Opportunities with Low Profile Cross Ventilated Freestall Facilities

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TAKE HOME MESSAGES

- LPCV facilities have the ability to minimize fluctuations in core body temperature by providing an environment which is similar to a cow’s thermoneutral zone.
- Heat stress and cold stress significantly decrease income over feed cost. Limiting environmental stress throughout the year can increase the efficiency of dairy cow feed.
- LPCV can improve pregnancy rates and reduce abortions by decreasing the impact of heat stress on reproductive performance.
- Improving a cow’s environment greatly reduces the impact of heat stress on present and future milk production.

INTRODUCTION

Low profile cross ventilated (LPCV) freestall buildings are one option for dairy cattle housing. These facilities allow producers to have control over a cow’s environment during all seasons of the year. As a result, an environment similar to the thermoneutral zone of a dairy cow is maintained in both the summer and winter, resulting in more stable core body temperatures. LPCV facilities allow for buildings to be placed closer to the parlor, thus reducing time cows are away from feed and water. Other advantages include a smaller overall site footprint than naturally ventilated facilities and less critical orientation since naturally ventilated facilities need to be orientated east-west to keep cows in the shade. Some of the other benefits to controlling the cow’s environment include increased milk production, improved feed efficiency, increased income over feed cost, improved reproductive performance, ability to control lighting, reduced lameness, and reduced fly control costs.

CHARACTERISTICS OF LPCV FACILITIES

The “low profile” results from the roof slope being changed from a 3/12 or 4/12 pitch common with naturally ventilated buildings to a 0.5/12 pitch. Figure 1 shows the difference in ridge height between 4-row naturally ventilated buildings and an 8-row LPCV building. Contractors are able to use conventional warehouse structures with the LPCV building and reduce the cost of the exterior shell of the building, but the interior components and space per cow for resting, socializing, and feeding in an LPCV building is similar to a 4-row building. Differences in land space requirements between the 4-row naturally ventilated freestall buildings and an 8-row LPCV building are also shown in Figure 1.

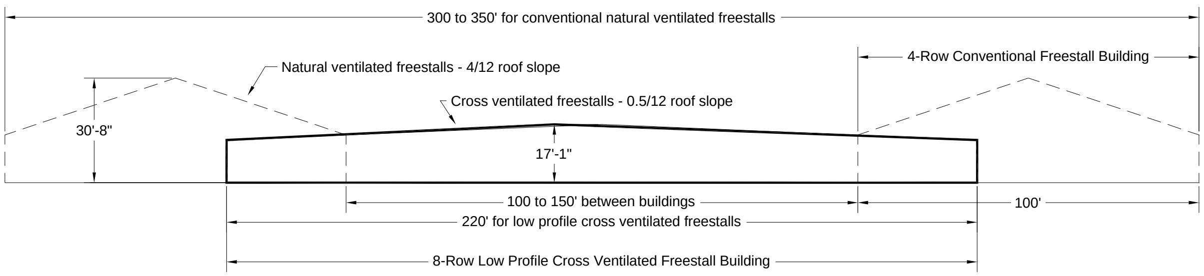

Figure 1: End Views of 8-row Naturally Ventilated Freestall Buildings and 8-row LPCV Freestall Building

Figure 2 shows an end view of an 8-row LPCV building. An evaporative cooling system is located along one side of the building and fans are placed on the opposite side. More space is available for fan placement and the cooling system parallel to the ridge rather than perpendicular because the equipment doors are located in the end walls.

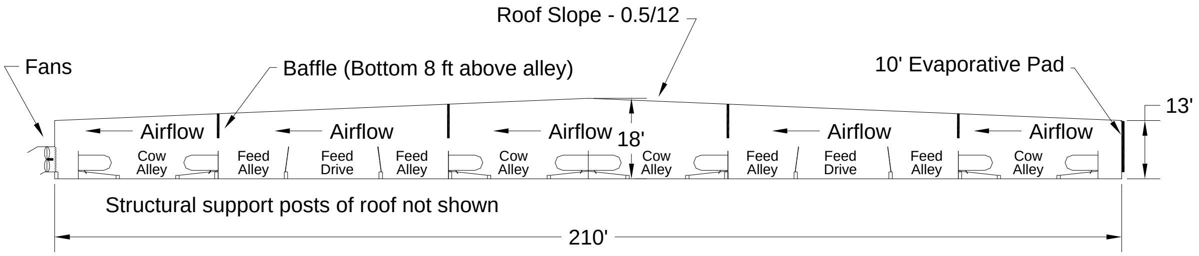

Figure 2: End View of an 8-row LPCV Freestall Building

Figure 3 shows a layout of an 8-row LPCV building with tail to tail freestalls. From a top view, this design simply places two 4-row freestall buildings side by side and eliminates the space between the buildings necessary with natural ventilation. One potential advantage of the LPCV, or tunnel ventilated, buildings is that cows are exposed to near-constant wind speeds. Inside the building the air velocity, or wind speed, is normally less than 8 miles per hour (mph) during peak airflow. The ventilation rate is reduced during cold weather with the wind speed decreasing to less than 2 mph

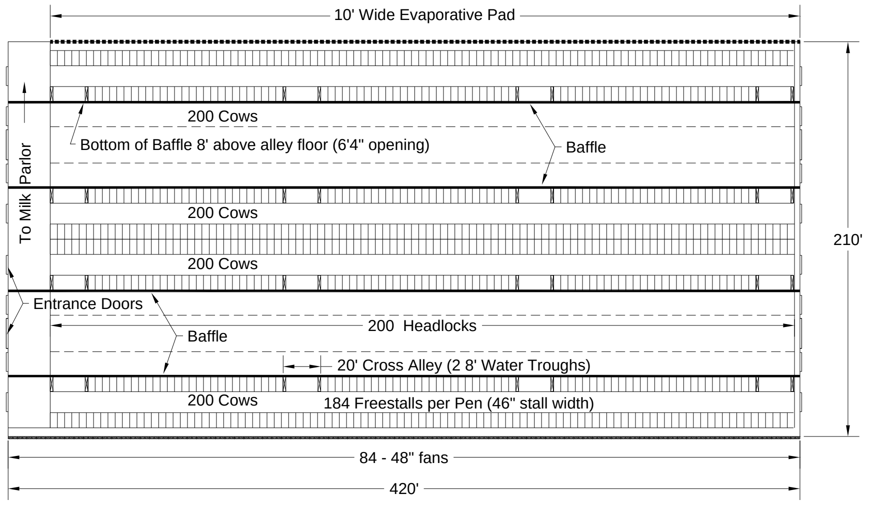

Figure 3: Top View of an 8-row LPCV Building (Adjustable Building Length Based on Cow Numbers)

PROVIDING A CONSISTENT ENVIRONMENT

Constructing a cross ventilated facility ensures the ability to provide a consistent environment year-round, resulting in improved cow performance. These buildings provide a better environment than other freestall housing buildings in the winter, spring and fall months, as well as the summer because of the use of an evaporative cooling system.

The ability to lower air temperature through evaporative cooling is dependent upon ambient temperature and relative humidity. As relative humidity increases, the cooling potential decreases, as shown in Figure 4. Cooling potential is the maximum temperature drop possible, assuming the evaporative cooling system is 100% efficient. As the relative humidity increases, the ability to lower air temperature decreases, regardless of temperature. The cooling potential is greater as air temperature increases and relative humidity decreases. Figure 4 also shows that evaporative cooling systems perform better as the humidity decreases below 50 percent.

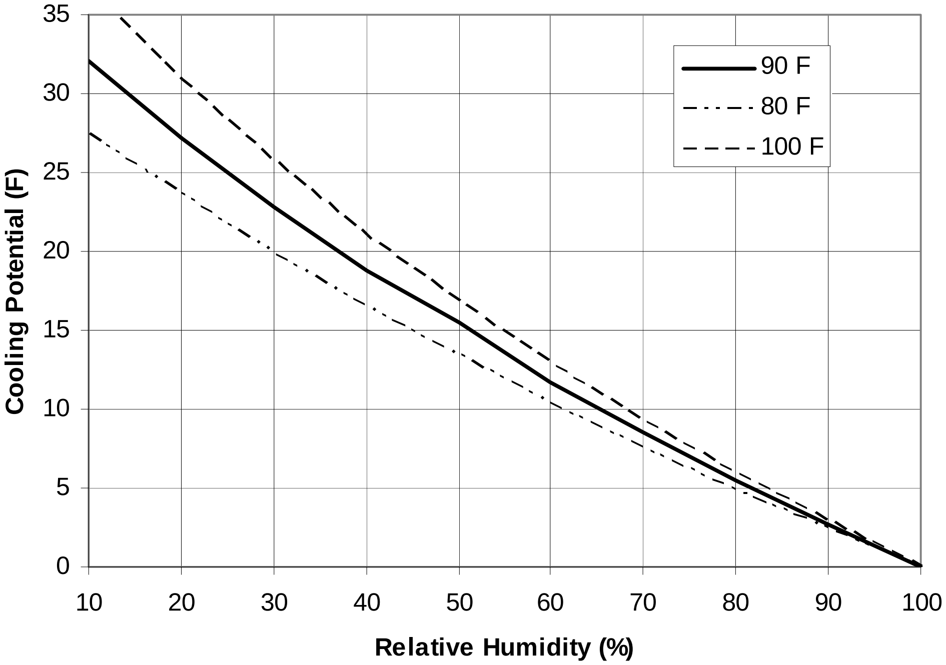

Figure 4: Impact of Relative Humidity and Temperature on Cooling Potential When Using an Evaporative Cooling System

LPCV DATA

Data loggers were used to evaluate the ability of an LPCV system to reduce heat stress under different environmental conditions. Temperature data collected shows the limitations of the evaporative cooling system to improve the environment inside the structure during periods of high humidity. Ambient barn intake and barn exhaust temperature, relative humidity, and temperature humidity index (THI) for 4 different days (July 1, 4, 26, and 29, 2006) with various conditions are presented in Figures 5 through 16. Temperature reduction using evaporative pads is compromised when humidity is high. Individual climates should be evaluated so realistic expectations can be set on how well the evaporative cooling system will improve the summer environment. Further research is needed to investigate the combination of soakers and evaporative cooling to reduce potential heat stress during periods of high relative humidity and high temperatures.

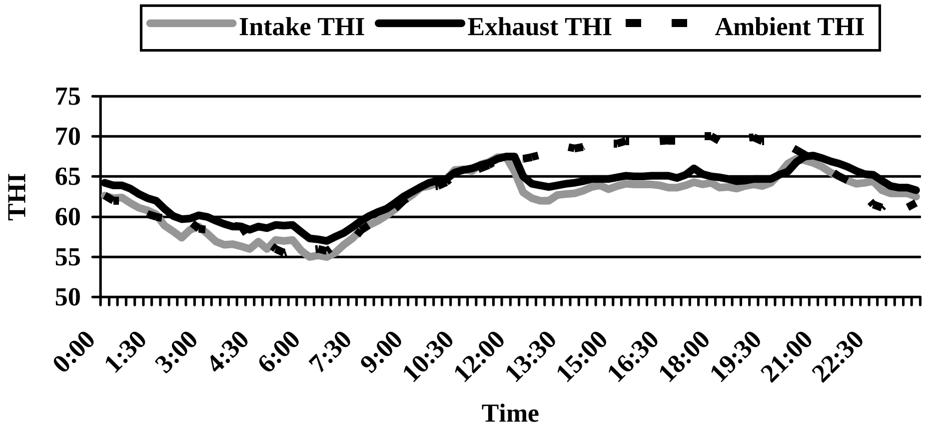

Figure 5: Cool Summer Conditions, Temperature (F) (7-4-06)

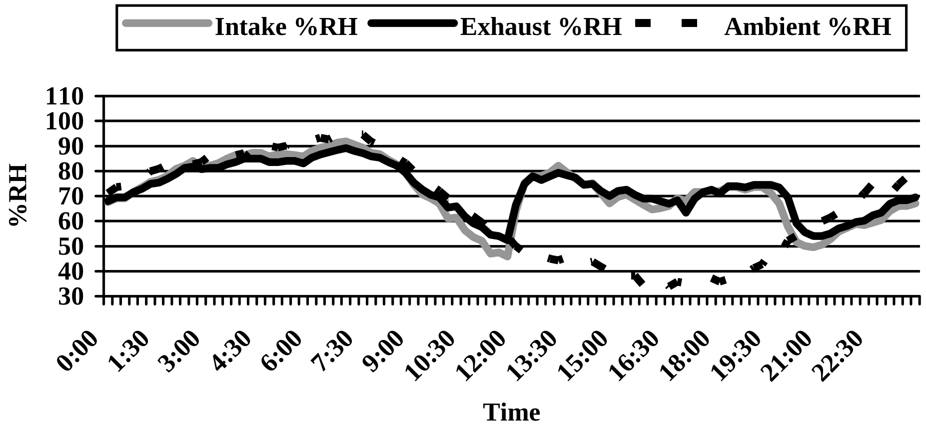

Figure 6: Cool Summer Conditions, Percentage of Relative Humidity (% RH) (7-4-06)

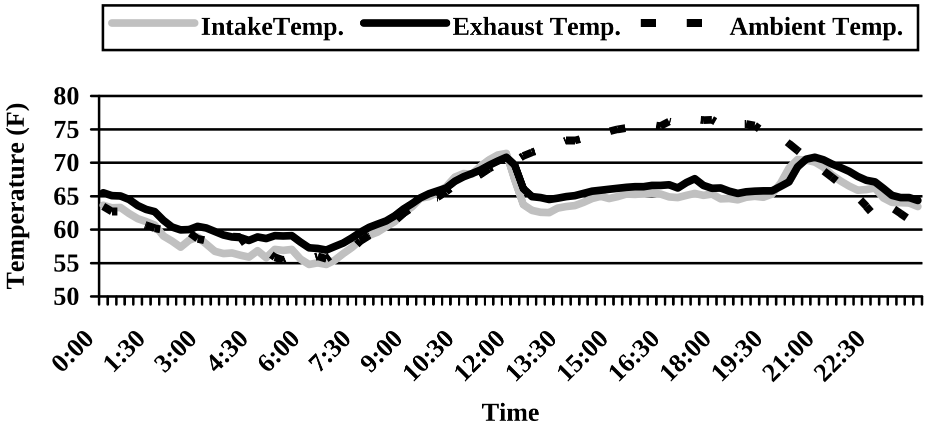

Figure 7: Cool Summer Conditions, THI (7-4-06)

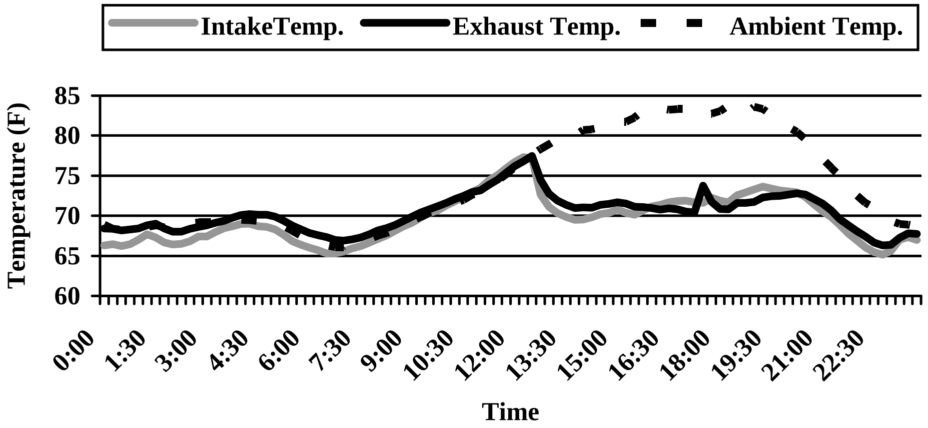

Figure 8: Average Summer Conditions (7-1-06)

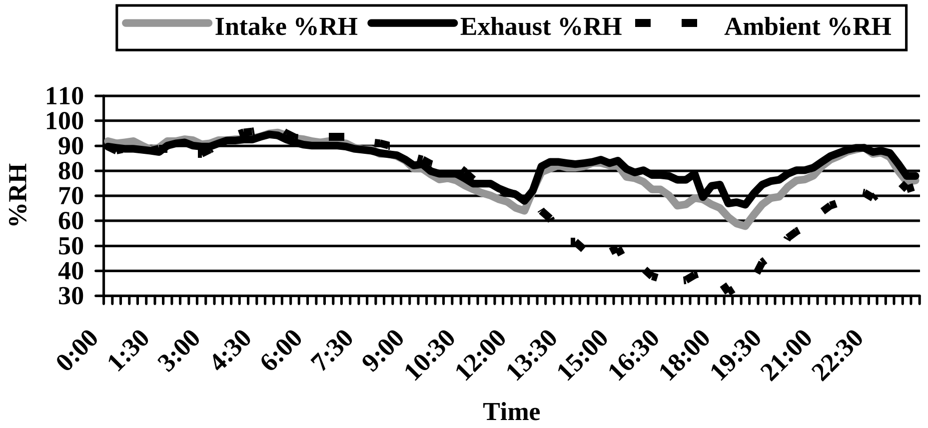

Figure 9: Average Summer Conditions, % RH (7-1-06)

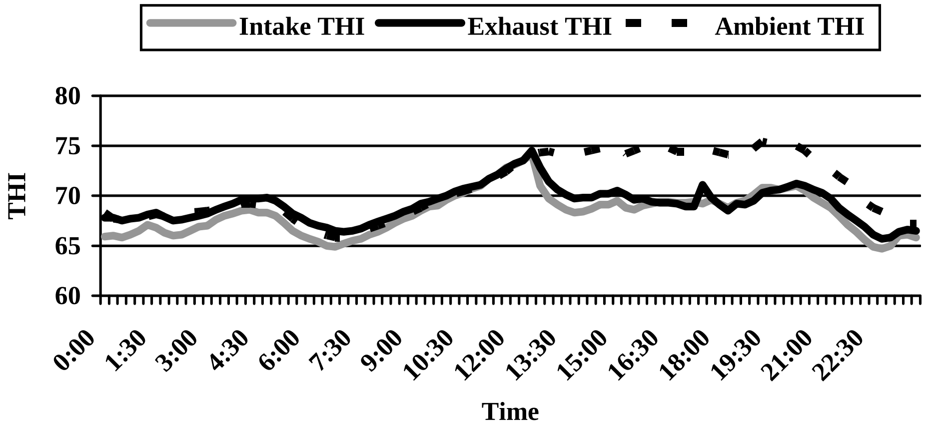

Figure 10: Average Day, THI (7-1-06)

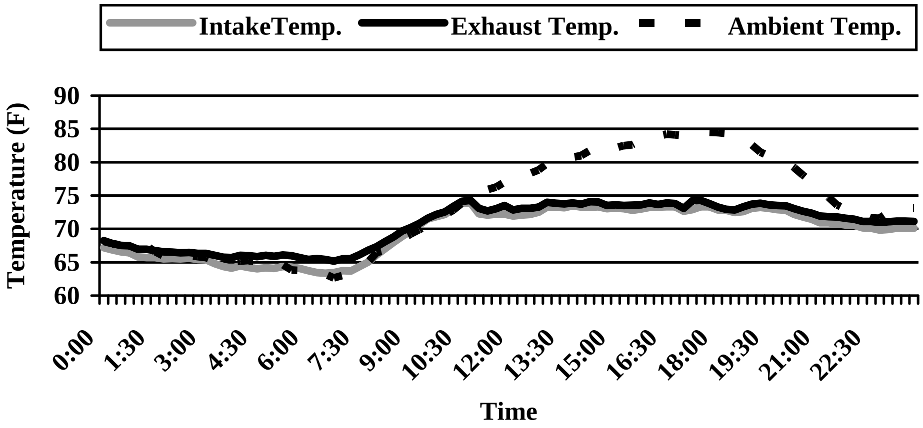

Figure 11: Humid Day Temperature (7-26-06)

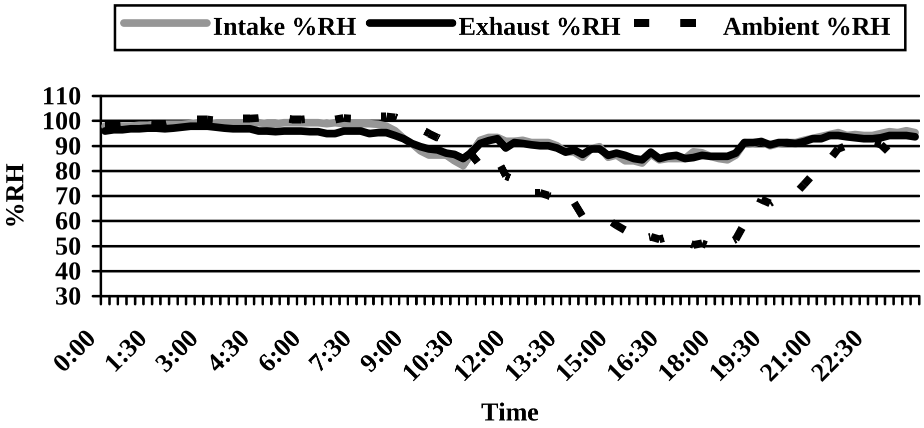

Figure 12: Humid Day Relative Humidity, % RH (7-26-06)

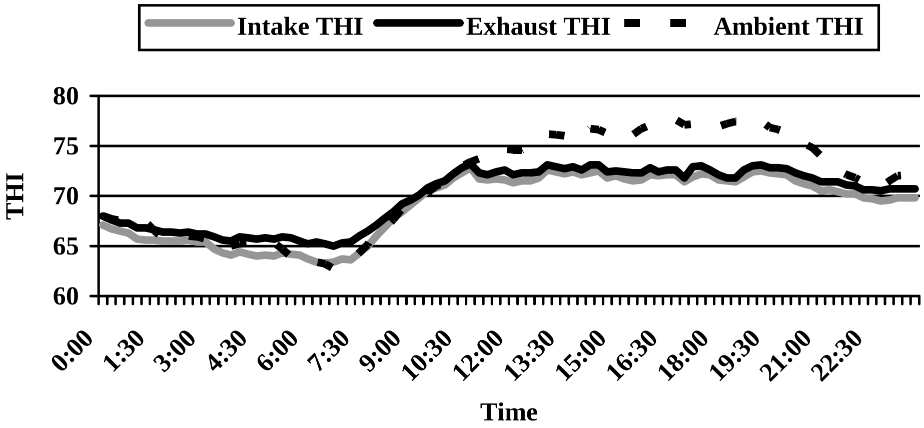

Figure 13: Humid Day, THI (7-26-06)

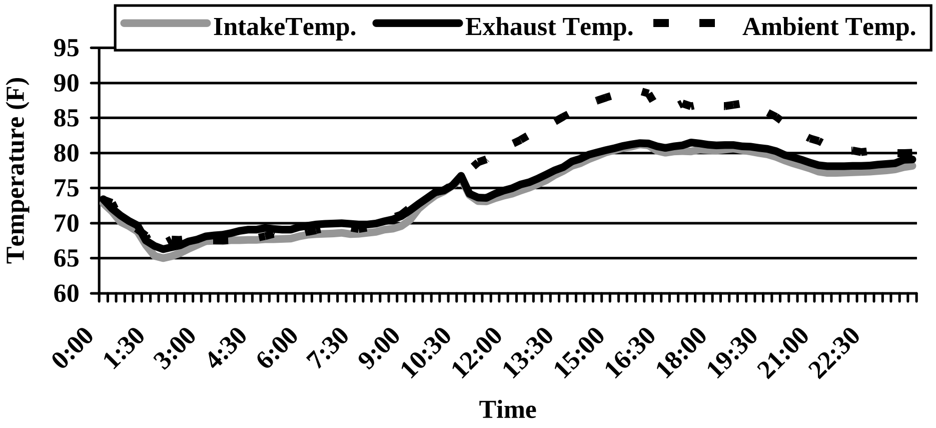

Figure 14: Very Humid Day Temperature (7-29-06)

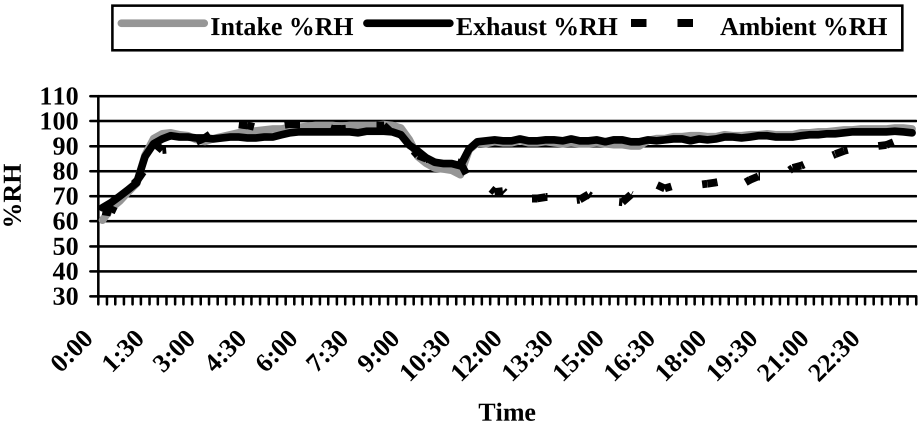

Figure 15: Very Humid Day, %RH (7-29-06)

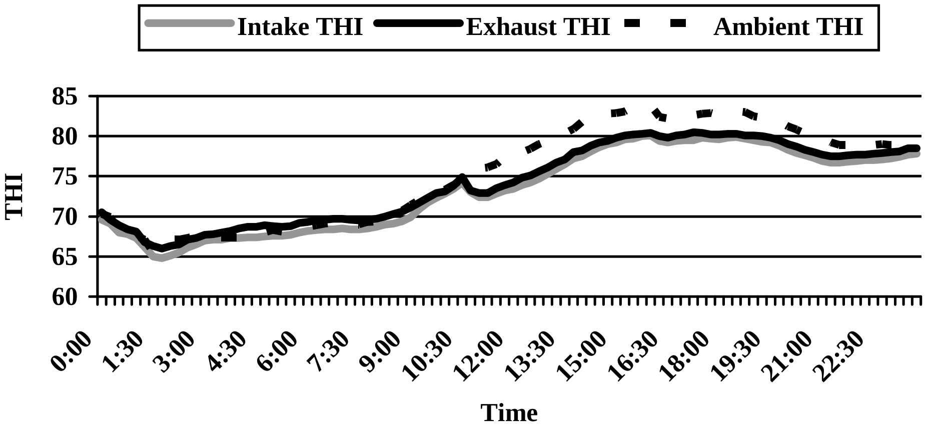

Figure 16: Very Humid Day, THI (7-29-06)

IMPACT OF LPVC FACILITIES AND CORE BODY TEMPERATURE

One of the major benefits of LPCV facilities is the ability to stabilize a cow's core body temperature. A heat stress audit was conducted on a North Dakota dairy to evaluate the impact of a changing environment on the core body temperature of cows. Vaginal temperatures were collected from 8 cows located in the LPCV facility and 8 cows located in a naturally ventilated freestall facility with soakers and fans. Data was recorded every 5 minutes for 72 hours using data loggers (HOBO® U12) attached to a blank CIDR® (Brouk 2005). Environmental temperature and humidity data were collected on individual dairies utilizing logging devices which collected information at 15 minute intervals. The environmental conditions and vaginal temperatures during the evaluation period are presented in Figures 17 and 18. Vaginal temperatures were acceptable in both groups, but the temperatures of cows housed in the LPCV facility were more consistent. Feedline soakers in naturally ventilated buildings are effective in cooling cows, but they require the cows to walk to the feedline to be soaked. On the other hand, cows in an LPCV facility already experience temperatures that are considerably lower than the ambient temperature. Reducing the fluctuations in core body has a dramatic impact on the production, reproduction and health of a dairy cow.

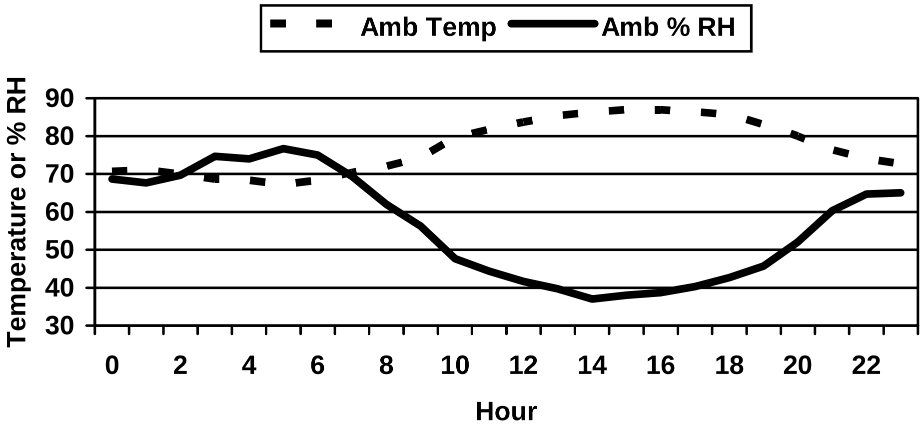

Figure 17: Ambient Temperature and % RH for Milnor, ND (July 6-9, 2006)

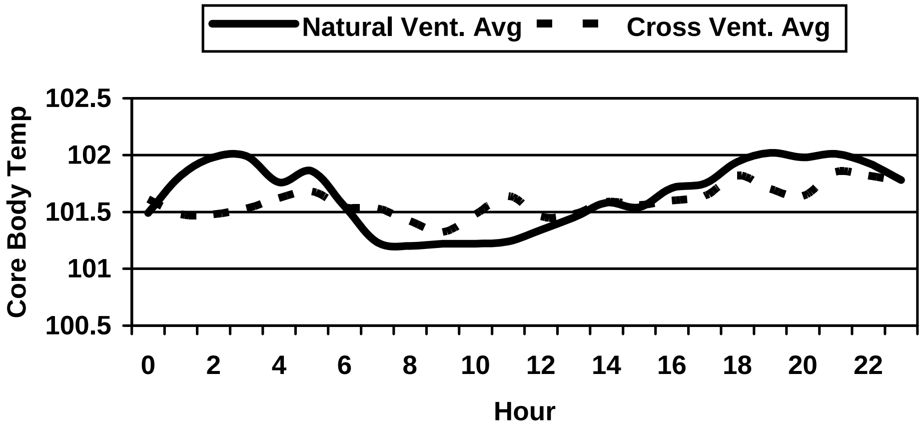

Figure 18: Core Body Temperature of Cows Housed in Naturally Ventilated (Fans & Soakers) and LPVC Freestalls (Evaporative Pads)

ENVIRONMENTAL IMPACT ON NUTRIENT REQUIREMENTS AND EFFICIENCY

Dairy cows housed in an environment beyond their thermoneutral zone alter their behavior and physiology in order to adapt. These adaptations are necessary to maintain a stable core body temperature, but they affect nutrient utilization and profitability on dairy farms.

The upper critical temperature, or upper limit of the thermoneutral zone, for lactating dairy cattle is estimated to be approximately 70 - 80°F (NRC, 1981). When temperatures exceed that range, cows begin to combat heat stress by decreasing feed intake (Holter at el., 1997), sweating, and panting. These mechanisms increase the cows' energy costs, resulting in up to 35% more feed necessary for maintenance (NRC, 1981). When dry matter intake decreases during heat stress, milk production also decreases. A dairy cow in 100°F environment decreases productivity by 50% or more, relative to thermoneutral conditions (Collier, 1985).

Compared to research on the impact of heat stress, little attention has been spent on cold stress in lactating dairy cattle. The high metabolic rate of dairy cows makes them more susceptible to heat stress in U.S. climates, so, as a result, the lower critical temperature of lactating dairy cattle is not well established. Estimates range from as high as 50°F (NRC, 1981) to as low at -100°F (NRC, 2001). Regardless, there is evidence that the performance of lactating cows decreases at temperatures below 20°F (NRC, 1981). One clear effect of cold stress is an increase in feed intake. While increased feed intake often results in greater milk production, cold-induced feed intake is caused by an increase in the rate of digesta passage through the gastrointestinal tract. An increased passage rate limits the digestion time and results in less digestion as the temperature drops (NRC, 2001). In cold temperatures, cows also maintain body temperature by using nutrients for shivering or metabolic uncoupling, both of which increase maintenance energy costs. These two mechanisms decrease milk production by more than 20% in extreme cold stress. However, even when cold stress does not negatively impact productivity, decreased feed efficiency can hurt dairy profitability.

To assess the effects of environmental stress on feed efficiency and profitability, a model was constructed to incorporate temperature effects on dry matter intake, diet digestibility, maintenance requirements, and milk production. Expected responses of a cow producing 80 pounds of milk per day in a thermoneutral environment with Total Mixed Ration (TMR)costs of $0.12/lb dry matter and milk value of $18/ hundred weight of milk (cwt) are shown in Figure 19. The model was altered to assess responses to cold stress if milk production is not decreased. In this situation, the decrease in diet digestibility results in an 8% decrease in income over feed cost as temperatures drop to -10°F ($6.94 vs. $7.52/cow per day).

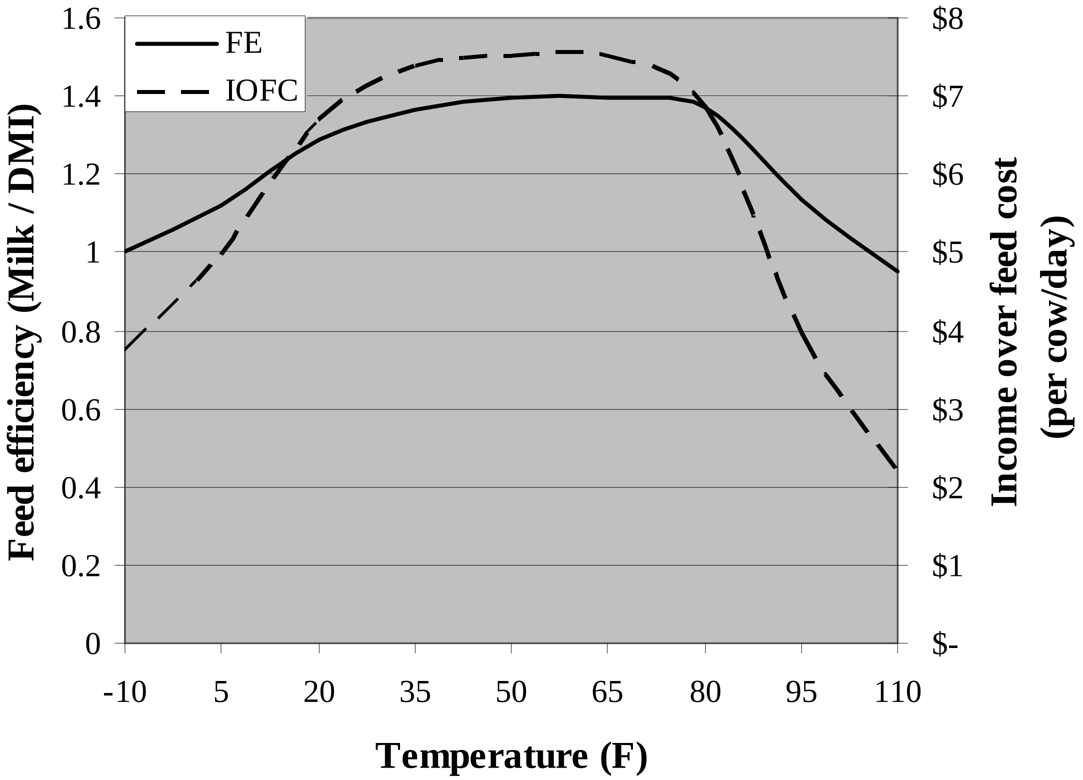

Figure 19: Responses to Environmental Stress, (Thermoneutral Production of 80 lbs/day, TMR Cost of $0.12/lb Dry Matter, and Milk Value of $18/cwt)

With these research results, cost benefits can be estimated for environmental control of LPCV facilities. Benefits of avoiding extreme temperatures can be evaluated by comparing returns at ambient temperatures to temperatures expected inside LPCV barns. For example, the model above predicts that income over feed cost can be improved by nearly $2 per cow/day if the ambient temperature is 95°F and barn temperatures are maintained at 85°F. Likewise, if ambient temperature is 5°F and the temperature inside the barn is 15°F, income over feed cost is expected to increase by $1.15 per cow/day.

Besides effects on feed costs and productivity, heat stress also has negative effects on reproduction, immunity, and metabolic health. These factors represent huge potential costs to a dairy operation. While responses to cold stress are not typically dramatic, increased manure production is a resulting factor. In this model, increased feed intake and decreased digestibility during cold stress also increased manure output by as much as 34%. This is a significant cost factor on many farms, requiring increased manure storage capacity and more acres for manure application.

ENVIRONMENTAL IMPACT ON REPRODUCTION

Even though cold stress has little effect on reproduction, heat stress can reduce libido, fertility, and embryonic survival in dairy cattle. Environmental conditions above a dairy cow's thermoneutral zone decreases ability to dissipate heat and results in increased core body temperature. The elevated body temperatures negatively impact reproduction, both for the female and the male.

The impact of heat stress can be categorized by the effects of acute heat stress (short-term increases in body temperature above 103° F) or chronic heat stress (the cumulative effects of prolonged exposure to heat throughout the summer). In acute heat stress, even short-term rises in body temperature can result in a 25 – 40% drop in conception rate. An increase of 0.9° F in body temperature causes a decline in conception rate of 13% (Gwazdauskas et al.). The impact of heat stress on reproduction is more dramatic as milk production increases, due to the greater internal heat load produced because of more feed intake (al-Katanani et al., 1999).

Declines in fertility are due, at least in part, to damage of developing follicles because of a lower production of the follicular hormone, estradiol. As a consequence, lower quality, aged follicles are ovulated and the resulting conception rate is decreased (Wolfenson, et al.). The lower estradiol levels also make it more difficult to find cows in heat, since a high level of estradiol is required for a cow to express heat or stand to be mounted. In herds that utilize artificial insemination (AI) and depend entirely on estrus detection, or the expression of cows in heat, heat detection decline by 10-20% is common during the summer months. Timed AI tends to result in a greater percentage of inseminations during the summer months as a consequence of the difficulty in finding cows in heat.

If, despite the reduced follicular quality, cows manage to become pregnant, a greater likelihood exists of embryonic loss due to heat stress. Many times, cows actually achieve ovulation and fertilization, but early embryonic loss often occurs during days 2 to 6 post-insemination and the observer believes that the cow never actually conceived.

The results of chronic heat stress are more severe in that there results a poor quality corpora lutea, which produces low levels of progesterone. As a consequence, fertility is negatively affected and a greater risk of twins exists for cows that get pregnant toward the latter periods of heat stress. The risk of late embryonic loss and abortion is approximately 2 to 2.5 times greater for cows bred during and immediately following heat stress. Chronic heat stress also greatly depresses feed intake and prolongs the period of time required for a cow to reach positive energy balance, thus causing excessive weight loss and delaying days to the first ovulation. Because of the severe challenges of impregnating cows during the summer, some herds decrease their efforts during that time.

Whether the decline in pregnancy rates is voluntary or not, drops in the number of cows that become pregnant create holes in the calving patterns. Often, there is a rebound in the number of cows that become pregnant in the fall. Nine months later, a large number of pregnant cows puts additional pressures on the transition facilities when an above-average group of cows moves through the close-up and fresh cow pens. Overcrowding these facilities leads to increases in post-calving health issues, decreased milk production, and impaired future reproduction.

Table 1 examines the economic impact of heat stress by describing the reproductive performance for a hypothetical 3200 cow Holstein dairy.

Table 1. Historical Reproductive Performance for a Hypothetical 3200 Cow Holstein Dairy

Date	# Eligible	Insemination Risk	# Bred	Conception Risk	# Preg	Pregnancy Rate
1-Jan	932	57%	531	30%	159	17%
22-Jan	905	57%	516	30%	155	17%
12-Feb	884	57%	504	30%	151	17%
5-Mar	868	57%	495	30%	149	17%
26-Mar	855	57%	487	30%	146	17%
16-Apr	845	57%	481	30%	144	17%
7-May	833	57%	475	30%	142	17%
28-May	831	57%	473	30%	142	17%
18-Jun	825	**46%**	376	**21%**	79	**10%**
9-Jul	883	**46%**	402	**21%**	85	**10%**
30-Jul	930	**46%**	424	**21%**	89	**10%**
20-Aug	983	**46%**	448	**21%**	94	**10%**
10-Sep	1041	**49%**	514	**24%**	123	**12%**
1-Oct	1078	54%	582	30%	175	16%
22-Oct	1049	57%	598	30%	179	17%
12-Nov	1014	57%	578	30%	173	17%
3-Dec	965	57%	550	30%	165	17%
24-Dec	945	57%	539	30%	162	17%
	16664	**54%**	**8974**	**28%**	**2513**	**15%**

As shown in Table 1, the herd has above-average reproductive performance through much of the year (insemination risk of 57%, conception rate of 30% and a pregnancy rate of 17%). However, during the summer season, as well as throughout the month of September, both insemination risk and conception rate decline, resulting in pregnancy rates that are well below average. As a consequence of these periods of poor reproductive performance, the herd's annual pregnancy rate is 15%. Based on economic models that evaluate the value of changes in reproductive performance, this subpar performance during the five 21-day periods costs the dairy approximately $115,000 (Overton, 2006).

While this simple spreadsheet illustrates how heat stress adversely affects reproductive performance, it does not capture the total cost of the issues created by heat stress. Consideration of the increased number of abortions commonly seen during heat stress, the impact of transition facility overcrowding, the negative affect on cow health, early lactation milk production, and future reproduction leads to estimated losses well beyond $135,000 per year, or at least $42/ cow/ year, using a milk price of $0.18 and a feed cost of $0.12.

ENVIRONMENTAL IMPACT ON MILK PRODUCTION

Though the impact of cold stress on milk production is minimal, the impact of heat stress on milk production can be very dramatic. Numerous studies have been completed to evaluate the economic impact of heat stress on milk production (Dhuyvetter et al., 2000), but because so many approaches are used to manage heat stress, standard evaluations are difficult. Heat stress not only impacts milk production during summer months, but it also reduces the potential for future milk production of cows during the dry period and early lactation. For every pound of peak milk production that is lost, an additional 250 pounds of production will be lost over the entire lactation.

A simple sensitivity analysis was conducted to observe the impact of heat stress on gross income. A net milk price of $18/cwt was used for this analysis. The milk production impact of 90-150 days of heat stress on gross income per cow is presented in Table 2. When daily milk production is reduced 2 to 12 pounds per day per cow, the gross income loss related to heat stress ranges from $32.40 to $324.00 per cow.

Table 2. Potential Loss of Gross Income for Different Lengths of Heat Stress

Reduction of Milk Production (lbs/cow/day)	90 Days of Lost Production (lbs)	120 Days of Lost Production (lbs)	150 Days of Lost Production (lbs)	Lost Income 90 Days ($.18/lb)	Lost Income 120 Days ($.18/lb)	Lost Income 150 Days ($.18/lb)
2	180	240	300	$32.40	$43.20	$54.00
4	360	480	600	$64.80	$86.40	$108.00
6	540	720	900	$97.20	$129.60	$162.00
8	720	960	1200	$129.60	$172.80	$216.00
10	900	1200	1500	$162.00	$216.00	$270.00
12	1080	1440	1800	$194.40	$259.20	$324.00

The impact of heat stress on future milk production is evaluated in Table 3. Gross income per cow per lactation is increased from $90 to $540 per cow/lactation as peak milk production is increased from 2 to 12 lbs/cow/day during periods of heat stress.

Table 3. Impact of Increasing Peak Milk During Heat Stress on Future Milk Production and Gross Income

Increase in Peak Milk Production (lbs/cow/day)	Additional Milk Production (lbs/lactation)	Additional Gross Income per Lactation ($.18/lb)
2	500	$90.00
4	1000	$180.00
6	1500	$270.00
8	2000	$360.00
10	2500	$450.00
12	3000	$540.00

LIGHTING

Light is an important environmental characteristic in dairy facilities. Proper lighting can improve cow performance and provide a safer and more pleasant work environment. Meeting the lighting requirement of both dry and lactating cows in an LPCV facility can be challenging, though, because lactating and dry dairy cattle have different lighting requirements. Dry cows need only 8 hours of light per day and 16 hours of darkness, while lactating dairy cows that are exposed to 16 hours of continuous light (16L) increase milk production from 5 to 16% (8% being typical), increase feed intake about 6%, and maintain reproductive performance (Peters et al., 1978, 1981; Piva et al., 1992). It is important to note, though, that 16L does not immediately increase milk production. A positive response can take two to four weeks to develop (Tucker, 1992; Dahl et al., 1997), assuming that nutrition and other management conditions are acceptable. However, cows exposed to 8 L versus 16 L during the dry period produce 7 lbs/day more milk in the following lactation (Miller et al., 2000).

Enhanced lighting for the milking herd is profitable (Dahl et al., 1997; Chastain and Hiatt, 1998). Producers report that increased light improves cow movement, observation, and care. Cows move more easily through uniformly lit entrances and exits, and herdsmen, veterinarians, and other animal care workers report easier and better cow observation and care. Workers also note that a well-lit area is a more pleasant work environment. Increased cow performance and well-being, plus better working conditions make lighting an important environmental characteristic in a dairy facility.

SUMMARY

LPCV facilities are capable of providing a consistent environment for dairy cows throughout the year. Changing the environment to reflect the thermoneutral zone of a dairy cow minimizes the impact of seasonal changes on milk production, reproduction, feed efficiency and income over feed cost. The key is to reduce variation in the core body temperature of the cows by providing a stable environment.

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