A discussion of common problems in paper machine vacuum systems helps mills correct the actual problem, not just its symptom

BY DOUGLAS F. SWEET, P.E.

Troubleshooting Guide Helps Mills Identify Vacuum System Problems

ALL WET-LAID PROCESS PAPER MACHINES have vacuum systems, and these generally operate without frequent problems. However, when difficulties occur within the vacuum system, it is often difficult to identify the actual problem and its cause. Many times, the symptoms get treated, rather than the problem itself. The troubleshooting guide in this article should assist mill maintenance and production personnel in quickly determining the causes of vacuum system problems and identifying the differences between vacuum pump problems and those external to the pump. The article will cover the most commonly occurring vacuum system problems.

When troubleshooting vacuum systems, as with any other operating problem, good techniques must be applied and questions must be asked. These questions include, "What changed and when?" and "Is this a problem or a symptom?". The vacuum system problems discussed in this article include:

- Low vacuum levels
- High horsepower—motor trip outs
- Hot pump operation
- Pump vibration

LOW VACUUM LEVELS. Low vacuum levels are one of the more common problems/symptoms experienced on a paper machine. The word "symptom" is really emphasized here, because the difficulty is rarely caused by the vacuum pump alone. However, the vacuum pump often gets changed out, only to discover the problem still exists.

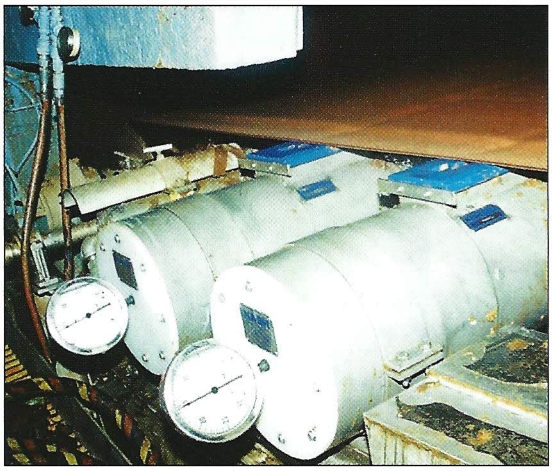
First, recognize that vacuum levels are a measurement of resistance to airflow, where the airflow is induced by the vacuum pumps and the resistance is the various dewatering processes and system piping. Changes in resistance to airflow are caused by various process variables, including sheet moisture, basis weight, refining, felt porosity, suction roll condition, machine geometry, and machine speed. The following sections describe the effects of sheet moisture and suction roll condition on vacuum levels.

In addition, the following sections discuss some typical causes of low vacuum levels, including: open valve in the vacuum line or header, plugged screens at the vacuum pump inlet, uncovered barometric seal leg from a pre-separator, or low seal water flow at the vacuum pump.

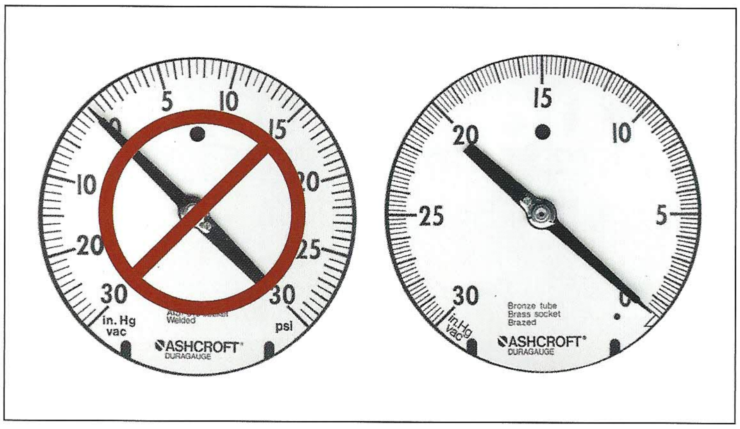
Sheet moisture. Typically, a drier sheet will allow more atmospheric air to flow through it. This is why flatbox systems are designed for higher air flows on the last suction boxes nearest the couch. As the sheet gets drier, it requires more vacuum capacity to maintain the same vacuum level. Additionally, if higher vacuum levels are desired, even more vacuum capacity is needed.

Cases have been observed in which a flatbox system is upgraded to increase sheet dryness entering the couch and, although the flatbox goal is obtained, the couch vacuum level drops. This lower couch vacuum is due to the lowered resistance to airflow from the drier sheet, which is caused by improved dewatering from the flatboxes.

Suction roll condition. Several problems can occur due to the condition of the couch or other suction rolls. First, the internal seal strips must be functional so that the rolls seal properly against the inter-



It is important to locate vacuum gauges at the suction box or roll as shown on these uhle boxes.

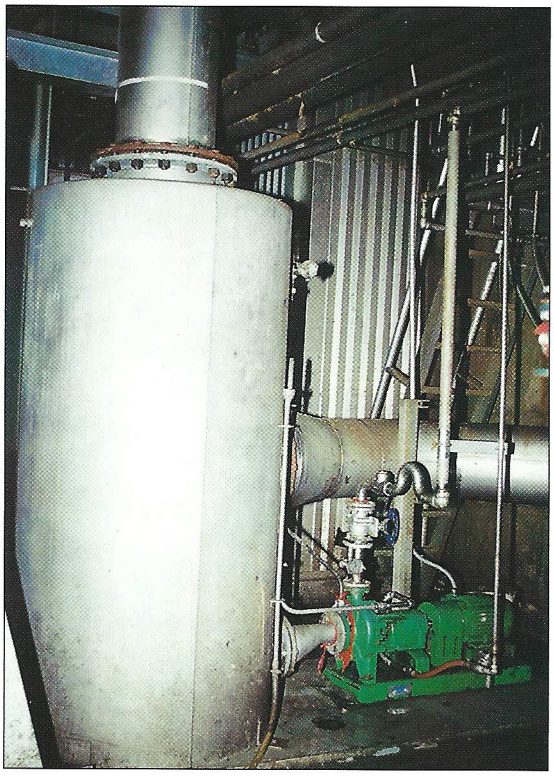


The 0 in.-to-30 in. Hg vacuum gauge (right) is the correct choice for paper machine vacuum systems. A compound vacuum/pressure gauge (left) does not provide the best accuracy.

nal surface of the shell. If the seal strips are binding in their holders, internal showers are not operational, or loading (pneumatic or other type) is not uniform, there will be an internal vacuum leak. This may be evident if the suction zone is covered with plastic while the paper machine is down and the suction roll vacuum pump is run. The vacuum level at the suction roll should be higher than normal. If not, you may be able to hear air leakage from within the roll.

Another vacuum related problem can occur when there are partially plugged holes in the shells of suction rolls. These plugged holes cause higher resistance to airflow and result in an unrealistically high vacuum level. Those mills that adjust refining based on couch vacuum may under or over refine due to couch roll problems.

Open vacuum line or header. Vacuum headers have a unique way of sprouting new pipe runs with isolation valves during weekend shifts. This apparently gets the papermaker through to the next shutdown when a pump can be changed or repaired. However, by that point, many of these new interconnections are forgotten and the original purpose becomes obscure. After a while, these valves are left open, making system analysis and troubleshooting almost impossible.



A vacuum pre-separator and special low NPSH pump can eliminate white water carryover to the vacuum pumps.

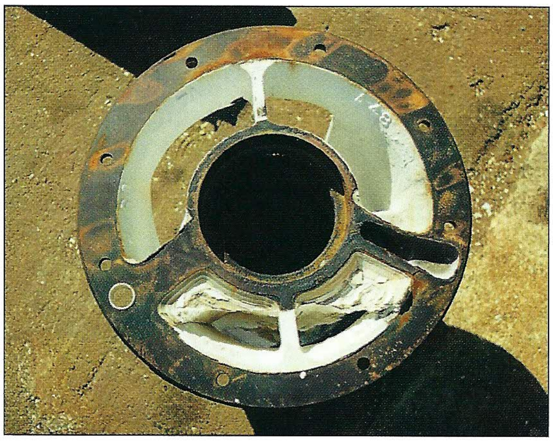
Always trace the vacuum piping to be sure the flatbox vacuum pump, for example, is connected to the flatboxes—and nothing else. Also, be sure that valves leading to other vacuum pumps or paper machine vacuum points are closed. In cases where spectacle blanks are used to separate vacuum services and pumps, be sure these are intact. Many hours have been spent chasing vacuum losses only to find that a spectacle blank made of carbon steel has the lower third of its area completely corroded away.

Plugged screens at the vacuum pump inlet. Many mills elect to keep startup screens in place at the vacuum pump inlet. This is not a problem, as long as the screens are of a substantial material. Also, it is important to locate the pump vacuum gauge directly into the vacuum pump inlet, below the screen, since there is usually a tapped connection at that point. This allows you to observe any increase in the vacuum at the pump compared to the level at the paper machine. The screens may have a tendency to blind over with felt hairs, fiber, old lunch sacks, etc.—all of which act as a throttling valve at the vacuum pump. This causes a high vacuum reading at the pump and a low vacuum reading at the process.

For example, one mill was ready to replace a uhle box because of what appeared to be poor sealing of the uhle box cover and inadequate end deckles. The "symptom" was a reading of only 6 in. Hg at the uhle box. There was no vacuum gauge at the vacuum pump, but the cast iron inlet flange and proximity beneath the flange was sweating and about 40°F colder than the ambient temperature. A gauge was installed in the pump inlet, on the pump side of the screens, and 23 in. Hg was measured. It was discovered that the inlet screens had been forgotten, and one particular screen was nearly blinded over. The cold temperature was due to the refrigeration effect from the rapidly expanding air across the plugged screen. The screen was cleaned off and the uhle box vacuum returned to satisfactory levels.

Uncovered barometric seal leg. Low vacuum can be caused when the vacuum level exceeds the limits of a vacuum pre-separator, seal leg, or seal tank system. High vacuum levels can draw all the water out of the seal tank, leaving the seal piping open to the atmosphere. Vacuum pre-separators operate with either a barometric seal leg (pipe) or with a low NPSH removal pump. The seal leg is the simplest design, but failure to correctly design, install, and operate this simple system will result in perpetual vacuum system problems, so a few basic engineering practices must be followed:

• The distance (elevation) between the bottom of the vacuum separator and the liquid level of the seal tank must be sufficient to overcome the vacuum



Rear view of vacuum pump cone showing heavy calcium carbonate deposits in discharge ports at the bottom. Note that the top inlet ports are relatively clean.

level.There must be 1.13 ft of elevation for every 1 in. Hg of vacuum level in the separator. In addition to this conversion, it is necessary to add another 3 ft to 5 ft for friction and a safety factor.

- The bottom of the seal leg pipe should extend down into the seal tank to a point about 6 in. from the bottom.
- The volume of the seal tank must be sufficient to allow the seal piping to fill with water when under vacuum and before there is water flow from the preseparator. Designing a seal tank with a volume equal to two times the seal pipe volume is sufficient. Some paper machines have been forced to operate at reduced vacuum levels due to poor system design and low installation levels of the pre-separators. Vacuum capacity and horsepower is then wasted when a vacuum in-bleed valve is required to limit vacuum levels.

Low seal water flow. Many paper machines operate with liquid ring vacuum pumps, and significantly reduced seal water flow can result in lower pump capacity. Vacuum pumps require 10 psig to 15 psig seal water at a point measured upstream of an orifice. However, a plugged orifice may not let the proper seal water flow pass, even when the correct pressure is indicated. Remember: Pressure does not indicate flow! To obtain reasonable accuracy, seal water pressure gauges should read 0 psig to 30 psig or 0 psig to 60 psig. A 0 psig to 100 psig gauge will not provide good accuracy around the desired level of 10 psig to 15 psig.

Note: Hot seal water—110°F to 120°F and higher—also causes reduced vacuum pump capacity. This is most often a system design issue and is not addressed here.

HIGH HORSEPOWER. How often do you get a call about the vacuum pump motor tripping out? It happens for a lot of reasons, and only occasionally does replacing the pump correct the problem. Again, to solve the problem, good troubleshooting skills must be employed and the questions of "what changed, and when did it change?" must be asked.

Two good starting points for determining horsepower requirements are the operating conditions, or vacuum levels, and pump speed (rpm). These are discussed in the following sections, along with the pump horsepower overloading caused by water overloading, backpressure, and internal buildup.

Operating conditions. It is important to determine if the pump is operating at a point well above design vacuum levels. Remember, the vacuum gauge location must indicate actual pump vacuum levels. Also, the vacuum gauge must be accurate. The recommended gauge type is a 0 in- to-30 in. Hg vacuum only gauge, not a compound gauge that reads both vacuum and pressure, since getting a positive pressure in a vacuum line on a paper machine is practically impossible.

Also, discussing vacuum gauges and their typical condition often leads you to believe that "a good gauge is still in the box". Always be sure of the accuracy of vacuum readings. In addition, it is impossible to operate with a higher vacuum level at the paper machine than at the vacuum pump. If a pressure drop in the piping exists, the vacuum pump will be at the highest vacuum level.

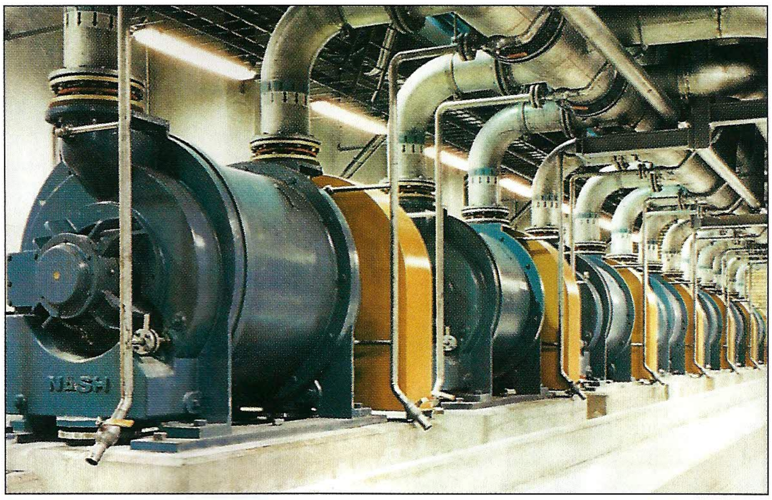
After determining the vacuum level, compare it to typical operating conditions. Higher vacuum levels usually, but not always, cause higher horsepower requirements. Be sure the selected drive motor will allow the pump to operate at the full range of vacuum levels. Otherwise, a vacuum relief (in-bleed) valve will be required to limit operating vacuum levels.

Pump speed. Be sure the actual pump speed is the same as what was originally intended for the installation. Sometimes, something as simple as the wrong motor getting installed—1,800 rpm vs. 1,200 rpm—can be the problem. This is more likely in a new system or after some motor maintenance.

Drive ratios of v-belts and gear reducers should be compared to the actual output speed or pump rpm. Drive manufacturers use the term "exact ratio" for determining the actual output, or driven speed. Also, with the newer, high efficiency motors, the full load speed is usually closer to the nominal rating of 1,200 rpm or 1,800 rpm. For example, selecting a drive based on 1,150 rpm (a common speed for older motors) and installing a new motor rated at 1,190 rpm would yield a 3.5% increase in pump speed, with a comparable increase in bhp.

Water overloading and air/water separation systems. Another common reason for high horsepower is severe water overloading. This can come from excess seal water or from the paper machine vacuum service (couch, uhle box, etc.) A liquid ring vacuum pump has a rating for a specific seal water flow and increasing this by even 25% or 50% does not typically cause a power problem. Flows that are two to three times the rated flow are most likely causing motors to overload, or belt drives to fail. Also, sudden slugs of water are problematic. These can be intermittent, causing difficult troubleshooting.

High seal water flows are caused by several reasons, including high seal water pressure, lack of orifices, and worn spray nozzles (if the pump has them)—or all of the above. Typical seal water pressure is 10 psig to 15 psig. Again, this pressure reading should be *before* the orifice and spray nozzle. As long as the orifices and spray nozzles are intact, seal water pressure can be up to 15 psig or 20 psig without difficulty. Beyond these pressures, excess water is only wasted and contributes to power problems.



Vacuum pumps with vacuum and seal water piping.

Older vacuum systems are often found to have worn spray nozzles or nozzles that have been removed and replaced with a straight pipe.The nozzle functions as an orifice and more than 20 years of continuous flow will enlarge the nozzle and allow as much as two times the desired flow to pass.

Excessive flows, called carryover, from the paper machine are usually detectable and can be resolved.The easiest way to detect carryover is to look at the water discharging from the suspect vacuum pump, if the flow is visible. Cloudy water discharging from a vacuum pump using clear seal water is a good sign of carryover.

Many vacuum systems have vacuum pre-separators between the papermaking process and the vacuum pumps. The purpose of the separator is to remove water and contaminants from the air stream prior to the vacuum pump. These are common on flatboxes and uhle boxes. Sometimes, these are also found on the couch or other suction rolls.

Locations for pre-separators are determined by the type of suction device and machine speed. Any stationary vacuum or suction box, as opposed to a suction roll, should have a separator before the vacuum pump. These applications would include flatboxes, transfer boxes, pick-up shoes, and uhle boxes.

Suction rolls, especially a couch or suction drum roll, should have pre-separators on machine speeds below 1,000 fpm.At these speeds, the water removed under vacuum gets entrained into the roll and internal suction box, and this will flow to the vacuum pump. At higher speeds, the water slings out of the suction roll shell due to centrifugal force. Under some conditions, there can be significant flows of entrained water from suction rolls on twin wire formers at higher speeds.

With an understanding of the application of air/water pre-separation equipment, there must also be some knowledge of the proper piping methods and auxiliaries such as seal tanks and low NPSH removal pumps. Even though a separator exists, the separated water must exit the system through a barometric seal pipe or low NPSH pump. As discussed earlier, the seal pipe and seal tank can be used when there is sufficient elevation between the separator bottom and the liquid level in the seal tank. Vacuum systems with limited separator elevations may require a low NPSH pump. There is a significant amount of engineering applied to the design and installation of these systems, and this will not be covered here.

However, the point is that air/water separation systems between the paper machine and the vacuum pump are extremely important and affect the vacuum pump operation. Some mills are operated without any form of pre-separation after the uhle boxes on the felts. Although it is not desirable for the water, chemicals, fiber, and felt hairs to pass through the vacuum pump, many liquid ring pumps run for years under these conditions.

For example, one mill that operated under these conditions had just gone through a press rebuild in order to improve press water removal. Previously, this machine did not have any separators between the uhle boxes and vacuum pumps. The machine was rebuilt and new vacuum pumps were added for the uhle boxes, but without pre-separators, because "we have run for 30 years without them." However, the rebuild incorporated the latest technology, including new uhle boxes, felt showers, new and heavier felts, and correctly applied vacuum capacities for the uhle boxes. Although the mill ultimately experienced better water removal, the uhle box vacuum pumps were always kicking out their motors. New separators and low NPSH removal pumps were rushed to the mill to handle the greatly increased water flows from the felts, which solved the overload and kick out problem.

Sometimes, the carryover problem comes as slugs due to pockets in the vacuum piping.This causes intermittent slipping of the v-belts that drive the vacuum pumps. Also, the fluctuating loads can be measured at the drive motor.This usually shows up at a fairly repeatable frequency - for example, every 20 or 40 seconds. Solutions include removing the pockets from the piping or adding separation equipment.

Backpressure. Another cause of pump overloading is associated with vacuum pump backpressure. Backpressure occurs when the vacuum pump is operating with a discharge pressure of greater than 1 psig. Well-designed vacuum systems operate with a discharge pressure of less than 0.5 psig. Proper discharge systems do not allow piping to run uphill and are designed for specific velocities. Older vacuum systems may have had additional vacuum pumps added to the system without modifying the discharge system and piping.The additional vacuum pump will push more air through undersized piping, causing additional friction and resulting backpressure on the vacuum pumps.

A second cause of backpressure occurs when the seal water leaving the pump is not removed from the discharge separator or vacuum pump sump at the same rate it entered. The discharge separator should be checked for free flow to an open drain. Systems with a discharge sump must have the water level in the sump regulated to hold it at proper levels. The first indication of high water levels in a sump or plugged water outlets in a discharge separator is water blowing out the exhaust stack.

Internal buildup within the pump. Internal buildup within the pump is another cause of pump overloading. This can be from lack of pre-separation or from calcium carbonate scale deposits. These deposits usually occur on the pump rotor and within the discharge ports. This buildup causes internal backpressure and does not allow seal water and air to exit freely. Many times, the scale and buildup can be removed with a de-scaler while the pump is shut down. Also, in the event of hard water, a chemical dispersant can be added to the seal water to keep the calcium carbonate in solution.

HOT PUMP OPERATION. A liquid ring vacuum pump operating at 130° F and above may be an indication of a problem, although the operating temperature does not necessarily damage the pump. The vacuum pump usually operates at a temperature 10°F to 25°F higher than the temperature of the seal water flowing to the pump. Most often, high pump temperature is an indication of low seal water flow. Low flow can be caused by plugged orifices or spray nozzles and/or low seal water feed pressure. As mentioned earlier, low seal water flow can be the cause of low vacuum levels. Therefore, vacuum pumps operating at unusually higher temperatures can be a sign that requires investigation.

High pump operating temperatures may also occur with proper seal water flows. Sometimes, the paper machine vacuum service is just hot, as with flatboxes or couch rolls on a linerboard machine with a steam box just ahead of the couch. The same would apply to vacuum steam boxes in the press section. In these instances, the elevated pump temperature is normal.

VIBRATION. Vibration in liquid ring vacuum pumps is an occasional problem and it is important to understand the causes in order to avoid replacing a good pump. In this article, we will not go into high frequency vibrations due to bearings. Mill maintenance and bearing analysis have progressed to the point where bearing problems can be picked up, in many cases, before they become serious. It is worthwhile to mention that most liquid ring vacuum pumps have 16 or 20 blades, which is helpful in determining blade pass frequencies.

Common causes. There are a few common causes of excess vibration that are easy to recognize, such as excess seal water or a deteriorated base or foundation. High seal water flows of two to three times the standard rating can cause a vibration or internal "knocking" within the pump, which may sound like a hammer bouncing around within the pump. This high seal water flow may also show up as high horsepower, as already discussed.

The problem of deteriorated bases and foundations are obvious and are only due to old age in the mill basement. In these cases, the pump may "rock" at low frequencies. This vibration may increase in pumps with poorly supported vacuum piping. The commonly used flexible hoses, at the pump inlet, help isolate the pump from vibration due to the system piping.

Scale buildup. Pump vibration occurring at one times the rotation frequency may be due to scale buildup on the rotor. While normal pump wear may be more uniform, and not heavily contributing to vibration, the buildup and removal of scale (calcium carbonate) is not so uniform. In mills with hard water, there are routine descaling procedures that can sometimes leave scale deposits attached to areas of the rotor. These deposits can cause the rotor to be unbalanced and will show up as vibration. Look for vibration just after these descaling procedures have taken place.

Stalling. A final word on vibration concerns the common occurrence of "stalling". A liquid ring vacuum pump operates with the development of a liquid ring due to centrifugal force of the spinning rotor. During startup, this ring of water develops as long as the vacuum pump has a free flow of air from the process.

In some systems, a valve may be closed in the vacuum line, minimizing or eliminating the free flow to the pump during startup. This is sometimes referred to as starting the pump "dead-headed". If the pump does not get a good airflow, it may only partially develop the liquid ring. This will not allow the pump to operate at typical vacuum levels and may even show up as pulses in the indicated vacuum level. The pump will vibrate slightly, or in some instances, it will shake enough to crack a concrete foundation. There may even be a random knocking sound coming from within the pumps. The problem shows up just after the pump has been started and not after it has been operational for hours or days.

The solution to the stalling problem is to start the vacuum pumps with all vacuum system valves open. Areas of the vacuum system with vacuum control valves, such as flatboxes, uhle boxes, and suction pickups, are candidates for stalling if valves are not in proper positions at startup.

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