Evaluating Milking Machine Performance

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Some aspects of milking system performance can be evaluated without special test equipment by anyone with observational and analytical skills. More detailed testing can be done by trained professionals, depending on their specific interests, test instruments, experience, and skill. This paper presents recommended test procedures and equipment required for three levels of complexity.

Level I: Simple machine checks and milking-time observations

The level of testing is not intended to replace regular machine testing and service by qualified technicians. It is intended to help identify possible machine or milking management causes of mastitis, teat condition problems, or slow or incomplete milking.

Test equipment: The equipment required for this entry level testing includes a stopwatch, a level, and a vacuum gauge of known accuracy. A simple mercury column is recommended for regular calibration of the test vacuum gauge. Because of the potential health and safety risks associated with mercury, a mercury column is not recommended for on-farm measurements. Mercury manometers should be used only as a reference instrument to check the accuracy of other gauges, transducers or recorders that are used for routine field-testing. They should be permanently wall-mounted in a protected area, and equipped with a rubber tube and T-piece for connecting the instrument to be tested.

Observations with machine not running

Teatcup liners: Note the condition of the teatcup liners and the size of the liners relative to the shells and the size of teats in the herd. Teatcup liners should:

- Be in good condition with no cracks in the short milk tube connecting to the claw, and no surface crazing or swelling evident on the mouthpiece lip or inner barrel. Distortion or cracking of the liners is an indication that they have been used beyond their rated life.
- Be designed to fit the teatcup shells. The cup should not distort the mouthpiece, but the liner should be held firmly enough not to twist easily in the shell. The length of the shell must match the design length of the liner so that it is mounted under the correct tension.
- Have a barrel diameter about 1 or 2 mm less than the average diameter of the teats after milk letdown (i.e. a barrel diameter around 21-22 mm for typical Holstein herds).
- Be long enough to collapse below the teat. The effective length of any liner is measured from the mouthpiece lip to the bottom of the location on liner barrel that the walls touch when milking vacuum is applied to the liner while mounted in the teatcup shell. The effective lengths of typical liners made of natural rubber or synthetic rubber, should be 130mm for liners up to 20mm bore; 135mm for 21-22mm bore; 140mm for liners of 23-24mm bore.

Claws. Note the condition of air vents in the claws or liners. The air vent in the claw should be clear and unblocked. The air vent in claws range from about 0.8mm to 1.2 mm in diameter admitting 7 to 12 L/min of air. Blocked air vents will reduce milking vacuum. Automatic shut-off valves in the claw reduce the amount of unintended air and debris admitted during unit falloffs.

Milkline. Measure the slope of the milkline. The milkline should slope towards the receiver with a minimum fall of 1% and preferably 1.5 to 2 %. It is especially important to maintain adequate slope of the milkline near the receiver and in areas of bends and fittings. Milk inlets should enter the upper half of the milkline. The milkline should be mounted as low as practicable above the cows and never more than 2 m above the cow standing level.

Dry testing - Machine running but not milking

Vacuum level: Check the operating vacuum and the reading on the farm vacuum gage compared to a separate vacuum gage of known accuracy. Farm gages are often damaged and inaccurate. Sometimes the indicator needle sticks and it will not move above the operating vacuum level to indicate a high operating vacuum if the regulator fails. Tap the face of the gage to check for a sticking needle. If the farm vacuum gage is not functional or inaccurate recommend that a functional gage be installed. Recommendations for system vacuum level are given below.

Regulator Response: Listen to the sound of air entering the regulator when the vacuum pump is running but with all units shut off. Open enough milking units so that the air admitted reduces the receiver vacuum by about 3 kPa (about 1" Hg). This should cause the regulator to close result in a noticeable reduction in the hiss caused by air entering the regulator. If the regulator does not appear to close, check the regulator filter and clean it if necessary. If cleaning does not improve the regulator sensitivity, then call the company service technician.

Falloff Test: A milking machine should have enough airflow capacity to supply the normal operating requirements of the milking machine plus unintended air admission that may occur during unit attachment or unit falloff. A unit falloff test can be performed to determine if the milking machine has sufficient reserve capacity. Measure the average vacuum in the receiver with all units in operation and all teatcups plugged. Then open one milking unit to admit air through all four teatcups and measure the average vacuum in the receiver again. If the milking machine has more than 32 units open a second unit to admit air. If the average vacuum level in the receiver falls by less than 2 kPa (0.6"hg) the system has sufficient reserve capacity to cope with unit falloff.

***Pulsation*.** Listen closely to each pulsator as a first check for uniformity between units. The sound of air entering the pulsator should be regular and intermittent. This simple check is made more sensitive by partially covering the air inlet with a finger. A continuous hiss indicates a leak (usually grit or dirt) under the pulsator valve seat. Check that the pulsator air filter or air inlet is clean and free of obstruction. Look inside each liner to ensure that they are not twisted in their shells. Look behind at least one liner in each cluster for signs of milk residues that may indicate a split liner. Feel that all liners are at least opening and closing fully in a pulsation cycle by turning on the vacuum shut-off valve to each cluster in turn and inserting a thumb into each teatcup in turn. These simple tests are a good indication of the uniformity of pulsation. If there is any doubt about pulsator performance call a qualified technician.

Milking-time Observations and Tests

Milking management can have a far greater influence on the success of the milking process than milking machine factors. A systematic review of milking procedures is perhaps the most important part of determining the source of milking related problems.

Cow Cleanliness: Note the condition of cows before milking. Cow cleanliness is a major determinant of both milking efficiency and the rate of intramammary infection. It is estimated that cows that enter parlors dirty, double cow prep time and reduce parlor throughput (Reneau, 1997). A French study demonstrated that teat cleanliness is a good predictor of herd average somatic cell count (Doumalin, 1995). Management practices that reduce teat end exposure to these organisms will reduce the risk of developing mastitis. Bedding sources that are clean, dry and comfortable will minimize pathogen growth. Inorganic bedding such as sand will reduce the number of pathogens if groomed daily. Further improvements in cow cleanliness can be made through removal of udder hair. It is a good practice to routinely remove udder hair twice yearly and keep tails trimmed or docked.

Cow Handling: Cow handling techniques should be examined if cows are hesitant to enter the milking area or are defecating frequently during milking. It is clear from recent research that human/cow interactions can have a large influence on the milking process (Seabrook, 1994). Cow handling is an important determinant of milking efficiency. The release of adrenaline within 30 minutes of milking can interfere with milk letdown and prolong unit on-time. Calm cows enter the milking parlor readily and do not generally defecate in the milking parlor.

Cow Grouping: Observe whether cows are grouped according to mastitis infection status. Uninfected cows should be grouped and milked in an order to minimizing exposure to cows known to be infected with sub-clinical mastitis. Also note the methods used for detection, handling and recording of clinical cases of mastitis. It is safe to assume that cows with several linear scores of ≥4 (SCC>250,000) are chronically infected. Most cows that consistently have linear scores <4 are uninfected. Cows that have a single elevated score, or fluctuating scores fall into the unknown category. Fresh heifers are generally put in the uninfected group until their first SCC is obtained. Fresh mature cows should be classified based upon their previous SCC status or cultures obtained at calving. In freestall-parlor operations, uninfected cows should be grouped together and milked first. Cows of unknown infection status are milked next and the infected cows are milked last. In stall-barns, infection status can be used to order the cows within the barn so that infected cows are always milked last. Alternatively, one or more milking units can be identified and always used on infected cows.

***Premilking Cow Preparation*:** Document premilking cow preparation procedures and the total amount of time spend in contact with each cow. Premilking preparation is performed to clean teats before unit attachment, check for clinical mastitis and abnormal milk and, to stimulate milk letdown. The combination of effective teat cleaning and fore-stripping will usually provide sufficient stimulation for milk letdown in Friesian cows.

Note the completeness of cover of the disinfectant on the teats. Teat end disinfection is important in reducing the number of bacteria at the teat end. It is well established that proper teat end disinfection, can reduce teat surface bacteria by 75% (Galton et al, 1986). The lowest milk bacterial counts have been shown to be produced with methods that wet and clean only teats (not the entire udder). If cows are clean, teats can be adequately disinfected by the use of pre-dipping without additional washing.

Pre-dipping is most effective in the control of environmental pathogens (*E. coli* and environmental streptococci) and has been shown to have limited effectiveness against coagulase negative staphylococci (Pankey et al 1987; Ruegg and Dohoo, 1987). A minimum contact time of 20-30 seconds is needed for effective disinfection. If washing is required to remove excess manure, the following principles should be followed: 1) only teats should be washed, 2) minimal water should be used, 3) teats should be thoroughly dried. The most important portion of the teat disinfection process is thorough drying of teat ends. Air drying is not a satisfactory substitute for manual drying with an individual cloth or paper towel. Water on teats aid in transporting bacteria and concentrating them at the opening of the teat canal. Cloth towels have the advantage of being more absorbent than paper. When cloth towels are used they should be disinfected by washing with bleach or very hot water and drying at high temperature in an automatic dryer. These methods have been demonstrated to significantly reduce pathogen numbers (Fox, 1997). To check the effectiveness of teat disinfection and drying, a clean swab can be rubbed across the end of the teat prior to unit attachment. A swab from a properly prepared teat will remain clean. A dirty swab indicates that teat preparation methods should be improved.

When teats are clean, fore stripping should be performed prior to teat end disinfection. In parlors, cows can be fore stripped onto the floor. This prevents the buildup of microorganisms in a fomite such as a strip cup. Cows in stall barns *should never* be fore stripped into the bedding. Bulk milk SCC problems cannot be solved without the incorporation of fore stripping into the milking routine.

Units Attachment: Measure the elapse time between first touching the cow and unit attachment (prep-lag time). To maximize milking efficiency, units should be attached from 45 to 90 seconds from *the beginning* of stimulation. Prep-lag times greater than 3 minutes result in more residual milk and lower milk yields. A high milk flow rate immediately after unit attachment followed by reduced milk flow rate and then increased milk flow a rise is an indication that the prep-lag time in insufficient. Effective support should be provided for the long milk tube and units should be adjusted so that cluster weight is evenly distributed on the 4 teats. Proper unit adjustment and long milk tube support results in fewer liner slips and unit falloff.

Unit Removal: Observe methods for unit removal and assess the amount of over-milking. Milking units should be removed promptly when the milk flow rate from the udder drops below 0.5 kg/min. Early unit removal may result in reduced milk yield and promote the development of sub-clinical mastitis to the clinical stage. Over-milking is time of highest risk for developing new mastitis infections and teat damage. A Danish experiment demonstrated that when the threshold setting on Automatic Cluster Removers (ACR) was raised from 0.2 kg/min to 0.4 kg/min the average unit-on time was reduced by 0.5 minutes and teat condition improved (Rasmussen, 1993). Higher threshold settings and shorter detacher delays can be applied to 3X herds with good cow prep, resulting in improved teat condition and milking speed. ACR function can be assessed by disconnecting the removal mechanism from the claw and observing milk flow in relation to the time that the unit is removed. Manual cluster removal should mimic the ACR process. Clusters should be removed by first shutting of vacuum to the claw and then removing teatcups. Machine stripping should not be routinely practiced.

Post-Milking Management: Evaluate the adequacy of post milking teat spraying or dipping by wrapping a paper towel around the teat. Post-milking teat antisepsis was initially developed to reduce the transmission of contagious mastitis pathogens and has been widely accepted. Spray applicators are preferred by some operators because of convenience and to keep teat dip from becoming tainted with contaminated milk. While it is possible to adequately cover the teat using a spray applicator, it is difficult to accomplish in practice. The last step in an effective milking routine is to ensure that the cows remain standing for at least 30 minutes after milking is completed. Most producers provide fresh feed after milking to encourage this behavior.

Milking Time And Average Milk Flow Rate: Average milk flow rate is a good indicator of the efficiency of milking. The average milk flow rate is calculated as the total milk yield divided by the total machine-on time. In milking parlors equipped with milk meters and automated data collection systems the average milking time and average milk flow rate for the entire milking herd can be easily calculated. If automated data collection is not available a random sample of about 10 cows from the herd will yield an estimate of the average flow rate for the herd to within +/-0.5 kg/min. A random sample of 30 cows will improve the estimate to within +/- 0.25 kg/min. Field studies in England, France and the USA yielded the following equation for average milking time for cows yielding 10 to 20 kg of milk <u>per milking.</u>

Average milking time (minutes) = 3 + (0.2 *x* kg milk yield)

Low average milk flow rates or longer milking times can result from interference with the letdown response due to uneasiness of the cows, inadequate cow stimulation, improper timing of unit attachment in relation to milk letdown, milking machine problems or overmilking because of improper detachment procedures.

Completeness Of Milking: The completeness of milking can be assessed by hand stripping each quarter immediately after the milking machine is removed. If milking units are being removed at the proper time the majority of quarters will have little or no milk present after unit removal. It is common for the slowest milking quarter to have some residual milk left after unit removal. A practical guide is that less than 20% of Quarters should yield more than 50 mL of milk when hand stripped immediately after unit removal.

Teat condition: Score teats for the severity of teat end "rings" or hyperkeratosis and note teat color immediately after units are removed. Record the number of teats with good condition (no ring or small ring with smooth skin, no roughness or fronding at the teat end, normal color after milking) and the number of teats with poor conditions (raised ring that is with rough and cracked giving the teat-end a “flowered” appearance or teats that have a blue color after milking). The criteria suggested by Mein et al

(2000) is that less than 20% of cows have teat condition considered to be problematic. Of the milking management or machine factors, the total time per day when milk flow rate is less than about 1 kg/min appears to have a major effect on teat-end condition. This is influenced by pre-milking udder preparation practices or degree of over-milking, as well as milking equipment such as the settings for ACR, high milking vacuum or liners with stiff mouthpieces.

Frequency of slipping or falling teatcups: Note the number of times the units must be adjusted by operators because of slipping or falloff. Mein and Reid, (1996) suggest a goal of less than 5% of cow milkings requiring correction by the operator(s). Heavy clusters, uneven weight distribution within the cluster or blocked air admission holes are other common causes of slips and falloffs. Note the stage of milking when the slips and falls occur. Flooding clusters or milklines tend to cause slipping or falling early in milking. Poor liner design or uneven weight distribution in the cluster are the most common causes of slipping and falling late in milking.

Sample Size and Statistics*:* Perhaps the most common weakness of teat evaluation procedures in commercial herds is that sample sizes are too small. One method for assessing and describing the teat condition status of a herd of cows is to measure the proportion of cows that have a particular teat condition classed as abnormal, e.g., more than 20% of cows with rough teat-ends. As the following table shows, the more cows that are scored, the more confidence there will be in the results of the evaluation. The 95% confidence level is normally the minimum acceptable for scientific publications; however for diagnosis of conditions on farms the risk of a false positive error is generally of less concern and a 90% confidence level may be sufficient. The following table gives the 90% confidence interval for varying sample size using a binomial distribution for analysis.

Number of cows Or quarters checked	90% confidence interval
25	+/- 12%
50	+/- 8%
75	+/- 5%
100	+/- 5%

For example, if we randomly sampled 25 cows and found that 5 cows (that is, 20% of the cows) had 'bad' teat-ends, the estimate of the true population average would be +/- 12 % which means somewhere between 8% and 32%. If 50 cows are randomly sampled and 10 of these (20%) had ‘bad’ teat-ends, the estimate of the true population of cows in the herd with this particular problem would be somewhere between 12% and 28% for a 90% Confidence Interval or 14% and 26% for an 80% CI.

Level II Testing: Pulsator Performance and Milking Vacuum Stability

Proper pulsator function is critical to the success of the milking process. Milking-time tests are the most direct method to determine the adequacy of vacuum production and vacuum regulation in any milking system. More detailed testing can be used to diagnose the cause of failure for either of these tests.

Test equipment: A single-channel unit or multi-channel vacuum recorder and at least 4 teatcup plugs are required for correct testing of pulsators. Because most pulsator testers include an option for measuring vacuum level, the pulsator test unit can be used as an accurate digital vacuum gauge and for measuring vacuum stability in the milkline and claw.

Pulsator Testing: These tests are done with milking units connected, pulsators operating and liners fitted with teat cup plugs. The objective of these tests is to determine if the pulsation system and all pulsators are operating according to the manufacturer's specifications. Pulsation testers are used to determine the pulsation rate and the duration of the four phases of pulsation. The main parameters of interest for pulsators are:

- Pulsation Rate should be repeatable from day to day and should not deviate more than 3 cycles per minute from one unit to the next.

- Pulsator Ratio should not differ more than 5 percentage units from manufacturers specifications or from one pulsator to another.
- The B Phase (milking or liner-open phase) of pulsation should be at least 30% of the cycle
- The D Phase (massage, rest or liner-closed phase) of the pulsation cycle should not be less than 15% and not less than 150 milliseconds.

Manufacturer's provide more detailed specifications for individual pulsator types. If any pulsation characteristics fall outside these guidelines, further checks by the manufacturer's representative are recommended.

ASAE specifies and ISO reccomends that the performance criteria for a vacuum stability in a milking machine is that the vacuum drop in or near the receiver does not exceed 2 kPa (0.6"Hg) during normal milking. Normal milking is considered to be the time that milking units are attached to cows including events such as teatcup attachment and removal, liner slips and cluster falloff. In addition the vacuum should not drop more than 2 kPa (0.6"Hg) below the receiver vacuum at any point in the milkline for at least 95% of the normal milking period.

The most useful sites of measurement are in the milkline, in or near the receiver (if necessary), and in the claw. Vacuum at these sites should be recorded while the system is under full milk and air flow conditions, that is, while clusters are being attached, while all clusters are on cows, and then as clusters are detached.

a) M**ilkline Vacuum Stability**: Connect the vacuum recorder to the milkline and record vacuum for 3 "turns" of a milking parlor, or for 15 minutes in a stanchion barn. Make sure that recordings are taken during the operation of all equipment that is normally operated during milking. If the vacuum drop in the milkline (average minus minimum) does not exceed 2 kPa (0.6" Hg) the milkline vacuum stability meets international standards.

b) **Receiver Vacuum Stability**: If the system passes the milkline vacuum stability test it is not necessary to record vacuum stability in the receiver. Additional measurements should be made in the receiver to determine if vacuum fluctuations in excess of 2 kPa (0.6"Hg) in the milkline are caused by milkline slugging or by inadequate vacuum production or regulation. Connect the vacuum recorder to the receiver and record receiver vacuum for 3 "turns" of a milking parlor, or for 15 minutes in a stanchion barn.

c) **Average Claw Vacuum**: Connect a suitable vacuum recorder to the claw using one of the following methods:

- Connect a suitable test T-piece between the long milk tube and the claw outlet.
- Insert a 12 or 14 gauge needle through the short milk tube of the liner. The needle should be at least 60 mm long to ensure proper location of the needle through the claw nipple and into the top of the claw bowl. The end of the needle should be located out of the milk flow stream.
- Use a claw fitted with a test port that is located out of the milk flow stream.

The vacuum at the regulator should be set so that the average claw vacuum during peak milk flow is between 35 kPa and 42 kPa (10.5 and 12.5" Hg).

Level III Testing: Complete Professional Machine Evaluation

Test equipment: These tests require the use of a vacuum recorder that can display the average, minimum and maximum vacuum recorded over a known or pre-set measurement period and an air flow meter. The air admission for an individual claw can be measured with a low range air flow meter. A flow simulator, as described by Stewart et al. (1997), can be constructed or purchased

Test Methods: A milking machine technician should perform a complete system evaluation after each 500-1000 hours of operation as part of a regular testing, service and maintenance contract. In addition a complete system evaluation should be performed on any new system, whenever modifications are made to the milking machine, or when milking time tests indicate that there may be a problem with the milking machine. A complete evaluation of the vacuum level and airflow in a milking machines includes the following measurements:

- Rate and ratio of all pulsators (Level II)
- Operating vacuum in the receiver and vacuum difference between the receiver and the vacuum pump, regulator and pulsator air line.
- The 'falloff' test to determine if the system has enough reserve capacity to cope with a unit falloff.
- Effective Reserve and Manual Reserve;
- Regulator "undershoot" or "overshoot" when 1 unit is opened and then closed (this is a simple test for a dirty or sticking regulator).
- Air used by components: Pulsation system, clusters, regulator, and other ancillary equipment.
- System Leakage
- Vacuum Pump Capacity

Other specialized dry tests that may be useful include:

- Vacuum in the mouthpiece chamber of the liner (MPC vacuum) during peak milk flow. The mouthpiece vacuum during milking can be measured for diagnostic purposes to determine if this is a cause of rings at the base of the teat and/or discolored or swollen teats after milking. According to Rasmussen (1997), the average MPC vacuum should be at least 10 kPa (3" Hg) less than the average claw vacuum during peak milk flow. Teat congestion and ring marks at the base of the teat appear to be reduced when average MPC vacuum does not exceed 20 kPa (6" Hg).
- Average claw vacuum, and vacuum drop through the long milk tube and through ancillary equipment using a milk flow simulator. A flow simulator is a useful tool to help determine the correct system vacuum level. The flow simulator described by Stewart et al. (1997) provides an easy, convenient and reliable method of measuring average claw vacuum, and vacuum drop through the long milk tube and through ancillary equipment such as sensors and milk meters at known water flow rates. The vacuum at the regulator should be set so that the average claw vacuum during peak milk flow is between 35 kPa and 42 kPa (10.5 and 12.5" Hg). Flow rates of 3.5 L/min to 5.5 L/min (1 gpm to 1.5 gpm) cover the range of expected peak flow rates for high producing cows. The results of vacuum measurements made using a flow simulator can be compared with the average claw vacuum recorded during milking to estimate the peak milk flow rate of individual cows. Flow simulators can be used as a reasonable estimate of the average vacuum in the claw but do not provide a reliable estimate of vacuum fluctuations in the claw or short milk tube during milking.

It is important to realize that there are many reasons to suggest changes a milking system including:

- Improve milking performance (speed/completeness of milking).
- Improve mastitis control and milk quality
- Decrease power/energy consumption.
- Decrease wear on pump components.

- Improve cleaning performance.
- Aesthetic or cosmetic reasons.

When the evaluation of the milking machine is completed, recommendations should be listed in order of priority according to their likely cost-benefit for the client, as follows:

Priority 1 - Urgent and important changes

Priority 2 - Important but not urgent improvements

Priority 3 - Cosmetic or other improvements

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