Methods for Measuring and Interpreting Milking Vacuum

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Paper Presented at the Sixth International ASABE Dairy Housing Conference
Minneapolis, Minnesota, USA, 16-18 June 2007

Abstract. *Techniques for measuring the level of milking vacuum are presented and discussed with reference to the specifications given in ISO Standard 5707 and ASABE standard S518. Common measurement and interpretation errors are illustrated in this paper along. Milking-time tests of average claw vacuum were shown to compare well to wet-tests (done with a milk flow simulator). Knowledge of simultaneous milk flow rate, either by using a flow simulator with a known flow rate or by estimating milk flow rate using milk meters improves predictive ability and can provide better information from measurements made on fewer cows. The wet tests provide a more accurate assessment of differences between system configurations because the liquid flow rate is more precisely known and the cow-to-cow variation is eliminated.*

Keywords. milking machines, testing, vacuum level, milking vacuum.

Introduction

There are numerous locations in a milking system to measure vacuum and many different ways in which these vacuum measurements can be averaged and analyzed. The Procedures for Evaluating Vacuum Levels and Airflow in Milking Systems, (NMC, 2004) developed by the Machine Milking Committee of the National Mastitis Council (NMC) are based on methods specified in ASAE (ASAE, 1996b) and ISO (ISO, 1996b) standards and is the accepted practice for testing milking system performance and for the interpretation of those test results.

Milking Time Tests

A milking-time test is a test performed while milking cows and with the milking system under normal use conditions. According to the NMC guidelines, accurate recordings of vacuum levels at various locations during milking provide the best means of demonstrating the adequacy of the vacuum production and regulation function of any milking system. The most direct measure of the milking system's effect on the cow is the vacuum in the claw of the milking unit and was the primary test location referenced in this study.

Interpretive guidelines have been developed that apply to vacuum in the claw when measured in a specific manner. These claw vacuum guidelines are meant to apply to the vacuum in the claw when measured as a 5 to 20 second average during the peak flow period of an individual cow. The measurements of average claw vacuum at peak milk flow should, furthermore, be made on a representative sample of cows in the herd (at least 10 cows, preferably randomly selected).

The recommended range in North America of average claw vacuum measurements made in this manner is between 36 and 42 kPa (10.5 and 12.5 "Hg). Average claw vacuum in this range during the peak flow period of an individual cow is generally considered to be a good compromise to allow cows to be milked gently, quickly, and completely. The guidelines for average claw vacuum commonly used in Europe are somewhat lower than those recommended in North America, however. These countries typically use the recommendations presented in the ISO milking machine standard of average claw vacuum during the peak milk flow period in the range of 32 kPa to 40 kPa (9.4 to 11.8"Hg) (ISO, 1996a).

Note the range for average claw vacuum in all of these documents is stated as a general guideline, not an absolute requirement. The choice of milking vacuum on any farm is based on many factors including the importance of speed and completeness of milking, the type of liner and the type of milking unit used on that farm. While the guidelines for average claw vacuum differ slightly between European and North American standards, both are based on the concept of a compromise between milking gently, quickly, and completely when choosing the average claw vacuum. This compromise is necessary because:

- Higher average claw vacuum results in quicker milking but milking that may be less gentle or complete.
- Lower average claw vacuum results in milking that is more gentle and complete but not as quick.

Large farms in North America tend to put a higher priority on milking cows quickly than European farms and therefore the convention in North America has been to recommend higher average claw vacuum. However, this is not a hard and fast rule and the decision on an individual farm depends on its' priorities and the type of equipment used.

As described later, the average claw vacuum is inversely proportional to the average milk flow rate. As milk flow rate increases, average claw vacuum typically decreases. Each cow has a different peak milk flow rate and the milking system must be adjusted to accommodate the vast majority of the herd. A dairy manager that places a high value on milking quickly might choose to adjust the milking system so the average claw vacuum stays above the low end of the recommended range: 32 kpA (9.5"Hg), ISO or 36 kPa (10.5"Hg), NMC) for the fastest milking cows (highest flow rate). A dairy manager who was more concerned with milking cows gently and completely might choose to adjust the milking system so the average claw vacuum stayed below the upper end of the recommended range: 40 kPa (11.8 "Hg), ISO or 42 kPa (12.5"Hg), NMC for the slowest milking cows (lowest flow rates).

Milking System Configuration and Guidelines for Selecting System Vacuum

The vacuum regulator is a device that holds the vacuum steady at one point in the milking system (usually a point near to the milk receiver jar). The vacuum at other points in the milking system differ from this system vacuum because of the variable flow of air and milk through the milking system during its normal use.

The milking system vacuum is a parameter the user sets to achieve the desired range of average claw vacuum during milking. There are three main factors that influence the difference between the steady system vacuum and the variable average claw vacuum:

1. The system configuration (long milk tube length and diameter, fittings in the long milk tube, and other parameters affecting frictional losses).
2. The flow rate of milk through the long milk tube (increased milk flow generally acts to increase the difference between system and claw vacuum)

3. The flow rate of air admitted into the milking unit (increased air admission also acts to increase the difference between system and claw vacuum)

The milk flow and air admission rates change constantly and these changes can account for dramatic changes in claw vacuum. Milking-tests that take into account these variable milk and air flow rates are more accurate than milking-time tests that do not. When the milking unit is first attached, the vacuum rises to the system vacuum and then falls quickly as milk flow starts. As the milk flow rate increases the average vacuum in the claw decreases. As the cow finishes milking, the milk flow rate declines and the average claw vacuum increases and approaches the system vacuum level. Under normal conditions very little air is admitted into the claw. However, if a liner slip occurs, a large volume of air is admitted resulting in a rapid, momentary drop in claw vacuum that is often larger than the vacuum difference produced by the changing milk flow rates.

The type of milking unit and ancillary equipment used affects the difference between the system vacuum and the average claw vacuum. The system vacuum should be adjusted to achieve the desired milking vacuum at the claw for cows during peak milk flow. The range of desired milking vacuum is meant to apply to "normal" milking conditions, not to the large and unavoidable changes in vacuum produced by occasional liner slips or other unplanned air admission.

Materials and Methods

<u>Example Average Claw Vacuum Recording</u>

It typically takes from 3 to 10 minutes to milk a cow. Figure 1 illustrates a recording of the final 1.3 minutes of a cow milking showing the instantaneous vacuum in the claw, rolling 5-second average claw vacuum (e.g. an average of the previous 5 seconds of instantaneous vacuum) and 5-second average milk flow rate. When the milk flow rate decreases the average claw vacuum increases. Figure 2 contains an expanded view of one of the 5-second windows in Figure 1.

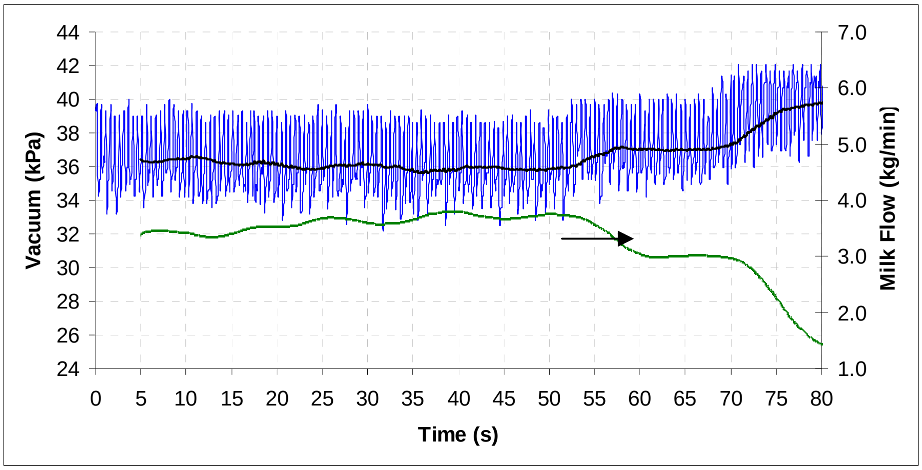

Figure 1. Simultaneous recording of milk flow rate and claw vacuum.

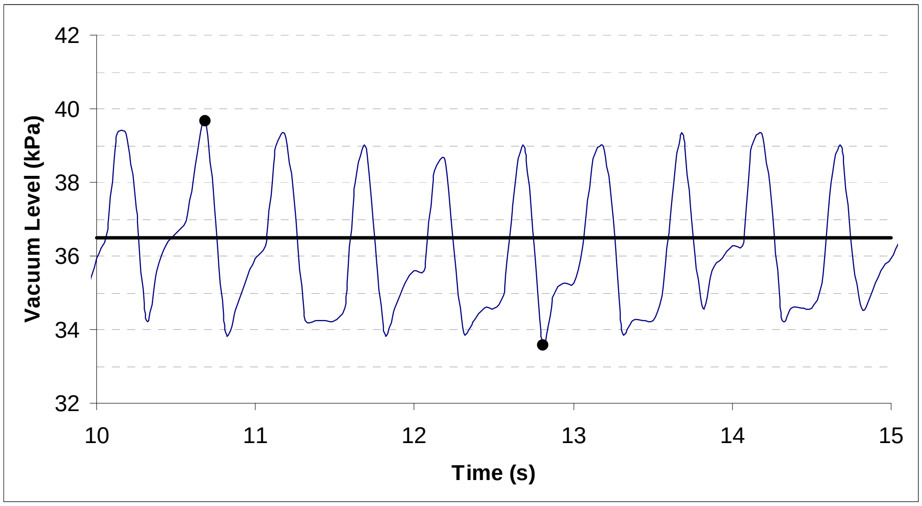

Figure 2. Expanded 5 second window of the vacuum recording in Figure 1.

Milk extraction from the udder is not continuous but rather milk is removed in 'squirts' much like the process of hand milking. Milk is extracted twice per second as the milking liners open and close on the front and then the rear teats. The vacuum in the claw also rises and falls twice each second because of the pulsed milk flow (increased milk flow = decreased vacuum). The guidelines for claw vacuum (or milking vacuum) cited in ISO (1996a) and ASAE (1996a) apply to the vacuum averaged over a 5 to 20 second window - NOT TO THE INSTANTANEOUS EXTREMES - of such a recording (represented by the dots on the graph in Figure 2).

In addition to these very fast changes in vacuum produced by 'squirts' of milk twice per second, there is also a much slower change in the average claw vacuum that accompanies the slower changes in the average flow rate of milk from the cow's udder. When the milking unit is first attached and the udder is full, the average milk flow rate is considerably higher than at the end of milking when the udder is nearly empty. The guidelines for average claw vacuum apply to the PEAK FLOW PERIOD (usually early in milking when the udder is full) and not to the periods of low milk flow.

Consequently, and as previously mentioned, the best way to determine the AVERAGE CLAW VACUUM DURING THE PEAK FLOW PERIOD is to record a series of 5 to 20 second 'snapshots' over the entire milking period of milking a single cow. The series of averages of each of these snapshots provides a picture of how the average claw vacuum changes over the range of average milk flow rates for each cow. The minimum value of this series of 5-second-average snapshots for each individual cow is taken as the average claw vacuum during peak milk flow for that cow. Air admission substantially reduces these readings and measurements taken during a liner slip should not be used for this analysis. It is usual for measurements taken during a liner slip to appear as 'outliers' in the data set.

The accepted guidelines for milking vacuum apply only to average claw vacuum over the time period intended by these documents (5 to 20 seconds). If the recording period is shorter, the resulting measurement of average claw vacuum will be unduly influenced by the rapid changes in vacuum caused by pulsed flow of the milk 'squirts' being removed from the udder twice per second (and/or by the even faster and larger instantaneous vacuum changes produced by a liner slip). If the measurement interval is too long, the resulting average claw vacuum is not representative of the value during the peak flow period.

Results

Wet Tests

Wet tests refer to tests done using a milking flow simulator (rather than a cow) to measure the influence of liquid flow rate (usually water) on average claw vacuum. When performing a wet test, the liquid flow rate is held constant at a known flow rate while recording the average claw vacuum. The intermittent air admission produced by liner slips is eliminated during a wet test. Wet tests thus remove cow-to-cow variation, which is considerable, and is a useful tool to quickly and accurately assess the effect of different system configurations on the average milking vacuum in the milking claw. The standard test points for a wet test are:

- No water flow - to confirm average claw vacuum is near to the system vacuum
- 1.9 kg/min (0.5 gpm, 4.2 lbs/min) (corresponding to the approximate median peak flow rate for cows).
- 3.9 kg/min (1.0 gpm, 8.6 lbs/min) (corresponding to the approximate peak flow rate of the fastest milking 10% of cows: ; one in 10 cows have a higher peak flow rate).
- 5.8 kg/min (1.5 gpm, 12.9 lbs/min) (corresponding to the approximate peak flow rate of the fastest milking 5% of cows; one in 20 cows have a higher peak flow rate).

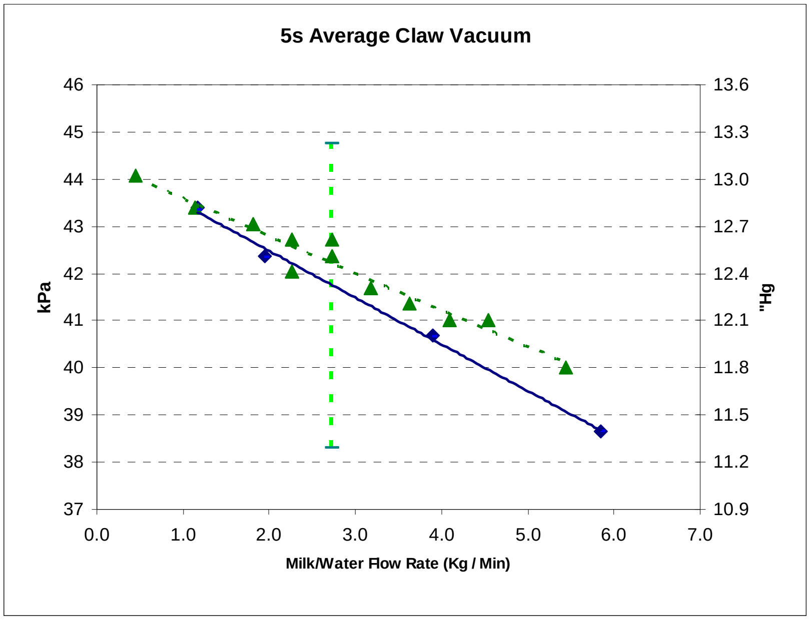

Figure 3. Example Average Claw Vacuum Measurements: wet test, milking-time test without known milk flow rate, and milking-time test with known flow rate.

Example

Measurements of average claw vacuum made on a low line milking parlor are presented in Figure 3. The vertical dashed line is the range of 5-second average claw vacuums measured on 15 cows. The exact flow rate was not known so the range has been plotted at about the mid point of the expected flow range. The sloped solid line (diamonds) is a wet test done with a flow simulator. The sloped dashed line (triangles) are 5-second average vacuum measurements made during milking-time tests with simultaneous milk flow rate estimated from milk meters installed on the farm. Several interesting results of this comparison are:

1. The wet test (flow simulator) agree reasonably will with the milking time test except at very high milk flow rates.
2. Knowledge of simultaneous milk flow rate, either by using a flow simulator with a known flow rate or by estimating milk flow rate using milk meters improves predictive ability and can provide better information from measurements made on fewer cows.
3. The wet tests provide a more accurate assessment of differences between system configurations because the liquid flow rate is more precisely known and the cow-to-cow variation is eliminated.

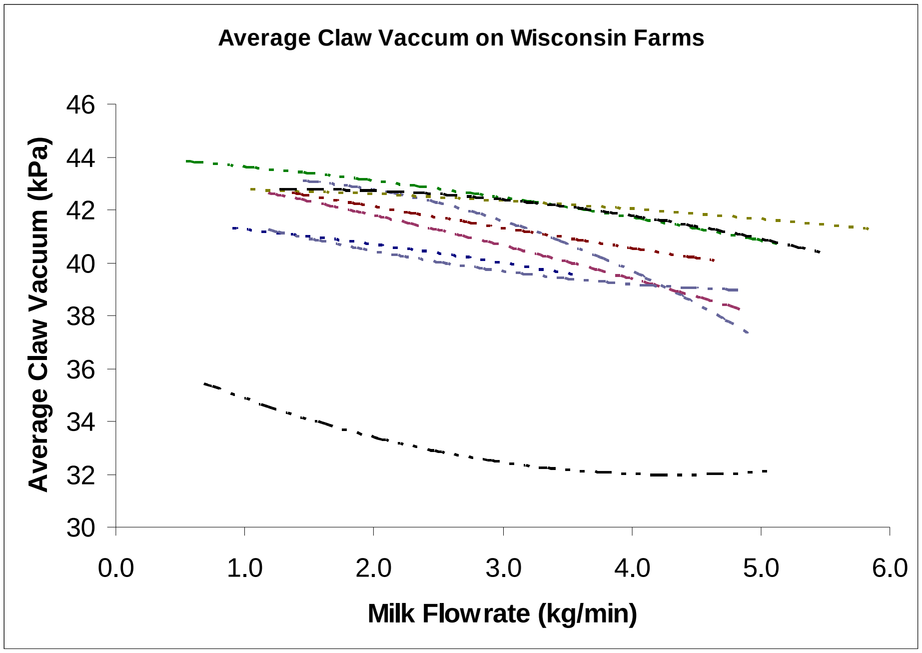

Figure 4. Average claw vacuum measured at known milk flow rates on Wisconsin milking parlors.

Measurements taken by faculty and staff at the University of Wisconsin-Madison Milking Research and Instruction Laboratory on milking parlors in Wisconsin are presented in figure 4 and Table 1. The relationship between average claw vacuum and milk/water flow rate is described well with a quadratic curve fit for each individual farm. Note that there are substantial differences in the vacuum/flow curves between farms due to differences in milk lift, long milk tube length and restrictions in the long milk tube.

Table 1. Vacuum Measurements on)Wisconsin Milking Parlors

	Ave.	Max	Min	Median
System Vacuum (kPa)	43.9	45.5	41.3	44
Average Claw Vacuum (kPa) at 2kg/min Flow Rate	41.1	43.0	34.2	42
Average Claw Vacuum (kPa) at 5kg/min Flow Rate	38.5	41.7	31.2	39

Conclusion

Techniques for measuring the level of milking vacuum with reference to the specifications given in ISO Standard 5707 (ISO, 1996a) and ASABE standard S518 (ASAE, 1996a) have been presented and common measurement and interpretation errors have been illustrated. Milking-time tests compare well with wet-tests (done with a milk flow simulator). Knowledge of simultaneous milk flow rate, either by using a flow simulator with a known flow rate or by estimating milk flow rate using milk meters improves predictive ability and can provide better information from measurements made on fewer cows, than test done when the milk/water flow rate is not known. The wet-tests provide a more accurate assessment of differences between system configurations because the liquid flow rate is more precisely known and the cow-to-cow variation is eliminated. The development of a predictive equation for the relationship between milking vacuum and milk flow rate for each individual milking parlor will aid in adjusting the milking system vacuum to balance quick and gentle milking.

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