Implementation of a Metering Size Press on PM2 at Georgia Pulp and Paper Macon Mill

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Executive Summary

The GPP-Macon Mill is in need of a strategic project to bring the mill into a better cost position. Currently the mill is limited by a machine bottleneck after the size press. A metering size press (MSP) can be installed to replace the current puddle size press to eliminate the production bottleneck. With the installation of a metering size press, starch can be added to the sheet at upwards of a 12 percent solids content. This higher solids content decreases the amount of drying needed after the size press. In addition to achieving a higher starch solids with the MSP, the necessary starch pickup can also be reduced to around 3.5 percent since less starch sizing penetrates the sheet with an MSP. The new metering size press can increase availability of the machine by causing fewer breaks due to a dryer sheet leaving the size press while maintaining the current sheet properties. However, availability may not be gained with an increase in machine speed. In case studies it has been shown that a machine speed up can be achieved with a metering size press.

WinGEMS analysis shows that replacement of the current puddle size press with a metering size press, decrease of starch pickup by 1.5% and a 5% speed increase on PM2 can net a cost savings of $9MM/year. These savings are due to less after size press drying required with the increased solids starch solution and starch cost savings from the decrease in pickup. With surface sizing starch being a major cost to the mill, the project can yield high returns.

The TIC for a metering size press was estimated at $14MM including all necessary components. For every project scenario evaluated, the TIC is the same since the equipment cost and installation procedure do not change. The projects were all compared to a base case that had improved 2% acceptance (reducing slab-off) instead of the current GPP mill. The best scenario available is a 5% speed increase and a change to 3.5% starch pickup (IRR=40.9%, NPV= $39.5MM). A second scenario includes a 5% speed increase and the original sheet furnish of 5% starch pickup (IRR=24.3%, NPV=$13.3MM). A final scenario was run with no speed increase, the original starch pickup of 5%, and availability improvement of 1% from reduced breaks (IRR=12.9%, NPV=$847,000).

Upon consideration of the full project analysis, it is recommended that GPP move forward with the option of installing a metering size press on PM2, increasing machine speed by 5%, and decreasing the starch pickup to 3.5%. This project yields a high IRR of 40.9% with low risk.

Project Background and Description

The GPP Macon mill was built in 1985 with one paper machine and expanded in 1990 with another paper machine. The mill produces two grades of uncoated freesheet on its two machines. Paper machine one (PM1) produces rolls at a basis weight of 24lbs / 1300ft^2. Paper machine two (PM2) produces sheets of paper at 20lbs / 1300ft^2. The mill is fully integrated and produces both softwood and hardwood pulp. PM1 uses a 30% softwood and 70% hardwood mix while PM2 uses a 40% softwood and 60% hardwood mix. Both machines use PCC for filler to increase opacity and titanium dioxide to improve brightness. PM1 uses 16% filler (weight %), while PM2 uses 20% filler. Both machines size their sheets using size presses; PM1 uses a metering size press, while PM2 uses a puddle size press. PM2 is currently the more profitable machine of the two due to the increased sales price realized by sheeting. However, PM2 is also the more costly machine to operate at approximately $40/FT more than PM1 due to increased softwood and filler in the furnish.

The Macon mill is currently facing a machine limit on production for PM2. The current bottleneck of PM2 is at the puddle size press and the excessive number of breaks associated with attempts to increase speed on the machine. A new metering size press on PM2 would allow for increased production that would provide increased revenue. The metering size press would also involve the addition of less water into the sheet, reducing the drying necessary in the after size press dryers. Additionally, the starch pickup could be decreased due to an increase in the effectiveness of the starch application to the surface of the sheet. One factor that may affect the anticipated benefits of this project is a limit to production due to the recovery limit, which the mill will reach in the late 2020's at the new machine speed.

Supporting Information

The sizing of paper aims to prevent the penetration of liquids into the sheet and can be done through internal sizing and surface sizing. Surface sizing has the added functionality of improving sheet printability and surface properties like surface strength and internal bond, which become particularly important for grades like uncoated freesheet. Ideally, surface size applied to a base sheet fills the pores on the surface and seals the sheet, preventing other liquids from penetrating the sheet, as depicted in Figure 1.

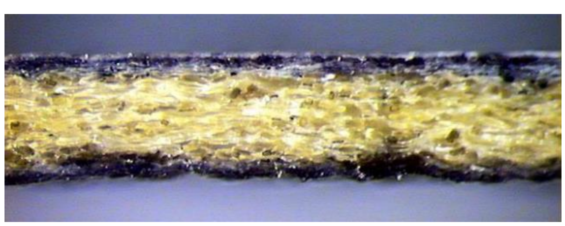

Figure 1. Surface sizing covering a fibrous substrate (1)

Traditionally, the application of such surface sizing has been performed with a "pond" or "puddle" size press (2). The puddle size press is set up with two rolls forming a nip through which the sheet is passed. As the sheet enters this nip, an excess of sizing solution is applied, forming a puddle between the sheet and each roll. As the sheet moves through the solution and into the nip, size solution is picked up onto the surface, and the nip transfers it to the sheet.

When applying size to uncoated freesheet grades, runnability problems sometimes arise (2,3). The problems can largely be attributed to the saturation of the sheet with size, paired with the sheet's low wet tensile strength (2, 4). Limitations on the speed of puddle size press systems have become apparent not only due to runnability problems, but issues associated with the hydrodynamics of the size solution puddle. As the machine speed is increased beyond 3300 feet per minute, turbulence causes the solution puddle to splash out of the nip, as shows in Figure 2 (5).

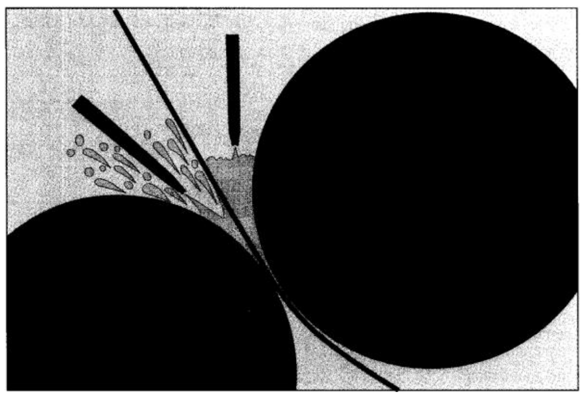

Figure 2. Turbulence in a puddle size press (6)

To avoid problems with turbulence, the solution may be diluted, but an increase in post-size press drying load results. In addition, running faster makes perfect matching of the roll speeds difficult, which could result in sheet scuffing or scrubbing (2). Overall, the puddle size press configuration is unsuitable for machine speeds greater than about 3300 feet per minute (6).

To resolve the issues posed by puddle size presses, the metering size press was developed. In this technology, the starch solution is extruded through a metering element and applied to a transfer roll. The transfer roll then applies a thin film of metered starch onto the surface of the sheet with pressure from a soft roll nip. Figure 3 shows a diagram of a metering rod size press operation where 20 is the sheet, 22 are the metering rod units, and 12 and 14 are the transfer rolls (7). Starch can be made down at a higher solids content in a MSP because a puddle solution is not required. The amount of starch that is desired for surface sizing can be applied as a high solids film. A typical value is around 10% starch solids for modern film metering size presses, although solids of up to 30% have been applied with some cost of less impregnation into the sheet (8). Rewetting can be significantly reduced by using a MSP with 10% or higher starch solids. Also, a film size press can reach speeds up to

5500 ft/min (9) while improving runnability and increasing availability of the machine. It is for these reasons that a film metering size press is recommended for the GPP Macon mill.

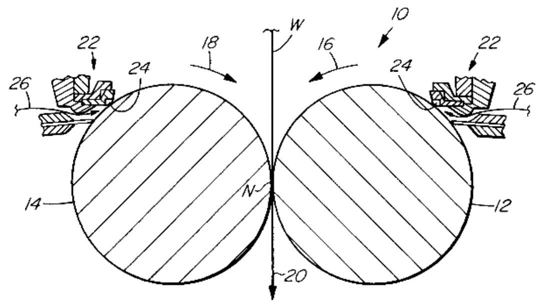

Figure 3. Metering size press transfer roll and metering rod diagram (7)

The introduction of the metered size press has offered several advantages to paper mills in the uncoated free sheet market, including higher machine speeds (over 3300 feet per minute) and efficiencies (10, 11). When compared to the puddle size press, a number of advantages are presented. The metering size press demonstrates significantly reduced sensitivity to the moisture content in the sheet, allowing for overdrying prior to the size press to be eliminated (2, 12). Base sheet defects, such as holes or slime spots, are also less harmful. The solids content of the size solution has minimal effect on the pickup by the sheet, as does internal sizing level. With reduced sensitivity to web defects and base paper variations, an estimated two to four percent improvement in overall efficiency can be achieved (10). This efficiency upgrade applies not only to the level of sizing, but also to the speed of the machine.

Furthermore, use of a metered size press offers an advantage over a puddle size press because it is possible to run with higher solids content (4). A higher solids size application reduces the load on the dryers after the size press and results in fewer breaks, largely due to less instability caused by the hydrodynamic forces present in a puddle (2, 4, 6, 13, 14). Studies indicate that break reductions of 70-90% could be expected on a regular basis (6, 9). The ability to apply sizing to the paper at higher solids content has also been shown to reduce the energy needed to dry the sheet after the size press (9).

Although there are many benefits to using a film metering size press, a few drawbacks are present in the way of routine maintenance. To keep the size press running at optimal conditions, consumables must be replaced fairly often. Since film size presses utilize a transfer roll to apply the sizing to the sheet, considerations for the properties of the roll must be taken to make sure application is even. According to RISI (15), the selection of roll covers and keeping the cover characteristics can improve the quality and runnability of the sheet. Usually, roll covers made of synthetic material are used to provide a soft roll for uniform distribution of sizing. For printing grades, a wide range of roll cover hardnesses can be used from 10-50 P&J, according to Allimand (16). The roll covers need to be replace every few weeks. There is a wide variety of roll covers that are offered in the market, though the main suppliers of roll covers are Voith and Valmet.

Another consumable that is specific to the metering rod film size press is the metering rod itself. Metering rods can be grooved, smooth, or wire wound. These different rods can distribute sizing or coating onto the transfer roll in different amounts or rates according to diameter and with different properties given the shape. The choice of rod can affect the sized sheet's properties and runnability. Grooved rods are recommended by Buschman for use in sizing writing grades (17). According to Allimand (16), the grooved rod needs to be replaced every 20 days. Metering rods are supplied by Buschman, Voith, Valmet, and UMV to name a few. A basic image of a grooved rod is shown in Figure 4.

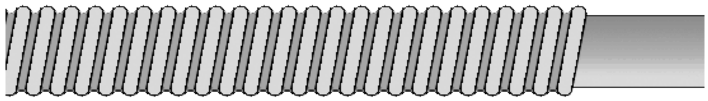

Figure 4. Grooved metering rod illustration

Case Studies

In a paper published in the Pulp & Paper Magazine by Altemeier et al, a case study on uncoated free sheet was examined at a mill in Oftringen, Switwerland. Specifically, the mill considered the changes that took place upon replacing its conventional pond size press with a metering size press. It was found that the new sizing method reduced interference from hydrodynamic forces and allowed sizing to be applied at a higher solids content. The higher solids application meant less water was being added to the sheet, and it resulted in decreased energy usage in the after size press dryers. Altemeier et al found that savings of $100,000/year could be achieved for a 1,000 tons-per-day machine. Improvements were also seen in porosity, formation and stiffness. According to Altemeier et al, porosity was reduced by up to 80 percent in some models. Formation improved as a result of the metering size press applying a more uniform distribution of ash contents to the paper. The transition to a metering size press was not found to have any effect on strength, retention, wet end stability, caliper or smoothness (18).

Metso Corporation also conducted a case study in 2005 on the Raubling mill in Bavaria, Germany involving the rebuild from a pond size press to a metering size press. Through the rebuild of the paper machine with Metso's ValSizer film transfer technology, production was increased as efficiency improved, and desired properties were maintained in each paper grade. In addition to improved machine efficiency, the simplified design of the size press along with its integrated control system made it much easier to operate and maintain. The new metering size press eliminated the bottleneck that was present with the former pond size press, allowing for improved runnability and fewer breaks on the paper machine. The Raubling mill was also able to increase the machine's average speed by 6 percent after the rebuild. Even after the rebuild, strength properties were retained in the sheet and the mill showed sustained results (19).

The results of Group 4 Engineering's full literature review for this project can be found in Appendix A1.

Scope of Work, Decisions, and Project Options

The goal of this project was to investigate the proposal to replace the puddle size press on PM2 with a metering size press and identify potential alternatives. The timeline of the project is summarized through key events highlighted in Figure 5. Key decisions made over the course of the project can be found in Table 1.

Several project options became apparent upon evaluating this project, largely relating to the amount of starch pickup and the machine speed for PM2. More specifically, the options were 1) install MSP, no speed up, 5% starch pickup; 2) install MSP, no speed up, 3.5% starch pickup; 3) MSP, 5% speed up, 5% starch pickup; 4) MSP, 5% speed up, 3.5% starch pickup; 5) increasing availability by reducing the amount of slab-off and optimizing the winder to reduce losses.

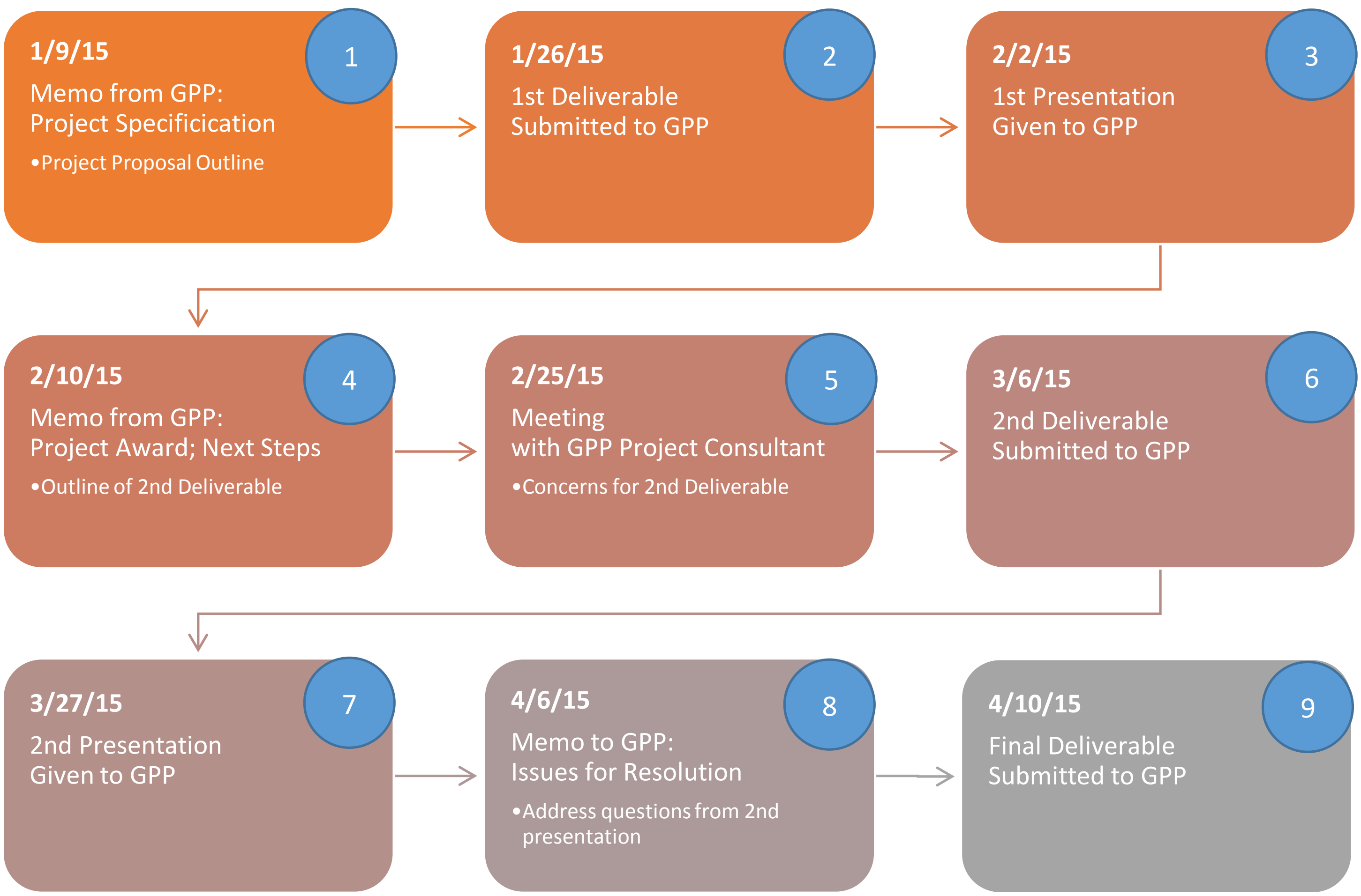

Figure 5. Timeline of project correspondence and events.
Numbers in circles indicate the time period referenced in subsequent sections

Table 1. Summary of decisions/conclusions and respective reasoning

Decision/Conclusion	Reasoning	Time Period
Replace puddle size press on PM2 with metering size press	Turbulence in nip causes excess breaks and quality issues. Installation of an MSP would eliminate this issue in the nip and allow the machine to run faster and more reliably.	2
Machine speedup of 10%	Increase machine speed to design capacity.	2
Increase starch solution solids from 6 to 12 %	No excess water needed in solution to provide a puddle for sizing application. Solids of up to 20% have been used in MSP according to literature.	5
Decrease starch pickup	Since starch will be applied more to the surface with the MSP compared to a puddle size press, less starch must be applied to the sheet to maintain an even distribution.	5
Increase in availability	Many breaks in the dry end occur after the size press. This is due to rewetting of the sheet followed by drying on cylinders. Less rewetting with a MSP translates to increased availability.	4
Wood available for increase in production	Mill Excel model data shows that wood procurement will not be an issue with a 10% increase in production on PM2.	4
No additional staff required	Operators currently working on the PM2 dry end can run the MSP with training.	4
No IR dryers in installation	Since picking of surface starch on ASP dryer cans is not a significant issue, IR dryers are not required for the installation.	3
No PM#1 Shoe press upgrade as alternative	Offset roll market is expected to decline, thus no increase in production on PM #1 is warranted.	3
No improvements in dryer hood	ASP dryers not limiting PM2	4
Equipment specialist recommended for installation	Expert needed to oversee the installation of equipment and to make adjustments to the process after installation. This is necessary to optimize the function of the MSP.	2
Downtime of 3-5 days for installation	According to the literature, MSP installation should not take more than a few days with 14 days being at the very longest downtime.	1
Starch cooking system can handle decreased solids	Basic starch cooking systems, either batch or continuous, would only require a change in dilution controls to facilitate the change. The anticipated change can be handled.	8

No extra space required for installation	Transfer rolls for the MSP are of comparable size to puddle size press rolls and metering elements are compact.	7
No machine speedup and focus on cost savings	The incremental tons produced with a machine speed increase have a lower margin.	4
Machine speedup of 5%	It is determined that a machine speed increase of 5% can be achieved without additional capital to upgrade machine drives.	4
Reduce starch pickup from 5% to 3.5%	Decrease in starch pickup has been observed on machines switching from PSP to MSP.	6
Valmet OptiSizer Film metering size press for installation	The grooved rod MSP is recommended for the application of surface sizing in UFS grades where metering blades are used more in higher basis weight grades. It must first be determined which supplier already is present for the paper machine before a final recommendation.	3
Make improvements in acceptance	A very low cost option would be for the mill to make improvements in acceptability by reducing slab off at the winder. An expert will be needed for this option.	4
Can increase filler content	Filler may be increased in a sheet with surface sizing because the surface strength needed for printing is provided by surface starch. Internal strength may be compromised with this option.	5
No coating	Market for coated sheets expected to decline faster than that for cut-size sheets.	3
Consult customer with regard to decreased starch pickup and increase in filler	Although filler content can be increased and pickup can be decreased, it is recommended that GPP consult with their customers before considering such changes that affect sheet properties.	8
Keep starch pickup at 5%	To account for customer preference, a starch addition of 5% to the sheet is maintained as an option for financial analysis.	7
No additional maintenance required for MSP compared	Although the MSP requires regular replacement of metering elements and roll covers, the cost of these items is not significant.	3
Sheeter capacity can handle production increase	Sheeting facility built over capacity of paper machine. With only 5% speed increase, there will be no conflict.	8

A simple process block diagram is provided in Figure 6 that compares the main differences between the recommended capital investment and the current mill situation. Currently the mill applies starch to the sheet on PM#2 at a 6 percent solids content. With the MSP, starch can be applied in a higher solids content solution of up to 12 percent. The difference in percent water versus percent starch is indicated by the size of the blue and yellow arrows, respectively, feeding into the size press in both flow diagrams. The amount of starch pickup also decreases in the flow diagram on the right; this is indicated by the reduced size of the yellow arrow feeding into the after size press dryers. Perhaps the most notable flow in Figure 6 is the water removal flow from the ASP dryers; the magnitude of this flow decreases significantly with the implementation of a metered size press.

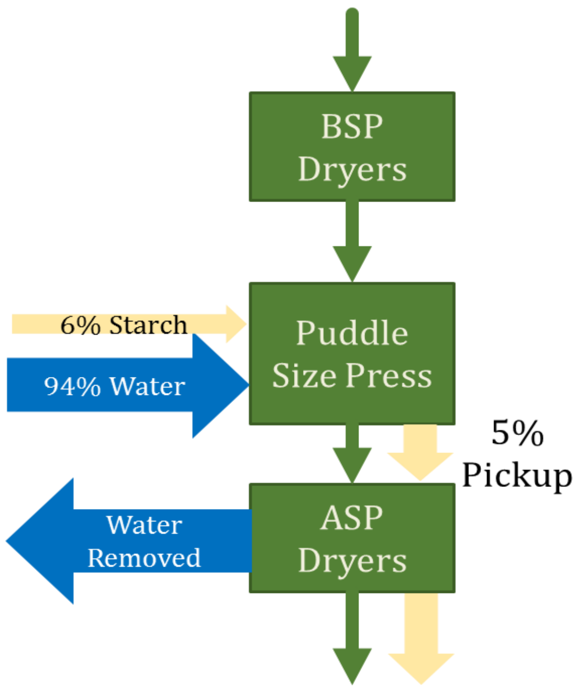

Figure 6. Block flow diagram representation of the proposed changes

A basic understanding of the process and the impacts of an MSP installation can be gained from Figure 6. However, in Figure 7, a more graphic representation of how the installation will look can be observed.

For current mill operations, the installation of the MSP would not require any dryer cans to be removed. The only difference in size between the PSP and the MSP would be the size of the housing body; even so, no dryer cans would need to be discarded. Provided they are still in good shape, the rolls from the puddle size press also have the option to be re-used in the new MSP.

All options evaluated, excluding the reduced slab-off option, used this setup; each differed only in the application of starch to the sheet and the speedup of the machine.

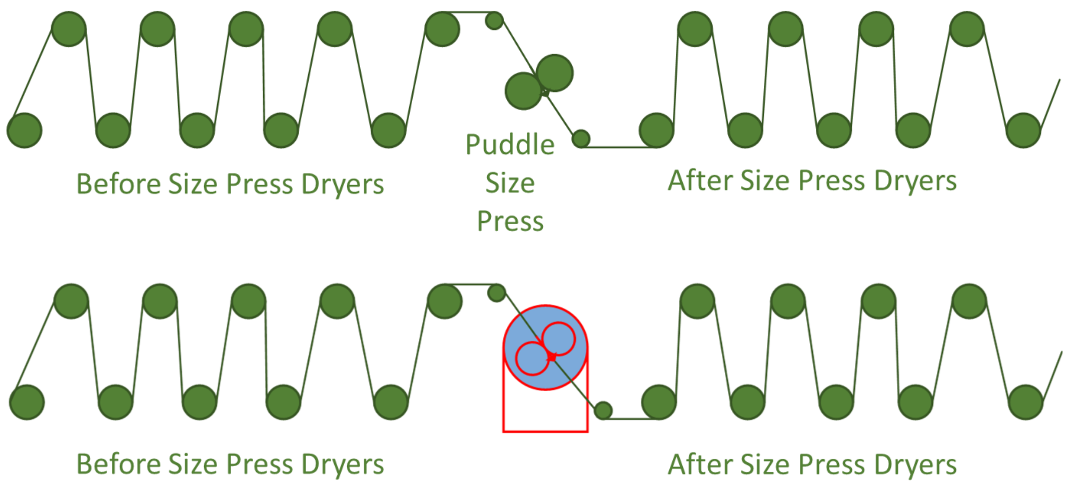

Figure 7. Equipment layout view of proposed change

Results of Process Modeling

To evaluate the potential effects on areas throughout the GPP Macon Mill, a WinGEMS model was used. In order to assure that the model accurately reflected the mill in its base case, changes were required. Before making changes to the WinGEMS model, however, certain assumptions were required. The first was that the proposed change to the size press technology would not be accompanied by any other significant changes in the mill unrelated to the project. Secondly, since the WinGEMS model does not account for tank or pipe sizes, it was assumed that all areas of the mill could handle the increased throughput associated with the proposed 5% speed increase for PM2. A more thorough evaluation of this assumption and its economic impacts is discussed in subsequent sections.

In order to validate the WinGEMS model and guarantee its accurate reflection of the mill's base case, several of the key factors related to this particular project were considered. With careful adjustments to the WinGEMS model, the parameters were matched, as shown in Table 2. Differences of less than 1% were assumed to be negligible.

Table 2. Validation of WinGEMS model with respect to key parameters of the base case

	EXCEL MODEL	(PER YEAR)	WINGEMS MODEL	(PER YEAR)	% DIFF
STARCH AT SIZE PRESS	18,000	Tons	18,000	Tons	0.1%
WATER EVAPORATED IN ASP DRYERS	264,000	Tons	265,000	Tons	-0.5%
PM1 PRODUCTION	257,000	Tons	257,000	Tons	0.0%
PM2 PRODUCTION	292,000	Tons	292,000	Tons	-0.1%

After establishing the reliability of the WinGEMS model, an evaluation of the proposed project was carried out. The major changes to the model that were made in order to simulate the project were the following: starch solution solids increased from 6% to 12%, starch in finished product decreased from 5% to 3.5%, availability increased from 94% to

95%, and PM2 production increased by 5%. A summary of the major effects as reflected in WinGEMS can be seen in Table 3.

Table 3. Major mill impacts as shown in WinGEMS model

	BASE CASE	(PER YEAR)	PROPOSED CASE	(PER YEAR)	% DIFF
STARCH AT SIZE PRESS	18,000	Tons	13,000	Tons	-29%
WATER AT SIZE PRESS	282,000	Tons	95,000	Tons	-66%
WATER EVAPORATED IN ASP DRYERS	265,000	Tons	78,000	Tons	-70%
STEAM DEMAND IN ASP DRYERS	795,000	MMBTU	235,000	MMBTU	-70%
PM1 PRODUCTION	257,000	Tons	256,000	Tons	0%
PM2 PRODUCTION	292,000	Tons	307,000	Tons	5%

As expected, the size press starch usage decreased, as did the size press water usage, by 30% and 66% respectively. More notably, the amount of water evaporated by the after size press dryers was reduced from 265,000 tons per year to only 78,000 tons per year. The significance of this change is shown by the amount of steam required by the after size press dryers, which was also reduced by about 70%.

The entire WinGEMS block layout used to simulate the mill can be found in the electronically submitted WinGEMS files. The layout for PM2 can be found in Appendix A2.

<u>Economic Evaluation</u>

The projects free cash flow analysis can be seen in Figure 8. The figure includes both the base case, the new base case with acceptance improvements, and several different project scenarios with the installation of a metering size press. The most profitable scenario is increasing the speed by 5% and reducing size press starch to 3.5% of sheet weight. This scenario gives the project an IRR of 40.9%. However, there is still a possibility that GPP's customers would not buy the product with reduced starch. Even if GPP cannot reduce starch due to customer complaints, PM2 can still speed up 5% but will not gain any cash savings from adding less starch to the sheet. A basic scenario of just adding a metering size press while keeping production and starch pickup the same was included to show if the speed increase was not possible due to unforeseen machine problems.

Table 4 has all scenarios IRR and NPV displayed. The best scenario observed involved decreasing starch in the sheet and increasing the speed. The cost savings from reducing starch is a key factor in making this project very successful. Reducing starch by just 1.5% increases the IRR by 16% and NPV by $36MM. However, even without changing starch pickup or machine speed, the steam savings and availability improvement from a metering size press will provide a project IRR of 12.9%.

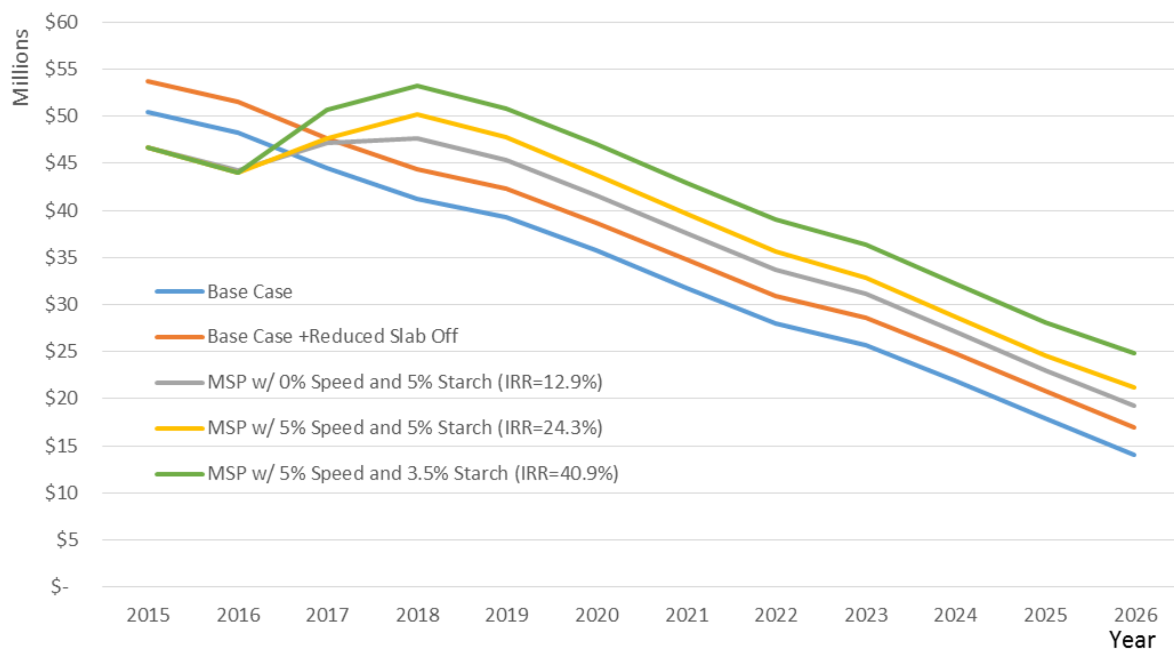

Figure 8. Free cash flow graph of for MSP

Table 4. IRR and NPV

Project Expectations	IRR	NPV
MSP, 0% Speed Increase, 5% Starch Pick-up	12.9%	$847,000
MSP, 5% Speed Increase, 5% Starch Pick-up	24.3%	$13,258,000
MSP, 5% Speed Increase, 3.5% Starch Pick-up	40.9%	$39,544,000

Capital Cost Estimation

Table 5. Equipment list for grooved rod metering size press

Qty	Unit and Control Description	Unit Cost ($)	Total Cost $	Delivered Cost $
1	Metering rod size press		3,156,000	3,472,000
2	47" diameter rolls			
1	Sheet breaker			
2	Spare rolls (incl. bearings & bearing housings)	278,000	557,000	613,000
1	Hydraulic unit and Control Panel		250,000	276,000
TOTAL				4,361,000

The equipment list is shown in Table 5. The prices were estimated from an Allimand A-sizer quote. The quote was verified by a project consultant as reasonable and comparable to other metering size presses. The equipment prices were scaled from a max machine speed 2500 fpm and 250 inches wide to match PM2's specifications of 3500 fpm and 350 inches wide. The prices were scaled using a 0.6 scaling factor for both speed and machine width. The equipment needed for install includes the size press with two rolls, spare rolls and bearings (in case of failures), hydraulics, and controls. Other items not included in the equipment list are the replacement parts such as rods and roll covers which are replaced frequently through regular maintenance and are not a large contributing factor to the equipment cost.

The total installed cost of the project is estimated to be $14MM. The estimate was calculated using the Dr. Phillips factoring method as seen in Table 6. Most of the project's cost factors are at mid-level since the project does not involve any expensive or cheap solutions. The factor for instrumentation and controls is set low because the cost of the control unit is accounted for separately from the size press. Contingency is also low since the technology has been proven by literature and there is less risk involved with installing a meter size press. Cost factors for land and new buildings were excluded from the project since the metering size press would only be replacing the current puddle size press. The estimate does not include working capital associated with the project. Working capital for the project will be needed with a production increase in order to procure wood and finishing materials for incremental tons.

Project Impacts on Operating Costs and Earnings

For better understanding of the financial impacts of the project an FEL-0 was performed. The project is projected to take place during the 2016 annual outage and installation will last approximately 15 days, however the FEL-0 accounts for 30 days of downtime for extra contingency and possible start-up difficulties. Table 7 displays the incremental revenue from the sale of additional tons. The incremental production was calculated by increasing the machine speed by five percent and calculating the yearly production using the OEE and a yearly run time of 350 days. Another factor included in the incremental production increase is the gradual production ramp-up to faster speeds by the end of 2017. The new production tons are subtracted from base case tons after acceptance improvements that will take place in 2015. The incremental revenue is calculated using a new sales price discounted at a 12.5% rate since the additional tons will most likely need to be sold at a reduced cost to customers. The sales price was assumed equivalent to that provided in the GPP mill Excel model. Figure 9 illustrates how the incremental revenue will be approximately $12MM from the 5% speed increase. The figure also shows that the net sales price will be approximately $50/ton less for the incremental tons.

Table 6. Factored estimate for metering size press

Direct Cost	Estimate	Low	Mid	High
Purchased Equipment	$3,684,000	1.00	1.00	1.00
Purchased Equipment Erection	$682,000	0.13	**0.19**	0.21
Instrumentation and Controls	$737,000	**0.20**	0.20	0.21
Piping	$819,000	0.13	**0.22**	0.26
Electrical Systems	$819,000	0.13	**0.22**	0.26
Foundations	$1,501,000	0.40	**0.41**	0.41
Service Facilities	$409,000	0.07	**0.11**	0.13
Freight	$368,000		**0.10**	
Sub-Total Direct Cost	**$9,018,000**		**2.45**	
Indirect Cost				
Engineering	$955,000	0.20	**0.26**	0.31
Construction Expenses	$819,000	0.20	**0.22**	0.23
Legal Expenses	$136,000	0.00	**0.04**	0.05
Contractor Fee	$614,000	0.13	**0.17**	0.18
Inflation	$819,000	0.20	**0.22**	0.26
Contingency	$737,000	**0.20**	0.24	0.26
Sub-Total Indirect Cost	**$4,079,000**		**1.11**	
Other Cost				
Spare Rolls	$631,000			
Hydraulic and Control Unit	$284,000			
Total Installed Cost	**$14,013,000**		**3.80**	

Table 7. Incremental revenue due to additional tons produced

Base Case	2015	2016	2017	2018
Base Case Price per FT	$ 1,013.72	$ 1,023.86	$ 986.93	$ 976.77
Base Case Discount	7.5%	7.5%	7.5%	7.5%
Base Case Net Sales per FT	$ 937.69	$ 947.07	$ 912.91	$ 903.51
Base Case FT per Year	297,920	298,515	299,112	299,711
Base Case Revenue per Year	$302,007,443	$305,637,573	$295,203,503	$292,747,460
Proposed Case	2015	2016	2017	2018
Incremental FT per Year	-	(13,698)	14,189	14,217
Incremental Discount	7.5%	7.5%	12.5%	12.5%
Net Sales per Incremental FT	$ 937.69	$ 947.07	$ 863.57	$ 854.67
Incremental Revenue per Year	$ -	$ (12,972,862)	$ 12,252,838	$ 12,150,896

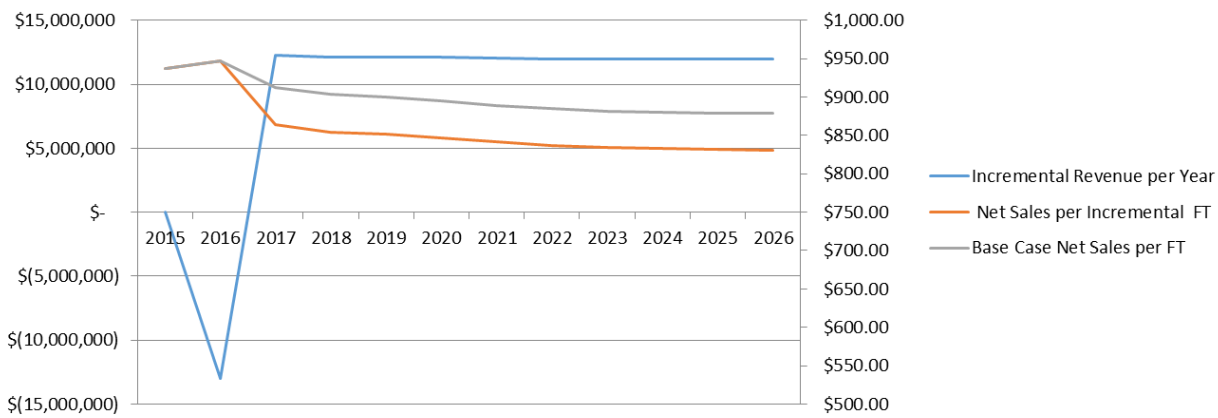

Figure 9. Incremental Revenue and Net Sales Prices for PM2

Further benefits from the project include cost reduction from starch pickup and ASP dryer steam usage. The cost of starch was estimated at $520/ton in 2015 based on the GPP Excel model. Starch is one of the mill's most expensive chemical costs at 29% of base case total chemical cost. A metering size press allows for starch sizing comparable to a puddle size press, while using less starch. However, using less starch will change the product furnish. These changes must be accepted by customers before implementation. Table 8 shows the calculations of the cost savings for decreasing starch pickup. Switching from 5% starch in the sheet to 3.5% saves the mill roughly $3.3MM/yr in chemical cost.

Further savings can be made through steam reduction in the ASP dryers. The pounds of water added from sizing is calculated in Table 9 using the starch pickup from Table 8. The current puddle size press is limited to using starch solutions at 6% solids which adds about 260,000 tons of water per year that must be evaporated. A modern metering size press can use starch up to 12% solids which greatly reduces the tons of water to 80,000 tons per year. This difference amounts to $3.3MM/yr saved by using less natural gas to generate steam.

Table 8. Starch savings calculations

Starch Usage	2015	2016	2017	2018
Base case PM2 FT	297,920	298,515	299,112	299,711
Base starch in FT	14,896	14,926	14,956	14,986
Base starch off PM2	15,641	15,672	15,703	15,735
Total starch used	17,909	17,945	17,980	18,016
Proposed Case PM2 FT	297,920	284,818	313,301	313,928
Proposed starch in FT	14,896	14,241	10,966	10,987
Proposed starch off PM2	15,641	14,953	11,514	11,537
Total Starch used	17,909	17,121	13,183	13,210
Incremental starch	-	823	4,797	4,807
Starch price	$520.00	$533.00	$546.33	$559.98
Incremental savings	$0.00	$548,600	$3,275,955	$3,364,569

Table 9. Steam savings calculations

ASP Steam Usage	2015	2016	2017	2018
Base Water Added to sheet (tons)	262,410	262,928	263,447	263,968
# of steam for evaps after size press	734,748,207	736,199,050	737,652,794	739,109,446
MMBTU	793,528.06	795,095	796,665.02	798,238
MMBTU /FT	2.66	2.66	2.66	2.66
@ 85% eff	3.13	3.13	3.13	3.13
Cost per FT	15.67	15.67	15.67	15.67
Total Cost	4,667,812	4,677,029	4,686,265	4,695,519
Proposed water added to sheet	262,410	226,585	78,432	78,582
# of steam for evaps after size press	734,748,207	634,437,644	219,610,169	220,030,736
MMBTU	793,528	685,193	237,179	237,633
MMBTU /FT	2.66	2.41	0.79	0.79
@ 85% eff	3.13	2.83	0.93	0.93
Cost per FT	15.67	14.15	4.66	4.66
Total Cost	4,667,812	4,030,545	1,395,170	1,397,842
Steam Savings	$0	$646,484	$3,291,094	$3,297,677

Other costs are expected to increase slightly for the incremental tons produced. Table 10 shows a list of assumptions and decisions as to how costs were handled with the speed increase. Using the GPP Excel model as a basis, the costs for incremental tons were calculated using the cost per ton numbers. All costs were inflated each year with a standard 3% inflation. Excel tables for the yearly calculated cost and working capital associated these assumptions can be found in Appendix A3.

The start-up costs for the project are described in Table 11. It is expected that operator and maintenance training will be necessary throughout both September and October of 2016. The training will be considered overtime in October since operators will be expected to perform extra duties for the annual outage as well. The cost for a consultant is also included for September through December 2016 to help with start-up, training, and trouble shooting for the new size press. The total start-up cost will amount to $160M.

Table 10. Incremental cost assumptions and decisions

Direct Cost	
Freight	Increases $10 per Incremental Ton
Fiber	All incremental tons are produced with wood, will need to buy additional wood at higher cost
Chemicals	Same chemical usage per ton as base case
Energy	Energy use for ton will be assumed equivalent since more black liqour is produced per incrimental ton
Finishing Materials	All new tons are packaged
Indirect Cost	
Maintenance	New asset must be maintained
Labor (Excluding Repair)	No extra labor
Operating Materials	Additional Operating Materials required for need equipment
Other Mill Fixed Cost	Equipment insurance
Depreciation	Must Account for New Fixed Capital + Incremental Capital (Maintenance) necessary because of the investment
Business Unit Overhead	Assume all incremental tons will be sold with current sales force, but with commissions at 2%
Sector Overhead	No additional Overhead
Corporate Overhead	No additional Overhead
Working Capital	Must purchase Incremental wood and finishing materials for speed up

Table 11. Start up costs

Hours per Month of Training per Operator	Sep	Oct	Nov	Dec	2016 Total
Number of Operators to be Trained	8.0	8.0	-	-	16.0
Pay Basis	4	4	0	0	
Base Cost per Operator per Day	Regular	OT	Regular	Regular	
Overtime Premium (2 Hours per Day)	$ 170.94	$ 170.94	$ 170.94	$ 170.94	
Operator Training Cost	$ 64.10	$ 64.10	$ 64.10	$ 64.10	
	$ 5,470	$ 7,521	$ -	$ -	$ 12,991
Number of Maintenance Workers to be Trained					
	2	2	0	0	
Base Cost per Maintenance Worker per Day	Regular	OT	Regular	Regular	
Overtime Premium (2 Hours per Day)	$ 170.94	$ 170.94	$ 170.94	$ 170.94	
Maintenance Worker Training Cost	$ 64.10	$ 64.10	$ 64.10	$ 64.10	
	$ 2,735	$ 3,761	$ -	$ -	$ 6,496
Number of Operators on Overtime during startup					
Cost of Startup Overtime Hours - Operators (4 Hours per Day)		0	2	0	
		$ -	$ 2,051	$ -	$ 2,051
Startup Consultants					
Cost of Consultants at $1,500 per Day, 20 Days per Month	1	1	1	1	
	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$120,000
Cost of excess materials					
					$ 20,000
Total Startup Costs					
					$161,538

The project was depreciated using a 7-year MACRS schedule. The project capital spending is expected to be evenly split between 2015 and 2016. Further analysis of depreciation can be seen in Appendix A3.

Sensitivity and Profitability Analysis

A sensitivity analysis was done to show the effects that certain parameters had on the IRR of the project (Table 12). The discount rate for incremental tons could be higher or lower than the assumed 12.5%. The project will only be slightly affected by the discount rate since it has no effect on the cost savings from reducing starch. Start-up cost will have little effect since there will be only minor training and specialist support. One factor that will influence the project's success is starch prices. A 25% increase in starch price will increase IRR by 2.5%. The IRR increases because the starch savings are proportional to starch price.

Table 12. Sensitivity analysis

	-25%	-10%	0%	10%	25%
Discount on Incremental Tons	42.0%	41.4%	40.9%	40.4%	39.7%
Start-ups Cost	40.9%	40.9%	40.9%	40.9%	40.8%
Starch Cost	38.1%	39.8%	40.9%	42.0%	43.6%

Table 13 accounts for all simulated data from an FEL-0 with a 5% speed increase and 3.5% starch pickup. Tax for the FEL-0 can be negative since losses would be accounted for elsewhere in the total mill analysis. In 2017 there is a massive difference in working capital needed for the purchase of wood and finishing materials for the incremental tons. The project analysis tables for other project scenarios can be found in Appendix A3.

Table 13. Project analysis

Project Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Incremental Tons per Year	0	-13,698	14,189	14,217	14,245	14,274	14,303	14,331	14,360	14,389	14,417	14,446
Revenue	0	-12,972,862	$12.25 MM	$12.15 MM	$12.13 MM	$12.09 MM	$12.03 MM	$12. MM	$11.98 MM	$11.98 MM	$11.99 MM	$12.01 MM
Direct Costs	0	-7,106,128	-103,576	8,446	124,701	245,338	370,510	500,374	635,095	774,843	919,792	1,070,124
Indirect Costs	0	2,260,338	$4.25 MM	$3.3 MM	$2.64 MM	$2.17 MM	$2.2 MM	$2.23 MM	$1.63 MM	$1.03 MM	$1.05 MM	$1.08 MM
Startup Costs		$161,538										
Total Costs	$0	-$4,684,251	$4.14 MM	$3.31 MM	$2.76 MM	$2.41 MM	$2.57 MM	$2.73 MM	$2.27 MM	$1.8 MM	$1.97 MM	$2.15 MM
Depreciation	$0	$2.26 MM	$4.25 MM	$3.3 MM	$2.64 MM	$2.17 MM	$2.2 MM	$2.23 MM	$1.63 MM	$1.03 MM	$1.05 MM	$1.08 MM
EBITDA	$0	-$6,028,272	$12.36 MM	$12.14 MM	$12.01 MM	$11.84 MM	$11.66 MM	$11.5 MM	$11.35 MM	$11.21 MM	$11.07 MM	$10.94 MM
EBIT	$0	-$8,288,610	$8.11 MM	$8.84 MM	$9.37 MM	$9.67 MM	$9.47 MM	$9.26 MM	$9.71 MM	$10.18 MM	$10.02 MM	$9.86 MM
Tax @35%	$0	-$2,901,014	$2.84 MM	$3.09 MM	$3.28 MM	$3.39 MM	$3.31 MM	$3.24 MM	$3.4 MM	$3.56 MM	$3.51 MM	$3.45 MM
After Tax Income	$0	-$5,387,597	$5.27 MM	$5.75 MM	$6.09 MM	$6.29 MM	$6.15 MM	$6.02 MM	$6.31 MM	$6.62 MM	$6.51 MM	$6.41 MM
Cash Flow	$0	-$3,127,259	$9.52 MM	$9.05 MM	$8.73 MM	$8.45 MM	$8.35 MM	$8.25 MM	$7.95 MM	$7.64 MM	$7.56 MM	$7.48 MM
New Fixed Capital	$7,025,621	$7,166,134	$144,728	$149,070	$153,542	$158,148	$162,892	$167,779	$172,813	$177,997	$183,337	$188,837
Change in Working Capital	$0	-$2,775,750	$6.36 MM	-$8,757	$12,799	$6,104	$5,291	$9,527	$15,807	$20,710	$22,344	-$667,505
Free Cash Flow	-$7,025,621	-$7,517,642	$3.01 MM	$8.91 MM	$8.56 MM	$8.29 MM	$8.18 MM	$8.08 MM	$7.76 MM	$7.45 MM	$7.36 MM	$7.96 MM
x Year 10 EBITDA (TV=5)	-$7,025,621	-$7,517,642	$3.01 MM	$8.91 MM	$8.56 MM	$8.29 MM	$8.18 MM	$8.08 MM	$7.76 MM	$7.45 MM	$7.36 MM	$49.29 MM
Discount Rate @ 12%	-$7,868,696	-$7,517,642	$2.69 MM	$7.1 MM	$6.09 MM	$5.27 MM	$4.64 MM	$4.09 MM	$3.51 MM	$3.01 MM	$2.65 MM	$15.87 MM
Net Present Value	$39,543,760											
IRR, %	40.9%											

Conclusions

Through mill analysis we found that PM2's acceptance was 84.5%. TAPPI guidelines defined the best in class possible for PM2 as 91% (18). Through changes in operating procedures and the purchase of a Duck knife, acceptance on PM2 can potentially be improved to 86.5%. The improvements would aim to decrease paper slab-off at the winder. The acceptance improvements were added to the base case. The project FEL-0 was performed using the new base case as a reference.

With the installation of a MSP to replace the current puddle size press on PM2, the GPP Macon mill can see a reduction in steam required by the ASP dryers. Without any other changes, and a TIC of $14MM, the IRR for the recommended project is 12.9%. It is for this reason that Group 4 Engineering recommends at least the replacement of the current puddle size press with a metering size press.

Debottlenecking of the paper machine limitation with the installation of a MSP presents the mill with the option of a speed increase on PM2. With an increase of 5%, no additional capital will be required for the machine. The option to install a MSP and increase the machine speed by 5% yields an IRR of 24.3%. Even with a 12.5% discount on incremental tons, an increase in production is also a good option.

The film application of a MSP compared to the pond application of a puddle size press requires less starch pickup onto the sheet for comparable sheet properties. A reduction in starch usage at the size press has been documented for MSP operations. Considering a reduction in starch pickup from 5% to 3.5% with a 5% speed increase, an IRR of 40.9% can be seen. Starch for surface sizing accounts for approximately 29% of the total chemical costs for the paper machine, making this reduction very profitable. However, the customer must be consulted about this change.

Since there will be a speed increase of 5%, the recovery limit is now forecasted to be met in 2026. GPP will have ample time to plan a recovery upgrade to combat this problem. Furthermore, a metering size will allow for even greater machine speed-ups, since there is currently no upper speed limitation for metering size presses.

Recommendations

Improving acceptance by 2% by improving slab-off operations is a very low cost option that can increase free cash flow independently of other options. It is recommended that this option is considered in addition to other projects as a way to immediately increase profitability without a significant capital expenditure.

All three major project scenarios as presented would improve the mill's cost situation. Installation of the MSP with a 5 percent speed increase, combined with a reduction of starch pickup from 5 percent to 3.5 percent, would generate the highest IRR at 40.9

percent. The lowest possible IRR for the project would be 12.9% in the unlikely scenario of no speed increase or reduced starch pickup. Most of the project free cash flow is derived from steam savings in the after size press dryers, as well as reduced starch in sheet. The after size press steam savings are the result of increasing the starch solids solutions from 6% to 12%. No changes will be need to the starch system, only changes in dilution control.

The final recommendation for the mill is installation of a MSP, a speed increase of 5%, and a decrease in starch pickup to 3.5%.

Future Work

If the GPP-Macon mill desires to increase the amount of filler in the sheet or increase the machine speed by more than 5 percent, it is recommended that the mill investigates these alternatives via a trial study. Additionally, the mill should verify with customers if a change in filler content to the sheet would be acceptable. A more in-depth financial analysis, where estimates fall between +/- 10 percent as in a FEL-1 or FEL-2, may also be of benefit to the mill.

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Appendix

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Implementation of a Metering Size Press to Facilitate Machine Speed Increase

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Executive Summary

The GPP-Macon Mill is in need of a strategic project to bring the mill into a better cost position. Currently the mill is limited by a machine bottleneck after the size press. A metering size press can be installed to replace the current puddle size press to eliminate the production bottleneck. This is due to increased starch consistency applied to the sheet in the size press which decreases the amount of drying needed after the size press. The new metering size press can increase availability of the machine by causing fewer breaks due to a dryer sheet leaving the size press while maintaining the current sheet properties. In case studies it has been shown that a machine speed up can be achieved with a metering size press.

Current Mill Situation

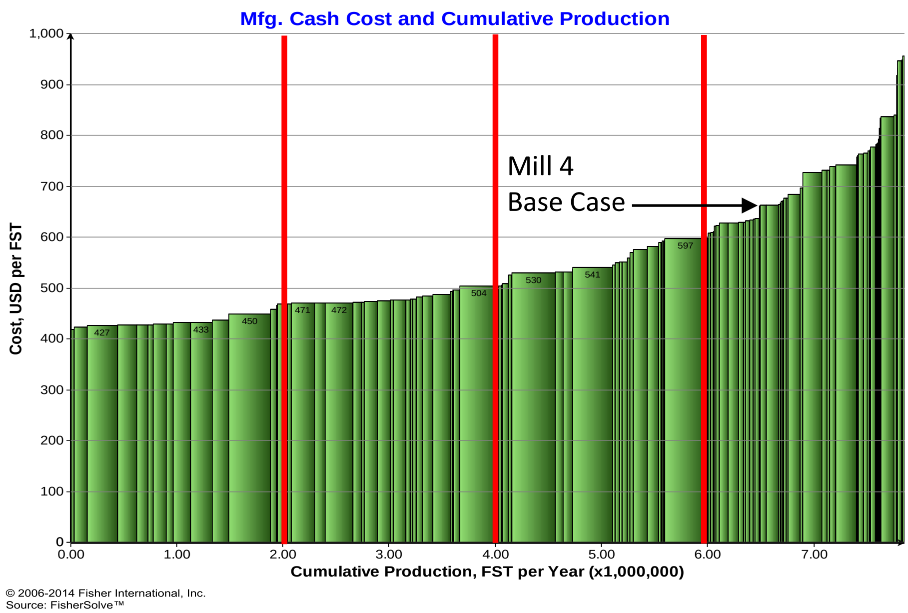


Figure 1. Cost per ton vs. production for UFS producers in North America (1)

The GPP mill is currently a fourth quartile mill with total cash cost at $650/FT, as shown in Figure 1, and is forecasted to become unprofitable in 2029. The mill is currently limited by the paper machine capacity, with the current bottleneck of PM2 at the puddle size press and the drying capacity of the after size press dryers. A new metering size press on PM2 would increase production to provide increased revenue. The new size press would add less water into the sheet, reducing the drying needed after the size press. This would allow the dryers after the size press to handle an increase in machine speed. The potential increase in production will add approximately 5-8 million dollars per year in free cash flow in the next ten years, as shown in Figure 2. One factor that reduces the effectiveness of this project is that the mill will reach the recovery production limit in 2020 at the new machine speed, which will inhibit potential production. Another issue is that the mill will become unprofitable in 2030 if the production limit is not overcome.

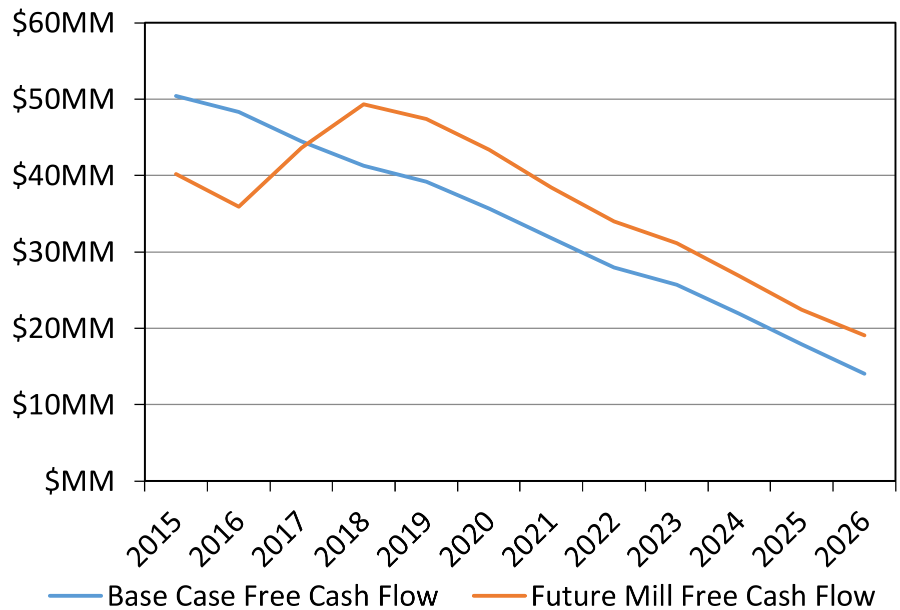


Figure 2. Free cash flow curves for the mill in the base and proposed cases

The GPP mill was built in 1985 with one paper machine and expanded in 1990 with another paper machine. The mill produces two grades of uncoated freesheet on its two machines. PM1 produces rolls at a basis weight of 24lbs / 1300ft^2. PM2 produces sheets of paper at 20lbs / 1300ft^2. The mill is fully integrated and produces both softwood and hardwood pulp. PM1 uses a 30% softwood and 70% hardwood mix while PM2 uses a 40% softwood and 60% hardwood mix. Both machines use PCC for filler to increase opacity and titanium dioxide to improve brightness. PM1 uses 16% (weight %) filler while PM2 uses 20% filler. Both machines size their sheets using size presses; PM1 uses a metering size press, while PM2 uses a puddle size press. PM2 is currently the more profitable machine of the two due to the increased sales price from sheeting. However, PM2 is the more costly machine to operate at approximately $40/FT more than PM1 due to increased softwood and filler in the furnish.

Table 1. Production and limitation forecast in proposed case

Project Year	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Base case PM2 FT	291,031	291,613	292,197	292,781	293,367	293,953
Proposed Case PM2 FT	291,031	279,875	320,528	322,703	323,349	321,039
Production Limitation	Machine	Machine	Machine	Machine	Machine	Recovery
Project Year	2021	2022	2023	2024	2025	2026
Base case PM2 FT	294,541	295,130	295,721	296,312	296,905	297,498
Proposed Case PM2 FT	320,486	319,931	319,375	318,818	318,260	317,701
Production Limitation	Recovery	Recovery	Recovery	Recovery	Recovery	Recovery

The expected production is currently 547,890 tons in 2015 with a 0.20% improvement in productivity in subsequent years. PM1 is expected to produce 256,858 tons and PM2 is expected to produce 291,031 tons. By adding a metering size press to PM2, the machine can potentially gain a 10% speed increase. The new production after a speed increase would be about 320,000 or 30,000 additional tons which are further detailed in Table 1. In 2020, the mill will become recovery limited and production will be limited, with PM1 gaining priority for max production.

Alternative

A metering size press can be installed to reduce chemical and energy costs without increasing machine speed. This is due to less starch applied per OD fiber at slower speeds, and less water passed on to the after size press dryers. Since the dryers are receiving less load, they can shed some steam usage, thereby lowering the mill's overall energy cost. The change in free cash flow with a metering size press installation is comparable to the proposed machine speed up if the starch solids charge is changed from 5% to 4%. Another positive of maintaining machine speed is that the mill will not have to worry about increasing their recovery capacity in five years without a recovery boiler upgrade. This gives a slower decrease in FCF as compared to speeding up the machine.

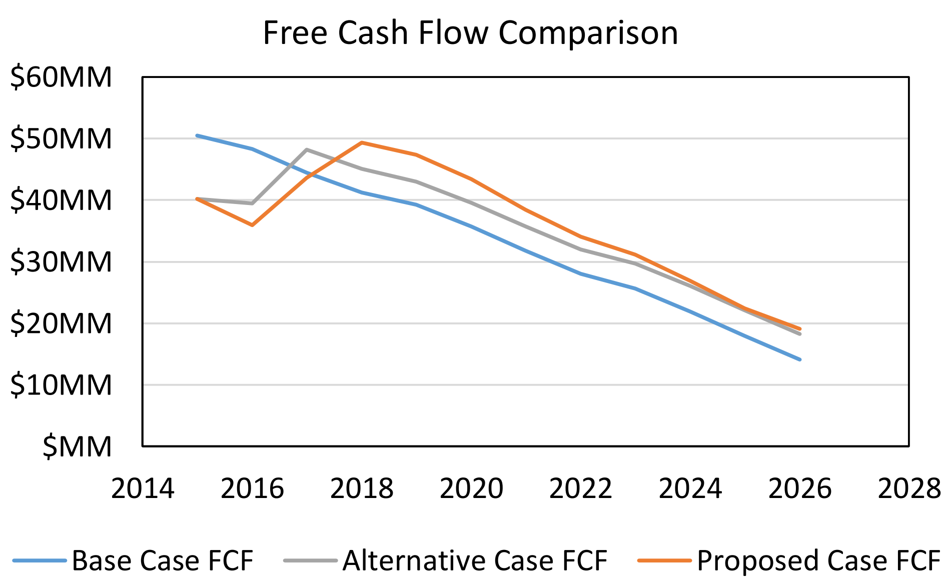


Figure 3. Free cash flow curves for the mill in the base, proposed, and alternative case

Another benefit of implementing the alternative is that the total cash cost of the mill will decrease by an average of $10/FT. However, neither of these solutions will save the mill from eventual closure due to such high cost.

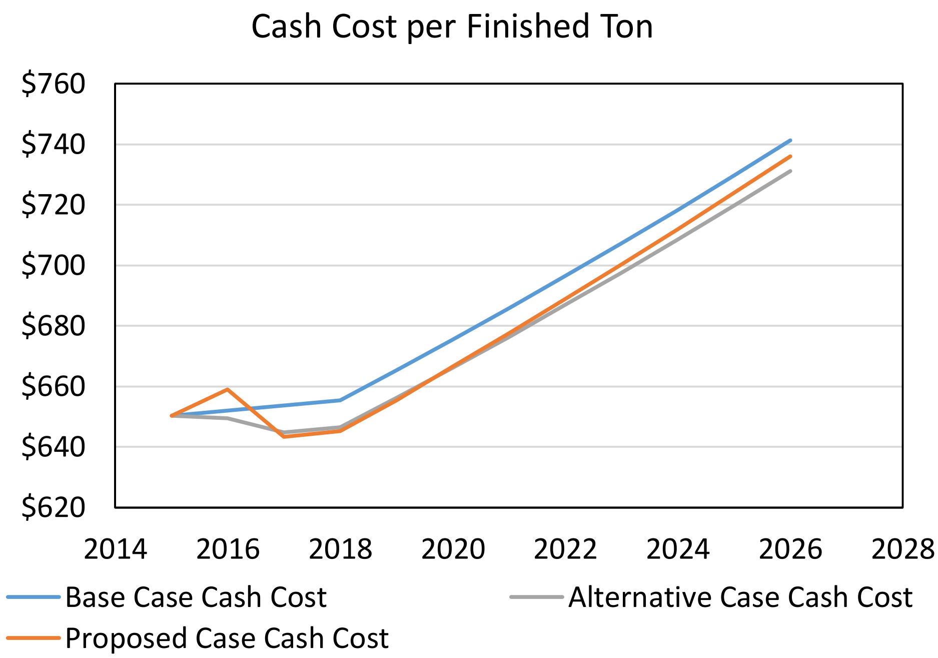


Figure 4. Cash cost per finished ton for the mill in the base, proposed, and alternative case

Key Concepts

The sizing of paper aims to prevent the penetration of liquids into the sheet and can be done through internal sizing and surface sizing. Surface sizing has the added functionality of improving sheet printability and surface properties like surface strength and internal bond, which become particularly important for grades like uncoated freesheet. Ideally, surface size applied to a base sheet fills the pores on the surface and seals the sheet, preventing other liquids from penetrating the sheet, as depicted in Figure 5.

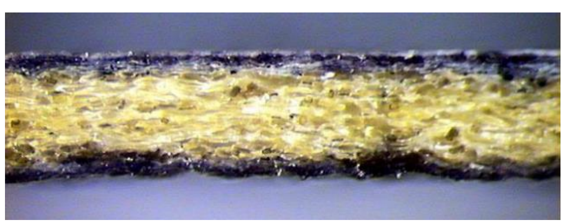


Figure 5. Surface sizing covering a fibrous substrate (2)

Traditionally, the application of such surface sizing has been performed with a “pond” or “puddle” size press (3). The puddle size press is set up with two rolls forming a nip through which the sheet is passed, as seen in Figure 6. As the sheet enters this nip, an excess of sizing solution is applied, forming a puddle between the sheet and each roll. As the sheet moves through the solution and into the nip, size solution is picked up onto the surface, and the nip transfers it to the sheet. The amount of solution that is transferred to the sheet is dependent on several factors, including nip pressure, moisture content of the sheet, nip width, and size solution solids content(3,4). Figure 7 shows that one of the most important factors affecting size pickup is the level of internal sizing in the sheet (3).

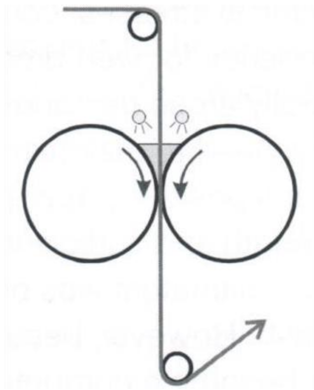


Figure 6. Basic schematic of a horizontal puddle size press (5)

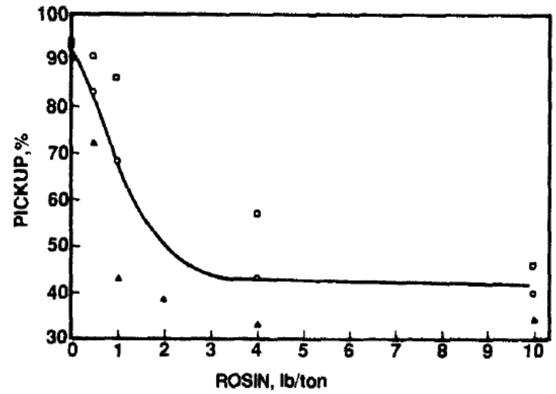


Figure 7. Surface size pickup as a function of internal sizing dose (6)

In seeking to optimize the moisture content of the sheet prior to entering the size press, overdrying sometimes occurs. When applying size to lightweight grades, runnability problems often arise as well (3,7). This can largely be attributed to the saturation of the sheet with size, paired with the sheet's low wet tensile strength (3, 8). Limitations on the speed of puddle size press systems have become apparent not only due to runnability problems, but issues associated with the hydrodynamics of the size solution puddle. As the machine speed is increased beyond 3300 feet per minute, turbulence causes the solution puddle to splash out of the nip, as shows in Figure 8 (4).

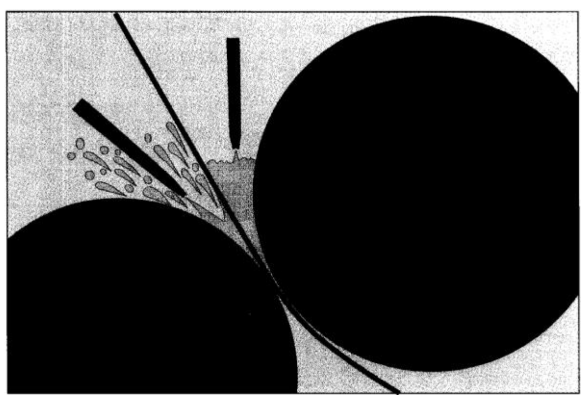


Figure 8. Turbulence in a puddle size press (9)

To avoid this, the solution may be diluted, but an increase in post-size press drying load results. In addition, running faster makes perfect matching of the roll speeds difficult, which could result in sheet scuffing or scrubbing (3). Overall, the puddle size press configuration is unsuitable for machine speeds greater than about 3300 feet per minute (9).

To resolve the issues posed by puddle size presses, an alternative technology known as the gate roll size press was developed in the 1960s. While initially adopted widely, it was soon found that the technology was ideally suited for low sizing applications like newsprint (10). Maintenance and sheet quality problems associated with the use of a gate roll size press on grades other than newsprint prompted several mills to reverse the change or find alternate sizing options (6). By the 1980s, the metering size press had been developed. In this technology, the size solution is applied to the rubber press rolls prior to the nip, and the size meets the sheet in the nip between the two rolls, as seen in Figure 9. As with the puddle size press, the size is transferred to the nip at this point (9).

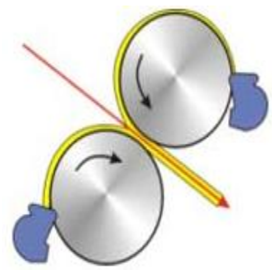


Figure 9. Metering size press application, with either blade or rod metering elements possible (11)

The introduction of the metered size press has offered several advantages to paper mills in the uncoated free sheet and lightweight coated markets, including higher machine speeds (over 3300 feet per minute) and efficiencies (12, 13). When compared to the puddle size press, a number of advantages are presented. The metering size press demonstrates significantly reduced sensitivity to the moisture content in the sheet, allowing for overdrying prior to the size press to be eliminated (3, 14). Base sheet defects, such as holes or slime spots, are also less harmful. The solids content of the size solution has minimal effect on the pickup by the sheet, as does internal sizing level. With reduced sensitivity to web defects and base paper variations, an estimated two to four percent improvement in overall efficiency can be achieved (12). This efficiency upgrade applies not only to the level of sizing, but also to the speed of the machine.

Furthermore, use of a metered size press offers an advantage over a puddle size press because it is possible to run with higher solids content (8). In grades where pigment is added, a metered size press can add pigments with solids contents up to 45% in comparison to the 15% achieved by traditional size presses. A higher solids size application reduces the load on the dryers after the size press and results in fewer breaks, largely due to less instability caused by the hydrodynamic forces present in a puddle (3, 9, 8, 15, 16). One report showed that break reductions of 70-90% could be expected on a regular basis (9). In another study, by Schachtl, the frequency of web breaks also decreased from an average of 14 per week to an average of six per week after the implementation of the metered size press (17). This equated to approximately $0.5 MM in savings per meter of useful width of the sheet, at a speed superior to that of flooded nip or puddle size presses. The same study reports that some pilot machines have been able to run at 5500 feet per minute in metered pigmentizing operations. The ability to apply pigments in higher solids content to the paper also allows less energy to be used to evaporate the moisture from the sheet (17). Steam savings in the after size press dryers often reach as high as 60% (9).

The only shortcoming that the Schachtl study found for metered size presses was a decrease in the z-directional strength of the sheet, since less binder penetrates the surface when utilizing a metered size press (17). However, this same phenomenon is responsible for a better ink/solvent holdout and higher ink gloss in printing. The higher concentration of starch size at the surface of the sheet can also lead to an increase in stiffness (6). An overview of the advantages and disadvantages of a metered size press can be seen in Table 2.

Table 2. Advantages and disadvantages of replacing a puddle size press with a metering size press

Advantages	**Disadvantages**
Higher solids sizing	Lower internal bonding strength
Much higher machine speed	
Fewer breaks	
Less energy for after size press drying	
Increased ink/solvent holdout and ink gloss	
Increased stiffness	

Several types of metering size presses exist, and there are a few technology options depending on the application. The applicator that transfers the size solution to the press roll is an important consideration. Short dwell blade coater heads are common, and can run at several different speeds. They are, however, expensive and take up a lot of space. Jet applicators are less space-demanding, though less common. An enclosed pond applicator is another option that is common in converting puddle size presses to metering size presses with minimal space requirements (3). The metering element can also be of several different types. The most common setup in starch applications is the grooved rod (shown in Figure 10), which provides volumetric metering (3, 8, 14, 16). Notably, load pressure onto the press roll does not have a significant effect on size weight for a grooved rod metering element. In volumetric metering, the amount of size pickup is dependent on the diameter of the wire and the grooves. In this case, the amount of size applied to the surface is most readily changed by modifying the solids of the solution or a rod/roll replacement, though both are slow to effect change (3, 14).

Pressure controlled metering elements can also be used, and provide much easier control of size weight application. Tip-loaded blades allow for very precise control and are common on slower machines. Metering with smooth rods also gives fine control of size application, and are common on machines running high solids size solution at high speeds (3, 13, 14). The roll cover used on the press rolls must be chosen according to desired lifetime of the cover. The premium rubber covers used on a puddle press can be worn in 4 to 6 weeks, while high performance rubber covers can last twice as long (16). Hard covers made with resin composites or polyurethane may be used, but are more common in coating applications (18).

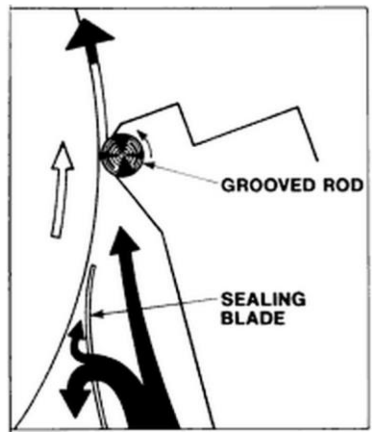


Figure 10. Grooved rod setup for size metering (10)

The metering size press can be configured with a downgoing web run or an upgoing web run (Figure 11). In converting from a puddle size press, the downgoing web run provides the easiest transition. While more expensive, an upgoing web run allows more space for drying installation and allows an operator to more easily evaluate tail feeding, web run, and coverage quality (3, 7, 19). Regardless of the web run configuration, an air turn is a very common installation immediately following the size press (3, 7). As the sheet exits the size press, the sizing is still wet on the surface. An air turn allows redirection of the sheet without contacting the surface. The element essentially comprises several air foils that are directed at the sheet, and provide good web handling and tension control without generating wrinkles on the sheet (3). This allows for not only better product quality, but better runnability. In addition, the air blown onto the sheet surface allows for more effective drying in the following section (20). The use of heated air in the air turn is possible, though increased temperature reduces the lifting force of the foils. A combination of heated and unheated foils would provide increased evaporation and good web handling capability (7).

Drying following the metering size press can have a significant effect on the quality of the product, as critical defects can arise in drying regardless of the effectiveness of the sizing technology. Infrared dryers are typically the first drying mechanism applied to the sheet. The IR dryers can be electric or gas-fired, an option that is largely decided based on the cost of energy, since the two systems have very similar efficiencies. The size film on the sheet should be reach about 75% dryness by the end of the IR dryers to avoid sticking on the subsequent drying cylinders. Too much IR drying, however, can result in size film defects. To mitigate such defects, the space between the IR dryers and the cylinders can be increased. Following the IR dryers are the drying cylinders. In order to avoid sticking to the rolls, the first two cylinders may be operated at lower temperatures. Alternatively, air float cylinders may be used at the beginning. These allow for contactless drying, eliminating the possibility of picking (3, 20, 21).

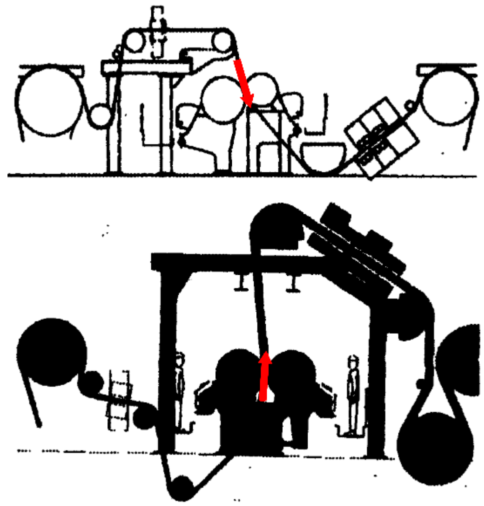


Figure 11. Downgoing (top) and upgoing (bottom) web runs, highlighted in red, with air turns and IR dryers (3)

As metered size presses become more common, new grades may potentially be developed. Surface sized grades may be upgraded to high quality coated grades should a producer decide to use the size press as a precoater instead of a size press (7).

Relevant Technologies

Current Metering Size Press Technology

According to McAuley, UFS mills are increasingly switching from old size press technology to metering size press technology. This is due to the low capital cost of a metering size press in comparison to returns from an increase in product quality and runnability of the paper machine (22). For modernizing mills, switching to a metering size press may be the best option for debottlenecking the paper machine. There is a wide variety of current technology on the market that is suited to all paper machines making all grades of paper.

There are two main types of metering size press that are offered on the market. These include film size presses which apply a thin film of sizing to a transfer roll by a metering rod or blade or with a gate roll and the spray nozzle applicator. Valmet (23) and Paperchine (24) offer spray nozzle size presses. A spray nozzle size press applies the size by spraying directly onto the sheet with a row of spraying nozzles (Figure 12).

Although a non-contact spray sizing system offers a higher amount of sizing with no speed increase and provides a dryer sheet coming out of the size press (23), the technology has not been proven effective in improving quality or runnability in woodfree grades (25).

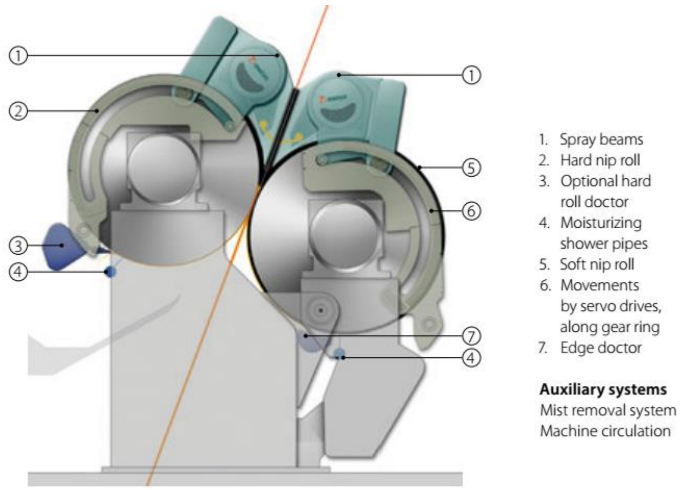


Figure 12. OptiSizer Spray nozzle size press offered by Valmet.

The most widely installed type of metering size press in mills producing UFS are the blade or rod type film metering size presses. According to FisherSolve (26), Valmet's SymSizer and Voith's Speedsizer are by far the most used models of metering size press in U.S. UFS mills (Table 3).

Table 3. FisherSolve output data for U.S. mills producing UFS with metering size press technology ("xxxx" indicates unreported data)

Mill Site	Equip. Supplier	Type of Equipment	Model	Year
NewPage Wickliffe	Voith	Metering Blade	SpeedSizer	1984
IP Ticonderoga	Valmet	Metering Rod	xxxx	1987
Domtar Hawesville	Valmet	Metering Rod	SymSizer	1988
IP Riverdale	Voith	Metering Blade	SpeedSizer	1989
IP Eastover	Valmet	Metering Rod	xxxx	1990
Domtar Marlboro	Valmet	Metering Rod	SymSizer	1990
G-P Port Hudson	Valmet	Metering Rod	SymSizer	1990
G-P Port Hudson	Valmet	Metering Rod	SymSizer	1990
G-P Camas	Voith	Metering Blade	SpeedSizer	1991
Mohawk Cohoes	Valmet	Metering Rod	SymSizer	1991
IP Eastover	Valmet	Metering Rod	xxxx	1991
Domtar Windsor	Valmet	Metering Rod	SymSizer	1991
Domtar Windsor	Valmet	Metering Rod	SymSizer	1991
Finch Glens Falls	Valmet	Metering Rod	SymSizer	1992
Domtar Ashdown	Valmet	Metering Rod	SymSizer	1993
Domtar Johnsonburg	Valmet	Metering Rod	SymSizer	1994
Domtar Ashdown	Valmet	Metering Rod	SymSizer	1995
Glatfelter Chillicothe	Valmet	Metering Rod	SymSizer	1995
MeadWestvaco Evadale	Valmet	Metering Rod	SymSizer	1995
IP Riverdale	Valmet	Metering Rod	xxxx	1995

Domtar Ashdown	Valmet	Metering Rod	xxxx	1996
PCA International Falls	Valmet	Metering Rod	SymSizer	1996
PCA Jackson	Valmet	Metering Rod	SymSizer	1997
Domtar Hawesville	Valmet	Metering Rod	SymSizer	1998
IP Georgetown	Voith	Metering Blade	xxxx	2000
Domtar Kingsport	Valmet	Metering Rod	SymSizer	2002

The SymSizer from Valmet takes the majority of customers in U.S. UFS mills and is known today as the OptiSizer Film. Valmet claims that over 200 OptiSizer Film size presses have been installed in new paper mills and in rebuilds worldwide. Also, excellent runnability, even distribution, and a wide range of applications can be achieved with the OptiSizer Film according to Valmet (27). The OptiSizer Film uses a metering rod to apply a film of sizing to a transfer roll, then to the sheet. Figure 13 shows the film press in an instillation.

Figure 13. OptiSizer film size press from Valmet (28)

The second most common metering size press in U.S. UFS mills according to FisherSolve output is Voith's SpeedSizer. Voith claims that 250 SpeedSizers have been installed since the size press was released (29). Also, highly uniform distribution of sizing and high running speeds can be achieved with the SpeedSizer according to Voith. The SpeedSizer utilizes the blade beam doctor blade with nozzle applicator which applies a film to a transfer roll, then onto the sheet (30). A SpeedSizer is shown in Figure 14 in installation.

Figure 14. SpeedSizer AT from Voith

These two film metering size presses can offer the customer at the paper mill an opportunity to increase machine speed with increased size press solids without sacrificing quality of the product. Also, a film size press can reach speeds up to 5500 ft/min (17) while improving runnability and increasing availability of the machine. It is for these reasons that a film metering size press is recommended for the GPP Macon mill.

Although there are many benefits to using a film metering size press, a few drawbacks are present in the way of routine maintenance. To keep the size press running at optimal conditions, consumables must be replaced fairly often. Since film size presses utilize a transfer roll to apply the sizing to the sheet, considerations for the properties of the roll must be taken to make sure application is even. According to Risi (31), the selection of roll covers and keeping the cover characteristics can improve the quality and runnability of the sheet. Usually, roll covers made of synthetic material are used to provide a soft roll for uniform distribution of sizing. For printing grades, a wide range of roll cover hardnesses can be used from 10-50 P&J according to Allimand (32). The roll covers need to be replace every few weeks. There is a wide variety of roll covers that are offered in the market. The main suppliers of roll covers or Voith and Valmet. Figure 15 shows the LunaFilm roll cover from Voith. Voith claims that this particular cover is extremely abrasion resistant and have characteristics specifically imparted for starch application (33).

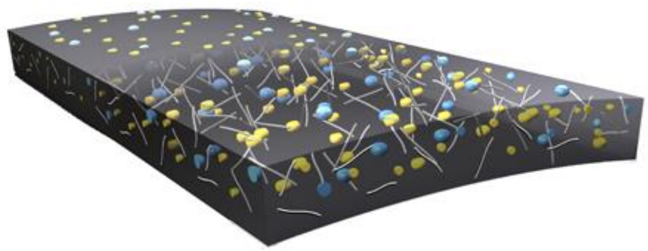


Figure 15. LunaFilm Roll Cover from Voith

Another consumable that is specific to the metering rod film size press is the metering rod itself. The blade on a blade metering size press must also be replaced. Metering rods can be grooved, smooth, or wire wound. These different rods can distribute sizing or coating onto the transfer roll in different amounts or rates according to diameter and with different properties given the shape. The choice of roll can affect the sheet properties and runnability. Grooved rods are recommended by Buschman for use in sizing writing grades (34). An image of a grooved rod is shown in Figure 16.

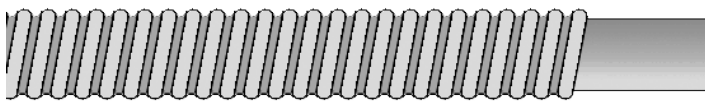


Figure 16. Grooved metering rod illustration

According to Allimand (32), the grooved rod needs to be replaced every 20 days. Metering rods are supplied by Buschman, Voith, Valmet, and UMV to name a few. Mills that replace old size press technology with a metering size press may also consider instillation of contactless drying after the size press. Brigl and Bergmeister GmbH in Niklasdorf, Austria made use of a high performance contactless dryer in addition to installing a new Voith SpeedSizer (35). Evaporation rates can be greatly improved with contactless drying and provide 22% of the ASP drying required in a size press operation (36) (Figure 17).

Gas IR --- 8 rows

		A	B
Sheet Moisture	Ctg	16.9%	13.3%
	Sizing	27.1%	22.8%
Ev Rate (Ave.)	Ctg	30.2 lbs/hr-ft^2	*(147.5 kg/hr-m^2)*
	Sizing	36.4 lbs/hr-ft^2	*(177.7 kg/hr-m^2)*
Drying Rate	Ctg	120.8 lbs/hr-ft	*(179.7 kg/hr-m)*
	Sizing	145.6 lbs/hr-ft	*(216.6 kg/hr-m)*
Water Removed	Ctg	31% of the Drying Required	
	Sizing	22% of the Drying Required	

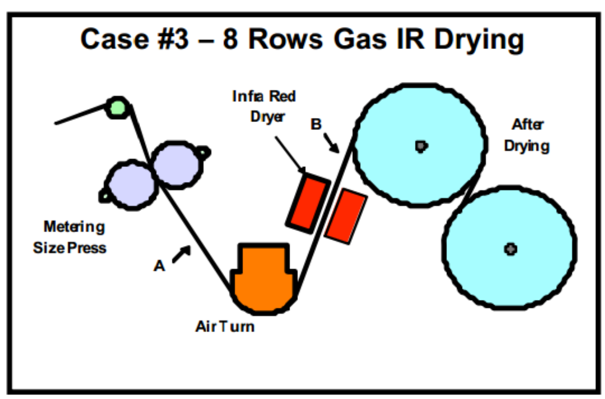


Figure 17. Results of Gas IR drying ASP

Infrared dryers in addition to air turn technologies can increase machine runnability and sheet properties. The before dryer cylinder drying can also virtually rid of sizing defects that are caused by sticking on the dryer cylinder. An image of a conversion project from a puddle size press to a film metering size press with infrared drying before the ASP dryers is show in Figure 18 (37).

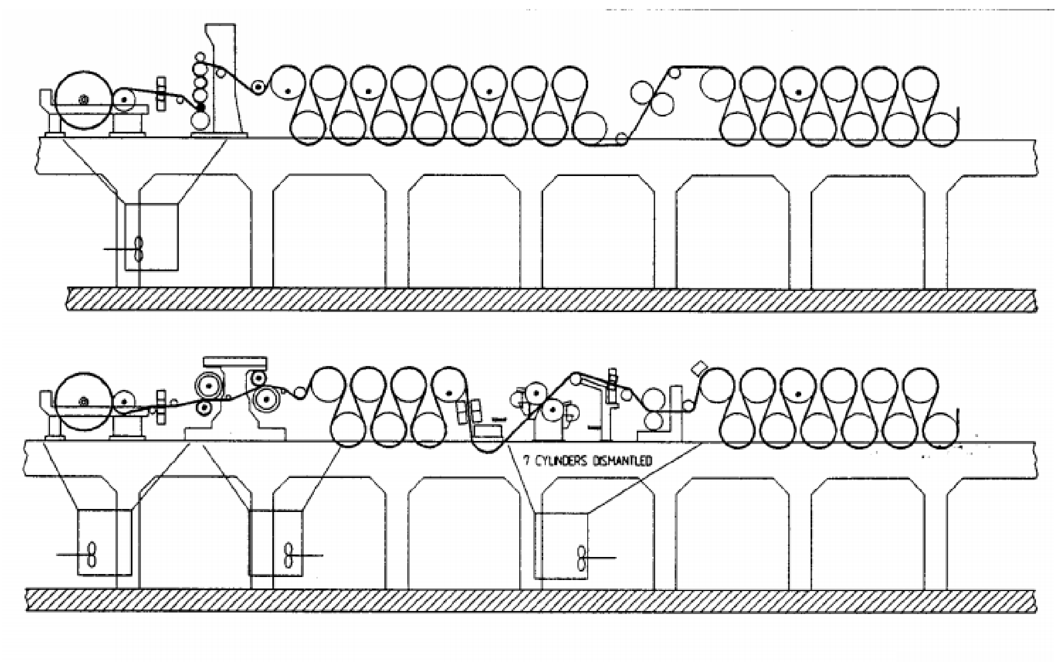


Figure 18. Replacement of puddle size press (top) with a metering size press, calendar stack, and infrared dryers (bottom)

Case Studies

In a paper published in the Pulp & Paper Magazine by Altemeier et al, a case study on uncoated free sheet was examined at a mill in Oftringen, Switwerland. Specifically, the study looked at how ash content in the paper was affected by the implementation of a metering size press over a conventional pond size press. Trials were carried out at the Omya AG pilot coating facility in Oftringen, Switzerland and at the Centre International de Couchage in Trois-Rivierés, Que. Compared to the control, these trials found that the ash content in the paper was increased by a range of 1.5 to 2 percentage points. This is important because it means that more filler content can be applied to the paper, which saves money since filler is cheaper than bleached kraft pulp. Taking data from our mill model's cost analysis, kraft pulp can cost between $65 and $85 per ton production compared with $32.85 and $62.89 per ton for starch and filler, respectively. With a metering size press, starch or other pigments and surface treatment are typically added on the applicator roll and applied to the paper at the nip. This application method allows interference from hydrodynamic forces to be minimized and hence allows surface treatments to be applied in higher solids contents. Applying the surface treatments in higher solids contents leads to energy savings since less energy is needed for drying. Altemeier et al found that savings of $100,000/year could be achieved for a 1,000 tons-per-day machine. Improvements were also seen in porosity, formation and stiffness. According to Altemeier et al, porosity was reduced by up to 80 percent in some models. Formation improved as a result of the metering size press applying a more uniform distribution of ash contents to the paper. The metering size press was not found to have any effect on strength, retention, wet end stability, caliper or smoothness.

Votorantim Celulose e Papel [VCP], a company producing coated woodfree (free sheet) paper in São Paulo, Brazil, was able to successfully implement a metering size press at their facility. At the Piracicaba mill where the trial was held, specialty papers of a wide variety are made from 100 percent eucalyptus hardwood pulp. The metered size press was installed on a 1973 paper machine that runs at a width of 4.2 m and a maximum speed of 800 meters per minute. The project involved the installation of a twin size high speed metered size press from BTG followed by gas infrared and an air turn. The metered size press allowed pigments and fillers to be applied to the web at solids contents upwards of 58 to 62%. The trial consisted of an 8-month learning curve to test areas for improvement in speed, runnability and properties related to the surface quality of the sheet. VCP's trial study found that the implementation of the metered size press allowed the machine to run at an increased speed. Properties such as bulk, print holdout, sheet and print gloss, brightness and surface roughness all improved as a result of adding the metered size press. In this case study, the Piracicaba mill was able to add value to their specialty grades, which justified the long learning curve for the metered size press (38).

Another study by Ryder et al looked at the advantages that the metered size press could have on light weight coated [LWC] paper. UK Paper conducted a trial study at their Sittingbourne Mill in which they compared the advantages and disadvantages of precoating their sheet with a metering size press. As in the study from Altemeier et al, UK Paper saw a reduction in energy demand and material costs, as precoating increased the solids and relative mineral content in the sheet. They also saw a decrease in downtime for their paper machine, since machine breaks occurred with lesser frequency after the metered size press was implemented. Some disadvantages they found were lower internal sheet strength and increased sensitivity to sheet stability for lighter sheets at high speeds. At the metering size press, binders and other surface treatments do not penetrate the sheet as much as they would on a conventional size press. The study found that three main variables specifically related to the metered size press have an effect on the amount of coating that can be applied. Softer roll covers and rods with wider diameters can increase the amount of coating transferred to the sheet. The loading pressure on the rod, typically in the range of 1 to 2.5 bar, can also have an effect on the amount of coating applied (15).

In the UK Paper trial study, improvement was quantified in these five essential areas:

- Sheet break reduction – Figure 19 shows that the installation of a metering size press reduced sheet breaks from 8 to 5 per week

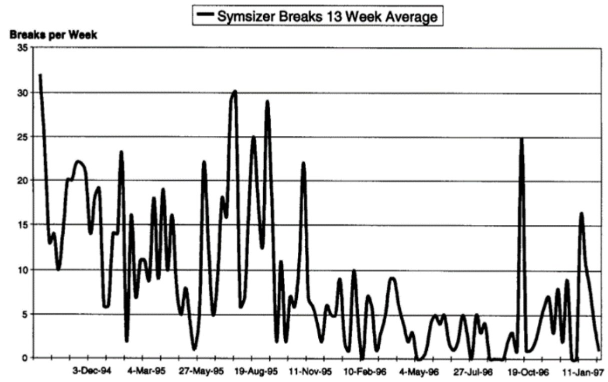


Figure 19. Size press breaks per week (15).

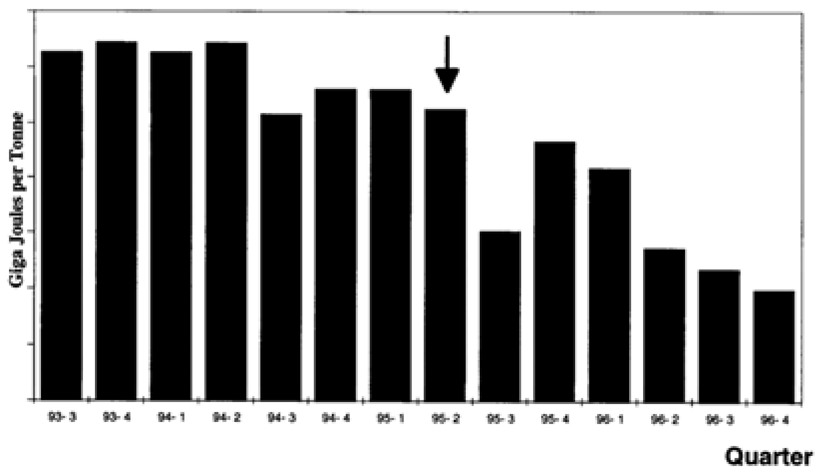


Figure 20. The energy used to produce each ton of paper was reduced (15)

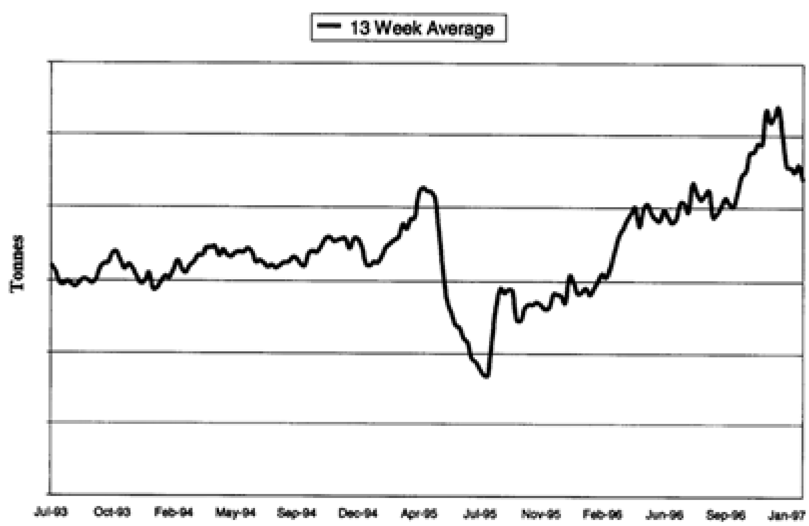


Figure 21. Production was improved as tonnage increased for the tested paper machine (15)

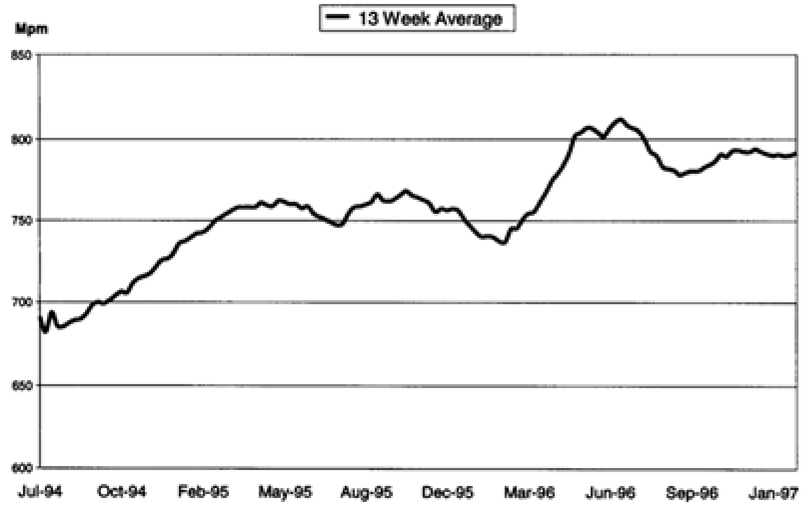


Figure 22. Speed was able to be increased from 750 meters per minute to 800 meters per minute (15)

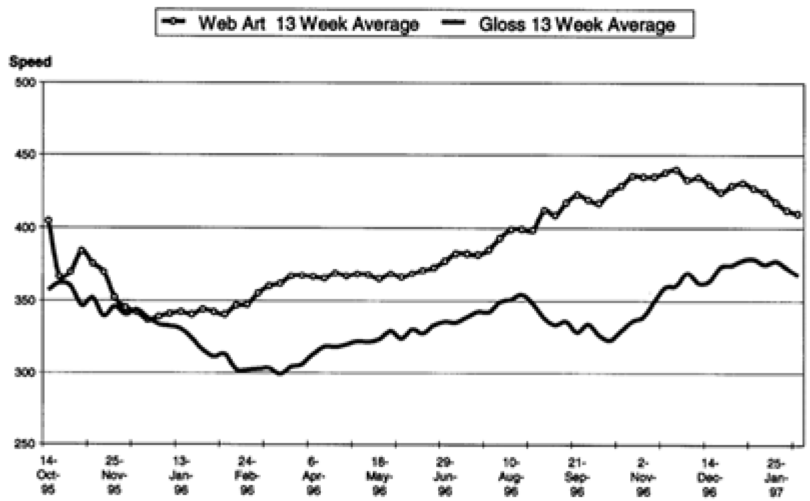


Figure 23. The supercalender was able to increase its speed from 350 meters per minute to 430 meters per minute (15)

According to UK Paper's report, the benefits of installing a metered size press outweighed the costs and they decided to install the equipment. However, many losses were realized during the trial due to downtime and cost of materials. Benefits from the metered size press installation were not realized for the Sittingbourne mill until a full 12 months after the project's installation.

Improving surface sizing operations for an educational paper machine (39)

A study was done on the pilot paper machine at University of Wisconsin Stevens-Point in 2014 to investigate how to better control the application of starch to the sheet and how to optimize all other surface sizing operations on the paper machine. On the current paper machine, the pond size press was outdated and had not been used on a regular basis for several years. Previous groups had tried to implement spray bars to apply the starch but ran into issues with keeping the starch warm and preventing the nozzles from plugging. These issues were primarily caused by retrogradation, a condition in which the starch clumps together if the temperature is not maintained at a high enough temperature. The team at UWSP therefore decided to not only modify the press, but also improve the starch kitchen, to reduce the retrogradation problem. To address the issues with the starch kitchen, the team added two new layers of insulation and a hot water line to the cook tank; and they added a layer of insulation to the day storage tank as well. After looking at previously used models of size presses, the research team at UWSP decided to model their size press after the metered size press. For their trial, they added a box to the size press that would control the flow of surface sizing to the sheet by controlling feed pump pressure and raising and lowering a gate at the front of the box. Results saw tensile strength increase by approximately 10 percent compared to the base paper on the same run with no size.

Metso Corporation: Top rebuild reference (40)

Metso Corporation also conducted a case study in 2005 on the Mondi Packaging Raubling mill in Bavaria, Germany around the rebuild from a pond size press to a film size press on PM7. Two grades of paper were tested: testliner (basis weights of 105-150 g/m^2) and corrugated container board (basis weights of 90-127 g/m^2). Through the rebuild of the paper machine with Metso's ValSizer film transfer technology, production was increased as efficiency improved, and desired board properties were maintained in each paper grade. In addition to improved machine efficiency, the simplified design of the size press along with its integrated control system made it much easier to operate and maintain. The new film coater size press eliminated the bottleneck that was present with the former pond size press, allowing for improved runnability and less breaks on the paper machine. Mondi Raubling was also able to increase the average speed of the machine by 6 percent over the average speed before the rebuild. Even after the rebuild, strength properties were retained in the sheet and the mill showed sustained results after the rebuild.

Equipment Installation of a Metering Size Press

In addition to consumables like roll covers and metering rods, there are quite a few pieces of equipment that may need to be replaced or upgraded on an existing paper machine to install a new film size press. Also, there are a few new pieces of equipment that will need to be considered for instillation. The entire system will need to be configured over time to account for the unique machine conditions.

For the GPP Macon mill, a film size press is recommended for its ability to apply a high quality layer of surface sizing to an UFS grade at higher machine speed and the higher solids content of starch solution that is possible with the film size press. A list of equipment that may be needed for a proper instillation at the GPP mill is shown in Table 4.

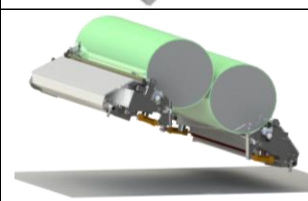
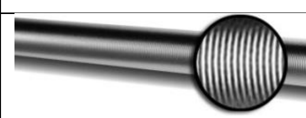
Table 4. Equipment Needed for Installation of a Metering Size Press

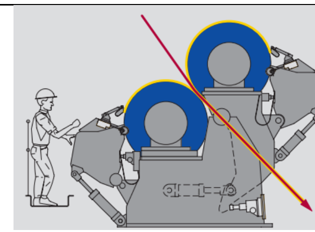
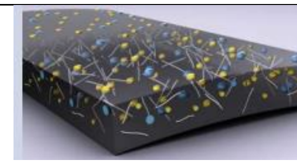
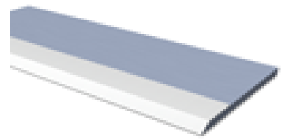
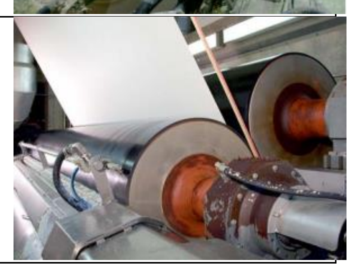
Section	Technology	Type	Installation
Size Press	Transfer Rolls	Stainless Steel	New
	Metering Element	Blade approach storage or Rod holders and beds	New
	Nozzle Distribution	Starch Feed to metering element	New
	Cleaning System	Wiper blade	New
	Roll Drivers	Mechanical drives	New/refit
	Pressure Application	Pneumatic rod loading	New/refit
	Control System	Flow rate and machine speed based	New
Starch Makedown	Supply	Pipes feeding size press for higher solids content	New/refit
	Cooking	Higher solids cook	Refit
	Storage	Controlled	Refit
	Starch	Cooked starch	Same
	Control System	Aligned with size press control	Refit
Consumables	Roll Cover	Soft rubber	New (replace 5 wks.)
	Metering Rod	Grooved	New (replace 20 d.)
	Metering Blade	Doctor blade	New (replace)
Other	Gas IR Dryers	With removal of 5 cylinder dryers	New
	Air Turn	With removal of 5 cylinder dryers	New
	Threading	Cylinder dryer approach	New/refit

Suppliers of Metering Size Press Equipment

Table 5 outlines major companies that supply metering size press technology. Voith and Valmet are the major suppliers of metering size presses in U.S. UFS mills (26). Voith supplies a blade metering size press along with replacement roll covers and blades. They also provide consulting services for new paper machine installations and rebuilds. This includes control systems, threading, sizing approach, and drives. Valmet is the leading supplier of metering rod size presses and they offer replacement roll covers and metering rods along with consulting services and whole-package services as mentioned above for Voith. The UMV TWIN Sizer is not commonly used in the U.S., but UMV offers package deals like Voith and Valmet along with 4 types of size presses (41). Paperchine, an AstenJohnson company claims that they have the most affordable sizing solutions on the market (42). Use of the ProSizer is not reflected in FisherSolve, however (26). Buschman Corporation is a major supplier of replacement metering rods and offers tailored solutions for paper machines (32). Both Andritz and PMP group offer compact sized metered sizing solutions for paper mills (43, 46). A typical installation of a metering size press in an existing mill will include consulting from a single company and installation of equipment from that company. The services may include configuration and testing after installation and troubleshooting once the equipment has been established. Most of the companies listed offer these services which is indicated in the Table 5 as Sizing Solutions in the Type Column.

Table 5. Suppliers of Metering Size Press Equipment

Company	**Product Line**	**Product**	**Type**	**Description**	**Picture**
UMV	TWIN™-Sizer		Sizing Solutions	Two-sided, thin film application with tailored equipment. Offers training.	
		INVO® Rod	Metering Rod	Volumetric or hydrodynamic premetering. High speed.	
		HSM	Metering Rod	Volumetric premetering. Low speed, low wear.	
		Gravure	Gate Roll	Volumetric premetering. Indirect. High control.	
Paper-chine	ProSizer		Sizing Solutions	Rod metering. Claims most affordable sizing solution on the market. Offers consulting services.	
Andritz	*Prime-*Coat	Film	Sizing Solutions	Compact design with flexibility in sizing application on one or both sides.	
Buschman	Dura™-Flow	Grooved	Metering Rod	Threaded rod gives consistent coat.	

Voith	Speed-Sizer		Sizing Solutions	Nozzle applicator with metering blade. Tailored equipment. High speed and uniformity.	
	Luna-Film	S, R, and E	Roll Covers	Film press roll covers that improve runnability on high speed machines.	
	Sky line		Doctor Blades	Cleaning blades and sizing application blades.	
Valmet	Opti-Sizer	Film	Sizing Solutions	Film application for high speed machines. Consulting offered.	
		Spray	Sizing Solutions	Direct spray of sizing through nozzles.	
	Roll Covers	Cote-Falcon	Roll Covers	Wear resistant roll cover for flexible use.	
		Size-Hawk ZL	Roll Covers	Wear resistant and provides uniformity.	

PMP Group	Intelli-Sizer™		Sizing Solutions	Compact design and dosing of sizing substance onto applicator rolls.	

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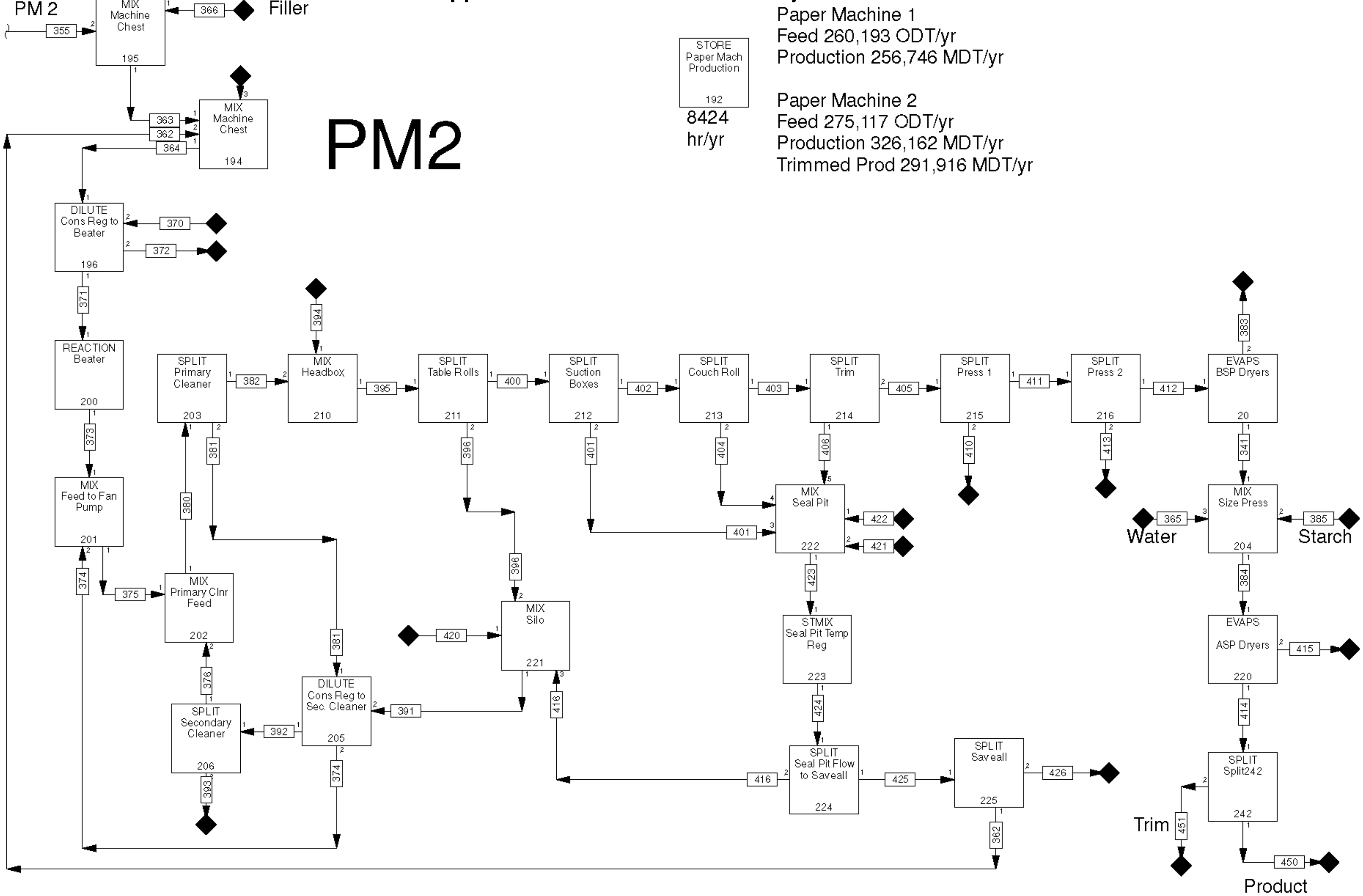
Appendix A2: WinGEMS blocks layout for PM2



Appendix A3: Economic Analysis Supplements

		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Direct Cost per Incremental FT													
Incremental Freight per Incremental Ton	$70.00	$0.00	$70.00	$72.10	$74.26	$76.49	$78.79	$81.15	$83.58	$86.09	$88.67	$91.33	$94.07
Annual Inflation of Freight starting in 2016	3.0%												
Fiber	PM2 Incremental TPY	0	-13,698	14,189	14,217	14,245	14,274	14,303	14,331	14,360	14,389	14,417	14,446
	Cost per Incremental fiber	0	132	146.80	151.21	155.74	160.41	165.23	170.18	175.29	180.55	185.96	191.54
Chemicals	Cost per Incremental FT	0.00	146.63	151.03	155.56	160.22	165.03	169.98	175.08	180.33	185.74	191.32	197.06
Energy	Cost per Incremental FT	0.00	62.16	64.03	65.95	67.93	69.96	72.06	74.22	76.45	78.74	81.11	83.54
Finishing Materials	Cost per Incremental FT	0.00	20.95	21.58	22.23	22.90	23.58	24.29	25.02	25.77	26.54	27.34	28.16
Total Direct Costs	per Incremental FT	0.00	431.53	455.54	469.20	483.28	497.78	512.71	528.09	543.94	560.25	577.06	594.37
	per Year	0	-5,911,043	6,463,473	6,670,692	6,884,554	7,105,273	7,333,068	7,568,166	7,810,801	8,061,216	8,319,658	8,586,386
Total Incremental Direct Cash Costs		0	-5,911,043	6,463,473	6,670,692	6,884,554	7,105,273	7,333,068	7,568,166	7,810,801	8,061,216	8,319,658	8,586,386

Indirect Cost per Year		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Incremental RAV		$0	$14,051,243	$14,472,780	$14,906,964	$15,354,173	$15,814,798	$16,289,242	$16,777,919	$17,281,256	$17,799,694	$18,333,685	$18,883,696
Maintenance Expense		$0	$281,025	$289,456	$298,139	$307,083	$316,296	$325,785	$335,558	$345,625	$355,994	$366,674	$377,674
Labor (Excluding Repair)		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Operating Materials		$0	$70,256	$72,364	$74,535	$76,771	$79,074	$81,446	$83,890	$86,406	$88,998	$91,668	$94,418
Other Mill Fixed Cost		$0	$140,512	$144,728	$149,070	$153,542	$158,148	$162,892	$167,779	$172,813	$177,997	$183,337	$188,837
Depreciation		$0	$2,028,002	$3,496,242	$2,538,884	$1,856,311	$1,371,674	$1,386,310	$1,404,251	$786,911	$165,033	$169,984	$175,083
Business Unit Overhead		$0	-$259,457	$245,057	$243,018	$242,661	$241,724	$240,676	$239,920	$239,617	$239,657	$239,775	$240,104
Sector Overhead		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Corporate Overhead		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Indirect Costs		$0	$2,260,338	$4,247,847	$3,303,646	$2,636,368	$2,166,916	$2,197,109	$2,231,398	$1,631,373	$1,027,679	$1,051,438	$1,076,117
Total Incremental Indirect Cash Costs		$0	$2,260,338	$4,247,847	$3,303,646	$2,636,368	$2,166,916	$2,197,109	$2,231,398	$1,631,373	$1,027,679	$1,051,438	$1,076,117
Total Incremental Cash Costs		$0	-$3,650,705	$10,711,319	$9,974,337	$9,520,922	$9,272,188	$9,530,177	$9,799,564	$9,442,174	$9,088,894	$9,371,096	$9,662,503

Working Capital	Wood Yard	$0	$467,465	$521,772	$538,500	$555,764	$573,582	$591,971	$610,950	$630,537	$650,752	$671,615	$0
	Finished Product	$0	-$3,243,215	$3,063,209	$3,037,724	$3,033,258	$3,021,544	$3,008,446	$2,998,994	$2,995,214	$2,995,710	$2,997,190	$3,001,301
	Total Working Capital	$0	-$2,775,750	$3,584,981	$3,576,224	$3,589,023	$3,595,126	$3,600,417	$3,609,944	$3,625,751	$3,646,461	$3,668,805	$3,001,301
	Change in WC	$0	-$2,775,750	$6,360,732	-$8,757	$12,799	$6,104	$5,291	$9,527	$15,807	$20,710	$22,344	-$667,505

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Incremental Replacement Asset Value	$0	$14,051,243	$14,472,780	$14,906,964	$15,354,173	$15,814,798	$16,289,242	$16,777,919	$17,281,256	$17,799,694	$18,333,685	$18,883,696
Project Capital	$7,025,621	$7,025,621										
Maintenance Capital	$0	$140,512	$144,728	$149,070	$153,542	$158,148	$162,892	$167,779	$172,813	$177,997	$183,337	$188,837
Total New Fixed Capital	$7,025,621	$7,166,134	$144,728	$149,070	$153,542	$158,148	$162,892	$167,779	$172,813	$177,997	$183,337	$188,837
Depreciation Factors	14.29%	24.49%	17.49%	12.49%	8.93%	8.92%	8.93%	4.46%	0.00%	0.00%	0.00%	0.00%
2016		$2,028,002	$3,475,561	$2,482,138	$1,772,550	$1,267,324	$1,265,905	$1,267,324	$632,952	$0	$0	$0
2017			$20,682	$35,444	$25,313	$18,077	$12,924	$12,910	$12,924	$6,455	$0	$0
2018				$21,302	$36,507	$26,072	$18,619	$13,312	$13,297	$13,312	$6,649	$0
2019					$21,941	$37,602	$26,854	$19,177	$13,711	$13,696	$13,711	$6,848
2020						$22,599	$38,730	$27,660	$19,753	$14,123	$14,107	$14,123
2021							$23,277	$39,892	$28,490	$20,345	$14,546	$14,530
2022								$23,976	$41,089	$29,345	$20,956	$14,983
2023									$24,695	$42,322	$30,225	$21,584
2024										$25,436	$43,591	$31,132
2025											$26,199	$44,899
2026												$26,985
		$2,028,002	$3,496,242	$2,538,884	$1,856,311	$1,371,674	$1,386,310	$1,404,251	$786,911	$165,033	$169,984	$175,083

Starch Usage	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Base case PM2 FT	297,920	298,515	299,112	299,711	300,310	300,911	301,513	302,116	302,720	303,325	303,932	304,540
Base starch in FT	14,896	14,926	14,956	14,986	15,016	15,046	15,076	15,106	15,136	15,166	15,197	15,227
Base starch off PM2	15,641	15,672	15,703	15,735	15,766	15,798	15,829	15,861	15,893	15,925	15,956	15,988
Total starch used	17,909	17,945	17,980	18,016	18,052	18,088	18,125	18,161	18,197	18,234	18,270	18,307
Proposed Case PM2 FT	297,920	284,818	313,301	313,928	314,556	315,185	315,815	316,447	317,080	317,714	318,349	318,986
Proposed starch in FT	14,896	14,241	15,665	15,696	15,728	15,759	15,791	15,822	15,854	15,886	15,917	15,949
Proposed starch off PM2	15,641	14,953	16,448	16,481	16,514	16,547	16,580	16,613	16,647	16,680	16,713	16,747
Total Starch used	17,909	17,121	18,833	18,871	18,909	18,947	18,984	19,022	19,060	19,099	19,137	19,175
Incremental starch	-	823	(853)	(855)	(856)	(858)	(860)	(861)	(863)	(865)	(867)	(868)
Starch price	$520.00	$533.00	$546.33	$559.98	$573.98	$588.33	$603.04	$618.12	$633.57	$649.41	$665.64	$682.29
Incremental savings	$0.00	$548,600	-$582,462	-$598,217	-$614,399	-$631,019	-$648,088	-$665,619	-$683,624	-$702,116	-$721,108	-$740,614

ASP Steam Usage	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Base Water Added to sheet (tons)	262,410	262,928	263,447	263,968	264,489	265,011	265,535	266,059	266,584	267,111	267,639	268,167
# of steam for evaps after size press	734,748,207	736,199,050	737,652,794	739,109,446	740,569,012	742,031,496	743,496,905	744,965,246	746,436,523	747,910,742	749,387,910	750,868,032
MMBTU	793,528.06	795,095	796,665.02	798,238	799,815	801,394	802,977	804,562	806,151	807,744	809,339	810,937
MMBTU /FT	2.66	2.66	2.66	2.66	2.66	2.66	2.66	2.66	2.66	2.66	2.66	2.66
@ 85% eff	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13
Cost per FT	15.67	15.67	15.67	15.67	15.67	15.67	15.67	15.67	15.66	15.66	15.66	15.66
Total Cost	4,667,812	4,677,029	4,686,265	4,695,519	4,704,791	4,714,082	4,723,392	4,732,720	4,742,067	4,751,433	4,760,817	4,770,220
Proposed water added to sheet	262,410	226,585	119,865	120,099	120,332	120,566	120,801	121,036	121,271	121,507	121,743	121,980
# of steam for evaps after size press	734,748,207	634,437,644	335,623,386	336,275,979	336,929,878	337,585,084	338,241,600	338,899,430	339,558,575	340,219,039	340,880,823	341,543,931
MMBTU	793,528	685,193	362,473	363,178	363,884	364,592	365,301	366,011	366,723	367,437	368,151	368,867
MMBTU /FT	2.66	2.41	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21
@ 85% eff	3.13	2.83	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.42
Cost per FT	15.67	14.15	7.13	7.13	7.13	7.13	7.13	7.13	7.13	7.13	7.13	7.12
Total Cost	4,667,812	4,030,545	2,132,196	2,136,342	2,140,496	2,144,658	2,148,829	2,153,008	2,157,196	2,161,392	2,165,596	2,169,809
Steam Savings	$0	$646,484	$2,554,069	$2,559,177	$2,564,296	$2,569,424	$2,574,563	$2,579,712	$2,584,872	$2,590,041	$2,595,221	$2,600,412

Install MSP, 5% speed increase, 3.5% starch pickup

Project Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Incremental Tons per Year	0	-13,698	14,189	14,217	14,245	14,274	14,303	14,331	14,360	14,389	14,417	14,446
Revenue	0	-12,972,862	12,252,838	12,150,896	12,133,033	12,086,176	12,033,784	11,995,978	11,980,858	11,982,838	11,988,761	12,005,202
Direct Costs	0	-7,106,128	-103,576	8,446	124,701	245,338	370,510	500,374	635,095	774,843	919,792	1,070,124
Indirect Costs	0	2,260,338	4,247,847	3,303,646	2,636,368	2,166,916	2,197,109	2,231,398	1,631,373	1,027,679	1,051,438	1,076,117
Startup Costs		$161,538										
Total Costs	$0	-$4,684,251	$4,144,270	$3,312,092	$2,761,069	$2,412,254	$2,567,618	$2,731,771	$2,266,468	$1,802,522	$1,971,230	$2,146,241
Depreciation	$0	$2,260,338	$4,247,847	$3,303,646	$2,636,368	$2,166,916	$2,197,109	$2,231,398	$1,631,373	$1,027,679	$1,051,438	$1,076,117
EBITDA	$0	-$6,028,272	$12,356,414	$12,142,450	$12,008,332	$11,840,838	$11,663,274	$11,495,604	$11,345,762	$11,207,996	$11,068,969	$10,935,078
EBIT	$0	-$8,288,610	$8,108,567	$8,838,805	$9,371,964	$9,673,922	$9,466,165	$9,264,206	$9,714,390	$10,180,317	$10,017,531	$9,858,961
Tax @35%	$0	-$2,901,014	$2,837,999	$3,093,582	$3,280,187	$3,385,873	$3,313,158	$3,242,472	$3,400,036	$3,563,111	$3,506,136	$3,450,636
After Tax Income	$0	-$5,387,597	$5,270,569	$5,745,223	$6,091,776	$6,288,050	$6,153,007	$6,021,734	$6,314,353	$6,617,206	$6,511,395	$6,408,325
Cash Flow	$0	-$3,127,259	$9,518,415	$9,048,869	$8,728,144	$8,454,965	$8,350,116	$8,253,132	$7,945,726	$7,644,885	$7,562,833	$7,484,441
New Fixed Capital	$7,025,621	$7,166,134	$144,728	$149,070	$153,542	$158,148	$162,892	$167,779	$172,813	$177,997	$183,337	$188,837
Change in Working Capital	$0	-$2,775,750	$6,360,732	-$8,757	$12,799	$6,104	$5,291	$9,527	$15,807	$20,710	$22,344	-$667,505
Free Cash Flow	-$7,025,621	-$7,517,642	$3,012,956	$8,908,556	$8,561,804	$8,290,714	$8,181,933	$8,075,825	$7,757,106	$7,446,178	$7,357,153	$7,963,109
x Year 10 EBITDA (TV=5)	-$7,025,621	-$7,517,642	$3,012,956	$8,908,556	$8,561,804	$8,290,714	$8,181,933	$8,075,825	$7,757,106	$7,446,178	$7,357,153	$49,294,806
Discount Rate @ 12%	-$7,868,696	-$7,517,642	$2,690,139	$7,101,847	$6,094,123	$5,268,898	$4,642,649	$4,091,464	$3,508,921	$3,007,386	$2,653,063	$15,871,608
Net Present Value	$39,543,760											
IRR, %	40.9%											

Install MSP, 5% speed increase, no starch pickup change

Project Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Incremental Tons per Year	0	-13,698	14,189	14,217	14,245	14,274	14,303	14,331	14,360	14,389	14,417	14,446
Revenue	0	-12,972,862	12,252,838	12,150,896	12,133,033	12,086,176	12,033,784	11,995,978	11,980,858	11,982,838	11,988,761	12,005,202
Direct Costs	0	-7,106,128	4,491,865	4,709,732	4,934,658	5,166,867	5,406,593	5,654,072	5,909,553	6,173,290	6,445,545	6,726,588
Indirect Costs	0	2,260,338	4,247,847	3,303,646	2,636,368	2,166,916	2,197,109	2,231,398	1,631,373	1,027,679	1,051,438	1,076,117
Startup Costs		$161,538										
Total Costs	$0	-$4,684,251	$8,739,712	$8,013,377	$7,571,026	$7,333,783	$7,603,701	$7,885,470	$7,540,926	$7,200,969	$7,496,982	$7,802,705
Depreciation	$0	$2,260,338	$4,247,847	$3,303,646	$2,636,368	$2,166,916	$2,197,109	$2,231,398	$1,631,373	$1,027,679	$1,051,438	$1,076,117
EBITDA	$0	-$6,028,272	$7,760,972	$7,441,164	$7,198,375	$6,919,309	$6,627,191	$6,341,905	$6,071,304	$5,809,549	$5,543,217	$5,278,614
EBIT	$0	-$8,288,610	$3,513,126	$4,137,519	$4,562,007	$4,752,393	$4,430,082	$4,110,508	$4,439,932	$4,781,870	$4,491,779	$4,202,497
Tax @35%	$0	-$2,901,014	$1,229,594	$1,448,132	$1,596,703	$1,663,338	$1,550,529	$1,438,678	$1,553,976	$1,673,654	$1,572,123	$1,470,874
After Tax Income	$0	-$5,387,597	$2,283,532	$2,689,387	$2,965,305	$3,089,056	$2,879,553	$2,671,830	$2,885,956	$3,108,215	$2,919,656	$2,731,623
Cash Flow	$0	-$3,127,259	$6,531,378	$5,993,033	$5,601,673	$5,255,971	$5,076,662	$4,903,228	$4,517,328	$4,135,894	$3,971,094	$3,807,740
New Fixed Capital	$7,025,621	$7,166,134	$144,728	$149,070	$153,542	$158,148	$162,892	$167,779	$172,813	$177,997	$183,337	$188,837
Change in Working Capital	$0	-$2,775,750	$6,360,732	-$8,757	$12,799	$6,104	$5,291	$9,527	$15,807	$20,710	$22,344	-$667,505
Free Cash Flow	-$7,025,621	-$7,517,642	$25,919	$5,852,721	$5,435,333	$5,091,720	$4,908,479	$4,725,921	$4,328,709	$3,937,187	$3,765,413	$4,286,407
x Year 10 EBITDA (TV=5)	-$7,025,621	-$7,517,642	$25,919	$5,852,721	$5,435,333	$5,091,720	$4,908,479	$4,725,921	$4,328,709	$3,937,187	$3,765,413	$21,012,485
Discount Rate @ 12%	-$7,868,696	-$7,517,642	$23,142	$4,665,753	$3,868,762	$3,235,880	$2,785,203	$2,394,299	$1,958,088	$1,590,164	$1,357,846	$6,765,458
Net Present Value	$13,258,256											
IRR, %	24.3%											

Install MSP, no speed change, no starch pickup change

Project Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Incremental Tons per Year	0	-14,966	3,019	3,025	3,031	3,037	3,043	3,049	3,055	3,061	3,068	3,074
Revenue	0	-14,173,654	2,606,987	2,585,297	2,581,496	2,571,527	2,560,380	2,552,336	2,549,119	2,549,540	2,550,800	2,554,298
Direct Costs	0	-7,712,360	-1,142,522	-1,100,364	-1,056,712	-1,011,519	-964,736	-916,311	-866,192	-814,324	-760,653	-705,121
Indirect Costs	0	2,236,322	4,054,930	3,112,334	2,445,337	1,976,623	2,007,641	2,042,525	1,442,738	839,013	862,679	887,099
Startup Costs		$161,538										
Total Costs	$0	-$5,314,499	$2,912,407	$2,011,969	$1,388,625	$965,103	$1,042,905	$1,126,214	$576,546	$24,688	$102,025	$181,977
Depreciation	$0	$2,236,322	$4,054,930	$3,112,334	$2,445,337	$1,976,623	$2,007,641	$2,042,525	$1,442,738	$839,013	$862,679	$887,099
EBITDA	$0	-$6,622,833	$3,749,509	$3,685,661	$3,638,209	$3,583,046	$3,525,115	$3,468,646	$3,415,310	$3,363,865	$3,311,454	$3,259,419
EBIT	$0	-$8,859,155	-$305,421	$573,328	$1,192,871	$1,606,424	$1,517,474	$1,426,122	$1,972,572	$2,524,852	$2,448,775	$2,372,321
Tax @35%	$0	-$3,100,704	-$106,897	$200,665	$417,505	$562,248	$531,116	$499,143	$690,400	$883,698	$857,071	$830,312
After Tax Income	$0	-$5,758,451	-$198,523	$372,663	$775,366	$1,044,175	$986,358	$926,979	$1,282,172	$1,641,154	$1,591,704	$1,542,009
Cash Flow	$0	-$3,522,128	$3,856,406	$3,484,996	$3,220,704	$3,020,798	$2,993,999	$2,969,504	$2,724,910	$2,480,166	$2,454,382	$2,429,107
New Fixed Capital	$7,025,621	$7,166,134	$144,728	$149,070	$153,542	$158,148	$162,892	$167,779	$172,813	$177,997	$183,337	$188,837
Change in Working Capital	$0	-$3,443,953	$4,206,715	-$1,863	$2,723	$1,299	$1,126	$2,027	$3,363	$4,406	$4,754	-$142,022
Free Cash Flow	-$7,025,621	-$7,244,309	-$495,037	$3,337,790	$3,064,439	$2,861,351	$2,829,981	$2,799,697	$2,548,734	$2,297,763	$2,266,292	$2,382,292
x Year 10 EBITDA (TV=5)	-$7,025,621	-$7,244,309	-$495,037	$3,337,790	$3,064,439	$2,861,351	$2,829,981	$2,799,697	$2,548,734	$2,297,763	$2,266,292	$11,861,604
Discount Rate @ 12%	-$7,868,696	-$7,244,309	-$441,997	$2,660,866	$2,181,207	$1,818,441	$1,605,807	$1,418,414	$1,152,918	$928,028	$817,247	$3,819,119
Net Present Value	$847,045											
IRR, %	12.9%											