Saving Energy With The Vacuum System

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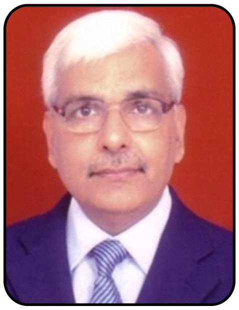

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ABSTRACT

There exists a great deal of energy saving potentials in the paper machine vacuum system of many mills. A vacuum system audit helps to reveal and realize this potential. The energy savings of 10 to 15% is generally possible especially in the older machines with little or no investment. However to achieve the greater savings, some investments in new technologies/pumps may be necessary.

The author had an opportunity to get involved in the studies of over 50 paper machines in the recent years and is pleased to inform the readers that most mills were benefited by the studies in some way or the other. Some mills could save power by 100 KW to 150 KW without any tangible investment. There is also an example of a mill that could save power up to 800 KW, however by investing in the new pumps and at the same time correcting the system. A large part of this saving resulted from the system corrections. Some of the case studies including the machines producing packaging grades of the paper are given in the paper

This paper describes the practical method of conducting a vacuum system audit and provide tips to the mill people to investigate their system on their own.

INTRODUCTION

Energy is becoming a very expensive commodity day by day and the paper mills are looking for ways and means to save the energy. Fortunately there exists a great amount of energy saving potentials in many areas of a paper mill and the Paper Machine Vacuum System that contributes significantly to the total electrical energy demand of a paper machine is a good candidate to investigate for energy saving opportunities.

Studies of several paper vacuum systems reveal that there exists the real and tangible potential of saving energy in the mills and the vacuum system audit help to realize the same.

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In addition to the energy savings, vacuum audits also help to improve the system and enhance performance of the paper machine operation.

The objectives of a vacuum audit may differ from mill to mill but by far the energy saving remains the main objective for most mills and no audit is complete without exploring the possibilities of saving the energy. A typical vacuum audit involves the determination of the required air flows and correlating it with employed capacities, measurement of vacuum levels at various points, speed, electric load and checking of the condition of vacuum pumps, pre-separators, piping and discharge system etc. Deep interaction with mill people and a reliable data collection is the pre-requisite of a good vacuum audit and should be accorded due importance.

A vacuum system audit offers many advantages and it is advisable to conduct the detailed audit at least once in five years as condition changes over the years and the system gets disturbed.

Necessity of a Vacuum Audit

A modern paper machine generally starts with a well-designed vacuum system but the system undergoes changes over a period of time leading to inefficiencies. There could be changes on account of external factors such as production upgrades, changes in paper grades, increase in the machine speed, change of furnish and felts etc. which have bearing on the performance of the vacuum system. Additionally the vacuum system itself may experience many changes such as changes in the pipe connections and routings, change of pulleys and motors etc. Many of the changes in the vacuum system are often driven by the need to solve the temporary problems such as emergency break down or low vacuum levels. Very often the problems for which the changes were made to provide the temporary solution are no more there but the provisions remain leading to the complications and un-necessary problems. Vacuum audits help to track the changes and shows the way to make necessary corrections.

Changes are made but very often data are not updated as was found during the course of several audits. Wrong data lead to erroneous conclusions and decisions. Vacuum audit helps to update the data.

The vacuum survey of an old mill made very interesting revelations and is worth mentioning here to demonstrate how things can go haywire if the due attention is not paid. The mill had 8 machines together producing 325 tons of paper per day. In all there were 47 vacuum pumps of various makes and sizes leading to the huge inventory and also the inefficiency. A good number of small pumps were added over a period of time leading to chaos in the piping system and increase in the power consumption that was whooping 2.72 MW. The machines could have been saved from the misery of a poor vacuum system if timely vacuum audits were done. This survey is shared in the form of a case study at the end of the paper.

Change is inevitable and will happen. The wisdom lies in following the changes and make due corrections. It is necessary to examine the vacuum system periodically and carry out a detailed vacuum audit preferably once in five-year period.

The advantage of a Vacuum System Audit are summarized below:

- Help to identify the energy saving potential.
- Help to identify the water saving potential
- Help to improve the over all efficiency of the vacuum system
- Help to update the data base
- Identify and help to resolve the vacuum related problems

There is increasing interest in vacuum system audits among the paper mills across the world and the mills are deriving the benefits from these audits.

Practical Method of Conducting A Vacuum System Audit

The collection of the preliminary vacuum data together with the main machine data and vacuum system lay out drawing is the first step of any good vacuum audit. This gives a fair idea of the system to the auditor and helps to quantify the extent of the work. It should be done well in advance to do some preliminary work before starting the actual audit at the mill site.

The policy of ***Trust But Verify*** is a practical philosophy and very helpful. While it keeps the interest of the mill people alive, it also helps the auditor to verify the data.

The vacuum audit involves the evaluation of the air flows requirement and some key measurements & observations which are described in the following paragraphs. The results obtained from these evaluations/measurements/ observations show the way to save energy and improve the over-all efficiency of the system.

1. Determine the Required Capacities & Correlate with the Applied Capacities

It is essential to find out first the airflow requirement for each vacuum application point and then correlate it with the applied capacities. The vacuum selection factors available in TAPPI Information Papers serve good reference guide for calculations of the air flow requirement. For example TAPPI Information Paper TIP 0502-01 gives vacuum selection factors for various application points of the paper machine while TAPPI information paper TIP 0404-27 offers information on the vacuum requirement for press felt conditioning. For calculating the airflow requirement for special formers like on-top formers and special dewatering boxes for which TAPPI factors are not available, one may refer to the vacuum data of paper machinery suppliers or take help from vacuum system suppliers/specialists. Once the specific air flows (usually expressed in m3/min/m2 or CFM/inch2) are known then total air flows can be calculated by multiplying the specific air flow by the area of the vacuum box in question.

After determining the required capacity for a particular application point it should be compared with the applied capacity. Any major variation between these two should be carefully evaluated. If the employed capacity is much higher than the required capacity and vacuum levels are good with no operating problem then there are good chances of saving energy. There are examples where mills employed excess capacities and suffered in the process.

It must be remembered that while TAPPI vacuum selection factors offer very good guidelines and work well for most cases but these should not be considered as the lines of stone. There are situations which calls for the field experience to arrive at the optimum air flow requirement. Some time grey matter matters more than the TAPPI factors. For example some of the old Beloit machines have very wide suction boxes which would require very high air capacities if the flows are calculated based on the TAPPI vacuum factors but in practice it is seen that such large flows are not necessarily required. For example, in case of a Beloit machine having a suction couch roll with a suction box width of 420 mm and drilled face length of 5180 mm, the air flow requirement comes out to be about 480 m3/min as per TAPPI factors but the roll was performing well even with the vacuum pump having capacity of 150 m3/min (almost 1/3rd of theoretical capacity) with no sign of poor dewatering.

2. Check the Vacuum Levels at the Vacuum Pump Inlet and the Application Point

Vacuum levels reveal a great deal of information about the vacuum pumps and vacuum system as a whole and should be measured carefully. It is advised to use a new vacuum gauge during the audit and check the vacuum levels at the pump inlet and vacuum application point preferably by the same gauge so that the error if any is offset while evaluating the difference in the vacuum levels. A vacuum loss of 25 mmHg between application point and the vacuum inlet is accepted in a well-designed pipeline but if the loss is high then it should be investigated thoroughly. The drop in vacuum could be due to restriction in pipe or the inadequate pipe size or leakages. It is quite usual to find the pipelines clogged or the valves partially closed. In case the pipe is clean and all the valves are fully opened then there could be a leakage or the pipe size itself is inadequate.

While the vacuum loss across the piping generally indicates the problem in the piping, the over all reduction in the vacuum level of a vacuum pump could be due to several reasons such as low pump speed, scale build up inside the pump, inadequate seal water flow, high seal water temperature and erosion in the capacity of the pump itself. The actual cause can be identified with the help of simple measurements such as electrical load, seal water temperature, pump speed and in combination with observations such as quality of the seal water etc. Step by step approach of ruling out the least suspected cause will help arrive at the most probable cause.

It is to be understood that the low vacuum levels do not necessarily mean that there is a problem with the vacuum pump and conversely the high vacuum levels do not guarantee that all is well with the vacuum system. The holistic view of the situation should be taken considering all the possible aspects to reach the right conclusion. For example in a Newsprint machine, the vacuum levels at suction press roll were found exceptionally good (above 550 mmHg) causing even sweating on the suction side of the pump but it did not lead to good dewatering from the press. The reason for the high vacuum level was a suspected restriction near the suction box. Such cases are encountered whenever there is a restriction in the vacuum piping. On the other hand reduction in the basis weight, using more open fabric or use of less refined furnish may result into the lowering of the vacuum levels.

3. Check the Pump Speed

It is advised to measure the speed of the pump with the tachometer or if the practical consideration do not allow the use of tachometer then the speed can be evaluated by taking the motor speed and diameter of pump and motor pulley. The actual speed should be correlated with the recommended speed of the pump. Lower pump speed generally lead to lower capacity and consequently the lower vacuum levels while increase in the speed will lead to higher power consumption.

There were many cases where the vacuum pumps were not running at recommended speed and in some cases the vacuum pumps were found to be operate close to the highest speed resulting in higher power consumption.

4. Measure the Electric Load of the Drive Motor

It is a common practice to measure and record the motor loads in the mills. The actual consumed power should be compared with the required power of the pump as per the pump curve and if the consumed power is found more (say 10% or more) than required power then the reasons should be investigated. There could be many reasons for high motor load such as water over loading, high pump speed, scale build up inside the pump and back pressure. The actual reason can be determined by analyzing the measurements/observations and eliminating the least suspected causes.

5. Check the Seal Water- Flow, Temperature and Quality

Both quantity and quality of the seal water is important for wellbeing and efficient operation of the vacuum pump. Inadequate quantity will lead to loss in vacuum while excess seal water will increase the load on the drive motor. In extreme circumstances the huge amount of excess water may even damage the pump also. Installation of proper size of orifices and pressure gauge in the inlet seal water line helps to control the seal water flow. Some mills use the flow meter to monitor the flow of seal water into the pump. Despite the measurement of the seal water flow, it could be some time difficult to ensure the recommended flow of water to the pump due to the carry over water from the process. One practical way of ensuring the right amount of the seal water is to throttle the seal water line valve to a point above the level when vacuum starts to drop. During the course of the vacuum audits, some pumps were found operating without any external seal water. Thankfully inefficient pre-separators did not do their jobs and allowed the entry of the process water that supplemented the seal water requirement.

It is important to monitor and control the seal water temperature and keep it under reasonable limit (say below 35 Deg C). High seal water temperature causes problems like scale build up inside the pump, cavitation and also has bearing on the efficiency of the pump. A seal water temperature of 30 to 35 Deg. C is most common in Indian Paper Mills. The higher temperature above this range should be avoided. It is easy to measure the temperature of seal water and also of the pump itself using a simple temperature gun but some mills do not pay much attention. In a particular paper machine mill, the seal water was found so hot that it was difficult to touch the seal water line. Mill was re-circulating the water from the vacuum pumps without giving it the opportunity to cool down. Later the mill installed the cooling tower and the seal water temperature was brought down to about 35 Deg. C.

The water should be clean and free from debris or else it will clog the pumps and also effect the operation of the cooling tower. The typical quality parameters for the seal water for a paper machine vacuum system are given below:

pH- 7.0 and above
Hardness- Less than 300 ppm as $CaCO_3$
Total Dissolved Solids (TDS)- Less than 1000 ppm
Total Abrasive Solids-Less than 50 PPM (Max 10 micron size)
Temperature- Max. 35 Deg. C

Lower the temperature, better will be the pump efficiency and lower the corrosion rate.

6. Inspect the Vacuum Piping and Pre-Separators

Very often the problems originate in the vacuum piping and pre-separators for which poor pumps are blamed. A visual inspection of the piping and pre-separators can help to reveal the problems. It is very important to have properly designed vacuum piping together with efficient pre-separation system as it greatly influence the over all performance of the vacuum pumps. These should be thoroughly checked during the audit. The most common problems found especially in the older machines are complicated piping lay out with numerous inter-connections, partially open valves and bleeding flanges etc. Cases of inadequate pipe sizes were generally encountered in the machines that were rebuilt for capacity upgrades and where vacuum pumps were added without changing the main piping that handled most of the air traffic.

It is indeed a challenge to ensure the prefect pre-separation and there were many cases where the pre-separators could not handle the water separation. The additional police separators had to be suggested for some cases where augmentation of the existing separators was not possible. The success lies in designing the system rightly in the beginning itself. The pre-separators are must wherever process carry-overs are expected (examples- wire section, couch rolls, suction press roll, press felt conditioning) and need to be sized and designed properly.

7. Inspect the Discharge System

Discharge system is often a neglected area and its inspection should be a part of any good vacuum audit. Broadly, there are two types of discharge system design- one having individual discharge separators/silencers for each pump and another having a common trench with exhaust air stack for all the pumps. The individual discharge separators are most common for the smaller machines while the bigger machine having large number of vacuum pumps generally adopt the common trench system. In general there are not much issues with the individual discharge separators but a poorly designed trench may pose few problems such as vibrations and sound due to over pressurization of the trench. There were few cases of over loading of the trench that resulted in the vibrations and sound. Additional vents were advised to install in the trench and the problems get resolved thereafter.

8. Evaluate the Capacity of the Vacuum Pumps.

The indirect measurements of the vacuum levels, pump speed, load and visual internal inspection can give fairly good idea of the health of the pump and indication about the capacity erosion. However after the audit of the vacuum system, it may be required/desired to measure the capacity of some target pumps. TAPPI Information Paper TIP 0420-12 describes the methods in detail. The pump needs to be isolated from the system and usually it may take half a day to make arrangement and test the pump. Data obtained from the capacity tests are some times challenging and should be correlated with clinical observations.

Case Studies

The vacuum audits of over 50 paper machines reveals the mines of information on the working of the vacuum system of various paper machines producing various grades of paper. Four case studies covering the machines from the different mills in India and abroad are presented below to offer a holistic view to the reader.

Case Study#1:

Type of Machine/Make:	Multi-Wire Machine/Beloit
Production:	650 TPD
Machine Speed:	600 m/min
Grades:	Container Board/Packaging Grade
Basis Weight Range:	127 GSM to 550 GSM
Furnish:	OCC
Stock Temp:	45-50°C
Sealing Water Temp:	40°C
Cooling Tower:	Running (but not efficiently)

Vacuum Data

Vacuum Pumps:	10 Nos. (8 Running + 2 Standby)
Pump Models:	Various sizes of Nash 904 and CL Series
Power Consumption:	2100 KW

Findings/Outcome:

1. Most of the pumps were old-some over 29 years. A replacement plan was suggested to replace the older pumps which would save power by 20%
2. Audit identified the immediate potential of power saving of 150 KW that did not call for any investment. This could be achieved by stopping one pump which was not required to be run for certain situations and reducing the speed of another pump that was running at higher than recommended speed.
3. Pre-separator area suffered from the poor layout and faulty design. Barometric legs of the wire boxes separator were not straight. Separator of one of the top felt was undersized. Some of the pre-separator tanks tended to suck the air from discharge side of the extraction pumps. Corrective measures were recommended.
4. House keeping was poor. Lot of debris went to the discharge trench dirtying the water. Seal water contained lot of fines affecting the efficiency of Cooling Tower that could not cool the water properly. The seal water temperature was high- 40 Deg. C. Apart from improving the house keeping, a gravity filter was recommended to remove the debris from the water before entering the cooling tower.

Case Study#2:

Type of Machine/Make:	Multi-Wire Machine/Hansol
Production:	550 TPD
Machine Speed:	600 m/min
Grades/Basis Weight:	Multi Layer Carton Board
Basis Weight:	250 GSM to 450 GSM
Furnish:	Recycled Fiber
Stock Temp:	40 to 45°C
Sealing Water Temp:	30°C
Cooling Tower:	Running

Vacuum Data

Vacuum Pumps:	6 Nos.
Pump Models:	Nash-Elmo 2BE3 420 and 2BE3 520
Power Consumption:	900 KW

Findings/Outcome:

1. The pumps have been in operation for about 7 years at the time of audit. All the six vacuum pumps were in operation and running well.
2. Power consumption was well below the industry average for similar product line.
3. Vacuum layout was good and did not have any serious issue.
4. There was a possibility of saving power by 50 KW but by going for the bigger pumps for two applications

Case Study#3:

Type of Machine/Make:	Fourdrinier with Top Wire/Beloit
Production:	250 TPD
Machine Speed:	800 m/min
Grades/Basis Weight:	Writing & Printing Paper
Basis Weight Range:	54 GSM to 100 GSM
Furnish:	Recycled Fiber (DIP)
Stock Temp:	40 °C
Sealing Water Temp:	35°C

Vacuum Data

Vacuum Pumps:	5 Nos.
Pump Models:	Nash CL 9001/9002 (with gear box drive)
Power Consumption:	1800 KW

Findings/Outcome:

1. There was a huge capacity miss-match. The applied total vacuum capacity was 1275 m3/min against the actual requirement of 930 m3/min.
2. The vacuum capacity was poorly distributed with bad combinations. For example the wire box application was combined with one of the felt uhle box and suction press low zone while couch low zone application was clubbed with suction press high zone.
3. All the pumps have come with the second hand paper machine and were over 30 years old. The pumps needed replacement.
4. Audit revealed the power saving potential of 45% by replacing the old pumps and making capacity correction.
5. The company replaced the pumps later on during one of the paper machine renovation project. The new pumps were procured according to the recommended capacity. A power saving of about 800 KW was achieved with a total investment of about rupees 2.0 crore.

Case Study#4:

Vacuum Survey the Paper Machines of an Old Integrated Wood Based Paper Plant

No. Of Paper Machines:	8 (Capacities ranging from 10TPD to 90TPD)
Total Mill Production:	325 TPD
Vacuum Pumps:	47
Power Consumption:	2.72 MW
Installed Power:	3.77 MW

Findings/Outcome:

1. The mill was about 70 years old at the time of vacuum audit in 2012. In general, most machines have more pumps than required. The pumps were of different makes and sizes leading to the heavy inventory. For example a small machine producing 10TPD had 5 vacuum pumps of 4 different sizes. Models and makes of some of the pumps could not be ascertained and the sizes were estimated based on the physical observations and measurements.
2. The vacuum system of the most machines (especially the older machines-PM#1 to PM#6) was evolved over a period of time leading to the chaotic layout. The small pumps were added now and then swelling the pump population to 47.
3. Three vacuum pumps were shut immediately after the audit resulting in the power saving of about 100 KW.
4. There was a practical difficulty in carrying out the limited rectifications owing to the complicated piping layout and space constrains. The mill was advised to scrap all the old and inefficient pumps and go for pumps with improved layout. This measure could have saved about 800 KW power but the mill did not get the opportunity to carry out the changes and was eventually shut down few years later.

Conclusions

1. Vacuum audits revealed the potential of energy savings and improvement of the system in most mills.
2. Mills showed increasing interest in the vacuum audits, however implementation part still requires more push and attention.
3. It is a good practice to carry out the vacuum system audits every 5 years.
4. The mill people can do a simple vacuum audit in-house with the soft tools provided in this paper.