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An Update on Dairy Cow Freestall Design

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Introduction

In the last few years there has been an unprecedented interest in free stall design and its impact on dairy cow health and performance. New facilities are being built in North America using radically updated stall designs and dimensions, with perceived benefits for the herd owner and dairy cow alike [2]. There has also been a significant amount of enlightening research published in the last year which serves to further improve our awareness regarding the design of the stall and its effect on cow behavior.

This article aims to update our original publication entitled “Flowchart for evaluating dairy cow free stalls” [8], retaining its structure, but serving as a companion piece, updating each of the steps with new knowledge gained through research or through practical experience learned from implementing new designs.

Resting Surface Cushion and Traction

Recent studies continue to demonstrate that dairy cows prefer stall surfaces which provide more cushion. Cows appear to prefer to lie in stalls with rubber crumb filled mattresses rather than on sparsely bedded hard rubber mats, water beds or concrete [13]. More recently, the same workers demonstrated a lying preference for thick foam filled mattresses over other less cushioned products [6].

Techniques of assessing surface cushion in the field still remain rather subjective, but the Clegg Impact Soil Tester (model 95051, Lafayette Instruments, Lafayette, IN) has been used recently to measure surface softness. This device measures the peak deceleration of a 20Kg hammer as it makes impact with a surface from a height of 30cm. The readings appeared to correlate well with stall preference [6], providing an alternative to the ‘knee test’ for the determination of the softness of a given stall surface. This study also discovered that many of the mattress products hardened and lost cushion over the time of the one year study period.

However, surface cushion may be altered by the amount of bedding used and other properties of the stall surface may be just as, or even more important, than cushion. A study at the University of British Columbia showed that even on a rubber crumb filled mattress, lying times could be altered by the amount of sawdust bedding used on top of the mattress. The addition of 1Kg of bedding to the stall made little difference to lying behavior compared to no bedding at all. However 7.5Kg of bedding increased lying time by over 1.3 h/d and altered stall standing behavior [10]. It is difficult to retain this amount of bedding on a sloped stall surface in conventional mattress stalls, but new designs have the mattress embedded into the stall platform, so that the rear curb protrudes and acts as a bedding retainer. It is important with these designs that wet bedding be removed from the rear of the stall frequently. Indeed, the amount of bedding used on any stall surface puts us into a difficult situation when we are attempting to maximize both cow comfort and udder health. Increased amounts of bedding improve comfort and lying times, whereas control of bedding bacterial counts and udder health require us to frequently remove the material, so that it does not remain in the stall incubating high numbers of potential udder pathogens [4]. Important questions therefore remain regarding the economics of greater bedding use and the impact of changes in cow behavior. In fact, we are still struggling to equate changes in cow behavior with improvements to cow health and productivity. However, we have recently documented changes in behavior of lame cows which have enhanced our understanding of the interaction between the cow and the stall surface, and how changes in stall use behavior may impact lameness [5].

It would appear that lame cows in rubber crumb mattress stalls spend more time standing in the stall during a stall use session (consisting of bouts of standing and lying during stall occupancy) compared to non-lame cows. Slightly lame cows compensate for this increase by decreasing time spent in the alley so that daily lying time of around 12 h/d is maintained. Some authors have previously noted that cows housed on mattress stalls spend more time standing in the stall than on other surfaces such as sand and deep bedded sawdust and suggested that this was a reflection of the cow’s preference to stand on a more cushioned surface rather than on concrete in an alley [11,13]. However, several research findings make this an unlikely interpretation. Firstly, we have documented no such increase in stall standing behavior in lame cows in sand stalls. This surface is also more cushioned than concrete and yet cows do not spend more time standing on it. Secondly, cows rarely stand in a stall that they do not use for lying [10] – suggesting that the standing activity is closely linked with lying behavior and thirdly, moderately lame cows in mattress stalls spend so long standing in the stall that other behaviors are compromised. They spend less time in the alley, as for the slightly lame cows, and they are unable to maintain daily lying time – lying for only 10 h/d. There is also a trend for them to spend less time eating. These changes would not be seen if this were a simple preference in standing surface. In fact, moderately lame cows spend so much time standing in mattress stalls that they only have time for 4.6 stall use sessions per day, compared to 8.5 for similar cows in sand stalls [5].

We believe that this change in behavior of lame cows in mattress stalls relates to fear and pain associated with the movements made by cows as they rise and lie down in the stall. Pain after rising and the fear and discomfort associated with lying again in cows with a sore foot keeps them standing for long periods in the stall. The fact that lame cows in sand stalls maintain normal patterns of stall use behavior means that some property of sand makes rising and lying easier. Therefore, as well as considering a stall surfaces' cushion, we must also consider its ability to provide traction. We would expect all loose bedded stalls to provide more traction than mat or mattress covered stalls, but as yet, we have only subjective assessments of this surface property. The challenge for manufacturers of new mattress products will be to provide traction to assist lame cows lying and rising in the stall, without increasing abrasive properties which would increase hock damage – which is already a greater problem in mattress stalls [14].

Without a doubt in our opinion, sand remains the gold standard bedding material – largely due to its ability to maintain normal daily activity patterns in lame cows. However, sand has other benefits. Hygiene scores in cows in sand herds are on average better than for cows in mattress stall herds [4]. In particular, udders are 50% cleaner in sand herds (Table 1).

Table 1. Least squares mean (SE) hygiene scores (Proportion scoring 3 and 4 for each zone using a 4-point scale to assess degree of cleanliness) in the high group pen on 12 free stall herds (6 sand and 6 mattress).

	Sand Herds	Mattress Herds	SE	P
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

We believe that the improved hygiene is due to one or a combination of the following factors:

- Sand appears to act as a cleaning agent, removing manure from the legs, udder and flanks
- Cows perch more in sand stalls with raised curbs and deposit manure in the alley rather than on the stall platform

- It is possible that lame cows are dirtier, they spend more time standing in the stall and their abnormal gait means that they may splash more manure up their legs during movement through the alleys.

When assessing the surface of the stall, we must now be mindful of both surface cushion and traction, and we therefore do not recommend the use of smooth covered, firm mattresses and rubber mats.

Figure 1. Re-modeled sand stalls 50 inches wide in a mature cow free stall pen.

Adequate and defined resting space

Since our previous article, research has shown that increasing stall surface area has an impact on resting and standing behavior. A Canadian study found that cows lay down for 1.2 h/d longer in wider stalls (52 compared with 44 inches wide) and spent less time standing in the stall [12] (Figure 1). The most recent recommendations for resting area place stall widths at 48 inches for first lactation heifers, 50 inches for mature cows and 54 inches for pre-fresh cows, measured between dividers on center [2, 4]. Where mixed ages and sizes are penned together, we suggest using the 48 inch dimension, or be prepared to tolerate dirtier stalls. The distance from the rear curb to the brisket locator should be 68 to 70 inches for first lactation heifers, and 70 to 72 inches for mature cows, depending on their size.

Figure 2. Brisket locators higher than 4 inches above the stall surface impede the forward thrust of the front limb when rising. Cows will tend to lie diagonally across the stall to give themselves more room. Note the long lower divider rail is rubbed shiny from cows lying against it.

We have also begun to appreciate more the impact of how the stall area is defined on cow movement and behavior. The brisket locator should be no higher than 4 inches above the stall surface so that the cow could lie with one forelimb extended if she chose to, and be able to thrust the fore-limb forward during the rising motion [8]. This forward thrust over the top of the brisket locator is a vital behavior that we would do well not to inhibit. Failure to provide for this movement is one of the major factors influencing how the cow positions herself in the stall. In stalls with high brisket locators, or where concrete has been filled above the level of the stall behind the brisket locator, cows will tend to lie diagonally in order to create a little more space for front leg movement when rising, along the diagonal (figure 2).

We are not in favor of rotating dividers 180 degrees so that the longer divider rail is located at the bottom, or divider designs that make the lower divider rail excessively long, which force cows to lie straighter in the stall. Instead, we recommend fixing the movement restrictions that make the cow want to lie down diagonally across the stall in the first place. Free of these restrictions, many cows will lie down straight in the stall.

Room to lunge and bob room

New barns continue to be built with obstructions to the lunge and bob movements of the head. The commonest mistakes being made are the continued use of the horizontal mounting bar for the dividers, making head to head platforms too short and providing inadequate front lunge space in stalls along a side wall.

Figure 3. A horizontal mounting bar is retained in this stall, but mounted below the bedded surface in a sand free stall. The bedding has been moved to show the bar and the right angle mounting bracket.

We appreciate that the horizontal mounting bar makes construction easier, however, when mounted in the area at the end of the lunge between the stall platform and a height of 40-42 inches above it (referred to as the 'bob zone'), they will impede the movement of the head when lying down and rising, and force more side-lunging. New stall dividers have improved vertical attachments that are mounted into the stall platform. One sand stall facility used a right angle mounting attachment to drop the horizontal bar down below the bedded level (figure 3). Both designs have been successful.

Engineers constructing stalls perceive a head to head stall to have an open front and be free of obstruction if we avoid bars and concrete that physically impede lunging. These are mechanical obstructions. However, ethologists also take into account the behavior of the cow and therefore also consider social obstructions. If one cow occupies a stall on a head to head platform that is only 15 feet long, she becomes a social obstruction to front lunging for the cow in the adjacent stall in front of her [1]. For the stalls to truly function with an 'open front', the head to head platform must be made longer. Anderson described the first head to head 2-row pen with an 18 foot stall platform [2]. By separating the cows' heads, he claimed improvements in cow lying position and in air quality and heat stress abatement. In existing barn constructions, a compromise on alley width may have to be made to achieve this platform length.

In open front head to head stalls with high neck rails, some farmers have complained of cows walking through the front of the stall. Injury does not usually result, but this practice is a frustration to those that wish to breed or treat a cow in the pen. To prevent this behavior, it has been suggested that a deterrent wire be hung across the front of the stall. This should avoid the bob zone and be mounted 40-42 inches above the stall surface. A single wire covered in polypropylene tubing provides enough deterrent, without being solid enough to cause injury to the cow should she venture beneath it.

It would appear that the modern Holstein cow requires 10 feet of length against a side wall to front lunge [2]. Stall dividers are not freely available for this length of stall. However, they may be mounted with a separation between the vertical mount and the side wall, keeping the cow's head away from the curtain wall (figure 4).

Figure 4. An open front stall against a side wall, with dividers mounted to provide space for front lunging.

It is questionable whether we should continue to build stalls in which cows must side lunge, however, it is clear that in most situations we must provide the cow with the option to do so if she chooses. The recommendation to make sure that the height of the upper edge of the lower divider rail is no higher than 11 inches above the stall surface at the position of the brisket locator remains a useful rule of thumb, and creates problems for many loop designs that cannot achieve this dimension without the neck rail being mounted too low. We have come to realize that not all wide loop dividers are created equally. The opening of a 2 3/8 inch outer diameter wide loop divider should be at least 35 inches and loops with narrower openings should not be used for mature cows. It is also important to leave a 5 inch space between the lower edge of the lower divider rail and the top of the brisket locator – this allows cows to work their leg free if it should get stuck between the two.

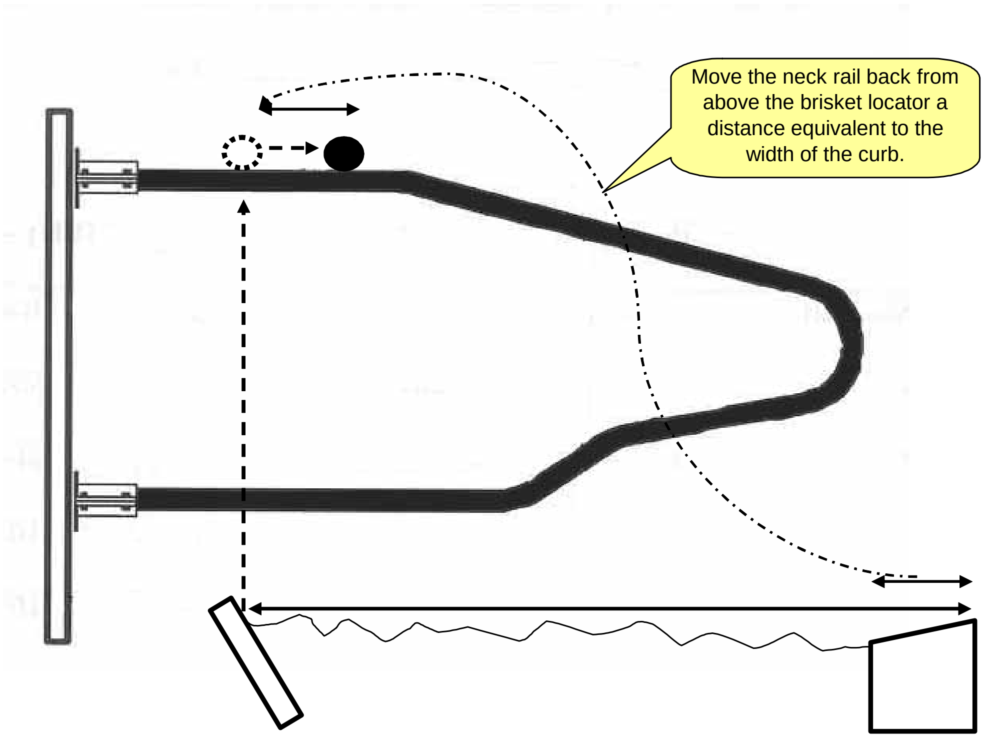
Correct neck rail location

No other part of stall design has given us as many problems as correct location of the neck rail – both vertically above the stall bed and horizontally from the rear curb. Current recommendations put the vertical height above the stall surface at 48 to 50 inches in mattress stalls [1]. In loose bedded sand stalls, the aim must be to maintain the neck rail between 44 and 50 inches above the bedded surface [4]. Many herds have lifted neck rails to these dimensions, however, it is debatable how effective this is in stalls where cows must still side lunge – where the upper rail of the divider remains the effective neck rail. However, if nothing else, in a compromised stall design, higher neck rails reduce the risk of cows becoming entrapped and breaking their backs.

In controlled studies, neck rail location did not appear to influence lying time or total time spent standing, however the vertical and horizontal location relative to the rear curb did influence the type of standing behavior. High neck rails appear to increase the amount of standing with all four feet on the stall platform [9]. With the neck rail located at 67 inches from the rear curb in a mattress stall, cows spent more time standing with all four hooves on the stall platform and less time perching with only the front two hooves in the stall, compared to when the neck rail was 60 inches from the rear curb [9].

It is common to find the neck rail located at 57 to 68 inches from the rear curb in both sand and mattress stalls – a huge variation, suggesting that we are not providing farmers with advice that works in practice.

Figure 5. Correct location of the neck rail in a loose bedded stall with a raised rear curb by moving the rail back from above a correctly positioned brisket locator a distance equivalent to the width of the rear curb.



It is unacceptable to locate the neck rail in a position where the cow must hit it in order to stand in the stall. If we are to encourage cows to lie down straight in the stall, we must allow them to stand straight with all four feet on the platform, rather than diagonally across the stall or perching with just the front two feet on the platform and the rear two feet in the alley. However, when trying to create recommendations for both sand and mattress stalls, the situation is complicated by the presence of the raised rear curb in the loose bedded stall – as cows prefer not to stand with their feet on top of a sloped or rounded curb. We also know that stall standing behavior is different in cows housed in sand and mattress stall barns with similar stall designs – so we are now comfortable in making different recommendations for stalls with mattresses and stalls with loose bedding such as sand.

In a mattress stall, the neck rail should be located vertically above the brisket locator or around 68 to 72 inches from the rear curb, depending on the size of the cow. This location should allow the cow to stand square in the stall with all four feet on the platform, while still ensuring that most of the manure falls into the alley if the cow defecates.

At this location in sand stalls, the cows will stand diagonally across the stall platform with their rear feet inside the curb. When these cows urinate and defecate, the rear of the stall becomes excessively soiled. Our research confirms that lame cows in sand stalls do not stand for long periods of time and maintain normal daily lying times [5]. We also know that the elevation of the front feet and stresses on the rear feet in a sand stall are not equivalent to that in a mattress stall, should the cow decide to perch, as the degree of elevation is usually much less. Therefore, our recommendation, in stalls with loops that locate the neck rail 44 to 50 inches vertically above the stall surface, is to move the neck rail from above the brisket locator toward the rear, a distance equivalent to the width of the rear curb in a sand stall. We therefore prefer curbs that are not too wide. Thus, in a mature cow sand stall with 72 inches from the rear lip of the curb to the brisket locator, with a 6 inch wide curb, the neck rail should be located 72 – 6 = 66 inches from the rear lip of the curb. For first lactation heifers with 68 inches from the rear curb to the brisket locator, the neck rail should be located 68 – 6 = 62 inches from the rear lip of the curb. In stalls with neck rails lower than 44 inches, the farmer must be prepared to make further adjustments to the neck rail location to ensure that the cow can rise without hitting the rail. At this location, the cow will be forced to perch, with the rear feet in the alley. We are prepared to tolerate this in sand stalls for the reasons outlined above, and in this location soiling of the stall bed will be prevented.

Responses of the cow to stall design problems

Diagonal lying

Cows that lie diagonally deposit manure in the rear corner of the stall and contaminate the bedding material with fecal matter. Manure is transferred directly to the flank and udder. Once located diagonally across the stall, the tail is more likely to hang in the alley and potentially lead to transfer of manure from the alley to the tail, to the flank, and to the rear udder [4]. In addition, in the dug out loose bedded stall, or any stall with an unprotected curb with a sharp edge, diagonal lying is a major cause of medial hock injury [8]. Measures such as moving neck rails, forcing cows to lie straight with modified dividers, and tail docking to reduce manure contamination are unnecessary if we just take a few moments to consider the reason for the diagonal lying in the first place.

Figure 6. Cows lying diagonally across stalls that are head to head layout, with a bob zone obstruction and concrete fill behind a high brisket locator.

Diagonal lying is a complex issue caused by a variety of stall design factors – involving lunge space, standing position, brisket locator design and social obstructions (figure 6). The stall design must allow for the normal rising and lying movements of the dairy cow. In particular, we must provide forward lunge room for the head, an unobstructed bob zone and we must allow for the forward stride of the forelimb as the cow rises, so that the leg can take the weight of the cow and facilitate the rising motion. Diagonal lying is a response by the cow to a failure to meet some or all of these requirements and we have included a flow diagram to help the investigator consider the possible causes and solutions.

Lame cows

Clearly the ability of a lame cow to rise and lie down will be further compromised by stall design problems such as inadequate resting area, low neck rails that are too near the rear curb, brisket locators that are too high and impediments to lunge and bob. While sand appears to allow lame cows to compensate for these design faults, smooth mattress surfaces do not.

Several authors have linked perching behavior with an increased risk of lameness, [3 7]. However, more recent studies would suggest that prolonged perching is a response of the cow to a mattress stall in which they are reluctant to lie down [10]. It is likely that this reluctance, and therefore degree of perching, is magnified when cows become lame.

Figure 7. Whether a cow stands with all four feet on the stall platform or perches, with the rear feet in the alley, is probably a function of poor stall design and lameness.

We believe that many of the cows that become entrapped in poorly designed stalls do so because they are lame and are struggling to get up in the stall. Many of these cows end up too far up the front end of the stall and struggle to free themselves. In addition, difficulties rising mean that the lower rear limb is dragged across the stall surface, increasing hock damage. It is noticeable that many of the cows with the worst hock swellings are those that are also foot lame.

In the short term, we recommend that severe and moderately lame cows be removed from compromised mattress stalls to an area such as a well managed straw bedded pack once they are recognized and for a recovery period. It remains to be seen whether improvements in mattress stall design discussed here allow lame cows to perform normal daily activity patterns and this will be the subject of future research.

Other Responses

Other responses of the cow to poor stall design include lying in alleys to avoid using the stalls all together, lying half in the stall and half in the alley or lying back wards in the stall, thereby avoiding obstructions to normal rising movements in the front of the stall, and rising and shuffling back in the stall on the front knees, sometimes until the rear feet rest in the alley, to gain enough space to thrust the forelimb forward. These behaviors, once noticed, are the signature of poor stall design and must be acted upon.

Conclusions

Assessment of the stall through the eyes of a cow using it remains the mainstay of troubleshooting free stall design. Recent research has increased our understanding of the effects of each of the components of the stall on the behavior of the cow, and we must realize these components act as a unit. Improving one design fault and leaving several other problems unchanged will have poor results in affecting overall cow use. We are beginning to make the connection between changes in cow behavior and effects on health and productivity, but we still have a long way to go to provide evidence of economic improvement for the farm, based on improvements to stall design. It must be realized that a facility or a new stall surface that may look adequate when used by a group of non-lame cows, may be completely unsatisfactory for lame cows. The challenge for the future of free stall construction is therefore to create stalls in which lame cows can maintain normal patterns of daily behavior. At present, a well designed and managed sand free stall provides the optimal resting space for our dairy cows.

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Figure 9. A flow chart for trouble-shooting reasons for diagonal lying in free stall barns.