Milking parlor evaluation – How to get started with assessments

Patrick J. Gorden, DVM, PhD, DABVP, DACVCP

Veterinary Diagnostic and Production Animal Medicine

Iowa State University College of Veterinary Medicine

Ames, IA 50011

Abstract

Dairy farmers have been utilizing machine milking to collect milk from cows for almost 200 years. Despite the long and storied history of machine milking, the milking machine plays an important role in the maintenance of quality milk production. As veterinarians, we are skilled in physiology and bacteriology but have little understanding of milk machine function. Veterinarians can expand their service offerings to improve milk quality by systematically evaluating machine function and understanding the impacts of recommended changes. Machine milking aims to help maintain good milk quality by creating an environment that removes milk in a clean, gentle, and complete manner. This environment is created by coupling machine settings with milking liners and the activities of milk harvest technicians to minimize overmilking of cows, as overmilking leads to unwanted changes in teats. However, evaluating milking equipment without assessing milk harvest technician activity, the cows and their environment, and overall farm management will often fail to lead to improvements in milk quality.

Keywords: milk equipment evaluation, claw vacuum, milk quality

Introduction

It has been known for centuries that milk from cows and other ruminants provides a significant nutritional resource. As population growth occurred throughout the world during the early 1800s, there were continuous attempts to make milk collection more efficient. Early attempts included locating farms near population centers. Labor was cheap and plentiful during these times, so mechanization was not considered practical. It was only when the countries of Australia and New Zealand became territories that the mechanization of the milking process began. In the early 1800s, simple cannulas placed into teats to drain milk into attached buckets were the first devices to mechanize milking. The power for such devices was provided by gravity and intra-mammary pressure. The first patent was applied for in 1836 by Burton. This technology was fraught with problems, especially the transfer of mastitis pathogens from cow to cow.[3]

Commercial manufacturing of double action milking units began in 1917 by Delaval, who introduced the Delaval Bucket Milking Machine, and Babson Bros., who manufactured the first Surge milker later that year. These units remained in production for over a quarter of a century and were used by about one-half of the dairy farmers in the United States who had machine milkers. Through the 1950's there was continued slow improvement of milking systems. Although most of the milking was still done utilizing bucket milkers, single and double parlors that milked cows directly into pipelines began to emerge. In 1930, the first rotary milking parlor appeared in the United States. Also, in 1930, Delaval introduced electronics with the release of the electromagnetic pulsator. This pulsator was utilized through the 1950s with great success until more sophisticated models replaced it. Since then, electronics have been incorporated into every milking and milking management aspect. Methods for evaluating milking system performance began to appear in the 1950s, along with improved methods for cleaning milking systems.[3]

This article aims to lay the foundation for understanding modern milking systems and how individuals should systematically assess these milking systems. There is a lot of individualization in evaluation processes and opinions on equipment function. Machine milking aims to help maintain good milk quality by creating an environment that removes milk in a clean, gentle, and complete manner. Therefore, it must be emphasized that when making recommendations, one should prioritize their findings from improvements that will improve milk quality on the farm to cosmetic enhancements.

<u>Guidelines for System Design and Evaluation of Milking Systems</u>

The American Society of Agricultural and Biological Engineers (ASABE) and the International Standards Organization (ISO) publish standards for the design and testing of milking systems. The following documents from ASABE relating to milking system design and testing are available on the ASABE website at www.asabe.org:

ASAE S300.4 – Milking Machine Installations – Vocabulary, Re-affirmed February 2008.

ASAE EP445.1 – Test Equipment and Its Application for Measuring Milking Machine Operating Characteristics, Re-affirmed February 2008.

ASAE S518.2 – Milking Machine Installations – Construction and Performance, Re-affirmed February 2008.

ISO documents can be ordered from the ISO website at www.iso.org. The following records relating to milking system design and testing are available:

ISO 5707:2007 – Milking Machine Installations – Construction and Performance.

ISO 6690:2007 – Milking Machine Installations – Mechanical Tests.

The National Mastitis Council (NMC) publishes <u>Procedures for Evaluating Vacuum Levels and Air Flow in Milking Systems</u>, which are guidelines for evaluating milking systems that incorporate the requirements from the engineering documents into a stepwise equipment evaluation procedure. This document is available from the organization's website (www.nmconline.org). It should be noted that NMC is not a standards-setting organization, so these documents must be utilized only as guidelines for evaluating milking system performance. When developing the post-evaluation report, one must be careful not to assert that the standards come from NMC but instead from the proper standards-setting organization.

Components of the Modern Milking Machine

To properly evaluate a milking system, the evaluator needs to know the essential components of a milking system and understand how a milking machine functions. There are many types of milking systems, from portable units that milk a few cows to very large parlors that milk 24 hours per day. No matter the size, all systems have the same essential components (Figure 1).

- A vacuum pump is a specialized air compressor that pulls the air source from the vacuum lines of the milking system and continuously expels it into the atmosphere.
- A means to control the vacuum level.
- A system of airlines and milk lines is closed except for the milking units and the regulator (if present) that moves air (vacuum) and milk away from the cow. There must be a means to separate the milk from the air inside the vacuum system and allow the milk to be exposed to a positive pressure system to move the milk to the storage tank. The receiver group usually accomplishes this, but in a bucket system, the floor pail acts as a storage vessel to separate the milk from the air.
- At least one milking unit to remove milk from the udder.
- A pulsation system to move the liner within the teacups.
- A system for cleaning and sanitizing the milking equipment between subsequent milkings.
- Some systems may have additional equipment, such as automatic detachers, meter systems for measuring milk production and parlor throughput, and pulsation monitoring systems.

Vacuum Pumps

Vacuum pumps compress air approximately 2 to 1 to provide the necessary energy (vacuum) to move air, clean chemicals, and milk (in systems that require the lifting of milk). Vacuum pumps range from 5 to 400 cubic feet/min (cfm) with horsepower requirements of 1 to 40 hp depending on the installation size. The sizing of the vacuum pump and the motor depends on the size of the milking system and the additional components that may be added (milk sweeps, air-lubricated regulators, etc.). In general, milk pumps and motors should be chosen to produce 35 cfm (1000 L/min) of adequate reserve plus 3 cfm (85 L/min) per milking unit for component (pulsators, milking unit, etc) air usage and to account for air leakage in the system and through the regulator. Therefore, a double twelve milking parlor should have a vacuum pump that will produce 107 cfm (35 cfm + (24 units * 3 cfm/unit)) or 3040 L/min (1000 L/min + (85 L/min * 24)).

As a rule of thumb, the vacuum output of a pump at 15” vacuum can be determined by multiplying the motor's horsepower by 7.5 – 10, depending on the pump type.

<u>Vacuum Regulation</u>

Milking systems are designed to maintain a stable vacuum within the milking claw. Of course, the air needs of the system will fluctuate depending on various activities, i.e., unit attachment, unit falloffs, milking, etc. Therefore, a system of vacuum regulation must be in place to maintain stable vacuum. There are two methods for preserving vacuum levels: a vacuum regulator and a variable frequency drive (VFD).

An installation with a vacuum regulator requires that the vacuum pump run at full speed (usually 60 hertz). Almost all vacuum regulators installed today are servo or air-operated. Servo-operated regulators are remote sensing, while air-operated regulators sense the vacuum inside the regulator. Both units do an excellent job of vacuum regulation, provided they are correctly installed and maintained. Proper installation requires that the regulator be placed on large enough pipes and installed as close to the sanitary trap(s) as possible.

The vacuum regulator maintains a stable vacuum by allowing more or less air into the milking system in response to vacuum changes. If there is a drop in vacuum in the system, the regulator senses the drop and responds by closing down, allowing less air into the system. If there is an increase in vacuum, the regulator will open more to allow more air to enter the system, thus causing the vacuum to drop. These regulators are designed to have a response time of 50 milliseconds if they function correctly.

A VFD method for controlling the vacuum level is accomplished by running the vacuum pump at different speeds depending on vacuum needs. The VFD is a tiny microprocessor that senses vacuum change and sends a signal to the vacuum pump to adjust the speed of the motor. When the vacuum is steady, the pump will run at a low frequency (i.e., 25 - 35 hertz). As the vacuum level drops, the VFD sensor recognizes the vacuum drop and sends a signal to the VFD to increase the pump frequency, thus producing more vacuum. As the vacuum need decreases, the pump will slow down to prevent the vacuum level from overshooting. VFDs are utilized as a method to save energy.

<u>Receiver Group</u>

The receiver group includes the receiver, sanitary trap, milk pump, and control panel. When milk enters the milk line, it should travel simultaneously with air in a laminar pattern. The milk line and receiver should be designed to flow slug-free along the bottom of the pipeline for at least 95% of the milking time.[3] The milk line shall have a continuous slope of at least 0.8% (1 in./10 feet). Milk lines can be installed in either a high-line or low-line configuration. In the high line configuration, the milk line is installed above the milking unit, and in a low line, the milk line is installed below the milking unit (see Figure 2). In a highline system, vacuum creates a slug of milk to raise the milk to the milk line from the milking unit. Therefore, milk is moved to the milk line by moving alternating milk slugs followed by air slugs. In a low-line system, energy for milk transport is provided by gravity. In low and high-line installations, once milk enters the pipeline, it should travel simultaneously with air in a laminar pattern. In high-line systems, the system vacuum must be adjusted for the vacuum needed to raise milk to the milk line. Most high-line systems have vacuum levels set approximately 1-3" higher than low-line ones.

The receiver is where air and milk, which have been traveling together until now, separate. Milk will travel to the milk storage area from this point via power supplied by the milk pump. A probe in the receiver activates the milk pump when the milk level in the receiver reaches a specified point. If milk passes through a plate cooler or chiller, the milk pump may have a variable speed motor to keep a steady milk flow through the cooling device.

Milking Unit

The milking unit is made up of stainless steel or durable plastic. The milking unit is attached to the milk line by a hose of a similar diameter as the claw outlet. Most of today's claws have a minimum outlet of 5/8", with some as large as 7/8".

All claws need some form of claw vent, found either in the claw itself or the individual liners. The vent helps assist the draining of the claw by reducing the hydrostatic head within the claw. These vents are large enough to allow 0.25-0.5 cfm of free air into the claw.

The teacups are made up of a rigid outer shell in which milking liners are installed. Milking liners are the only portion of the milk machine that comes in contact with the cow. There are several hundred different liners on the market owing to the considerable disagreement amongst dairymen regarding which are the best liners to milk cows properly. Liners are made of either natural, synthetic, or silicone rubber. There are also differences in mouthpiece opening, length, liner thickness, ability to re-tension, single or two-piece construction, and shape. Liner shapes are round, triangle, or square. Liners collapse around the teat depending upon the liner shape. Both round and square liners collapse against the teat at two points, even though the square liner has four long sides. The triangle liner collapses in three points against the teat skin. During milking, a continuous vacuum is present within the claw and liners to remove milk from the claw. It is essential to realize that the teat end is constantly exposed to vacuum, even when the liner is closed.

Pulsation Control

The pulsation system controls the actual process of milking the cow. The pulsator is an air valve that alternates the flow of vacuum and atmospheric air into the pulsation chamber between the liner shell and the liner. As vacuum is introduced into the pulsation chamber, the vacuum level reaches a level higher than inside the liner barrel, causing the liner to open. This allows milk flow to occur due to the difference in pressure in the teat compared to the airspace below the teat. As atmospheric air is introduced into the pulsation chamber, the liner collapses around the teat end to massage out the congestion (edema) that has collected during the milking process. Note that the liner only collapses around the teat end (see Figures 3 and 4). Thus, liner closing only mediates congestion within the teat end, not the entire teat.

Pulsators can be set to pulsate all four quarters simultaneously, called simultaneous pulsation or alternating. With alternating pulsation, two liners are opened while the other two are closed, and vice versa (see Figure 3). The alternating pattern can be either front to back or side to side. The pulsation cycle is divided into four phases, representing one complete liner opening and closing. The A Phase is when the vacuum is being moved through the pulsation lines into the chamber, causing the liner to open. The B Phase is when the liner is completely open (see the left side of Figure 4). The C Phase is when the vacuum is removed from the pulsation chamber and replaced by air, causing the liner to close. The D Phase is the closed phase when the liner is in contact with the teat end to massage the edema out of the teat end (see the right side of Figure 4).

The pulsator function is defined by its rate, ratio, and proportions of the cycle with each phase. The pulsator rate is the number of complete cycles that occur per minute. The pulsator ratio is the proportion of the cycle for which the liner is opening or open (A & B Phases) versus the proportion for which it is closing or closed (C & D Phases). Pulsator rate and ratios vary from farm to farm, but most farms use a rate of 45 – 65 beats per minute and ratios from 50:50 to 70:30 milk to rest ratio. The ASABE guidelines state that pulsators must provide at least 30% in the B phase (milking phase) and not less than 15% and 150 milliseconds (ms) in the D phase (massage phase).[2]

Figure 5 displays a pulsation graph from a vacuum recorder used to evaluate pulsator function on-farm. The graph shows that the pulsator rate is approximately 60 beats per minute, and the ratio is approximately 60:40. The B Phase has a minimum of 40% (390 ms). The D phase has a minimum of 27% (272 ms) of the pulsator cycle.

The air supply to each pulsator may be drawn directly into the pulsator from the atmosphere or through a filtered air system. The filtered air system prevents the pulsators from fouling due to dirt accumulation within the working areas of the pulsator.

<u>Automatic Cluster Removal</u>

To increase labor efficiency and provide more consistent milking of cows from milking to milking, many dairy farms have installed Automatic Cluster Removers (ACRs). ACRs utilize a retractable arm or cord to remove the milking unit from the udder once the vacuum has ceased. The end of milking is determined with either a milk meter that senses milk flow per minute or a sensor that uses conductivity or optical density to determine when milk flow drops below a set threshold.

Most ACRs come with a default setting from the factory of ~0.8 lbs./min. In addition, they also have a delay setting, which is the time between when the sensors determine that the end of the milking flow rate has been reached and when the milking unit is removed. Most milk quality consultants feel ACRs should be adjusted with an end-of-milking endpoint set at 2 lbs./min or higher and a delay time set as low as possible.

ACRs have a letdown delay usually set between 90-180 seconds. The letdown delay prevents the ACR from prematurely removing the milking unit due to delayed milk letdown after the milking unit is attached to the udder. On farms with good pre-milking stimulation, 90 seconds is usually sufficient for milk letdown to occur. On farms milking cows 4-6 times per day in early lactation, the letdown delay may need to be adjusted to prevent overmilking of these cows.

Conclusion

Development of milk equipment analysis to expand your practice can initially be daunting. However, individuals need to realize that no matter how large or complex the milking system is, the basic components of all systems are just multiples of the basic units. Applying NMC's Procedures for Evaluating Vacuum Levels and Air Flow in Milking Systems systematically and understanding the influences of your recommendations on milking unit performance and impacts on the cow will lead to successful improvement in parlor performance. Additionally, it must be remembered that milking equipment is only one contributor to overall milk quality on a dairy. So, evaluating milking equipment without assessing milk harvest technician activity, the cows and their environment, and overall farm management will often fail to lead to improvements in milk quality.

References

1. ASAE EP445.1 Test Equipment and Its Application for Measuring Milking Machine Operating Characteristics, July 1996, Published by American Society of Agricultural and Biological Engineers, St Joseph, MO, Available at www.asabe.org.
2. ASAE S518.2 Milking Machine Installations – Construction and Performance, July 1996, Published by American Society of Agricultural and Biological Engineers, St Joseph, MO, Available at www.asabe.org.
3. Bramely, AJ, FH Dodd, GA Mein, and JA Bramley Editors, Machine Milking and Lactation, Insight Books, 1992.
4. Delaval website, www.delaval.com.
5. Reinemann, DJ, PL Ruegg, N Schuring, Introduction to Milking Systems, UW-Madison Short Course, 2000.
6. Reinemann, DJ, The History of Vacuum Regulation Technology, NMC Annual Meeting Proceedings, 2005, 124-132.

Figure 1 - Diagram of the basic milking system adopted from Reinemann[6]

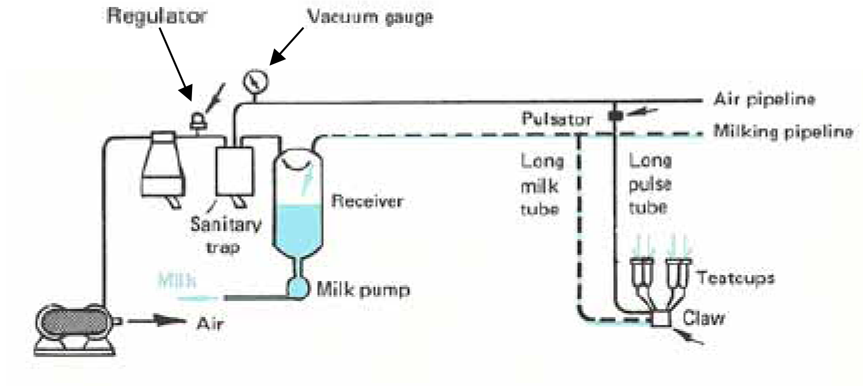

Figure 2 – Diagram of high and low line milk line installations.[1]

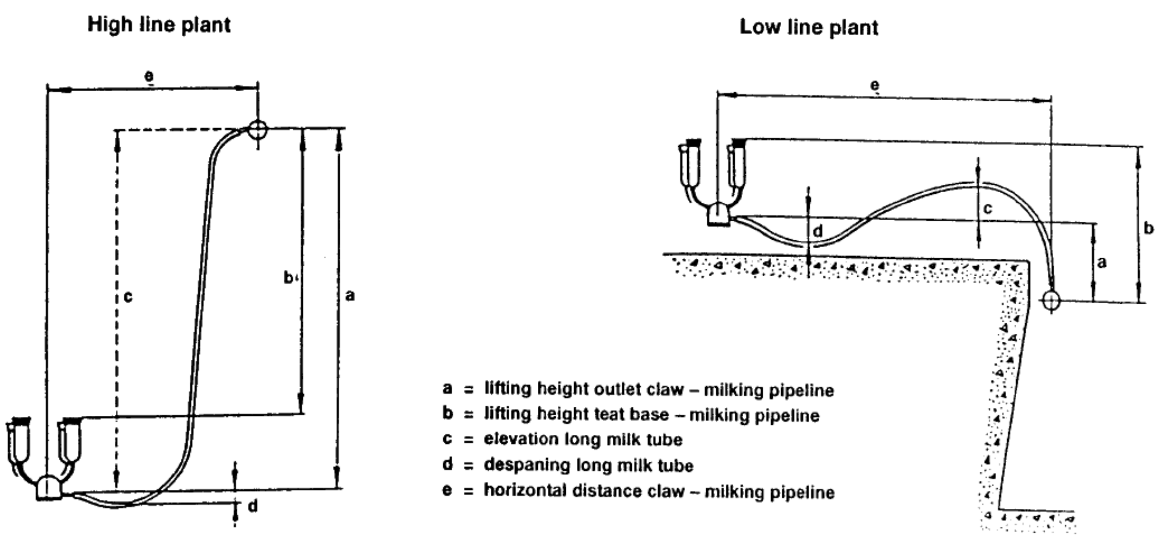

Figure 3 - Adopted from the Delaval website.[4]

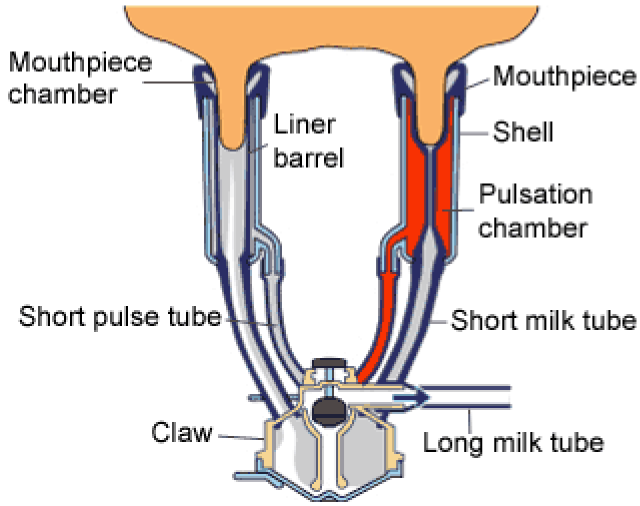

Figure 4 – Graph of a pulsation cycle depicting liner position and milk flow.[5]

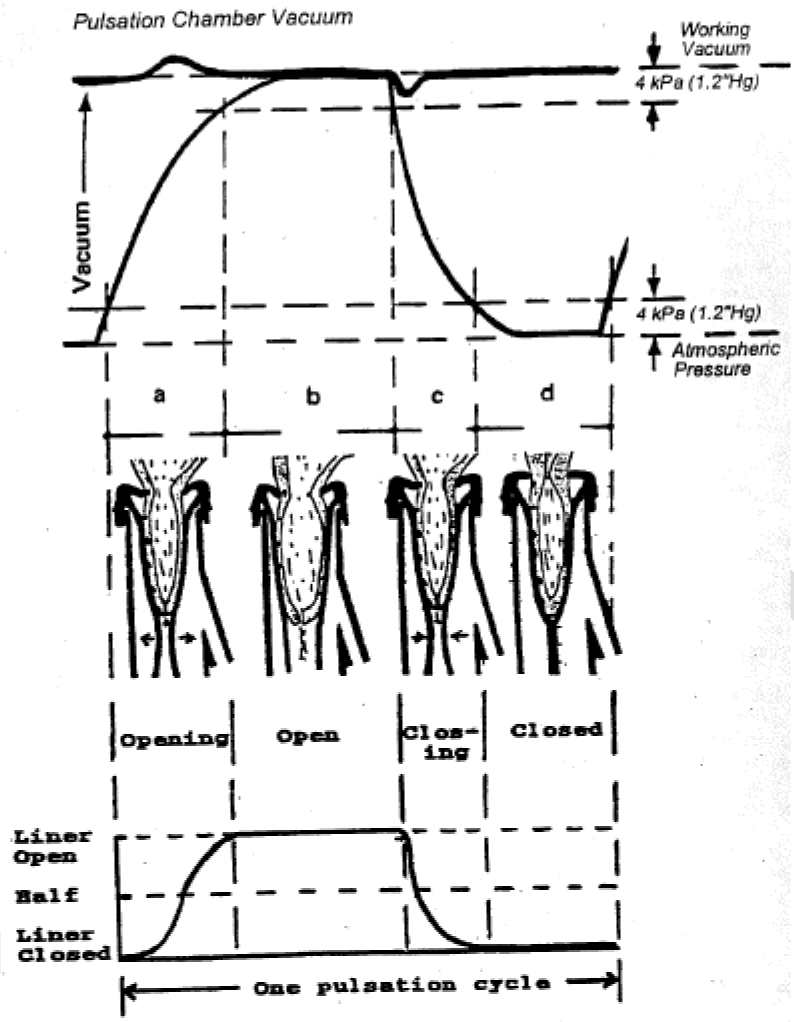

Figure 5 – Pulsation graph from a vacuum recorder.