Retrocommissioning and Energy Efficiency – Applying this Concept to the Paper Machine Vacuum System

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ABSTRACT:

Paper machine vacuum systems have a reputation of being somewhat difficult to understand, troubleshoot and optimize. Problems associated with these vacuum systems often are not identified. This leads to the statement, "You can get the sheet to the reel with a poorly operating vacuum system". Besides the ongoing efforts to maintain and optimize all of the papermaking processes, consider that the vacuum system can have as much, or more, connected horsepower as the entire paper machine. This can be from 700 hp on a small, specialty machine, to 7000+ hp on a large linerboard machine.

Paper machines and supporting processes are designed and installed based on expected ranges of production rates using specific furnishes, headbox consistency, chemistry, refining, retention, fabric design, etc. The configuration of the paper machine is determined based on mutually agreed criteria for these and other variables. The vacuum system is designed and installed to satisfy these production specifications. During the years and decades following installation, many of these operating variables can be, and are altered. However, the vacuum system consists of significant hardware and piping which usually experiences little modification.

Retrocommissioning describes the process to identify and correct less-than-optimal performance within the vacuum system, without retrofitting or replacement of significant components. Concurrent to the optimization process is the ability to achieve significant energy reduction. Experience with **Retrocommissioning** of vacuum systems usually provides energy reduction of 10 – 15% of existing operating power. Some systems have had the potential to remove 20 – 25% of operating power.

This presentation will explain the procedures of **Retrocommissioning**, as applied to the vacuum system, and includes case studies to emphasize the positive results from optimization.

DISCUSSION:

Retrocommissioning is a relatively new term used to describe the effort to increase the energy efficiency within a building, system, or manufacturing process. It has been given the abbreviation of **RC$_X$.**

The American Council for an Energy-Efficient Economy (ACEEE) describes it as:

> ***Retrocommissioning****…is a systematic process for identifying and implementing operational and maintenance improvements in a building and ensuring continued performance over time.* ***Retrocommissioning*** *intends to optimize the operation and maintenance of building subsystems as well as how the systems function together. The RCx process focuses on operational and maintenance improvements and diagnostic testing* <u>*rather than capital improvements*</u> *(although some needed capital improvements may be recommended as a result).*

Natural Resources Canada discusses $RC_{X,}$ as related to improving energy efficiency, as:

> ***Retrocommissioning*** *may help to resolve problems with the original design or construction, or to address problems that have developed over the life of the building (or process).*

Nexant, a firm specializing in energy management and energy efficiency describes RC_X as:

> *The Industrial Recommissioning Program (IRCx) helps industrial energy users capture and sustain energy savings through measures requiring little to no capital investment. Industrial recommissioning (or* ***retro-commissioning****) is a systematic process designed to optimize the energy-efficient performance of industrial equipment and processes by identifying and correcting operational deficiencies.*

All papermaking processes can benefit from thorough examination to discover less than optimum performance, production bottlenecks, and excessive energy consumption. Typical paper machine optimization includes commonly executed projects, most of which are capital intensive. These include:

- Former dewatering optimization
  - Automated table elements (I-Table®)
  - Top wire formers
  - Enhanced vacuum measurement and control
  - New and/or optimized high vacuum elements
- Press Upgrades
  - Addition of suction pick-up (containerboard machines)
  - Double felting (containerboard and pulp)
  - Sheet stabilization and elimination of open draws
  - Roll cover and fabric optimization
  - High loaded press nips and shoe presses
- Dry End Upgrades
  - Spoiler bars
  - Stationary siphons
  - Reel and winder upgrades

These are not new concepts, and many are actively sought after as part of annual, or 2 to 5-year capital budgets. We have always referred to these projects as **REBUILDS**.

Applying **Retrocommissioning** concepts to a paper machine results in significant opportunities for energy reduction, while offering process optimization as a by-product. Typically, these are much less capital intensive projects compared to the usual scope of paper machine rebuilds. Other energy intensive areas of the paper mill should be examined with respect to RC_X. These can include, and are not limited to:

- Stock cleaning
- Dryer steam and condensate system
- White water recovery
- Machine room ventilation
- Paper machine vacuum system

All of these processes have at least one common characteristic. Marginal performance or lack of optimization of each of these processes does not have an obvious impact on paper machine performance (production rates, efficiency, or quality). Another way to state this is –

You can get the sheet to the reel with a screwed up (fill in blank) system.

This presentation will focus on the Paper Machine Vacuum System and how to apply RC_X principles. Examining the vacuum system reveals several typical characteristics, including the following.

1. The vacuum system can require as much, or even more horsepower than the paper machine itself. This can easily be 2000 to 6000 horsepower, on a large paper machine.
2. The vacuum equipment will consist of components which are often part of the original vacuum system that was installed when the paper machine was new. It is not uncommon to have 1940, 1950, or 1960 vintage vacuum pumps connected to a paper machine. Regardless of multiple rebuilds of the paper machine, or no rebuilds, the vacuum system and its network of piping and controls are frequently some of the oldest equipment in the mill.
3. The vacuum system often evolves into becoming larger than necessary, due to poor vacuum capacity distribution and mis-applied vacuum control components.

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, furnish, additives, fabrics, etc.) However, changing the hardware of the papermaking process may require removing, reconfiguring, or eliminating equipment which has been bought, paid for, and installed. Making decisions to modify the process are often preceded with studies and trials requiring papermakers with enough initiative and spirit to make significant changes. Often, these modification projects fit very closely with the RC_X principle of low cost endeavors.

Results from many RC_X projects have been very positive, and several case studies will be presented. First, however, some typical vacuum system issues are presented and none of these should surprise anyone.

1. Poor vacuum measurement at the former and/or poor vacuum control – This is present in almost every system studied. It is surprising how often an uncontrolled vacuum table is observed on containerboard machines and this causes maintaining of sheet test properties to be difficult to manage. **Figure 1** shows an automatic low vacuum control valve which has been bypassed, and now using a manual gate valve for control. Without controlling sheet formation with vacuum, this leaves only headbox consistency, refining, and rush/drag as adjustable variables contributing to sheet development.

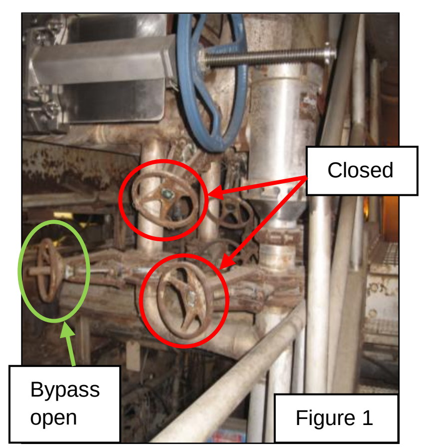

Figure 1

Initial low vacuum elements are essential to sheet formation and accurate vacuum measurement and control are essential. Problems in this area include: excessive vacuum levels too early, causing sheet sealing, and swinging vacuum levels creating MD dewatering variations.

Resolving these problems generally do not require replacing table elements, but simply adding components for accurate vacuum measurement and control. Then, setting up the table can be accomplished with the help of the fabric supplier and ranges of vacuum levels can be established for each grade. Operators then will need to trust the automated system but still need to observe the process from outside the control room.

2. Under performing vacuum dewatering components, such as flatboxes, tri-vac, couch and suction press – Some paper machines have evolved to a point where there is an excessive amount of higher vacuum elements on the table. Or, some formers are still in their original configurations with 6, 8, and even 10 flatboxes, with too many slots per element. **Figures 2 & 3** show these examples. Dewatering is usually limited because there is inadequate vacuum capacity to develop reasonable vacuum levels. Also, some operators resist operating table vacuum elements with graduated/increasing vacuum levels. The answer is not to add another vacuum pump, but to remove some of the vacuum elements. Also, the remaining elements require their covers to be replaced with modern, low friction materials (such as silicon nitride) and much less slot area. A reworked table with fewer flatboxes and significant slot area reductions often can provide added dewatering with less vacuum capacity. Additionally, fewer vacuum elements, and minimizing slot quantities per element, will significantly reduce table drive horsepower even though vacuum levels have increased. Sheet consistency has been improved by 2 to 6% before the couch following these modifications.

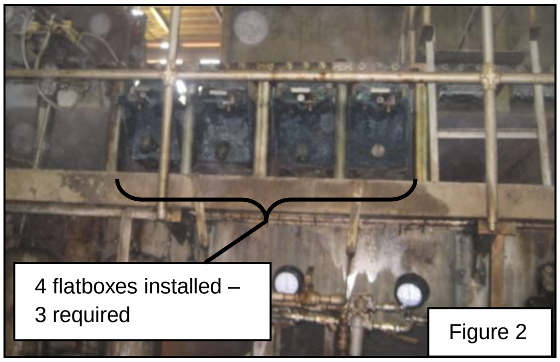

Figure 2

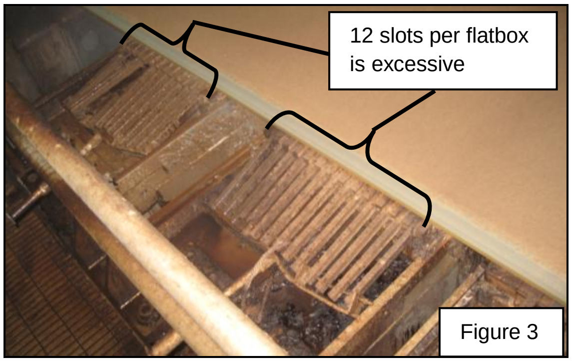

Figure 3

Within the former and press, all suction rolls need to be examined to determine if their function in dewatering is accomplished. For example, many suction couch rolls may only contribute to 1 or 2% consistency increase, even though the necessary vacuum capacity may be 25 to 40% of the entire vacuum system. Also, even though vacuum induced water removal is accomplished, roll doctors are essential to remove extracted water from the shell surface and avoid rewetting. Double doctors have provided 1 – 2% sheet consistency improvement, where previously another vacuum pump would have been added.

Within the press, examine the capability of a suction press roll compared to the water removal capacity with modern press fabrics and roll cover options. Some older pulp or containerboard machines are still operating with a 2nd suction press, which can work just as well with a few modifications and no vacuum. A press section may have evolved to require one or more suction transfer rolls, with associated vacuum pumps and operating horsepower, when modifications in press geometry and sheet/fabric runs can eliminate a suction roll. Additionally, evaluate the cost of suction roll maintenance, spare rolls, and downtime to change these rolls when considering options to eliminate a suction roll.

3. <u>Excessive quantity of uhle boxes and/or uhle box slot areas</u> – This is an issue found almost as frequently as the lack of table vacuum control. If you buy a press section, it generally is supplied with two uhle boxes per felt. That covers all possibilities for felt conditioning with virgin or recycled furnish and assorted chemical cleaning scenarios. But, evaluating felt performance and life may reveal where a uhle box can be removed. Also, determine the necessary uhle box slot area based on machine speed. Either of these issues may result in the ability to reduce vacuum capacity, vacuum pump power, and press drive horsepower.

   Each press will be different. Pick-up felts typically will have two uhle boxes as these are the "work horse" fabrics in the press. A 3rd press felt often can work well with a single uhle box. Examine used felt analysis reports with the fabric vendor and evaluate if the felt is filled or just compacted, when removed. This can allow decisions to be made concerning felt design, dewatering needs, and felt cleaning programs.

   While discussing uhle boxes and press dewatering, a low cost feature to optimize pressing involves measurement of press water flows. This only requires weir tanks to collect the water from each felt and press nip (**Figure 4**). Adding a level transmitter to each weir compartment allows real time measurement of press water flows (**Figure 5**). Trending of these flows provides valuable information relative to felt performance, roll covers, felt cleaning, etc. Remember that <u>maximizing press exit solids is the goal</u>, and the ability to analyze where and how water is removed will be essential in optimizing the press.

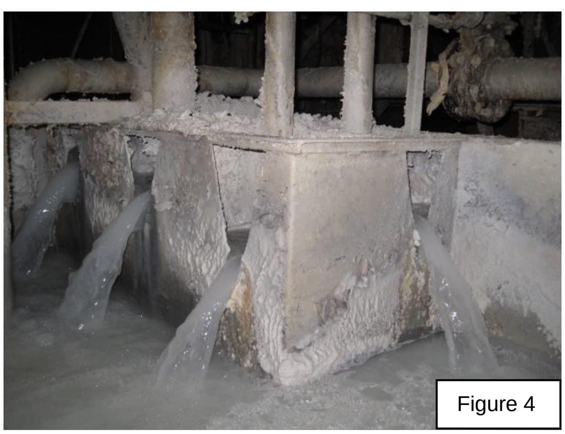

Figure 4

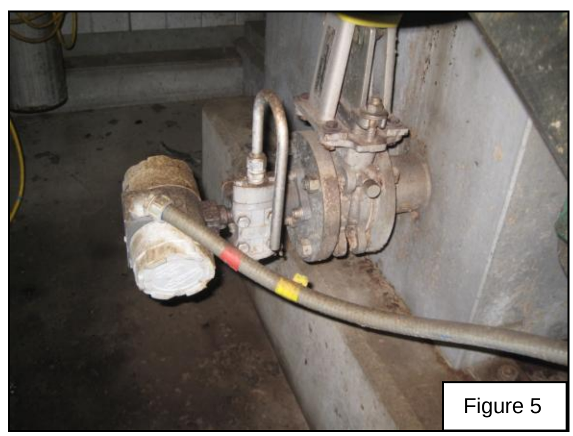

Figure 5

   Nip dewatering is not as effective or controllable unless press nip and uhle box flows can be measured.

4. <u>Consistently open vacuum inbleed valves allowing significant wasted vacuum capacity and associated horsepower</u> – These valves are common to limiting vacuum at various points within the vacuum processes. An inbleed valve is the correct means of vacuum control for a liquid ring vacuum system. These are also used for centrifugal systems

where atmospheric air must be bled into the system to prevent surging of the exhausters.

Study of the vacuum systems often reveal that many of these inbleed valves are <u>always</u> open. Some are found to be in manual mode, and may even be manual valves. Consistent atmospheric inbleed is an indication of excess vacuum capacity, and wasted system horsepower. **Figure 6** suggests the cost associated with vacuum inbleed valves which are always open. Usually the vacuum system can be corrected where pumps can be slowed down or replaced with smaller units to properly align the vacuum system capacity with the vacuum demand of the paper machine.

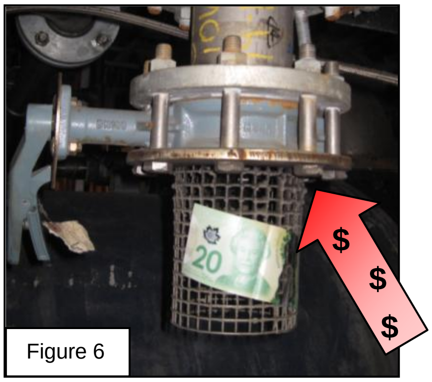

Figure 6

5. Poor vacuum system seal water control and management – Seal water for a liquid ring vacuum system is usually not well monitored or controlled. Vacuum systems can be operating with some pumps starved for seal water, while others are getting excessive flows. Too little seal water reduces vacuum pump performance and excessive water adds to system operating power with little or no benefit to the vacuum system.

   Water quality (temperature, cleanliness, scaling properties, tendency for corrosion or erosion of the vacuum pumps) generally determines the life of a vacuum pump. The key to long vacuum pump life and minimizing capacity loss is clean seal water. Preventing contamination of seal water is accomplished with well designed separator systems and extraction pumps where required. Some mills must recirculate seal water while purging 5 to 10% of the total flow. These systems can work well as long as pre-separation systems are working properly. Some seal water systems are using hard water, or the water becomes contaminated where scaling of the vacuum pump's internals becomes a problem. These mills are often battling frequent vacuum pump motor overloads.

   Correction of seal water problems can include adding proper components for flow control, such as orifices, spray nozzles, pressure gauges (**Figure 7**) and manual pressure adjusting valves. Some mills examine their fresh water makeup and find that they can use the vacuum pumps as the point of entry for makeup water and actually recover some heat from the vacuum pumps to preheat the water.

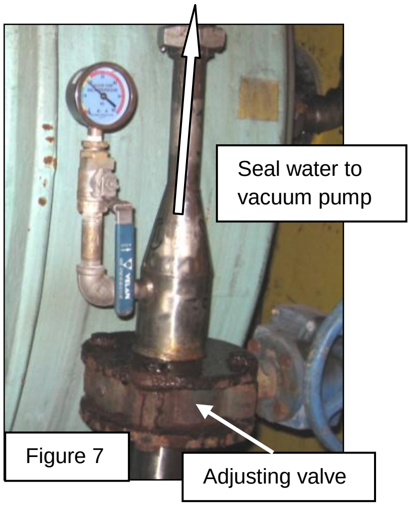

Figure 7

The following are four case studies demonstrating the positive impact of $RC_{X,}$ as applied to vacuum systems.

<u>Case #1: Specialty Paper Machine - 126" (3200 mm) wire width, 800 – 1000 fpm (245 – 300 mpm)</u>

Demonstrating that even small paper machines offer opportunities for energy savings and optimization, this paper machine had only three (3) vacuum pumps with total installed power of 525 hp. Operating power was 490 hp (368 kW).

Two opportunities existed to reduce vacuum system horsepower. The flatbox system was being operated correctly with graduated vacuum levels, however, there was excess vacuum capacity causing a vacuum inbleed valve to always remain open (**Figure 8**). Also, the uhle box vacuum system consisted of a single vacuum pump where each half connected to a single uhle box on each of the two press felts. The uhle boxes had two 5/8” slots (**Figure 9**) , which was excessive for a machine running no more than 1000 fpm. Two 5/8” slots would be acceptable for 3000 fpm.


Figure 8

The flatbox and uhle box pumps were therefore oversized and all that was required was to change v-belt drives to slow down the vacuum pumps. Less vacuum capacity for the flatbox pump allowed the inbleed valve to be closed some of the time. The uhle boxes were modified to provide just a single 5/8” slot. The pump was slowed to a speed providing a higher vacuum factor with a single vacuum slot, which can improve dewatering.

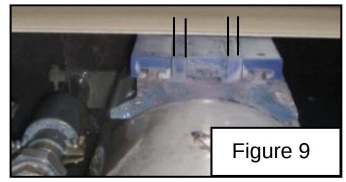
Figure 9

Results Summary: Operating power reduction for the system (with lower pump speeds) was approximately 120 hp (90 kW), or about 25% reduction in total power required by the system.

<u>Case #2 Kraft Bag Machine – 254” (6450 mm) wire, 1350 – 2950 fpm (410 – 900 mpm), 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 couch exit solids was quite low, at about 20% consistency. 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 one 6000 cfm vacuum pump per zone. Due to a bearing failure on one of the vacuum pumps, the high vacuum zone had <u>no pump connected</u> during the study because it was removed for repair. A tri-vac preceded the couch and its operating vacuum 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 well 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 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 operating fewer 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 containing 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 reconfigured 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 10 & 11**). This was designed for a 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 12**).

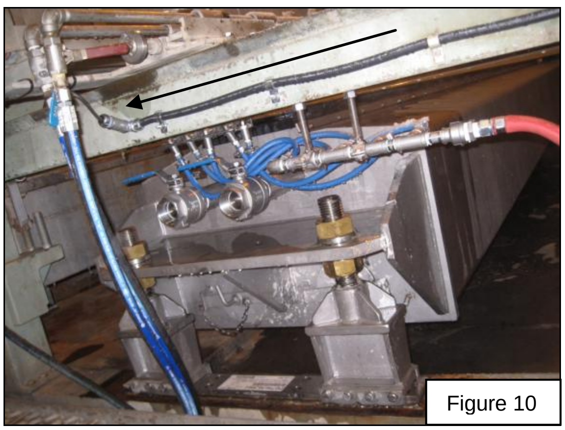

Figure 10

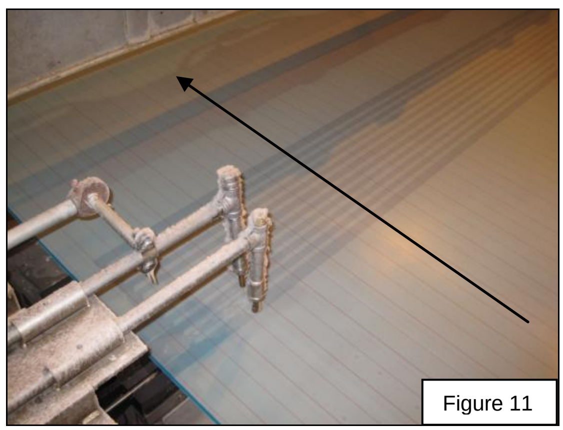

Figure 11

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.

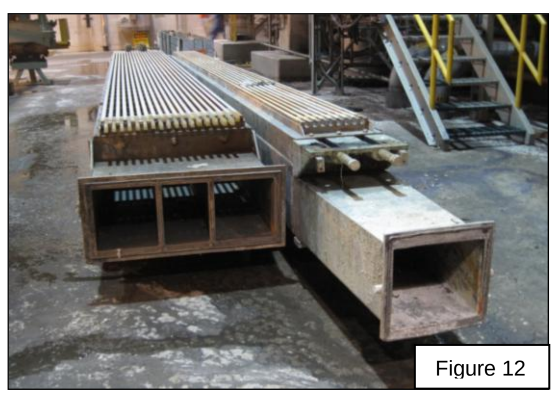

Figure 12

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 and more agressive vacuum levels, at the three high vacuum zones (flatbox and duo-vac). Following several steps to gradually increase vacuum levels and measuring sheet solids after each change, <u>exit solids eventually reached 28%</u>. The system was allowed to continue to operate at these settings. Successive measurements of couch solids typically indicated 26+%. 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.

Results Summary: Three (3) vacuum pumps removed (12,000 cfm), 450 horsepower (338 Kw) saved, 150 gpm (570 lpm) of seal water saved, 6% increase in couch solids, 3 - 5% steam savings, 1 week gained in life for all three felts, and runability during grade changes improved.

Case #3: <u>Gap former, 375" wire (9520 mm) with single nip press (shoe press) producing printing and business papers with basis weights from 46 to 56#/3000 ft² at speeds of 3600 to 3900 fpm (1100 – 1190 mpm)</u>.

This machine was originally installed with a vacuum system consisting of two 1750 hp, multi-stage centrifugal exhausters. During the next 25 years there were two rebuilds of the former and press, with each rebuild adding at least one vacuum pump. The vacuum system was studied in 2010 and several opportunities were presented where the vacuum system could be reconfigured to redistribute vacuum capacity and correct some design problems with vacuum control.

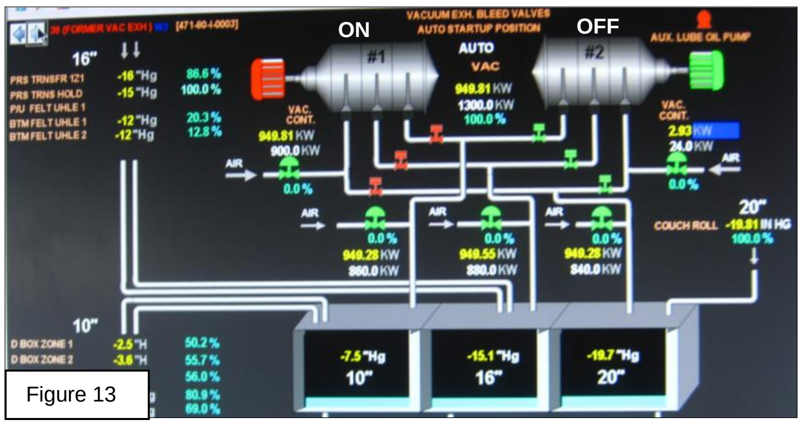

Figure 13

These opportunities were very significant and a plan was developed to make piping and control modifications during the following 2 ½ years. This resulted in being able to shut down one of the two centrifugal exhausters and the largest of three vacuum pumps. The screen shot from the DCS (**Figure13**) shows the right-hand exhauster not operating. Production rates were not affected. Project costs were about US$900,000 with a 1.5 year payback.

Results Summary: 1 vacuum exhauster and one vacuum pump removed from operation, saving 1600 hp (1200 kW). This was a 40% reduction from the original operating power.

<u>Case #4: Pulp Dryer – 202" wire, 340 fpm, Dominion fourdrinier</u>

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 below 28%, and could be improved.

The suction couch had two vacuum zones which were connected to a single vacuum header that was piped to three vacuum pumps (**Figure 14**). 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.

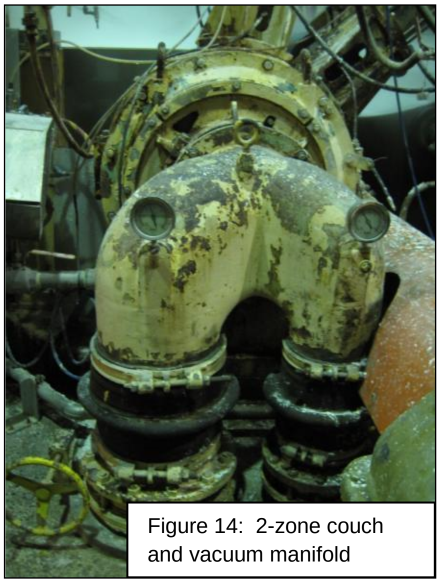

Figure 14: 2-zone couch and vacuum manifold

The flatbox system had more than adequate vacuum capacity and provided 12 – 15" Hg at the last three flatboxes. Rather than propose changing piping to segregate vacuum supply to all three elements, the recommendation was to not use any vacuum at the first couch zone, and to only separate the vacuum source for the flatboxes and second couch zones.

The couch had two small diameter lumpbreaker rolls, with one at each suction 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 and increased vacuum at the second couch zone.

The rebuild progressed into 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. This was 14% smaller than the original vacuum system, 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 15 & 16**). 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 15 - Before

Figure 16 - After

The local electric utility, BC Hydro, participated in financing the project due to significant energy savings provided by six new and more efficient pumps. 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.

Results Summary: 580 hp (435 kW) savings and 500 gpm of seal water requirement removed from the system. Existing motors and gear reducers were retained to drive the new equipment, saving at least $1 million.

Conclusion:

Retrocommissioning (RC_X) should be explored with every vacuum system, because every system can be improved and optimized, with reduced energy consumption. Often, electrical energy savings will be significant at 20%, 25% reductions, or more. Vacuum system optimization is always a positive result which usually benefits production, machine efficiency, and steam consumption.

The four case studies presented have an annual energy savings of 17.5 gigawatt hours. This is worth $875,000 annually, at a rate of $0.05 per kWh.

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