weir boxes, supplemented by means of measuring shower water supply with rotometers, assists in providing accurate information necessary to perform water balance testing in the press section. This paper discusses the approach and method implemented to establish a monitoring program that is used to determine the impact of varying press nip loadings, and press shower flows/pressures on press section water removal. Modification to seal pit weir boxes provided a means to conduct accurate, on-line, water- removal and water balance studies by individual positions within the press section.

Application: This paper presents a useful method to understand and baseline a mill's pressing operations using water balance testing.

We developed a press-monitoring program for our No. 4 linerboard machine, including water balance testing, to quantify and take some of the mystery out of what occurs during the pressing operation.

Whenever the No. 4 PM experienced issues around runnability especially related to high levels of wet end breaks, the area of focus was usually around the press section. Often the solutions were very expensive. They frequently consisted of changing out press felts, redesigning the felts, or increasing the amount of chemical cleaning. They also required increased downtime to batch clean press felts and a significant amount of mill personnel man hours. Other issues related to machine runnability problems included the following:

- Having to slow the machine down and add steam every time we turned on the felt cleaning showers.
- Streaking the paper every time we cleaned the felts—twice per day. Sometimes getting customer complaints.
- Changing felt conditioning programs.
- Chasing showering designs and locations.
- Evaluating roll cover issues.

Big Island's PM 4 paper machine was designed to produce a daily average of 625 saleable tons of recycled linerboard. It currently averages about 800 saleable tons/day from 100% old corrugated container (OCC). Its grade structure is from 26–42 lb./1000 ft^2 basis weight. The machines' maximum speed is 2500 ft/min. It trims 188 inches at the reel.

The No. 4 linerboard machine press section contains two straight through roll presses (**Fig. 1**). All press rolls are felted. The design loading is 1500 pounds per linear inch [PLI (262.5 kN/m)] for the first and 2000 PLI (350 kN/m) for the second. We currently load the first press to 1250 PLI (219 kN/m) and the second press to 1900 PLI (332.5 kN/m). The first press rolls are blind drilled. The second press rolls are smooth. There are two uhle boxes per position in the first press and one uhle box per position in the second press. There is a steam shower under the transfer roll between the presses. There are lazy steam showers over the uhle boxes in both positions in the second press.

PRESS SECTION MONITORING

Since "the primary objectives of pressing are to remove water and to consolidate the web," [1] we decided to focus on the water balance in the press section, to address machine runnability issues. By better understanding the water balance in the pressing operation, we could answer many questions regarding factors that affect water removal, sheet temperatures, and drying efficiency, including energy use. We found that during monitoring of press-uhle box weir flows, the same numbers were being recorded day after day. There were little or no changes in weir flow over the felt life (we changed the felts every six weeks) or by grades produced.

We monitored the flow for each individual press by the height in a 60-degree V-notch as the water overflowed the vacuum drop-leg seal pits (**Fig. 2**).

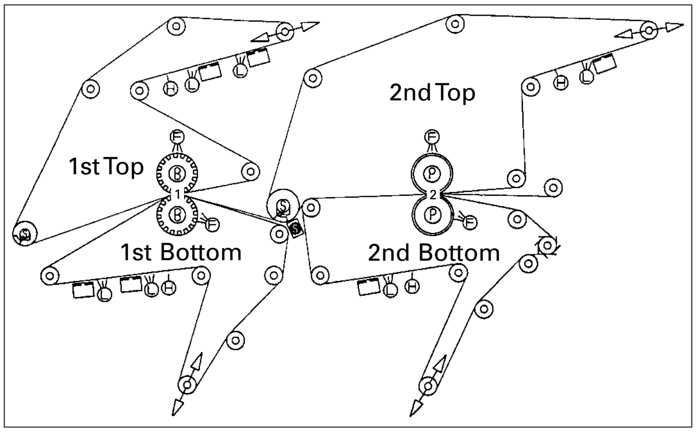
The vacuum supplier provided templates for converting height in the weir to flow rate in grams per meter. These templates were attached to each individual weir box. Due to high flow volumes and fluctuations in flow in the first top (pickup felt) weir, we modified the opening to a large 90-degree V-notch.

To validate accuracy of previously recorded weir data, we instituted a new program to monitor the weirs on a daily basis by measuring the liquid height with a ruler and converting to gallons per minute flow using Ingersoll-Rand *Cameron Hydraulic Book* weir tables [2]. These tables can also be found in the U.S. Filter/Permutit *Water and Waste Treatment Data Book* [3].

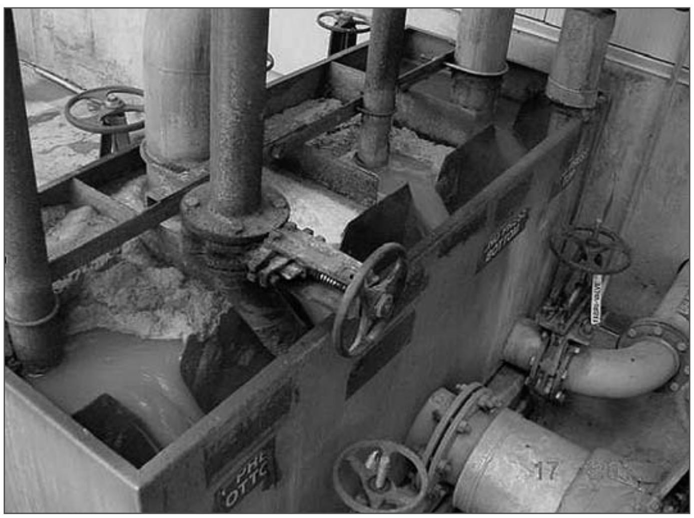
Water balance testing

Previously recorded weir data was consistent with newly established monitoring data when compared over two complete felt cycles. We recorded weir flows measurements in a water balance spreadsheet created in Microsoft Excel software (**Fig. 3**).

We determined total flow measurements from the weir boxes and saveall pans using a 21-L collection bucket and a



1. No. 4 paper machine press section diagram.



2. Monitoring the weirs and measuring the liquid height.

stopwatch. The saveall pan collects and contains the excess shower water not removed in the uhle boxes. This water drains down a pipe from each felt to the drain. Some assumptions estimating press section shower flows were made using tables supplied by shower nozzle manufacturers based on operating feed pressures.

To estimate the sheet consistency entering the press section, we dried couch trim grab samples overnight in an oven and calculated moisture content. We grabbed samples after each press (primarily during sheet breaks). In addition to gathering water balance information, a spreadsheet was started to collect information regarding other key parameters around the press section, including vendor-supplied information, such as the following:

- Felt calipers
- Uhle box vacuums (had to replace all field gauges)
- Shower pressures (had to replace all field gauges)
- Sheet temperatures into/out of and around the press section
- Water balances using the gamma gauge
- Felt moisture and filling analysis
- Felt permeability using water jet equipment.

When we evaluated the collected weir flow data, the water measurement calculations would not balance. Based on weir flow measurements, using conversion tables, exit press consistencies were calculating less that 40%, which conflicted with gamma gauge measurements of 45%. Much of the information gathered was not coinciding with the "excepted train of thought" regarding what was actually occurring in the press section. For example, we thought the second press felts (both top and bottom) would start to remove more water to compensate as the first press felts (both the top and bottom felt) started to fill, compact, and wear. However, we found no data to support this premise. The data gathered also started to conflict with data supplied by vendors—especially the moisture data for calculated sheet consistency entering and exiting the press.

In order to verify the accuracy of the most recent measurements taken, we implemented the following steps:

- Installed sight glasses on both bottom-felt position separators. Sight glasses showed that the first bottom separator was constantly flooded. This resulted in the associated separator vacuum pump continuously carrying a large volume of water. Based on this information, we upgraded the first bottom felt uhle box separator pump. This allowed for measuring the full volume of water over the first bottom felt weir.
- Switched to "bucket and stopwatch" method to measure weir flows.
- Installed flow meters on a set of high-pressure and low-pressure showers to establish the relationship of shower pressure versus shower flow. This also provided a means to measure the amount of retained water versus amount of water discharged through the saveall pan.
- Changed pressure gauges on all of the press section showers.
- Implemented a maintenance program to assure that all the shower nozzles were clean and open.
- Calibrated all of the vacuum transmitters.
- Lifted the vacuum constraints on the second press felts
- Obtained a better feel for the level of accuracy from outside data sources.

The next step was to generate a more accurate method to measure the seal pit weir flows. We accomplished that by installing a large pipe with a gate valve on the back of each seal box (**Fig. 4**). Measurements could then be accurately taken by opening the valve and dumping the entire water flow into either a 75- or 55-gal polypropylene container (Fig. 4). We verified and calibrated the actual gallon capacity of the containers using a 21-L bucket. The calibration consisted of filling the containers with water from the 21-L buckets until they reached a specified fill level. This fill level could then be converted to gallons.

The process involved opening the valve on the backside of each weir box until there was no flow going across the V-notch on the other side. We used a stopwatch to measure the fill rate to calculate the flow from the weirs in gallons per minute.

Due to the large discrepancy between the measured flows in the container and the estimated flows using the V-notch calculation from the conversion tables, we calibrated the container several times and even cross-checked calibration using a larger container (**Table I**).

Next, we evaluated the press section water balance by confirming actual press section shower flow rates. To do that, we installed rotometers on both the low-pressure and the high-pressure water lines. We could then isolate and measure the flow through each shower by turning one on and leaving the other showers off. We could also vary the shower pressures to deliver different flows and verify actual flows by the rates measured through the rotometers (**Table II**).

Attempting to account for the effect, and water contribution, from the press section steam shower presented a major challenge. As shown in Fig. 1, the press section steam shower is located on the transfer roll between the first and second presses. If we incorporated the condensate from the steam shower into the water balance, the calculated solids exiting the press were extremely low. If we assumed that contribution to the water balance from the steam shower was negligible, the water balance calculations in the Excel spreadsheet yielded reasonable results. In fact, often when assuming negligible contributions from steam shower condensate, the water balance calculations result exactly matched those obtained by using a gamma gauge.

The steam shower contributes significantly in increasing the sheet temperature and consistency exiting the press section. Increasing the sheet temperature 10°C during pressing generally improves the sheet dryness at least 1%. Under dryer-limited conditions this could allow as much as a 5% increase in machine speed (4% due to the dryness increase and 1% due to temperature increase).

Steam showers are extremely useful primarily due to their high latent heat condensation. One kilogram of steam will heat 100 kg of water by 5.6°C. It is known that the key to effectiveness of a steam box is using steam as energy transfer medium which must be condensed into the sheet. The condensing rates are influenced by [4]:

- Condensing surface available
- Air in the condensing zone
- Steam temperature.

Press Section Balance- May 11th, 2001							
Baseline balance							
06/12/2002							
	tph	gpm					
Dry stock Production rate into press section	31		124				
Solids off couch	22.1%						
amount of water into 1st press section from st	436	gpm					
amount of water into 1st press by showering							
1st uhle - 1st top	12	gpm			Balance check		
2nd uhle - 1st top	12	gpm			total showers in	106	gpm
high pressure shower - 1st top	20	gpm			total in	542	gpm
1st uhle - 1st bottom	12	gpm			total out	542	gpm
2nd uhle - 1st bottom	12	gpm			difference =	0	gpm
high pressure shower -1st bottom	20	gpm			1st press takes this amount of sheet water=	223	gpm
roll lube shower - 1st top	9	gpm					
roll lube shower - 1st bottom	9	gpm					
estimate felt cleaning dribble		gpm					
leaving from 1st top saveall pan	16.3	gpm					
leaving from 1st bottom saveall pan	6.8	gpm					
leaving from 1st top seperator weir	196.1	gpm					
leaving from 1st bottom seperator weir	104	gpm					
estimate 1st bottom roll lube to ground	6	gpm					
					enter split between 1st & 2nd press=	0.6364	
solids off 1st press					37%		
amount of water leaving 1st press from sheet	213	gpm					
Press section steam shower @ 10,000 lbs/hr with 10% loss					gpm		
(This is a direct contribution of water to the actual sheet)							
amount of water into 2nd press	213						
press consistency into the 2nd press	37%						
amount of water added into second press by showering							
uhle - 2nd top	12	gpm					
high pressure shower - 2nd top	20	gpm					
uhle - 2nd bottom	12	gpm			total showers	82	gpm
high pressure shower -2nd bottom	20	gpm			total in	295	gpm
roll lube shower - 2nd top	9	gpm			total out	295	gpm
roll lube shower - 2nd bottom	9	gpm			difference =	0.0	gpm
estimate felt cleaning dribble		gpm			2nd press takes this amount out=	62	gpm
lazy steam contribution to 2nd top	0	gpm					
lazy steam contribution to 2nd bottom	0	gpm					
2nd press roll cooling shower		gpm					
leaving from 2nd top saveall pan	15.34	gpm					
leaving from 2nd bottom saveall pan	6.5	gpm					
leaving from 2nd top seperator weir	59	gpm					
leaving from 2nd bottom seperator weir	57.67	gpm					
2nd bottom roll lube to press pit.	6	gpm					
Solids out press						45.1%	
amount of water leaving 2nd press with sheet	151	gpm					
sheet off reel	33.2		132.8	gpm			
Moisture of reel	6.8%		9	gpm			
dry stock off reel	31		124	gpm			
design for high pressure showers is 25 gpm at 400 psig							
design for low pressure showers is 18 gpm at 45 psig							

3. Water balance spreadsheet using Excel.

The condensing surface (the sheet) is probably the most limiting factor in the condensing rate. The greater the ratio of exposed surface area to the mass of the sheet, the better the energy transfer to the sheet. Therefore, a lightweight, dry, porous sheet is easier to heat than a heavyweight, wet, nonporous sheet.

Due to the variables in heat transfer and condensing rates when using a steam shower, calculating the energy transfer is practically impossible. Therefore, the exact condensing rate or amount of water the steam box contributes to the press section can not be accurately calculated.

At this point we decided to assume water contributions from the steam shower are negligible and the water balance method developed provides consistent results.

4. The author dumping flows from back of seal pit weir box.

	1st BOTTOM	1st TOP	2nd BOTTOM	2ND TOP
Weir inches	5	6 5/8	3 5/8	4
Conversion from table (gal/min)	70.8	248	32	40.5
From nash template (gal/min)	75	N/A	32	42
75 gal. bucket and stopwatch (gal/min)	103.3	217.2	61.38	51.03
50 gal. bucket and stopwatch (gal/min)	103.97	223.4	61.7	51.56

I. Comparison chart of water balance testing machine.

Equivalent slot width =

$$\frac{\left[(A \times B) + \frac{A^2}{4}\right] \times \left(\frac{D}{C}\right)}{D} = ?\ \text{in}^2$$

Dwell time =

$$\frac{\text{Equivalent slot width}}{(E/5)} = ?\ \text{seconds}$$

Velocity =

$$\frac{F}{(\text{Equivalent slot width})\ (D)} = \frac{\text{ft}^3/\text{min}}{\text{in}^2}$$

Equivalent slot width =

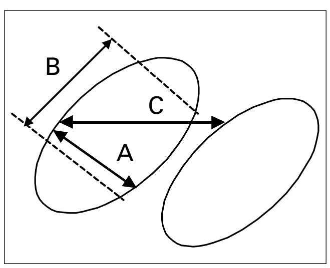
$$\frac{\left[(0.75 \times 1.875) + \left(\frac{0.75^2}{4}\right)\right] \times \left[\frac{208}{1.625}\right]}{208} = ?\ 1.137\ \text{in}^2$$

Dwell time =

$$\frac{1.137}{(2500/5)} = 0.00227\ \text{s}$$

Velocity =

$$\frac{3786}{1.137 \text{x} 208} = 16\ \frac{\text{ft}^3/\text{min}}{\text{in}^2}$$



A = Width of slot
B = Length of rectangular section of slot
C = Spacing between slots
D = Felt width (208 in)
E = Max speed (2500 ft/min)
F = Vacuum pump capacity (3786 ft^3/min)

5. Uhle box capacity.

EXPERIMENTAL TRIALS

Having successfully established a press section water balance testing method and reliable tools, we ran a number of press section trials to evaluate the effects of the following:

- raising and lowering couch solids by putting on or taking off the tri-vac box on the fourdrinier.
- increasing the first press loading (from 1250 to 1500 PLI (design)).
- increasing second press loading (from 1900 to 2000 PLI (design)).
- positioning lube and high pressure showers in the first and second press positions.
- shutting showers completely off each of the first and second press positions.
- lowering high pressure shower operating pressure.
- operating with or without certain showers (lubes, roll, high pressure, showers).

We also confirmed uhle box operating capacities in the first and second press, as well as dwell time and velocities with the current-style uhle boxes.

CONCLUSIONS

We learned several significant items from the water balance testing and tools that were developed during this study. A great deal of the results supported the findings from work that was performed using the gamma gauge. The following is a summary of the findings from the study:

1. Shower operating pressures and flows can affect press stability and runnability. All manual pressure gauges were replaced and the DCS transmitters calibrated to match actual readings.
2. Although the actual flow rates differed, the second press top and bottom weir flows remained fairly constant throughout felt life, regardless of grade changes, tonnage changes, etc. The first press bottom position also varied very little.
3. The first press compensated for much of the changes in water removal off the couch. We were not able to confirm a change in exit press solids with a change in couch solids off the couch due to the tri-vac box being on or off, tonnage changes, etc.
4. The only factors or parameters that affected water balance changes off the second press were:
   - Loading the second press to 2000 PLI
   - Cutting the showers off, which increased the ability of the second press to decrease sheet moisture (Note: When changing either of these parameters, we saw a dramatic decrease in steam load to the dryer section.)
5. At current speeds and production rates, the second press is marginal in uhle box dwell time and velocity capacity (**Fig. 5**).

Achieving maximum cleaning and performance from press felts requires large volumes of water. Previous studies indicate that proper dwell times with sufficient airflow will yield increased water removal and decrease press felt moisture ratio [5]. The felt moisture ratio is defined as the weight of the water in the felt divided by the dry felt weigh and is calculated as:

$$\text{MR}= \frac{\text{g/m}^2 \text{ water (Scanpro measurement)}}{\text{fabric g/m}^2 \text{ (felt supplier design parameter)}}$$

Path forward

Based on the work from this study, we charted the following path forward:

- Opportunities for exit press solids reside in the optimization of the capacity of the second press. This includes the use of the press section steam shower.

PSIG	SHOWER FLOW	SAVEALL FLOW	% TO SAVEALL
25	12	0.94	8
35	15	1.27	8
45	17	1.79	11
200	18	6.61	37
225	19.5	6.83	35
250	21	7.15	34
300	22.5	7.57	34
350	24	7.89	33

II. Shower flows in gal/min.

PM4 Cond Wt	Reel Moist	Mach Speed	Mach Width	Press Solids	TAPPI Dry eff	Dryer Area	BW	Calculated lbs./hr fiber	lbs./hr H_2O press	lbs./hr H_2O reel
37.6	0.07	2177	15.667	0.45	6.01	13336	34.968	71558	87460	5386
37.6	0.07	2177	15.667	0.467	6.01	13336	34.968	71558	81671	5386

PM4 Cond Wt	Reel Moist	Mach Speed	Mach Width	Press Solids	TAPPI Dry eff	lbs./hr H_2O reel	steam consumption	cost/hr	%time on grade	total cost
37.6	0.07	2177	15.667	0.45	6.01	82073	155940	$1,559.40	1	US$ 13,510,602.32
37.6	0.07	2177	15.667	0.467	6.01	76285	144941	$1,449.41	1	US$ 12,557,699.83
									TOTAL SAVINGS per year	US$ 952,902.49

5. Project steam saving calculated using dryer energy consumption (lbs. steam/lbs. water evaporated).

- We now can evaluate the effect of proposed improvements off the couch and in the press section, which makes it easier to prioritize capital expenditures (**Fig. 6**).
- It is easier to define changes in felt designs and chemical cleaning programs
- Provides a good tool to cross check outside vendor testing and study work.
- Provides an important tool to check runnability in the press section quickly. Press section operations are now baselined.
- Seldom do runnability issues lead to a "goose" chase around the press section. We can now more easily narrow down to the critical issues.
- Provided an educational experience for all those involved in our pressing operations – vendors, management, chemical suppliers, etc.

One of the major benefits of developing methods of performing a press section water balance is to provide consistent information on what is really happening in the press section (to mill personnel and vendors to solve problems). In doing so, this takes a lot of guess work out of trying to figure out what is going on, why, and how each respective parameter can affect press and machine runnability performance. It can also facilitate base-lining pressing operational standards. It was determined that the presses will deliver fairly stable output day-in and day-out, as long as attention to detail is focused around showering, cleaning, loading, etc. Finally, another major benefit is using press section water balance testing to assist in understanding factors which affect machine performance and where to focus our resources and capital for future improvements. **TJ**

LITERATURE CITED

1. Smook, Gary A., "Section 16.9 Pressing (17)" in *Handbook For Pulp and Paper Technologists*, (TAPPI/CPPA) Joint Textbook Committee of the Paper Industry, Atlanta, Georgia, USA, and Montreal, Quebec, Canada, 1989, p. 229.
2. Westaway, C.R., and Loomis, A.W., *Cameron, Hydraulic Data*, 16th Ed., Ingersoll-Rand, Woodcliff Lake, New Jersey, 1984.
3. Permutit, "Discharge from triangular notch weirs with end contractors," *Water and Waste Treatment Data Book*, Zurn Company, 1991, p. 36 (now published by U.S. Filter Corporation, a Vivendi Environnement company).
4. Cutshall, K., Bell, N., and Hudspeth, D., " Hot Pressing," *TAPPI Notes: 1988 Practical Aspects of Pressing and Drying Seminar Discussion*, TAPPI Press, Atlanta, 1988, p. 181.
5. Bennett, J, and Tehan, J., " Effect of uhle box variables on press fabric moisture ratio," *1994 TAPPI Papermakers Conference Proceedings, Book 2*, TAPPI Press, Atlanta, 1994, p. 535.

Received: July 19, 2001
Accepted: December 20, 2001

This paper was originally presented at the 2001 TAPPI Engineering Conference.

This paper is also published on TAPPI's web site (www.tappi.org) and summarized in the July *Solutions! for People, Processes and Paper magazine* (Vol. 85 No. 7).

INSIGHTS FROM THE AUTHOR

This paper is the result of a very successful project to resolve some machine runnability problems.

I had worked on felt monitoring and press felt optimization on other machines, but used a slightly different approach to the data gathering this time.

The most difficult part of the project was reporting the results. There were already perceptions on why different issues existed. When hard data exists, come people struggle with the results if they differ from previous opinion.

From this project, I learned how important it is to baseline an operation. I learned the importance of setting parameters and having them as a reference point to go back to while troubleshooting. The most surprising aspect about my findings was how consistent the pressing operation is from day-to-day (assuming all shower/leading parameters are set).

We intend to use a similar approach to understanding the other areas of the paper machine–forming, drying, stock approach, etc.

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