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Fan Placement and Heat Stress Abatement in Four-row Freestall Barns

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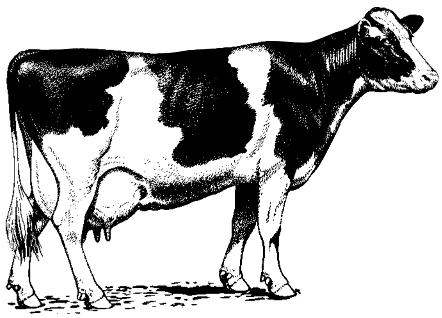

Heat stress abatement in freestall barns should be a major concern for dairy producers and dairy industry advisors. Under modern management systems, lactating dairy cows spend more than 90 percent of the day in the freestall barn. Without effective freestall cooling systems, significant production and reproduction losses will occur. In terms of cow comfort, the effective temperature is a function of air temperature, humidity, air flow, and solar radiation. Heat dissipation from the dairy cow at temperatures above 60°F is largely due to evaporative losses from the skin with a much smaller portion lost via lung cooling. Thus, the goal of heat stress abatement in freestall barns should be to provide protection from solar radiation and maximize evaporative losses from the skin. Heat dissipation from the skin is increased by increasing air exchange, air flow and the evaporation of supplemental water applied to the skin.

Freestall Barn Design

Barn Orientation

The first freestall barn design criteria to be considered should be the orientation of the structure. Barns with a north-south orientation have a greater solar radiation exposure than barns with a east-west orientation (Figures 1 and 2). Sunlight can directly enter north-south oriented barns both in the morning and afternoon. While the afternoon sun is the most detrimental, during hot summer weather morning sun can also modify cow behavior. Because cows seek shade during the summer, direct sunlight will reduce stall usage. Thus, utilization of stalls located on east and west outside walls of north-south oriented barns are greatly impacted when in the direct sunlight. It is also important to consider that with greater sidewall heights, that afternoon sunlight can reach much of the west half of the structure. Protection from direct sunlight is vital for effective heat stress abatement. Barns with a east-west orientation will provide greater protection from direct sunlight than north-south orientations. When working with a north-south oriented barn, shades can be used on the west wall to reduce the amount of sunlight entering the building (Figure 3). These curtains should be lowered about 1 p.m. each day and raised about 8 p.m. The use of automatic curtains that slowly lower in the afternoon as required to provide shade may be the best choice. It is important to note that the curtain provides protection from direct sun, but it also blocks natural airflow. Therefore, the curtain should be lowered only during the time when protection from direct sunlight is required. The use of a minimum of 90 percent shade cloth or reflective curtain material is recommended for the curtain material.

Air Exchange

Natural air exchange or building ventilation rates are influenced sidewall opening, eave opening, building width, ridge opening, and wind speed. Mechanical ventilation rates should exceed 470 cfm (cubic feet per minute) per 1,400 pound cow. During the summer, greater ventilation rates could increase water evaporation rates, and thus increase skin heat losses. During summer weather, open sidewalls will provide maximum air exchange. In general, open sidewall buildings will have ventilation rates that exceed the recommendq4ions. In general, sidewall heights on 4-and 6-row freestall buildings should be 14 to 16 ft high and be a minimum of 75 percent open. However, when trying to achieve maximum water evaporation rates, increased air exchange is important to prevent significant increases in relative humidity inside the barn.

Building size and design can influence ventilation rates. Data presented in Figure 4 demonstrates the effect of building width upon ventilation rates at different wind speeds. As building width increases, greater wind velocities are required to provide adequate ventilation. While, two-row barns may be adequately ventilated with a 1 mph wind, six-row barns require 3 mph wind for adequate ventilation. In addition, stocking rates and available area influence the need for ventilation (Table 1). Heat units produced per square foot of building increase with increased stocking. When comparing four-and six-row barns, reduced area per cow increases the heat load in six-row barns.

In addition to building width and sidewall height, ridgt‡openings are required. Armstrong and others (1999) observed greater increases in afternoon respiration rates relative to morning rates when cows were housed in barns with ridge coverings as compared to opening ridges. The ridge open should be two inches per 10 feet of building width.

Roof slope is another critical design consideration. Heat rises, and roof pitch can either enhance or reduce airflow out of the ridge opening. In four and six-row buildings, roof slope should be 4/12 to enhance airflow and air exchange. Utilizing less slope in these barns has been shown to increase afternoon respiration rates. Two-row barns with a mono-slope roof often have a 3/12 or 2/12 pitch. This may be adequate considering the narrow width of the building. However, if two mono-slope units are built facing each other with only a feed road between, one essentially has a four-row barn and the 4/12 roof pitch would be recommended.

Wind shadow can be a major problem in some cases. In general, to minimize the effect of wind shadow, buildings should be at least 100 ft apart or 1.5 times the building width. Any obstruction of natural airflow reduces air exchange. Buildings, equipment and stored forages may all reduce airflow in freestall buildings if adequate separation is not allowed. The most noticeable problem associated with wind shadow is the fact that cattle will seek natural air flow. This will result in overcrowding in areas of the barn which are not affected by wind shadow.

Water Location and Requirements

Water intake increases during heat stress, and one of the critical factors in managing heat stress is to provide adequate access to water. It is important to locate a water at each crossover, and there should be a maximum of 25 stalls between crossovers. Crossovers should be 14 feet wide to allow cattle to pass through the crossover while others are drinking. Crossover width is critical to avoid bottlenecks in cow flow. Ideally, two feet of tank perimeter should be provided for each 10 to 20 cows in a pen. In warmer climates, total tank perimeter for a pen is equal to 15 percent of the pen size times two. Data collected during the summer of 2000 indicated that a greater percentage of the water was consumed from the tank located in the center alley when three alleys were provided per pen. This may indicate that additional area and/or drinking space may be needed in this crossover alley. In addition to enough water space, water flow rates must be adequate to maintain water levels. To meet peak flow demands, well capacity or pumping capacity should be 20 to 30 gallons per 100 cows.

Supplemental Cooling

Fan Placement

Freestall barns that are correctly designed will provide maximum natural ventilation. However, additional cooling equipment is necessary if high levels of milk production are desired. In addition to maintaining high levels of production, heat abatement measures must be cost effective, returning greater profits to the dairy producer. Two studies were conducted in 1999 and 2000 to evaluate different cooling systems in four-row freestall barns located in northeast Kansas.

1999 Study

Ninety-three multiparous Holstein cows averaging 130 DIM (days in milk) were assigned to one of three cooling treatments. Cows were blocked by lactation number, DIM and production. Cows were housed in one of three identical 100 cow pens on a commercial dairy farm equipped with 84 freestalls per pen (Table 2). The barn was 100 feet wide and 420 feet long. The sidewall height was 12 feet and the roof had a 4/12 slope.

Treatment 1 (2S) was located in the southeast quarter of the building and consisted of a double row of fans (14, 36-inch diameter circulation fans with 0.5 horsepower motors) mounted every 24-feet over the freestalls. Each fan had an air delivery rate of 10,000-11,500 cfm and was angled down at 30°.

Treatment 2 (F&S)was located in the southwest quarter of the building and consisted of a row of fans (seven,36-inch diameter circulation fans with 0.5 horsepower motors) mounted over the freestalls and another row (7,36-inch diameter circulation fans with 0.5 horsepower motors) over the cow feed lane. Both rows of fans were mounted every 24 feet and angled downward at 30° and delivered air at the same rate as those listed above.

Treatment 3 (F&2S)was located in the northwest quarter of the building and consisted of a double row of fans (14, 36-inch diameter circulation fans with 0.5 horsepower motors) mounted every 24 feet over the freestalls, and a row of fans (seven, 36-inch diameter circulation fans with 0.5 horsepower motors) mounted every 24 feet over the cow feed lane. The angle and air delivery rate was the same as described above.

Each pen was equipped with similar sprinkler systems consisting of 2.5 gph nozzles spaced every 78 inches on center at a height of 8-ft above the headlocks. Sprinklers were on a 15 minute cycle with 3 min on and 12 min off. Sprinklers were activated when the temperature was above 75° F. The designed application rate was .04 inches/feet square of surface area which consisted of 12 feet square per headlock or 24-inch feeding space. Total application rate was 50 gallons per cycle. Fans of all treatments were activated when the temperature was above 70° F both day and night.

Initial treatment averages (Table 3) for DIM and milk production were similar for all treatments. Cows cooled with the F&S system produced 4.5 pounds more ($P<.05$) milk than the 2S system, while those under the F&2S system were intermediate. Dry matter intake was numerically similar for all treatments. All cows increased body condition score during the trial. Cows under the 2S system tended to have a greater increase as compared to the F&S treatment. This is likely due to similar DMI and lower production for the 2S system.

2000 Study

During the summer of 2000 another study was conducted to determine if fans were only needed over the feedline. One hundred mid-lactation Holstein cows averaging 173 DIM and producing 97.6 lb/ cow/day of milk were blocked by milk production and DIM and randomly assigned to one of 4 pens of a four-row freestall barn. Two replicates, north and south halves of the barn, contained two pens each. Fan treatments were 36 inch fans mounted every 24 feet on the feed line (F) or 36 inch fans mounted every 24 feet on the feed line and over the center of the head-to-head freestalls (F&S). All pens were equipped with feed line sprinklers that operated on a 15 min cycle (3 minutes on and 12 minutes off) when temperatures were above 75° F. All fans operated when the temperature was above 70° F. A switchback design with five two-week periods was utilized to evaluate fan placement. Cows and treatments were switched at the start of each period within each replicate.

Cows were milked 2 times, and milk production was measured every two weeks throughout the 10 week trial. All pens received the same diet. Amounts of feeds offered and refused were measured and recorded daily. Dry matter content of the diet and refusal of each was determined twice weekly. Cow respiration rates were measured on three separate days under heat stress. Fifteen cows were randomly selected from the 25 study cows in each pen and respiration rates were measured in the morning between 7 a.m. and 8 a.m., during the afternoon between 3 p.m. and 4 p.m., and at night between 11 p.m. and 12 a.m. on each of the three days.

Pen feed intakes (54.0 vs. 52.7 lb / cows / day; Figure 5) tended to be greater (P=0.11) when FS was used rather than F. Cows exposed to treatment F&S produced more (P<0.01) milk (85.6 vs. 79.8 lb / cows / day; Figure 6) during the trial than those exposed to the F treatment. Respiration rates were lower (P<0.06) in the morning (71.7 vs. 79.3 breaths / cows / m), at night (76.0 vs. 80.1) and daily (79.4 vs. 83.2) under the FS treatment compared to the F treatment (Figure 7). Afternoon respiration rates were unaffected by treatment.

This study clearly demonstrated that in a four-row freestall barn, greater milk production and a lower respiration rate was obtained by locating fans on both the feed line and over the freestalls. Based on respiration rates, the duration of heat stress was reduced by the F&S treatment demonstrated by lower respiration rates in the morning and at night. Appropriate fan location in combination with feed line sprinklers reduced heat stress in lactating dairy cattle housed in a four-row freestall building.

Recommendations

Fans should be mounted above the cows on the feed line and above head-to-head freestalls in a four-row freestall barn. If 36 inch fans are used, they should be located no more than 30 feet apart. If 48 inch fans are used, they should be located no more than 40 feet apart and operate when the temperature reaches 70° F. Fans should be mounted out of the reach of the cattle and in a manner that will not obstruct equipment movement. Fans should create an airflow of 800-900 cfm per stall or headlock. Feed line sprinklers should be used in addition to the fans. Feedline sprinkling systems should wet the back of the cow, and then shut off to allow the water to evaporate prior to another cycle beginning. Application rate per cycle should be .04 inches / ft^2, and sprinklers should operate when the temperature exceeds 75°F.

Summary

Effective freestall barn cooling is comprised of three steps. First, enhance natural ventilation through building design that allows for maximum natural ventilation and protection from solar radiation. Critical areas include barn orientation, sidewall height and clear opening, roof slope, ridge opening, building width and removal of wind shadow. Failure to follow design criteria will reduce natural ventilation. In addition, removal of natural and artificial barriers to wind will increase building ventilation rates.

Second, provide adequate water space and volume. Water consumption increases as temperatures increase. So, it is critical to have adequate water available for all cows. Critical areas are water space per cow, water location, crossover width, and a correctly designed water delivery system.

Third, use effective supplemental cooling systems that are cost effective. Using feed line sprinklers, which wet the cow and then allow the water to evaporate, are effective in reducing heat stress. For every pound of water evaporated,1,000 BTUs of energy are required. By wetting the cow, a major portion of the energy used to evaporate the water is derived from the cow. By utilizing short wetting cycles, several wet-dry cycles can be implemented each hour. In addition to the feed line sprinklers, fans are needed to increase air circulation. This not only provides some cooling effect, but more importantly, increases the evaporation rates by moving drier, less humid air over the body surface of the cow. Fans should be mounted over the freestalls and feed line. Failure to do this will result in a loss of 5 to 6 pounds of milk per cow per day during the summer months.

Heat abatement measures can be effective and profit generating. Data collected by Kansas State University faculty indicates that effective cooling systems increased gross farm income by $81 to $116 per cow per year. Cooling systems should enhance natural air exchange in the freestall building and increase body surface cooling of the cow. Supplemental fans and feedline sprinkling systems are effective in increasing body surface cooling of dairy cattle, thus reducing heat stress, increasing milk production and increasing dairy operation profitability.

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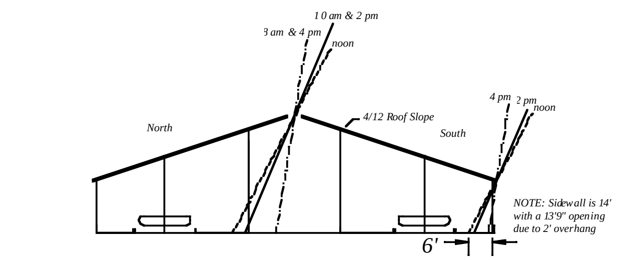
Figure 1. Sun angles of a north-south oriented freestall barn.

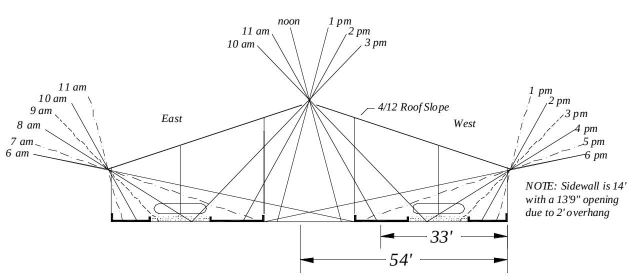


Sun Angles for E-W Freestall - August 21st

40 Degrees North Latitude (Omaha - Springfield)

Source: JP Harner III, Personal communication

Figure 2. Sun angles of an east-west oriented freestall barn.

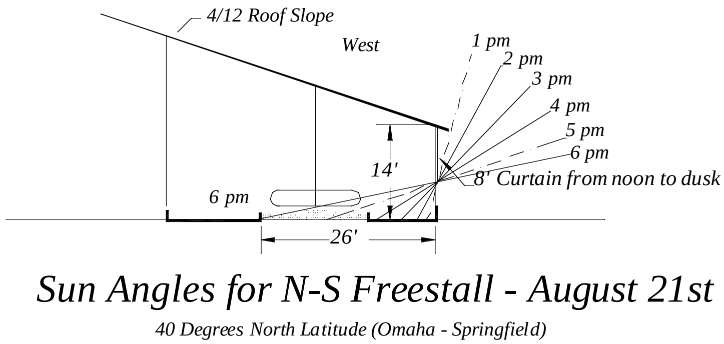


Sun Angles for N-S Freestall - August 21st

40 Degrees North Latitude (Omaha - Springfield)

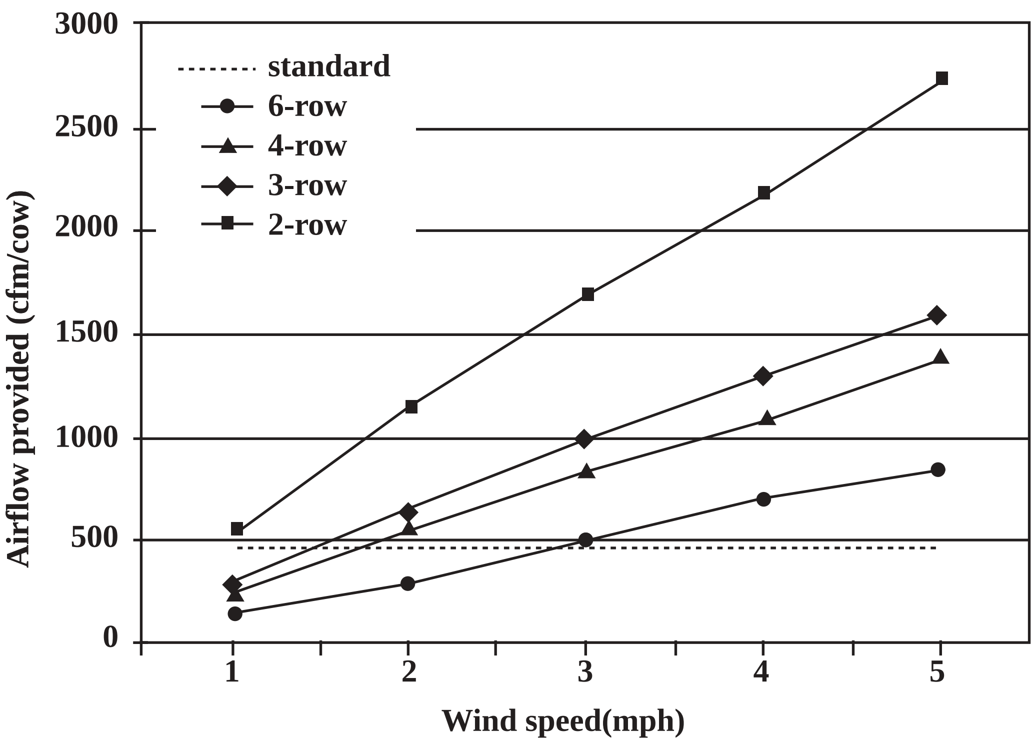
Source: JP Harner III, Personal communication

Figure 3. Effect of curtain on west wall of north-south oriented freestall barns.



Source: JP Harner III, Personal communication

Figure 4. Effect of building width upon airflow rates.



Unitized air exchange rates of common barn configurations for low to moderate wind speeds. Assumes 12-ft. sidewall height; 9-ft. effective opening height for 2- and 4-row barns, 8 ft. for 3-row 6-row configurations; wind approaches barns at an angle from perpendicular, and 1 cow per row per 4 feet of barn length.

Table 1. Available feedline space, square footage and heat produced by cows in different styles of freestall barns*

							Stocking Percentage (cows/stalls)			
Barn Style (ft.)	Pen Width (ft.)	Pen Length (ft.)	# Stalls	Sq. Ft./ Cow	Feedline Space	BTUs/ cow/hr.	100% BTUs/ sq. ft.	110% BTUs/ sq. ft.	120% BTUs sq.ft.	130% BTUs/ sq. ft.
4-Row	39	240	100	94	29	4500	48	53	58	63
6-Row	47	240	160	71	18	4500	64	70	77	83
2-Row	39	240	100	94	29	4500	48	53	58	63
3-Row	47	240	160	71	18	4500	64	70	77	83

*Based on a cow weighing 1,500 pounds and producing 70 pounds of milk per day. (Smith, et al, 2000)

Table 2. Description of building and cooling treatments of 1999 study.

Building description:
Building type: Four-row
Orientation: East-West (2% slope to west)
Dimensions: width-100 ft, length-420 ft, sidewall height-12 ft, roof slope-4/12
Configuration: Four pens with 84 stalls per pen and 100 headlocks per pen

Cooling System [1]	2S	F&S	F&2S
SPRINKLERS			
Sprinklers location	feed line	feed line	feed line
Nozzle rating, gph	25	25	25
Nozzle type	180	180	180
Sprinkler cycle	on - 3 minutes off - 12 minutes	on - 3 minutes off - 12 minutes	on - 3 minutes off - 12 minutes
Sprinkler height, ft	8	8	8
FANS			
Rows over freestalls	2	1	2
Rows over feedline	0	1	1
Number of fans	8	8	8
Total number of fans	16	24	16
Fan spacing, ft.	24	24	24
Fan diameter & hp	36 in. (1/2 hp)	36 in. (1/2 hp)	36 in. (1/2 hp)
Fan airflow/stall, cfm stall	1,900	950	1,900
Fan airflow/headlock, cfm/head	0	800	800

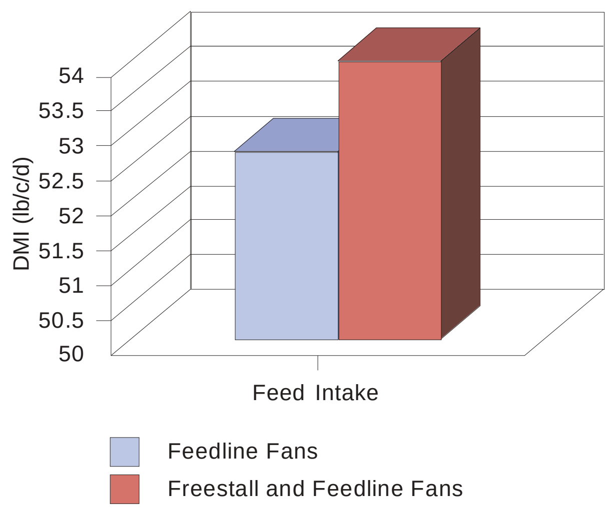
[1]2S=two rows of fans over freestalls, F&S = one row over the feedline and one row of fans over the freestalls and F&2S= one row of fans over the feedline and two rows of fans over the freestalls. (Brouk, et al. 1999.)

Table 3. Summary of milk yield, body condition, and feed intake of dairy cows housed in a four-row freestall barn with three different cooling systems during the summer of 1999.

	Cooling System [1]		
Item	2S	F&S	F&2S
Initial milk, lb	114.5	115.5	114.8
Initial days in milk	131	128	131
Average milk, lb	93.3 [a]	98.8 [b]	96.5 [ab]
Dry matter intake, lb	55.6	56.2	56.3
Change in body condition	+.52	+.39	+.21

[1] 2S=two rows of fans over freestalls, F&S=one row of fans over the feedline and one row of fans over the freestalls, F&2S=one row of fans over the feedline and two rows of fans over the freestalls.
[ab] Means with uncommon superscript differ *(*P<0.05) (Brouk, et al., 1999.)

Figure 5. Summary of feed intake of dairy cows housed in a four-row freestall barn with two different cooling systems during the summer of 2000.



Means differ at P = 0.11

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