# Save Energy with Efficient Vacuum Pumps and System Design


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## INTRODUCTION

Vacuum System is the heart of the Paper Machine but it gets little attention as long as the vacuum pumps are operating reliably and acceptable production is available. Vacuum is also a very expensive commodity as it contributes significantly to the total electrical energy requirement of the paper machine. Thus the vacuum system of a paper machine deserve due attention.

Liquid ring vacuum pumps are used on most paper machines and a vacuum system consisting of several pumps serving various suction points of a paper machine is by far the most reliable and efficient. Overall efficiencies of 0.9 kW/m$^3$/min are very common today.

The piping and separators are integral and important part of the paper machine vacuum system. Proper design of piping can help insure an efficient and reliable system. Many problems that are often thought to be problems of the pump, originate in the piping system. This paper covers the liquid ring vacuum pump system for a Paper Machine and deals with the issues that influence the efficiency and operation of the vacuum system. The paper also gives some practical case studies of Indian Paper Mills showing the energy saving achieved by installing energy efficient pumps.

## Liquid Ring Vacuum Pump System: Reliable and Efficient

A common characteristic of the papermaking process is constant change: changes in basis weight, changes in freeness and changes in felt permeability, among others, occur continuously. A liquid ring vacuum system because of its unique characteristic is able to cope with these changes easily and thus best suited for the paper machine. The basic feature of a liquid ring vacuum pump as shown in Figure 1 is that its airflow capacity remains fairly constant over wide range of vacuum levels. The power consumption increases slightly with increase in vacuum.

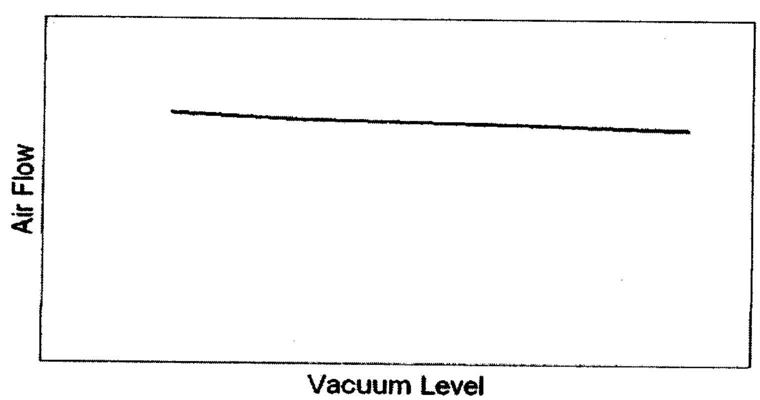


Fig. 1 : Characteristics of Liquid Ring Vacuum Pump


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It is this constant volume - variable vacuum characteristic that help the liquid ring vacuum pump to deal with changes in the variable in paper making process.

In practice, a single paper machine is required to produce various grades of paper with wide variations in basis weight. If basis weight changes, the resistance to the flow of air through the paper web will increase with increase in basis weight and a higher vacuum will be needed to maintain the same airflow through the web. As can be seen from the Figure 2, a liquid ring vacuum pump that displays a constant volume and variable vacuum characteristic will be best suited to meet the changes caused by the change in basis weight.

Similarly in felt conditioning, the liquid ring vacuum pump will be able to achieve good result despite the changes in the felt permeability. New felts are open and require only a low-pressure drop to keep it clean. However as the felts get older, their permeability decrease due to compaction, the pressure drop must increase to drive out the water and dirt from the felt. A liquid ring vacuum pump just does that. See Figure 3.

It is because of the adaptability of Liquid Ring Vacuum Pump to the varying process conditions, most paper machines still today use the liquid ring vacuum pumps to serve the requirement of dewatering and felt conditioning. The most practical liquid ring vacuum pump installation typically is number of separate pumps connected to various suction points of the machine. This arrangement is by definition the most reliable. It is seldom that two or more pumps will be down at the same time while the failure of a single pump or a motor can be handled by bleeding from

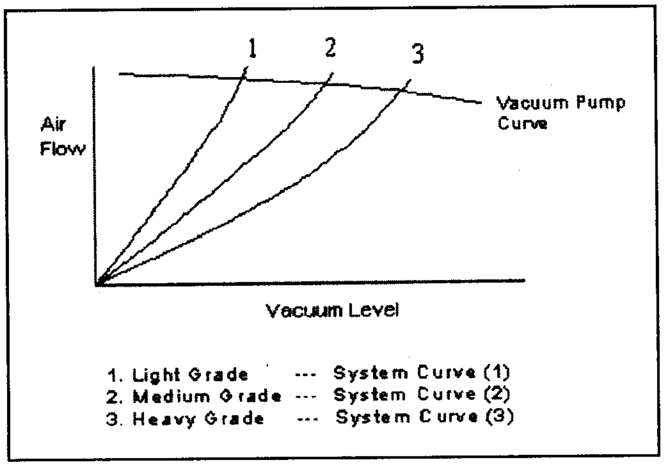


Fig. 2 : Grade Variation - Air Flow Vs Vacuum

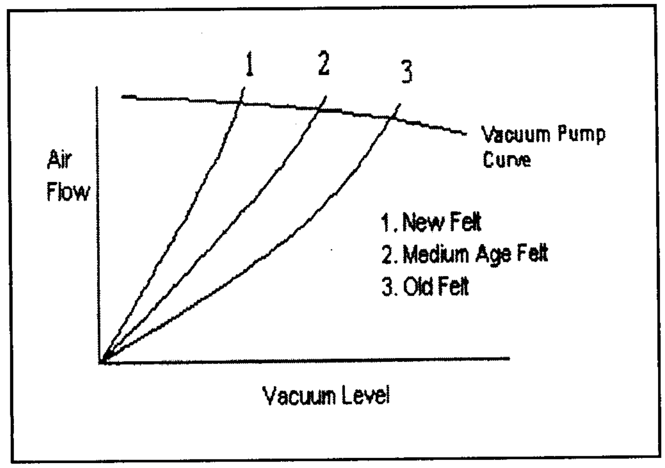


Fig. 3 : Felt Life - Air Flow Vs Vacuum

the neighbouring pumps or by utilizing a by pass line permitting connection of any of the installed pipe any suction points. It is likely that the machine speed might have to be reduced some what but a complete shut down of the machine can be safely avoided.

Liquid ring vacuum pumps are not only the most reliable but also the efficient means of creating vacuum required in paper making process. Further the manufacturers of liquid ring vacuum pumps have put tremendous efforts in improving the energy efficiency of the pumps by continuously upgrading the design and reducing the various energy losses such as friction (hydraulic as well as mechanical), flow, slip and other losses. Overall efficiencies of 0.9 kW/ $m^3$/min are very common today.

## Practical Methods for Monitoring the Efficiency of Liquid Ring Vacuum Pumps

The efficiency of a vacuum pump is practically expressed in terms of kW/ $m^3$/min and can be measured by measuring the power input and determining the air displacement capacity of the pump.

It is important to monitor the efficiency periodically as the loss of efficiency will eventually cause the loss of vacuum level effecting the performance and operation of the machine. Fading vacuum level is usually the first sign of undue degradation in the capacity of the vacuum pump and shall be attended.

The most practical way of measuring the pump capacity in the mill condition is by utilizing the orifice method. The orifice method although is not as accurate as the standard methods but it can provide an indication of the efficiency of the pump with the accuracy level within +/- 10%. The orifice test method does not require any special expertise and can be conducted by mill people.

Videoscope is also a helpful tool in inspecting the internal condition of especially large pumps and estimating the capacity loss. This can also be done at mill site but require the special tools and expertise.

For accurate measurement of the capacity, the pump must be tested according to the internationally recognized standards such as HEI or Pneurop. These tests require a very elaborate arrangement and can normally be done only at the manufacturer's test bed.

It is usual to expect an efficiency loss of 1% per year on well-designed and well-manufactured vacuum pump due to normal wear and tear. Efficiency drop could be much higher if the metallurgy used for construction is of poor quality and exact tolerance are not maintained specially in control port area. In the early stages (up to 10 years), a simple repair usually will restore the original efficiency. However the older pumps may need major overhaul or even some time replacement of major parts.

With increase in the speed and width of the paper machine, the demand of better and bigger pumps is on increase. Manufacturers of liquid ring vacuum pumps are continuously upgrading their products by way of providing major advantage with respect to increase in the pump capacity, less power consumption, reduced water usage and noise generation and extended pump life and performance.

## Key Considerations in Improving the Efficiency and Performance of the Paper Machine Vacuum System

Vacuum piping and the separation is an integral part of the paper machine vacuum system design and is as important as the selection of the vacuum pump itself. There are numerous considerations that must be taken into account while designing the vacuum system. The key design considerations that help in improving the performance and efficiency of the vacuum system are explained below:

### 1. Inlet Piping and Pre-Separators

Incorrect inlet pipe sizing may often result in excessive pressure drops, thus robbing the process of vacuum. Very often a 5 to 10'' Hg loss in vacuum levels may occur because the piping is too small or old and partially plugged.

These excessive pressure drops can also result in reduced capacity, which can be illustrated with a simple example given below:

Let us assume that the airflow requirement at suction point is 3000 ACFM @ 15'' Hg Vacuum. If the piping is undersized, and there is 5'' Hg vacuum loss due to restriction in pipe line, 20'' Hg vacuum would be required at the vacuum pump in order to obtain 15'' HgV at the application point.

Ignoring temperature for a moment, the formula for calculating the relationships between volume and pressure is:

$$P1V1 = P2V2$$

Pressure is measured in Inches of Mercury Absolute,

So P1 = 30 –15 = 15'' Hg A (at the application point)

and P2 = 30 – 20 = 10'' Hg A (at the pump)

V2 = 3000 ACFM measured at vacuum pump

15 x V1 = 10 x 3000

so, **V1 = 2000 ACFM**

In this example, a 5'' Hg pressure drop means a loss of 1/3rd of the capacity. Such examples may not be many but do exist in actual world. The example illustrate that the excessive pressure drops between the application point and the pump can cost heavily in terms of final vacuum levels, capacity and eventually poor performance of the process itself. Any loss exceeding one or two inches of Hg between the paper machine service and the vacuum pump shall be investigated thoroughly and corrected. The common causes for the vacuum loss (that can be determined by installing the vacuum gauge at the respective points) are restriction in pipeline (inlet as well as discharge), breathing from flanges, liquid carry over and incorrect pipe size etc.

A few basic design principles should be followed for vacuum piping. Prior to separation equipment, (where there is liquid in the line), piping should be sized so that velocity is below 3500 fpm. For dry air i.e. after the water has been removed from the air in separators, the pipe diameter can be sized based on the maximum velocity of 5500 fpm. The volume used in calculating velocities should be based on ACFM values rather than atmospheric volumes or SCFM. In case of borderline selection, it is suggested to for the next large pipe size.

Vacuum piping containing liquid runs must slope downward toward the vacuum pump with no low points in the line as water will tend to build up in the low points area causing fluctuation in vacuum levels and erratic air flows. If the volume of water is great enough, air velocity will eventually pull a slug of water into the pump and can even cause damage to the rotor if the slugs are of sufficient quantity.

It is recommended to install pre-separators whenever the carryovers from the process are expected. Pre-Separators offer the following advantages:

- Help reduce electrical load on the pump.
- Protect the pump from erosive and corrosive liquid and thus prolong the pump life.
- Separating the liquid from the air, it is possible to reduce the pipe diameter after the separation and thus save cost.
- Separators help keep the process water out of the pump and thus make it feasible to have closed loop re-circulated seal water system.

Separators should be suitably designed to ensure the separation of liquid form the air. Recommended velocities for separation are 500-700 fpm. The design may vary depending upon the service.

Barometric Legs are typically used when there is sufficient headroom. The vertical height of the barometric leg must be adequate to prevent liquid from being sucked into the vacuum pump. Effective barometric dropleg length (bottom of the separator to top of seal pit overflow) is calculated as follows: L = 1.13 ft. x (vacuum in Hg) + 3 ft. The calculation is made based on maximum anticipated vacuum.

Some services such as basement felts do not have adequate room to accommodate the barometric legs. In such cases a centrifugal pump with very low NPSH capabilities is required to get rid of the water. Well designed packaged separator/pump systems are available today.

**2. Discharge Piping and Discharge Separator/Silencer**

Care must be taken in sizing of the discharge piping away from the Vacuum pump as well. Inadequate sizing of discharge piping and discharge sump or trench often leads to back pressure build up which in turn increase the load on the pump. The backpressure in the discharge pipe can also adversely effect the paper machine operation by causing fluctuations in vacuum levels and airflows. In a well-designed discharge system, the backpressure shall not exceed 1 psig.

It is not unusual to find in older vacuum systems that vacuum pumps have been gradually added in overloading the discharge system and rendering it undersized. The excessive load in the discharge sump/trench not only causes the backpressure but also generate excessive noise.

In order to ensure a good separation after the vacuum discharge, a separation velocity of 500 fpm is recommended. The velocity for exhaust air (after the separation has occurred) can be considered as 8000 fpm.

**Some Examples of Energy Saving Using Energy Efficient Pumps in Paper Mills in India**

**Case Study #1**

Production Capacity: 60 TPD (Two Paper Machines)

Paper Grade: Fine Paper

Action Taken: Replacement of Vacuum Pump by Original Nash CL 2002 Pump in 1997

Duty Conditions: Air Capacity: 52 $m^3$/min, Vacuum Level: 450 mmHg

Old Pump Details: Absorbed Power-63 kW, Motor-75 kW

Nash CL 2002 Pump Details: Absorbed Power- 47 kW, Motor-55 kW

Power Saving: 25%

Payback Period: Less than one year

This mill eventually replaced all 5 Nos. locally made pumps by Nash pumps gradually and ordered Nash pump for new project in the year 2005.

**Case Study #2:**

Plant Capacity: 150 TPD (Three Paper Machines)

Paper Grade: Fine Paper

Action Taken: Replacement of Vacuum Pump by Original Nash CL 2002 Pump in 2000

Duty Conditions: Air Capacity: 51 $m^3$/ min, Vacuum Level: 510 mmHg

Old Pump Details: Absorbed Power-65 kW, Motor-75 kW

Nash CL 2002 Pump Details: Absorbed Power- 48 kW, Motor-58 kW

Power Saving: 25%

Payback Period: Less than one year

This company eventually replaced another locally made 5 pumps of various sizes by Nash Pumps and also ordered Nash Pumps for new project in the year 2006.

## SUMMARY

1. A liquid ring vacuum system is best suited for the paper machine.
2. Liquid Ring Pump manufacturers are continuously improving capabilities to manufacture large and efficient vacuum pumps that offer economic solution to the papermaking.
3. Vacuum Pumps efficiency shall be measured periodically to ensure that there is no significant degradation in vacuum levels.
4. Vacuum piping is often a neglected area and due care shall be taken to design the vacuum piping as it is as important as the vacuum pump itself.

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