HEALTH

DEDICATED *to the* DEDICATED

Heat Abatement

Elanco

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If we have failed to acknowledge anyone, we apologize and sincerely appreciate the numerous contributions to our knowledge base around heat stress in dairy cattle. We look forward to many more opportunities in the future.

Photos of equipment used for heat abatement systems in this article are not endorsements or recommendations of that specific equipment or brand. They are simply examples of equipment that may be used for various heat abatement systems. Contact a local dealer or installer who can address your specific needs for a heat abatement system.

CONSEQUENCES OF HEAT STRESS

Photo compliments of Dr. Gordie Jones

INTRODUCTION

Dairy cows are among the most sensitive to heat stress of any domestic animal. Heat stress negatively affects dairy cattle during a portion of the year in most dairy-producing countries of the world. Economic losses associated with heat stress incurred by U.S. dairy farmers have been estimated at approximately $900 million per year (St. Pierre et al., 2003).

The optimal temperature range for dairy cattle is 40 to 60°F. High milk-producing dairy cows can exhibit mild heat stress at ambient temperatures as low as 65°F, with heat stress susceptibility directly related to level of milk production and dry matter intake.

Cow(s) standing, perching, and panting to combat heat stress – such actions increase chances of lameness and laminitis

TEMPERATURE-HUMIDITY INDEX (THI)

In addition to environmental temperature, humidity is also important in determining if a cow may become susceptible to heat stress. As the humidity increases, the ability to cool cows by evaporative cooling is reduced; thus, a combination of temperature and humidity or temperature-humidity index (THI) is an important consideration when evaluating heat stress load. Current standards denote 68 as the typical THI when cows begin to suffer mild heat stress. In high producing cows, that value is lower due to the added metabolic heat that is a by-product of additional feed intake and milk production. Increasing milk production from 77 to 99 pounds per day lowers the threshold for heat stress by 9°F (Berman, 2005).

The THI for dairy cows differs from the heat index (as reported for meteorological purposes) for people due to physical and physiological difference in humans and cattle. **Figure C1 on page 6** demonstrates the interaction of ambient temperature and humidity or THI in dairy cattle as well as in humans. This manual will focus solely on the interactions of environmental humidity and temperature in dairy cows.

In very low relative humidity environments (10 to 20%), such as that commonly seen in the southwest US, cows typically start to experience mild heat stress at 75 to 77°F (THI = 68). In high relative humidity environments (50 to 60%), such as those commonly seen in the Midwest or southeast US, cows typically experience mild heat stress at 72°F. In extremely high relative humidity environments (80 to 90%), cows experience severe heat stress at environmental temperatures in the low 80s. Many areas of the country experience summer temperatures greater than 90°F with high relative humidity; thus, cows experience severe and even dangerous heat stress for portions of the day. The relative degrees of heat stress **(Figure C1)** are mild (THI = 68), moderate (THI = 72), severe (THI = 80), and dangerous (THI > 90). Combining the metabolic heat produced by a few hundred cows with high environmental temperature and humidity, the opportunity for heat stress becomes quite apparent, especially considering cattle are not very heat tolerant. Even in the evening, when environmental temperatures usually decline, relative humidity often increases, meaning the THI may remain above the THI threshold for dairy cattle.

How do dairy cattle respond to these changes in the heat index? **Figure C2 on the following page** illustrates the effects of THI on cow body temperature over a 3-day period in a cross-ventilated barn utilizing high-pressure misters to cool cows (Tom Bailey, Elanco Dairy Business, data on file). Cow body temperatures, barn temperatures, and humidity were collected every 5 minutes over the three-day audit period. The red line represents hourly mean cow body temperatures (right vertical axis scale) from 8 cows over the 72-hour audit period while the black line (left vertical axis scale) is the calculated barn THI. The black squares represent milking times over the 72 hours. In this facility at a THI of 79, body temperatures reached 104.5°F or greater. On the second day of the evaluation, the heat index declined from 74 to 64; however, body temperatures remained between 102.8 and 104.5°F. Body temperatures did not return to normal (101.5°F) until the heat index reached 65. The dashed line indicates the body temperature point where embryo loss is possible (102.2°F). Cow body temperatures were well above this mark until the heat index dropped below 65.

The threshold for heat stress is even lower for higher producing cows. In an attempt to prevent cows from over-heating, fan and soaker operation should be initiated at a THI of 65-66 in specific groups of cows with higher production, higher dry matter intake, and those cattle eligible for breeding.

DAIRY COW HEAT PRODUCTION

In addition to the effects of environmental temperatures and humidity, dairy cows generate a considerable amount of internal heat through the processes of rumination and metabolism. A high-producing dairy cow can produce 4,500 to 6,000 BTUs per hour, or roughly the equivalent amount of heat produced by a 1,500-watt hair dryer each hour (Harner et al., 2000). Heat production is increased 27.3% in cows producing 41 pounds of milk per day and 48.5% in cows producing 70 pounds of milk per day, compared to non-lactating cows (Purwanto et al. 1990). Combining high environmental temperature and humidity with the heat generated by a few hundred cows, the likelihood for heat stress is quite high during warm seasons.

HEAT STRESS AND COW BODY TEMPERATURE

When experiencing moderate, prolonged heat stress, a cow's body temperature may rise to 103 to 104°F. As the THI moves into the severe or dangerous zone, body temperature may rise to 105°F or higher. With a prolonged body temperature of greater than 106°F, there is a high probability of death. In warm climates, the environmental temperature and humidity (high THI) may create conditions where severe heat stress can occur through evening hours, preventing a cow's core body temperature from returning to normal (101.5°F).

Figure C3 on page 7 demonstrates the effect of ambient temperature and humidity (THI) on cow body temperature (Tom Bailey, Elanco Dairy Business, data on file). Body temperatures were recorded every 5 minutes in eight cows via an intravaginal temperature monitoring device. Five minute temperature readings were averaged to give hourly temperature readings over 72 hours. Cow body temperatures (solid dark blue line) were above 102.5°F for the majority of the monitoring period and fluctuated over time. Body temperatures

Figure C1. Temperature Humidity Index (THI) is used to predict the thermal stress on dairy cows based on the combination of actual temperature and relative humidity

DAIRY COW TEMPERATURE HUMIDITY INDEX (THI)

Temp °F \ Humidity %	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90
72	64	65	65	65	66	66	67	67	67	68	68	69	69	69	70	70	70	71	71
74	65	66	66	67	67	67	68	68	69	69	70	70	70	71	71	72	72	73	73
76	66	67	67	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75
78	67	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75	76	76
80	68	69	69	70	70	71	72	72	73	74	75	75	76	76	77	78	78	79	79
82	69	69	70	70	71	72	73	73	74	75	75	76	77	77	78	79	79	80	80
84	70	70	71	72	73	73	74	75	75	76	77	78	78	79	80	80	81	82	83
86	71	71	72	73	74	74	75	76	77	78	78	79	80	81	81	82	83	84	84
88	72	72	73	74	75	76	76	77	78	79	80	81	81	82	83	84	85	86	86
90	72	73	74	75	76	77	78	79	79	80	81	82	83	84	85	86	86	87	88
92	73	74	75	76	77	78	79	80	81	82	83	84	85	85	86	87	88	89	90
94	74	75	76	77	78	79	80	81	82	83	84	86	86	87	88	89	90	91	92
96	75	76	77	78	79	80	81	82	83	85	86	87	88	89	90	91	92	93	94
98	76	77	78	80	80	82	83	83	85	86	87	88	89	90	91	92	93	94	95
100	77	78	79	81	82	83	84	85	86	87	88	90	91	92	93	94	95	96	98
102	78	79	80	82	83	84	85	86	87	89	90	91	92	94	95	96	97	98	100
104	79	80	81	83	84	85	86	88	89	90	91	93	94	95	96	98	99	100	101
106	80	81	82	84	85	87	88	89	90	91	93	94	95	97	98	99	101	102	103
108	81	82	83	85	86	88	89	90	92	93	94	96	97	98	100	101	103	104	105
110	81	83	84	86	87	89	90	91	93	95	96	97	99	100	101	103	104	106	107

HUMAN HEAT INDEX

Temp °F \ Humidity %	40	45	50	55	60	65	70	75	80	85	90
72											
74											
76											
78											
80	80	80	81	81	82	82	83	84	84	85	86
82	81	82	83	84	84	85	86	88	89	90	91
84	83	84	85	86	88	89	90	92	94	96	98
86	85	87	88	89	91	93	95	97	100	102	105
88	88	89	91	93	95	98	100	103	106	110	113
90	91	93	95	97	100	103	105	109	113	117	122
92	94	96	99	101	105	108	112	116	121	126	131
94	97	100	103	106	110	114	119	124	129	135	
96	101	104	108	112	116	121	126	132			
98	105	109	113	117	123	128	134				
100	109	114	118	124	129	136					
102	114	119	124	130	137						
104	119	124	131	137							
106	124	130	137								
108	130	137									
110	136										

Stress threshold for lactating cows. Respiration rate may exceed 60 BPM. Milk losses begin ~ 2.5 lbs/cow/day. Reproductive loses are detectable and rectal temperatures may exceed 102.5°F. Caution for people depending on age, exposure and activity. People may not feel heat stress until 80°F and 40% humidity.

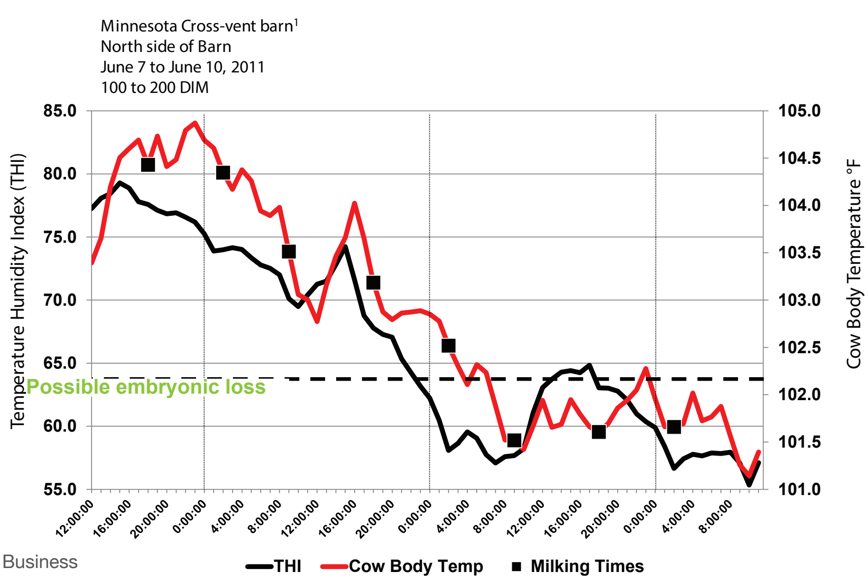
Mild to moderate stress for lactating cows. Respiration rates may exceed 75 BPM. Milk losses ~ 6lbs/cow/day. Rectal temperatures will exceed 102.2°F at 72 to 73 THI and may be closer to 103.5°F and above at a 78 to 79 THI. Extreme caution for people depending on age, exposure, and activity.

Moderate to severe stress for lactating cows. Respiration rate exceeds 85 BPM. Milk losses ~8.7 lbs/cow/day. Rectal temperate exceeds 104°F. Danger for people depending on age, exposure, and activity.

Severe stress! Life threatening conditions for lactating cows. Respiration rates are 120-140 BPM. Rectal temperatures may exceed 106°F. Extreme danger of heat exhaustion and/or heat stroke for people when working in these conditions.

Adapted from Reneau, J. 2012

Figure C2. Effect of THI on dairy cow body temperature



Data by Bailey, Elanco Dairy Business

increased at each of two daily milkings (red squares), which was likely an effect of heat stress conditions in the holding pen and parlor. Following each milking, body temperatures approached the critical level of 104°F. **Figure C4** represents the same herd the following year after heat abatement strategies were implemented. Note that with heat abatement, body temperatures (right axis scale) fluctuated but did not exceed 103°F even though ambient temperatures (left axis scale) were slightly higher than the previous year and cows were being milked 3 times per day versus 2 times per day in the prior year.

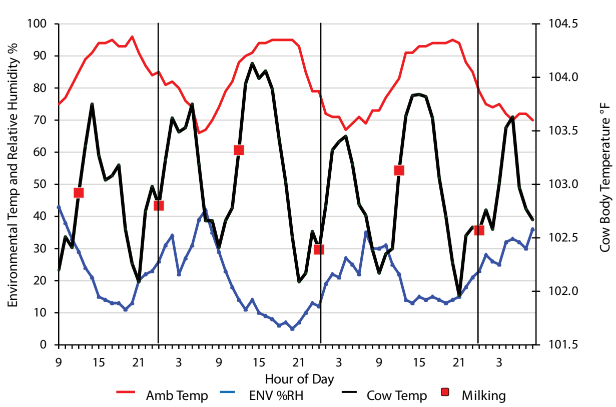
BODY TEMPERATURE AND RESPIRATION RATES

In cattle, an estimate of body temperature can be made by measuring respiratory rate. Because cows are quite dependent on respiration (expired air) for dissipating body heat, respiratory rates increase with body temperature. **Figure C5 on page 9** demonstrates the high correlation between body temperature and respiration rate. As body temperatures increase, respiration rates increase proportionately. Breathing rates can be monitored by observing movements of the flanks or the nostrils as cows respire.

To estimate a cow's body temperature based on respiration rate, count respirations for 20 seconds, and multiply by 3 to determine respirations per minute. Apply the respiratory rate to the chart to get an estimate of body temperature. For example, normal respiratory rate for cattle is 40 to 45 times per minute, which equates to a body temperature of 101.5°F. At 60 respirations per minute, cows are in heat stress with a body temperature of approximately 102.5°F. If the respiratory rate is 80 breaths per minute, a cow's body temperature can be estimated at 103.0 to 103.5°F. It is best to determine respiratory rates while cows are at rest and not being moved.

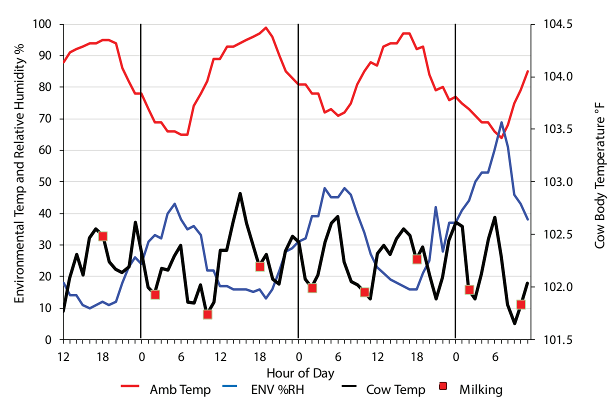
Cows often experience the most severe heat stress challenge while in the milking parlor holding pen. If heat stress is suspected while

Figure C3. Impact of temperature, humidity, and time of milking on cow temperature when heat abatement systems are <u>not</u> used.



Data by Bailey, Elanco Dairy Business

Figure C4. Impact of temperature, humidity, and time of milking on cow temperature when heat abatement systems are used.



Data by Bailey, Elanco Dairy Business

cows are in a holding pen, respiration rates can be recorded before cows are moved into the holding pen and again immediately upon exiting the milking parlor. To determine the approximate mean body temperature for cows in a group, obtain rates from 10 to 12 cows in each group being monitored.

The respiration rates of cows can also be monitored late in the evening when ambient temperatures have declined. Even though environmental temperatures may drop, an increase in humidity can cause the THI to be higher in the evening compared to the day. If respiratory rates remain above 60 per minute, heat abatement strategies should continue during the evening hours. Some of the highest body temperatures have been recorded between 11:00 p.m. and 2:00 a.m. In addition to evening hours, cows should be observed in the early morning to determine if core body temperature has returned to normal (101.5°F) during the night hours.

CONSEQUENCES OF HEAT STRESS

Heat stress in the dairy cow impacts several body systems, resulting in severe and interrelated effects that can negatively impact a number of physiological and production parameters. The overall impact depends on the severity and duration of heat stress and the resulting elevation in body temperature. Direct effects of heat stress in dairy cows include:

- reduced milk production (35 to 50% in non-cooled cows and potentially 10 to 15% in cooled cows)
- reduced feed intake (up to 50% in non-cooled cows and 10 to 15% in well cooled cows)
- rumen acidosis
- milk fat depression
- reduced reproductive efficiency
- early calving and lower birth weights in calves
- laminitis or lameness
- compromised immune system
- increased incidence of infectious diseases, including mastitis and metritis
- body weight loss and reduced body condition score

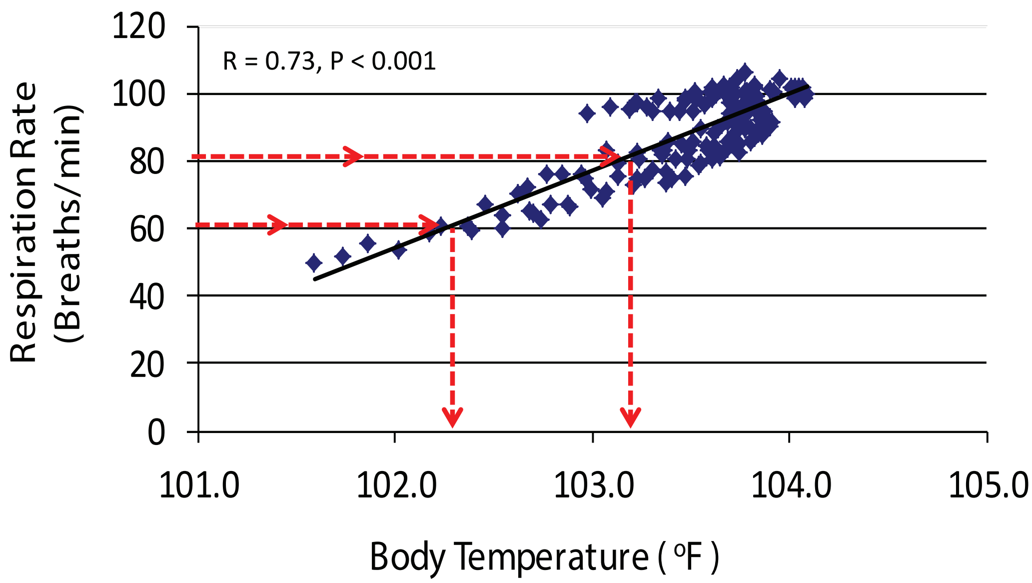
Milk Production Losses

Summer heat stress impacts milk production. **Figure C6 on the following page** shows a herd that suffered a significant drop in milk production during summer heat stress periods. For two consecutive years, test day and 150-day milk production declined over 20 pounds per day during warm months compared to production in the cooler months. After fans and feed lane soakers were installed, the decline in summer milk production was less than 10 pounds per cow per day, and production recovered more rapidly as the weather cooled. Cows also tended to produce milk at higher levels in subsequent cooler months.

Production and Metabolic Losses

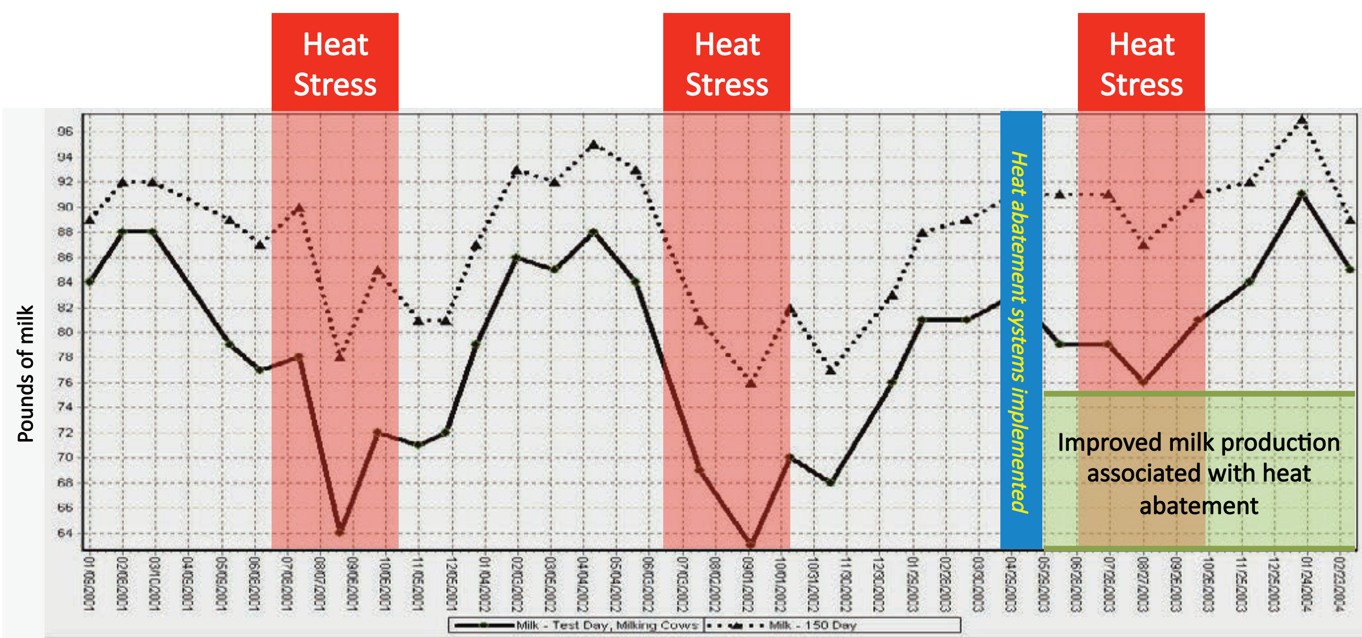
Cows under heat stress commonly undergo various degrees of reduced milk production, with the magnitude related to the severity and duration of the heat stress episode. A decline in milk yield and excessive loss in body weight or body condition are primarily related to reduced feed intake; however, the decrease in milk production cannot be explained completely by reduced feed intake. Rhoads et al. (2009) determined that heat-stressed dairy cattle do not mobilize body fat when dry matter intake declines, as seen in cows during early lactation. In fact, milk production may decline 15 to 20 pounds per day while dry matter intake may only decline 4 to 5 pounds. Furthermore, they demonstrated the decline in dry matter intake accounted for only approximately 50% of the decline in milk production. The other 50% was due to a cow's body partitioning or diverting glucose (blood sugar used for milk production) away from the

Figure C5. Relationship between respiration rate and body temperature



Smith et al., 2003

Figure C6. Milk production during summer heat stress before and after heat abatement system implementation



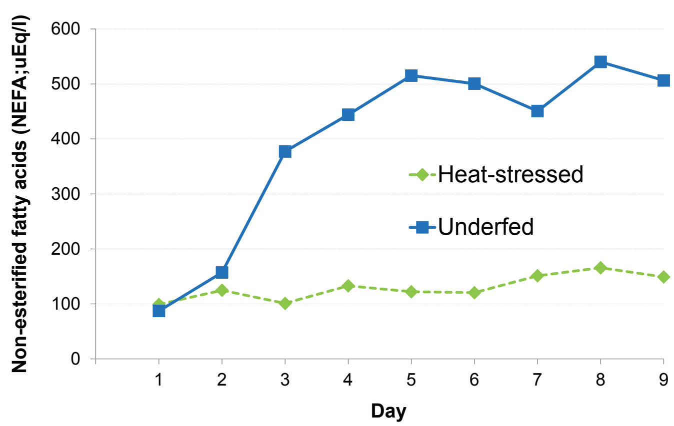
Elanco customer data on file. Reference #2713 mammary gland for use by other body systems. If glucose is utilized for other body functions, it is less available to the mammary gland for lactose production; thus, milk production is reduced.

Figure C7 demonstrates the difference in non-esterified fatty acids (NEFA) utilization for energy in underfed cattle compared to heat-stressed cattle. Underfed cattle (dry matter intake of underfed cattle equal to intake of heat stressed cattle) not experiencing heat stress will mobilize body fat; hence, the circulating NEFA concentration is increased. On the other hand, a heat-stressed cow will avoid burning fat for energy as mobilizing and burning fat will increase the energy of metabolism and heat increment by 14% compared to using glucose as an energy source. Cattle in a heat-stressed environment are often short on available glucose, so they should be fed to increase glucose precursors or propionate. Under severe or prolonged heat stress, cows may utilize body protein sources, breaking down muscle as a source of amino acids for gluconeogenesis (the production of glucose).

Cows under heat stress may also be susceptible to acidosis for a number of reasons. Because feed intake is reduced during heat stress nutritionists often increase the concentrate to forage ratio to increase ration energy, possibly resulting in lower rumen pH and a more acidotic rumen environment. With less forage in the diet, there is less cud chewing and reduced saliva production, reducing the amount of bicarbonate available to the rumen. Severely heat stressed cows tend to breath with their mouth open resulting in more CO_2 being blown off through the respiratory system, increasing the potential for metabolic acidosis. Cows open mouth breathing also have a tendency to lose saliva (rumen buffering capacity) through drooling. Dietary changes and acidosis may also have a negative effect on milk components, especially milk fat. Milk fat is typically lower during summer months. A portion of lower milk fat is likely due to some of the physiological changes associated with heat stress.

Heat stress may also negatively affect gastrointestinal health and function and induce leaky gut syndrome in the dairy cow (Sanz-Fernandez et al., 2015). Cows with leaky gut have reduced nutrient absorption and increased release and absorption of the endotoxin lipopolysaccharides (LPS) from the gut. The release of LPS into circulation stimulates an immune response and negatively affects liver function. Altered liver function may contribute to ketosis and fatty liver at subsequent calvings.

Figure C7. Heat stress and adipose mobilization in dairy cows



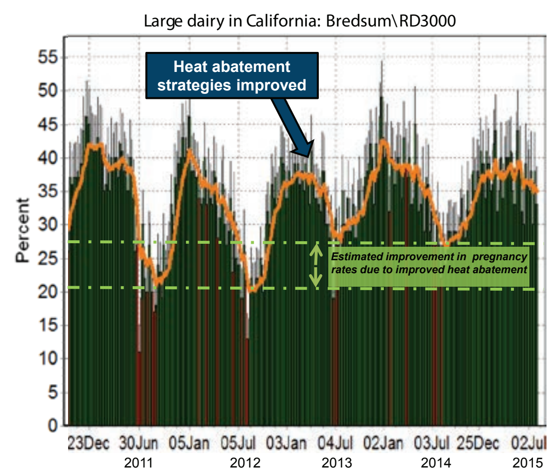
Adapted from Wheelock et al., 2006 and Rhoads et al., 2009

REPRODUCTIVE LOSSES

Heat stress can reduce reproductive efficiency in a number of ways. First, during periods of heat stress, cows are less active and less likely to exhibit estrous activity (show heat). Duration of estrous expression (heat) is reduced in cows experiencing heat stress. Possibly even more critical, in cows that conceive, the bovine embryo is highly susceptible to heat stress during the first six days of embryonic life **(see Figure C8)**. If body temperatures exceeds 102.2°F, the cow is at a greater risk of early pregnancy loss, possibly reducing conception rate by as much as 30%. Reproductive losses can occur even with body temperatures less than 102.5°F, (Hansen, 2007). Early pregnancy losses from heat stress are not often readily apparent as estrous cycle length may not be altered. The only indication of a problem may be a reduction in reproductive efficiency as measured by lower conception rates or pregnancy rates. **Figure C9** shows pregnancy risk data from a large California dairy. Two key observations can be made from this data. First, during summer heat stress, reproductive efficiency decreases, but those losses can be partially mitigated by improved heat abatement strategies. Although a heat abatement program may not restore pregnancy rates to levels achieved during cooler months, improvements in heat abatement lessened the negative impact of summer heat stress on reproductive efficiency. Second, reproductive losses can occur prior to obvious signs of heat stress, and reduced fertility may extend for 60 days after the heat stress period.

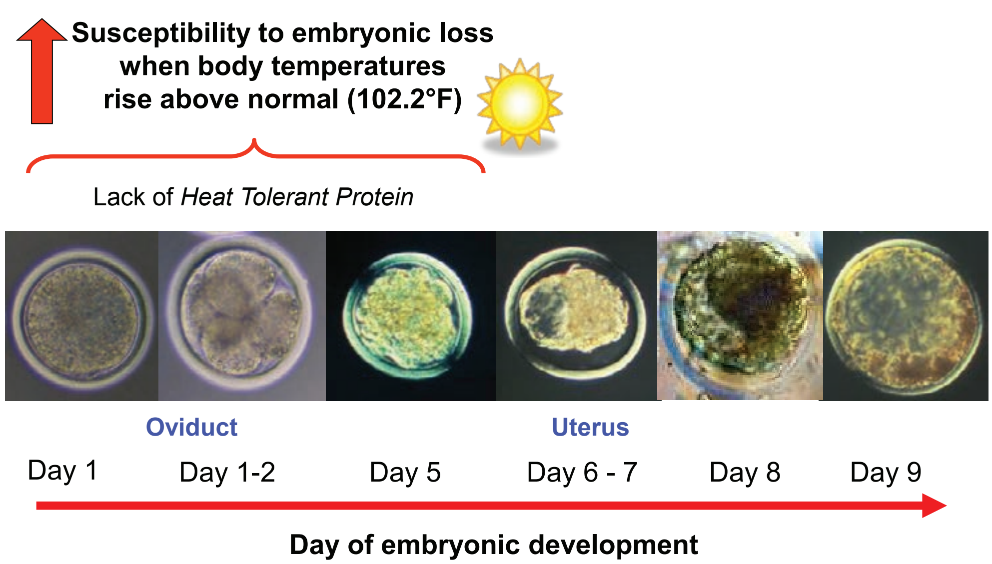
Under severe or prolonged heat stress, an increased incidence of abortion may be seen due to the production of stress hormones such as cortisol. Cows near term may calve early (Dahl et al., 2016), resulting in an increased incidence of weak or still born calves, plus an increased incidence of retained fetal membranes and metritis.

Figure C9. Improvements in pregnancy risk with implementation of improved heat abatement



Data on file with Elanco

Figure C8. Heat stress and embryonic development in dairy cows



Hansen, P. J. 2007

LAMENESS AND LAMINITIS

Cows experiencing heat stress are more susceptible to lameness and laminitis. If cows are suffering some level of rumen acidosis associated with heat stress, they are more prone to laminitis. Because respiration is easier when standing compared to lying down, cows tend to stand more during heat stress, putting additional pressure on feet and legs. Cows housed in free stall barns may perch or stand with all or front feet in stall to ease breathing in times of heat stress.

DRY COW COOLING

Dry cow cooling is a critical component of The Vital 90™ Days. The first day of the dry cow period should be considered the first day of the next lactation. During the dry period, the mammary gland is being prepared for the next lactation. Mammary secretory cells are growing and developing in preparation for milk production. Hormonal signals from the calf cause the mammary gland to increase milk secretory cell numbers and milk-producing ability. A cow calves with essentially the maximal number of the secretory cells that she will have for that lactation.[1] Nutritional and environmental management of the dry cow period and The Vital 90™ Days[2] is critical for a successful lactation.

Researchers at the University of Florida have conducted numerous studies evaluating how cooling dry cows impacts performance during the dry period and subsequent lactation **(see Table 1 on the following page for citations)**. In these studies, cows were divided into two groups at dry off, cooled and non-cooled. Cows remained in their assigned group for the full 45- to 46-day planned dry period. Cooled cows were provided feed lane soakers and fans while non-cooled cows received no heat abatement (no fans or soakers). Study cows were monitored through the dry period and calving. Post calving, all study cows (cooled and non-cooled) went into the same lactation group with cooling throughout the subsequent lactation. Milk production and other parameters were monitored from calving through 140 to 294 days of lactation, depending on the study.

Figure C10 on the following page illustrates the results of one of the studies (do Amaral et al., 2009). Cows that were cooled during the dry period produced significantly more milk beginning at day 70 and continuing through the remainder of lactation. Udder biopsies showed that cooled cows had a larger number of functional mammary secretory cells, contributing to an increased capacity to produce more milk.

Of the six studies conducted at the University of Florida during the summer months between 2008 and 2013 **(see Table 1 on the following page)**, all showed an increase in milk yield in cows cooled during the dry period compared to non-cooled dry period cows. In these studies, the increase in average daily milk production ranged from 5.1 to 16.5 pounds in cooled cows compared to non-cooled cows. In the study where the difference was 5.1 pounds of milk per day, the 3.5% fat corrected milk difference was 10.1 more per day in cooled cows, indicating higher milk fat yield in these cows. In addition to increased milk production, cooled cows consumed more feed at calving **(see Figure C11 on page 14)**. In one study, Tao et al. (2012) showed birth weights of calves from cows cooled during the dry period were increased approximately 13 pounds and weaning weights were increased 27.7 pounds compared to calves from cows not cooled during the dry period.

[1] Capuco AV, Wood DL, Baldwin R, Mcleod K, Paape MJ. Mammary cell number, proliferation, and apoptosis during a bovine lactation: Relation to milk production and effect of bST. *J Dairy Sci.* 2001;84:2177-2187.

[2] The Vital 90 is a trademark owned or licensed by Eli Lilly and Company, its subsidiaries, or affiliates.

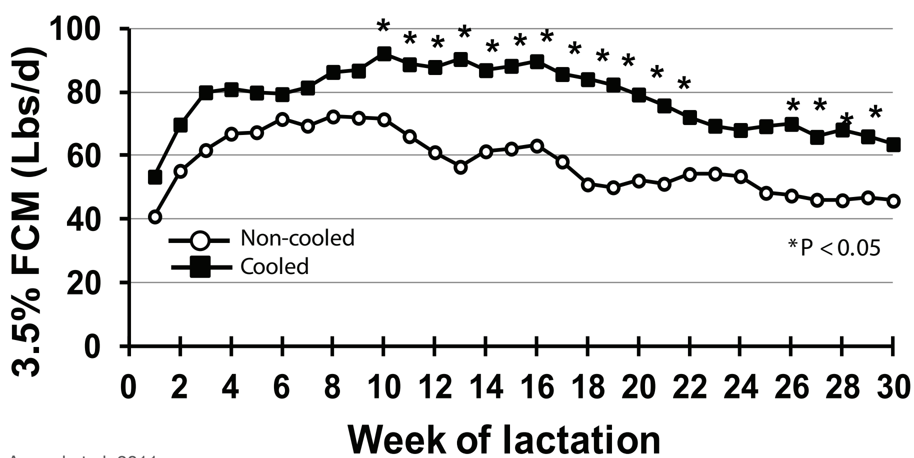
Furthermore, non-cooled, dry cows calved on average 2 to 8 days prior to their anticipated calving date and had reduced immune function compared to cooled cows (Thompson et al., 2014). Although all cows have compromised immunity around calving, heat stress further exacerbates immune dysfunction. After calving, non-cooled cow's neutrophils (white blood cell that helps fight infection) were less able to consume (phagocytosis) and kill (oxidative burst) invading bacteria **(see Figure C12 on page 14)** compared to cooled cows. Thus, heat-stressed cows are less able to defend against bacterial-causing diseases such as mastitis, metritis, and other infections occurring during The Vital 90™ Days. Cooling cows during the dry period and late gestation may influence the subsequent performance of their heifer calves. Dahl et al. (2015) demonstrated that heifer calves from cows not cooled during the dry period had lower pre-pubertal growth rates, had poorer reproductive performance, and produced less milk during their first lactation than heifers from cows that were cooled.

Table 1. Studies summarizing the effect of dry cow cooling on milk production in subsequent lactation

Study Site	Cooling Method	Lactation Period (d)	Milk Yield (lb)		Cooling Advantage (lb)	P-value
			Cooled	Non-Cooled		
Florida[1]	Fans & Sprinklers	210	74.1	57.6	+16.5	0.04
Florida[2]	Fans & Sprinklers	140	75.9	70.8	+5.1	0.09
Florida[3]	Fans & Sprinklers	280	74.6	63.6	+11.0	0.03
Florida[4]	Fans & Sprinklers	294	74.8	60.9	+13.9	0.01
Florida[5]	Fans & Sprinklers	280	74.4	66.0	+8.4	0.10

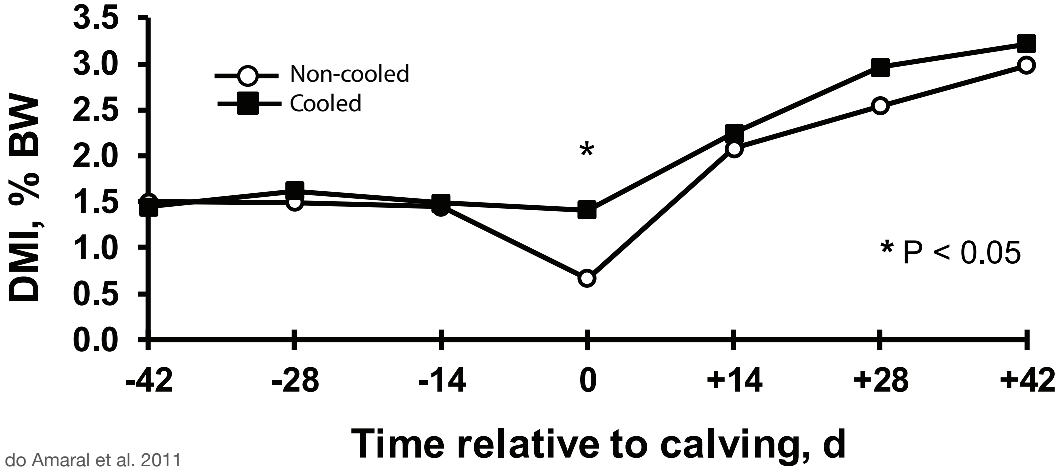
[1]do Amaral et al., 2009
[2]do Amaral et al., 2011
[3]Tao et al., et al., 2011
[4]Tao et al., 2012
[5]Thompson et al., 2014

Figure C10. Cooling cows prepartum and milk production in the subsequent lactation



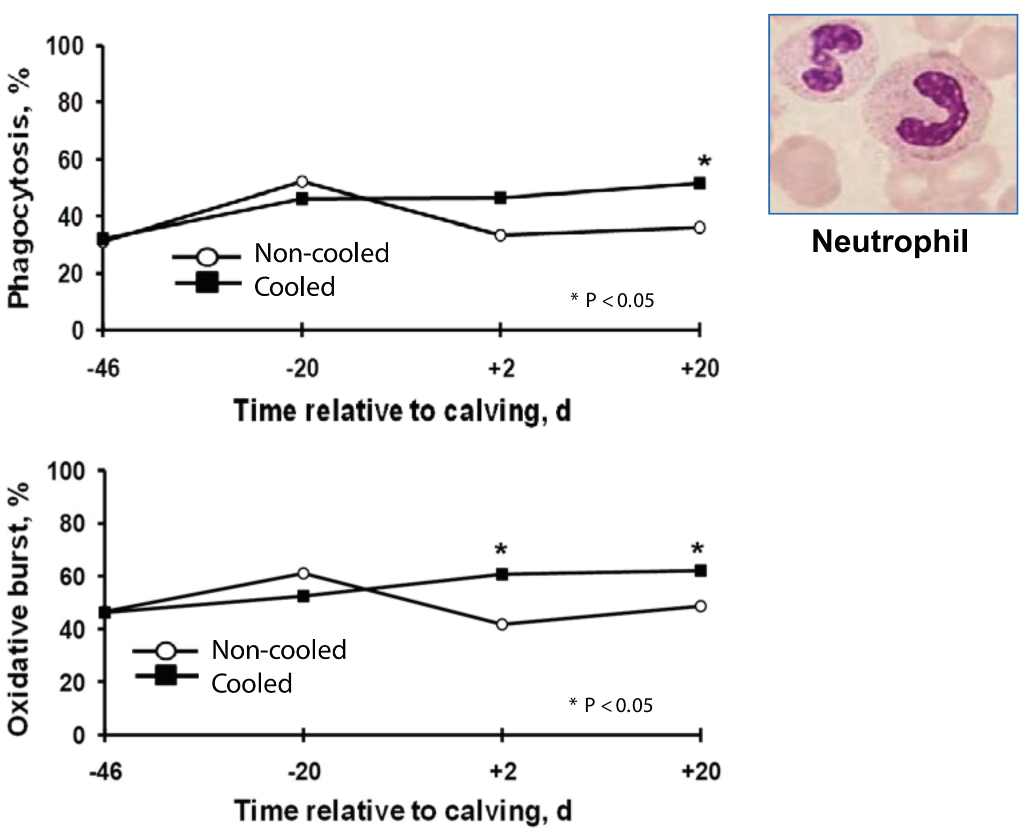
do Amaral et al. 2011

Figure C11. Cooling cows prepartum and dry matter intake (DMI)



do Amaral et al. 2011

Figure C12. Cooling cows prepartum and neutrophil function after calving



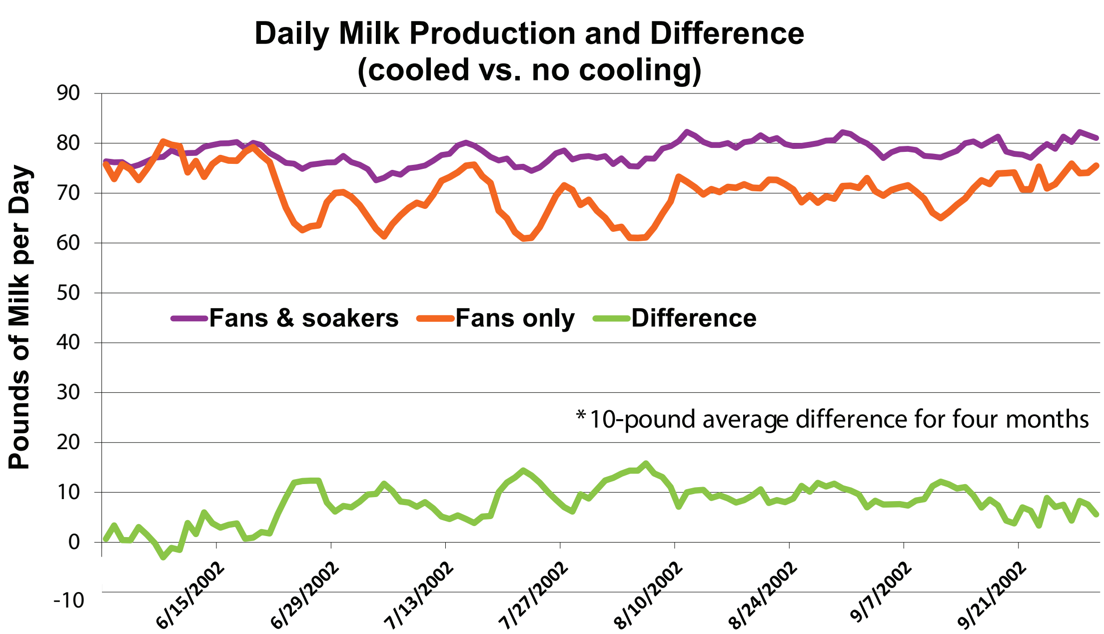
do Amaral et al. 2011

COST OF COOLING DAIRY COWS

Installation of an effective cow cooling system, including fans and soaker lines along feed lanes and holding pens, can represent a significant investment. Dairy farmers often ask, "Will I see a return on this investment?" This question is best answered by providing case studies where effective heat abatement systems have been installed. In one such example, milk production was compared before and after addition of feed lane soakers to existing fans in a large, Midwestern freestall dairy farm. Milk production in 6,000 cows cooled with fans alone was compared to milk production in 6,000 cows cooled with fans and feed lane soakers. Beginning in late June and continuing through September 2002, cows cooled with fans and soakers produced on average 10 pounds more milk per day compared to cows cooled with fans alone **(see Figure C13)**. This difference represented 60,000 additional pounds of milk production per day for approximately four months.

Heat abatement provides economic returns to a dairy, regardless of herd size. Other potential benefits include a decrease in lameness, an increase in reproductive efficiency, a decrease in rumen acidosis, a decrease in other health-related events, and a potential decrease in the number of cows leaving the herd prematurely.

Figure C13. Seasonal milk production in herd with fans or fans and soakers



Harner, Smith, Brouk, and Murphy. 2002. Unpublished field data from Midwestern Dairy. Kansas State Cow Comfort consortium

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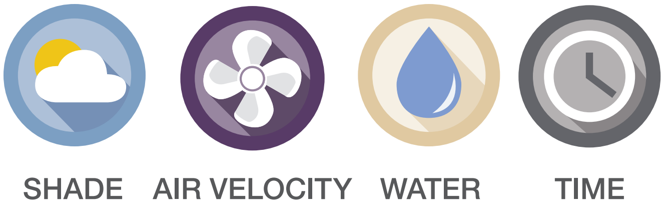
MECHANISMS OF HEAT ABATEMENT

INTRODUCTION

Heat abatement, or cooling of dairy cows during periods of heat stress, is critical for maintaining production efficiency, reproductive performance, and cow welfare[3]. This section of the manual addresses the mechanics for cow cooling. The principles and recommendations listed are a compilation of information on heat abatement from numerous sources. Always consult your local experts when installing a new heat abatement system or upgrading an existing systems.

COMPONENTS OF COW COOLING

There are four primary components of cow cooling:



All four of these components are required for effective cow cooling.

AREAS FOR COW COOLING INTERVENTION

When implementing cow cooling strategies, start with the area(s) where heat stress is most severe or heat abatement is easiest and most economically implemented. The following order of priority should be considered in most operations:

- **Milking center holding pen:** Cows often suffer heat stress when crowded into holding pens, especially during hot weather. This area is often the simplest and least expensive to equip with soakers and fans.
- **Far-off and close-up dry cows:** Extensive research (see Consequences section) has shown that cows cooled with fans and feed lane soakers during the dry period have increased milk yield during the subsequent lactation plus, these cows have improved immune function. Pre-pubertal growth and reproductive performance of heifer calves from cows cooled during the dry period are improved compared to heifer calves from non-cooled cows (Dahl et al., 2016).
- **Maternity pens:** Soakers and fans over feed lanes, and fans over free stalls or bed packs are effective cooling methods that will increase dry matter intake.
- **Fresh cow and heifer groups:** Feed lane soakers and fans over free stalls or bed packs contribute to increased dry matter intake in early lactation.
- **High production lactating group:** Soakers and fans over feed lanes and fans over free stalls or bed packs are recommended for this group of cows (see Consequences section).
- **Milk parlor:** Effective air velocity will help cool cows, especially if the cows are soaked in the holding pen prior to parlor entry. Air velocity in the parlor also improves the environment for employees during warmer weather.
- **Milk parlor exit lane:** Soakers that thoroughly wet cows prior to the cows returning to pens or lots should be considered if there is limited opportunity to soak cows in other areas. Ample drinking water should be provided in exit lanes.
- **Hospital pen:** Soakers and fans over feed lanes and fans over free stalls or bed packs should also be incorporated in hospital pens.
- **Work areas:** Fans over work areas, such as foot trimming tables, management or palpation rails, and cattle chutes are important for cow and employee comfort.

[3] Elanco Animal Health is dedicated to the welfare of livestock. Heat stress is a major consideration in the welfare of dairy cattle. Management of heat stress is thus a strategy that should be considered by all dairy operations.

SHADE STRUCTURES

Shade structures should be provided for outside cattle. Shade should be placed over feed bunks and utilized in cattle resting areas. Shade cloth should be solid and block 90 to 100% of UV rays. The direction of shade over feed bunks is dependent on the orientation of feed bunks. A north-south orientation of shade structures allows for afternoon drying of the bedding area. If the feed lane shade is orientated north-south, it should be large enough to provide coverage of the bunk and the cow platform throughout the day to maximize feed intake and prevent heating of feed. Shade structures should be tall enough (at least 12 feet high) to allow for adequate air flow throughout the day and to allow for equipment access (i.e., feed trucks, vacuum trucks, tractor graders, etc.).

Follow these guidelines when constructing shade structures:

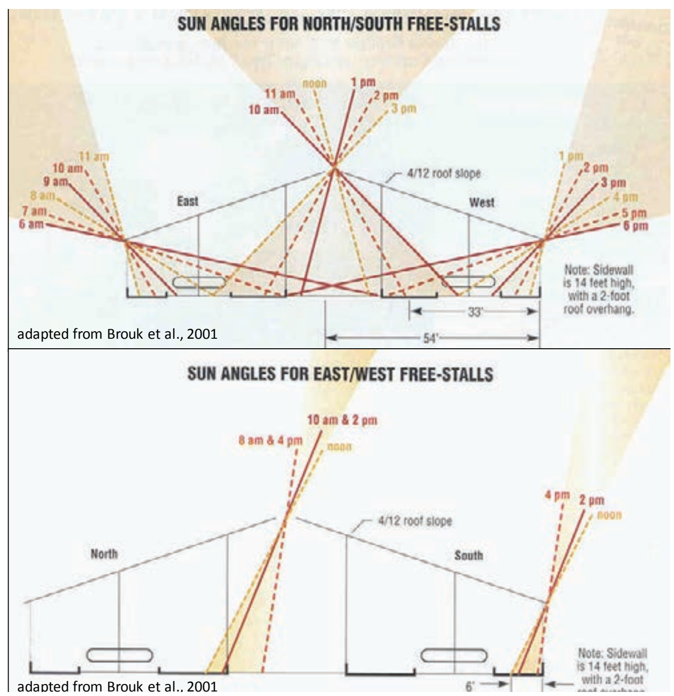
- **Open lot and pasture shade recommendations:** Shade structures in open lots or pastures should provide coverage of at least 65 square feet per cow. Shade structures should be 12 to 16 feet in height and 20 to 32 feet in width.
- **Feed lane shade recommendations:** Feed lane shade structures should be 12 to 16 feet in height and 20 to 32 feet in width.
- **Holding pens shade:** Cover the holding pen with solid shade (minimum 90% UV block).

Feed lane shade for cow cooling

FREE STALL AND BED PACK BARNS

Adequate air velocity can be achieved by normal air movement in naturally ventilated free stall or bed pack barns. Natural air flow can be maximized if the structure is designed and constructed properly. The following are some basic recommendations for design of naturally ventilated barns:

- Roof pitch of 4:12
- For every 10 feet of barn width allow 2 inches of ridge opening
- 14 to 16 feet open sidewall height
- East to west orientation to minimize morning and afternoon sun exposure in the barn compared to north to south oriented barns **(see picture below)**.



Barn orientation influences sun exposure and shade requirements.

Coral shade for cow cooling

Perlins for attaching shade cloth to north to south oriented barns. Arrows indicate eyebolts for running cables to attach shade cloth.

If barn is oriented north to south, cloth shade should be added to barn.

- 90% UV block shade cloth should be used.
- Perlins between shade arms may be added for additional support.
- Shade cloth attached to perlins via cables anchored to perlins by eyebolts
- Shade cloth should be open at the top (1 foot) and bottom (3 feet above ground) to allow natural airflow.
- Barns with curtains will need to anchor shade support arms above and below the curtains but keep shade cloth open above (1 foot) and below (3 feet) for ventilation.

HEAT ABATEMENT IN PASTURED DAIRY CATTLE

Dairy cattle on pasture are also subject to heat stress in warm weather. Even in herds where lactating cows are confined, dry cows are often housed in pastures or lots. As previously discussed, cooling the dry cow is one of the top priorities when considering the implementation of a heat abatement system. In pastured dairy cattle, the only source of shade may be natural vegetation. Cows will congregate under trees, causing these areas to become quite muddy and boggy in wet weather. These conditions can result in udder contamination and possibly contribute to mastitis. Extensive congregation around trees may ultimately lead to the death of trees. If shade space is limited or there is an excessive buildup of mud, these areas may have to be fenced off. If shade is limited, shade structures can be constructed in pasture lots as described above.

Cows on pasture using trees as shade – note mud under tree where cows congregate

In some areas of the country, soaker lines mounted on center pivot irrigation systems can be utilized to cool cattle on pasture. Cattle tend to congregate underneath the spray, so the center pivot needs to be continuously moving or moved occasionally as the area beneath becomes boggy. When the center pivot is moved, care needs to be taken that cattle are moved from the path of the wheels to prevent serious injury to cows. If the system is moving continuously, cow sensors should be placed in front of the wheels.

In these systems, water from the spray nozzles on the center pivot soaks the cattle. Natural air flow evaporates the water, thus providing evaporative cooling. On days with little or no wind, these systems may not adequately cool cattle. In addition, cattle are still subject to radiant heating from direct sun exposure.

Lack of drinking water near the spray can be a problem with center pivot irrigation systems. One solution is to mount water troughs directly between the wheel assemblies at each center pivot tower.


Water troughs mounted on center pivot


Cows on pasture being cooled by center pivot irrigation

AIR VELOCITY AND FANS

Maintaining adequate air velocity is critical to avoid stagnation of air year round and to cool cows during warm periods. Regardless of the barn system, air velocity should be at least **4-6 mph (equal to 360 to 540 feet per minute [fpm])** during periods of heat stress (multiply mph by 90 to convert to fpm, ie, 1 mph is approximately 90 fpm). This rate of air flow is considered **effective cow velocity (ECV) (Dr. Mike Wolf, VES Environmental Solutions, LLC, Chippewa Falls, WI)**. It is important to maximize both ventilation (air exchange) and air velocity (air speed), to remove stagnant air and provide ECV.

Fans properly spaced to provide effective cow velocity to prevent heat stress

Fans are used to augment air velocity in naturally ventilated barns or serve as the sole method of air movement in tunnel and cross-ventilated barns. Fans should be arranged over feed lanes and stalls. Positioning of fans is dependent on fan size and capacity. During periods of heat stress or when ambient temperatures are above 65°F, ECV (4 to 6 mph; 360 to 540 fpm) should be achieved in resting and feeding areas and in holding pens. Consider variable speed fans for new barns or when replacing older fans. These can be a higher initial investment, however, they will potentially offer significant energy savings over time.

In tunnel-ventilated barns, fans are placed at the closed end of the barn such that air is pulled the length of the barn. In cross-ventilated barns, fans are placed on one side of the barn with air movement across the barn. If air velocity is not adequate at cow level, baffles or supplemental fans may be needed to assist air movement and provide ECV.

Tunnel and cross ventilated barns can effectively cool cows as long as ECV is met.

FAN CHARACTERISTICS

Fans are typically rated based on capacity to move air as measured in cubic feet at atmospheric pressure per minute (CFM). As a general rule, the larger the fan blade diameter, the higher the CFM capacity. Fan output is a function of fan speed (RPM), blade size, and blade material. If two fans have equal blade diameter and RPM, the fan with the lowest current rating is usually the more efficient; if two fans have equal airflow, but one operates at a slower speed, it is usually quieter and more efficient. Operational costs and efficiency varies widely across brands and generally range between 8.3 to 18.6 CFM per watt.

Typical fan airflow outputs are as follows:

- a 36-inch fan can move 11,000 CFM (with a test range of 6,400 to 13,000 CFM[4]);
- a 48-inch fan can move 20,000 CFM (with a test range of 14,100 to 23,000 CFM[4]);
- a 50- to 52-inch fan can move 30,000 CFM (with a test range of 15,000 to 36,000 CFM); and
- a 72-inch fan can move 65,000 CFM (with a test range of 50,000 to 80,000 CFM).

Several factors need to be taken into consideration when choosing fan size. Larger fans (50 to 72 inches) with exposed blades have both advantages and disadvantages. One advantage is that larger fan capacity means fewer fans are required. Also, fans with variable speed drives and programmable logic controllers improve energy and operation efficiency over a greater temperature range. Larger fans may also have high pressure misters that can be used to lower air temperatures in dry climates with low relative humidity, such as in the Southwest. In climates with higher humidity, misters are not as effective as stand-alone systems for effective heat abatement. An additional advantage is that larger, exposed blade fans are typically more energy efficient than basket fans, reducing energy costs over the long term. A disadvantage of larger fans include the larger size may not be feasible in some facilities, especially those with low ceiling height. In addition, larger fans are more costly to buy and install, but may prove a better investment over time because of their energy costs savings.

FAN MAINTENANCE

Poor maintenance can reduce fan efficiency by more than 40%. The following maintenance procedures must be performed routinely to ensure the lifespan of fans used in heat abatement systems:

- Check fan operation and conduct routine maintenance before each cooling season.
- Clean fan blades and fan grills. Dirt and dust will decrease fan efficiency.

Maintaining clean fans is critical for both air velocity (ECV) and efficiency

- If required, oil fans regularly.
- Repair and replace damaged fans.
- Check fan alignment and orientation.
- Check and tighten belts on belt drive fans.
- Clean and calibrate thermostats.
- Manage louvres on fans in cross-vent barns and tunnel barns. The bottom louvre (especially if made of aluminum) is prone to freezing in position during the winter. When all louvres are tied together (see photo below), they may be difficult or impossible to open during the winter. It may be preferable to keep the bottom louvre independent of all other louvres, especially during snow or freezing weather, or to use louvre material that is less prone to freezing (see picture).

Check louvres, especially in cold weather. Decouple bottom louvre during winter because of freezing shut. If freezing occurs, all louvres will be in closed position when fans are turned on.

[4] Data from Bioenvironmental and Structural Systems Laboratory, University of Illinois, Department of Agriculture and Biological Engineering. Retrieved from www.bess.uiuc.edu

MEASURING STATIC PRESSURE AND AIRFLOW RATIO

Static pressure is defined as the difference in air pressure between the inside and outside of an enclosed building (Zulovich et al., 2008). Static pressure should be measured in tunnel and low profile cross-ventilated (LPCV) barns to determine if air inlets are adequate based on the capacity of fans to pull air through the barn. As a fan "pulls" air through a barn, a resistance to that flow is created by friction at points along the sides and obstructions in the barn. This restriction to flow is similar to that of water moving through a pipe due to friction in the pipe wall. Other restriction points are also present in the barn, including cows, structural posts, freestall hardware, water troughs, and partitioning walls. This resistance creates a negative or static pressure.

Resistance to air flow is also created by restrictions in the size of the openings along the side or end of a barn, opposite the fans. If these openings are too small, air flow through the barn will be reduced, and added strain will be placed on fans. Evaporative cooling pads at air inlets also restrict air flow across the barn in cross-ventilated barns. Airflow in the barn can be affected by wind speed outside the barn when airflow is being directed against the fans. Other restrictions to airflow in these systems include weather-protecting fan cones and any structures or equipment located within several feet of the fan exhaust.

Both the number of fans operating within the barn and fan "competition" for airflow across the barn can increase static pressure. Fans are tested to determine the cubic feet per minute of output based on various static pressures. As static pressure in the barn rises above 0.05 inches water (manometer[5] measurement), fan efficiency of individual fans decrease (i.e. reduced CFM). Every fan operates at different efficiencies based on static pressure within a barn. Tunnel-ventilated and LPCV barns typically operate at a static pressure of 0.10 inches of water or less. Every dairy with cross or tunnel ventilated barns should have a manometer to measure static pressure in barns so fan capacity can be adjusted to maximize efficiency. Otherwise, an excessive number of fans may be operating, reducing individual fan efficiency along with placing extra stress on fan motors and belts. Manometers are inexpensive and are critical for managing the barn for efficient summer and winter ventilation.

AIRFLOW RATIO FOR EVALUATING FANS

An additional consideration for fans in LPCV barns or tunnel-ventilated barns is the airflow ratio. Air flow ratio is defined as the airflow (CFM) at 0.20 inches of static pressure (SP) divided by the airflow (CFM) at 0.05 inches of static pressure **(see Table M1 on the following page for BESS performance tests for CFM rating at 0.05 SP and 0.10 SP, the 0.10 is noted because this is a typical operating SP within a given barn system)**. A higher airflow ratio means a specific fan provides fairly constant airflow (CFM) as static pressure increases. Remember as SP increases within a barn, the fan may/will decrease the number of CFMs it is able to move because of the negative pressure exerted within a barn system. The static pressure is indicated for specific fans, however the static pressures presented on **Table M1** are noted at 0.05 SP and 0.10 SP. For each individual fan and static pressure at 0.20 SP, go to the website for BESS labs and click on your specific fan to find the CFM rating at 0.20 SP. For example, one manufacturer's fan

[5] A manometer is an instrument used to measure static pressure, which is reported in inches of water.

Table M1. Agricultural Ventilation Fans, Performance, and Efficiencies.[6]

Test #	Model	Size	Cone	Shutter	Air Flow (CFM) 0.05" SP	VER (CFM/W) 0.05" SP	Air Flow (CFM) 0.10" SP	VER (CFM/W) 0.10" SP	Air Flow Ratio*
Acmes									
07204	BDR54J	54"	Y	A	25100	27.7	23500	24.5	0.76
04274	**DDPSV54J-C**	**54"**	**Y**	**A**	**25500**	**25.4**	**23800**	**22.1**	**0.77**
Airstream									
14172	77-0151-IB, 77-0163-IB	54"	Y	B	26000	26.4	24000	22.7	0.69
American Coolair									
14216	FGBCDD54L	55"	Y	B	26400	26.2	23400	22.2	0.61
10239	MNBCCE54L	55"	Y	A	25300	29	23300	25.6	0.69
10252	**MNEFC54L**	**55"**	**Y**	**A**	**26100**	**27.7**	**24000**	**23.9**	**0.74**
11400	MNEFDD54L	55"	Y	B	25900	25.8	23200	21.3	0.68
14228	NBCXM54L	55"	Y	B	25900	26.3	23400	23	0.63
14235	NEFXM54L	55"	Y	B	24700	27.8	22700	24.1	0.66
J & D Manufacturing									
12637	VSA55G3C11E	55"	Y	A	24300	25.3	22300	22.1	0.66
09061	VSA55G3C11E	55"	Y	A	25000	22.7	23100	20.2	0.74
Val-Co									
12243	954335	54"	Y	A	25200	24.5	23200	21.8	0.73

may have a rating at 25,300 CFM at 0.05 inches of static pressure but decrease to 19,000 CFM at 0.20 inches of static pressure. This would give an airflow ratio of 0.75, which would be considered a good to average airflow ratio. Table M1 shows 2 highlighted fans, one fan at 55 inches in diameter and an additional fan at 54 inches diameter. The CFM rating for one fan at 0.05 SP is 25,300, at 0.10 SP it has a CFM rating of 23,900 and at 0.20 SP a rating of 19,800 CFM (the 0.20 SP rating was obtained by clicking on the individual fan in performance tests for BESS labs and going to "test results"). By dividing 19,800/25,300, an airflow ratio of 0.77 is calculated. An additional fan noted in **Table M1** is for a fan with a 0.05 SP CFM rating of 26,100, at 0.10 SP the rating is 24,000 CFM, and at 0.20 SP the rating is 19,400 CFMs. This would give an airflow ratio between 0.05 SP and 0.20 SP of 0.74. Always check with the BESS labs website for the latest fan ratings, as ratings are constantly changing with manufacturer's upgrade and BESS lab test results and updates.

*These ratings for SP and CFM were obtained from the BESS lab test results website on or about Sept 1, 2015.

The first estimation for fan capacity (CFM) should be based on the manufacturer's rating as determined by testing at an independent, certified laboratory, such as the Bioenvironmental and Structural Systems Laboratory at the University of Illinois[5]. Most fans are rated either by (1) air volume output in CFM at a specified static pressure (in inches of water) or (2) energy consumed (i.e., wattage of electrical consumption, or watt). Combining these two components provides a comprehensive rating for fan efficiency: **X CFM/watt at X inches of static pressure**

For example, a low-efficiency fan will have a rating of 17 CFM per watt at 0.05 inches of static pressure, and a high-efficiency fan will have a rating of 20 CFM per watt at 0.05 inches of static pressure.

[6] Information obtained from BESS Lab, Bioenvironmental and Structural Systems Laboratory, Department of Agricultural Engineering, University of Illinois, Urbana-Champaign, Illinois. Retrieved from www.bess.uiuc.edu. Values obtained on September 1, 2015.

The following example demonstrates why static pressure, air velocity, and fan efficiency should be evaluated. The airflow inside a LPCV barn was recently evaluated and found to have a static pressure of 0.19 inches. Fans were rated by BESS laboratories to have an output of 24,000 CFM at 0.05 inches of static pressure. There were approximately 172 52-inch diameter fans in the barn. The opening at the baffle was determined, and the number of cubic feet of air provided based on the opening was calculated. It was determined that the operating efficiency in CFM for each of the 172 fans was 16,000 CFM, representing a decrease of 30% in air output. The effective cow velocity was mapped for the 172 fans, and this averaged approximately 400 feet per minute away from or downstream from the baffles within the barn.

After air flow evaluation of the barn was completed, 52 fans were turned off. Static pressure was reduced to 0.10 inches. With the decrease in static pressure, CFM of each of the remaining 120 fans increased to 23,000, for an improved efficiency of 30%. Effective cow velocity away from the fans remained at an average of 400 feet per minute. Decreasing the number of fans by 30% provided a substantial savings in energy cost and was derived by knowing the operational static pressure and CFM per fan. This provides an example of a company that marketed fans without evaluating the barn for operating static pressure. Furthermore, the company failed to follow up with the customer, and demonstrated no appreciation for the cost of energy. This also underscores the importance of a manometer in the barn for monitoring static pressure and managing air flow in cross-ventilated and tunnel barns.

No two LPCV or tunnel barns are built the same. Dairy operators should seek the assistance of an engineer to design their barns, taking into consideration the proper number of fans, baffle height (if included), distance across the barns, air inlet size for both summer and winter ventilation, and correct operation for each specific system. Operators should seek a fan supplier that will assist in the engineering of the barn system, who will conduct follow-up evaluation once heat abatement equipment is installed, and that will be available for on-going maintenance of the system.

FAN AIRSTREAM WIDTH FOR EFFECTIVE COW VELOCITY (ECV)

An additional consideration in determining the appropriate fan system is the width of ECV downstream from the fan, and the distance at

Table M2. Effective cow velocity and air stream cone width (feet) for 36 and 48 inch fans

Distance from fan (feet)	Air stream velocity (mph[1]) and air stream cone width (feet)	
	36 inch fan	48 inch fan
10	7.1 mph/6.6 ft	9.6 mph/7.6 ft
15	5.8 mph/7.9 ft	7.9 mph/9.4 ft
20	5.0 mph/10.2 ft	6.8 mph/11.2 ft
25	4.5 mph/12 ft	6.1 mph/13 ft
30	4.1 mph/13.8 ft	5.6 mph/14.8 ft
35	3.8 mph/15.6 ft	5.1 mph/16.6 ft
40	3.5 mph/17.4 ft	4.8 mph/18.4 ft
45	3.3 mph/19.2 ft	4.5 mph/20.2 ft
50	3.2 mph/21 ft	4.3 mph/22 ft

[1] One mph is approximately 90 feet per minute, thus 4 mph is approximately 360 feet per minute of effective cow velocity (ECV)

which there is no longer an ECV. **Table M2 on the previous page** demonstrates that as fan diameter increases, air speed or velocity away from the fan becomes critical for ECV. A 48-inch fan by one manufacturer may have an ECV of 450 feet per minute in a cone that is 16 feet wide, or the approximate width of head-to-head free stalls, at a distance of 35 feet downstream from the fan. Another fan may only have an ECV of 350 feet per minute (100 fpm less) in a cone that is 16 feet wide at the same distance of 35 feet downstream from the fan. An important measure is at what distance from the fan is the airspeed no longer at an ECV of at least 360 fpm. This can vary greatly as fan diameter increases from 36 to 72 inches.

AIR VELOCITY AND LOW VOLUME/ LOW SPEED OR HIGH VOLUME/ LOW SPEED FANS

Overhead or ceiling-type fans operate at high volume/low speed (HVLS) or low volume/low speed (LVLS). These fans are generally mounted over a central feed lane, a drive-through feed alley, or a bed pack area. These fans are typically 10 to 20 feet in diameter, moving or driving an air flow pattern down and then outward away from a center point on the floor or the feed alley. Fan spacing is typically based on the size of the air pattern below the fan.

High volume/low speed or low volume/low speed fans are typically purchased for their "energy-efficiency:" however, research has not shown them to provide an adequate ECV (4-6 mph; 360 to 540 fpm) for cows in free stalls where fans are installed over the central feed alley (Ludington et al., 2004) or immediately under the fan in a bed pack barn. As the air pattern or airflow velocity is projected across the floor, it diminishes as it encounters obstructions like stem walls, headlocks, and cows. Often, air velocity at the free stall level is inadequate to impact heat stressed cattle. Furthermore, cows should spend at least 50% of their time lying down and resting; therefore, impactful airflow should be directed where cows spend the majority of the day.

Overhead high volume/low speed and low volume/low speed fans may fail to provide adequate ECV. *Photo compliments of Dr. Jeffery Bewley, University of Kentucky.*

One area of heat abatement where the LVLS or HVLS fan may be considered is in the holding pen. These fans will direct air downward into and around cows, maintaining an effective cow velocity for cow cooling if cows are thoroughly soaked. Height of the holding pen, however, may limit the use of these specific fans in this area.

FAN LOCATION AND VENTILATION SYSTEMS

Feed lane fans

Fans, in combination with a soaker line system, are an effective method of cooling cows while at the feed bunk. Air velocity over a cow's back effectively reduces body temperature by evaporative cooling. Soaking along a feed lane also encourages cows to move to the bunk to eat, thus improving feed intake. Air flow over the cows-side of the feed lanes should achieve ECV (4 to 6 mph; 360 to 540 fpm). Fan diameter will dictate fan spacing and design to maximize airflow over the greatest surface area of the cow.

Free stall fans

As with feed lanes, air flow rates are critical for providing ECV over free stalls. Fans should be directed over the center of head-to-head stalls and over the center of outside rows in a three-row configuration. Dairy operators often ask if fans should be mounted side-by-side on a vertical support post over head-to-head stalls. To date, there is no data to support a significant increase in ECV with two fans mounted side-by-side on the same vertical post in head-to-head stalls (Brouk et al., 2001); however, the number of fans mounted is dependent on ECV and the width and distance of the ECV cone produced by the respective fan. A common arrangement is to alternate fans on opposite sides of support posts over the center of head-to-head stalls.

Holding pen fans

Systems should be designed to generate air velocity over the greatest surface area of the cow and ECV should be achieved (4 to 6 mph; 360 to 540 fpm), targeting the upper range of velocity. If the holding pen has adequate height, fans can be mounted in rows with airflow from the parlor toward the back of holding pen:

- 36-inch fan rows every 20 to 24 feet with 3 feet between fans (6 feet on center)
- 48-inch fan rows every 24 to 36 feet with 4 feet between fans (8 feet on center)
- 50-inch fan rows every 30 feet with 6 feet between fans (12 feet on center)
- 72-inch fan rows every 60 feet with 9 feet between fans (18 feet on center)

**These are broadly suggested fan spacing. Fan spacing is always dependent on manufacturer's suggestions, motor size, blade number and design, RPMs, and dependent on determined airstream width and effective ECV distance downstream from the fan.

The following tips are important to consider when installing holding pen fans:

- Consider variable speed fans for new barns or when replacing older fans. These may have a higher initial investment cost; however, they will potentially save substantially in energy cost over time.
- Fan height should be as low as possible but at a minimum of 8 feet and out of reach of cows and contact by machinery. Check OSHA requirements for fan height based on fan type.
- Fans can be mounted higher if using a drop hose soaker system such as an I-wob. In narrow holding pens (less than 24 feet across) or those with low ceilings, fans can be placed along a side wall, but beware of obstructions to air flow outside the barn.
- Air velocity should be directed toward the rear of the holding pen, with velocity also directed between cows for the largest cow surface area of evaporative cooling.
- If possible, take advantage of prevailing winds. Prevailing winds alone are typically variable and not dependable for adequate cooling of cattle as they may be blocked by walls or cattle.

PARLOR VENTILATION

The biggest challenge of operating a ventilation system in the milking parlor is balancing cow and employee comfort. Employees may be in the parlor for 8 or more hours per day, so comfortable air flow in the parlor is an important consideration. Employees have an entirely different temperature comfort zone compared to the dairy cow's comfort zone of 40 to 60°F. All too often, the regulation of airflow and temperature in the parlor is managed by the employees, who adjust to their own comfort at the expense of the cow's comfort.

Ventilation in the parlor can be obtained with positive pressure fans and ventilation tubes that bring outside air into the parlor. A plenum with a fan and extension tubes may be used if it is impossible to install direct fans and tubes. Bringing in fresh air from the outside is always preferable to recirculating stagnant air in the parlor.

Air velocity moving through the parlor should be 3.5 to 4 mph (315 to 360 fpm) at cow level in the milking parlor, with some air flowing into the parlor pit for employee comfort. Care should be taken that the air flow does not cause teat spray to drift into the faces of the employees. Dairy operators can measure air velocity in this area with a wind meter to ensure adequate ECV. Air velocity generated in the parlor should continue out of the back of the parlor into the holding pen. From here, air flow should continue into the holding pen. Ventilation of the holding pen can be provided by either positive pressure fans or tubes along the length of the holding pen, as long as ECV should be achieved.

Some dairies use positive pressure ventilation with high performance fans in the parlor. In these systems, the volume of air in the parlor should be exchanged each minute. To determine the adequate air flow rate for a parlor, the volume of the parlor in cubic feet should be calculated. For example, in a parlor 60 feet wide by 150 feet long by 16 feet in height, the volume of the parlor would be calculated by multiplying 60 feet by 150 feet by 16 feet to equal 144,000 cubic feet. This is the minimal amount of air that should be exchanged each minute. Twenty percent should be added to account for any inefficiency in the system and to increase ECV. The total recommended air volume exchanged each minute would be 172,800 cubic feet. In a closed parlor system, high performance fans are capable of providing positive pressure airflow of 172,800 CFM, at an air velocity of approximately 350 to 400 feet per minute with air moving down the parlor, over cows, and into the holding pen. In some situations, additional "push fans" may be required to move a large air volume out of the back of the parlor. Dairy operators should check with qualified ventilation experts to determine the specific needs for each barn.

POSITIVE PRESSURE TUBE VENTILATION SYSTEMS

Positive pressure tube systems (PPTS) offer the ability to deliver fresh air from the outside to holding areas or where cattle are housed via a fan and collapsible tube system **(see photograph)**. Outside air delivered by these systems generally has a lower temperature and humidity compared to recirculated air. The goal of PPTS is to provide 60 fresh air exchanges per hour. In these systems, fans bring outside air into a series of large-diameter, collapsible tubes, with the air exiting a number of smaller air jets that deliver air onto cattle at air speeds of 400 fpm. In addition, air jets onto and between cows in a vertical air stream (porous flow) rather than blowing across the tops of the cows.

Positive pressure tube ventilation system

Air speed in PPTS should be 300 to 400 feet per minute at the level of a cow's back (approximately 5 feet above the floor surface). Throw distance, or the distance from a fan with desired air flow, is determined by the diameter of the discharge hole. At a fixed static pressure, a larger hole diameter increases throw distance. A challenge in a PPTS is achieving an adequate air flow (400 fps) at cow level, so the tubes should be located as close to cows as possible. This can be a challenge in some holding pens with tall crowd gates as the crowd gate has to pass beneath the tubes. In a tube system, cows still need to be soaked to achieve cooling. Soaker nozzles should be installed between air tubes.

In a PPTS, consistent discharge speed is critical for ECV over a cow's back. Tubes usually need to be greater than 1.15 times the diameter of the fan. Tubes that are undersized for the fan used will result in excessive air speed near the fan. This moves air rapidly beyond the tube discharge holes with less than adequate airspeed or ECV exiting from holes located near the fan. Always consult with an expert before installing PPTS.

GENERAL RECOMMENDATIONS FOR FAN USAGE

The following guidelines should be considered when installing cooling fans:

- Fans should start operating at 65°F and run continuously. Do not turn fans off during soaking cycles.
- Provide ECV (4 to 6 mph or 360 to 540 fpm) over cow beds and feed lanes.
- Fan height should be as low as possible but at a minimum of 8 feet above the ground. Fans should be out of reach of cows, people, and above equipment operating zones, especially if fan blades are exposed. Check OSHA requirements.
- Fan spacing is dependent upon fan diameter and capacity.
- Angle fans downward, approximately 15 to 30 degrees or toward the cow area or base below the "downstream" of next fan.
- Airflow from all fans should be in the same direction and in the direction of prevailing winds.

COOLING PADS FOR LOW-PROFILE, CROSS-VENTILATED (LPCV) OR TUNNEL BARNS

Cooling pads have been used effectively for years in poultry barn cooling systems. In recent years, they have become more popular in dairy barn systems. Cooling pads are made of a cellulose material and are typically installed along the side of the barn opposite fans in low-profile, cross-ventilated (LPCV) barns. Pads are generally 10 feet in height and come in sections 2 to 5 feet in width. As air is pulled through the cooling pads, water circulating within the pads cools the air as it exits the pad and continues across the LPCV.

There are several challenges with cooling pads: (1) as environmental humidity increases, the ability to cool air entering the barn is decreased; (2) pads decrease or restrict ECV across the barn, and (3) pads become dirty and clogged with water minerals and dirt and require replacement on a regular basis (approximately every 3 years).

Cool pads and installation cost approximately $60 per linear foot. Thus the cost to replace cooling pads in a 1,000 ft barn would be approximately $60,000 every three years. After 3 years of use, pads develop a calcium-like substance that impedes air flow through the pad and across the LPCV barn. Because of the impedance of airflow across the barn, fans often operate at a higher static pressure, decreasing fan efficiency (see manual section on Optimal Static Pressure). It is not uncommon to see cool pads replaced with adjustable curtains on the side-walls of the barn to increase air flow and ECV across LPCV barns. Along with side curtains, a soaker system should be installed over the feed lane in the LPCV barn.

DRINKING WATER

Drinking water requirements increase as milk yield and environmental temperatures increase. A cow producing 60 pounds of milk per day requires approximately twice the drinking water compared to a dry cow, regardless of environmental temperature. Using the predictive equation from Murphy et al. (1983), Beade (1994) demonstrated that cows producing 80 pounds of milk per day consumed 2.5 gallons more water per day when exposed to an average environmental temperature of 81.3°F versus those exposed to a lower environmental temperature of 56.1°F. Furthermore, cows producing 100 pounds of milk per day at the higher temperature consumed over 5 gallons more water than cows producing 60 pounds of milk per day at the same environmental temperature **(see Table M3)**.

Table M3. Predicted daily water intake for dairy cattle as influenced by milk yield and environmental temperature.

Cool Season (Ave. 56.1° F)		Warm Season (81.3° F)	
Milk Yield (lb/d)	Water Intake (Gal/d)	Milk Yield (lb/d)	Water Intake (Gal/d)
0	12.6	0	15.8
40	20.6	40	24.0
60	23.9	60	27.0
80	27.2	80	29.6
100	30.4	100	32.2
120	33.6	120	34.8

Adapted from Beede, 1994: http://dairy.ifas.ufl.edu/dpc/1994/Beede.pdf

Lactating and dry cows should always have access to adequate clean, fresh drinking water. The following are recommendations for supplying drinking water to dairy cows:

- Provide at least 3 feet of linear watering space per 10 cows or approximately 4 inches per cow in free stall or bed pack barns or corral housing systems. There should be at least two watering areas regardless of group size. Water should be within 80 feet (20 free stalls) of any cow in a confined housing system.
- If available, a cow will consume greater than 10% of her daily water requirement immediately following milking. If possible, water troughs should be placed along milking parlor exit lanes. Water troughs should provide 2 linear feet of water space for each cow exiting the parlor at one time. For example, 80 linear feet of water space would be recommended in a double 40 parallel parlor where one side is released at a time. In rotary parlors where cows are released continuously the number of cows trying to access water at one time is less predictable. In a smaller rotary system (ex. 36 stalls or less) it is recommended that there be two linear feet of water space be available for each stall on the rotary. In larger rotary systems that number could be 75% of the two linear feet per stall or for a 72 stall rotary, 128 feet of linear water space (72*2*0.75=128).

Heat stress increases water requirements and intakes

- Keep water troughs clean for increased water intake.
- If possible, offer water in the holding pen.
- Monitor water flow rates during high water demand.
- Plumbing for soaker lines should be on a separate system from drinking water.
- It is recommended that water trough areas are shaded

Cleaning water troughs increases water intake

Provide adequate number of water troughs, especially as cows leave milking parlor - cows consume approximately 10% of daily water requirements immediately after milking. It is always preferable to shade water troughs.

EVAPORATIVE COOLING

Evaporative cooling is defined as a reduction in temperature resulting from the evaporation of a liquid from a surface, thus removing latent heat from that surface. The evaporative surface can be air molecules or skin. In low humidity climates, air temperature can be reduced by as much as 20°F by the evaporation of micro droplets (mist) in air. This form of evaporative cooling becomes less effective as the air becomes saturated with increasing relative humidity. As the humidity within the barn environment increases, the ability to evaporate moisture on the surface of the skin decreases. The efficiency of cooling the air through evaporative cooling is markedly reduced when the relative humidity exceeds 55%.

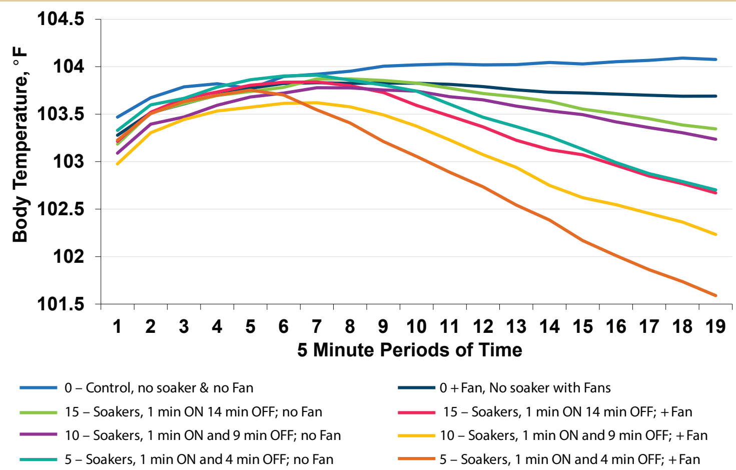
Cattle do not perspire as do humans. Cows have large sweat glands on the nose and around the udder, and moisture can accumulate in these areas but, based on body mass, cattle sweat only about 10% the volume of humans, (Keown et al., 2005). Therefore, mechanically applying soaking water for evaporation is essential to cooling cows.

Evaporative cooling can be accomplished even in humid climates by applying water directly to the skin of the cow. Using a low pressure (15 to 20 psi) water supply line and specially designed nozzles, large droplets of water can be specifically directed over the backs of the cows, thoroughly soaking their skin from the shoulder area to the hooks. Soakers should be on 1- to 1.5-minute wetting cycles, dependent upon nozzle flow rate. The objective is to thoroughly wet the largest surface area along the back and down the sides of the cow. This water can then be evaporated during the “water off” cycle by moving air across the cows with fans, achieving an ECV.

Brouck et al. (2002) evaluated the effect of evaporative cooling with fans and/or water application at various intervals in cows experiencing heat stress (85°F, 45% humidity; **see Figure M1 on the following page**). In summary, fans alone were unable to decrease body temperature during periods of heat stress, and soaking alone only produced a modest decrease in body temperature. Soaking, in addition to fans, mitigated heat stress. Shortening the interval between soakings resulted in the most effective cooling and greatest decrease in body temperature. Even with the most frequent soaking intervals with fans providing ECV, it required 30 minutes before cooling effects were evident and cow body temperature began to decrease. The lag in decrease of cow temperature following the start of cooling procedures is also demonstrated in **Figure M2**. In this study by Brouck et al. (2004), cow cooling was measured by vaginal temperature at 5-minute intervals following soaking cows every 10 minutes with fans set at various speeds. As air speed or ECV increased, rate of cow cooling accelerated. In conclusion, both of these studies demonstrated that the best approach to heat abatement was the combined use of soakers and fans, providing an ECV of 300 to 540 fpm.

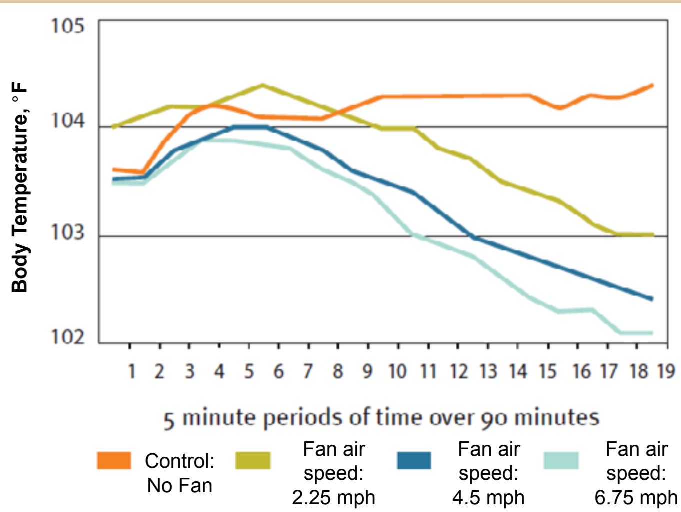
If both fans and soakers cannot be installed simultaneously over the feed lane, first install soakers. Fans, however, should be in place over free stalls. Application of water with low-pressure soaking cools cows more efficiently than fans alone over feed lanes.

Figure M1. Effect of soaker frequency and fan cooling on cow body temperature.



Brouck et al., 2002

Figure M2. Effect of fan speed on cow body temperature when soaking is used



Brouck et al., 2004

HIGH PRESSURE MISTERS

High-pressure misters should first be differentiated from a low-pressure soaker system. A low pressure soaker system cools the cow with the application of large water droplets for a fixed period of time (1 to 2 minutes) with fans providing ECV. Air flow over the cow promotes evaporation of the water from the skin, resulting in evaporative cooling. As water is evaporated from the skin, heat is removed. One pint of water applied to the skin of a cow and allowed to evaporate can release 1,000 BTUs of heat from the cow.

High pressure misters provide cooling by a different mechanism. Misters attempt to cool the air around the cow by forcing water through special nozzles at high pressure (100 to 1,000 PSI). The nozzles emit very fine droplets of water that evaporate in the air stream, theoretically cooling the air coming from a circulating fan. This cooled air then flows to the area around the cow. The ability to cool the air is variable and less effective at higher humidity when droplet evaporation is significantly reduced. To humans, this air feels cool, so it is assumed that this system will effectively cool cows under any environmental condition; however, the perception of cool to humans does not always equate to cool cows.

Air temperature monitoring and monitoring cattle body temperatures with cattle respiratory rate are management tools that can be used to evaluate the cattle comfort zone. Dairy farmers should not rely on the human perception of “cool” as this differs drastically in cattle. Water droplets from the misters do not reach the skin of the cow because of their thick hair-coat, so misters do not provide evaporative cooling from the skin as do soaker systems.

The ability to effectively cool the air within a barn is dependent on the barn air temperature and the relative humidity. The greatest challenge to using misters is that humidity in the air will impact the ability to decrease the air temperature. As the humidity increases, the ability to decrease the temperature of the air circulating in a barn decreases. The ability to cool air at various temperature and humidity combinations is a science known as psychrometrics.

Using a psychrometric chart, where the atmospheric air temperature is 90°F and relative humidity is 10%, theoretically, the temperature should drop approximately 30°F (to an ambient temperature of 60°F, which is well below the heat stress temperature for dairy cows). However, in order to achieve a drop of 30°F in barn temperature, air must be saturated by water droplets to a relative humidity of 100%. That would mean the system is also operating at 100% efficiency. It is very unlikely that 100% saturation efficiency can be achieved in a barn system. A more realistic estimate would be 30 to 50% efficiency. For barns in the Upper Midwest, Southeast, and Northeast, misters or cool pads, generally can only decrease the barn air temperature by 10 to 12°F. If the barn temperature is 75°F with a relative humidity of 40%, misters may provide cooling below a 68 THI. In general, if THI within the barn increases above 75 or as the respiratory rate of a group of cows exceeds 60 respirations per minute (which equates to a body temperature of 102.5°F), misters will not provide adequate heat abatement. Rather, dairy operators should utilize a soaker system installed over the headlocks. If this switch is to be triggered automatically, this operation would require a sophisticated system for monitoring the THI within the barn to automatically turn off the misters and initiate the soaker system.

Using misters as the primary source of cow cooling may work well in areas where humidity is typically low (i.e., between 10 to 40%, such as in the Southwest). However, in areas with high temperatures and humidity (i.e., around 70% during the day and 100% during the night), misters should not be used as the primary source of cow cooling. Where misters are used, soaker lines should be installed over the headlocks for cooling as the THI reaches 75 and cows experience moderate heat stress.

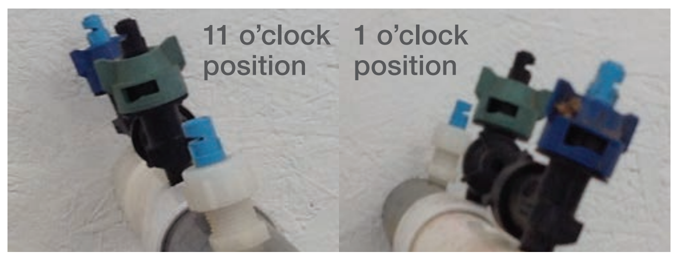
FEED LANE SOAKERS

Typically, when soaker use is indicated they should be turned on from 1 to 1.5 minute periods. Soaker off time varies, with cycles shortened from 15 minutes to 5 minutes as the ambient temperature increases. Soaker cycles should come on automatically at 68°F and possibly a couple of degrees lower in higher milk-producing herds or groups.

Feed Lane Soaker Installation

Proper placement of nozzles on a feed lane soaker system is critical for thorough wetting of cows and prevention of wetting of feed. **Figure M3 on the following page** illustrates proper soaker system placement along the feed lane. **Table M4 on page 37** contains information concerning water line diameter and volume of water delivered, and **Table M5 on page 37** outlines maximum distance of water lines when using various nozzles. In addition, the following guidelines should be used when installing a feed lane soaker system:

- Nozzles should be spaced 7.5 to 8 feet apart along the soaker supply line or at intervals to allow some overlap of the 120-degree spray pattern.
- Determine the length of the soaker line needed for each feed lane, and divide that length in feet by 7.5 to determine the number of nozzles needed for that section. The greater number of nozzles, the more water usage and, thus, the greater the required soaker line size. See **Table M4** to determine the PVC pipe size needed for each pen or zone.
- Mount the soaker line with appropriate-sized angle iron. Secure the soaker line with hose clamps to prevent sagging of the line.
- Nozzles should be positioned at 1 o'clock or 11 o'clock (depending on the direction viewed) on the soaker line to increase the width, spread, or "fan" of water coverage and to ensure adequate cow coverage from the shoulders to the tailhead. **(see photographs)**. Poor nozzle placement results in inadequate cow coverage. Provide soaker water coverage of the largest surface area of the cow.

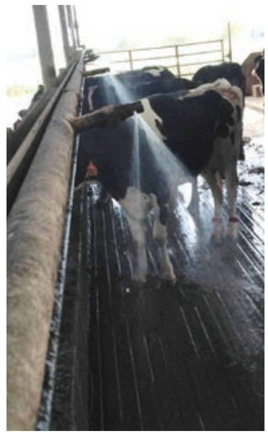


Example of proper soaker nozzle placement at 11:00 or 1:00 position on the soaker line

- Line pressure on the soaker line should be 15 to 20 psi. If the line pressure is significantly greater than 20 psi, the droplet size from the nozzle will be too small, creating a mist rather than the desired large droplets. If incoming water pressure is high (40 to 60 psi), a pressure-reducing valve will need to be installed in the system.
- The height of the soaker line affects the angle of nozzles and cow coverage. Place nozzles above the manger rail or headlocks. If cows have a wither height of 58 to 60 inches, install the soaker line at 64 to 66 inches above the cow platform. This will reduce spray drift onto the feed bunk.
- The soaker line mounts need to be sturdy to prevent cow damage; use an angle iron for S80 PVC pipe support.
- Use quick-caps for easy maintenance.

Appropriate nozzle placement and improper nozzle placement are presented in the photos below. With proper placement, maximal surface area of soaker coverage is accomplished without excessive drift into feed. Adequate cow cooling requires maximal square inches of water coverage. Improper placement, such as placing the soaker too high, can result in wet feed and a possible reduction in dry matter intake.

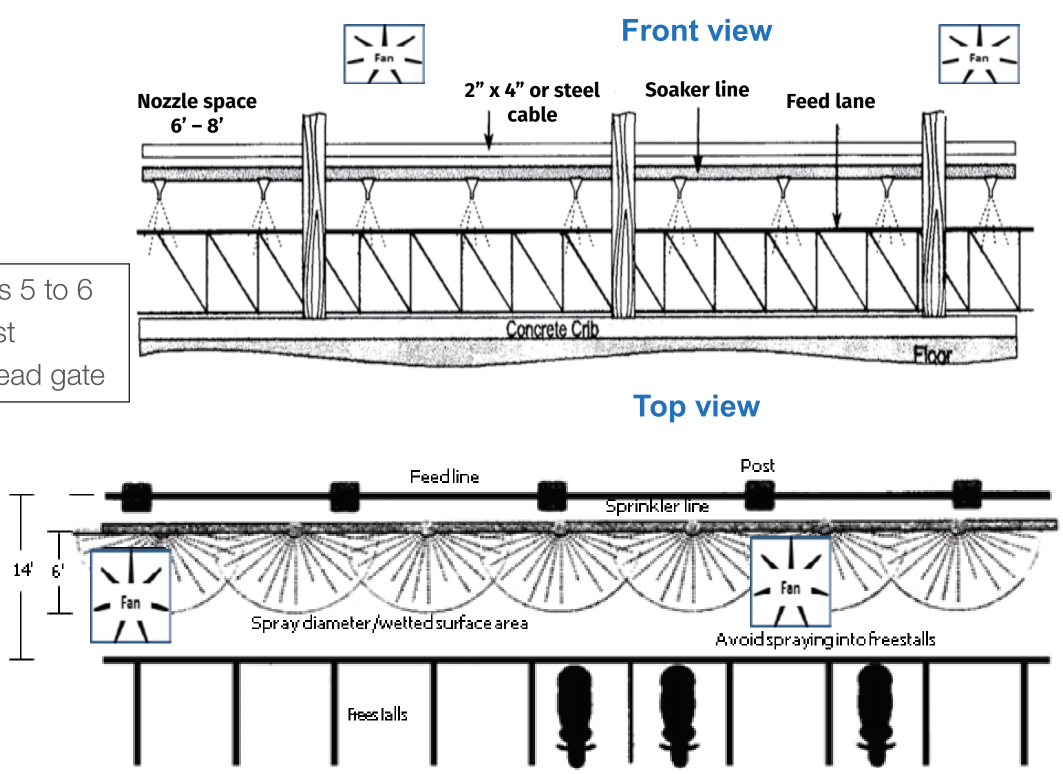
Example of proper soaker nozzle placement at feed lane



Examples of improper soaker nozzle placement at feed lane – both examples are poor angle of spray and not soaking of entire back of cows, neither take into account soaking of the greatest surface area of the cow.

Figure M3. Diagram of soaker system for feed lane cooling

*Mount soaker lines 5 to 6 feet above floor, just above neck rail / head gate



Harner et al., 1999

Table M4. Pipe diameter and water delivery capacity

	Pipe diameter			
	1 inch	1.5 inch	2 inch	2.5 inch
Approximate water volume delivered @ 20 PSI	15 gallons	30 gallons	60 gallons	120 gallons

NOTE: As the distance between nozzles is decreased the number of nozzles required for a section of soaker line is increased thus decreasing the length of line that can be used for a given pipe diameter. The only time all cows will potentially be at the soaker line is after milking, 2 to 3 times per day. At all other times cows will be intermittently dispersed at the feed bunk.
*6 ft centers for nozzles is a waste of water resources.

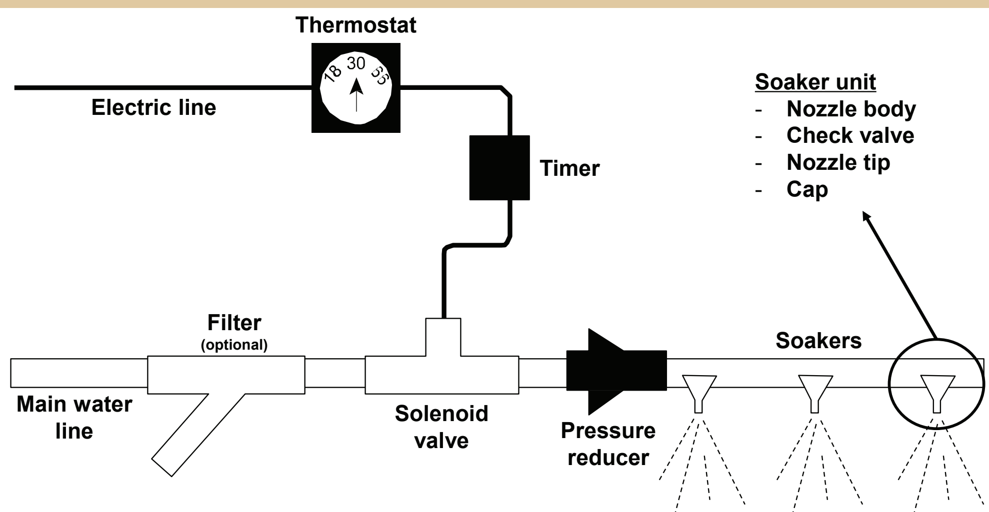
Table M5. Maximum length of soaker lines on 8 foot or 7.5 foot centers with different nozzles

	Maximum length of soaker line on **8 foot** centers[1]			
Pipe diameter @ 20 PSI	1 inch	1.5 inch	2 inch	2.5 inch
Blue Tip Nozzles (0.7 gallon/min)	170 ft	340 ft	680 ft	1360 ft
Green Tip Nozzles (1.0 gallon/min)	120 ft	240 ft	480 ft	960 ft

	Maximum length of soaker line on **7.5 foot** centers[1]			
Pipe diameter @ 20 PSI	1 inch	1.5 inch	2 inch	2.5 inch
Blue Tip Nozzles (0.7 gallon/min)	150 ft	300 ft	600 ft	1200 ft
Green Tip Nozzles (1.0 gallon/min)	100 ft	200 ft	400 ft	800 ft

[1] Friction loss is considered in the calculation, leading to a decreasing PSI. As pipe diameter increases, friction loss is decreased. Consider check valves for opening nozzle, typically 10 PSI
*6 ft centers are too close, a waste of water, and decreases length of soaker line. Water usage increases over 20% with 6 ft compared to 7.5 ft centers.

Figure M4. Diagram of soaker system components



Harner et al., 1999

SOAKER SYSTEM COMPONENTS

Figure M4 on page 37 illustrates soaker unit components. Timers and thermostats, are some of the most important components of the soaker system. They can be adjusted to control the frequency of spray cycles and cycle durations. The thermostat controls the start of soaker cycles and can be set to control multiple "zones" with solenoids (1 to 4 zones). Some controllers automatically increase soaking frequency as ambient temperature increases. Manual (on/off) water applications is not recommended for holding pen or free stall soaker systems. Workers in the parlor area should NOT turn water on and off. Controllers can also be electrically "connected" to the milk pump so water is only on during the milking process.

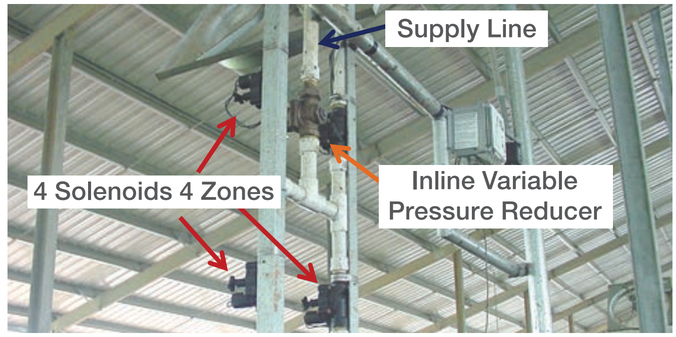
Timers and preset delays for holding pens or freestall barns are optional. They allow the dairy operator to turn water off while cows are away from the freestall barn. Water will automatically come back on at a preset time. A delay switch inactivates the water on cycle for 1 to 80 minutes.

Filters

Soaker water line filters can be a challenge to keep clean. In some hard water areas, filters will fill and plug within weeks. In general, filters are not recommended however 200-micron filters or higher may be used. If filters clog, select a larger-sized filter. At the current time, we do not typically install filters, as they can be difficult to manage.

Electric Solenoid Valves

Electric solenoid valves must match soaker pipe size and flow rate. Producers can purchase solenoids to be "normally closed," but they will need to know (1) the flow rate, or gallons per minute, flowing through the solenoid and (2) if the timer control for solenoid is 120V, 24V, or 18V. A 24V solenoid with a 120V timer may require a relay or low-volt reducer in the line between the timer or control box and the solenoid.



Soaker Line Controls

Pressure Reducers

Often water line pressure on dairies is 40 psi or higher. Higher water pressure creates more small droplets or mist while lower water pressure produces a larger water droplet size to soak through the hair and down to the skin of the cow. Using an adjustable or a variable pressure valve reduces line pressure to 15 to 20 psi. A variety of pressure reducer valves are available and are based on the size of the "springs" in the brass pressure reducers; six to ten springs are needed for different psi requirements. Operators should use a pressure reducer set at 15 to 20 psi for application of water in holding pens and free stall barns. Adjustable or variable pressure reducers are preferred over fixed pressure reducers because they can be adjusted for desired water droplet size

Nozzles and Tips

Nozzle tips should provide 0.5 to 1.0 gallons of water per minute. The nozzle body should have a check valve and a valve cap. Check valves on nozzles are typically set at 10 psi to prevent lines from draining between water cycles.

The nozzle body is threaded directly into a ¼-inch tapped/threaded hole in the S80 soaker supply line. Producers should only drill and direct tap ¼-inch NPT (pipe thread) into S80 PVC or steel pipe as wall thickness is inadequate for drill and tap in thinner walled pipe such as S40 PVC. Schedule 80 pipe should only be used for the soaker supply line.

Schedule 40 pipe can be used for other lines to decrease installation cost. Schedule 40 couplers, accessories, and ball valves also can be used with S80 soaker supply line to reduce costs.

A paddle bit, or a flat bit with a point, is preferable to a round drill bit for drilling into PVC pipe. The point of the paddle bit prevents the bit from “skating” off the pipe. A 7/16-inch bit should be used to drill a hole for the ¼-inch tap, checking the first hole drilled and tapped for a tight fit of first nozzle before continuing. If a tight fit exists, pipe dope or Teflon tape is not needed. See the photos below displaying this process.

Installation of nozzle body into PVC pipe

When using the tap, only drill to a depth approximately ½ to ¾ of the tap shaft. Using the full tap depth may cause the nozzle not to thread or ‘seat’ tightly. Use pipe dope or Teflon tape if needed. The minimum pipe diameter for drill and tap is 1-inch for feed lane soakers.

Nozzles are available in brass, which is sturdier for low installation, and nozzles with diaphragm check valves prevent line from draining between cycles. Ball and spring check valves and filters are prone to calcium build-up from hard water but can be cleaned using milking system cleaning agents.

FEED LANE SOAKER UNIT PARTS

TeeJet® Clamp-on Nozzle Body

TeeJet® clamp-on nozzle body with a check valve and quick TeeJet® caps (QJ17560A-1-NYB for 1-inch PVC pipes) are recommended for some installations. To attach the sprinkler nozzle body, drill a 3/8-inch hole in the PVC pipe. The diaphragm check valve stops water flow at 10 psi so pipes stay full for the next cycle.

TeeJet® Threaded Nozzle Body

The TeeJet® threaded nozzle body screws into the tapped ¼-inch hole. Drill and tap ¼-inch national pipe thread (npt) into a 1-inch or larger pipe (S80 PVC or galvanized steel is preferred). It is important to note that the minimum pipe diameter is 1 inch. The following are recommended nozzle choices:

- brass (with internal screen and ball check valve)
  - CP1322, TeeJet® body DR ¼-inch npt
  - CP1325 TeeJet® cap, brass
  - 11750-PP-10, check valve
- plastic (with side diaphragm check valve).
  - QJ8360-NYB, TeeJet® body with check valve, ¼-inch npt (quick-cap)
  - 25600-4-NYR, Quick TeeJet® quick –cap, plastic
  - 8360-NYB, TeeJet® body with check-valve, ¼-inch npt (screw-cap)
  - CP8027-NYB, TeeJet® cap, plastic

TeeJet® Nozzle Tips

TeeJet® nozzle tips create a 120-degree spray pattern. The Turbo FloodJet® (TF) is a polymer nozzle that delivers large droplet size and comes in various sizes. The most commonly used are:

- TF-VP5 - 0.7 gallons per minute at 20 psi (0.5 gallons per minute at 10 psi); and
- TF-VP7.5 - 1.1 gallons per minute at 20 psi (1.0 gallons per minute at 10 psi).

Quick TeeJet® Caps with Gaskets

Quick TeeJet® caps with gaskets are used to secure nozzle tips to the nozzle body without tools. The parts number for this product is 25600-4-NYR.

INSTALLATION TIPS

The following tips will aid in the installation of the soaker system:

- Create a drill bit guide or jig for drilling holes in S80 PVC pipe **(see photograph)**.
- Weld plate steel with an appropriately sized hole to make a 3-sided jig for drilling **(see photograph)**.
- Secure PVC pipe to angle iron with pipe clamps prior to drilling and tapping.
- Mark drill holes with felt-tipped marker at 7.5 foot intervals.
- Snap jig over S80 PVC pipe and angle iron to keep drill holes aligned.
- Free-hand drilling will “skate” off the PVC pipe, especially if using a round bit. Use a 7/16-inch paddle bit to minimize “skating” off pipe.
- Nozzle spacing will depend on water supply, water demand (line length), and nozzle volume (0.7- to 1-gallon nozzle).
- Test first nozzle fitting before continuing.
- Use pipe dope or Teflon tape on nozzle threads for a watertight seal, if needed.
- After installing nozzles, loosen pipe clamps and roll PVC such that water is applied evenly between both shoulders and hooks. Lines should be adjusted to allow for maximum water coverage.

OTHER CONSIDERATIONS

Use a shim or a spacer between the angle iron and the vertical support of the barn at the feed lane. This prevents water from dripping onto the stem wall of the headlocks and creating water puddles and “soggy-feed” on the stem wall.

Steel pipe can be used, but it requires special considerations. Steel pipe should be coupled with a radiator hose or reinforced rubber coupling.

Drill bit jig

Improper soaker placement results in wet feed. Soaker lines are too high causing water ‘drift’ and poor cow coverage

Steel pipe coupled with radiator hose

NOZZLE SUPPLIES FOR SOAKER SYSTEM

TeeJet® Clamp on nozzle with check valve

TeeJet® Quick Cap with gasket

TeeJet® Turbo FloodJet Nozzle

TeeJet® threaded nozzle body

TEEJET® TURBO FLOODJET® NOZZLES

TF-VP5
0.7 gallon per minute
at 20 psi

TF-VP7.5
1.1 gallon per minute
at 20 psi

TF-VP10
1.4 gallon per minute
at 20 psi

Note:

- Tip selection determined by water supply capacity
- TF-VP5 or TF-VP7.5 most commonly used
- Shorter ON cycle time with TF-VP7.5, but water supply is more critical

TEEJET® BRASS NOZZLE BODY, CHECK VALVE, AND CAP

Turbo FloodJet nozzle TF-VP5

Brass cap CP1325

Strainer and check valve 4193A-5-24

Nozzle body CP1322

QUICK TEEJET® WITH SIDE DIAPHRAGM CHECK VALVE

Quick TeeJet® nozzle body, check valve and cap

Turbo FloodJet nozzle TF-VP5

Quick TeeJet cap and gasket 25600-1-NYR

Nozzle body and check valve QJ8360-NYB

If damage (i.e., skid-steer) to the steel pipe occurs, the rubber coupling can be easily removed and the damaged section of the steel pipe replaced. Second, we suggest a contractor is hired to drill and tap nozzle holes in steel pipe.

Use a flex hose or an adjustable union connector for the water supply line, which allows for soaker line rotation and adjustment of nozzle angle after installation.

Flex hose connection for water supply line

Square tubing **(see photograph)** can be used for the soaker line. A 2-inch square tube has approximately a 75 gallon per minute capacity at 15 to 20 psi. When installing the square tubing, consider soaker line length, capacity and number and size of nozzles as a square line has a higher capacity than a corresponding round line will. Calculate the water capacity of the system using length of the line, nozzle volume per minute, and nozzle spacing. If demand for water volume is greater than the carrying capacity of the pipe, there may be inadequate volume of water to soak the cows the entire length of the soaker line. If the water volume is inadequate for the number of nozzles, cows at the end of the system may not get adequately soaked.

Square tubing can be used for soaker line

WARNING: Square tubing can be used for a soaker line, it does however present challenges with proper angle of nozzles and soaking. A 2 inch square tube has a carrying capacity of approximately 75 gallons of water at 20 PSI. This square tubing **(see photograph above)** had 126 1-gallon nozzles on 6 foot spacings or a demand of 126 gallons of water per minute. The end nozzles of this soaker line did not receive adequate water volume to provide soaking and therefore did not work. Also, this square tube was supplied with a 2 inch round pipe with a water capacity per minute of 60 gallons. Always make sure that the supply line is adequate for water demand to the soaker line and that the soaker line can carry an adequate volume of water to the nozzles.

FEED LANE SOAKER OPERATION

Soaker nozzles should deliver 0.5 to 1.0 gallons of water per 1 minute cycle. The “time off” cycle should be reduced as ambient temperatures increase. Approximately 0.7 gallons of water should be delivered per 1 minute cycle; therefore, water on-time is typically 1.2 to 1.4 minutes. An example of a soaker line controller is presented in the **photograph on the following page**, and the use of zones for soaking cows is presented in **Figure M5 on page 44**.

Controller box with 4 solenoid outlets

The following are guidelines for using a feed lane soaker system:

- Set the feed lane soaker system to initiate a soaking cycle at a temperature of 66 to 68ºF (dependent on herd or group production).
- Initial settings at lower temperatures (66 to 72ºF) are for 1 minute on-times per zone with a 10-minute off cycle. With four operational zones, the period from the start of one cycle in a zone to the start of the next cycle in that same zone would be 14 minutes. Adjustments in soaker on-times should be discussed among the dairy management team. For a thorough soaking cycle, the on-time should not be less than 1 minute using 0.7 gpm nozzles.
- At higher temperatures or humidity (THI), set soakers to come on at shorter intervals. For example, at 82ºF or higher, soaker on-time will remain at a 1-minute minimum, but off-time should be reduced to only 2 to 3 minutes, such that time between cycles is 6 to 7 minutes. In extremely hot conditions, one of the four zones may be running at all times.
- Some control boxes (Edstrom 440 and 110) have a "SMART" mode that automatically reduces off-time intervals as ambient temperatures increase above 68ºF. With these systems, set the high temperature point at 82ºF.
- Position nozzles at the 1:00 or 11:00 o'clock position every 7.5 to 8 feet. Spacing nozzles at 6-foot intervals creates a 23% increase in water usage.
- Small-diameter pipe (1-inch) can be supported by a tight cable; however, the pipe will twist and the nozzle angle may have to be adjusted **(see photograph)**. To avoid twisting and sagging, mount lines with an appropriately sized angle iron.
- Larger pipe (1½-inch or greater) should be supported by an angle iron **(see photograph)**.
- Provide drain valves at each end of the line to drain the line for winter **(see photograph)**.

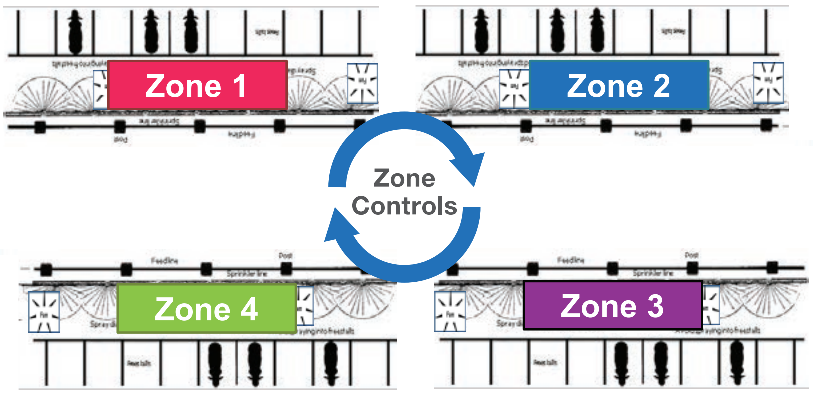
Cable mounted PVC can twist and maintenance is required for nozzle angle adjustment

Soaker line mounted on angle iron

HOLDING PEN COOLING

The milking center holding pen is often the area of most significant heat stress on the dairy cows because of the high concentration of cows in a confined space. Holding pens should not be overcrowded, especially during times of high heat and humidity. Each cow should have at least

Figure M5. Illustration of '4 zone' soaker system



Outside water supply is routed to the center of the barn. Water is then directed to the 4 zones with solenoids. The controller then sends a signal to zone 1 solenoid, water is ON. Water is OFF in all other zones (2, 3, 4). Controller will then switch to zone 2, all other zones are then OFF. Cycling through zones reduces water usage compared to all zones operating simultaneously. Also a smaller soaker line pipe diameter may be used because only one quarter of the system is ON in the barn at one time.

15 square feet of space at maximum capacity, and crowd gates should not overly crowd cows into a small area. Total time in the holding pen should not exceed 45 minutes per milking, even for the last cows to enter the milking center. Time in the holding pen is time away from feed and bedding. If cows are spending more than 15 to 20 minutes in holding or waiting areas prior to or after the holding pen or milk parlor, fans and soakers should be considered in these areas.

Although the holding pen is often the most hostile environment for heat stress, it is often the easiest and least expensive to equip with a heat abatement system. Fans and soakers can be installed with relative ease in most holding pens, even in older facilities. Holding pen soaking should thoroughly wet the back of the cow but then stop to allow the water to evaporate prior to another cycle beginning. In addition, holding pen soaking, when done correctly, has minimal risk of causing wet udders entering the parlor **(see photograph)**.

In a study designed to measure the impact of holding pen heat stress, Harner et al. (2000) determined that body temperature decreased by 3.5°F and milk production increased 1.7 pounds per cow per day when cows were cooled in the holding pen.

Holding pen soaking should thoroughly wet the cow. Also note that wetting the cow's back does not cause wet udders entering the parlor.

Milk production also increased by 5 pounds per day when cows were cooled for 30 minutes, five times per day in the holding pen.

For effective heat abatement in the holding pen:

- Reduce time in holding pen.
- Prevent overcrowding.
- Improve ventilation with open ridge caps and open side walls for hot air to escape.
- Install fans and a soaker system.

The following guidelines should be applied to holding pen cooling with soakers and fans:

- Holding pen fans should be set to come on at 65°F ambient temperature. Between 65 and 68°F, the

soaker system should come on for 1 to 2 minute cycles with an off or idle period of 10 minutes.
- As ambient temperatures increase to 78°F or higher, soakers should continue on for 1 to 2 minutes, but the off time should be reduced to 5 to 6 minutes for a total cycle from the start of one soaking to the start of next soaking of 6.5 to 8 minutes.

A system control panel that operates the solenoid allowing water flow can be linked to the milk pump circuitry so water is on only during milking. Another important tip is DO NOT rely on manual on-off valves to control the soaker system. In manual systems, workers often forget to turn the system on. Place the temperature probe from the control box at cow level but away from drifting water from soaking lines. The holding pen control box should be set to turn on at 65°F with a wetting frequency of 1 to 1.5 minutes and 10 minutes of downtime. Holding pens are typically 10 to 15 degrees warmer than the ambient temperature when full. Remember, cows may generate 5000 BTUs of heat per hour.

HOLDING PEN SOAKER SYSTEMS

The design of the holding pen soaker system can vary and is dependent upon location and set-up of the holding pen. Following are a few options for holding pen soaking systems.

Single row of high capacity soaker nozzles

Dairy operators can install a single row of high capacity soaker nozzles. Options for single row, high capacity soaker systems in the holding pen include the I-wob or the Nelson® D3000 spray head.

The I-wob system is a single row of high capacity soaker nozzles **(see Figure M6 on the following page)**. The components of the I-wob system are shown in **Figure M7 on the following page**.

When using the I-wob system, follow these guidelines:
- Use a low voltage, 1.5 inch solenoid which is in a normally closed position.
- Use at least a 1.5-inch diameter central water supply line.
- Water supply pipe diameter is determined by the number of I-wobs and the output volume.
- The area 15 to 20 feet from the parlor should not be covered by the soaker zone to allow for a drip-dry area.
- Install the water supply line level and not following the slope of the holding pen floor **(see Figure M7)**.
- The I-wob drop line must be at least 2 feet in length. Try to maintain the length that comes from the factory. I-wobs should have some “play” or a slight wobble when operating.
- The I-wob nozzle should be approximately 12 inches below the bottom of the fans.
- I-wob nozzles should be at least 9 feet above the cows’ backs or approximately 14 feet or higher above the holding pen floor **(see Figure M6)**. At that height and with adequate water volume and pressure, cows should be soaked within a 40 foot diameter of the I-wob nozzle.
- I-wobs are placed on 20 to 24 foot centers between each row of fans.
- I-wobs come with a gooseneck, drop line, 10-pound pressure regulator, and soakers **(see Figure M7)**.
  - Use a blue tip nozzle with the I-wob that supplies 3.5 gallons of water per minute.
- Do not install a check valve between the water supply line and the pressure regulator of the I-wob to avoid damage (blow out) to the pressure regulator. When check valves are installed, they must be placed downstream, on the water supply side of the pressure regulator.

- The I-wob supply line should have a crook or gooseneck on top of the supply line in the 12 o'clock position, so that when the water shuts off between cycles the entire supply line will not drain. Otherwise, if the water drains from the system, it may take a few minutes to fill the supply line and obtain adequate water volume for soaking cows.

The Nelson® D3000 system and spray head is illustrated in **Figure M8**. This system provides 360-degree coverage with a coverage diameter of 28 feet with a water pressure of 20 psi.

When using the Nelson® D3000 system, follow these guidelines:

- Use 3TN nozzles #25 red and #25 gray plate (#9542). Set the system at 4.8 gallons per minute at 20 psi.
- Use a mini-regulator drain check valve.
- The pressure reducer (providing 15 to 20 psi at nozzle) may be located in the supply line or distribution lines.
- Install the system on a 24-foot center and 9 feet above the floor at a minimum of 3 feet above the cows' backs.

Figure M6. Single row I-wob soaker system for holding pens

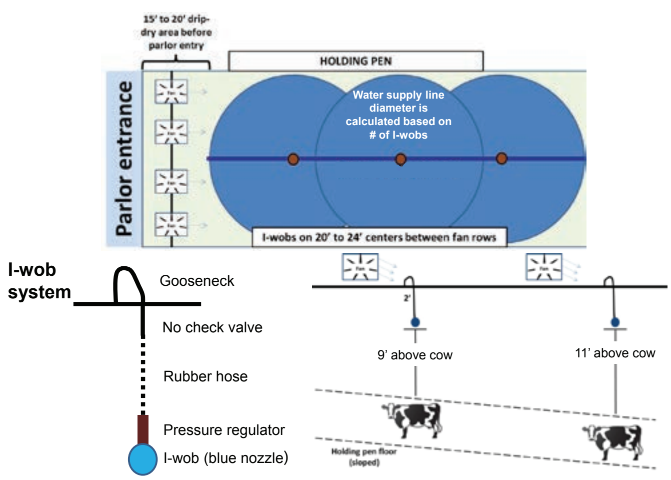


Figure M7. Components of the I-wob soaker system for holding pens

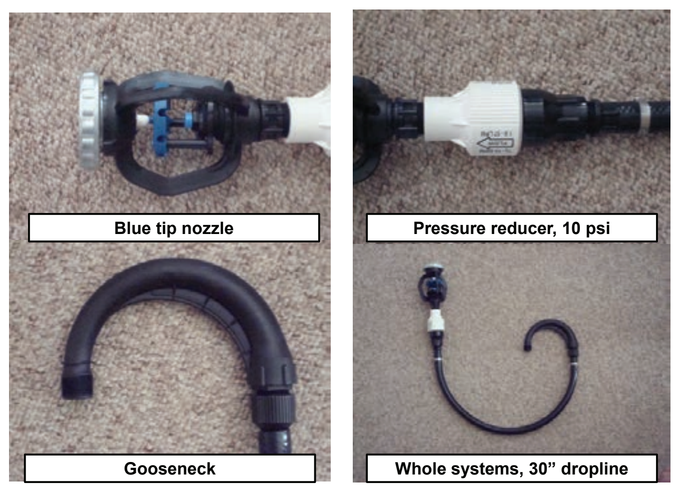
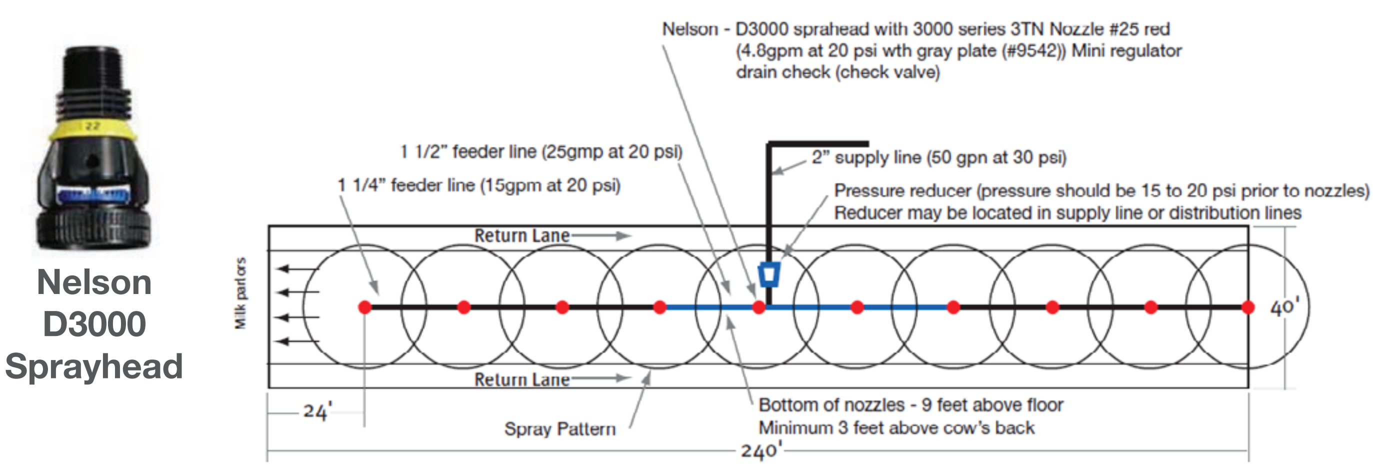


Figure M8. Nelson® D3000 illustration



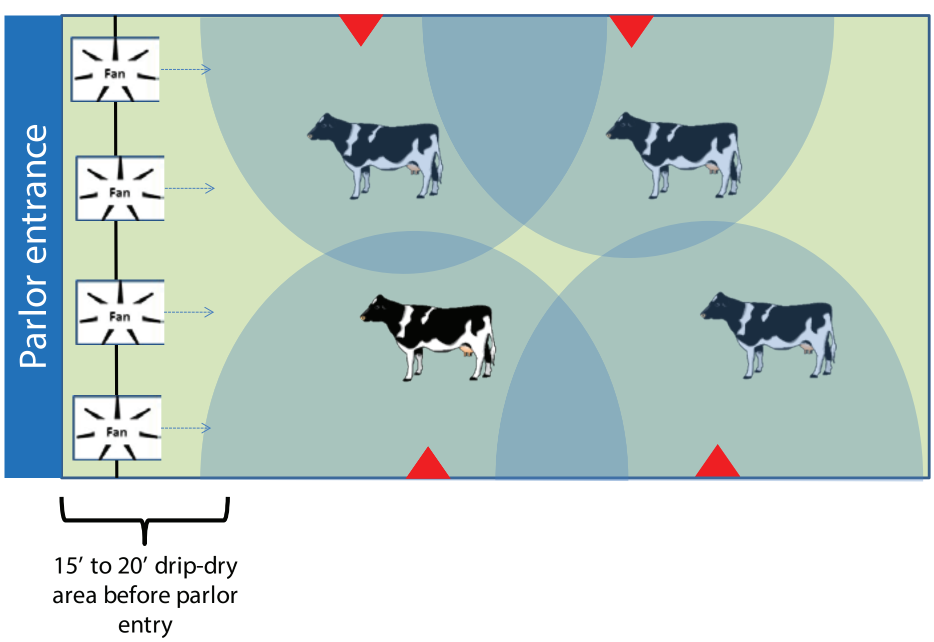
HIGH CAPACITY SOAKER ON SIDES OF HOLDING PEN

High capacity soakers on the sides of the holding pens **(see Figure M9)** are an option when the holding pen has a low ceiling and, thus, little room for a central water line and drop hoses. The RainBird® Plastic Impact Sprinkler 2045-PJ low angle nozzle (LAN-1) (part # B46000-10-LA) is an excellent choice for this application **(see photograph)**. RainBird® nozzles provide 3.5 to 4 gallons of water per minute at 25 psi with a 22-foot spray radius. Nozzles can be staggered on each side of the pen or in a single row down one side of the holding area. Install the nozzles in 15- to 20-foot-long intervals, 6 to 7 feet above the floor for adequate coverage. In this system, the water supply line is clamped to a rail on the side of the holding pen **(see photographs)**. Each nozzle has a water demand of 3.5 to 4 gallons per minute, so a 1-inch diameter line is capable of supplying 14 gallons of water per minute for up to three RainBird® nozzles on each side of the parlor.

High capacity soaker nozzle mounted on the side of holding pen and RainBird low angle nozzle.

High capacity soaker nozzle on side of holding pen

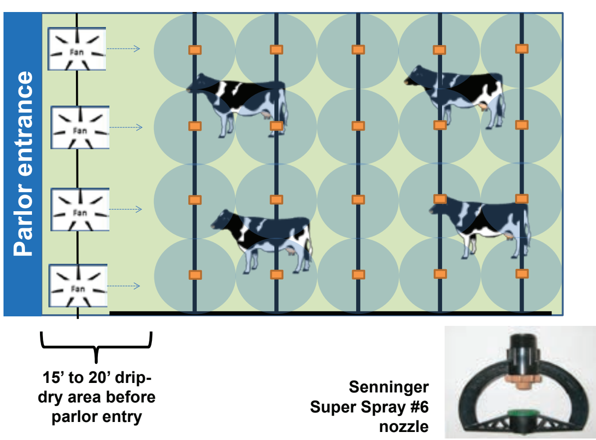
Figure M9. High capacity soakers on side of holding pen



Grid Soaker System over Holding Pen

The grid soaker system in the holding pen **(see Figure M10)** is also a viable option for cow cooling in wider holding pens **(see photographs)**. With this system, the Senninger Super Spray sprinkler head with a #6 to #12 convex deep groove pad nozzle is a good choice **(see Figure M10)**. This nozzle allows for 360-degree coverage with a 16 to 20 foot diameter of coverage. This system will provide over 1.4 gallons per minute at 10 to 15 psi water pressure. When installing the grid system, use a large main water supply line (at least a 1½-inch diameter) with ¾ to 1 inch PVC pipe drop hoses. The soaker should be on 8 to 10 foot centers and positioned 8 to 10 feet above the holding pen floor.

Figure M10. Grid soaker system for holding pen



Grid soaker system in holding pens

Senninger Super Spray nozzle in the grid soaker system in holding pens

PARLOR EXIT COOLING

Decreasing body temperature in a heat-stressed cow requires significant soaking time. As demonstrated in Figures M1 and M2, time is required for cooling to begin even when adequate heat abatement systems are employed. Once body temperatures are elevated, it typically takes an hour or more of soaking and ECV to reduce body temperature back to normal. An important question is, "Can I soak the cow and decrease body temperature within the time allotted?" The answer is simple: Exit lane soaking should always be used in conjunction with holding pen soaking. Exit lane soaking alone is not adequate to reduce elevated body temperatures. Exit lane soaking has inherent flaws. First, even if a large volume of water is provided, soaking time is often inadequate. Second, water often has to run continuously, wasting water resources **(see photographs)**.

Exit alley or exit platform cooling should thoroughly wet the cows after milking, cool cows for the return to pen, and always be used in conjunction with holding pen soaking. The following considerations should be noted when installing parlor exit cooling:

- Use a system that provides large droplets at low pressure that soaks cows to the skin yet does not cause cows to balk when exposed to the spray.
- Showerheads and watering wand spray heads work well.
- Typically 1 to 1.5 minutes of soaking time is adequate.
- A wand or an electronic eye can be used to turn on the water flow.
- Trigger a closed solenoid to open and release water for a set time.
- Control spray time with a timer.
- Set a trigger so that when cows are under the shower, they don't hesitate to enter the water stream.
- Caution: The electronic eye of the trigger can get dirty quickly and fail to operate properly

Milking Parlor Platform Cooling

For parlor exit cooling to be effective, cows must be adequately soaked. To accomplish this, nozzles are often placed on 6-foot intervals along the parlor wall. When milking is completed, rapid exit bars rise, and a toggle switch is tripped. Cows exit the milking stalls and stand on the parlor cow platform. After a 10-second delay, a solenoid is triggered and water is sprayed over the cows for one minute. Cows then exit the milking center being completely soaked. The photographs show a double parallel parlor and a side-by-side parlor, both with excellent holding pen soaking systems and fans in addition to the cow platform soaking.

Exit lane soaking: Large water volume can't compensate for inadequate soaking time

Exit lane soaking: In-line single alley spray provides good soaking time but water may be running continuously, wasting water resources

(Left) Tee-jet nozzles along cow platform in the parlor for soaking after milking. Rapid exit goes up, there is a 10 second delay to allow time for cows to step out, and the soaker line is activated for 1.5 to 2 minutes. Soakers are set on 6 foot centers on the cow platform. **(Right)** Soaker nozzles along cow platform within the parlor

TIMERS, CONTROLLERS, SOLENOIDS, PRESSURE REDUCERS, TIPS, AND NOZZLES

This list is not intended to endorse or omit specific dealers. It offers a list of U.S. suppliers who have most of the materials discussed in this manual

TIMERS/CONTROLLERS

Edstrom Industries
819 Bakke Ave.
Waterford, Wisconsin 53185
800-558-5913
www.agselect.com
e_service@edstrom.com
Products: Edstrom Controller, Solenoids, Filters, Pressure Reducer kits, Times and Preset

Farmland Irrigation
3721 Arch Ave.
Grand Island, Nebraska
Keith Jardine, Dealer
308-381-1509
Products: Senninger irrigation nozzles, holding pen soaker nozzles, I-wobs

Visions Inc.
PO Box 278, 201 East St. South
Vernon Center, MN 56090
800-338-5756, 507-549-3434
svriesen@visioninc.us
Products: Zone controller (EC120R0), Solenoids

MANUFACTURERS

TeeJet Agricultural Spray Nozzles
www.teejet.com
Products: Soaker nozzles for feed lanes

Nelson Irrigation Nozzles
www.nelsonirrigation.com
Products: Soaker nozzles for holding pens

Senninger Irrigation Nozzles
www.senninger.com
Products: Soaker nozzles for holding pens; small ¾-inch to 1.25-inch pressure regulators

Rain Bird Irrigation Nozzles
www.rainbird.com
Products: Soaker nozzles for holding pens

Dancon Products
www.dancon.com
Products: Model 191 - Preset timers push-button delay switch 80 minute range, 120 bolt PresetTime/preset time 5. (Also available at Edstrom at www.agselect.com.)

SOAKER NOZZLES, SOLENOIDS, IRRIGATION PARTS DISTRIBUTORS

Farmland Irrigation
3721 Arch Ave.
Grand Island, Nebraska
Keith Jardine, Dealer
308-381-1509
Products: Senninger irrigation nozzles, holding pen soaker nozzles, I-wobs

QC Supply
Schuyler, Nebraska
68661-0581
800-433-6340
www.qcsupply.com
Products: Edstrom dealer of controllers, solenoids, and filter kits

Dave Reinecker
Reinecker Ag Products
7270 Old Harrisburg Rd.
York Springs, PA 17372
717-528-8428
daragprod@supernet.com
Products: Edstrom dealer of controllers, solenoids, and filter kits

Norbco. Inc.
Paul Garrett
4754 State Route 233
PO Box 370
Westmoreland, New York
13490
315-853-3936
Products: Edstrom dealer of controllers, solenoids, and filter kits

Fairbank Equipment
5018 South Antelope Dr.
Grand Island, Nebraska
800-441-7550 or 308-381-4266
3700 Jewell St,
PO Box 13237
Wichita, Kansas
316-943-2247
www.fairbankequipment.com
Products: TeeJet dealer of feed lane soaker nozzles

Farmer Boy Ag
50 West Stover Ave
Myerstown, PA 17067
www.farmerboyag.com
800-845-3374

Paul B. Zimmerman
50 Woodcorner Road
Lititz, Pennsylvania 17543
717-738-7350
Products: TeeJet dealer of feed lane soaker nozzles

Ag-Chem/AGCO Parts
Distribution Center
300 Russel Drive
Middletown, Pennsylvania
800-760-8800
Products: TeeJet dealer of feed lane soaker nozzles

Mid-Atlantic Irrigation Co., Inc.
1803 West 3rd Street
PO Box L
Farmville, Virginia 23901
888-442-0240
http://www.irrigationparts.com

NetaFim
www.netafim-usalandscape.com
Products: Solenoid, pressure regulators

Bermad
International company with dealers in Florida, Texas, and California
Tom Gerardi
Manager, South East Region
Ocala, Florida
Office: 352-629-6838
Fax: 352-629-3553
Mobile: 352-895-1508
Email: 428CJ@att.net
www.bermad.com

LARGE SOLENOID VALVES

Farmland Irrigation
3721 Arch Ave.
Grand Island, Nebraska
Keith Jardine, Dealer
308-381-1509
Products: Senninger irrigation nozzles, holding pen soaker nozzles, I-wobs

Grainger
http://www.grainger.com

Schaben Industries
Columbus, NE 68601
Bakersfield, California
1-800-274-1025

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