Advances in machine milking: The influence of milking on teat condition and mastitis risk

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The main milking-related contributors to mastitis risk, identified by an IDF group of experts in 1987 (IDF 215, 1987), were reviewed by Mein et al (2004) in light of accumulated research results and field experience over the intervening 17 years. These authors concluded that:

> *Most new infections are caused by factors other than the milking machine. Direct and indirect milking machine effects might account for 6-20% of new mastitis infections in an "average herd".*

Following is a summary of the milking-related contributors to mastitis risk of most practical interest to dairy advisors along with some suggested diagnostic tools to aid the practitioner in assessing the major milking machine-related contributors to mastitis risk.

Contamination or the number of bacteria present on teat skin and at the teat orifice

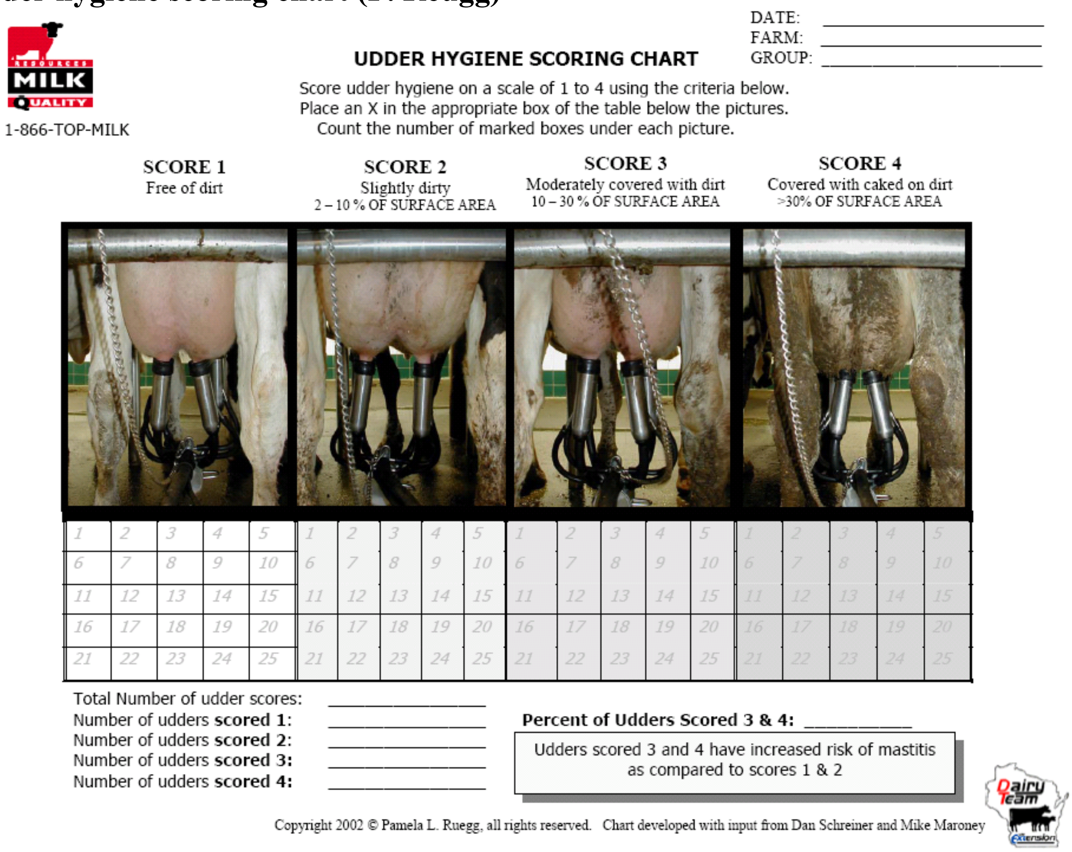
Mastitis risk is a numbers game. The New Infection Rate (NIR) is reduced by keeping bacterial numbers low on or near the cows' teat-ends. Herd management and milking management practices probably have over-riding effects compared with the potential contribution from milking machines.

A simple method developed and validated by Dr. Pamela Ruegg (Schreiner and Ruegg, 2003) for scoring udder hygiene has proved an invaluable tool to monitor the effect of the cow environment on udder cleanliness. Udder hygiene scores showed a significant association between poor udder hygiene and increasing individual cow linear score and the prevalence of intramammary infection with an environmental pathogen was reported. In fact, cows with udder scores of 3 and 4 were 1.5 times more likely to be infected with a major pathogen than cows with scores of 1 or 2. The study reported only a weak association between leg hygiene score and the prevalence of pathogen isolation from the udder. Although environmental conditions are quite different in Australia compared with Wisconsin, the tool is likely to have value in any climate. The tool allows for a quick and easy assessment (usually no more than 20 minutes), and more importantly, provides a quantitative measure of performance that can be used to test the efficacy of different animal management strategies.

For more difficult and challenging cases, a more quantitative method was developed to identify the relative magnitude of specific organisms present on teat skin (Reinemann et al, 2008). A soft paper towel moistened with water is used to recover soil and bacteria from all four teats of each individual cow. Bacteria are then recovered from the towel and suspended in a sterile water solution. This solution is then cultured. This method has proven more reliable and repeatable that previous methods using swabs to recover bacteria from teat skin. This 'wipe test' is particularly useful in determining whether environmental contamination is a potential source of unusual organisms appearing in the milk storage tank.

Segregating cows into temporary 'clean' and 'infected' groups is a very powerful tool for minimising exposure of uninfected cows to milk from infected cows. If this is not practical, dedicated milking units may be used for infected cows and disinfected to reduce cow-cow transmission of contagious bacteria during milking.

Udder hygiene scoring chart (P. Reugg)


DATE: ______________________
FARM: ______________________
GROUP: ______________________

1-866-TOP-MILK

UDDER HYGIENE SCORING CHART

Score udder hygiene on a scale of 1 to 4 using the criteria below.
Place an X in the appropriate box of the table below the pictures.
Count the number of marked boxes under each picture.

SCORE 1 Free of dirt	SCORE 2 Slightly dirty 2 – 10 % OF SURFACE AREA	SCORE 3 Moderately covered with dirt 10 – 30 % OF SURFACE AREA	SCORE 4 Covered with caked on dirt >30% OF SURFACE AREA

1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
6	7	8	9	10	6	7	8	9	10	6	7	8	9	10	6	7	8	9	10
11	12	13	14	15	11	12	13	14	15	11	12	13	14	15	11	12	13	14	15
16	17	18	19	20	16	17	18	19	20	16	17	18	19	20	16	17	18	19	20
21	22	23	24	25	21	22	23	24	25	21	22	23	24	25	21	22	23	24	25

Total Number of udder scores: ______________
Number of udders **scored 1**: ______________
Number of udders **scored 2**: ______________
Number of udders **scored 3**: ______________
Number of udders **scored 4**: ______________

Percent of Udders Scored 3 & 4: __________

Udders scored 3 and 4 have increased risk of mastitis as compared to scores 1 & 2

 Chart developed with input from Dan Schreiner and Mike Maroney

Teat health and the resistance of teat canal to bacterial invasion

NIR is reduced by pulsation characteristics that provide effective teat massage. 'Effective pulsation' involves much more than the present industry pre-occupation with recording and analyzing pulsator rate and ratio and perhaps the percentage or duration of the a, b, c & d phases of pulsation. The key factor is the cyclic compression applied by the closed liner to the teat tissues to overcome the dilating and congesting effects of the milking vacuum. The main variables affecting liner compression are:

- teat size and shape
- geometry and mounting tension of the liner
- physical properties of the liner material
- pressure difference across the liner barrel

Inadequate liner compression will result in teat tissue congestion during milking. Excessive liner compression will result in an increase in hyperkeratosis (roughened teat ends). Cyclic over-pressure can be used as a relative measure of liner compression. Over-pressure values of about 8-12 kPa (2.5-3.5 inHg) above atmospheric pressure applied for about 15% or 150 ms within each pulsator cycle appear to optimize pulsation for most commercial liner designs.

A simple cow-side measurement technique has been developed to measure the over-pressure applied by liners (Mein, 1992). This method can be used to classify liners into general categories of low, medium and high compression liners. This information is not generally available from manufacturers and this test is a useful tool to help farmers choose liners that manage both teat tissue congestion as well as teat-end hyperkeratosis. The average OP can be estimated by measuring the vacuum level in the teatcup pulsation chamber at which milk flow just starts or stops within a pulsation cycle. The point at which milk starts or stops flowing occurs when the compressing force applied to the teat by the liner walls is exactly balanced by the distending force induced by the vacuum level within the liner.

To make the measurement, a pair of liners is disconnected from the normal pulsation system and the short pulse tube is connected temporarily to a hand-operated vacuum pump and digital vacuum gauge by means of a small three-way tap. The liners are opened slowly by using the hand-pump to evacuate the pulsation chamber. The vacuum level at which milk starts to flow from each teat is noted on the digital gauge. Because the OP is influenced by teat size and depth of teat penetration into the liner, measurements should be made on one or two teats of at least 10 different cows, preferably at a standard time of 1 min after teatcup attachment, in order to obtain repeatable average values.

Methods have been developed for scoring a variety of teat conditions including:

- Hyperkeratosis
- Teat congestion (both at the teat-end and in the teat barrel)
- Teat skin infections

It is important to understand that these different teat tissue responses have different causes and, therefore, different remedies. Technotes developed by the Countdown Downunder program are excellent tools for diagnosis and they also provide guidelines for addressing teat condition problems. More recent and more extensive guidelines have been published (Ohnstad et al. 2007).

Although measuring pulsator performance (rate and ratio) is one of the most basic milking machine assessment methods, knowledge of how to adjust pulsation controllers is in remarkably short supply in the USA, and perhaps also in Australia. In order to achieve a balance between milking quickly and gently:

- the massage phase of pulsation should be as short as possible while still managing teat congestion;
- the milking phase of the pulsation cycle should be as long as possible while still managing teat congestion.

For common liner types this balance is achieved with d-phase of 150 to 200 milliseconds and b-phase of 500 to 600 milliseconds. The a and c phases of pulsation can vary according to the volume of the pulsation chamber, length of long pulse tubes and restrictiveness of pulsator air ports. A rational approach to setting pulsation characteristics is to measure the pulsation phases specific to the installation at each farm and adjust BOTH the pulsation rate and ratio to achieve the desired phase durations. In older pulsation controllers there are, typically, a very narrow range of rates and ratios to choose from. In modern controllers the rate and ratio can be adjusted over a wider range and combination of pulsator rate and ratio.

Recent research at the University of Wisconsin Milking Lab has provided greater insight into the interaction between pulsation characteristics, milking vacuum level and liner compression. As in every aspect of milking, it is inappropriate to make recommendations about one of these factors, without considering the others. For example:

- The milking (or b-phase) of pulsation can be increased when lower milking vacuum is used.
- Liner compression can be reduced when milking vacuum is reduced.

An estimate of the teat-end congestion resulting from combinations of increasing milking vacuum level and increasing b-phase duration are illustrated in Figure 2. The contour lines (of equal congestion) follow a diagonal path from high vacuum and low b-phase to low vacuum and high b-phase. This is an indication of the interactive effects between vacuum level and b-phase duration. The same level of congestion will result for longer b-phase duration and low vacuum as for short duration b-phase and higher vacuum levels. The percentage change in peak milk flow rate over this same range of milking conditions is shown in Figure 3. While it is possible to continue to increase milk flow rates with higher vacuum levels, this effect becomes diminished at high vacuum and long b-phase duration. In addition, the degree of teat congestion increases dramatically at these more 'aggressive' settings.

These studies confirm that, as milking vacuum increases, congestion of the teat-end tissues occurs more rapidly in the b-phase of pulsation. Recommendations for maximum b-phase duration should therefore take into account the milking vacuum level. Furthermore, the liner compression required to manage teat-end congestion increases as the milking vacuum level increases. Therefore, recommendations for liner compression also should take account of the milking vacuum level. Field and experimental studies indicate that increasing liner compression increases hyperkeratosis, especially in high-producing herds milked 3 or more times per day.

Vacuum Fluctuations and bacterial penetration of the teat canal

Air speeds > 2 m/s (6.5 ft/sec) up the short milk tube may assist bacterial penetration into or through the teat canal. Normal liner movement is much too slow to generate air speeds > 2 m/s. Vacuum fluctuations in the milk line or receiver are too slow to increase the NIR unless they increase the frequency of slipping liners or cluster falls. Correlations linking unstable milkline or receiver vacuum with increased mastitis are likely to be associative rather than cause-effect relationships.

High cyclic fluctuations in cluster vacuum (up to 20 kPa; 6 inHg) are unlikely to generate air speeds > 2 m/s in the absence of sudden, unplanned air admission through one of the teatcups. If, however, sudden air admission occurs within a cluster that induces such high fluctuations, the NIR is likely to be higher than 'normal'. The 'RPG' hypothesis remains unproven. It is unlikely that small transient RPGs can produce enough energy to penetrate the teat canal.

The real action takes place within an individual cluster due to a sudden, transient air inrush through a teatcup when:

- a liner slips or squawks loudly
- a cluster is kicked off or detached abruptly
- a cow is machine-stripped vigorously enough to break the seal between a teat and the liner mouthpiece

Such events can produce "acute irregular vacuum fluctuations" characterized by large (15-30 kPa; 4.5-9 inHg) transient drops in claw vacuum (often lasting less than 1-2 sec) with very fast rates of change (150-300 kPa per sec; 45-90 inHg/s). The resulting high transient pressure gradients between the claw and adjacent liners can increase the NIR by accelerating milk droplets to speeds > 2 m/s towards the teat-ends in adjacent teatcups within the same cluster.

Quarter milking (eliminating the common claw as in AM Systems) might be expected to reduce cross contamination within udders. However, other more dominant factors are likely to mask this modest potential improvement. The widespread use of more stable clusters, larger-bore SMTs and larger, free-draining claw bowls has probably already reduced the potential gain from eliminating the claw in many milking systems.

Figure 1. Congestion estimates for increasing average claw vacuum and b-phase duration for a liner which applies medium compression (OP = 12 kPa).

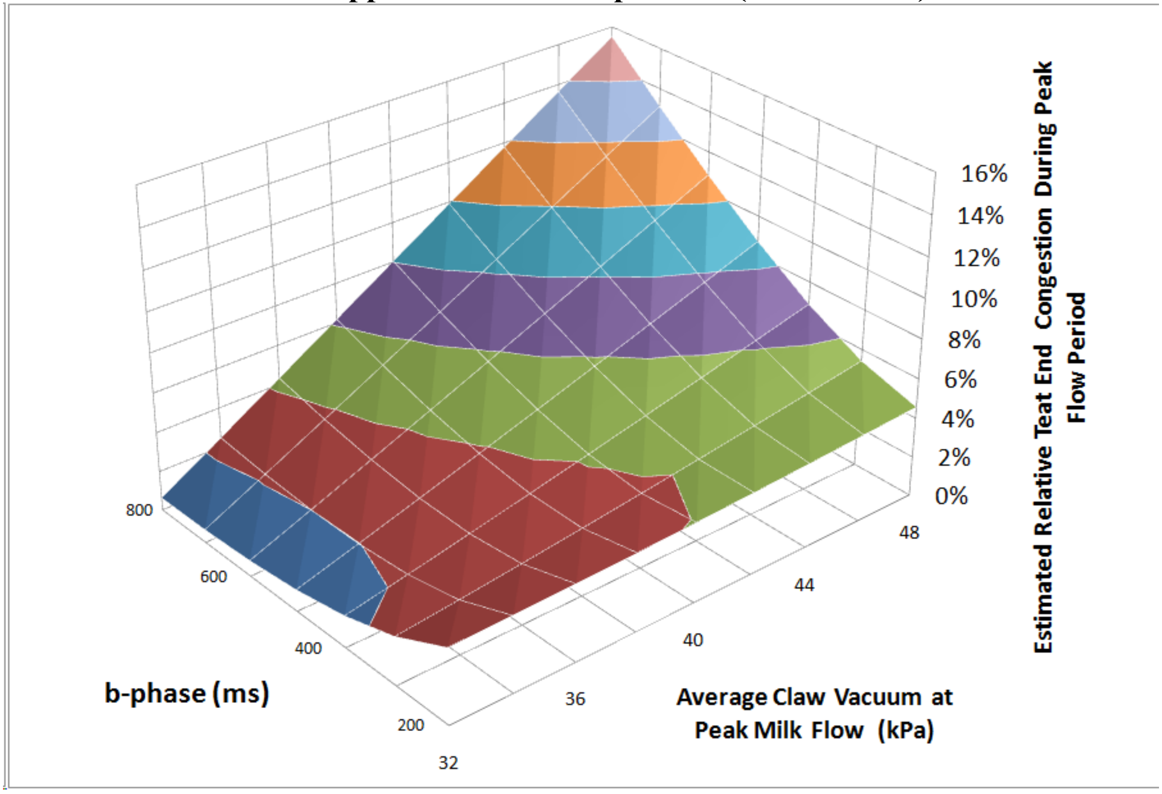
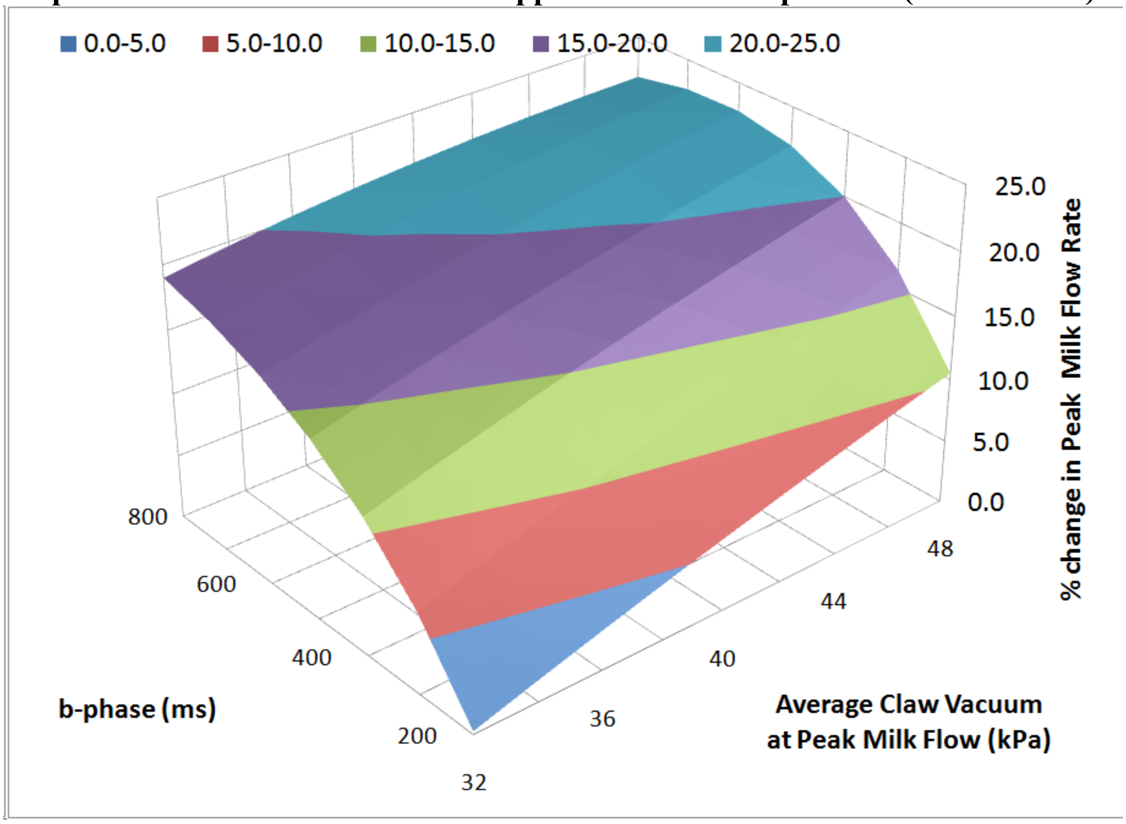


Figure 2. Percentage increase in average milk flow rate for increasing average claw vac. and b-phase duration for a liner which applies medium compression (OP = 12 kPa).



Take Home Points

- Sanitation is the predominant effect on mastitis risk. Keeping bacteria away from the teat end is the most effective way to reduce the incidence of mastitis. Use the tools presented here to aid in diagnosis and mitigation.
- Milking is a compromise between quickness, gentleness and completeness. To minimize mastitis risk, don't sacrifice gentleness at the expense of quickness or completeness.
- The average vacuum in the claw at peak flow and during low flow are the most important vacuum measurements for the milking machine. Start here and don't over-analyse other less important measures (such as vacuum fluctuation).
- Use teat condition to assess the adequacy of the milking vacuum level and the liner.

Acknowledgements
To the giants upon on whose shoulders I stand, especially Frank Dodd and Graeme Mein.

References

Details of the specific references in this paper as well as a plethora of other milking machine testing procedures can be found at the University of Wisconsin Milking Research and Instruction Lab web sites using the search function: www.uwex.edu/uwmril

IDF 215: 1987. Machine milking factors affecting mastitis - a literature review. In International Dairy Federation Bulletin 215, Machine Milking and Mastitis, pp 2-32.

Mein, G.A. 1992. Action of the cluster during milking. Machine Milking and Lactation, eds. A.J. Bramley, F.H. Dodd, G.A.Mein and J.A. Bramley. pp122-123. Insight Books, VT, USA.

Mein, G.A., D.J. Reinemann, N. Schuring and I. Ohnstad, 2004. Milking Machines and Mastitis Risk: A Storm in a Teatcup. Proceedings of the 43rd annual meeting of the National Mastitis Council, USA

Mein, G.A., and D.J. Reinemann, 2007. Making The Most Of Machine-On Time: What Happens When The Cups Are On? Proceedings of the 2007 meeting of the NMC.

Mein GA and DJ Reinemann, 2009. Biomechanics of Milking: Teat - Liner Interactions. Paper Number: 09743, Written for presentation at the 2009 ASABE Annual International Meeting, Reno, Nevada, USA

Ohnstad, I, GA Mein, JR Baines, MD Rasmussen, R Farnsworth, B Pocknee, TC Hemling and JE Hillerton, 2007. Addressing Teat Condition Problems. Paper presented at the annual NMC meeting. Teat Club International contact: ian.ohnstad@thedairygroup.co.uk

Reinemann, DJ, GA Mein, MD Rasmussen and PL Ruegg, 2005. Evaluating Milking Performance, International Dairy Federation, Bulletin 396/2005, Brussels, Belgium, 29 pp.

Reinemann, DJ, RD Bade and PD Thompson, 2008. Method for Assessing Teat and Udder Hygiene. Paper No. 083796, Written for presentation at the 2008 ASABE Annual International Meeting.

Ruegg Udder hygiene Scoring chart is available at:
http://www.uwex.edu/milkquality/PDF/UDDER%20HYGIENE%20CHART.pdf