Improving the Paper Machine Vacuum System with Vacuum Audits

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ABSTRACT

This paper highlights the importance of the paper machine vacuum system audits and suggests a practical approach to carry out the comprehensive vacuum audits. The paper also explains the significance of various key measurements which helps to identify the energy saving potential and improve over all performance of the vacuum system. The experience gained from the audits of over 30 paper machine vacuum system conducted by the author in India and abroad is shared by way of examples and case studies.

Introduction

Paper Mills of the World are showing increasing interest in the vacuum audits and the vacuum system of the paper machine has started getting the attention that has been over due to it. However much of the focus still remain on the trouble shooting and adequate attention is not generally paid to the system that may not be affecting paper making process but may be quietly costing dearly to the mill in terms of energy costs. Studies of several paper vacuum systems reveal that there exists the real potential of saving energy in many mills and there are opportunities to improve the over all performance of the system. Vacuum audits help to identify these opportunities and show the way to improve the system. Examples given in the paper demonstrate that in some cases a very little or no investment was required to reduce the energy consumption without compromising on the performance of the paper machine operation.

A vacuum audit could be designed to deal with a particular issue that a mill seeks to resolve or achieve a specific goal that the management has set in but no audit is complete without exploring the possibilities of saving the energy. A typical vacuum audit involves the interaction with mill people, determination of the required air flows and correlating it with employed capacities, measurement of vacuum levels, speed, electric load, 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 5 years as condition changes over the years and system gets disturbed.

Why Vacuum Audits?

Modern paper machines generally start with a well designed vacuum system, however as river of time flows, rot starts to set in due to the various changes that takes place over a period of time. There could be changes on account of machine rebuilds, production, paper grades, machine speed, furnish and machine clothings etc. Apart from these changes, the vacuum system itself undergoes many changes such as addition of pumps, changes in the pipe connections and routings, change of pulleys and motors etc. Many of the changes in the vacuum system are driven by the need to solve the problems such as low vacuum and provision for standby vacuum pumps to deal with emergency situation. Very often the emergency situation for which the changes were made to provide the temporary solution is no more there but the provisions remain that lead to un-necessary problems.

There was case of a 30 TPD paper machine that started its life with 4 Nos. Vacuum Pumps each having the capacity of about 55 m3/min and over the years it went on to add 2 more vacuum pumps each of the same capacity as earlier ones but without adding any vacuum service or increasing the production capacity. Papermakers demanded even more capacities to deal with imaginary vacuum scarcity. This machine suffered from excess of capacity. One pump was eventually shut down leading to the saving of 65 KW power.

There was another example of a fine paper machine that was rebuilt two times as a result of which 4 to 5 pumps were added crowding the ground floor, complicating the piping lay and putting pressure on existing discharge system.

During the audit of several machines, many cases were encountered where the changes were made in pulleys, motors, vacuum services connections but the data were not updated leading to erroneous conclusions and decisions. In some cases the pumps were not connected to the right application for which the pumps were intended and designed for.

Change is inevitable as demonstrated by above examples and it is important that the system is examined periodically and make the necessary corrections. A five year period is good time to conduct the detailed vacuum audit and clean up the house.

A comprehensive study of the vacuum system offers the following advantages:

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

As evident from the number of requests for vacuum studies flowing in from

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various regions, more and more mills across the globe are recognizing the importance of the vacuum audits and striving to optimize the system.

A Practical Approach to the Vacuum Audits

It is important that the objectives of the audit are identified and goals are set in consultation with the mill people so that the focus and content of the audit can be defined. The preliminary vacuum data together with the main machine data and vacuum system lay out drawing helps to quantify the extent of the work and should be made available well in advance.

Some simple but key measurements and observations which help to reveal the hidden problems and identify the energy saving potentials are discussed in the following paragraphs:

Air Flows:

Determination of required air flows for each application and correlating it with employed capacities is one of the important steps that help to identify the hidden problem and also the potential for saving energy. 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. In a particular mill a Nash CL 2002 with a capacity of 50 m^3/min and having a drive motor of 75 KW was employed for a suction press holding zone that required only a capacity of 20 m^3/min with a vacuum level below 250 mm Hg. The mill was advised to shut down this pump and connect the press to the smaller pump available in the machine. The mill saved a power of 30 KW without any investment. At times, the holding zone pump was shut completely in some grade of papers.

TAPPI Information Paper TIP 0502-01 gives the paper machine vacuum selection factors especially for fourdrinier machines, press section, cylinder mould machines and tissue formers. TAPPI TIP 0404-27 offers information on the vacuum requirement for press felt conditioning. For calculating the air flow requirement for special formers like on-top formers and special dewatering boxes, one must take help of the vacuum system suppliers, paper machinery suppliers or the vacuum application specialists. Once the specific air flows (usually expressed in $m^3/min/m^2$ or CFM/inch^2) is known then total air flow can be calculated by multiplying the specific air flow by the area of the vacuum box in question.

While TAPPI vacuum selection factors offer a very good guide lines and work well, there are cases 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 usually have very wide suction boxes and would call for large flows if 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 m^3/min as per norms but it was performing reasonably well with an employed air capacity of 150 m^3/min (almost 1/3rd of theoretical capacity).

Vacuum Levels

Paper makers often complain about the low vacuum levels and tend to demand more vacuum. Hence the vacuum levels need to be checked thoroughly and carefully during the audit. It is a must to measure 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 drop of 25 mmHg between application point and the vacuum inlet is accepted in a well designed pipe line but if the loss is high then it indicates a restriction in pipe or the inadequate piping. This should be investigated. Very often the pipe lines are found clogged or the valves are 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 adequate.

While the vacuum loss across the piping indicates the disease in the piping, over all low vacuum level could be due to many reasons such as low pump speed, internal scale build up, erosion in the capacity of the pump, inadequate seal water flow and high seal water temperature etc. The real cause can be identified with the help of other measurements and observations and a fair assessment of the problem can be made by considering the effect of above mentioned factors and ruling out the least suspected causes.

Low vacuum levels do not necessarily indicate the problem with the vacuum pumps and similarly the high vacuum levels do not guarantee that all is well with the vacuum system. One must take the holistic view of the situation and conclude accordingly. In a Newsprint machine, the vacuum levels at suction press roll were 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 to the air flow. On the other hands the low vacuum levels can be caused by change in furnish, basis weight and fabric etc.

Pump Speed

The speed of the pump should be checked with tachometer wherever possible and in case 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 measured speed should be correlated with the given speed of the pump. Lower pump speed generally lead to lower capacity and consequently the lower vacuum levels. Increase in the speed will lead to more 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 run close to the highest speed resulting in higher power consumption.

Motor Load

Most mills measure the electric load and record in the log book. The actual consumed power should be correlated with pump power at the running pump speed from the pump curve. If the consumed power is found more (say 10% or more) than the power derived from the curve 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 etc. All these reasons should be properly investigated. Process water carry over was found to be the main reason of over loading.

Seal Water

Both quantity and seal water temperature is important for well being 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 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 measure the flow of seal water. Conducting vacuum audit is never boring- one can expect the unexpected. In one case it was found that two of the vacuum pumps (both Elmo Models) ran without external seal water for almost 5 years as the seal water line was connected to the wrong place. Fortunately the pre-separators were not working well and the process water carry over made up for the seal water. A blessing in disguise!

It is important to measure 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 Degree 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. In a particular newsprint 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 pump 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 30 to 35 deg C.

Vacuum Piping and Pre-Separators

Proper design of the vacuum piping system together with efficient pre-separation system is a blessing and greatly contribute to the over all performance of the vacuum system. These should be thoroughly checked during the audit. Very often the vacuum pumps bear the blame for the problems which originate in the piping and pre-separators. The visit to the paper machine basement and keen observation of the piping system usually reveals many hidden problems. Most common problems especially in the older machines are complicated piping lay out with numerous interconnections, partially open valves and bleeding flanges etc. Cases of inadequate pipe sizes have been generally encountered in the machines which are rebuilt for increase in production and where vacuum capacities are added without changing the main piping that handles most of the air traffic.

Inefficient Pre-Separators can be a big menace and spoil the pump and its efficiency. 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. Extraction pump for pre-separator tanks should be designed to work under vacuum.

Vacuum system lay out was found wanting in many mills and some mills suffered from space constraints.

There was unusual case of a paper mill where some of the barometric leg separators were found sitting on the ground floor with no height available for the barometric leg to function. Barometric Separators without Legs! The separators were well designed and of very good construction but installed at wrong place- A case of right equipment sitting at wrong place. These separators came along with the second hand machine that the mill has bought and erectors installed them on the ground floor as apparently no convenient place was available on the machine floor. The mill agreed to make way and relocate the separators to their rightful place.

Discharge System

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. Inadequate sizing of the discharge silencers/trench cause back pressure built up and sound. Pressurized trench may also cause the vibrations. Over loading of the discharge trench is generally encountered on the paper machines which under went re-built adding the vacuum pumps which resulted in the overloading of the discharge trench.

There is a strange case of a poorly designed discharge system that is worth mentioning. The discharge of the vacuum pumps was connected to tightly closed channel that was extremely small and not designed to handle the large flow of air/water mixture. The huge pressure built up inside the channel broke the concrete surface releasing a portion of concrete slab that hit the roof. The mill later installed the exhaust pipes to release the pressure and also installed the individual discharge separators for some pumps.

Vacuum Pump Capacity Measurement

The most practical way of measuring the pump capacity in the mill conditions is by utilizing the orifice plate method. TAPPI Information Paper TIP 0420-12 describes the methods in detail.The pump need to be isolated from the system and usually it may take half a day to make arrangement and test the pump. Portable vacuum flow measuring devices are also available in the market. Data obtained from the capacity tests are some times challenging and should be correlated with clinical observations.

Capacity measurement tests are usually carried out only for few short listed pumps suspected of erosion of the capacities as the test calls for considerable preparation and is time consuming.

Depending upon the size and type of the machine, it may take 1 to 2 days to carry out the vacuum audit and duration could be much longer if it involves the capacity measurement of the pumps.

Case Studies

Data collected from the vacuum audits of over 30 paper machines offer the wealth of information on the working of paper machine vacuum systems. Two case studies covering the machines from the mills in India and abroad are presented below:

Case Study#1:

Type of Machine/Make	:	Multi-Wire Machine/ Beloit
Production	:	650 TPD
Machine Speed	:	600 m/min
Grades/Basis Weight	:	Container Board/Packaging Grade- 127 GSM to 550 GSM
Furnish	:	OCC
Stock Temp	:	45-50^{o}C
Sealing Water Temp	:	40^{o}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:

1. Power Saving Potential: 150 KW without any investment. This could be achieved by reducing the speed of a 904-T2 pump that was running at higher speed than required speed and shutting down one of the pump that was not required in some situations. There was a potential of saving additional 20% power but that would call for replacement of some old pumps.
2. In general pre-separator area had lot of issues. Barometric separator for wire boxes was not working properly due to the faulty design and poor lay out. Legs were not straight. A new design of barometric separator suitable for handling high flow was recommended. Barometric separator for one of the top felts was not properly sized and accordingly increase in size was recommended. Some of the pre-separator tanks tended to suck the air from discharge side of the extraction pumps. Accordingly check valves were recommended for the extraction pump delivery side.
3. Seal water was quite dirty and contained lot of fines affecting the efficiency of Cooling Tower. As a result of this problem the temperature of the seal water high (around 40 deg C). It was recommended to install a gravity filter for filtering the seal water and improve the efficiency of cooling tower to bring down the temperature of seal water as much as possible (say 30 to 35 degree)
4. Most of the pumps were old-some as old as 29 yrs. Mill was advised to devise the replacement plan for the older pumps in steps.

Case Study#2:

Type of Machine/Make	:	Fourdrinier with Top Wire/Voith
Production	:	300 TPD
Machine Speed	:	850 m/min
Grades/Basis Weight	:	Writing & Printing Paper
Furnish	:	Recycled Fiber (DIP)
Stock Temp	:	45 ^{o}C
Sealing Water Temp	:	30^{o}C

Vacuum Data

Vacuum Pumps	:	16 Nos.14 running+2 standby). Includes pumps for Deculators
Pump Models	:	Various Models of Nash/Elmo/ Kakati.
Power Consumption	:	1500 KW

Findings:

1. Power Saving Potential: 100 KW with little or no Investment. This could be achieved by reducing the speed of the pump running for press holding zone and re-arranging some of the pumps.
2. Number of the pumps were rather high for the given machine. The main reason of large number of pumps was the successive rebuild of the machine over a period of time. There were some applications which were served by two small pumps instead of one pump due to the availability of smaller pumps. It was advised to re-arrange the pumps and to replace some smaller pumps by bigger pumps to reduce the pumps population to 12.
3. Some of the pre-separators were not working properly. Pre-separator for couch roll was sucking the air from the delivery side of extraction pump. It was advised to re-size the pre-separator and install the check valve in the delivery side of the extraction pump to arrest the sucking of the air.
4. Discharge Trench was highly pressurized causing vibrations some of which were transferred to vacuum pumps and piping. It was advised to provide additional vent pipe to give the immediate relief and eventually the separate silencers for two big pumps were suggested for long term solutions. For isolating the pumps from vibrations, flexible bellows between the pump and piping were recommended.

Conclusions

1. There exists a definite potential of saving energy in most mills.
2. Mills are showing increasing interest in the Vacuum System Audits.
3. Pre-separation area needs more attention.
4. Very often data is not updated after changes are made.
5. It is advisable to carry out the vacuum system studies every 5 years.