# 1. Milk Harvest

**Section Contents**:





## Purpose – Milk Harvest

The milk harvesting system is the most important technology used on a modern dairy and accumulates more hours of use than any other piece of equipment. Careful design, selection, installation, maintenance of this equipment is critical to optimal performance, efficiency and quality of milk harvest.

The milking process is responsible for quickly and efficiently harvesting the milk produced by the dairy herd 2 or 3 or more times per day, 365 days per year. A significant amount of energy must be expended to extract milk from the dairy cow and transport the milk to on-farm storage. The milking system is an assembly of separate components that are connected together thru electrical and piping systems to perform the task above.

The centerpiece of the milking system is the vacuum pump and is the primary electrical energy user. The vacuum pump operates whenever milking or washing the milking equipment takes place, and on large modern dairies this can be 24-hour a day, 7-day a week. Total energy used by the vacuum pump can comprise 26% of all electrical energy used on California dairies.

The vacuum pump produces a negative pressure to facilitate removal of milk from the cow and provides air movement that assists milk flow from the claw to the receiver. Presently there are four main types of vacuum pumps that are in use:

1. Sliding vane rotary pump
2. Water-ring
3. Rotary lobe type pump

4. Turbine

Each type of vacuum pump offers different advantages and drawbacks that require careful consideration when selecting.  They also vary in their energy use characteristics and their adaptability to energy conserving measures that should be taken into account.

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## Equipment - Vacuum Pumps

### Sliding Vane Rotary Pump

The rotary vane vacuum pump is perhaps the oldest and most efficient type still being used for milking systems.  This pump uses sliding vanes set in slots in a rotating shaft.   With centrifugal force, the vanes are forced outward against the housing.  Oil lubrication forms a seal between the vanes edge and housing.  Figure 1-1 below shows a cross section of the vane pump.  Note that the center of rotation of the rotor is not at the center of the housing.  As the shaft and vanes rotate through one revolution, the volume between two adjoining vanes varies from near zero to a maximum volume and back to near zero.  Where the volume in increasing, the air is sucked into the pump through the inlet.  When the volume is decreasing, the air is compressed and squeezed out of the pump into the outlet.

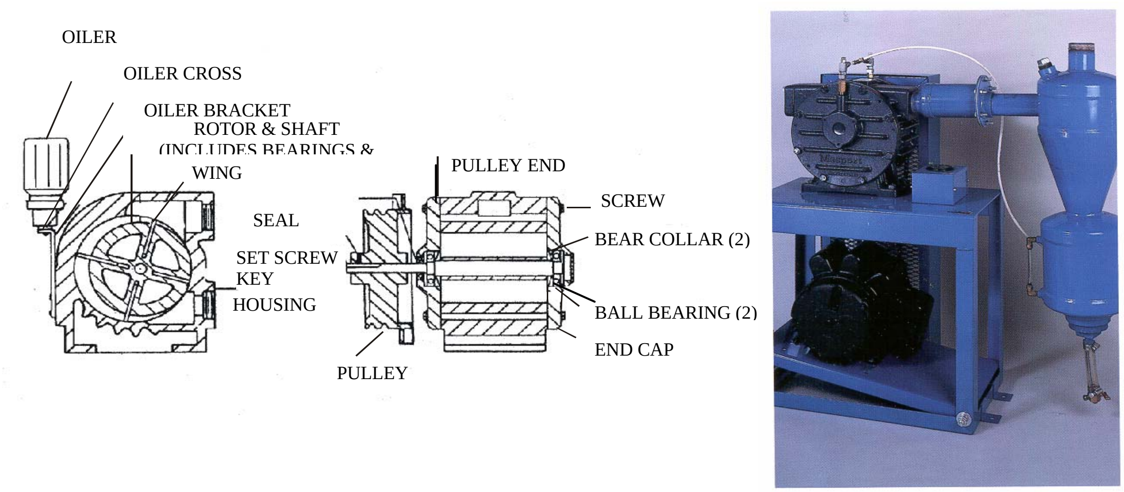



Figure 1-1. Sliding vane vacuum pump (Masport Vacuum Pump)

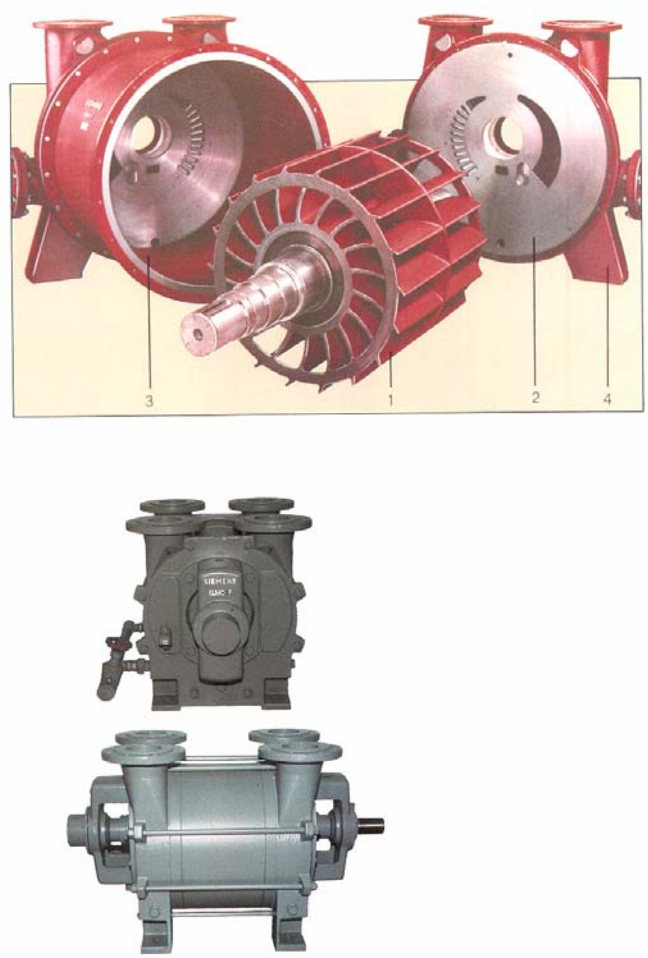
Lubrication of the sliding vane pump is crucial. This includes the vanes and the two end bearings. Two oiling systems are used. One could be termed passive and the other type is active. The passive type would be a drip system where the oil rate is dependent on the vacuum inside the pump. When vacuum levels are low, say during the washing cycle, lubrication may be reduced. This may be during a time when lubrication is most needed. To overcome this deficiency, a positive oiling system has been introduced.

Unfortunately, some of the oil used for lubrication becomes atomized and entrained in the air stream discharged from the pump. This is unacceptable if the oil is discharged to the atmosphere. Oil reclaimers were added to the exhaust to remove oil mist from the air. This oil can be re-used. However, some oil still escapes, often coating the ground and surrounding surfaces.

## Water Ring

The water ring or water seal vacuum pump is quite similar to the vane pump in principal but much different in operation. Instead of the sliding vanes pressing against the pump housing, this rotor has rigid blades and the outer seal between these blades and the inside of the housing is a ring of water. These pumps are quiet and no oil is needed. The cross section in Figure 1-2 shows the same offset between the center of the rotor and center of the housing.

Water becomes entrained in the exhaust air. This water must be removed before the air is discharged to the environment. The recovered water can be either (1) disposed of and make-up water added to the system or (2) recycled through a cooling device and returned to the vacuum pump reservoir. Because of contamination of the water with milk and air contaminants, this water must be changed periodically.




The simplicity of the Seimens pump, along with its superior design characteristics, ensure greater reliability and lower maintenance expenses. I - The all stainless steel rotor is cast with short, rigid blades, further strengthened by reinforcing rings at both ends and a full length tapered hub. 2- The design of the discharge and suction ports has an important impact on the efficient operation of any water sealed pump. The ports on the Seimens pump are designed to compensate for motor size, and vacuum levels required, through its specially patented variable discharge port design. 3 & 4 – Two flat port plates enclose the rotor in axial direction. The clearances, maintained by separate thrust bearings, keep the rotor in a properly centered position.

Figure 1-2. Water ring vacuum pump (Siemens)

## Rotary Lobe (blower) Pump

A more recently introduced vacuum pump is the rotary lobe that was first used as a blower to deliver air, as the name implies, rather than developing a partial vacuum on the inlet side. This pump has two rotating ductile iron shafts with two lobes on each shaft. An end view of the "shaft" resembles a figure eight. See Figure 1-3. These two shafts (impellers) rotate in opposite directions with a pair of timing gears to maintain proper orientation between them. See cut away view in Figure 1-3. Because there is no contact between the rotating impellers and the cast iron housing, no lubrication is needed in the pump. The timing gears at each end of the pump are generally lubricated with an oil bath and splash method. Seals prevent oil from entering the pump; thus, the discharge air from the pump is oil free. Close tolerances between the two impellers and the housing give high efficiency and allow the pumps to develop vacuums up to 15 inches Hg.

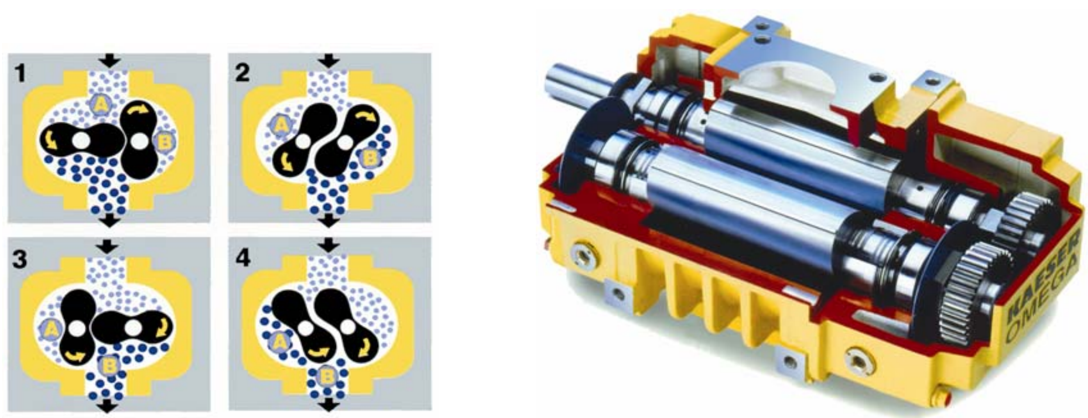



Figure 1-3.  Blower (lobe) vacuum pump (Kaeser Compressors, Inc.)

The high temperatures in the pump may cause milk, for instance, to dry on the internal surfaces. Periodically this pump should be cleaned to maintain good performance. This is done by admitting water on the inlet side. (Follow manufacturer's recommendations).

## Turbine

The turbine vacuum pump is the only one currently in use that is not a positive displacement pump.  The turbine operates like a centrifugal pump or fan by using the mass and momentum of the air to create a vacuum.  Turbine vacuum pumps feature a high temperature discharge that is free of oil.  The turbine pump is the least efficient with an efficiency about half that for a vane or rotary lobe pump.

The turbine pump housing and turbine (impeller) are both made of aluminum. The impeller has the characteristic shape of a turbine blade. See Figure 1-4. The rpm of the turbine is higher than the other vacuum pumps with speeds up to 5,000 rpm listed in the literature. With two outboard bearings and no internal lubrication, the discharge air is clear of oil. Because of greater clearance between the turbine and housing, one might think that the capacity would decrease faster with increasing vacuum than the vane pump. This does not seem to be the case.

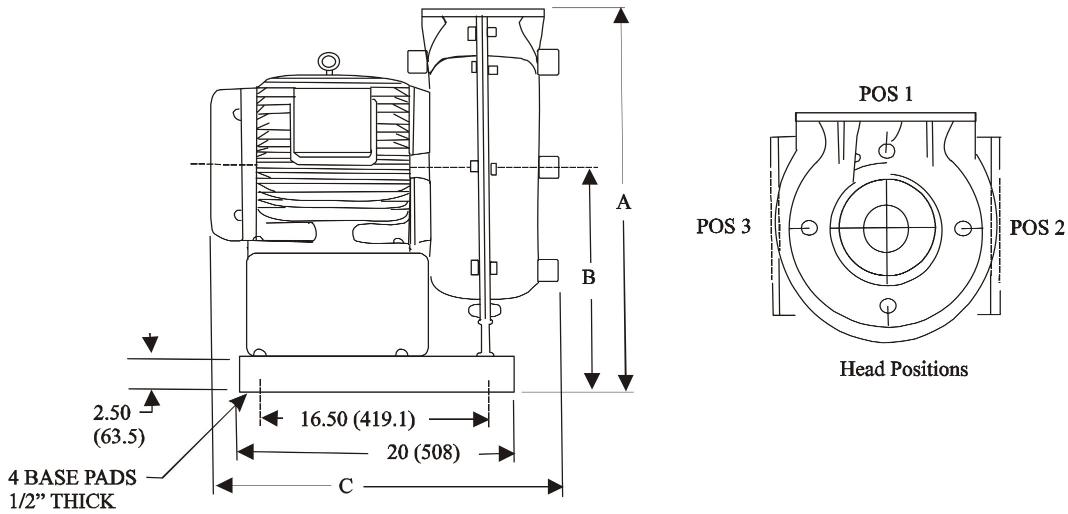



Figure 1-4.  Turbine vacuum pump

Table 1-2 shows the distribution of vacuum pump types in California.  The survey was conducted by the University of California Cooperative Extension.  Since the introduction of the variable speed drive for vacuum pumps there may have been a shift from water

Table 1-2  Distribution of Vacuum Pump Types

| |
|---|
| 37% Oil vane |
| 25% Lobe/Blower |
| 27% Water Ring |
| 9% Turbine |
| 2% Did not know |

Source: UCCE Survey of 1997 of vacuum pump types – Appendix E

ring to lobe/blower and from oil vane to lobe/blower because of the concern for oil being discharged into the environment.

In 1993 tests were conducted on various types of vacuum pumps as selected dairy farms in New York State.  The tests were conducted to measure the efficiency of the vacuum pumps in terms of air delivery [cubic feet per minute (ASME)] per kiloWatt of input power while operated at various vacuum level under farm conditions.  The results of these test are presented in Figure 1-5.

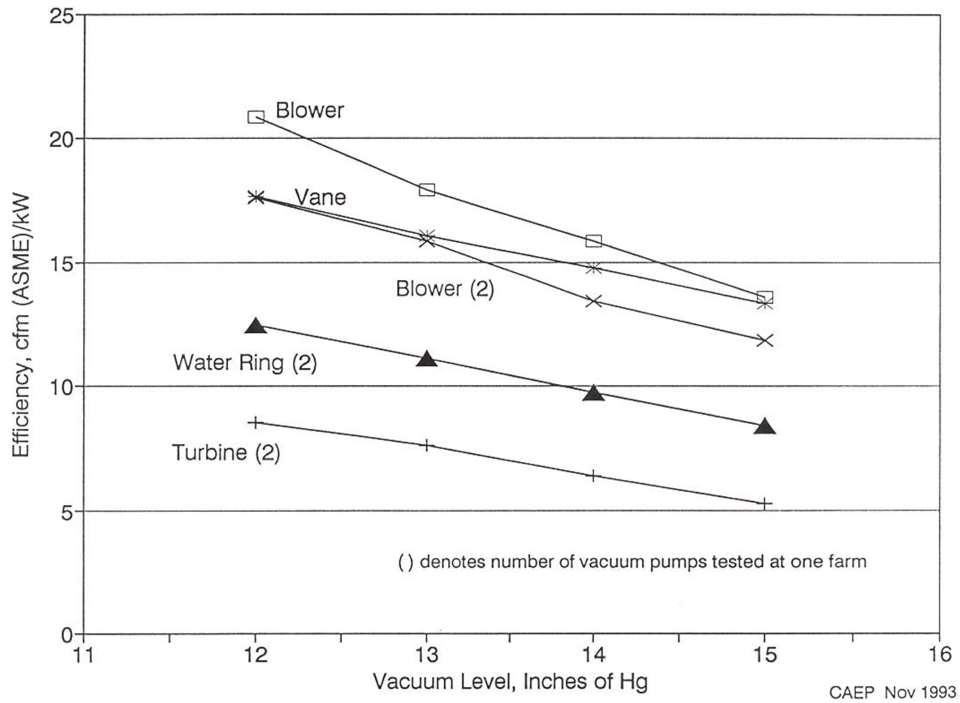



Figure 1-5. A Review of Vacuum Pump Technology (David C. Ludington, Stanley A. Weeks)

The efficiency of all pump types decreases as the vacuum level was increased. This indicates that more efficient operation can be gained by operated at the lowest possible vacuum level at the vacuum pump. This means operating that the lowest vacuum level at the milking unit and minimizing the drop in vacuum between the milking unit and the vacuum pump.

## Vacuum Pump Sizing

Correctly sizing the vacuum pump for the dairy allows the pump to meet the vacuum needs of the milking center during normal operation and washing and control energy operating costs. Current sizing guidelines (ASAE Standard S518.2 Feb03, Milking Machine Installations – Construction and Performance.) recommends the following:

- Basic reserve of 35 cfm
- Incremental allowance of 3 cfm per milking unit
- Additional allowances for ancillary equipment such as milk meters, vacuum operated automatic take-offs, etc.

Providing vacuum pump capacity in excess of this guideline increases capital costs for equipment and life cycle energy operating costs. Oversized vacuum pumps are commonly found in existing installations for a number of reasons. Previous guidelines have specified pump capacities of up to 10 cfm per milking unit. Some current installations are also in excess of this guideline with the belief that the extra vacuum capacity is needed to ensure an adequate wash.

To calculate the required vacuum pump capacity and horsepower, click on the following link: _Calculators

The "*Washing and Water Heating*" section of this guidebook provides instructions for tuning the CIP process for effective cleaning and a vacuum demand that is less than is required to meet the minimum effective reserve for milking.

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## Milk Harvest Energy Utilization Indices (EUIs)

The major energy user in the process of milk harvest is the vacuum pump. Delivery of a continuous stable vacuum supply to each individual milker unit is critical to the milk harvest process.

Conventional vacuum systems relied on vacuum pumps that operated at full capacity and a vacuum regulator to control airflow thru the milking system. Although effective at providing adequate milking vacuum, a large portion of the total vacuum pump capacity is never utilized and is vented to the atmosphere by the regulator.

EUIs for conventional vacuum systems can easily range from 70 to 100 kWh per cow-year and represent a significant portion of total electrical use. The conventional vacuum system offered little if any means of controlling energy use.

Introduction of the variable speed drive (VSD) technology for controlling vacuum in a milking system has allowed for a dramatic reduction in energy use, while still producing equivalent vacuum stability. The VSD is able to adjust the rate of air removal from the milking system, by changing the speed of the vacuum pump motor; to equal the rate air is admitted to the system at a given vacuum level. All of the energy used to move air through the conventional vacuum regulator is saved.

The EUIs achieved by VSD equipped vacuum pumps are reduced to 25 to 50 kWh per cow-year. Energy operating costs are reduced by up to 60 % by running the vacuum pump at reduced speeds.

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# Milk Harvest Energy Conservation Measures (ECMs)

## Efficiency of Vacuum Pump

When purchasing a vacuum pump buy the pump that:

- has the highest relative efficiency (see Figure 1-5),
- that can be driven by a variable frequency drive, and
- do not oversize the vacuum pump.

## Variable Frequency Drive for the Vacuum Pump

(Photo Courtesy of DeLaval)

(Westfalia-Surge)

Figure 1-6. Variable frequency drive and drive installed on vacuum pump

Conventionally, vacuum pumps had operated at constant speed removing air from the milking system at a rate of 7 to 10 cubic feet per minute (cfm) per milking unit primarily to insure good washing. Research in 1982 showed that the actual airflow was below 3.6 cfm/unit 99 percent of the time. The difference between the air removed by the vacuum pump and what actually "leaked" into the system was admitted through a regulator. There was a common misperception that a larger vacuum pump capacity with greater horsepower was necessary to provide stabile vacuum levels and to insure proper cleaning.

Today there is a technology that can reduce the energy used by up to 60 percent. This technology is called a variable frequency drive (VFD). The VFD is electrically installed between the motor on the vacuum pump and the switch that currently controls the motor. A second device that monitors the vacuum level is installed in the vacuum line. This device sends an electrical signal to the VFD that varies with vacuum level. The VFD compares this signal with the set point. As the actual vacuum level differs from the set point, the speed of the motor/vacuum pump is changed to compensate for the change in vacuum level. If the vacuum is too low the motor will go faster and if the vacuum is too high the motor will be slowed. With a VFD, the air removed by the vacuum pump equals the air entering the milking system and there is not need for a conventional regulator.

**Advantages of Using a VFD:**

- Save Energy and Dollars – The system can have a payback of less than 2 years. The savings depend on the hours the vacuum pump operates per day and the amount the vacuum pump is oversized. Energy saving can be estimated by the following:

  Annual savings (kWh) = [Horsepower of present vacuum pump – 0.25 x no. of milking units] x 0.9 x Hours of operation per day x 365

- Noise Reduction - The noise level can be reduced by many decibels.

- Vacuum Pump Lasts Longer. The reduced RPMs of the vacuum pump reduces wear.

- Stable Vacuum - With good design and proper installation, vacuum stability can be better than with a conventional regulator.

Figure 1-7. VFD vacuum pumps on California dairy

To calculate estimated annual savings of VSD on a vacuum pump, click on the following link: Calculators

## Applications

Additional factors to consider for VFD application on the following types of vacuum pumps.

### Sliding Vane Rotary Pump

The rotary vane pump is one of the most efficient vacuum pumps in use. Most vane pumps work well on variable frequency drive - vacuum regulation with minimal efficiency loss at reduced speeds. Some vane pumps begin to rattle at low speeds because reduced centrifugal force is not strong enough to hold the vanes firmly against the pump housing. Some vanes may actually move away from the housing and then move back producing a rattle. Some vane pumps have springs in the rotor that force the vanes out against the housing. These pump can be operated at a lower rpm without the rattle.

Special attention should be directed to the oiling system on the vane pump. Failure of an oiling jet can cause rapid failure of the pump. Oil discharge from the exhaust is one of the biggest drawbacks to the vane pump. Oil reclaimers minimize the amount of oil discharged but some oil vapors are still emitted. This oil vapor tends to condense and precipitate out of the air stream after it has exited the exhaust system, causing an oil film to form in the vicinity of the discharge. Water vapor is also present in the exhaust air. Oil reclaimers tend to condense and accumulate this water. Oil reclaimers need to be drained of water regularly. The application of a variable speed vacuum regulator greatly improves the effectiveness of the oil reclaimer and virtually eliminates the oily residue in the vicinity of the discharge. The variable speed vacuum regulator also greatly increase the amount of water accumulated by the oil reclaimer.

When a vane pump is plumbed to a system as a backup to a main pump, extreme care should be taken that no vacuum from the system and the main pump feeds back to the vane backup pump. Vacuum applied to a vane pump while it is not running will cause the oiling system to fill the pump with oil. A vane pump so filled will not start or run should it ever be needed. Most slide type isolation valves leak too much air to prevent the pump from filling with oil. A vent should be installed between the slide valve and the vane pump to vent any air leakage past the slide valve. Care should be taken that gravity will not fill the pump with oil either.

### Rotary Lobe Type Pump

The rotary lobe pump is also a very efficient vacuum pump that works very well with variable frequency vacuum regulation. The efficiency of the rotary lobe pump tends to decrease slightly faster at lower speeds than vane pumps. This is because the amount of slip air through the close tolerances of the pump stays the same as the delivered air decreases.

A 10 hp rotary lobe pump tested on a dynamometer required 2 hp input power to develop 4 cfm at 14 inches of mercury. Since the discharge air is free from oil, heat recovery can be installed to reclaim heat from the discharge air. This reclaimed heat can be used to preheat water or it can be used for space heating.

### Water Ring Vacuum Pumps

The centrifugal nature of the ring of water limits the ability of the water ring pump to operate with a variable speed regulator. Once the centrifugal force is insufficient to overcome the vacuum, the water ring distorts. This distorted ring can cause very high torque requirements and overloaded motors, as water must be squeezed out of the rotor where the ring is too thick.

The water ring pump also has a lower efficiency than the vane or rotary lobe pumps. The capacity and efficiency of the water ring pump varies with the supply water temperature and therefore can exhibit wide performance fluctuations throughout the year. The low efficiency and inability to operate with a variable speed vacuum regulator severely limits the opportunity for energy conservation with water ring pumps.

### Turbine Vacuum Pumps

The turbine vacuum pump is the only one currently in use that is not a positive displacement pump. The turbine operates like a centrifugal pump or fan by using the mass and momentum of the air to create a vacuum. Turbine vacuum pumps feature a high temperature discharge that is free of oil. The turbine pump is the least efficient with an efficiency about half that for a vane or rotary lobe pump.

Energy conservation measures with a turbine pump are limited to recovering waste heat for water or space heating. The low efficiency has deterred attempts to apply a variable speed vacuum regulator to the turbine pump. There is a real concern that the high slip of a centrifugal pump will cause rapid overheating if the turbine pump is operated at a reduced speed.

## Regulator Location and Efficiency on Conventional Vacuum Systems

Conventional vacuum systems incorporate a vacuum pump operating at a fixed speed/airflow, a vacuum regulator and a load. The load consists of the air admitted by the components that make up the milking system including milking units, pulsators, claws, other device that admits air during operation and air leaks. To maintain a set vacuum level, the vacuum pump must remove air from the milking system at the same rate as air is being admitted

Since the air admitted is dynamic and the pump out rate is constant, a vacuum regulator is necessary to admit the difference between the pump capacity and the air load. The typical vacuum regulator is a mechanical device that adjusts the rate of air admission into the system. The vacuum regulator provides airflow into the system so that the sum of the air admitted by the milking system plus the air admitted through the regulator exactly matches the fixed airflow at the vacuum pump.

When the air load is low, the regulator must admit nearly the entire pump capacity. When the load increases the regulator must close and admit less air. The difference in vacuum level that occurs between the regulator in the fully open - full flow state and fully closed state will be greater than zero. This is an inherent attribute of mechanical vacuum regulators. The National Mastitis Council (NMC) has established that a vacuum drop of 0.6 inches of mercury below the stable vacuum level is acceptable to allow the regulator to close.

To illustrate this, consider the following example. A water tank that has a constant out flow with a float controlled input valve to maintain the water level in the tank. When the water out flow is increased to a new gpm, the level of water in the tank will decrease. Lowering the float and further opening the input valve. The new level of water in the tank will be that point where the float valve is opened far enough to again balance the outflow. This new level will be lower than the original level because of the interval that occurs between opening of the input valve and establishing new outflow.

Regulator efficiency, as determined by the NMC test, measures how close to fully closed the regulator is by the time the vacuum level drops to 0.6 inches of mercury below the set point. Regulators that fully close and admit no air before the vacuum level drops to 0.6 inches of mercury below the set point are considered 100% efficient. Regulators that have not fully closed at 0.6 inches of mercury below the set point are less than 100% efficient. Regulator efficiency is determined by measuring the system airflow reserve at 0.6 inches of mercury below the set point with the regulator operating (Effective Reserve) and dividing this by the system airflow reserve at 0.6 inches of mercury below the set point with the regulator forced closed (Manual Reserve).

The location of the vacuum regulator has a significant impact on the regulator efficiency and subsequently, the vacuum system efficiency. It has been common practice to locate the regulator away from the receiver to minimize the noise in the milking parlor and to allow the regulator to draw cleaner air that is freer of cow hair and dirt.

Installing the regulator in locations away from the receiver introduce losses that decrease efficiency. Frictional head loss is the reduction of vacuum level due to the friction of the airflow within the pipe. Frictional head loss increases both with increased airflow and with increasing resistance of the pipe. Long lengths of small diameter pipe with many elbows and other fittings will have much higher resistance to airflow than a short length of large diameter pipe with no fittings. Frictional head loss between the regulator and the receiver causes the vacuum level at the receiver to be lower than the vacuum level at the regulator.

During periods of low airflow at the receiver, such as normal milking or group changes, there is little airflow between the receiver and the regulator. This low airflow causes minimal vacuum drop between the regulator and the receiver. In contrast, during periods of high airflow at the receiver, such as unit attachment or unit fall off, there is a large airflow between the receiver and the regulator. This high airflow causes a larger vacuum drop between the regulator and the receiver.

The vacuum difference between the regulator and the receiver is then dependent on how much air is flowing through the receiver. A regulator that requires 0.6 inches of mercury below the set point to close fully will only achieve 100% regulator efficiency when the vacuum level is the same at the receiver as is at the regulator.

Consider what would happen to this regulator if there were a vacuum drop between the regulator and the receiver of 0.2 inches of mercury during peak airflow. By the time the regulator has dropped 0.4 inches below set point, the receiver has dropped the full 0.6 inches. The regulator will still be admitting air to the system even though the receiver vacuum drop exceeds the 0.6 inches of mercury standard. To improve the efficiency of the regulator it is necessary to reduce frictional head loss between the regulator and receiver. This is best accomplished by locating the regulator as close to the receiver as possible, thereby minimizing the resistance of the pipe between the regulator and receiver.

In addition to improving the vacuum regulation at the receiver, improving the regulator efficiency also has a substantial energy saving potential. Minimum standards for effective reserve are directed towards ensuring that the load (air flow) never, or very rarely exceeds the vacuum pump capacity. Systems with low regulator efficiencies require more pump capacity to achieve the minimum effective reserve standard. A 20 hp pump operating with a 95% efficient regulator will have a higher effective reserve than a 30 hp pump with a 60% efficient regulator. High regulator efficiencies indicate the effective reserve and manual reserve are very close, and high volumes of air are not being introduced at the regulator and pumped through the system.

Relocation of the vacuum regulator to provide better regulator efficiencies can allow belt sheave ratios to be reduced to slow the pump down and lighten the load on the motor and save energy. A smaller vacuum pump and motor could also be used if conditions allow.

Improving regulator efficiency has the potential to save considerable money. Dairies pay for manual reserve in energy costs, oversized pumps, larger air lines and greater installation costs. The return from that investment is the effective reserve. It is therefore highly desirable to keep the effective reserve as close to the manual reserve as possible. This can only be accomplished with high regulator efficiency.

## Variable Speed Vacuum Regulation

As was noted in the previous section, it is necessary for the air inflow rate of the vacuum system to exactly match the pump out rate of the vacuum pump in order to maintain the desired vacuum level. When a pump operates at fixed speed and flow rate, this balancing of the inflow and pump out rate is accomplished by a vacuum regulator.

An alternative method of balancing the inflow rate with the pump out rate is to regulate the speed of the vacuum pump. So that the pump out rate exactly matches the vacuum load inflow rate. This control method eliminates the need to admit extra air through a regulator.

The energy savings attainable by implementing a variable frequency drive “vacuum regulator” are significant. Reducing the pump out rate by 50% reduces energy consumed by 50%. A typical milking system averages approximately ¼ hp of vacuum demand for each milking unit. Using the current pump-sizing standard of 35 cfm plus 3 cfm per milking unit to assure adequate reserve results in potential energy savings of 30 to 50%.

Consider the following example for a double 24-milking parlor. The pump size at 35 cfm plus 3 cfm per unit results in a 179 cfm pump. At 10 cfm per hp the smallest pump for this parlor would be 20 hp. During operation the average vacuum demand of this parlor would be equivalent to 12 hp or 120cfm.

A conventional system with a vacuum regulator would supply 120 cfm of air to operate the milker system by having the regulator admit 80 cfm of air to balance the pump capacity of 200 cfm.  By applying a variable speed "vacuum regulator", the average electrical demand and energy use for this parlor would be equivalent to 12 hp for a 40% savings.  Older standards required even more vacuum capacity and systems with 10 cfm per milking unit are commonly found on older parlors.  Energy savings on these older systems can be as high as 80%.

Variable speed drive "vacuum regulators" consist of a sensing element, a controller, and a variable frequency motor drive.  The sensing element is an electronic vacuum transducer that converts the vacuum signal into an electrical signal for processing by the controller. The controller is a microprocessor-based computer that monitors the vacuum level signal from the transducer and determines the appropriate speed to operate the vacuum pump in order to maintain the desired vacuum level.  The controller contains the operator interface where vacuum level settings and tuning parameters are adjusted.

The variable frequency motor drive is a device that converts standard line voltage at 60 Hz to a variable frequency and variable voltage output to drive a 3 phase induction motor.  By reducing the frequency and voltage supplied to the motor, the speed and the power consumed by the motor will be reduced.  For a vacuum system, a motor running on a 30 Hz supply will run at half its rated speed and will consume half of the normal energy.  For more information on variable frequency drives see the VFD section of this guidebook.

As with conventional, mechanical regulators, placement of the sensing element of a variable speed regulator is very important.  The sensing element of a variable speed regulator consists of an electronic vacuum transducer and any plumbing needed to connect the transducer to the vacuum system near the receiver.  The sensing element should be located as close to the receiver as possible noting the following limitations:

- Vacuum lines carrying air away from the receiver typically get contaminated with water, CIP residue, milk foam, and other contaminants.  These contaminants may affect the sensing element and reduce the sensitivity of the vacuum regulator. Residue of CIP agents and milk can form a crust on the diaphragm of the transducer, permanently reducing the sensitivity and accuracy of the transducer.

  It is therefore recommended that the transducer be located a short distance from the vacuum line with a sensing tube from the transducer to the vacuum line.  This sensing tube should automatically drain any contaminants that may enter.  There should be no sags or other liquid traps that would inhibit the draining of the tube.

  For short distances (less than 10 feet) a ¼ inch vacuum hose is adequate for connecting the transducer to the vacuum line.  For distances over 10 feet, ¾ inch pipe is recommended.  PVC pipe works well for this sensing tube.  A short ¼ inch vacuum hose connects the transducer to this sensing pipe.  All points in this sensing tube must slope downwards towards an automatic drain, or back into the vacuum line.

- High velocity air in the vicinity of the sensing element interface causes turbulence that can cause small errors in the vacuum readings at the transducer. Any protuberance into the airline causes turbulence. To minimize this turbulence, insert hose barbs or pipe adapters into the main airline as shallow as possible and square to the main airline wall. Angled or very deep set fittings cause higher turbulence at the end of the fitting and will result in vacuum reading errors, particularly at high airflows.

  For milking systems with two receivers, the main air lines that supply each receiver should be bridged together with the same size pipe as the main air lines. The sensing point should then be inserted in the center of this bridge line. This line will experience much lower air velocities and will provide a very accurate and responsive vacuum reading at the transducer.

The electronic control of a variable speed vacuum regulator does not require that the vacuum level drop in order to achieve full capacity. Therefore the regulator efficiency of a variable speed system should not be less than 100%. The electronic controller maintains the vacuum level exactly at set point until the pump is running full speed. A variable speed vacuum control is capable of regulating vacuum level more precisely than a top quality mechanical regulator.

High-speed acceleration and deceleration along with proper tuning assure that transient demand fluctuations are quickly corrected for during the milking phase. Due to these high speed acceleration and deceleration capabilities, the electronic controller of a variable speed regulator should allow the vacuum pump to respond to fluctuations more slowly during the washing. Thereby minimizing stress on the pump, motor, belts, and VFD transistors during air injected CIP cleaning when large vacuum demand fluctuations are normal.

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## Operator Level Checks – Milk Harvest

### **Vacuum System**

Vacuum Level

1. Check vacuum level with a quality gauge that is independent of any variable speed vacuum sensor. This gauge should be permanently mounted near the receiver or should be easily connected to a test port near the receiver. Gauges permanently installed can suffer shortened life from contamination by moisture and residue carry over from the receiver and trap. Use of a test port valve to isolate the gauge except during periodic vacuum level checks will reduce this contamination.

2. Vacuum levels that have drifted from desired value cause performance changes, efficiency changes, and herd health changes.

   - High vacuum levels cause injury to cow, higher air flow, higher power requirements by the vacuum pump, and reduced vacuum pump capacity.

   - Low vacuum levels cause slow milk out and can cause health problems if there is inadequate collapsing of the liner during the rest phase of pulsation.

Variable Speed Vacuum Pump Operating Speed

1. Motor running faster than normal.
   - Check for leaks; i.e. cracked pipes, joints, split liners, leaking gaskets on filter, trap, receiver, milk line.
   - Check for loose pump belts. This requires higher motor speed to reach the same pump speed.
   - Check system vacuum level. High system vacuum will cause higher pump speed.

2. Motor running slower than normal.

   - This can cause performance problems if the cause of the low pump speed is plugged air vents or malfunctioning pulsators.
   - Check system vacuum level. Low system vacuum will cause lower pump speed.

3. Motor speed is erratic.

   - Variable speed vacuum sensor fouled or sensor line plugged or leaking.
   - Split liner, cracked or disconnected pulsator tube, or faulty pulsator admitting excessive air in cycles.

Vacuum Pump Temperature

1. The vacuum pump temperature should be measured near the end of milking using an infrared thermometer or adhesive temperature strip.

2. Small changes in end of milking temperature are normal when the ambient air temperature changes.

3. A significant temperature rise usually indicates that service is required.

   - Check the system vacuum. Higher vacuum levels will cause higher pump temperatures.
   - Check for exhaust restrictions. A restricted exhaust will cause higher pump temperatures.
   - For rotary vane pumps, check that the oiling system is functioning properly.
   - For lobe blower pumps, high temperatures can indicate a lubrication problem or that the pump needs cleaning.

Vacuum Pump Motor Temperature

1. The vacuum pump motor temperature should be measured near the end of milking using an infrared thermometer or adhesive temperature strip.

2. High motor temperatures can indicate a high load on the motor or a problem with the supply voltage to the motor.

   - The causes of high pump temperature will likely cause a rise in motor temperature as well.
   - Imbalanced or low line voltage and imbalanced motor currents will cause a rise in motor temperature without a rise in pump temperature.

## Cleaning Rotary Lobe Vacuum Pumps

Rotary lobe pumps accumulate residue from milk foam and wash chemicals on the rotors during normal operation. This accumulation must be removed periodically to maintain the tolerances in the pump. Pumps that have not been cleaned as required run hot and require more input power because of the friction of this accumulation.

Rotary lobe pumps are cleaned by introducing soap and water to the inlet of the pump while the pump is running. Care should be taken to prevent a slug of water from entering the pump as this can destroy the pump. Allow the pump to run for a while after washing to dry the rotors. Some milking equipment companies have introduced automatic controls to automatically wash the pump on a regular basis.

**Other subcomponents in the milking system include:**

- Pulsation system
- Milking units
- Automatic detachers
- Milk transfer pumps
- Milk meters
- Vacuum, milk, wash and pulsation lines
- Vacuum regulators and controllers
- Backflush systems
- Numerous configurations of milking stalls (herringbone, parallel, flat barns, swing, tandem, and rotary parlors).

These components are low energy users compared to the vacuum pump. However, proper operation of these components is critical to the success of milk harvest.

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## Glossary of Milk Harvest Terms

**Air Injector:** A device that allows the controlled, cyclic admission of air during cleaning and sanitizing to produce slug flow conditions.

**Clean-in-Place (CIP):** The capacity to clean the milking system by circulating appropriate solutions through it without disassembly.

**Distribution Tank**: An air vessel or chamber, in the main airline between the vacuum pump or interceptor and the sanitary trap, which acts as a manifold for other pipelines.

**Effective Reserve:** Air flow rate, measured with all teatcups plugged and operating, that can be admitted at or near the receiver in pipeline milking machines to induce a vacuum drop of 0.6" of Hg below the working vacuum level in the receiver. An indication of the reserve pump capacity actually available to maintain system vacuum when extra air is admitted. (Based on the assumption that a vacuum drop of 0.6" has little or no effect on milking performance and that I sufficient to allow the regulator to close

**Manual Reserve**: The air flow rate measured at the same position and conditions as for effective reserve except that the regulator is disabled. This is the reserve pump capacity available, if the regulator could close completely at 0.6"below the working vacuum level, to maintain the system vacuum when extra air is admitted through units during milking.

**Milkline:** A pipeline which carries milk and air during milking and has the dual function of providing milking vacuum and conveying milk to a receiver.

**Milk Meter:** A device between the cluster and milkline for measuring a cow's milk yields in either mass or volume.

**Pulsator:** A device for producing cyclic pressure changes.

**Pulsator airline:** The vacuum line connecting the main airline to the pulsators.

**Pulsator Controller:** A mechanism to operate pulsators, either integral with a single Pulsator (self-contained Pulsator) or system controlling several pulsators.

**Receiver:** A collecting vessel under vacuum that receives milk from one or more milklines or milk transfer lines and feeds the receiver milk pump.

**Receiver Milk Pump:** A pump for removing milk under vacuum in the receiver, moving the milk through filters and inline cooling systems, and discharging to atmospheric pressure in a storage tank, refrigerated or non-refrigerated.

**Regulator:** An automatic valve designed to maintain a steady vacuum in a milking system.

**Regulator Efficiency:** The effective reserve expressed as a % of the manual reserve (ER/MR). Should be maintained at 90% and above.

**Sanitary Trap:** The vessel between the milk system and the air system to prevent movement of liquid from one to the other.

**Vacuum Pump:** An air pump which produces vacuum in the system.

**Variable Frequency Drive:** VFD is a device that is installed on the motor of the vacuum pump. The VFD controls the motor/pump speed to maintain a vacuum level set point. As vacuum level differs from the set point, the speed of the motor/pump is changed to compensate for the change in vacuum level. With a VFD, air removed by the pump equals the air entering the milking system, and the vacuum regulator is eliminated. Energy savings are realized by not moving air thru the system that was admitted by the vacuum regulator.

**Wash Pipeline**: A pipeline which, during the CIP process, carries cleaning and disinfectant solutions from the wash sink to the milkline. The wash pipeline is not usually in use during milking.

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  Bou-Matic – www.Bou-Matic.com

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- The Coburn Company, Inc. – www.coburnco.com

- BECO Dairy Automation Inc. - www.becoknows.com

- The Schlueter Company - www.schlueterco.com

- Paul Mueller Company – www.muel.com

- Ross-Holm, Inc – www.ross-holm.com

- Etron – 1401 Peruville Road, Freeville, NY 13068;
  Ph: 607-898-3553

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