Evaluate the Efficacy of Your Cooling System with "Heat Stress Audits" of Core Body Temperature

M. VanBaale[1], J. Smith[2], C. Jamison[3], R. Rodriguez[3], and L. Baumgard[1]
The University of Arizona[1], Kansas State University[2], and Monsanto Dairy [3]

Introduction

The effects of heat stress on animal production are well known and have been investigated and documented for a number of years. It is commonly accepted that a temperature humidity index (**THI**) ≥ 72 creates a stressful environment for lactating dairy cattle. The basic thermoregulatory strategy of a dairy cow is to maintain a core body temperature higher than ambient temperature to allow heat to flow out from the core via four basic routes of heat exchange (conduction, convection, radiation, and evaporation).

When ambient temperature conditions approach body temperature, the only viable route of heat loss is through evaporation. If ambient conditions exceed body temperature, heat flow will reverse and an animal becomes a heat sink. Therefore, estimating the thermal environment around animals is necessary in order to understand their cooling needs.

Because of the typical location of cooling equipment relative to animals and the large variety of animal positions (i.e. location within a pen), there are a wide range of micro-environments present within a facility. As a consequence, cows experience differing levels of heat stress within a day. Thus, accurately determining the degree of heat stress a cow is experiencing over time is a challenge.

Traditionally, respiration rate (**RR**; breathes/minute) has been used as a tool to measure the severity of an animal's heat stress. Although RR will vary with body weight and milk yield, it is a relatively accurate tool for determining the degree of heat stress. Recently, cattle housed in the Animal Research Complex (**ARC**; Tucson, AZ) environmental facility under thermal neutral conditions (65.8 ± 1.0 ˚F; 63.5 THI ± 0.7) for 48 h followed by heat stress (98.0 ± 1.5 ˚F; 79.6 THI ± 1.0) for 16 out of 24 h/d for 3 d had RR of 50 during thermal neutral and 71 during heat stress conditions, respectively.

It has been demonstrated that if the skin surface temperature of a dairy cow is below 95 ˚F the temperature gradient between the core and skin is large enough for an animal to effectively use all four routes of heat exchange. Infrared thermography guns have been shown to be a low cost approach to estimate actual skin surface temperature. However, because of variability in skin surface moisture at a given point in time, the accuracy of infrared guns to predict an animal's heat load may be limited. For example, if an animal recently walked under a shade after being out in the sun (solar radiation) the infrared measurement of skin will not be reflective of cows under the shade that were not recently exposed to the sun.

Core body temperature (**CBT**) has been shown to decrease in cooled cows compared to non-cooled cows. Recently, cattle housed in the ARC environmental facility under thermal neutral conditions (65.8 ± 1.0 ˚F; 63.5 THI ± 0.7) for 48 h followed by heat stress (98.0 ± 1.5 ˚F; 79.6 THI ± 1.0) for 16 out of 24 h/d for 3 d had vaginal temperatures of 101.8 ± 1.0 ˚F during thermal neutral and 103.5 ± 2.5 ˚F during heat stress conditions, respectively.

Heat Stress Audits 2005

During the winter of 2005 Monsanto Dairy Technical Services and Drs. Smith and VanBaale collaboratively designed a project to record intra-vaginal temperatures of lactating and dry mature dairy cows utilizing a continuous temperature logging device (Hobo® U12 Stainless Temperature Data Logger, Onset Computer Corporation; Bourne, MA) attached to a blank controlled internal drug release device (**CIDR**; not containing hormones). The observational project was designed to gather 72 h of temperature readings, recorded at 5 min intervals, with allowance of appropriate time for device equilibration after insertion. Cows were selected based on days in milk (**DIM**) and milk production, or days carried calf (**DCC**) in the case of dry cows.

The data loggers were inserted into eight cows in a pen (lactating and/or dry) and continuous CBT was monitored and recorded during each on-farm audit throughout the collaborative project. Dairies were selected based on geography and facility design. An attempt was made to gather data across a wide range of geographies (climatic conditions), herd sizes, facility types, and heat stress abatement strategies.

Census data collected at each dairy site included pen sizes, milking frequency, milking times, average milk production, holding pen facility design (to include holding pen heat abatement facilities), and timing of cow movements. Ambient temperature and humidity was collected at the dairies utilizing logging devices, which collected temperature and relative humidity at 5 min intervals over the same 72 h period as the data loggers. Ambient temperature and humidity recording devices were positioned on and around the dairies audited (away from direct sunlight), including the holding pens, in an attempt to correlate the ambient conditions with the core body condition. If ambient devices were not available (due to logistics and supply situations, not all dairies had enough ambient devices available), outside temperature and relative humidity data was gathered utilizing the global positioning system (**GPS**) coordinates of the facility and WeatherPlot, a subscription service available via the internet which can provide such data with a high degree of localization and accuracy.

The recorded data was individually downloaded from each intra-vaginal device. All data were aligned by 5 min intervals and then imported into Microsoft Excel. The individual device data was then collapsed in a pivot table to be examined in hourly increments over a 24 h period. Each hour of the 24 h period represents a summary of that hour on 3 consecutive days, with eight devices contributing 12 data points/h/d. Specifically, each hour is a summary of 12 x 8 x 3 data points, or 288 individual data points within that hour. A standard format was agreed upon for presentation of the data. So when observing data from several dairies, the observer can safely assume that the data has been collected, collated, and presented in a consistent fashion across dairies.

Results

During this collaborative effort, data was collected in 24 states (Figure 1) from over 40 herds, milking ~ 125,000 cows. A consistent observation throughout the auditing was the impact of holding pen cooling, or the lack thereof. Specifically, a holding pen (designed to allow 15 sq. ft/cow), without proper cooling, is an area where dairy cows may experience severe heat stress (Figure 2); however, if properly cooled, vaginal temperature will be reduced each time cows are brought to the parlor (Figure 3).

Another observation was the impact of shade compared to no shade (Figure 4). Lactating cows provided with shade had lower CBT during the hottest times of the day compared to those without shade. Not surprisingly, the benefit from shade was greatest when outside temperatures were the hottest. The implementation of sprinkler line misters without shade was compared to shade alone. Shade alone maintained CBT at lower levels then misters alone (Figure 5). Outside ambient conditions, type of facility, and the availability to apply water to cows will impact the ability to maximize the combination of shade and water use for evaporative cooling.

Figure 1. States where a heat audit was performed (denoted by stars).

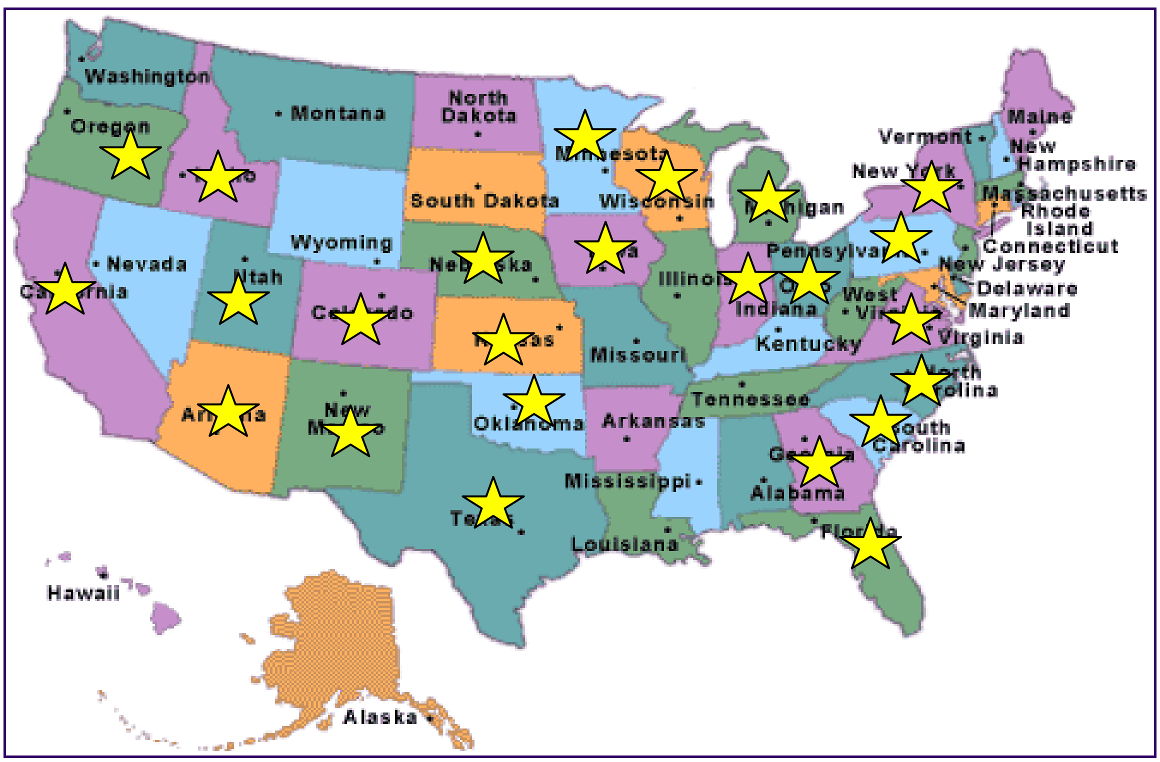
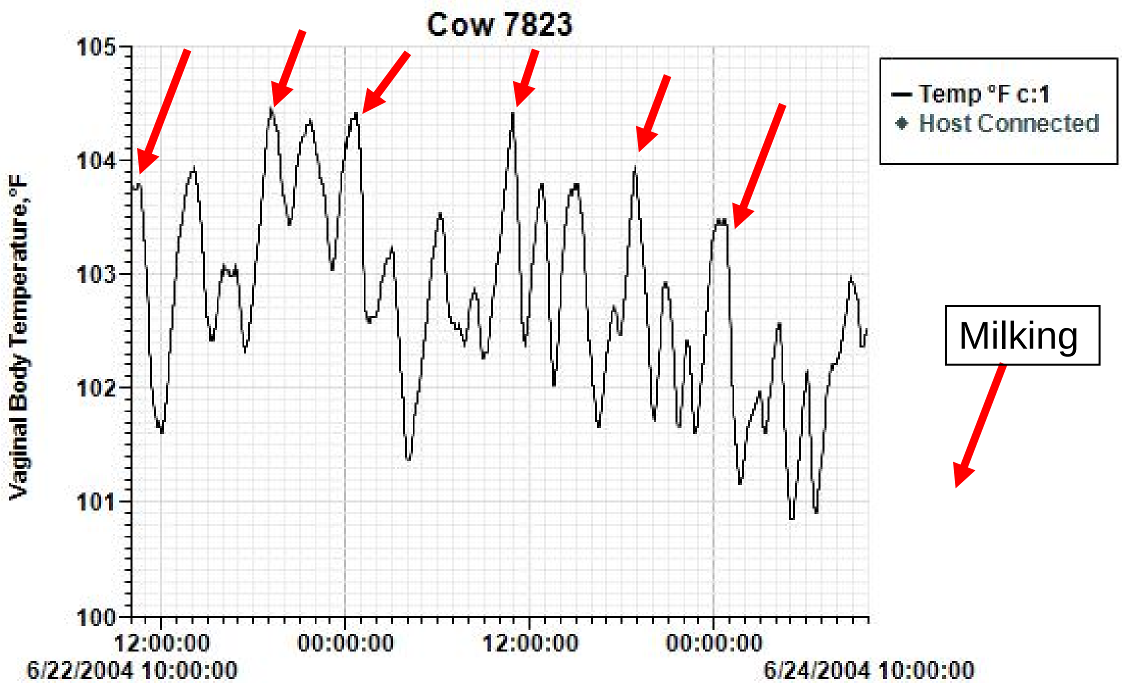


Figure 2. Two 24-hour periods of CBT from a single cow in a holding pen.



On Arizona dairies the most widely used evaporative cooling systems are Korral Kool (**KK**; Mesa, AZ) coolers and fans with sprayers/misters (**SF**). Korral Kool coolers are built into the center of a shade and the system injects micron-sized (30-65 microns @ 300 psi) water droplets into fresh air moving down the cooler; thus cooling the air around the cow.

Figure 3. Effects on core body temperature of cows experiencing excellent holding pen and parlor exit lane cooling.

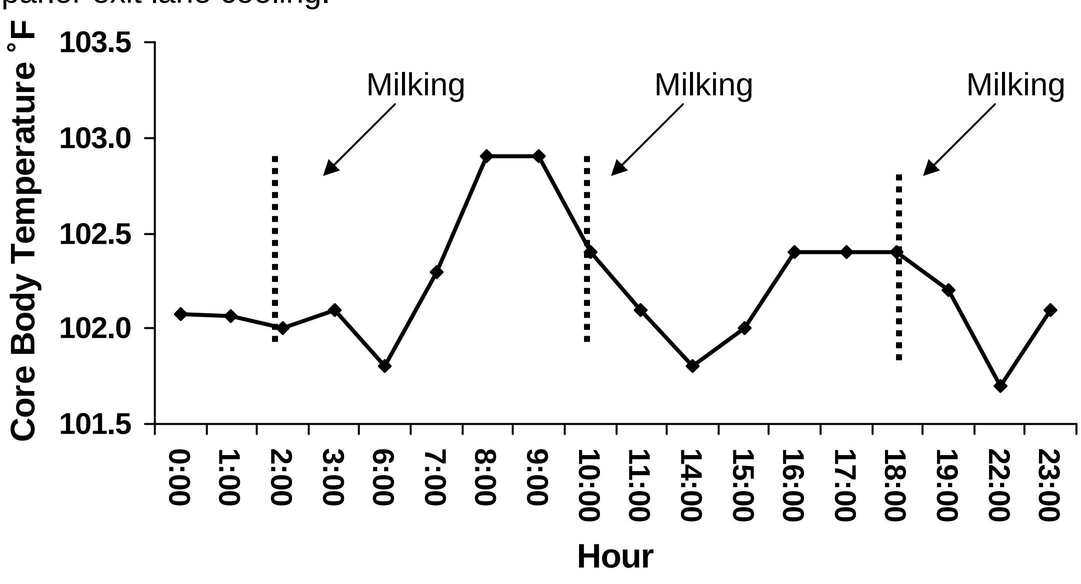
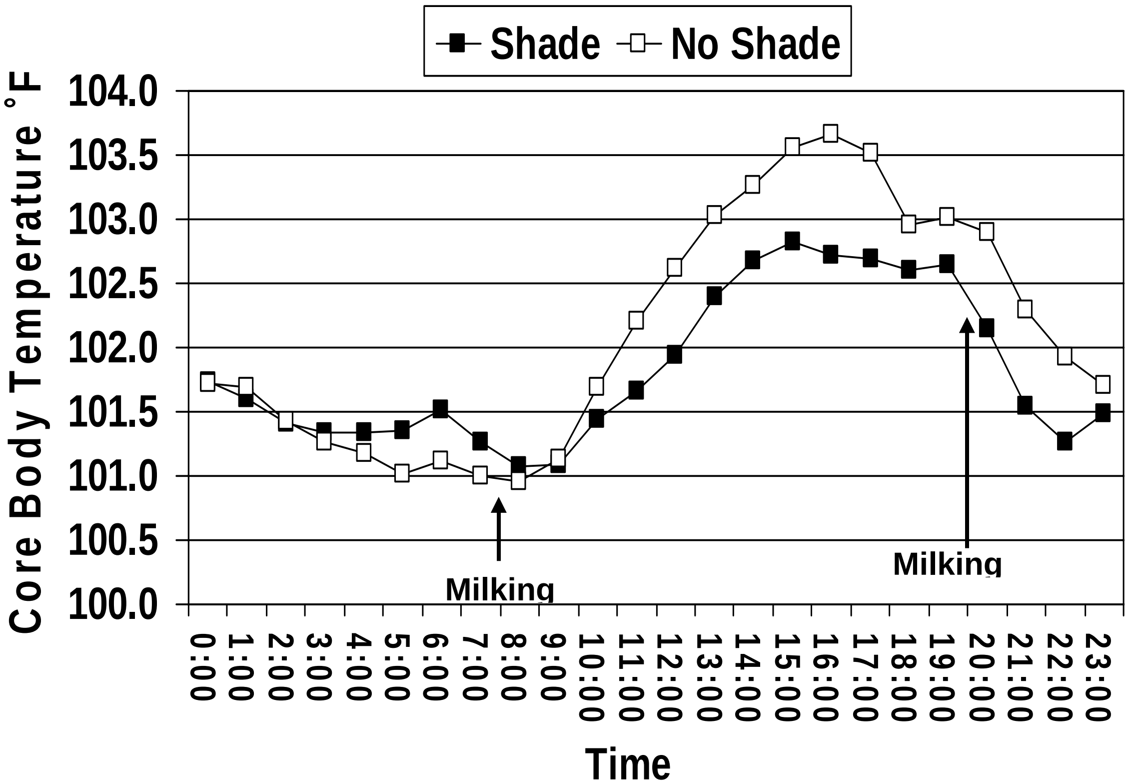


Figure 4. Core body temperature with or without shade.



Advanced Dairy Systems-Shade Tracker (**ADS-ST**; Chandler, AZ) is also installed into the shade's structure, but is located on the western or eastern edge. It is a SF system, that is equipped with variable speed water injection (5-15 microns @ 250-1250 psi) into the air stream and the fan itself has a range of motion of up to 270º; thus cooling areas around or under the shade structure, depending on the sun's position during the day. The effects on CBT for cows housed under KK coolers with 2 and 5 horse power (**hp**) fan motors compared to cows (from the same dairy) housed under ADS-ST fans are illustrated in Figure 6. The observations on this particular herd were impressive in the fact that CBT was lowest for cows housed under the 5 hp KK and highest for those housed under the 2 hp KK and the CBT of cows housed under the ADS-ST fans was in between, suggesting that the 5 hp KK was doing a better job of maintaining CBT compared to the fans; however, the fans appear to be out performing the 2 hp KK.

As mentioned earlier, we collected data from a variety of facilities throughout the summer of 2005. Within a facility the minimum, average, and maximum CBT temperatures from all cows were collected; but only the averages were typically reported. However, Figure 7 shows both the average, minimum and maximum CBT observed from 8 multiparous cows housed in a tunnel ventilated barn in western Kansas. Regardless of the time of day and outside ambient temperature (80 ± 10 °F) the maximum CBT was never more than a degree Fahrenheit higher than the minimum; and overall average CBT only exceeded 102.5 °F for 2 h/d.

Discussion

One primary goal for this project was to better understand interactions of climate, facilities, production, reproduction, and heat stress. Gathering and attempting to understand data from a wide array of differing facilities in different climates with different production levels and management schemes, hopefully, will allow us to move forward into a more specific targeted use of the recording devices in subsequent summers. In general, our results tended to agree with what our current knowledge predicted, i.e. cows get hot when climatic and management factors subject them to conditions which exceed their inherent ability to dissipate heat generated and absorbed. These data should allow us to refine our expectations. Specifically, observations from this project suggest that the data loggers are an effective tool to monitor, and ultimately fine tune, currently installed heat abatement systems; as well as suggesting a need for future improvement. The project was not designed as a publishable study; therefore caution is advised in over interpreting the data. However, the project does demonstrate the feasibility and usefulness of using intra-vaginal temperature recording devices to monitor body temperatures of lactating and dry dairy cows.

Figure 5. The impact on core body temperature for close-up dry cows provided only shade or only misters.

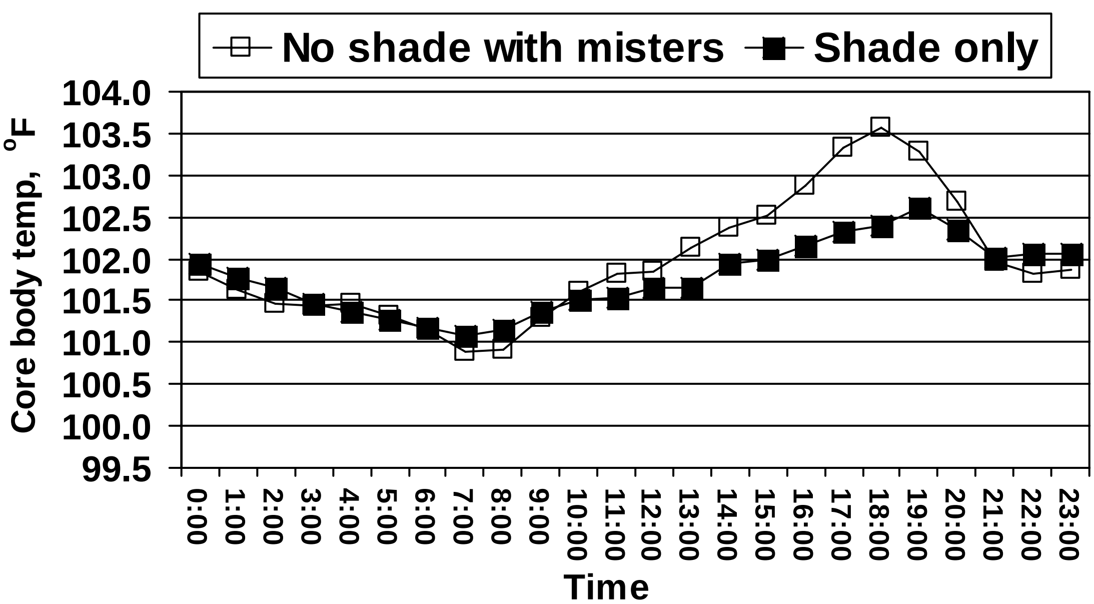


Figure 6. Effects on core body temperature of multiparous lactating cows housed in a dry lot facility with 2 or 5 horse powered Korral Kool Koolers or oscillating fans with misters.

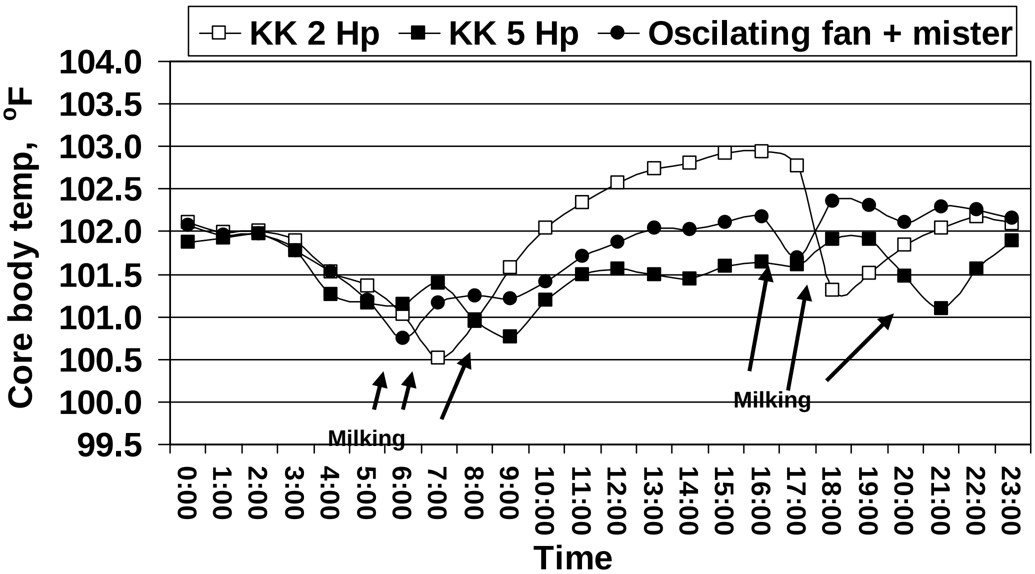
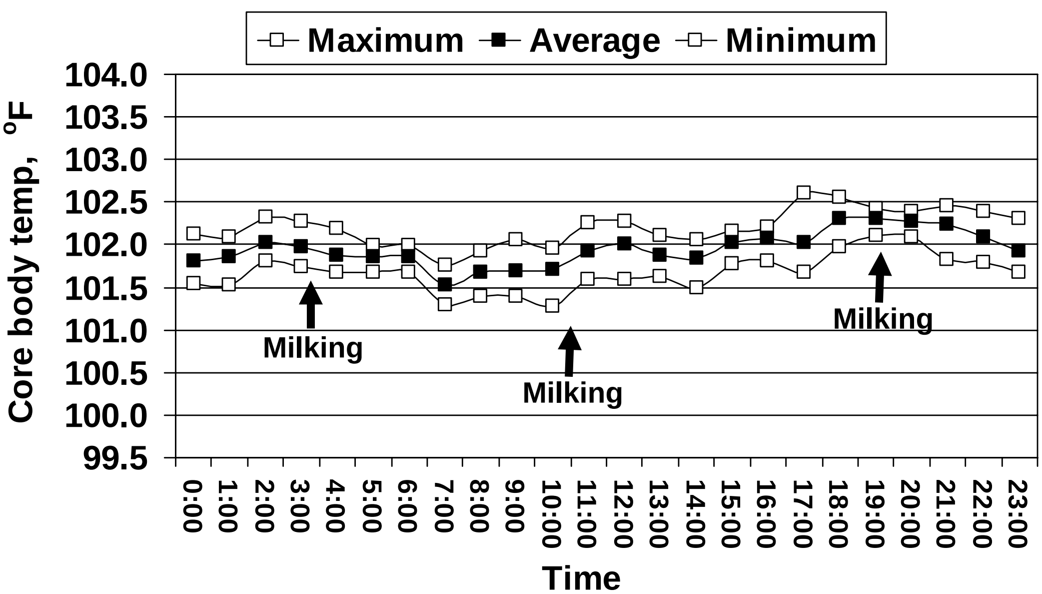


Figure 7. Core body temperature of multiparous lactating cows housed in a four row tunnel ventilated freestall barn.



More work needs to be done to completely understand the data; however as new technologies come to market, these data should prove useful in answering questions of how and when such technology can fit into a particular dairy production system. This technology allows a cow's CBT to be monitored and recorded 24 h/d as they move throughout a facility. Utilizing a CBT probe to continuously monitor vaginal (core body) temperature allows a producer to accurately determine where and when cows experience the most heat stress. As a consequence, management decisions can be made to improve cooling and reduce heat stress; thus, improving cow performance.

In addition, parlor exit sprinklers have demonstrated that when a cow enters a corral with a wet body surface, the moisture will evaporate; thus cooling the cow for an additional period of time depending on weather conditions. The effects of barn and cooling system design are important factors in determining the efficacy of cooling on dairy facilities. Factors critical to the correct design and cooling system are obviously dependent on the geographic location of the dairy. Specifically, daily average high and low temperature, annual rainfall, and humidity as well as prevailing winds are critical factors.

Conclusion

Dairy producers are in business primarily to make a profit, which can be realized by increasing the price received for their product or decreasing the cost of producing it. Cooling systems installed in dairies located in hot semi-arid climates like AZ can contribute up to 20 % of the total construction cost ($300 to $600/cow). In addition, since variable expenses such as electricity and water can cost $0.10 to $0.15 cow/d it is critical that the investment is paying off and cows are being cooled efficiently and effectively. Using intra-vaginal probes to monitor CBT of dairy cows is an inexpensive effective means of evaluating the impact of heat on cows with in a facility.