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MILK HARVESTING SYSTEMS FOR HIGH-PRODUCING COWS

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SUMMARY

The principles for milking the high-producing cow are the same as for any other dairy cow: her teats should be clean and dry for milking; she should be milked gently, quickly and completely with minimal machine stripping or overmilking. However, these principles need to be applied in different ways because high-producing cows have: 1) a lower pre-milking stimulus requirement compared with low-producing cows, 2) higher peak milking rates and higher average flowrates (in spite of this, high producers take longer to milk), 3) poorer teat-end condition, 4) higher risk of new mastitis infections.

Although less time and effort is needed for deliberate manual stimulation in high-producing herds, there is a progressively greater need for meticulous care and attention to ensure teats are clean and dry before milking to minimize the increased risk of mastitis. Healthy teat skin provides the best defence against all types of mastitis pathogens. Teat condition can be improved, and milking times per cow reduced by use of excellent milking procedures and adjusting the take-off settings of automatic detachers.

The new performance-based ISO international standards for milking installations can be used, with confidence, to evaluate the “system” components of existing milking systems. The results of milking-time tests (measurements or observations made while milking cows) are the best and most direct indicator of the performance of milking units.

INTRODUCTION

This presentation is a reappraisal of a paper produced for a seminar on "Managing the 30,000-pound Herd" organized by the American Dairy Science Association in 1992 (1). At that time, it was stated that existing national and international standards for milklines and milking units might not be adequate to cope with the higher milk flow rates from high-producing herds. Compared with the challenges of feeding and breeding management for a herd averaging 45 kg milk per cow per day throughout lactation, however, it was concluded that milking was likely to be the easiest part of managing such a herd. The top cows in excellent herds were producing at or above this level six years ago, and they were being milked successfully.

A number of interesting papers on the science or practice of milk harvesting have been published in the intervening six years. The new information supports some of the conclusions presented in 1992 but other conclusions need to be modified now.

What’s new since 1992? This paper provides a brief outline of the advances in knowledge, experience and understanding which support or challenge the 1992 recommendations and which will continue to change milk harvesting practices and systems.

Pre-milking udder preparation

In 1992, it was concluded that present-day, high-producing Friesian/Holstein cows appear to need little or no manual stimulation to maximize their milk yield. Because the "half-life" of oxytocin in the blood is about 4 min, oxytocin concentration is seldom a limiting factor. Therefore, good pre-milking udder preparation should ensure that teatcups are applied to visibly clean dry teats that are "plump" with milk, with a minimum of time and effort.

Subsequently, an excellent review and analysis of research herd studies in the US and Europe by Reneau and Chastain (2) concluded that:

- although some cows may come into the parlour dripping with milk, less than 10 s of cleaning and teat manipulation is not an adequate stimulus for consistent letdown response in all cows, especially those in late lactation;
- a teat cleaning and drying procedure that results in a quality stimulus of 10-20 s is adequate to sanitize teats and achieve consistent milk letdown in most cows;
- the optimum "window of time" to apply teatcups is 60-90 s after the cow's teats and udder are first touched by the milker (commonly referred to in USA as the "lag-time"). This window allows time for milk letdown to occur in most cows and makes optimum use of the milk ejection hormone.

Analysis of the combined data from five independent US studies (2) indicated that a stimulus of 10-20 s per cow and a time-delay of 60-90 s after the teats are first touched by the operator reduced average milking time per cow by 0.6 min (a gain of more than 10%), increased mean milk yield per cow by 0.3 kg/milking (a gain of 1%), and resulted in optimum parlour throughput. Reducing the machine-on time has important consequences for improved teat condition, as we shall see later.

Put Cups on when Teats become Plump with Milk: Picking the best time to attach teatcups has benefits for cleaner quicker milking out, improved teat condition and slightly higher milk yield per cow (2,3,4). Putting cups on too soon usually results in teatcup crawling during the first minute of milking. Teatcups will crawl higher up the teats if milk flow slows or stops at this time because "drainage" milk has been removed from the udder cistern and teat sinuses before the main milk is ejected from the alveoli into the milk ducts and cisterns. When teatcups crawl early in milking, then milk harvesting is less complete and less efficient near the end of milking because the milk pathways between the cistern and teat sinus become more restricted more quickly.

In many herds milked with an otherwise good milking routine, the simplest way to match the timing of cup application with milk ejection would be to delay the time of cups on by 30-60 s. On rotary platforms, this change might require nothing more than moving the cups-on operator to a position about 60 s past the cow entry point.

As a simple check, watch the claw bowls during the first minute of milking. When teatcups are applied too soon, milk flow into the claw bowl typically slows or stops after about 15-20 s of initial flow, then full flow does not start (or restart) until about 1 min after cups on.

Peak milking rates, average flow rates, and average milking time per cow

Contrary to the expectations of many farmers, it is not reasonable to expect high-producing cows to milk out in 5 minutes flat. Although peak milk flow rates for top cows in early lactation averaged 5.5-5.7 kg/min, their average milking times were relatively slow. Top cows milked twice per day took nearly 10 min/cow to milk (average yield = 25 kg/milking) while the group milked thrice daily took almost 7 min for an average yield of 16 kg/milking (1).

Other studies published since 1992 (2,5,6,7) provide much better evidence for the broad guideline that:

- cows with an average yield of 10 kg milk per milking should milk in about 5 min (plus or minus 1 min),
- cows averaging 15 kg milk per milking should take about 6 min (plus or minus 1 min),
- add about 1 min to average milking time per cow for each additional 5 kg of milk per milking.

If teatcups are applied too soon, before milk letdown occurs, these guidelines for typical average milking times should be extended by about 1 minute.

Teat condition

Healthy teat skin provides the best defence against all types of mastitis pathogens. Furthermore, smooth healthy teat skin is easier to clean and easier to keep clean compared with rough or damaged teat surfaces. In 1992, comprehensive data from Sieber (8) was used to illustrate the general deterioration in teat end condition associated with increasing 305-day milk production. Cows which produced less than 5500 kg of milk in a 305-day period had a much higher proportion of normal teat ends (30%) than higher producers. The proportion of teat ends classified as "normal" fell to less than 9% for cows which produced more than 8200 kg of milk in 305 days. Sieber's results showed that the severity of teat end abnormalities increased and the proportion of normal teat ends decreased as the average milking time of individual cows increased from 4 min or less to 6 min or more.

Based on these highly significant changes, poorer teat end condition seemed to be an unavoidable and inevitable consequence of milking high-producing cows (1).

This conclusion was premature! A Danish study (9) has provided the springboard for a "quantum leap" towards better teat condition for high-producing cows milked in US dairy herds. Milking time was reduced by 0.5 min per cow with no loss of milk yield when the end-of-milking setting for automatic cup removers was raised from a flow rate threshold of 0.2 to 0.4 kg/min. Teat condition improved markedly in the early detachment group of cows. Incidence and prevalence of sub-clinical mastitis were not affected but significantly fewer cows in the early detachment group developed clinical mastitis (9).

During the past 2 years, the threshold flowrate has been increased from a default setting of 0.3 kg/min (for BouMatic detachers) to 0.4 kg/min for herds milked twice per day, and to levels as high as 0.7 kg/min for some herds milked thrice daily. At the same time, the typical setting of 13 s time delay for cup removal has been shortened to 0-5 s. The net effect, in the commercial herds involved in the field study, has been to reduce milking times by up to 1 min or more per cow with no loss of milk yield, no change in SCC or mastitis levels. In addition to quicker milking, the major benefits have been improved teat condition and calmer cows, especially the fresh cows. The most surprising discovery of this on-going experimental work has been to find so little milk left in a typical udder following early removal. For example, average strip yield is a mere 25 ml per cow in the herd with the highest threshold setting of 0.7 kg/min and 3 s delay time.

It is tempting to conclude that cows milk out more quickly and completely if the teat tissues can be maintained in a soft, supple and compliant condition. It is likely that other factors have contributed to these excellent results, however. To date, the results have been obtained in herds with good pre-milking teat preparation, calm consistent milking routines, narrow-bore liners, and milking units that are positioned carefully on the udder by the operator(s) at the start of milking.

New mastitis infections

A simulated genetic selection study in Germany indicated that incidence of mastitis will increase with increasing milk production (10). Given the present rate of genetic gains for milk production, new infection rates will increase by about 1% per year without positive selection for udder health in a progeny-testing program (M. Goddard, personal communication).

Many factors contribute to an increased infection risk for high-producing cows. Apart from the greater disease risk associated with their faster metabolic rates, the teats of these top cows tend to leak more easily and more frequently when they walk or when they lie down. Leaky teats probably result in higher infection risk. Results of a series of milking experiments involving high bacterial challenge showed clearly that cows which milk faster have a higher risk of infection (11). These results supported earlier work showing that cows with more patent teat canals also had a higher risk of infection during their dry periods (12). Thus, high-producing cows may have a higher rate of new infection because of the indirect relationship between high production and high milking rates (i.e. more “open” teat canals).

Another contributing factor may be that liners slip more frequently on high-producing, tight-uddered cows (13). It is well-known that liner slip is linked with increased rate of new mastitis infections (14). Furthermore, work in progress in The Netherlands suggests that the rate of clinical mastitis may be higher in cows with poorer teat-end condition. Teat end condition deteriorates as milk yield increases (8) unless the settings for automatic cup removers can be optimized (9).

IMPLICATIONS FOR DESIGNING MILKING HARVESTING SYSTEMS

Units per operator

The likely combination of longer milk-out times and shorter pre-milking udder preparation times in high-producing herds means that milking systems should be designed with more units per operator for more efficient labor utilisation. The effects of daily milk production on cow throughput are illustrated in the modeling results of Reneau and Chastain (2). If milk yield is increased from about 14 to 18 kg per cow per milking, for example, the predicted steady state throughput falls from 68 to 61 cows per hour in a Double-8 parlour, from 80 to 71 cows per hour in a Double-10 parlour, and from 91 to 82 cows per hour in a Double-12 parlour.

In high-yielding herds, highly automated parlours should be planned to provide 20-24 units per operator, i.e. a D-10 or D-12 for 1 operator, or a D-20 for 2 operators. Parlours with one unit per stall are preferred for high-producing herds so that low-level milklines can be installed. The basis for this will be explained later.

The "system" components of a milking system

In the six years since 1992, national and international standards for the construction and performance of milking machine installations have been revised extensively. The revised standards incorporate new performance specifications to provide a common basis for evaluating the great variety of types and sizes of milking systems used throughout the world. For the first time, the main performance specifications are the same for international (15) and American (16) standards. The new performance criteria can be used, with confidence, to evaluate the "system" components of existing milking systems. For designing new installations, each of these standards includes guideline tables of recommended sizes for system components such as vacuum pumps, airlines and milklines. Because of subtle variations in the specified design criteria, some of the guideline tables in the ISO and ASAE informative annexes differ markedly.

These new performance-based standards have led to cost-effective improvements in milking and cleaning performance in many milking systems. In general, vacuum pump capacities, airline and milkline sizes have been reduced in USA but increased elsewhere. In USA, fewer 100 mm (4 inch) milklines are being installed and significantly lower amounts of hot water and chemicals are required to clean milking systems that have been correctly designed. In existing installations, the common problem of inefficient vacuum regulation has been resolved by eliminating unnecessary vacuum pump capacity and by mounting the regulator sensor closer to the sanitary trap.

What is the "right" vacuum level for milking?

According to guidelines given in ISO 5707, the system vacuum should be set to achieve a mean claw vacuum within the range 32-40 kPa during the period of peak milk flow for a representative sample of cows. A recent Danish report on milking at lower vacuum, using mean claw levels within the range 26-39 kPa (17), concluded by endorsing the ISO guideline. On the other hand, market pressure from US dairy farmers is for higher vacuum levels so they can milk more cows per hour and per day. To increase milking speed, some US veterinary consultants are now advising their farmer clients to set the operating vacuum for a milking system with a high-level milkline to 54-57 kPa so that the mean claw vacuum is maintained close to 40-42 kPa.

It is common knowledge that increasing the system vacuum level results in faster milking times. Carefully conducted research studies have shown that milking can be successful with vacuum settings as high as 70 kPa. An added bonus is that the frequency of liner slip is reduced as vacuum level is raised. On the other hand, outbreaks of clinical mastitis, high cell counts, or poor teat condition frequently are linked with an unsuspected high vacuum problem on dairy farms. It is necessary to reach a compromise between machine settings for fast milking and for maintaining healthy teats and udders because the benefit of higher vacuum level may be offset by higher strip yields, higher incidence of teat end abnormalities, and more machine-induced teat congestion and oedema.

Dealers are understandably cautious about implementing advice from a veterinary consultant to set the system vacuum above 50 kPa. Generally system vacuum should be set so that mean claw vacuum during peak milk flow is about 40-42 kPa to milk cows as quickly as possible while still maintaining gentle milking conditions. Nevertheless, provided that cow preparation procedures are excellent and the milking system is adjusted to minimize the low flowrate period of milking, it is possible to experiment with raising the mean claw vacuum level above 42 kPa. This implies that parlors with low-level milklines could be set to a system vacuum above 45 kPa and highline systems could be set above 50 kPa under certain circumstances. Individual milking systems should be modified, before raising the system vacuum, according to the following steps.

a) Reduce the vacuum drop between claw and milkline. Low milking vacuum results from problems such as excessive milkline height, restrictions in the milk tubes, excessive vacuum drop across ancillary components, blocked air vents, excessive air admission through air vents or air leaks into the cluster. Raising system vacuum to compensate for unnecessarily high vacuum drop between the claw and milkline results in a greater increase in claw vacuum when milk flow falls near the end of milking, which is the riskiest time for teat damage, discomfort and new mastitis infections. Therefore, the aim is to keep the milkline as low as practicable. The implication is that low-level milklines are preferred for milking high-producing herds. Furthermore, milk tubes should be as short as possible and any kinked or flattened hoses replaced because they cause slightly greater vacuum drop and slightly slower milking.

b) Minimize detacher take-off delays (preferably less than 5 s) and then optimize the flowrate threshold (that is, reduce the resistance setting). Both scientific evidence and recent field experience suggest that changing the detacher settings will produce much bigger improvements in teat condition and milking speed, compared with the effects of raising the system vacuum or increasing the diameter of the milk hose. When changing detacher settings, remember to monitor strip yields by hand-stripping a representative group of cows before and after making changes.

When the detacher settings are optimized for a given farm, the system vacuum could be raised about 1-2 kPa per week. The system vacuum should NOT be set above 50 kPa if detachers are not installed and/or not optimized and if milking procedures are inadequate.

The veterinary consultant should be responsible for deciding if pre-milking hygiene and management procedures are adequate to reduce the greater risks associated with milking at higher vacuum level.

A competent observer (the dealer or the veterinary consultant) should be responsible for monitoring any changes in the mean strip yields per cow within one week after the system vacuum is raised, and watching for any changes in teat condition during the month after such a change.

Performance of the "milking unit" components of a milking system

The new ISO and ASAE standards become less specific as they get closer to the "cow end" of the machine. There are no specifications for liner bore, effective liner length or liner tension, for example, and no guidelines for weight of the cluster or uniformity of weight distribution between the four teatcups. Similarly, field tests of milking systems usually stop short of any systematic analysis of performance of milking units because most of us tend to measure the things which are easy to measure (such as vacuum pump capacity, system vacuum level or vacuum stability) rather than those which may be more important. As a result, "milking is not going well in some modern milking installations which meet or exceed International Standards Organization standards" (18).

Biological responses of the teats and udder to the milking unit and/or operator.

Details of four of the most practical and useful short-term measures of performance of the milking unit have been described (19). These measures are:

- Mean milking time per cow (relative to the mean yield per cow per milking).
- Frequency of liner slips and falls requiring corrective action by the milker (per 100 cows).
- Amount of available milk left in the udder when cups are removed (mean strip yield/cow).
- Teat condition scored just after milking.

Ideally, teats should be as soft and supple just after milking as before milking. Usually, teats are thicker after milking with wide-bore liners, or after milking at a high vacuum level (20). Teats that are slightly swollen or hard after milking (due to congestion or oedema), or slightly blue or purple in colour (cyanotic) result from machine-induced circulatory impairment. A simple procedure has been developed by for systematic measurement of short-term changes in teat colour, teat firmness, swelling of the teat base, and degree of closure of the teat orifice after milking (21).

Behavioural responses to milking.

Frequency of flinching, stepping or kicking (the "FSK" response) has been proposed as an indicator of comfort/discomfort while the milking unit is on the cow. Preliminary results of cow behaviour in 20 UK parlours indicate that differences in cow behaviour between parlours can be assessed by systematic observation of dunging/urination, paddling/stepping, cow reaction to having her teats touched after milking, and cow entry/exit times (22). The trickiest part of this type of study is the difficulty of distinguishing between environmental effects (such as flies or stall design), operator effects, interactions between machine and operator, and milking machine effects. Furthermore, results in commercial herds will depend to a large extent on whether cows are accustomed to having their teats touched after milking.

Mean claw vacuum measured with an artificial udder as a flow simulator.

A flow simulator (23) provides an easy, convenient and reliable method of measuring **mean claw vacuum, and vacuum drop** through the milk hose and through ancillary equipment such as sensors and milk meters. Results can be compared with ISO specifications for the maximum additional vacuum drop caused by fittings in the milk hose, i.e. not more than 5 kPa at a milk flow rate of 5 kg/min and an airflow of 8 l/min. Furthermore, results can be compared with the mean claw vacuum recorded during milking to estimate the peak milk flow rate of individual cows.

No claims are made for the accuracy of, or the implications of, claw **vacuum fluctuations** measured with the flow simulator (23). The over-riding effects of tiny air leaks past the artificial teats makes such measurements misleading, frustrating and unreliable.

Changes in vacuum measured in the liner mouthpiece chamber.
High mouthpiece vacuum is considered to be uncomfortable for cows but there is not much published information. Recent results (24) link high mouthpiece vacuum to increased teat thickness measurements, poorer cow behaviour and higher incidence of clinical mastitis.

Uniformity of weight distribution between the four teatcups on an artificial udder.
Uneven weight distribution between the four quarters of an udder is one of the most common causes of incomplete milking, uneven milk-out, and liner slips. Ideally, the milking unit should hang squarely on the udder so that about 25% of the total cluster weight is applied to each udder quarter throughout milking. This rarely occurs in practice (22). Incomplete milking has been related to light cluster weight, poor cow position, poor cluster positioning, and lack of indexing for cows in the parlour (22).

CONCLUSIONS AND RECOMMENDATIONS

The new performance-based ISO international standards for milking installations can be used, with confidence, to evaluate the “system” components of existing milking systems. However, these new standards and test procedures are less useful for evaluating the performance of the milking unit. This is partly because most of the ISO test procedures are conducted as “dry tests”, that is, tests conducted with the machine running but not milking, and with only air flowing through the machine. This type of test has been described loosely, but incorrectly, as “static testing”.

The results of milking-time tests are the best and most direct indicator of the performance of any milking system. Milking-time tests describe measurements or observations made while milking cows. Immediate additional testing and service is recommended if:

- cows appear to milk slowly, unevenly or incompletely;
- teatcups slip or fall frequently;
- teat condition is poor;
- or if cows appear nervous or uncomfortable.

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