

Large data set analysis to determine refiner plate total cost of ownership

JOHN DEJARNETTE, HUMPHREY MOYNIHAN,
AND PETER W. HART

ABSTRACT: Efficient process data storage and its subsequent analysis are vital to the profitable operation of a paper mill. An evaluation of refiner plate performance was conducted for an integrated paper mill. Trials with two new plate patterns were compared with the incumbent pattern; the goal was to increase refiner plate life.

Plate life increased with both new design patterns, and the mill selected one of the two new choices. However, additional impacts to paper machine performance and mill maintenance costs were not considered in the selection decision. A large data set analysis tool was used to identify unrealized savings of 1.5% with reduced fiber usage (basis weight) on the paper machine's most prevalent grade. The large data analysis indicated that this unrealized benefit with the alternate plate design was *not attainable* with the chosen plate design.

Assessment of the overall cost of ownership for any item in a paper mill can be a complex task. The purchase price is easily understood, but it does not convey the impact of an item's performance on mill operations. Until recently, the effort to collect and evaluate the process data to calculate this impact was considerable; a large amount of data had to be manipulated using a computer spreadsheet or statistical software. Often, this data analysis required a large amount of time and effort by the user just to remove outlier data attributed to upset mill conditions, and to inaccurate or redundant values.

An integrated paper mill conducted refiner plate trials with the intention of increasing refiner plate life; the paper machine uses 100% recycled furnish to produce corrugated medium. The refiner is a 36-in. double disk design. The refiner plates installed in this primary stock refiner are noted for their unusually short life span of 300 h. This paper machine typically produced a basis weight higher than target in order to meet grade quality specifications. The mill evaluated two new plate designs (denoted as B and C), which were compared to the incumbent plate design (denoted as A) (**Table I**).

Refiner Plate Design	Life Span, h	Relative Price
A	300	\$
B	900	\$\$\$
C	600	\$

1. Performance values for refiner plate sets.

As a result of a cursory trial data evaluation based on the purchase price, the upgraded plate design C was selected for improved plate life. These plates offered twice the run time at the same cost per set of plates as the incumbent plate design (design A). This straightforward conclusion from the initial evaluation was claimed to satisfy the purchasing goals set by both the mill and corporate procurement. On the other hand, mill operations personnel suspected that paper quality was better and that paper basis weight was reduced when plate design B was used. Nevertheless, initial attempts to evaluate process trial data with respect to the different refiner plate patterns were time consuming with no impacts quantified.

Corporate research and development personnel re-examined the data from the refiner plate trials more thoroughly using computer software to analyze big data sets. The trademarked WEDGE

(Wet End Diagnostic GENius) software system was developed by the Finnish Pulp and Paper Institute in 1991 as a paper machine diagnostic tool [1]. It was originally distributed by Savcor Forest Oy (Mikkeli, Finland), but newer versions are distributed by Trimble Inc. (Sunnyvale, CA, USA). This tool allows the viewing, monitoring, and processing of online process information (PI) data such that outlier and erroneous data can be easily identified and quickly removed prior to subsequent data analyses.

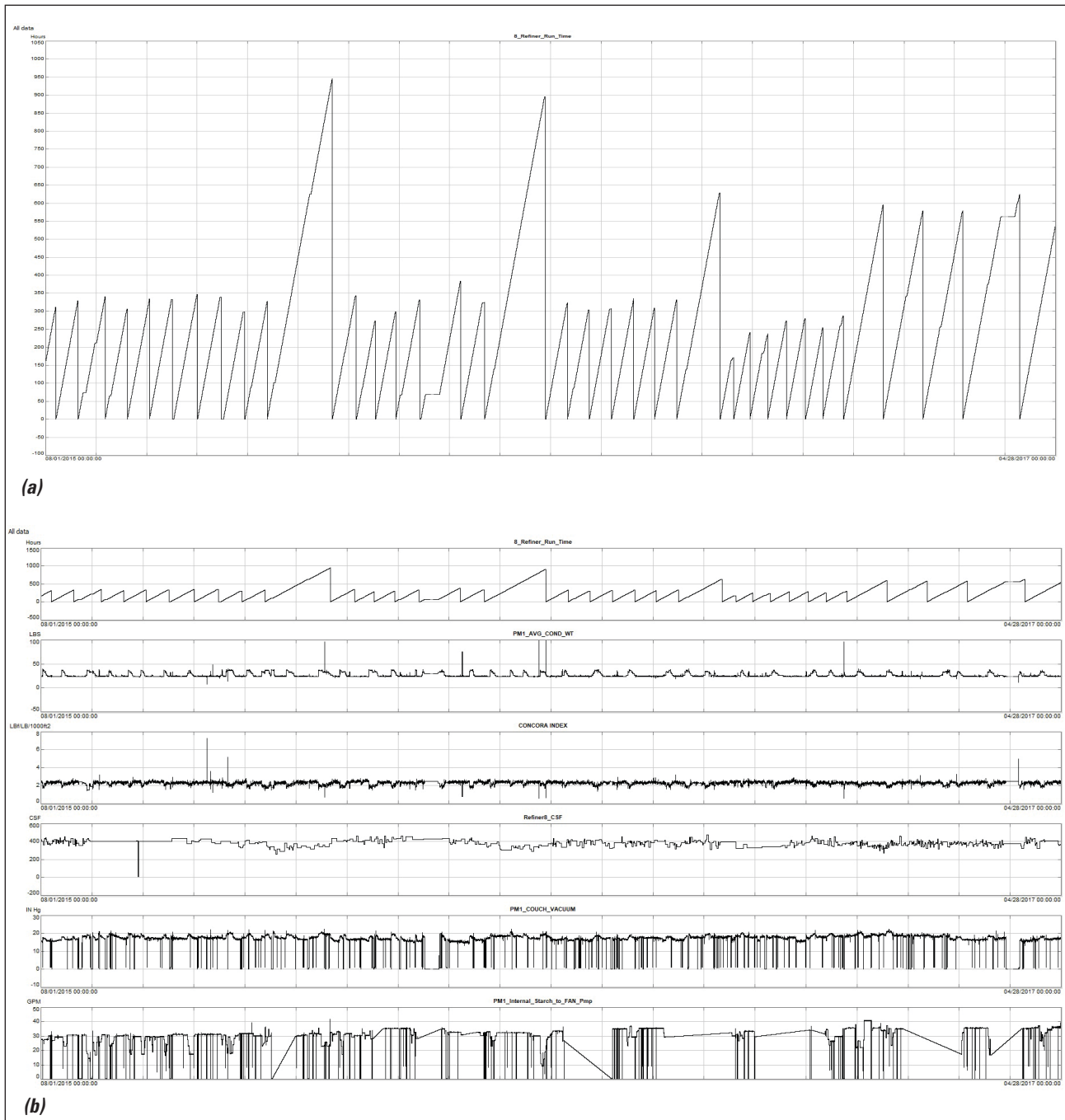
Through the use of visual graphical data display, multiple parameters were simultaneously examined and manipulated. Basic statistical values (i.e., average, standard deviation, maximum, and minimum) were compared across the defined time periods. Outlier data were removed from the time periods that were associated with machine downtime and upset operating conditions. Filtered data from the same defined time

periods were used for all process analyses. The resulting filtered data sets were subsequently analyzed by Minitab 17 (Minitab LLC; State College, PA, USA) for detailed statistical analyses. These analyses allowed for the impact of plate design on paper basis weight to be assessed much more quickly than by traditional approaches.

METHOD

Mill PI tags that contained relevant refining characteristics and machine performance measurements during the refiner plate trials were identified for data analysis. These tags included: refiner run time; refined pulp freeness (CSF); average conditioned paper basis weight; couch vacuum pressure; internal starch

added to the fan pump; and laboratory-measured flat crush of corrugating medium (concora corrugating medium test (CMT) index; TAPPI Standard Test Method T809 om-11 “Flat crush of corrugating medium [CMT test]”). Using WEDGE software, these values were sampled on an hourly basis during a 20-month period of mill operations (**Fig. 1**). This



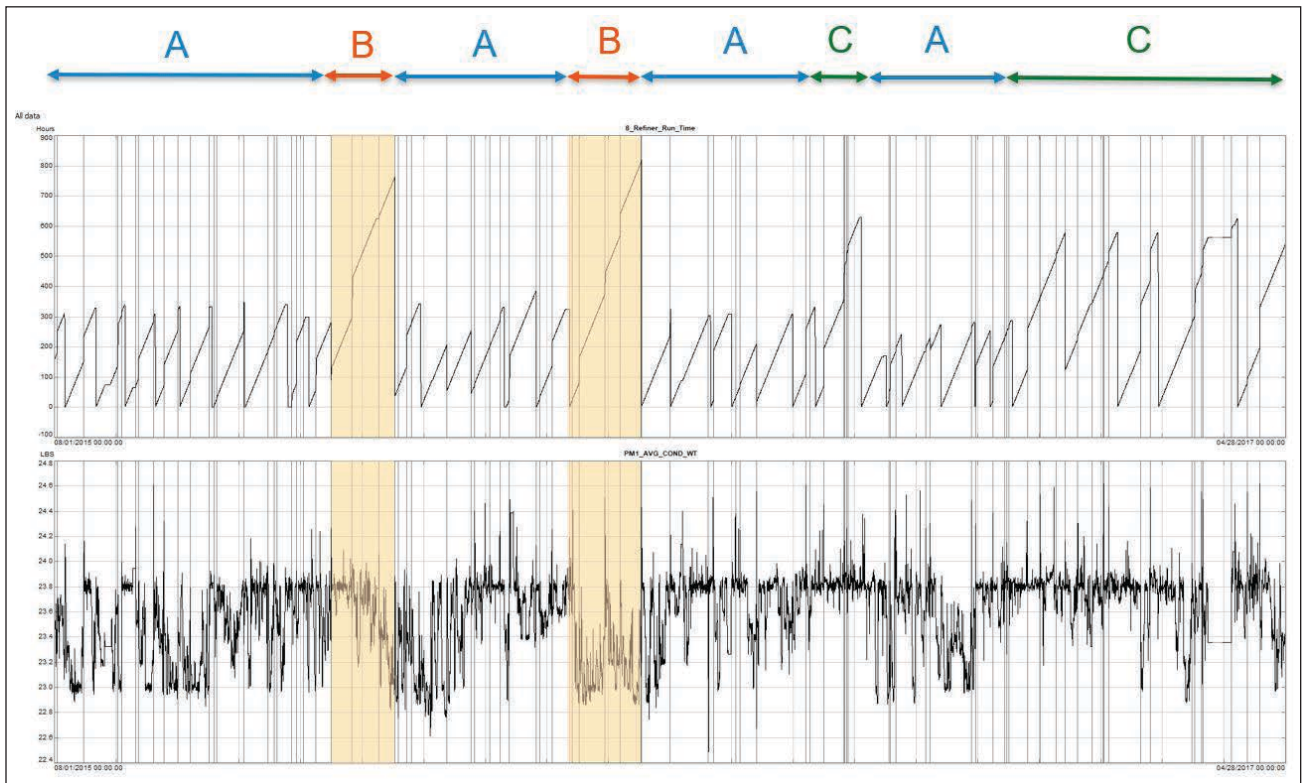
1. Raw mill data sampled hourly from 8/1/2015 to 4/27/2017 prior to large data set analyses. a) Data values of paper machine no. 1 (PM1), refiner 8 accumulated refiner plate run time; b) Data values (from top to bottom): refiner run time; PM1 average conditioned paper basis weight; CMT (concora) index; refiner 8 CSF; PM1 couch vacuum; and PM1 internal starch added to fan pump.

Paper Machine:	PM1		
Grade:	23 lb/1000 ft ²		
Basis Weight:	+/-5% total average lbs		
	average	-5%	+5%
	23.46	22.29	24.63
Couch Vacuum:	10–22 in. Hg		

time interval was chosen to include the baseline operations prior to the trials, the trials with the various plate patterns, and the subsequent operations with the chosen plate pattern.

The study was limited to only the most prominent paper grade made by the paper machine, which represents ~80% of the run time. The data sets were filtered of all time periods representing paper machine downtime and out-of-specification process conditions according to the following criteria:

II. Defined machine operating values for data filtering for in-specification corrugating medium.

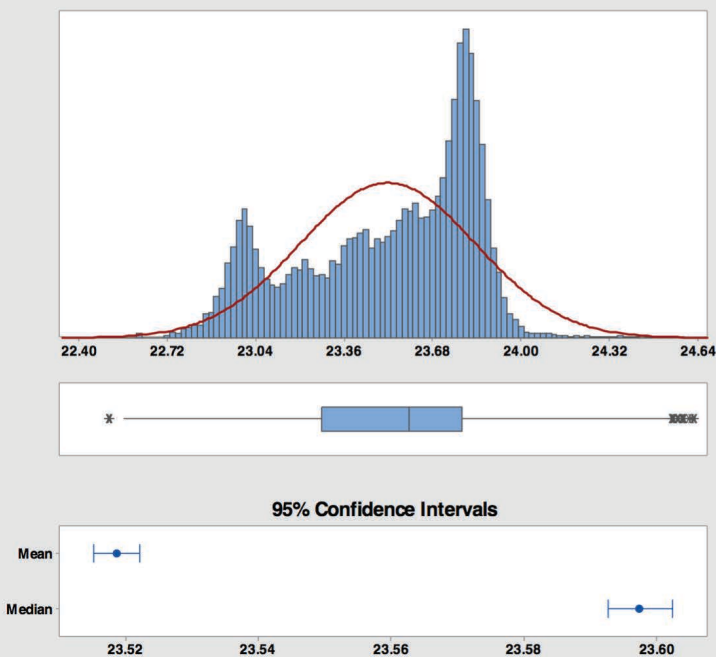


2. Refiner plate run time relationship to paper machine basis weight. (Note: Raw process data was filtered by parameters in Table II. Labels A, B, and C identify time intervals during which the different plate designs were installed in the refiner. The top graph displays refiner 8 accumulated run time [top] and PM1 conditioned paper basis weight [bottom]. Refiner plate B is highlighted in orange for ease of identification. Vertical lines indicate time points where outliers were filtered from the raw process data.)

Measurement	Unit	Design A	Design B	Design C
8_Refiner_Run_Time	hours	158.8	398.2	289.7
PM1_AVG_COND_WT	lb/1000 ft ²	23.52	23.36	23.72
CMT (CONCORA) INDEX	lb/(lb/1000 ft ²)	2.357	2.377	2.313
PM1_COUCH_VACUUM	inches of Hg	16.84	17.62	17.57
PM1_Internal_Starch_to_FAN_Pmp	gpm	30.16	28.19	32.4
No 8 Refiner KW	kW	976.4	945.4	1026
Refiner8_CSF	mL	331.7	390	370.5

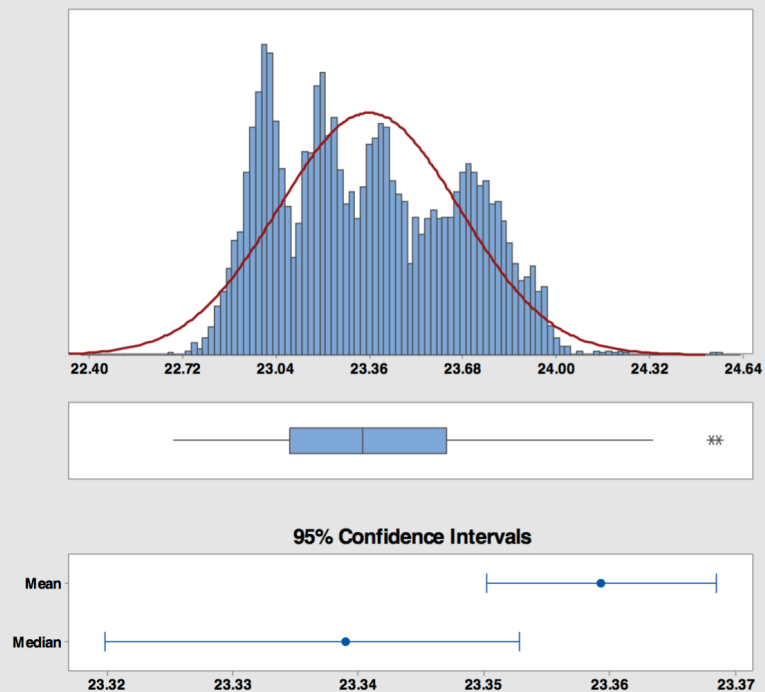
III. Machine performance values for various refiner plate designs.

Summary Report for lb/ 1000ft²
Condition = A



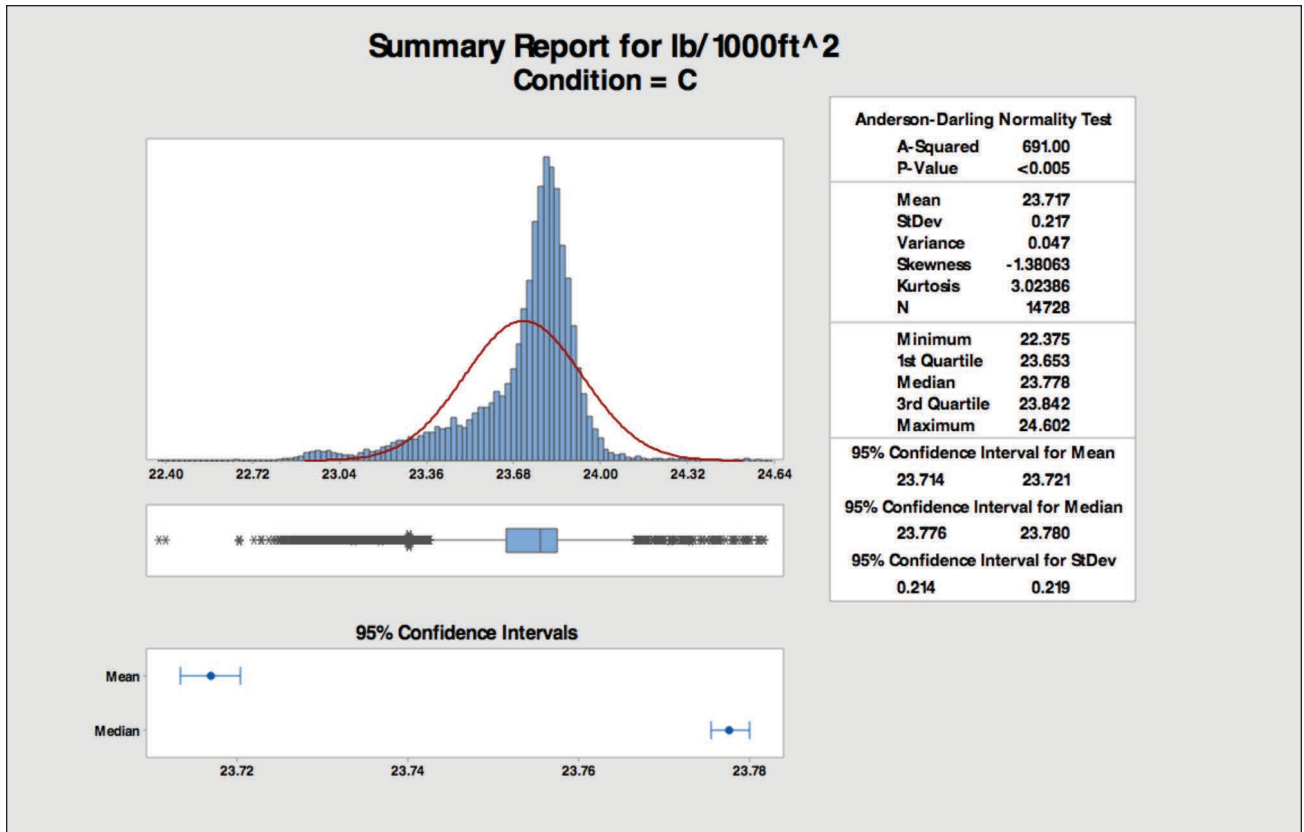
Anderson-Darling Normality Test	
A-Squared	855.03
P-Value	<0.005
Mean	23.519
StDev	0.317
Variance	0.101
Skewness	-0.509382
Kurtosis	-0.721099
N	33294
Minimum	22.509
1st Quartile	23.279
Median	23.597
3rd Quartile	23.785
Maximum	24.629
95% Confidence Interval for Mean	
	23.515 23.522
95% Confidence Interval for Median	
	23.593 23.602
95% Confidence Interval for StDev	
	0.315 0.320

Summary Report for lb/ 1000ft²
Condition = B



Anderson-Darling Normality Test	
A-Squared	46.46
P-Value	<0.005
Mean	23.359
StDev	0.310
Variance	0.096
Skewness	0.252265
Kurtosis	-0.929438
N	4425
Minimum	22.688
1st Quartile	23.087
Median	23.339
3rd Quartile	23.623
Maximum	24.556
95% Confidence Interval for Mean	
	23.350 23.368
95% Confidence Interval for Median	
	23.320 23.353
95% Confidence Interval for StDev	
	0.303 0.316

3. Sample distributions of paper basis weight (opposite and above) for the three refiner plate conditions; note that the x-axis is the same for all conditions (figure continued on next page).



3 (con.). Sample distributions of paper basis weight (opposite and above) for the three refiner plate conditions; note that the x-axis is the same for all conditions.

basis weight not within 5% of the average for the paper grade, and couch vacuum falling outside the 10 to 22 in. of Hg range (**Table II**). The filtered data ensured that subsequent statistical analyses did not include any shutdown periods, paper machine breaks, or out-of-specification paper. Paper machine operating conditions were then compared for the different plate patterns installed (**Fig. 2**).

RESULTS AND DISCUSSION

Average refining conditions, pulp characteristics, and paper machine performance were determined for each of the three plate patterns (**Table III**). This initial data summary was calculated within the WEDGE software in a matter of minutes. The filtered data sets were then exported into Minitab for further statistical analysis; the numerical distribution of the paper basis weight for the various data sets can be seen in **Fig. 3**. Statistical analyses (analysis of variance [ANOVA], Mood Median Test,

and Kruskal-Wallis Test) established the validity of the preliminary observations of reduced basis weight when plate B was used and increased basis weight when plate C was used when compared to plate A (control).

The collected data for each of the refiner plate sets did not exhibit a normal distribution profile, and in some cases, the distribution profiles were multimodal; these data sets are examples of non-normal distributions. A higher average CMT index, a critical strength property for corrugating medium, was obtained when using plate B. Plate B consumed 30 kW less refiner power and produced a pulp with 60 mL higher CSF than the plate A, and consumed 80 kW less refiner power and produced a pulp with 20 mL higher CSF than the plate C. Savings in starch use were apparent, but it was determined during the data analysis that the starch addition flow meter was unreliable and was frequently inaccurate. Improved product quality and reduced production cost were seen

with the B plate design; however, these unrealized benefits were not factored into the purchasing decision. The savings in mill maintenance costs for the refiner plate changes, based on expected plate life, were also not considered.

Use of the B plate would have saved the mill 1.5% per year in fiber costs when compared to the chosen design (C plate); this fiber cost savings far exceeded the extra yearly cost incurred by purchasing B versus C plate. Additionally, there would be a 50% savings in mill maintenance costs and an 8% reduction in refining energy if B had been chosen instead of C. The total cost of ownership of plate B would have been significantly lower for the mill; hence, a change to refiner plate B was recommended to the mill by corporate R&D.

CONCLUSIONS

This case study indicates it is possible to significantly lower the total cost of ownership for refiner plates by analyzing all of the process data captured by a mill

data historian. Such large data set analyses can potentially identify significant operational impacts that have not been considered in previous analyses. This case study clearly demonstrates that refiner plate replacement costs may be overwhelmed by the impact of refiner plate design on machine performance (e.g., lower pulp fiber usage [basis weight] and refiner energy). The large data set analysis that was used allowed a detailed comparison of baseline and trial refiner plate pattern performance; this analysis approach can be used as a model for future refiner plate evaluations. **TJ**

LITERATURE CITED

1. Paulapuroand, H. and Ritala, R., IFAC Proceedings Volumes 24(6): 597(1991).
[https://doi.org/10.1016/S1474-6670\(17\)51207-0](https://doi.org/10.1016/S1474-6670(17)51207-0).

ABOUT THIS TECHNICAL BRIEF

Cite this article as:

DeJarnette, J., Moyhihan, H., and Hart, P., *TAPPI J.* 18(6): 391(2019).
<https://doi.org/10.32964/TJ18.6.391>

DOI: <https://doi.org/10.32964/TJ18.6.391>

ISSN: 0734-1415

Publisher: TAPPI Press

Copyright: ©TAPPI Press 2019

[About this journal](#)

ABOUT THE AUTHORS

DeJarnette is senior researcher, Moynihan is senior research engineer, and Peter W. Hart is director, Fiber Science, at WestRock, Richmond, VA, USA. Email DeJarnette at John.DeJarnette@westrock.com.



DeJarnette



Moynihan



Hart