THE 20, 30, 40 YEAR OLD VACUUM SYSTEM OF THE FUTURE

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ABSTRACT:

Remove the paper machine and the vacuum system is the next largest system in the paper mill. It can contain more than half mile of 2" to 30" diameter pipe, maybe a hundred valves, several air/water separators, and of course, vacuum pumps, and/or blowers, with their associated motors, starters, foundations, separators, etc. Liquid ring pumps will also have their seal water systems with discharge separators, sumps and even cooling towers. A small vacuum system may need only three or four vacuum pumps. The largest systems observed operate with fifteen to twenty pumps. Installed power will vary from a few hundred to six, seven, or eight thousand horsepower.

It is common to modernize and rebuild paper machines. These rebuilds occur to accomplish many goals, including higher production rates, producing different grades, and improved sheet dewatering. The vacuum system isn't ignored too much during these rebuilds, but eventually they become compromised. Issues can include excessive maintenance, high operating cost, misapplied or excessive vacuum capacity.

This presentation will present common issues related to the vacuum system and address opportunities for improving its performance and efficiency to meet present and future needs of the papermaking process. The examination of the system is not to try to replace it, but to review optimization potential. Positive results from these efforts usually include enhancement of former and press performance, reduced operating costs, energy reduction, and lower maintenance.

DISCUSSION:

Recall a presentation from a TAPPI conference several years ago where the statement was made concerning **Vacuum System Rule #1 –** ***You can get the sheet to the reel with a screwed up vacuum system*****.** This was followed with the likely comment from a papermaker,

"There is nothing wrong with my vacuum system."

At that point, the papermaker was referred to **Vacuum System Rule #1**.

Examining the vacuum system reveals several typical characteristics, including the following.

- 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.
- The vacuum equipment will consist of components which were 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 operating within a vacuum system.
- Many systems contain obsolete pumps, where new parts have not been available for over 30 years. 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.
- The vacuum system often evolves into becoming larger than necessary, due to poor vacuum capacity distribution and misapplied vacuum control components. This larger, or excessive, vacuum system will have proportionally greater energy consumption. Most vacuum systems can have 15 – 20% extra operating power, and some can be up to 40% excess.
- The "old" way of managing the vacuum system is "you can't have too much vacuum". This explains the previous point.

- Every paper machine vacuum system is a candidate for optimization. It doesn't matter if it is 50 years old or 5 months old.

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.

Here are some questions to ask concerning the vacuum system of the future.

Can you modernize a vacuum system when it looks like the pumps went into the basement, and the paper mill was then built around them?

Yes, there always seems to be a way to upgrade an old vacuum system, even when it appears that space is limited. First, be aware that old vacuum pumps were quite large considering their vacuum capacity. The highest capacity liquid ring pump from the late 1950's was relatively large, weighed 16 tons, but was only 10,000 cfm. Modern liquid ring pumps can be 15,000 to over 20,000 cfm and can have a footprint comparable to that old model (Figures 1, 2 & 3). Also, consider that the vacuum system will be analyzed and likely found to now have excess capacity. Therefore, less total vacuum capacity will be required with the reconfigured system.

Following a thorough study of the system, a plan can be developed to begin modernization of the system. It is likely that system optimization will include modifications to the vacuum dewatering components on the paper machine (flatboxes, uhle boxes, suction rolls) resulting in less total capacity being required. This often allows a pump or two to be shut down and removed. The once occupied space is now the location for the first of modern and efficient pumps to be installed.

This step can be repeated with the intent of replacing the entire system, or can end at any time. Try to use the newest and most efficient equipment where it has the greatest positive impact. For example, replace a couch vacuum pump before the pump on the press or uhle boxes.

Fig. 1: 1950's – 10,000 cfm

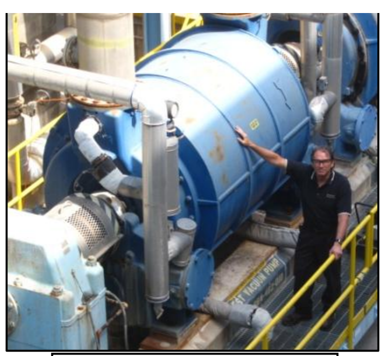

Fig. 2: 1960's – 14,000 cfm

Fig. 3: 1990's – 20,000+ cfm

We have some 1940's and 1950's vintage vacuum pumps. We are able to get them rebuilt. Why not just let them be overhauled so they are like new?

The answer is to try to avoid spending money to rebuild obsolete, inefficient equipment. Some of these systems may have had two pumps driven by a single motor (Figure 4). These old motors may not be quite as efficient as newer ones, but often they require very little maintenance. This often applies to synchronous motors, which also are effective at improving the mill's power factor.


Figure 4

Consider, for example, to replace two old pumps with a single, larger vacuum pump. Usually the overall footprint will be smaller. Total vacuum capacity may actually increase by 40 – 50% in cases where the old pumps are in the 75% (of new performance) range. Or, the worn pumps may actually be providing enough vacuum capacity and replacement payback may be even more attractive with a single pump providing below the original new capacity. System analysis will likely reveal which path to take.

It is true that these old pumps can be rebuilt and returned to newer condition, but performance may only reach 90% of new capacity. There are no new OEM parts available for these pumps. The cost to remanufacture these pumps is much more expensive based on cost per cfm.

Meanwhile, operating power and seal water consumption is always greater than newer models. Seal water consumption for this vintage of pumps can easily be 200 - 300% of newer designs.

We have vacuum pumps from the 60's and 70's. Can they be made to be more efficient?

They are no "kits" to rebuild these pumps into higher efficiency or higher capacity units, but many opportunities still exist for improving a system with these pumps. These are found in the majority of paper mills, and are the CL series of Nash pumps (Figure 5). These have been reproduced by other suppliers into bolt-in replacements with approximately equal performance to the original models. New OEM parts are still available and these pumps can often be rebuilt to new performance specifications. Also, modifications may be possible to allow reduced seal water consumption for high vacuum models. Opportunities available to bring a system with these pumps into the 21st century include:

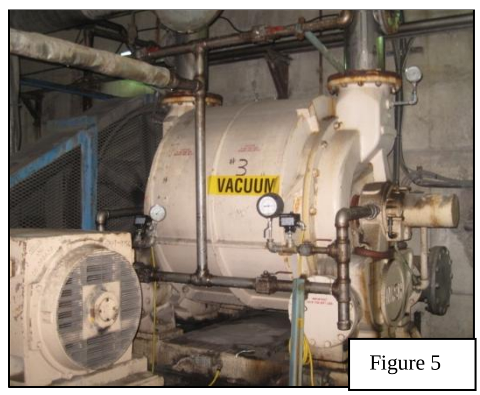

Figure 5

- Use fewer pumps
- Optimize the system and reduce the pump speed and power where possible
- Control seal water to minimize power consumption

As with the very old system, there are likely more pumps operating than are now necessary to accommodate the paper machine's requirements. Ignore past practices about never having too much vacuum capacity.

We have a centrifugal exhauster vacuum system. It is 35 years old, but aren't these efficient already?

These exhauster systems were more efficient than liquid ring pumps which were developed in the 1960's, but eventually liquid ring models were improved to provide comparable, and even higher efficiencies than exhausters. Remember that many vacuum systems are found to now be providing excess capacity because many changes have been made to the papermaking processes. These exhauster systems should be studied and evaluated as closely as liquid ring systems. Many exhauster systems consisted of two multi-stage units operating in parallel. Some have been modified to create a very efficient hybrid vacuum system consisting of an exhauster and liquid ring pumps. Others have evolved to allow one of the exhausters to be shut down (Figure 6) following system changes and adding a liquid ring pump to a special application, such as a couch.

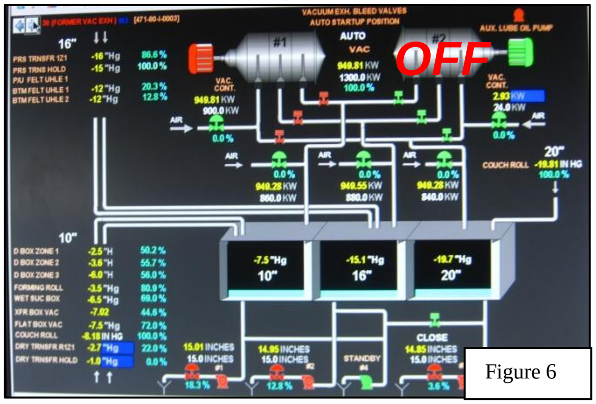

Figure 6

A few of these systems have been found to be operating at higher speeds than as originally installed. Some recommendations were made to mills suggesting to speed up these 5000 – 6000 rpm units by another 1000 rpm. The expected benefit was to achieve higher vacuum airflows and higher vacuum at the couch. However, this did not result in significant improvements and the cost was substantial for larger motors, speed increasers and added operating power. These systems should be studied again for energy savings opportunities.

A potential feature of exhauster systems was the capability to add heat recovery equipment, including additional discharge piping and heat exchangers. But, many older systems eventually abandoned this part of the process, or never even installed it. A few mills have had success with heat recovery from exhauster vacuum systems.

We want to explore nip dewatering. How does our vacuum system need to be changed?

First, the system needs to be studied, primarily the uhle box systems. Where uhle box dewatering emphasizes sheet water removal through absorption using drier felts, nip dewatering enhances press nip intensity due to felts operating wetter. Too much water in the nip creates crushing, and can be a problem with marginal felt dewatering capability. Remember that felt conditioning and cleaning is still going to be important and this requires consistent and uniform felt showering and dewatering capability.

Uhle boxes need to be evaluated and compared to available vacuum capacity. Many systems are found to have excessive slot area, and therefore excessive vacuum capacity. If you buy a press section, it generally is supplied with two uhle boxes per felt. This 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.

Coinciding with optimization of the uhle box dewatering process is the need for measurement of uhle box water removal. Devices have been developed to measure these flows, but often this can be accomplished with weir tanks (Figure 7) and level transmitters. Flows from each felt need to be measured, but not necessarily from each uhle box if there are two on one felt. Where top felt uhle boxes usually will have a seal tank for the elevated vacuum separator, these seal/weir tanks may be able to be modified and allow a level transmitter to be added (Figure 8). The level transmitter is then providing a value to the DCS which can yield a calculated flow rate (gpm or lpm).

Trending of these flows provides valuable information relative to felt performance, roll covers, felt cleaning, etc. Remember that maximizing press exit solids is the goal, and the ability to analyze where and how water is removed will be essential in optimizing the press.


Figure 7

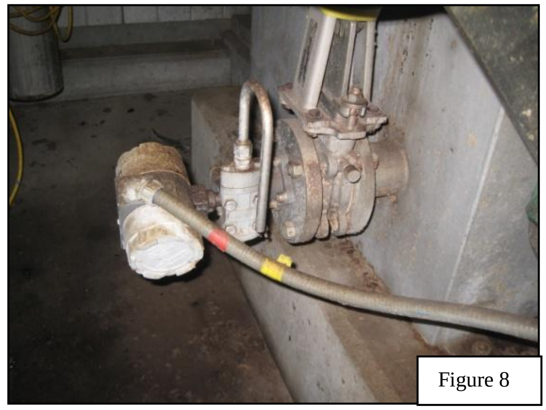
Figure 8

We have been using river water, or mill water for vacuum pump seal water and would like to reduce our mill water consumption. What should be considered if we use a cooling tower for our vacuum pump seal water system?

Minimizing seal water consumption is important since seal water systems can require from 0.5 to 2 million gallons of water per day. Seal water for vacuum pumps is often poorly controlled. Too little water decreases vacuum system performance and too much water adds to vacuum system operating power. Unless a vacuum pump motor is overloading, no one will suspect that there is excessive seal water consumption.

Regardless of efforts to manage seal water consumption, the important step is to assure each pump gets the correct flow of water and this may reduce water consumption by 5 to 30%. The simplest method is with orifices, spray nozzles and proper water supply pressure. Assurance that each pump has the correct hardware (orifices and spray nozzles) and that the supply pressure is monitored and controlled (usually at 10 psi) is the first step in this process. Some mills have been able to reduce seal water flow by a half million gallons per day, or more, just by regulating the water flow correctly.

A follow-up effort can reduce the remaining flow by 40 – 50% from the “ideal” flow rate. This requires creating a cascaded water system where the coolest water is flowing to the high vacuum pumps, where it does the most good for pump performance. The discharged water from these pumps can be recovered and pumped to the rest of the vacuum system. Many seal water systems were originally designed to operate like this, but over time the process was abandoned or modified.

Recovery of warm, heated seal water should also be considered as an option, especially in colder regions. A vacuum system can heat the water by 20 - 30°F, and this water can be used where fresh, colder water is presently used. Where the seal water system is cascaded, this heats the water by up to 50°F above the incoming temperature. Many mills have used recovered, heated seal water for machine showers with little additional heating.

Finally, cooling towers have been used to reduce clean water consumption down to a minimum level (Figure 9). A clean water purge is still necessary and this may be 3 to 5% of the original once-through flow rate. However, most cooling tower systems became problem systems for multiple reasons, including: poor design practices, improper cooling tower specification, inoperative vacuum system separator systems, and lack of any means of filtration.


Figure 9

A key issue is that once a cooling tower is installed, it needs to be monitored to prevent a contaminated seal water problem from causing a serious issue with the cooling tower. Seal water quality should be measured and tracked, daily, to look for signs of contamination. Often, the mill's chemical supplier can take on this simple task. Figures 10 & 11 show splash fill components with heavy fiber accumulation and contaminated water.

The tower is outside the mill and in some cases becomes the responsibility of the powerhouse, which often is operating one or more very large cooling tower systems. In this case, the tower for the seal water system gets ignored until the paper mill discovers that the water has become too hot, or flow has greatly reduced.

This is not an attempt to discourage the use of cooling towers in a vacuum system, but to point out common and avoidable pitfalls. Without getting into details about system design, a few significant points are made.

- If existing discharged seal water is clean (free of fiber and felt cleaning chemicals), a cooling tower is probably a suitable choice for cooling seal water with little added maintenance.
- If existing discharged seal water is contaminated (cloudy, foaming, containing fiber) a cooling tower <u>should not be considered</u> until subsystems (usually separators and extraction pumps) are investigated and are made to be functioning properly.
- These are considered to be "dirty water" systems and cooling towers need to be specified accordingly. Many good splash-fill designs are available and film-filled towers should not be used.
- Consider some means of filtration for the seal water.

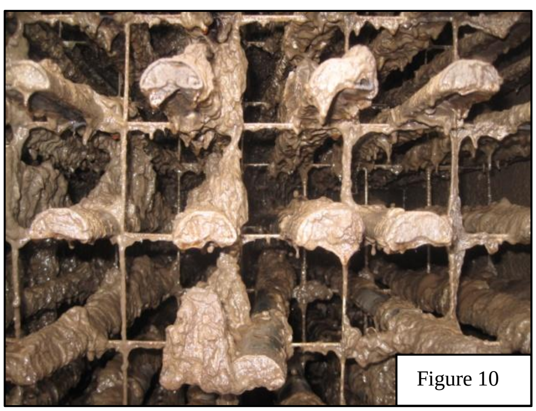
Figure 10

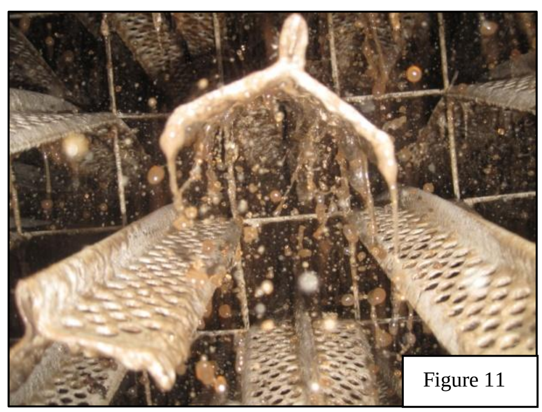
Figure 11

How do I know the condition of my vacuum pumps? What is a good way to measure vacuum airflow or pump capacity?

Vacuum pump performance can be measured by testing using multiple orifices installed at the pump inlets. This method requires removing inlet piping to allow installation of the orifice plates. However, on larger pumps this can be 12", 14" and larger piping to be removed and reinstalled, requiring several hours to test a single pump. Where inlet spray nozzles are installed in the inlet piping that is removed for testing, seal water needs to be increased through remaining seal water ports to make up for the water not being added at the spray nozzles. Also, accurate vacuum measurement is very critical to provide a useful test result.

A good alternative to testing is a fiberscope inspection of the pump's internals. This is done during a machine shutdown and requires at least 15 – 20 minutes per vacuum pump. Modern fiberscopes have high resolution digital imaging and pictures can be recorded showing critical areas within the pump (Figure 12). The person doing the inspection needs to be very familiar with this procedure and what to be looking for. Vacuum pump performance is not measured, but is estimated based on the visual inspection. Accuracy of these estimates is as accurate as a field test. An advantage of the internal inspection is the ability to observe erosion/corrosion which may be due to poor quality seal water or whitewater carryover. Also, internal scaling can be discovered in the discharge ports which can explain low pump performance rather than worn out internals.

Figure 12 – Fiberscope Photos

Rotor blades at ID (tapered bore)

Rotor blades viewed toward inlet port of cone

Rotor blades at OD viewed toward center or end body shroud

Depending on the results of these inspections or tests, it can be determined if they need to be repeated yearly, every other year, or even longer periods.

What instrumentation is absolutely necessary for a vacuum system of the future?

Instrumentation is critical for monitoring any process. However, since the vacuum system seems to operate with a wide range of variables, vacuum instrumentation and control becomes neglected. Probably 80% of observed vacuum systems have these issues.

A very essential area of vacuum measurement and control lies within the forming section. Low vacuum elements are responsible for establishing many sheet properties and often these components are operating with poor measurement and control valves are either in manual, or are bypassed. Similarly, higher vacuum elements may not be well controlled either and this often leaves potential for additional dewatering before the press.

The couch is sometimes the only vacuum component with automatic measurement and trending capability. No control of couch vacuum is usually needed.

Uhle box vacuum measurement and trending is important to optimize press performance. Where nip dewatering is attempted, uhle box vacuum becomes an adjustable feature to promote nip dewatering. Additionally, combining uhle box vacuum measurement and control with flow measurements from uhle boxes and press nips provides the essential data for maximum press performance. All world-class paper machines, producing any grade, have these features.

Just because vacuum and pressure transmitters provide data to be displayed on a colorful screen, in a comfortable control room, don't believe this data will always be accurate. Vacuum transmitters require routine checks and calibration to accurately measure small changes in vacuum, which can be equal to a few inches of water. Some industrial quality gauges are necessary across the vacuum process. These are essential to help verify transmitter values and for troubleshooting or process analysis.

Seal water pressure control is important for liquid ring vacuum pump systems. Local gauges are usually used for fine tuning pressure at each pump (Figure 13).

Figure 13

Seal water flow measurement is sometimes measured with a flowmeter in the supply header, or in the discharge of the sump pump after the vacuum pumps. Where seal water is recirculated, or discharged to another process, measuring conductivity and/or turbidity is useful to show if preseparation systems are not working properly.

CONCLUSION:

Do not be disappointed that there is no unique or revolutionary kind of vacuum system for all of the many dewatering applications on paper/board/pulp or tissue machines. Considering the title of this paper is **The 20, 30, 40 Year Old Vacuum System of the Future.** The intent is to show there are many aspects related to development of the optimum vacuum system, and this does not absolutely require all new equipment. The papermaker, mill engineer or mill manager may be asking one or more of the questions presented here. These are common inquiries made as vacuum systems are studied. Therefore, providing answers and suggestions for next steps for the vacuum system are relative to today's and future production needs.

The **Vacuum System of the Future** will not be that different from most of today's systems, and it certainly doesn't need to be a completely new system. Analysis will determine options for reconfiguring, retrofitting, or replacing vacuum equipment. Generally, options and opportunities will become very evident after evaluating present vacuum capacity requirements, maintenance issues, energy conservation, etc. As mentioned in the beginning, <u>all vacuum systems are in need of some form of optimization</u>. Benefits resulting from these efforts can include improved papermaking operation and machine efficiency, reduced horsepower within the vacuum system and paper machine, and lower maintenance.