TEAT MANAGEMENT: LIFE OUTSIDE THE PARLOR

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INTRODUCTION

Infection of the mammary gland with environmental bacterial pathogens is the most significant udder health problem facing the dairy industry in North America and many other parts of the world. Forty years ago, Neave et al. (1966) stated that the rate of new intra-mammary infection is related to the number of bacteria that the teat end is exposed to, and several studies have made associations between clean housing, clean cows and lower bulk tank somatic cell counts (Bodoh et al., 1976; Barkema et al., 1998; Barkema et al., 1999). In addition, Bartlett et al. (1992) found that an index of environmental sanitation based on the amount of manure on the cow and in her environment was a predictor of the occurrence of coliform mastitis, and Ward et al. (2002) noted that in four study herds, the lowest incidence of mastitis occurred in the herd with the cleanest cows and the most satisfactory beds.

Despite the improvements made in so many other areas of the dairy industry, our ability to keep cows clean and to reduce the bacterial load at the teat end has improved little. Increases in herd size, poor stall design, infrequent alley scraping and manure removal, pressure for milkers to increase parlor throughput, and changes in the availability and use of different bedding materials have all worked against significant progress in this area.

The predominant sources of coliforms and environmental streptococci (*S.uberis, S.dysgalactiae, Enerococcus spp.*) are manure and bedding materials. The cleaner we can keep the cows and the lower the bacterial count of the bedding, the fewer problems we will see.

TIME BUDGETS

Once the cow leaves the parlor – what does she do? From an analysis of 250 total 24-hour time budgets, we have collected from 208 cows housed in 17 freestall barns in Wisconsin, the average time spent performing each of five key behaviors is shown in Table 1. On average, cows spend 2.6 h/d milking – reflecting the three times a day milking schedule most large freestall dairies operate at. Other components of the cow's day are also fixed and non-negotiable. The cow has to spend a large proportion of the day eating. The TMR fed, free stall housed dairy cow eats for an average of 4.4 h/d (range 1.4-8.1).

Note that this is about half the time that a grazing cow spends eating per day – pasture cows average around 8-9 h/d eating. She also needs to drink around 95 liters of water per day (more in hot climates) and she will spend an average of 0.4 h/d at or around a waterer. With these fixed non-negotiable time slots, we have already taken 4.4 + 0.4 + 2.6 = 7.4 hours out of the time budget, leaving under 17 hours remaining in the pen.

Table 1. The mean (range) 24-h time budgets for 208 cows filmed over 250 filming periods on 17 freestall barns in Wisconsin

Activity **N=250**	**Mean (h/d)**	**Range (h/d)**
Time lying down in the stall	11.3	2.8-17.6
Time standing in the stall	2.9	0.3-13.0
Time standing in the alley	2.4	0.2-9.4
Time drinking	0.4	0-2.0
Time feeding	4.4	1.4-8.1
Time milking	2.6	0.9-5.7

Time left in the pen will be spent performing three activities – lying down, standing in an alley and standing in a stall. The average freestall cow spends 2.4 h/d standing in an alley socializing, moving between the feed bunk and stalls and returning from the parlor. Once in the stall, the average cow spends 2.9 h/d standing in the stall (range 0.3-13.0) and 11.3 h/d lying in the stall (range 2.8-17.6) on average – but note the wide ranges in these behaviors. Lying behavior is typically divided into an average of 7.2 visits to a stall each day (called a lying session), and each session is categorized by periods standing and lying – called bouts. The average cow has 13.6 lying bouts per day and the average duration of each bout is 1.2 h (range 0.3-2.9). Most cows will stand after a lying bout, defecate or urinate, and lie back down again on the contra-lateral side.

From this analysis of cow behavior, it is clear that in order to limit the bacterial challenge at the teat end we must:

1. Limit the splashing of manure on the udder as the cows walk around alleyways
2. Limit contamination of the stall bed when the cow rises in the stall and defecates
3. Provide a comfortable stall so that we maximize lying time and time out of the alleyways

MANURE TRANSFER TO THE TEAT END

Several different methods of hygiene scoring have been documented (Cook, 2002; Schreiner and Ruegg, 2003; Reneau et al., 2005) and some have been used to prove that poor hygiene results in udder health problems. Schreiner and Ruegg (2003) used a 4-point udder hygiene scoring system to document the degree of contamination of 1250 cows in 8 herds. Udder hygiene scores averaged 22% score 3 and 4 and 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.

Reneau et al. (2005) used a more complex scoring system to document hygiene in 1,093 cows in 8 herds and showed a significant association between udder and lower leg hygiene and individual cow linear score measured within 2 days of recording.

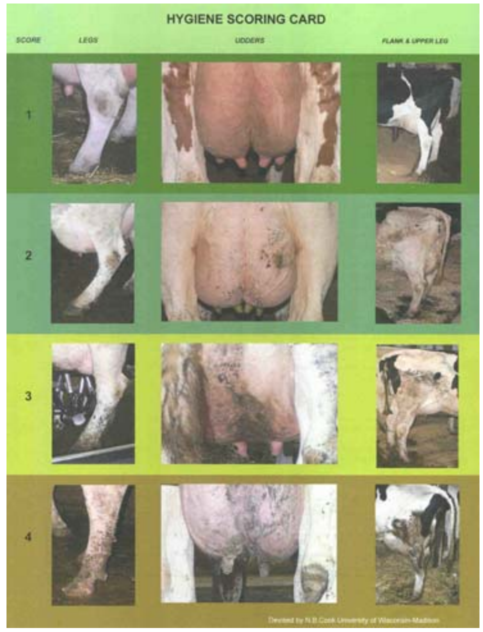
We have used the simplified multi-zone hygiene scoring system in Figure 1, scoring the udder, lower legs and upper leg and flank zones of cows on a 1-4 scale to communicate the reasons for manure contamination of the udder. There are four basic manure transfer mechanisms to the udder, and the relative importance of each differs with the type of housing under consideration:

1. **Direct Transfer**. Cows may lie down in a manure contaminated stall or bedded area (or sometimes in a traffic alley!) and transfer bacteria directly to the udder.
2. **Leg Transfer**. Cows may walk through manure, coating their feet and legs, which transfers bacteria to the teat ends and bedding when the cow lies down and the udder comes to rest (Abe, 1999).
3. **Splash Transfer**. Cows walking though deep liquid slurry will splash manure up toward the udder.
4. **Tail Transfer**. In some situations, the tail may become heavily contaminated with manure and transfer bacteria to the rear udder and flank areas (Abe, 1999).

The pattern of manure contamination and the mechanism of transfer therefore becomes a very important concept to communicate to the herd owner and we calculate the proportion of scores 3 and 4 in each zone, rather than a mean hygiene score. During investigations, we typically score 20% of the cows in each pen, or all of the cows in small herds.

Figure 1. A hygiene scoring card which documents the degree of manure contamination on a 1-4 scale for each of three zones, the udder, the lower leg

and the upper leg and flank. The score sheet is available at http://www.vetmed.wisc.edu/dms/fapm/fapmtools/4hygiene/hygiene.pdf



The hygiene scoring data from 60 farms collected by the SVM food animal production medicine group suggests that on average, 16-23% of udders are score 3 and 4 and have an elevated risk of infection (Table 2). While tie stall cows generally have cleaner lower limbs and less leg transfer, direct transfer is the predominant means of manure contamination of the udder – from manure deposited on the stall surface. Upper leg and flank scores are usually much poorer than in free stalls, reflecting the risk associated with spending around 22 hours per day in a tie stall.

In contrast, the lower legs of free stall cows are far more contaminated than tie stall cows and leg transfer is a significant risk for udder contamination. Splash transfer in poorly draining alleys is also significant.

Table 2. Median and upper quartile proportion of hygiene scores 3 and 4 for each zone for cows in 60 Wisconsin dairy herds by housing type (46 Freestall and 14 Tiestall).

Housing Type	**Proportion Hygiene Scores 3 and 4 (%)**					
	Udder		**Lower Leg**		**Upper Leg and Flank**	
	Median	**Top 25%**	**Median**	**Top 25%**	**Median**	**Top 25%**

Freestall n=46	16	10	64	52	15	11
Tiestall n=14	23	13	22	13	26	19

There are multiple reasons for the state of leg hygiene that we see in freestall barns – these include: frequency of manure scraping and removal, stocking density, width of the alley, type of flooring, pen layout, length of the pen and slope of the alley. Unfortunately, there is very little that can be done to influence it once a facility has been built.

In the design phase, we can work towards keeping cleaner cows by recommending two-row pens instead of three-row pens – they have 20% more alley surface area per cow, putting a gentle slope (~1-2%) on the alley so that urine drains, building wider alleyways and creating deeper grooving patterns. Slatted floors may work for smaller farms, but I have yet to be convinced that they work for pens with more than 100 cows – they are simply too traumatic to the cow's feet. Similarly automatic scrapers and flush systems that operate while the cows are in the pen have not yielded significantly improved leg hygiene overall.

A very common finding however, is for cows in sand bedded herds to be cleaner than in mattress herds bedded with sawdust (Table 3). This finding may be due to the cleaning effect of sand, differences in cow behavior in barns with the two different types of bedding surface, and less slipping and splash transfer in sand bedded herds.

Table 3. Least squares mean (SE) hygiene scores (Proportion scoring 3 and 4 for each zone) obtained independently by two observers from a minimum of 20 cows in the high group pen on 12 free stall herds (6 sand and 6 mattress) compared using 1-way ANOVA.

Zone	**Proportion Hygiene Scores 3 and 4 (%)**		**SE**	**P Value**
	Sand	**Mattress**		
Udder	16.7	33.3	4.2	0.02
Lower Leg	39.2	74.2	8.6	0.02
Upper Leg and Flank	1.7	11.7	2.1	0.01

LIMITING MANURE CONTAMINATION OF THE STALL BED

Cows defecate on the stall platform when they stand in the stall and when they are lying down. With cows entering a stall 7 times a day for 14 lying bouts, we must design the stall so that when she is lying, we position her so that her rear end lies over the back edge of the stall or the stall alley, and when she is standing, she defecates and urinates into the alley, not into the stall. This is a difficult challenge!

The cow is positioned in the stall (something we refer to as 'indexing') by several physical and social barriers. We tend to see more diagonal lying and more stall contamination when there are obstructions to the forward lunge and bob of the head, obstructions to the forward thrust of the front leg as the cow rises and when the resting area is of insufficient length.

Forward lunge obstructions may be physical – for example, the stall is simply too short to allow forward lunge, or a divider loop mounting rail is placed in the bob zone at the end of the lunge between 4 and 38 inches above the stall surface, or social – this occurs in stalls positioned in a head to head layout, where the platform is too short. Even though there may be no physical obstructions to front lunge, timid cows will not lunge into the face of a dominant cow when the space is occupied in front.

When cows rise in the stall, they prefer to extend their front leg forward to take weight, before raising the back end. To do this, there must not be an obstruction higher than about 4 inches above stall surface in the brisket area. Many poorly designed stalls have brisket locators that are higher than 4 inches and in these stalls the cow must modify how she rises – unfolding her front legs rather than launching one forward for stability, and some cows lie diagonally , so that their front legs have a little more space when they get up.

The negative consequences of the design flaws already mentioned have been tolerated in the industry because we have used restraint to limit the effects of diagonal lying. Stalls have been built that are too narrow and too short for the cows. While we may be able to keep these stalls clean, we have only recently realized that the reduction in lying time caused by providing insufficient space has cost us dearly in lameness and culling.

Frequently, farmers respond to stall contamination by altering the easiest thing to move in a stall – the neck rail. Neck rails position the cow in the stall when she is standing and they are often moved too close to the rear curb, making cows perch half in and half out of the stall. Even worse, the neck rail is so far back and too low so that the cow must hit it when she rises in the stall. This is unacceptable.

While a contaminated stall maybe a risk for udder infection, an unused stall is most definitely a risk for inadequate rest, lameness problems and early herd removal. We therefore have to find the right balance between comfort and cleanliness. We have taken the view that we are going to build stalls that provide adequate resting space for the cow – whatever their size, and make adjustments to stall design that help index the cow and reduce contamination of the bedding.

Most mature Holstein cows now measure 1.9m from nose to tail when they are lying down – so we build stalls against a side wall 3m long and we have lengthened the head to head platform to 5.2m, to provide lunge space in front of the cow. In head to head stalls, we provide a deterrent wire, covered with 7cm wide PVC pipe, level with the tops of the cows' heads, to limit problems of cows passing through the open front, while still keeping the front lunge and bob space free. Other dimensions are given in Table 4, with a diagram in figure 2.

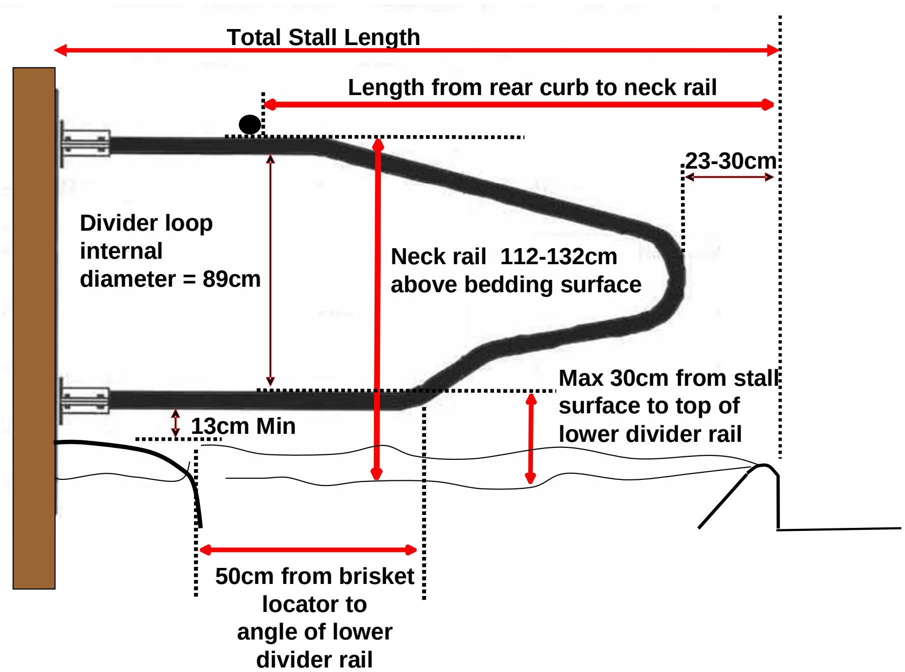
Table 4. Target stall dimensions for dairy cows with a range of different body weights

Stall Dimension (cm)	**Body Weight Estimate (Kg)**				
	455	**545**	**636**	**727**	**818**
Total stall length facing a wall	244	244	274	305	305
Curb to curb distance for head to head platform	488	488	518	518	549
Distance from rear curb to brisket locator	163	168	173	178	183
Center-to-center stall divider placement (Stall width)	112	117	122	127	137
Height of brisket locator above stall surface	7.6	7.6	10	10	10
Height of upper edge of bottom divider rail above stall surface	28	28	30	30	30
Height below neck rail	112	117	122	127	132
Horizontal distance between rear edge of neck rail and rear curb for mattress stalls	163	168	173	178	183
Rear curb height	20	20	20	20	20
Rear curb width (loose bedded stalls	15	15	15	15	15

For indexing the cow without causing injury and discomfort, we use a divider loop with the upper edge of the lower divider rail located at 30cm above the stall surface, where the angle of the loop occurs at 50cm behind the brisket locator. The interior diameter of the loop is 89cm, which places the lower edge of the neck rail at 127cm above the stall surface.

While some farmers have removed brisket locators that are too high or too close to the rear curb, we believe that we need something to help position the cow when she is lying in a wider stall. Smoother more rounded brisket locators that are 12cm high or less have become available and are moderately effective, although some cows choose to lie over the top of them. We have developed a concrete brisket slope design which appears to position the cow effectively and enable her to rise without obstruction to her front leg movement – by sloping the concrete gently to allow the foot to be placed on the slope when rising.

Figure 2. Configuration of freestall divider loop, brisket slope and rear curb.



Neck rails are located in mattress stalls directly above the correctly located brisket locator – so that the cow is able to stand squarely in the stall. In deep bedded stalls, where the neck rail is at least 122cm above the surface, we move the rail back a distance equivalent to the width of the rear curb, so that cows take a step back and perch half in and half out of the stall. While we will not tolerate this behavior in a flat, mattress stall, we are prepared to tolerate it in a deep loose bedded stall, because the front foot elevation is much less and the problems of managing a deep bed soiled with urine and feces are too great.

MAXIMIZING LYING TIME

Cows lie down for longer in stalls with softer surfaces, and in the past four years we have seen the marketing of softer foam filled mattresses with the aim of providing more cushion. Attempts to provide increased cushion with organic bedding are usually met with disaster due to the retention of material with a high bacterial count. I maintain that cushion must be provided by the mattress itself and organic bedding used on top of the mattress is merely there to absorb moisture. As such it should be removed and replaced every 24 hours.

Many larger freestall dairies with anaerobic digesters have persisted with the approach of using digested manure solids in a deep loose bed, which is very comfortable and soft, but very few have managed to control udder health in the upper Mid-West. It is likely that hot dry climatic conditions with low humidity are required to make this option successful.

We have observed the greatest success in maximizing resting times for both lame and non-lame cows and improving udder health status using sand bedding – either deep beds, or 2-3 inches of sand over a mattress fitted a few inches below a raised curb. This latter design, called the Pack Mat™ has the advantage of using half as much sand as a deep bed, while still maintaining the behavior advantages for lame and non-lame cows that we have observed in deep sand stalls.

Sand stall management has not been without its challenges. Fresh sand has to be added to the stalls 1-3 times per week and the surface needs to be cleaned of manure and leveled frequently. We prefer systems that redistribute sand from beneath the divider loops over rakes that stir sand up from deeper in the stall. Sand particles must also be cleaned from the teats prior to milking which often requires inserting an extra dry wipe into the teat preparation routine. In a database of over 70 herds that we store for mastitis herd investigations, sand bedded herds appear to average ~80,000/ml lower bulk tank somatic cell count (BTSCC) than herds using organic bedding and almost one third fewer clinical mastitis cases. These udder health savings are worth approximately $60 per cow per year.

Mastitis outbreaks do occur in sand bedded facilities, and while fresh sand may be inert and have a very low bacterial count, sand contaminated with milk, urine and feces may grow large populations of bacteria. Commonly, sand bedded facilities start to see contamination problems in their third year after construction, and clinical *Klebsiella* mastitis is a common presentation in the hot summer months in Wisconsin. Table 5 shows the median and upper and lower quartile bedding counts for coliforms and streptococci for 82 sand bedding samples collected from 23 farms. These counts would suggest that coliform mastitis would not be a risk, but streptococcal infection would be a major problem. In fact, in these 23 herds, the proportion of mastitis due to gram negative pathogens averaged 75%, and mastitis due to streptococci was rarely a major problem.

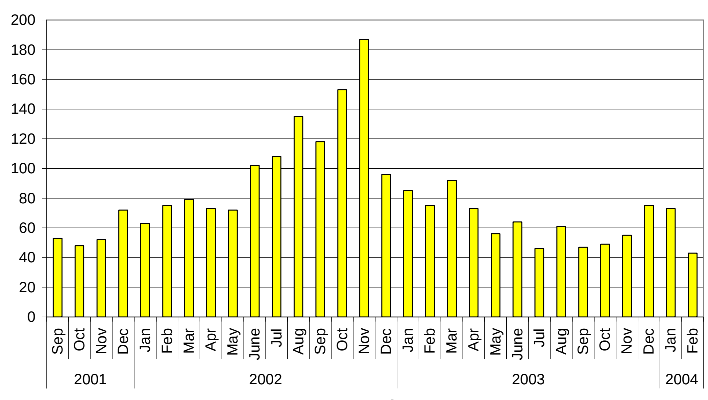
Table 5. Coliform and streptococci counts (CFU/ml) for 82 used sand bedding samples collected from random stalls from 23 herds.

Used Sand Bedding Samples	**Count CFU/ml**	
	Coliform Count	**Streptococci Count**
Median	50,000	6,650,000
Upper Quartile	10,000	2,612,500
Lower Quartile	134,250	14,787,500

We have found significant gram negative mastitis problems (*Klebsiella spp* in particular) at a coliform threshold of ~100,000/ml, and this is typically used as our intervention level rather than the 1 million CFU/ml widely quoted in the literature. Even lower counts have been used in very cold weather during the winter. Streptococcal counts in sand can rarely be kept below 1 million /ml, and high counts usually reflect the duration of sand retention in the beds – ie. we can keep the count lower by increasing the turnover rate of the material. In my experience, associated streptococcal mastitis problems are a good indicator of poor teat end cleaning procedures in the parlor.

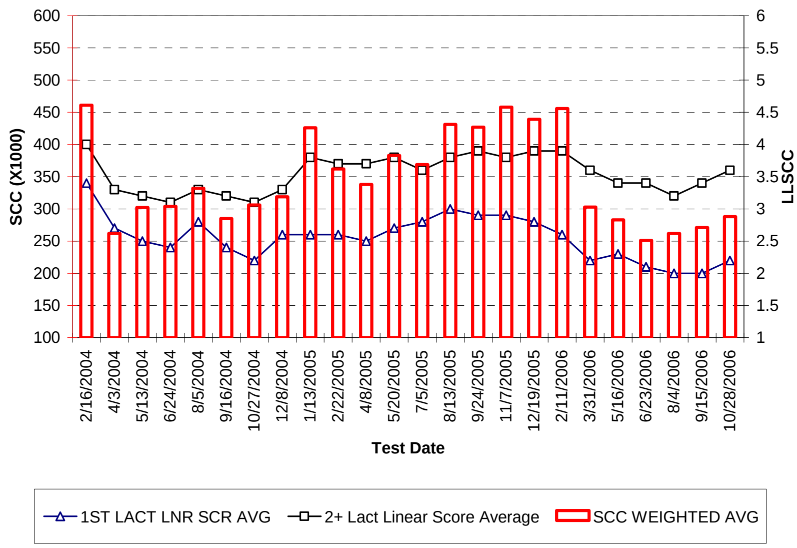
We have successfully improved the rate of clinical mastitis and lowered herd BTSCC by removing contaminated sand bedding and changing to coarser screened sand rather than fine sand (Cook, 2006). The 1314 cow dairy shown in Figure 3 was suffering an extremely high gram negative clinical case rate in the summer of 2002. Following sand removal and replacement, the case rate was halved in 2 months and returned to target levels within 6 months.

Figure 3. Clinical quarter cases of mastitis by month before and after sand removal from the free stalls in a 1314 cow dairy in November 2002.



A 1400 cow dairy was visited in February 2006 with contaminated compacted sand stalls. The sand was removed and replaced with coarse washed mason sand. Not only did cow comfort improve, but clinical treatment rate and bulk tank SCC was halved within one month (Figure 4). In these herds, we now keep the coliform counts in the bedding less than 10,000/ml and see many fewer gram negative clinical cases.

Figure 4. Somatic Cell Count response (monthly average weighted SCC, forst lactation and mature cow linear score) at a 1400 cow dairy where sand was removed from stalls in February 2006 and the fine sand replaced with coarse washed mason sand.



It is now commonplace for our sand bedded herds to completely remove the sand from the rear third of the stall every 6-12 months and start afresh.

Correlations between bedding counts and teat end contamination have been made (Zdanowicz et al., 2004) and confirm that higher correlations are generally made for organic bedding than for sand. In particular, the correlation between streptococcal sand bedding counts and teat end counts is low (r=0.28, P=0.06), compared with that for *Klebsiella spp* (r=0.40, P<0.05). More research is needed to fully understand the transfer mechanisms of pathogen groups from the bedding to the udder, but in the mean time, these anecdotal reports confirm that dramatic improvements in udder health can be achieved by lowering the teat end challenge from contaminated bedding.

The secret to the success of certain types of sand, including recycled sand may be in the particle size as it is apparent that there are few differences in bacterial load (Kristula et al., 2005). Note the differences in particle size between the three types of manufactured sand in table 6. While we associate torpedo and mason sand with relatively few udder health problems, we have encountered mastitis issues with the use of #8 sand that have been reduced by switching to mason sand. The large amount of fine particles in the #8 sand may create a different microenvironment in the sand bedding, may lead to greater compaction and reduced cushion and surface drainage, or it may simply be that the finer sand is more difficult to clean off the end of the teat than the more coarse sand particles, leading to greater teat end contamination.

Table 6. Sieve analysis for different grades of sand. Proportion of the sand passing through each screen size is listed, where size 4 is the largest opening and size 200 the smallest.

Screen Size	Torpedo Sand	Mason Sand	#8 Sand
4 (largest)	99	100	100
8	84	99	100
16	67	93	99
30	50	80	96
50	21	15	47
100	4	0	9
200 (smallest)	0	0	1.5

CONCLUSIONS

There remains ample evidence in the field that clinical mastitis relates to the exposure of the teat end to large numbers of bacteria. Udder hygiene and bedding management remain the cornerstones of limiting this bacterial exposure to environmental pathogens, and well managed sand bedded stall facilities continue to out perform other systems of management with regard to udder health.

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