Cow Comfort Issues in Freestall Barns

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Large scale dairies have become very popular in the past decade because of the adoption of new housing styles and the development of new production-enhancing technologies. These technologies allow producers to enhance labor efficiency, increase profits and improve the quality of life for both dairy owners and workers. To support the high production levels expected of or modern dairies, facilities must be designed to provide a comfortable place for cows to lie. Designs must also consider the initial and on-going cost to maintain the stalls. These objectives often are antagonistic and the producer must select a design that considers both criteria. Current research has shown stall usage increases with increased stall size and the use of certain stall base materials. The task for the producer is to weigh the value of the expected increased milk production, lower health costs, and/ or increased longevity in the herd against the extra costs incurred.

Freestall Design – Manure Curb Height

The key freestall dimensions to consider are curb height, stall width, stall length, neck-rail height, and freestall divider mounting specifications. If curbs are too low, manure may enter the stall when manure it being removed from the barn and if too high, cows will be reluctant to back out of the stalls. A curb height of 10" is normally recommended, but often will be 9.5" if a 2"x10" plank is used to form the curb. Some people advocate a lower curb height. For example, Cook and Nordlund, 2004b, recommends an 8" curb and moving the neck rail back the width of the curb to force cows to stand in the perched position with sand based stalls. They are not concerned with cows perching since their work indicates cows do not spend prolonged times standing half in and half out of sand stalls and the elevation of the front feet will be less with the lower curb.

Construction of the manure curb differs for stalls filled with bedding materials (sand, manure solids, lime, etc.) than from flat surface stalls that are covered with a cushion of some type (mattresses, mats, waterbeds, etc.). Manure curbs for sand stalls normally are 4-6" wide and are used to hold the bedding material in the stall. Since the level of the bedding material changes with the amount of material in the stall, the manure curb is often chamfered in the direction of the cow to prevent the cow from having to lie against the sharp edge when the bedding level is low. With flat surface stalls, the height of the added cushion needs to be considered. Having a 10" curb with a 4" mattress in effect becomes a 14" curb. Most recommendations for this total curb height are between 8 and 12".

Freestall Design – Stall Base Slope

Normal recommendations have been to have stall bases constructed with a slope of 1-4% from the manure curb to the brisket locator. This has been done because cows prefer to lie uphill and to allow any liquids (urine, milk, rainwater, etc.) entering the stall to drain away from the stall bed and to the manure alley. Sand stalls are often filled fuller in the front than in the back to provide this upward slope. If stalls ever become lower in the front that the back they will cause problems for the cow attempting to rise. Field observation suggests that excessive slope can cause cows to lie with their feet protruding into the manure alley. No research was found to support the choice of this dimension, but local contractors have been installing mattresses over bases with 2-3% slopes and reported no problems. Sand stalls when freshly filled may have a greater slope upon filling, but cow's feet penetrate the surface and they move sand to make a comfortable bed.

Freestall Design – Cow Space Needs

Figure 1 shows the motion of a cow rising or reclining. It shows the three areas that must be provided within the freestall: body space, head space and lunge space. Different authors have suggested the proper length of each of these based on their work. Obviously, these values vary with the size of the animal.

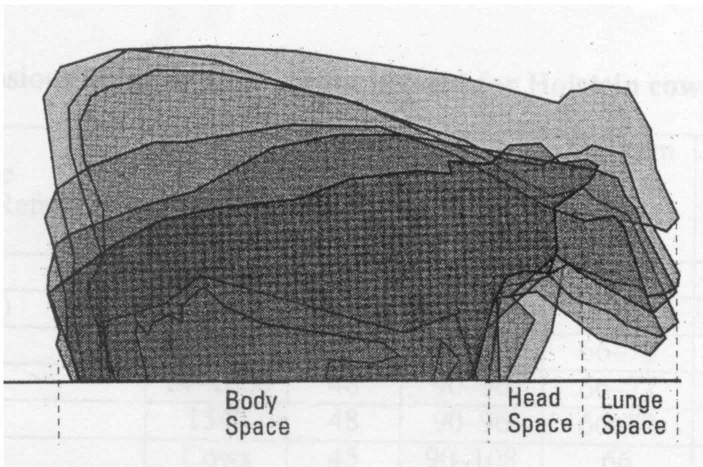


Figure 1: Space envelop for rising and resting cow.

Tables 2 and 3 show some of the variation in current recommendations. Both show the need for stall length to increase as animal size increases, but assume different animal weights. It is commonly accepted that the average Holstein cow in the U.S. is larger than a decade ago, and lends credibility to increasing stall sizes. Genetics, nutrition and the use of custom heifer raising possibly have caused this increase in size. When making a decision on stall size, you should know the relative size of your cows and how you plan to group them. Making the stall size the same for all pens of a new facility allows the manager flexibility on how to use the pens, but complicates the decision on what size stall to build. Building all stalls to meet the needs of your largest cows will result in smaller cows using the stalls incorrectly, but making stalls too small for large cows will make them uncomfortable and having the potential to decrease stall usage. A quick summary of cull cow receipts may be used to define the normal range of cow sizes in your herd.

Table 2: Suggested freestall dimensions for various size cows (McFarland 2003).

Cow Weight:	1200 lb	1450 lb	1650 lb
Body Space	62-64"	66-68"	70-72"
Head Space	17"	18"	19"
Lunge Space	14"	15"	16"
Total Stall Length-Open Stall Front	6.7 to 7.2'	7 to 7.5'	7.5 to 8.2'
Total Stall Length -Closed Stall Front	7.7 to 8.2'	8 to 8.5'	8.5 to 9'

Open Stall Front – cows can lunge through the stall front, Closed Stall Front – cows can not lunge through the stall front

Table 3: Suggested freestall dimensions for various size cows (Cook and Nordlund, 2004b).

Cow Weight:	1400 lb	1600 lb	1800 lb
Body Space	68-70”	70-72”	72”
Total Space-Open Stall Front	8.5’	9’	9’
Total Space-Closed Stall Front	9’	10’	10’

Freestall – Length of Stall to Brisket Locator

Brisket locators, previously know as brisket boards, are placed in the stall to position the cow when she lies down. The base of the brisket locator is normally placed 66-72” from the manure curb and defines the amount of space a cow has for her body space. Experience has shown that 66” stall beds and high brisket boards have not provided enough space for large cows and they lie with their rump extended past the manure curb and sometimes even have their udders straddled across the edge of the manure curb. Originally these locators were made of wood placed at an angle to accommodate the shape of the animal as she rested the front of her body against them. Often the space in front of the brisket board was filled with concrete to prevent a build-up of bedding materials. Less rigid materials, which allow some flexibility as cows move, are now being used in place of boards and have resulted in the use of this new term. Anderson (cite?) observed animal behavior and suggested that properly designed stalls should allow cows to stretch their feet forward when lying down and have the ability to extend their feet into the space in front of the brisket locator when rising. He observed that a cow usually swings her foot high enough to clear a 4” obstacle and suggested this be the maximum height of a brisket locator above a mattress or sand bedding. He discouraged the use of brackets to support the brisket locators from the lower pipe of the stall divider because it obstructed the extension of the cow’s foot. In addition he suggested a 5” space should be provided between the top of the brisket locator and the bottom of the stall divider to prevent leg entrapment of the animal. This recommendation is easy to implement with mattress stalls since the brisket locator can be attached to the stall surface, but becomes a challenge with sand based stalls that often do not have a base to attach them. These recommendations led to the new recommendation relating to stall design in that the surface in front of the brisket locator should not be elevated above the stall surface to allow the cow space for her feet.

Freestall Design – Total Stall Length

As mentioned earlier, total stall length should provide body space, head space and lung space. Tables 2 and 3 reflect different author’s view of this need based on differences in cow sizes they reference. Open front stalls allow a cow to extend past the stall perimeter when rising either by placing their head in an adjacent stall in a head-to-head arrangement or with extra space provided in front of the stall for single rows of stalls. Closed front stalls have some type of barrier that prevents the cow from lunging outside the perimeter of the stall. If stalls are too short to allow cows to lunge forward, a stall divider that allows the cow to lunge to the side should be selected. Cows normally prefer to lunge forward and if allowed to do so often will lie straighter in their stall. Cows that are forced or prefer to lunge to the side often lie at an angle in the stall which results in more manuring in the stall and the increased problems associated with it. Anderson (2003) reported that at a study farm with 16’, open front, head-to-head freestalls, cows lunged diagonally 34% of the time when the facing stall was empty and 81% of the time when the stall was occupied. At another farm, cows lunged diagonally 68% of the time with the original 8’ closed front stalls and 44% of the time with modified stalls that had open fronts and loops with 38’ wide side openings. This information supports the decision to build closed front stalls longer than 8’ and the choice of a stall divider which allows diagonal lunging in case a cow is concerned with lunging into an occupied stall. Whereas, research by Wagner-Storch et al. (2003) and Fulwider and Palmer (2004c) both reported results that contradict this idea. Their research was conducted in a 4-row, tail-to-tail, freestall barn which had all 8' stalls. The exterior of stalls were closed front and the interior row had open front stalls. At no time did open front stalls have more cows lying or occupying them than did the closed front stalls and for most of the observed times the closed front stalls had significantly higher usage than the open front stalls.

Freestall Design – Neck Rail Placement

Neck rails are placed in the front of the freestall (Figures 2 and 3) to position the animal when she enters the stall. These normally are placed directly above the base of the brisket locator which provides sufficient space for the animal to stand with all four feet in the stall and positions the cow so she defecates in the manure alley. For higher neck rails the neck rail should be moved back toward the manure curb about 2" to reflect the shape of the cow. Cook's (cite?) current recommendation for sand based stalls is to shorten this distance by the width of the manure curb, forcing cows to perch rather than stand with all four feet in the stall. This recommendation is based on observation that cows normally will not stand on the manure curb, which encourages the cow to place her hind legs inside or outside of the manure curb. Having cows stand with all four feet in the stall and the back feet inside the manure curb leads to increased manuring in the stall, dirtier stalls, and increased labor to maintain the stalls. Neck rail mountings should allow the neck rail to be moved forward or backward as experience shows the stall bed is too short or too long, based on excessive animal perching or frequent manuring in the stall.

Recommendations for neck rail height above the stall surface changed the most in recent years. Placement of the neck rail too low makes it difficult for animals to rise without hitting the rail and discourages stall use. Previous recommendations specified a minimum distance between the stall surface and the bottom of the neck rail to be 42". Current recommendations are for neck rails be mounted 48-50" above the stall base surface. Proper placement of neck rails is easier in mattress based stalls since they have a constant surface level and the neck rail height is defined as the distance above the stall surface, whereas surface elevation in sand stalls depends on the amount of sand in the stall at any one time, so neck rail height is measured from the top of the manure curb.

Recent work by Fulwider and Palmer (2004) has shown that the percentage of time cows lie in a stall increased significantly when the neck rail was raised from 45" to 50" in a mattress based freestall barn (Table 4). A fifty cow pen had half of the stalls modified and the other half left unchanged. Stall usage was recorded before stall changes and a 5-week acclimation period was allowed before stall usage was again measured. There was no significant change in stall usage for the existing stalls, but a significant increase in the percentage of stalls with a cow lying in the modified stalls was observed (40.0 to 51.4%). This research was done in a 4-row, tail-to-tail barn, with 46" wide and 8' long stalls (open front on inside rows and closed front on outside rows). Results indicated stall usage can be increase by changing neck rail height, etc. without changing stall width or length. To increase the neck rail height for this research new stall divider types were installed and the stall divider mounting rails in the front of the stalls were removed. Field experience has shown that removing horizontal mounting pipes (chin clippers) often will increase stall usage because cows dislike hitting these rails as they attempt to rise. The increase in stall use was significant and demonstrates the importance of proper stall design, but does not prove the neck rail height alone caused the increase.

Table 4: Effect of neck rail height on the percentage of freestalls with cows lying in them.

	Before Neck Rail Change 1-29 to 2-26-03	After Neck Rail Change 4-03 to 5-01-03
Average Stocking Density	96%	94%
45" Neck rail before and after - Percent of stalls with cows lying	42.1[b]	43.8[b]
45" Neck rail before , 50" after - Percent of stalls with cows lying	40.0[b]	51.4[a]

[a,b] Percentages with different superscripts differ ($P < .05$).

Freestall Design – Stall Width

Stalls should be wide enough to allow animals to recline and rise easily. If stalls are too wide, animals will tend to stand and lie at an angle in the stall. Smaller cows often will lie backward in the stall which causes manure to be deposited in the front of the stall. Both of these situations can lead to dirty cows and additional labor to clean stalls because animals will deposit manure on the stall surface. For the average mature Holstein herd, 46-48" wide stalls often meet these requirements the best. Larger stalls, 48-50" wide, may be considered for extremely large or pregnant dry cows. Often 48" stalls are built as a convenience to the builder, whereas, 46" stalls would offer the advantages mentioned, plus allow more stalls per barn.

Tucker et al., 2004, reported the effect of cow lying and standing behavior and milk production (Table 5). In this research 42", 46" and 50" wide stalls were compared. The number of lying events in 24 hours, the duration of lying bouts, total lying times, and milk production were compared. For factors relating to cows lying in stalls there was a significant advantage of the 46" stall over the 42" stall, but no advantage of the 50" over the 46" stall. Increasing stall width decreased the amount of time cows were half in and half out of stalls and increased the amount of time they stood with all four feet in the stall.

Table 5. Lying and standing behavior and milk production for three stall widths (n=27).

	Stall width		
:	42" Stall	46" Stall	50" Stall
Lying events (number per24 h)	12.3	11.9	11.9
Duration of lying events (h per bout)	1.1	1.2	1.2
Total lying time (hrs per 24 h)	12.3	13.0	13.0
Perching (min per 24 hr)	85	66	58
Standing four feet in stall (min per 24 h)	53	50	68
Total time standing in stall (min per 24 h)	138	116	126
Milk production (lb per 24 hr)	103	101	102

Freestall Divider Design

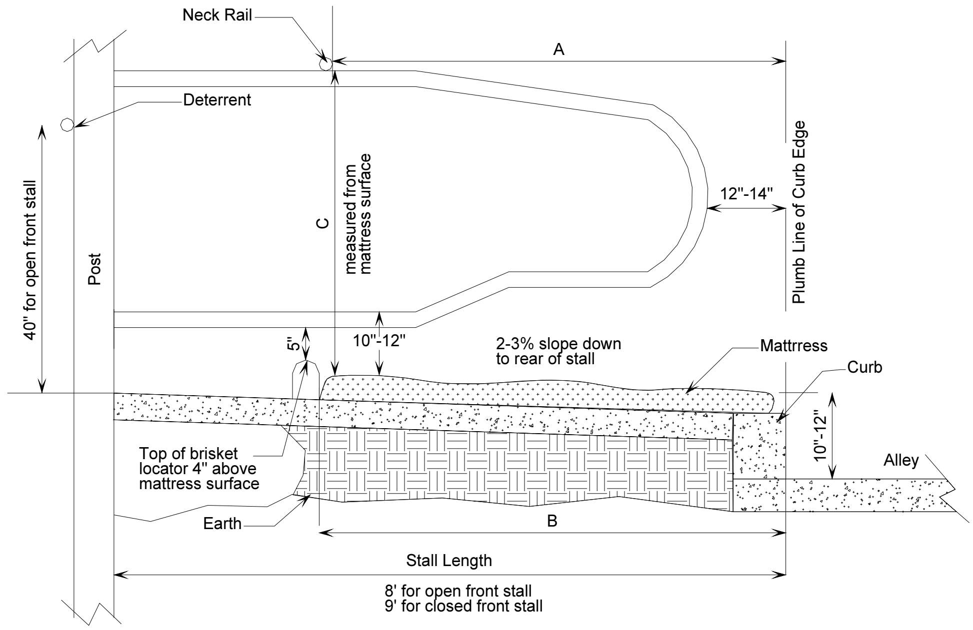
There are many different freestall stall divider designs currently being marketed, and they are often referred to by names such as side-lunge, wide loop, straight loop, etc. Whichever stall divider type is selected, its length should allow 14" space between the end of the divider and the manure curb once the stall dividers are mounted (Bickert et al., 2000). Allowing additional space encourages cows to walk along the backs of the stalls and/or to enter another cow's space. Allowing less space may result in cows hurting themselves by hitting the divider as they enter the stall. In practice 12-14" appear to work very well to eliminated these problems. Remember, barns having different stall lengths, should have different length stall dividers.

Another important dimension is the distance from the top of the stall divider's bottom rail to the stall base surface. If the stall divider provides sufficient space for the animal to lunge to the side, then the bottom rail needs to be high enough to discourage the animal from crawling over it when lying down. Field observation suggests this bottom rail should be 11-12" above the stall surface. In the past, producers have reported dissatisfaction with extremely wide loop designs because cows got jammed in them and they tended to encourage cows to lie at an angle in their stall. This was probably caused by the divider being mounted too low, which allowed the cow to craw over the lower divider bar. Current stall design recommendations with their higher neck rail placement and the associated raising of the lower rail of the divider appears to have solved this problem. A second consideration with stall divider design is the amount of space provided at the rear of the stall. Sufficient space is needed to accommodate the cow when lying down, but excessive space below the bottom of the divider results in cows lying at an angle in the stall. Choosing a divider with a lower rail which extends straight past the brisket locator 12'-24' before rising to provide space for the cows hook bones will minimize this problem. New stall divider designs which support higher neck rail placement should have the rear part of the top rail taper down several inches to allow the cow's head to easily clear the divider when turning as she backs out of the stall.

Barns with rows of head-to-head stalls allow animals to lunge into the stall in front of them. This feature saves space, but can also lead to animals exiting through the front of the stall or being jammed between neck rails as they stand and try to walk through. This is especially true of the newer designs with higher neck rail placements. To discourage this, a deterrent (strap, cable or pipe) may be placed between the rows of stalls. Deterrents must be high enough to allow the cow to lunge forward unobstructed, but low enough to prevent her from exiting through the adjacent stall. Current recommendations specify this deterrent to be placed 40" above the stall base surface on 8' stalls and 34' for 9' stalls.

Mattress Based Freestall Design

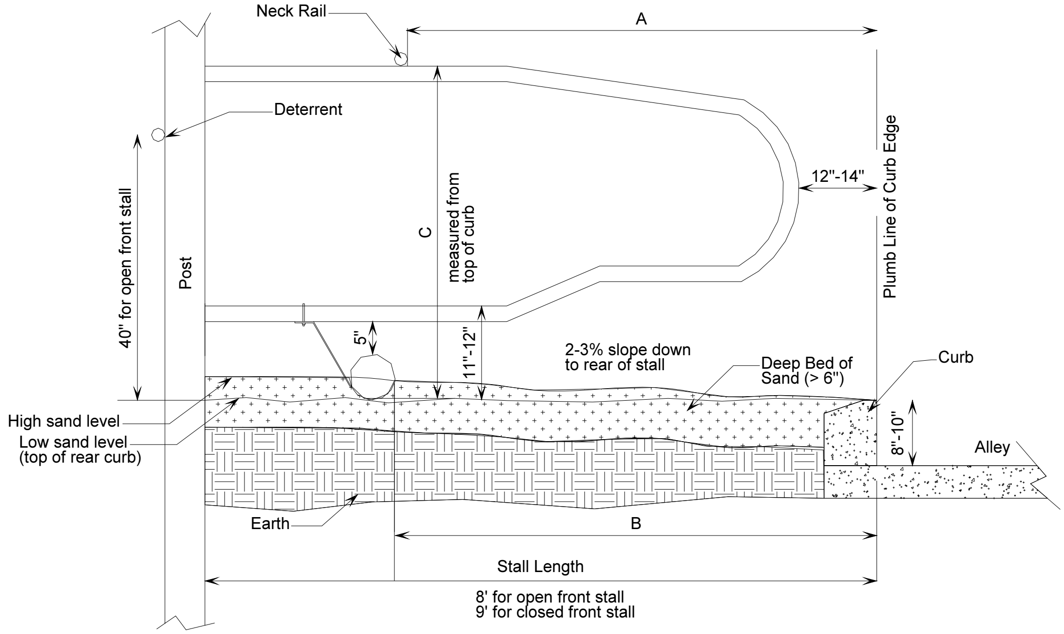
Figure 2 is an example of a mattress based freestall and Figure 3 is an example of a sand freestall for average sized Holstein cows. Notice how dimensions vary depending on the type of animal (First Lactation, Milking Cows (Lactation > 1), and Dry Cows). These are only guidelines, stall design should be based on size of cow expected to use the stall and you should consider the fact that freestalls that are too large cost extra money to build, result in dirty cows, and/or extra labor to keep stalls clean. Stalls that are too small lead to increase injuries, increased culling rates, and the potential for loss of milk production because cows do not use the stalls as much as otherwise would be possible. Figure 2 shows the proper placement of the mattress on the stall base surface, with the rear of the mattress being installed 2-3" ahead of the read edge of the stall so it will not hang over the edge even after some settling occurs.



Average Holstein	Weight	A	B	C	Width
First Lactation Cow	1300 lb.	68"	70"	48"	46"
Milking Cow	1500 lb.	70"	72"	50"	46"-48"
Dry Cow	1600 lb.	70"	72"	50"	48"

Example Mattress Based Freestall Design
for Average Sized Holstein Cow

Figure 2:



Average Holstein	Weight	A	B	C	Width
First Lactation Cow	1300 lb.	68"	70"	48"	46"
Milking Cow	1500 lb.	70"	72"	50"	46"-48"
Dry Cow	1600 lb.	70"	72"	50"	48"

Example Sand Based Freestall Design
for Average Sized Holstein Cow

Figure 3:

Bedding Material Choices

Freestalls are often thought of as having two components, a stall base constructed of clay, concrete, wood or some other material and a bedding surface. With deep sand freestalls, sand supports both functions. Whatever components are selected, freestalls should conform to the shape of the cow when she is resting, provide cushion when she is reclining and traction when she is rising

Many different freestall combinations have been tried over the years with different costs and results. Cows dislike concrete-based stalls unless a thick bedding surface is maintained on top of them. Straw, sawdust, manure solids, and other organic bedding surface materials have been used successfully over concrete bases, but their cost is sometimes prohibitive. Organic bedding materials have also been shown to promote growth of bacteria and are associated with a higher incidence of mastitis. Wood-based stalls have not been successful because wood rots and gets slippery when wet. Clay-based stalls can provide cow comfort but require a large maintenance effort since cows dig holes in the stalls. Producers have used rubber tires in freestall bases. Cows seem to like tires in stalls, and bedding requirements are decreased, but getting the tires installed properly is very important. Tires should be of the same size, placed tightly together, and carefully packed with material to hold them in place. Tires can make it difficult to remove soiled bedding. Different types of rubber mats have been tried over the years with mixed results. Some get slippery and promote hock damage, and others have deteriorated in a short period of time.

Mattress-based stalls currently are very popular, and for most producers the choice of freestall bases is between sand and mattresses. Mattress-based stalls normally have some rubber particles, water, or other type of filler that conforms to the animal's body and may offer an insulating effect during cold weather. They have a cover that provides animal traction, may be waterproof, and is durable enough to withstand animal traffic. The initial cost of mattress-based stalls is normally $75-125/stall, and their expected useful life is between 4 and 7 years. Mattress-based stalls need to have some type of absorbent bedding applied to them, but the amount is less than deep-bedded stalls over concrete. The initial investment in sand-based stalls is low, but the labor to fill and maintain them, the cost of the sand used, and the adverse effects the sand has on manure handling and storage often results in a high maintenance cost.

Sand versus Mattresses - Performance and Producer Satisfaction

A survey of Wisconsin producers who increased herd size by at least 40% from 1994 to 1998 (Table 6) showed no significant difference in DHI milk production or somatic cell counts between those using sand and those using mattresses after their expansion (Palmer and Bewley, 2000). Producers using sand seemed to be more satisfied with cow comfort, and less satisfied with manure management and bedding issues than those using mattresses. Sand users reported significantly higher satisfaction scores for cow cleanliness and hock injury, whereas mattress users reported significantly higher satisfaction with bedding use and cost, and manure management. Culling rates, although not significantly different, showed a slight numeric advantage to sand users.

Table 6: Average production and producer satisfaction values of herds using mattresses or sand bedding.

Freestall Bedding Type	Mattresses	Sand
Number Herds	69	145
DHI 1998 RHA Milk(lbs)	22,519	22,539
Avg. Linear SCC	2.88	2.80
Culling Rate (%)	34	32
Cow Cleanliness*	4.12	4.47
Hock Damage*	4.22	4.72
Bedding Use and Cost*	4.25	3.95
Manure Management*	4.32	3.43

* Average satisfaction reported on a scale of 1 (very dissatisfied) to 5 (very satisfied)

An Iowa study, which was designed to evaluate six different freestall surfaces, found that stalls ranked differently by week of trial, with cow preference switching between sand and mattresses (Thoreson, 2000). Sand ranked highest in the summer, but usage declined from summer to winter. Wagner-Storch et al., 2003, reported temperature appeared to affect cow preference for a particular stall base, with lying percentages higher for mattress based stalls during hot and cows temperatures, but were higher for sand stalls during moderate temperatures.

Cook et al., 2004a, studied the differences in behavior of nonlame cows, slightly lame cows, and moderately lame cows in 6 free stall barns with sand bedding (SAND) vs. 6 free stall barns with rubber-crumb geotextile mattress surfaces (MAT) in Wisconsin dairy herds. All lactating cows in the 12 herds were observed and given a locomotion score based on a 4-point scale: 1 = nonlame, 2 = slightly lame, 3 = moderately lame, and 4 = severely lame. Herd size, stocking density, rolling herd average milk yield, annual turnover rate and mean ambient temperature on visit day were not statistically different for there

MAT or SAND herds (Table 7). Culling rate although not statistically different showed a numeric advantage for SAND herds (36.5 vs 28.8) which is consistent with the results reported by Bewley et al. 2003. The major finding was that the average herd prevalence of clinical lameness was significantly higher in MAT herds than SAND herds (24.0 vs 11.1), where clinical lameness was defined as cows having a locomotion score of 3 or 4.

Table 7: Least square means and SE of herd level background data for 6 herds using mattresses (MAT) and 6 herds using sand bedding (SAND).

	MAT	SAND	SE	*P*
Herd size (no. cows)	304.7	297.7	30.2	0.87
Cows in pen (no.)	77.3	95.8	7.8	0.12
Stocking rate (high pen %)	107.8	108.0	5.0	0.98
Rolling herd average milk yield (kg)	11,241	11,912	547.5	0.41
Annual turnover rate (%)	36.5	28.8	2.9	0.09
Mean ambient visit temperature (°C)	7.2	8.3	0.4	0.73
Herd prevalence of clinical lameness[1] (% all milking cows)	24.0	11.1	1.7	<0.001

[1]Clinical lameness includes cows that had locomotion scores of 3 and 4 and were either moderately or severely lame. Locomotion score scale: 1 = nonlame, 2 = slightly lame, 3 = moderately lame, 4 = severely lame.

Subsets of 10 cows per herd with locomotion scores of 1 to 3 were observed via video cameras for 24-h periods (Table 8). There was no difference is the lying time between MAT and SAND barns (11.66 vs 12.01), and cows in MAT herds spent more time standing in free stalls per day than cows in SAND herds (3.44 vs 1.83) which agrees with the findings of Fulwider and Palmer, 2003. Cows in SAND barns were also found to spend more time feeding than MAT barns (4.65 vs 4.08) and had a higher number of stall use sessions (7.57 vs 6.92). The proportion of lying bouts greater than 60 minutes was higher for SAND herds than MAT herds (0.61 vs 0.49).

Table 8: Mean daily activity patterns (h/d) for 60 cows in 6 herds using mattresses (MAT) and for 60 cows in 6 herds using sand bedding (SAND).

Daily activity	MAT	SAND	*P*
Time lying in stall	11.66	12.01	0.56
Time standing in stall	3.44	1.83	0.002
Time up in alley	2.27	2.34	0.66
Time up feeding	4.08	4.65	0.03
Time up milking	2.58	3.21	0.37
Number of stall use sessions	6.92	7.57	0.03
Proportion of lying bouts >60 minutes	.49	.61	0.03

Cook also documented how daily activity patterns of cows vary by locomotion score between MAT and SAND herds. Activity patterns were consistent in cows in SAND herds across all locomotion scores with little variation. Nonlame cows in MAT herds behaved similar to all cows in SAND herds, apart from a small but significantly higher time up in stall. In contrast, cows in MAT herds that were slightly lame and moderately lame showed modifications in behavior. Differences in standing times were 0.73 h/d for cows that were not lame, 2.32 h/d for cows that were slightly lame, and 4.31 h/d for cows that were moderately lame in MAT herds compared with equivalent cows in SAND herds. In MAT herds, the increase in time spent standing in the stall in moderately lame cows was associated with a significant reduction in stall use sessions per day, which impacted daily lying time. As time standing up in stall increased, time spent performing other activities was reduced. Time up milking was largely unchanged, but time up in alley was significantly reduced ($P < 0.05$). Moderately lame cows in MAT herds had significantly ($P = 0.003$) fewer mean number of stall use sessions at 4.62 compared with moderately lame cows in SAND herds at 8.50. This result was interpreted to imply that as cows became moderately lame it was easier for them to get up and down in a sand based stall than a mattress based stall.

Preference Testing of Different Mattress and Rubber Mat Type Stall Bases

Cow preference for different stall base surfaces were conducted over at three year period at the University of Wisconsin Arlington Farm. Results were reported by Palmer (2003), Wagner-Storch et al. (2003), and Fulwider and Palmer (2003). The following 16 different stall base types were tested:

- SAND - Washed mason sand 8-9" thick when filled (EXP1)
- CONC - Concrete (EXP1)
- WATR - Water beds by Alanta Waterbeds, 2 layers of vulcanized rubber filled with three gallons CaCl and 13 gallons water(BOTH)
- Rubber filled mattresses (fabric covered bases with different rubber interiors)
  - PMFoam – Pasture Mat's foam pad over multi-cell crumb rubber base (BOTH)
  - PMFelt – Pasture Mat's felt pad over multi-cell crumb rubber base (BOTH)
  - UltiMat – Ulti-Mat's thick mat of compressed rubber pieces under a cover (EXP2)
- Foam filled Mattresses (fabric covered bases with different foam interiors)

- ComfyC1 – Sikkema's Comfy Cow, polyethylene with Cow-flex top cover (BOTH)
  - Foxworthy – Foxworthy's Foamat Bedding System - thick foam base (EXP2)
  - DelavalM100 – DeLaval's M100-foam filled base with green cover (EXP2)
  - ComfyC2 – Sikkema's Comfy Cow, polyethylene with Supermat cover (EXP2)
- Cork filled mattresses (fabric covered base with cork interior)
  - CCCork – Cow Comfort Corkmat by Amorim Cork (EXP2)
- Rubber mats
  - DelavalCZ - DeLaval's comfort zone milk mat (EXP1)
  - Humane - Humane's Supreme Comfort Pad -rubber mat with foam interior (EXP2)
  - Kraiburg - Kraiburg's Softbed II -rubber mat over foam interior (EXP2)
  - J+DCuch - J+D's Heavy Cush, thick rubber mat with vented bottom (EXP2)
  - BergSDP - Berg's Simplex Dairy Pad (EXP2)

Two main cow preference experiments were conducted and referred to as Experiment 1(EXP1) and Experiment 2 (EXP2). Some stall surfaces which proved to be preferred by cows during EXP1 were retained for EXP2 and these are referenced above as being in both experiments (BOTH). Palmer, 2003, showed that stall base type affects cow preference. This study reported the stall usage for a 4-row freestall barn with 100% stocking rate. Observations of cows lying or occupying stalls (standing or lying) were recorded for a nine month period. Sand and rubber filled based stalls consistently had larger stall use percentages; concrete and soft rubber mats consistently the lowest percentages; and foam filled mattresses and waterbeds percentages were intermediate. The sand based stalls had the highest overall lying percentage, but mattress based stalls had the highest stall occupied percentages. Cows appear to prefer to stand on soft surfaces provided by mattresses or soft rubber mats to sand stalls or concrete alleys. The lying percentage advantage of sand over Mattress-I type (68.7% > 65.2%) was small compared to the stall occupied advantage of Mattress-I type over sand (88.3% > 79.0%). This suggests cows like to lie down on both stall bases, but prefer to spend non-lying time standing in Mattress-I type based stalls rather than on concrete manure alleys. Some stall base types were consistently inferior to others. Lying percentages for concrete and soft rubber mats were always below the average lying percentages. One mattress type consistently ranked higher than the other for lying and stall occupied percentages, which indicates not all mattresses are equally desirable to cows and making general statements about "mattresses" may be misleading. The length of time cows are exposed to the different stall bases affects lying and occupied percentages. The waterbed based stalls required a longer adaptation time whereas use of soft rubber mat based stalls in this trial decreased over time.

After the initial results were published by Palmer (2003) it was discovered that one mattress types was installed with two different compositions. Data were reanalyzed and these two mattress types (PMFoam and PMFelt) were analyzed separately by Fulwider and Palmer (2003). Table 9 shows the updated values.

Table 9: Cow Preference values for different stall base types for Experiment 1 for 4-row barn with 100% stocking density after mattress type was reanalyzed and PMFoam and PM Felt analyzed separately for nine month period starting May 9, 2001.

Stall Base Type (Previous)	% Stalls with cow lying (Rank)	% Stalls Occupied[1] (Rank)
SAND (Sand)	69%[a](1)	79%[d](4)
PMFoam (Mattress-I)	68%[a](2)	89%[a](1)
PMFelt (Mattress-I)	61%[b](3)	87%[b](2)
ComfyC1	57%[c](4)	84%[c](3)
WATR (Waterbed)	45%[d](5)	62%[f](6)
DelavalCZ (Soft Rubber Mat)	33%[e](6)	65%[e](5)
CONC (Concrete)	23%[f](7)	39%[g](7)

[1]% Stalls Occupied = % Stalls with cow lying, standing half-in and half-out, or standing in stall.
[abcdefg] Means within rows with same letter are not significantly different (P<.05)

When EXP1 this mattress type was reanalyzed as PMFoam and PMFelt the results showed a significant difference in cow preference between the PM version that contained a 1" layer of foam over the 1" layer of felt. Both of these stall bases had the added material inserted under the cover and over the rubber filled bladder. There was no significant difference between SAND and the PMFoam mattress type for % stalls with a cow lying in them (69 vs. 68%), but a very large difference in the amount of time cows stood in mattress stalls versus sand stalls (89 vs. 79%).

Table 10 shows the results of EXP2 on the 101% stocking density side of the barn. Three of the stall base types from EXP1 were retained and five new types installed. Results show three mattress types (Foxworthy, PMFoam and UltiMat) were preferred by the cows. Preferences for three others were considered intermediate (PMFelt, ComfyC1 and Humane) and two were considered inferior (Kraiburg and J+DCush).

Table 10: Results of EXP2 testing of three existing and five new types of mattress and rubber mat stall bases on the 101% stocking density side of the barn for six month period starting June 19, 2002.

Stall Surface Type (Class)	% Stalls with cow lying	% Stall Occupied[1]
Foxworthy	62 %[a]	91 %[a]
PMFoam*	60 %[a]	88 %[ab]
UltiMat	59 %[a]	84 %[bc]
PMFelt*	53 %[b]	81 %[c]
ComfyC1*	52 %[b]	81 %[c]
Humane	51 %[b]	73 %[d]
Kraiburg	43 %[c]	64 %[e]
J+DCush	42 %[c]	65 %[e]
Average	52 %	78 %

[1]% Stalls Occupied = % Stalls with cow lying, standing half-in and half-out, or standing in stall.
[abcdefg] Means within rows with same letter are not significantly different (P<.05)
* Stall base types from EXP1

Table 11 shows the results of EXP2 on the 66% stocking density side of the barn. Three of the stall base types from EXP1 were retained and four new types installed. Two stall base types appeared to be preferred by cows (DelavalM100 and PMFoam). Waterbeds and ComfyC2 types intermediate and BergSDP and CCCork were considered inferior.

Table 11: Results of EXP2 testing of three existing and four new types of mattress and rubber mat stall bases on the 66% stocking density side of the barn for six month period starting June 19, 2002.

Stall Surface Type (Class)	% Stalls with cow lying	% Stall Occupied[1]
DelavalM100	49%[a]	62%[a]
PMFoam*	47%[a]	60%[a]
ComfyC2	35%[b]	50%[b]
WATR*	32%[b]	40%[d]
ComfyC1*	20%[c]	29%[d]
CCCork	18%[cd]	25%[de]
BergSDP	16%[d]	23%[e]
Average	32%	41%

[1]% Stalls Occupied = % Stalls with cow lying, standing half-in and half-out, or standing in stall.
[abcdefg] Means within rows with same letter are not significantly different (P<.05)
* Stall base types from EXP1

Tables 10 and 11 show the relative order of cow preference for different stall base types. The % Stalls with cow lying and % Occupied followed similar trends for both sides of the barn and foam or rubber filled mattresses were consistently preferred over rubber mats. As in EXP1 there was a lot of variation in stall use for the stall base types tested, again confirming the thought that it is unfair to make generalizations about mattress and rubber mat based stalls.

Table 12 shows the results of using a Clegg hammer to test the relative hardness of different stall bases and the correlation of these values with cow preference values from EXP2. The CIV/H values had a correlation coefficient of -.90 with % Stalls with cow lying and a -.84 correlation coefficient with % Stalls occupied. Higher Clegg values were associated with harder stalls and correlates with cow preference for different stall bases. These results were interpreted to imply the softer a stall base is, the lower its Clegg value, and the more desirable it is for cows. From these results it appears that the Clegg hammer may be a useful tool for evaluating the softness and cow acceptance of different stall bases.

Table 12: Clegg impact test results in the 101% stocking density pen with results shown in order of % Stalls with cow lying.

	Clegg Value1	% Stalls with cow lying[2]	% Stalls Occupied[2]
Foxworthy	1.6	62 %[a]	91 %[a]
PMFoam*	4.6	60 %[a]	88 %[ab]
UltiMat	2.6	59 %[a]	84 %[bc]
PMFelt*	6.1	53 %[b]	81 %[c]
ComfyC1*	6.1	52 %[b]	81 %[c]
Humane	6.0	51 %[b]	73 %[d]
Kraiburg	7.1	43 %[c]	64 %[e]
J+DCush	7.3	42 %[c]	65 %[e]

[1]Clegg Value = Average peak deceleration of the Clegg 20-kg hammer's impact with stall surfaces from a height of 30 cm as measured in CIV/H.
[2]Cow preference for different stall types on the 101% stocking density side of the barn for six month period starting June 19, 2002.

Use of Rubber Alley Mats

Previous work by Fulwider and Palmer, 2003, indicated that cows lie down as much time in well designed mattress stalls as in sand stalls, but spend more time standing in mattresses based stalls. Cook et al., 2004a found the same to be true. Different reasons have been proposed to explain these phenomena. In the fall of 2003 rubber alley mats (RAM) were installed over all alleys in the same pen as stall preference studies had been conducted earlier. Table 13 shows the effect of rubber alley mats on stall use (Fulwider and Palmer, 2003). Stall use was recorded for 31 days before the RAM's were installed. A three week acclimation period was given to allow cows to adjust their behavior patterns and then stall activities were recorded and the results compared to the before values. No change in the amount of stalls with a cow lying in them was found, but the percent of stalls with cows standing in them decreased significantly. Before the concrete alleys were covered with a soft material, cows preferred to spend time standing in mattress or rubber mat based stalls, but after installation of the RAM's they increased the amount of time standing in the rubber covered alleys. This was interpreted as cows preferring to stand on soft surfaces. In other words, cows preferred to stand in soft stalls when hard concrete floors were the alternative.

Table 13: Effect of rubber alley mats (RAM) on stall use.

	Before RAM's 8-10 to 9-11-03 (97% Stocking Density)	After RAM's 10-1 to 10-23-03 (92% Stocking Density)
% of Stalls with Cows Lying	46^{a}	48^{a}
% of Stalls with Cows Standing	23^{a}	10^{b}

[a, b]Means within rows with the same letter are not significantly different (P<.05)

Conclusions

Modern dairies must be designed to support efficient production, and cow comfort is one of the most important factors to consider when developing these designs. Freestalls should be sized to match the size of cows to be housed in them. Making the stall size the same for all pens of a new facility allows the manager flexibility on how to use the pens, but complicates the decision on what size stall to build. Building all stalls to meet the needs of your largest cows will result in smaller cows using the stalls incorrectly, but making stalls too small for large cows will make them uncomfortable and having the potential to decrease stall usage. Making stalls too large increases building costs, results in dirtier cows, and/or extra labor to keep stalls clean. Making freestall too small can lead to increased injuries, increased culling rates, and the potential for loss of milk production because cows do not use the stalls correctly. Current recommended freestall designs with larger sizes and higher neck rail heights have proven to increase stall usage. A controversy continues to exist relating to the relative value of sand and mattress freestalls. A survey of Wisconsin producers who increased herd size by at least 40% showed no significant difference in DHI milk production or somatic cell counts between those using sand and those using mattresses after their expansion. Producers using sand seemed to be more satisfied with cow comfort, and less satisfied with manure management and bedding than those using mattresses. Culling rates, although not significantly different, showed a slight numeric advantage to sand users. Cows in well designed mattress stalls lie down as much as in sand based stalls, but spend more time standing in mattress or mat based stalls than in sand stalls, whereas cows using sand based stalls spend more time standing in alleys. Other research has shown that non-lame cows lay down the same amount in both types of stalls, but lame cows do spend less time lying and more time standing in mattress based stalls. One study reported the average herd prevalence of clinical lameness was significantly higher in mattress-based stall herds than sand-bedded stall herds. There is a strong correlation between stall softness and cow preference. Not all mattresses and rubber mats are preferred equally so making generalizations about them as a group is not valid. Rubber filled and foam filled mattresses are preferred over concrete and rubber mat stall bases. Placing rubber alley mats on manure alleys can decrease the amount of time cows stand in mattress or mat based stalls, therefore their use on all manure alleys should be discouraged.

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