MAKING IT WITH LESS (equipment, energy, water, and other stuff)

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Abstract:

Paper machines and supporting processes are designed and installed based on expected ranges of production rates using specific furnishes, headbox consistency, chemistry, refining, retention, fabrics, etc. The configuration of the paper machine is determined based on everyone's "best guess" of the needs for sheet formation and dewatering. Following start-up (and sometimes before start-up) one or more of the process variables have changed. As time progresses, more variables are altered and easily modified components are changed accordingly (chemistry, production rates, additives, fabrics, etc.) However, changing the hardware of the papermaking process may require removing or eliminating equipment which has been bought, paid for, and installed. Making decisions to modify the process are often preceeded with studies, trials, and papermakers with enough initiative and spirit to make significant changes. Results can be very positive.

Case studies are presented about paper, containerboard and pulp machine optimization projects which were justified based on projected electrical energy and steam savings, and productivity improvements. Each project involved studies and/or trials to identify equipment which had little or no impact on sheet water removal in the former and press. Unnecessary equipment (flatboxes, couch, uhle boxes and vacuum pumps) were removed during the optimization process. Outcomes typically exceeded expectations for increased machine speed, energy savings and efficiency improvements.

Discussion:

Case #1: Kraft Bag Machine – 250" wire width, 2200-3000 fpm, 37-78#/3000 ft^2

This machine had a fourdrinier and tri-nip press. The mill had already experimented with shutting off 3 of the 5 flatboxes. Early table dewatering is with six (6) gravity and six (6) vacuum foils, and since drainage was very good at gravity and low vacuum elements, fewer high vacuum elements were required. A problem existed however with combining all of the vacuum airflow of the original 5-flatbox system to one or two flatboxes. This resulted in undersized piping and separators. The revised system was to remove the remaining two flatboxes and replace them with a single unit using five (5) ½" slots. Photos below (Figures 1 & 2) show old flatbox piping and separators, and the new, larger separator for the single, new flatbox.

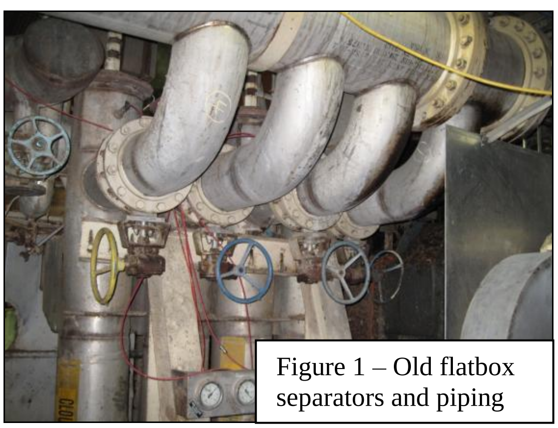

Figure 1 – Old flatbox separators and piping

Figure 2 – New single flatbox separator

The new flatbox system needed a single, large separator and associated piping. Also, following the removal of the rest of the flatboxes, less total flatbox capacity was required and this allowed swapping of a larger vacuum pump with a smaller pump which was connected to the suction couch. The new, 5-slot flatbox is shown in the next photo (Figure 3). Note sheet color change at the initial slot indicating rapid dewatering.

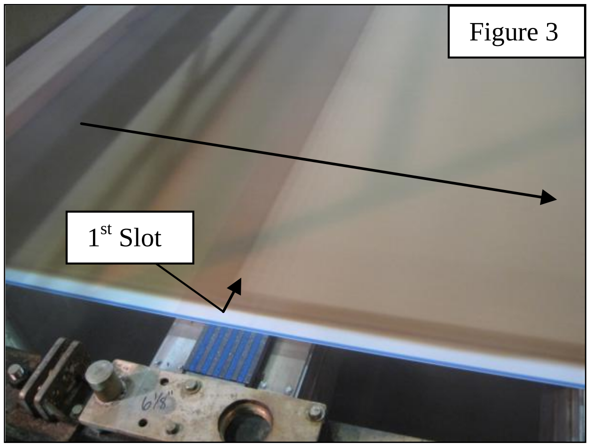

Figure 3

In the press, each of the three felts had two uhle boxes each. The 10" and 12" diameter uhle boxes excessive slot area provided by their herringbone covers. Equivalent slot area was 1.16 in. to 1.75 in. and was more than required for the 2500 – 3000 fpm machine speeds. The uhle box vacuum system still included three 1950's vintage pumps, plus one newer model. (Figure 4) Vacuum capacity and large slot areas yielded uhle box vacuum factors of only 8 to 12 cfm/in².

Past projects were proposed to replace the old vacuum pumps but other than a small amount of horsepower and maintenance savings, justification was not possible. These previous project attempts were based on replacing all existing vacuum system capacity of the three old pumps, or about 15,000 cfm.

After reviewing the uhle box system performance with very low operating vacuum and excessive slot area, a plan was agreed on to reduce slot widths on all uhle boxes to only two ½" slots each. Herringbone covers would be abandoned since modern seamed felts operate well with slotted covers. Both pick-up uhle boxes would be replaced, and only one new 1st bottom uhle box will replace the existing two uhle boxes. A single new uhle box was proposed for replacing the two 3rd press units, but to save cost, the existing units were converted to a single ½" slot each. No lube shower would be used between the two boxes so these would function about the same as a single uhle box with double slots. The three new uhle boxes were to be 16" diameter.

Since required uhle box capacity was reduced, new vacuum system capacity required only a single, new pump. (Figure 5) Vacuum system operating power was to be reduced by 280 hp. The revised uhle boxes and vacuum system provided a vacuum factor of 18 cfm/in². A new 12,000 cfm vacuum pump was purchased.

The project was well planned and coincided with an annual mill shutdown. Start-up went extremely well and the machine ran for 7 days without a sheet break. This is quite remarkable for any machine following a long shutdown. Vacuum system power savings was at the 280 hp level, and press drive horsepower was reduced by 70 hp due to the new uhle box arrangements. Press exit solids improved by over 1% and a measured 5% dryer steam reduction was achieved.

2 less vacuum pumps + one less uhle box + less slot area for uhle boxes and flatboxes = 5% steam savings + 350 hp savings.

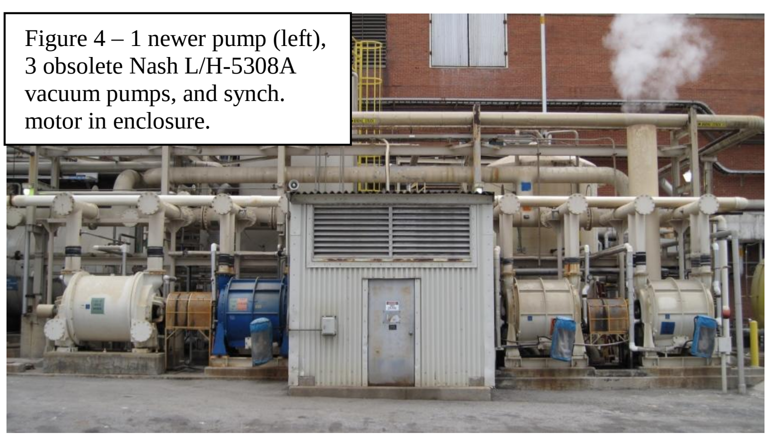
Figure 4 – 1 newer pump (left), 3 obsolete Nash L/H-5308A vacuum pumps, and synch. motor in enclosure.

Figure 5 – Newest vacuum pump on right

Case #2: Coated Fine Paper – 326” – Voith Duoformer, 4700-5000 fpm, 30 – 45# 3300 ft^2

This is a gap former followed by two (2), 2-zone flatboxes just prior to the suction couch. Machine speed is typically 4750 fpm. Sheet solids across both flatbox elements increase from about 11% consistency to almost 17%. Drainage study data indicated that most, if not all, of the dewatering was done by the initial 2-zone flatbox.

System operation was providing graduated vacuum levels across the four flatbox zones, but with only 1.5” Hg of vacuum change between zone #1 and zone #4. Results showing most water removal by the initial 2 zones is not unexpected. Water removal is impacted more by vacuum levels than by dwell time. Since extracted sheet water provides lubrication at the flatbox cover and forming fabric interface, a lack of water due to almost no dewatering results in added friction and higher forming section drive horsepower.

It was assumed that four suction zones, each with 6 slots, varying from 1” slots to 5/8”, do not dewater any better than only two suction zones with the same vacuum differential. Therefore, a recommendation was made to shut off vacuum to the first of the 2-zone flatboxes. Vacuum trials helped to prove that only one of the flatboxes was required. The first flatbox was selected to be shut off because it had wider slots (1” and ¾”) than the second flatbox (3/4” and 5/8”), and less slot area would yield higher vacuum levels, if needed. All flatbox cover material was silicon nitride. (Figure 6)

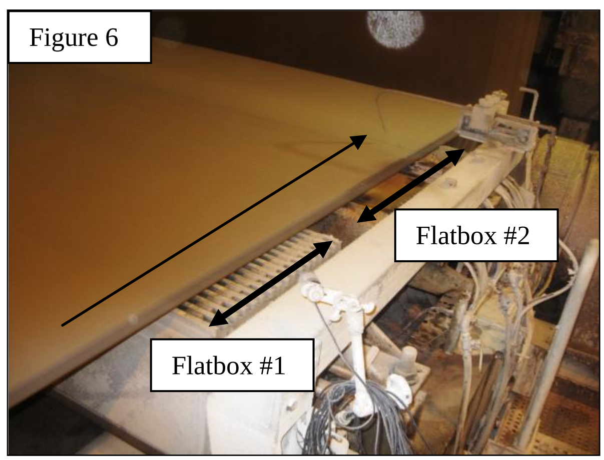

Figure 6

The initial step was to graduate the vacuum levels to provide a more aggressive change across the four zones. Rather than begin at 13” Hg and end at 14.5” Hg, vacuum was reduced at the first three zones to yield 7.0”, 12.0”, 13.0” and 14.1” Hg at the four zones. This change alone resulted in reduced former drive load of 41 hp, for a 2% power reduction. Shutting off zone #1 of the first flatbox reduced power by 239 hp (11%), and was lowered another 105 hp when the #2 zone was shut off. At the final step of the trial vacuum was adjusted at the second flatbox to 15” Hg at zone #1, and 17.8” Hg at zone #2. Total former power reduction from start to finish was 403 hp, or almost 19% less than at the start of the trial. Table 1 provides the data recorded during the vacuum/dewatering trial. Note this trial was complete in just over 3 hours.

DATA POINT:	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Time	10:10A	10:55A	11:15A	11:50A	12:30P	1:00P	1:20P
WT Roll Amps	49	49	44	42	40	38	38
WT Roll Helper Amps	49	49	45	42	40	38	37
Couch Amps	39	38	34	33	31	30	29
Ret. Roll Amps	47	46	44	44	43	42	42
Top Wire Amps	55	53	51	49	48	49	49
Total Former HP	2156	2115	1960	1876	1804	1771	1753
Flatbox Header Vac.	14.5	14.9	15.1	15.0	16.5	19.1	19.3
FB#1, Z #1	13.3	7.0	2.0	0.0	0.0	0.0	0.0
FB#1, Z #2	13.5	12.0	10.9	10.6	5.8	0.0	0.0
FB#2, Z #1	14.1	13.8	14.1	14.0	15.6	17.5	15.0
FB#2, Z #2	14.2	14.1	14.1	14.1	15.7	17.9	17.8
Reel Speed	4579	4578	4578	4578	4593	4593	4593

Table 1

The week following the trial included a machine shutdown and the first flatbox was lowered from the wire.

Forming fabric life was averaging 12 weeks, and trial fabric designs were attempting to reach an 18 week shutdown schedule. Verification that 18 weeks was not confirmed, but removing 400+ former drive power, with all of this being related to drag load, should have made this possible.

Energy savings alone was worth over $140,000 per year. Almost no investment was required to achieve this savings.

Summary: 2 less flatbox vacuum zones + graduated vacuum = 430 hp savings, or 19% drag load reduction. Extended fabric life is likely.

<u>Case #3: Kraft Bag Machine – 254” wire, 1350 – 2950 fpm, fourdrinier, bleached and unbleached kraft bag.</u>

The paper machine former and press was reviewed for process optimization and potential for energy reduction. One of the significant items noted was that the couch exit solids was quite low, at about 20% consistency, with both couch vacuum pumps operating. More important, was that gamma gauge data indicated the suction couch contributed no more than 1% to the consistency increase before the press. The press had a suction pick-up, and this reduced some of the negative impact of low couch solids.

The suction couch had two vacuum zones, and utilized two 6000 cfm vacuum pumps. Due to a bearing failure on one of the vacuum pumps, the #2 couch vacuum zone had <u>no pump connected</u> during the study because the pump was removed for repair. A tri-vac preceded the couch and operating vacuum at the #3 zone exceeded the vacuum level at the #1 couch zone. As an experiment, the vacuum pump connected to the #1 couch zone was shut off. With <u>no couch vacuum</u>, the machine ran with no measurable changes.

Previous vacuum-dewatering trials had indicated that higher flatbox vacuum could yield 23+% sheet solids. Therefore, a project was developed to focus on increasing sheet dewatering at the table vacuum elements, rather than try to determine how to improve water removal at the couch. Since this was associated with a study to reduce energy within the paper machine and its vacuum system, the cost savings potential for not operating the two 300 hp couch vacuum pumps was significant.

Following a review of proposals to upgrade the high vacuum table elements and coinciding modifications to the vacuum system, decisions were made to proceed with the project. The existing flatbox system consisted of two, 8-slot flatboxes followed by a tri-vac with each zone provided with 6 slots. These connected to a vacuum source including one 2000 cfm and three 4000 cfm vacuum pumps. A small amount of vacuum capacity was bled from the system to the low-vac elements (vacuum foils). Total vacuum capacity for the former was 26,000 cfm with 1275 connected motor horsepower.

The proposed system is as follows:

- Eliminate and remove one of two flatboxes
- Replace remaining 8-slot flatbox cover with 6-slot unit
- Replace tri-vac with duo-vac
- Eliminate vacuum to couch
- Eliminate three vacuum pumps totaling 12,000 cfm

Earlier vacuum trials provided a confidence level that higher flatbox vacuum would allow improved sheet solids to the press. Removing suction zones was justified since the couch was doing almost nothing toward water removal. Trials with no vacuum on the couch also showed that this did not negatively impact driving the fabric. This fourdrinier also has a wire turning roll.

Vacuum capacity for each of the remaining three high vacuum zones were adjusted to progressively increase the vacuum factors and expected vacuum levels. The final vacuum zone before the press was the new #2 zone, of the new duo-vac (figure 7 & 8). This was designed for high vacuum level and high vacuum capacity, with only five (5), ½" slots. One of the previous 6000 cfm couch pumps would connect to this. The new duo-vac was to be supplied with a new vacuum separator to handle the higher vacuum airflows. The flatbox and tri-vac removed from the table are shown below, sitting on the operating floor. (Figure 9).

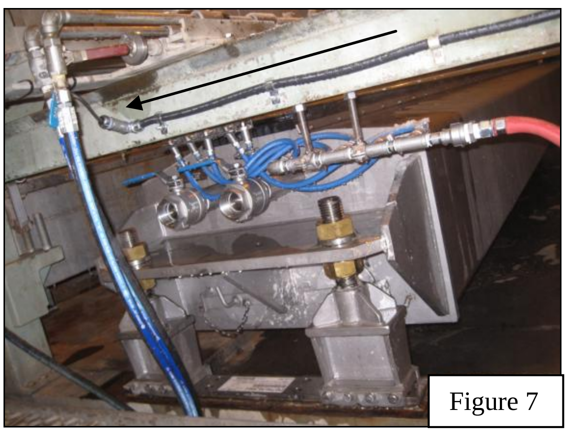
Figure 7

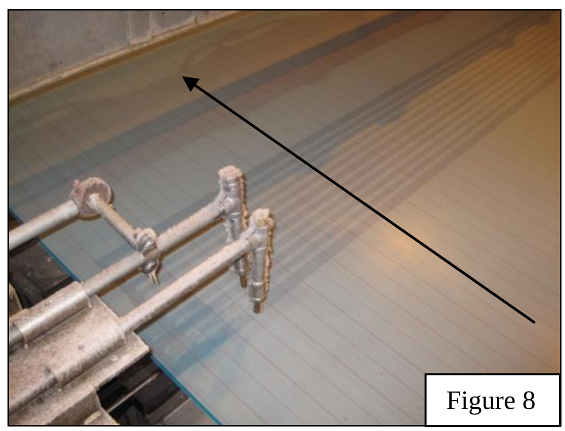
Figure 8

The project received a lot of attention because of the significant energy savings and potential up-side with less sheet water into the press. Additionally, the local electric utility was supporting the project with a portion of the cost. The initial vacuum study was in July 2010 and the annual shutdown where the modifications were made was in April 2011.

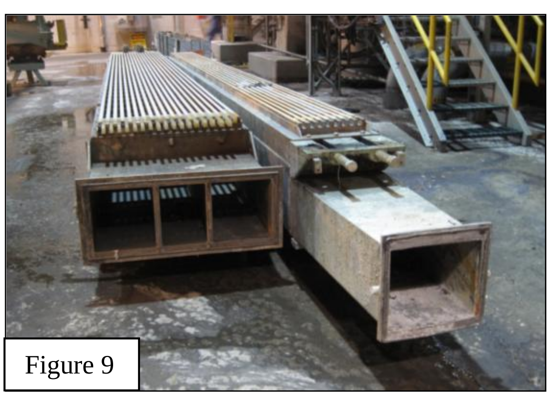
Figure 9

Following successful design, construction and installation of equipment and new piping, the paper machine started up and was allowed to get production leveled out for about a day. Then, trials began with adjusting all table vacuum elements to provide graduated vacuum levels, with historically low vacuum levels at the three remaining high vacuum zones (flatbox and duo-vac). With these three elements at about 3.5" Hg, 5.5" Hg and 9" Hg, respectively, as the sheet progressed toward the now "non-vacuum" couch, exit solids was measured at 22%. Following several steps to gradually increase vacuum levels and measuring sheet solids after each change, exit solids eventually reached 28%. Final vacuum levels were 4.3" Hg, 7.2" Hg and 15.3" Hg at the three vacuum zones. The system was allowed to continue to operate at these settings. Successive measurements of couch solids indicated 25+% consistency over the following several months.

During these trials table drive power was measured and there was almost no change between the initial and final trial with low and high vacuum.

Forming fabric life appears to have had little change. But, due to less water handled in the press, felt life has increased. Average life for the pick-up and 3rd press felt has increased by 8% and 12%, respectively.

Machine efficiency (uptime) has averaged 92 - 93% since these modifications. This value has not changed following the modifications. But due to market conditions, grade changes increased by about 15 per month and runability during grade changes has improved.

Steam consumption has reduced by 3% since the modifications.

Summary: 2 less flatboxes + no couch vacuum + 3 less vacuum pumps = 5% couch solids increase + 8 to 12% longer felt life + 3% steam reduction + elimination of couch roll maintenance + 450 hp savings + 150 gpm of seal water savings.

Case #4: Pulp Dryer – 202" wire, 340 fpm, Dominion fourdrinier

A vacuum survey was conducted on this pulp dryer, which was built in 1964. This study was to precede a project to yield increased production and double felting of the 1st and 3rd presses. While reviewing dewatering on the table, effective low and high vacuum elements and good vacuum control provided reasonable sheet solids at 24 – 25% before the couch. Couch exit solids was not as good as it could be and was below 28%.

The suction couch had two vacuum zones which were connected to a single vacuum header that was piped to three vacuum pumps (Figure 10). Operating vacuum was 15" Hg at both zones. The 2-zone couch roll was intended to have low vacuum, at the initial zone, of around 10" Hg and high vacuum, at the second zone, with a target of 20" Hg. Over time the system had evolved into a common vacuum source for both couch zones, and the flatboxes, resulting in lower maximum couch vacuum.

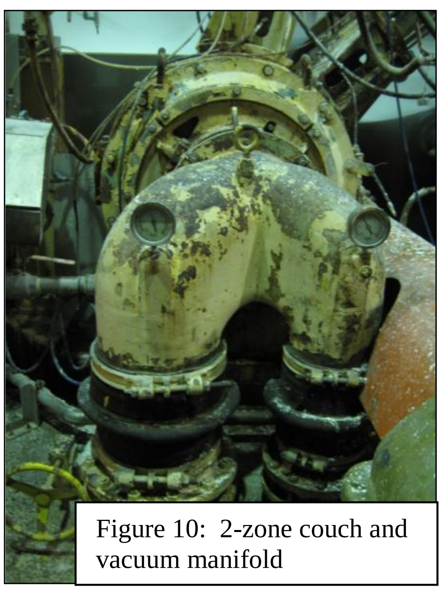

Figure 10: 2-zone couch and vacuum manifold

Rather than propose changing piping to allow the first zone to have a separate vacuum source, the proposal was to not use any vacuum at the first couch zone. The couch even had two small diameter lumpbreaker rolls, with one at each suction zone. The flatbox system had more than adequate vacuum capacity and provided 12 – 15" Hg at the last three flatboxes. Since the flatboxes are capable of higher vacuum than the initial couch vacuum zone, the recommendation was made to just remove vacuum entirely from the first zone.

Higher vacuum is necessary to remove any more water at the couch. During a trial, the first zone was disconnected from the vacuum system and the first lumpbreaker was raised. This was successful.

The rebuild progressed as a successful project with excellent results. The vacuum system was upgraded to replace six original 6000 cfm pumps with five 5000 cfm and one 6000 cfm pump. No additional new pumps were required, even though two more uhle boxes were added for the two new top felts. Less vacuum capacity at five of the six pumps was acceptable based on successful trials and not attempting to add "safety factors" to a good design. Before and after photos show the 1964 vintage and 2011 model vacuum pumps (Figures 11 & 12). Note, the new vacuum system was designed to utilize three existing 600 hp motors, gear reducers, and foundations from the old system, with pumps being driven in tandem. Most of the existing vacuum piping was used with the new pumps due to their similar inlet and outlet configurations.

Figure 11 - Before

Figure 12 - After

The local electric utility, BC Hydro, participated in financing the project due to significant energy savings provided by five pumps which were 17% smaller, and the fact that all of the new pumps were new and more efficient designs than those from the 1960's. BC Hydro's Power Smart program literally put their money where their mouth was by providing a check for CAN$1.1 million in a ceremony at the mill. Energy savings with the new vacuum pumps was projected at 3.7 gigawatt hours per year.

Summary: Analysis + removal of unnecessary vacuum application = 6 new vacuum pumps + 580 hp savings + 500 gpm of seal water savings

Case 5: Newsprint – 334" Beloit Bel Baie II, 3700 – 4000 fpm

This Bel Baie former has been operating since the mid 1970's with six 10,000 cfm vacuum pumps connected to the suction couch. A common feature of the Bel Baie II suction couch was a low zone with a very wide, almost 90 degree, suction area, followed by 10" wide (MD) high vacuum zone. No high vacuum suction box has been added following the couch on this former. The couch roll is preceded by two flatboxes and these were operating at 3" and 6" Hg.

Couch solids has been in the 17% range. Vacuum levels for the low and high couch were typically 17" Hg and 22" Hg, respectively. Since the vacuum level at the low couch zone was relatively high, and is significantly higher than the preceding vacuum boxes, the consideration was made that sheet sealing may be present (yes, even on newsprint). A trial was planned to determine the impact on couch solids as low couch vacuum is decreased. The importance of this trial is the potential to remove a portion of the vacuum capacity and allow a full vacuum pump to be uncoupled from the system. Electrical power savings potential is approximately 480 horsepower for the vacuum pump.

A 10" manual inbleed valve was added to the low vacuum header to allow vacuum reduction by bleeding in atmospheric air. The trial was set up when the forming fabric service engineer was available with a gamma gauge. Baseline sheet consistency data is shown in the diagram (Figure 13).

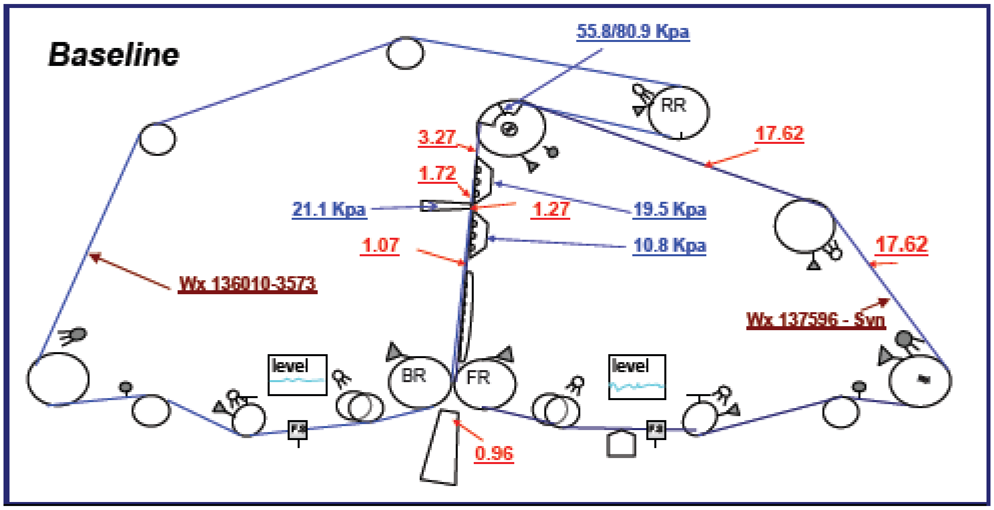

Figure 13

As indicated on the Bel Baie diagram (Figure 13), low and high couch vacuum levels were 55.8 kPa (16.4" Hg) and 80.9 kPa (23.8" Hg), respectively. Next, low couch vacuum was reduced by 1.0" Hg for each point in the trial. The initial test with 15.5" Hg yielded a significant increase in couch solids, measured at 18.8%. At 14.5" Hg couch solids reduced to 18.0%. This fell again to a level equal to the initial consistency of 17.6% at a vacuum level of 13.5" Hg. Three successive tests from 12.5 down to 10.0" Hg yielded sheet solids of 16.9% to 16.7%. The data is also shown below (Figure 14).

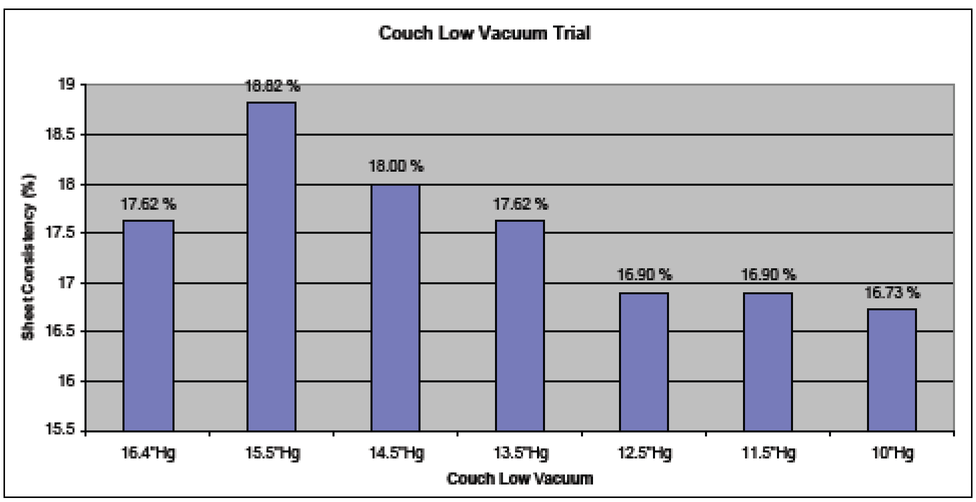

Figure 14

Theoretically, vacuum airflow reduction, to provide a change from 16.4" Hg down to 13.5" Hg, would be 20% of the original vacuum capacity provided by 3 ½ pumps. Therefore, removing a complete vacuum pump would exceed this and operating vacuum would be around 12" Hg with only 2 ½ pumps connected. Some more study is needed to determine where another ½ of a vacuum pump may be removed from the rest of the system to accommodate the goal of uncoupling one vacuum pump from the system.

Summary: Fooling around with the process (vacuum & dewatering trials) = opportunities for energy savings (one pump removed saves 480 hp)

<u>Case #6: One more kraft bag machine – 254" wire, 2500 - 2700 fpm, 43 – 60#/3000 ft²</u>

This former was studied and, as observed on many machines, had an excessive number of flatboxes. Additionally, the highest vacuum (final three units) of these flatboxes had too many slots for these drier positions. Six (6) slots per box were used for the first four elements and eight (8) and nine (9) slots per box were used for the last three elements. Also, vacuum graduation was not very consistent.

A combination of poor graduation and extra high vacuum elements were considered to be adding to table drive horsepower. A brief trial was run and confirmed that about 50 – 100 hp could be removed from the table drive load. This is entirely due to friction between the flatbox covers and forming fabric.

The vacuum system did not consist of liquid ring pumps, as were the rest of these case studies. This was a <u>multi-stage exhauster</u> system with two, identical centrifugal exhausters, operating in parallel (Figure 15). Each exhauster has a 2000 hp motor. Since centrifugal exhausters have different operating characteristics compared to liquid ring (positive displacement) pumps, <u>operating horsepower increases with vacuum airflow</u> (mass flow). Therefore, by shutting off one or more flatboxes, airflow through the exhausters is reduced and this decreases vacuum system horsepower. During the vacuum trials this was also measured and was confirmed to also provide energy savings.

Figure 15

2000 hp motor and speed increaser

Multi-stage exhauster

A project to modify the flatbox system was presented to mill personnel and to the local electric utility. The utility helped to fund the vacuum-energy study and would be able to assist with funding for these modifications. The project was relatively simple. The 9-slot flatbox, just prior to the final flatbox, was to be removed, the flatbox before this one was to be relocated to replace the 9-slot element. The final flatbox had 8 slots and the cover was to be replaced with a new, 5-slot cover constructed of silicon nitride. Before and after flatbox configurations are shown in the following photos (Figures 16 and 17).

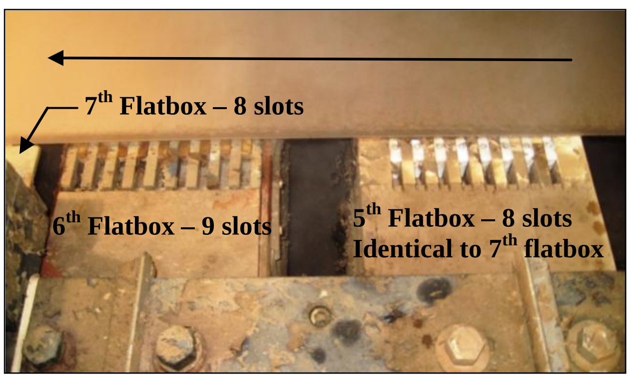

Figure 16 – Before

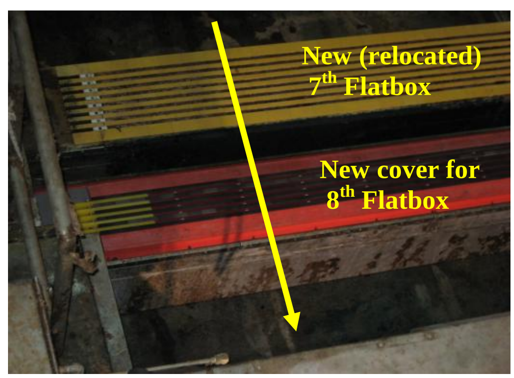

Figure 17 - After

The study which revealed these findings was a vacuum-energy audit of the entire vacuum system, and was mostly funded by the utility. Confirmation of energy savings must be realized before energy efficiency incentives can be provided to utility customers. Fortunately, this mill had very good datalogging and trending capability so no new power measurement equipment needed to be added. Four to five weeks of operation allowed a comfortable value of total energy consumption associated with the project. Graphic data for before and after conditions are shown. (Figures 18 and 19).

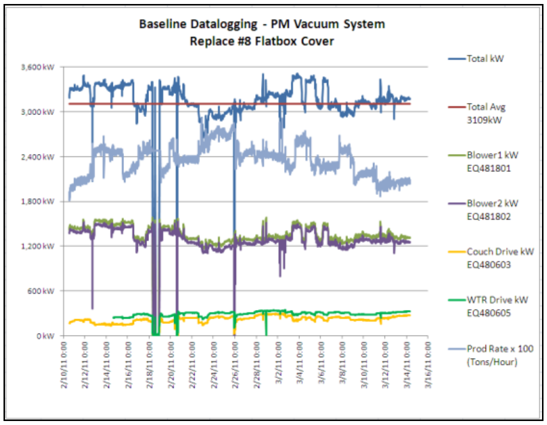

Figure 18

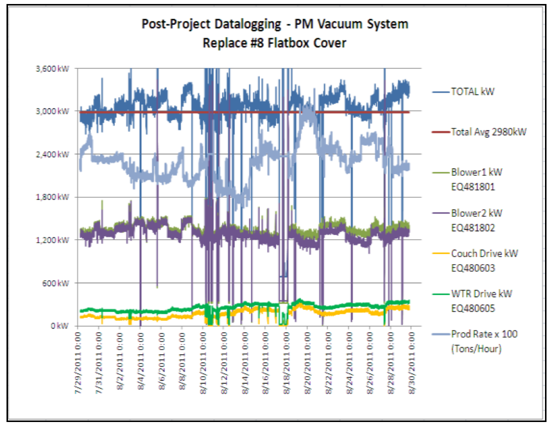

Figure 19

Verified energy savings were 129 kW, or 172 horsepower. Annual energy savings was projected at about 1.1 million kWh, and is worth about $38,500 per year (utility has significant hydro resources yielding lower power rate). Approximately 25% of the savings was due to forming fabric drag load reduction and the rest was from reduced power at the vacuum exhausters. Additionally, the new ceramic flatbox cover cost about $37,000 and 70% of this was paid by the utility because of the confirmed energy savings.

Summary: Remove 8-slot and 9-slot flatboxes + replace with one 5 slot flatbox = 172 hp (129 kW) savings

Conclusion:

Sometimes you need to walk into a mill (it might be your mill) as if you have never been there before. Try to look at various components of the papermaking process and ask yourself, "Does this process work as intended?" or "Does it need to be, or can it be modified?" If a motor or pipe is connected, the process costs money to operate. With these thoughts in mind, consider if change is needed. Forget theory for a minute and try something different.

Since energy savings was one of the driving forces for each study, there is often justification to pay for the modifications. Total electrical energy savings provided in all case studies except #5 (no changes implemented yet) were 1980 horsepower, or 1485 kilowatts. Total annual savings is 12.6 gigawatt-hours.

References:

All of these case studies were by-products of vacuum system studies by Doug Sweet & Associates, Inc. Cooperation by papermakers, technical and maintenance personnel allowed system trials to be performed. Before and after operating data was measured and verified to comply with management and utility requirements. It is noted that no sheet breaks occurred during the trials.