Heat Stress Abatement in Four-Row Freestall Barns

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Introduction

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 over 90% 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 (Kibler, 1950). 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 (Figure 1). 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.

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 1400 pound cow (Bickert, et al., 1997). During the summer, greater ventilation rates could potentially 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 which exceed the recommendations. In general, sidewall heights on 4- and 6-row freestall buildings should be 14-16 ft high and be a minimum of 75% 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 2 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, 2-row barns may be adequately ventilated with a 1 mph wind, 6-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 rates. When comparing 4- and 6-row barns, reduced area per cow increases the heat load in 6-row barns.

In addition to building width and sidewall height, ridge 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 open ridges. The ridge open should be 2 inches per 10 ft of building width.

Roof slope is another critical design consideration. Heat rises and roof pitch can either enhance or reduce air flow out the ridge opening. In 4- and 6- row buildings, roof slope should be 4/12 to enhance air flow and exchange. Utilizing less slope in these barns has been shown to increase afternoon respiration rates (Armstrong, et al., 1999). 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 2 mono-slope units are built facing each other with only a feed road between, one essentially has a 4-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, build-

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ing should be at least 100 ft apart or 1.5 times the building width. Any obstruction natural air flow reduces air exchange. Buildings, equipment and stored forages may all reduce air flow 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 ft in width to allow cattle to pass through the crossover while others are drinking. Crossover width is critical to avoid bottlenecks in cow flow. Ideally, 2 feet of tank perimeter should be provided for each 10-20 cows in a pen. In warmer climates, total tank perimeter for a pen is equal to 15% of the pen size times 2. 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 cross-over 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 20-30 gallons per 100 cows.

Supplemental Cooling

Freestall barns which 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 4-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-ft in width and 420-ft in length. The sidewall height was 12-ft and the roof had a 4/12 slope.

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

Treatment two (F&S) was located in the southwest quarter of the building and had a row of fans (7, 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 angled downward at 30° and had the same air delivery rate as those listed above.

Treatment three (F&2S) was located in the northwest quarter of the building and had a double row of fans (14, 36-inch diameter circulation fans with 0.5 horsepower motors) mounted every 24-ft over the freestalls and a row of fans (7, 36-inch diameter circulation fans with 0.5 horsepower motors) mounted 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/ft sq of surface area which consisted of 12-ft sq/headlock or 24-inch feeding space. Total application rate was 50 gallons/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/c/d of milk were blocked by milk production and DIM and randomly assigned to one of 4 pens of a 4-row freestall barn. Two replicates, north and south halves of the barn, contained 2 pens each. Fan treatments were 36 in. fans mounted every 24 ft. on the feed line (F) or 36 in. fans mounted every 24 ft. 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 on and 12 off) when temperatures were above 75*F. All fans operated when the temperature was above 70*F. A switch back design with 5 two-wk periods was utilized to evaluate fan placement. Cows and treatments were switched at the start of each period within each replicate.

Cows were milked 2x and milk production was measured every two weeks throughout the 10 wk 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 (0700-0800 hr), afternoon (1500-1600 hr) and at night (2200-2300 hr) on each of the three days.

Cows exposed to treatment F&S produced more (P<.01) milk (85.6 vs 79.8 lb/c/d) during the trial than those exposed to the F treatment. Respiration rates were lower (P<.06) in the morning (71.7 vs 79.3 breaths/c/m), at night (76.0 vs 80.1) and daily (79.4 vs 83.2) under the FS treatment compared to the F treatment. Afternoon respiration rates were unaffected by treatment. Pen feed intakes (54 vs 52.7 lb/c/d) tended to be greater (P=.11) when when FS was utilized rather than F.

This study clearly demonstrated that in a 4-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 4-row freestall building.

Recommendations

Fans should be mounted above the cows on the feed line and above head-to-head freestalls in a 4-row freestall barn. If 36 in. fans are utilized, they should be located no more than 40 ft. apart. If 48 in. fans are used, they should be located no more than 30 ft. 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. Feed line sprinklers should be utilized 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. Sprinklers should operate when the temperature exceeds 75°F.

Summary

Effective freestall barn cooling is comprised of 3 steps. First, enhance natural ventilation through building design which 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 reduced 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. Therefore, 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, utilize effective supplemental cooling systems which are cost effective. Using feedline sprinklers which wet the cow and then allow the water to evaporate are very 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 utilized to evaporate the water is derived from the cow. By utilizing short wetting cycles, wet-dry cycles can be implemented each hour. In addition to the feedline 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.

Heat abatement measures can be effective and profit generating. Systems should enhance natural air exchange in the freestall building and increase body surface cooling of the cow.

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

Sun Angles for N-S Freestalls
August 21st—40° latitude

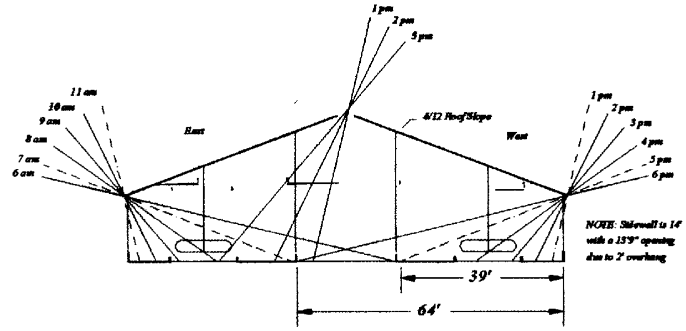
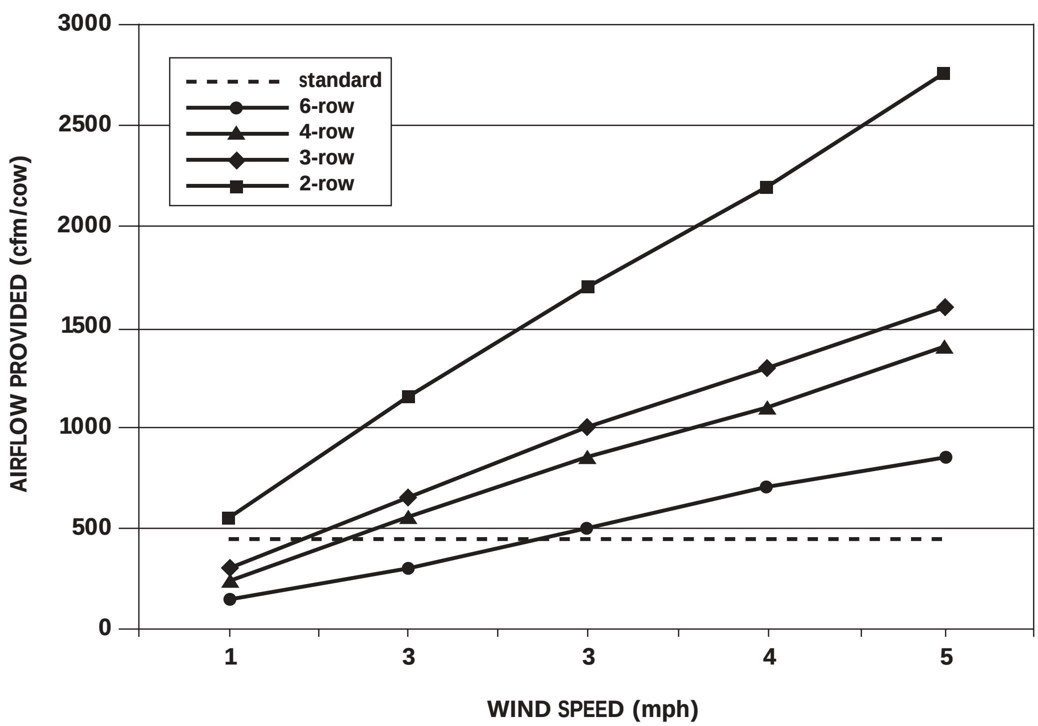


Figure 2. Effect of building width upon airflow rates.



Unitized air exchange rate of common barn configurations for low-to-moderate wind speeds (assumes 12-foot sidewall height; 9-foot 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).

Chastain, 2000.

Table 1. Available Feedline Space, Square Footage and Heat Produced by cows in Different Styles of Freestall Barns*

Barn Style	Pen Width (ft.)	Pen Length (ft.)	# Stalls	Sq. Ft./ Cow	Feedline Space	BTUs/ cow/ hr.	Stocking Percentage (cows/stalls) 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: 4 row
Orientation: East-West (2% slope to west)
Dimensions: width-100 ft, length-420 ft, sidewall height-12 ft, roof slope-4/12
Configuration: 4 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 feed line	0	1	1
Number of fans per row	8	8	8
Total number of fans	16	16	24
Fan spacing, ft	24	24	24
Fan Diameter & hp	36 in (½ hp)	36 in (½ hp)	36 in (½ 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 of fans 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)

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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	93.9[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)

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