The Effect of CowKühlerZ Evaporative Cooling System on Heat Stress Abatement in Lactating Dairy Cows

FINAL REPORT
March 31, 2014

Submitted To: John Struck
CowKühlerZ
asiintl@connectnc.net

Submitted By: William H. Miner Agricultural Research Institute
P.O. Box 100, 1034 Miner Farm Rd.
Chazy, NY 12921

Catherine Ballard, Director of Research
518-846-7121 ext. 112
ballard@whminer.com

Sarah Williams, Research Intern
518-846-7121 ext. 151
williams@whminer.com

Richard Grant, President
518-846-7121 ext. 116
grant@whminer.com

INTRODUCTION

Dairy cattle experience heat stress whenever the effective ambient temperature exceeds the upper limit of their thermoneutral zone (Armstrong, 1994). The effective ambient temperature is determined by air temperature, relative humidity, air movement, and solar radiation. Arizona researchers (Zimbelman et al., 2009) have determined that the THI threshold for loss in milk yield should be 68 for cows producing greater than 77 lb/d rather than the traditional THI threshold of 72. Cattle become more sensitive to thermal stress as milk production increases due to greater metabolic heat output.

Dairy cattle respond to heat stress in several ways including greater standing time, reduced eating activity, greater water consumption, less rumination, lower dry matter intake, and reduced milk production and reproductive performance (West, 2003; Tapki and Sahin, 2006). Although numerous studies have been conducted that evaluate cow response to heat stress, few studies have been conducted in the northeastern United States where episodic heat-stress periods are typical. Anecdotally, dairy farmers in this region often state that bouts of heat stress that occur early in the summer (June), or late in the summer (September), have the most dramatic negative effects.

The economic consequences of heat stress on dairy herds has been documented and discussed by several researchers (DeVries, 2012). DeVries (2012) presented data showing that the economic loss for heat-stressed cows with minimal abatement ranged from greater than $600/cow/yr for Florida and Texas to $72/cow per year for Wisconsin. The annual hours of heat stress for Florida and Texas, as assessed by a THI > 70, were 49 and 36%, respectively, whereas Wisconsin was only 9%. There are dramatic differences by region of the US in severity of heat stress, but St-Pierre (2001) still estimated a greater than 2:1 return on investment for heat stress abatement in New York.

The short- and longer-term consequences of heat stress on health issues such as lameness is perhaps under-appreciated, especially more moderate heat stress typical of northern states. Cook et al. (2007) observed the behavioral and lameness changes that occurred between early June and September as THI ranged from 56.2 to 73.8. Even with these mild to moderate heat stress conditions, lying time decreased from 10.9 to 7.9 h/d from the coolest to the hottest conditions while standing in the alley increased from 2.6 to 4.5 h/d.

CowKühlerZ, is an evaporative cooling system designed and manufactured from ARATO. CowKühlerZ are composed of a number of specially designed and engineered push-fit connectors combined with a state-of-the-art flexible piping material. According to the manufacturer, a unique nozzle system delivers a very precise spray pattern designed to optimize evaporative cooling while minimizing water use. CowKühlerZ are also engineered to allow for maximum system flexibility with the ability to be adaptable to nearly all barn configurations, being mounted in front of the fans or suspended from the ceiling.

The objective of this study was to assess the impact of various configurations of the CowKühlerZ system on the behavioral and productive responses of dairy cattle during August and September in Northern New York State.

MATERIALS AND METHODS

Cows, Facilities, and Treatments:

Facility description. The study was conducted from August 6 through September 23, 2013 using high producing Holstein cows housed in two pens at the Charles J. Sniffen Dairy Education and Research Facility (William H. Miner Agricultural Research Institute, Chazy, NY). Both pens had similar configurations with 68 head-to-head arrangement of stall beds, 94 headlocks and 4 water troughs per pen. Dimensions of the stall beds are 50 in wide, 102 in long, and 50 in high at the neck rail. The stall beds are covered with 67-in long Animattresses (Ani-mat, Inc, Sherbrooke, QC, Canada), bedded twice weekly with approximately 22 lb of kiln-dried sawdust. Soiled bedding was removed and clean sawdust redistributed across the mattresses at the start of each milking. The sidewalls of the barn are 14-ft high. Cross alleys at the ends of each pen are 12 or 13 ft wide by 17 ft long; feed alleys and back alleys are 96 ft long and 14 ft wide or 10 ft wide, respectively. Feed and back alleys are covered with rubber mats (Animat, Saint-Élie d'Orford, QC) and scraped every 2 h with an automatic scraper system (Houle, Drummondville, QC). Walking distance was less than 300 ft from all pens to the parlor.

Pen 1 had minimal heat abatement with four 52-in fans located 8-ft over the center of the stalls and spaced 40-48 ft apart. There were no fans located over the feed alley because a catwalk precluded fan attachment. Pen 1 served as a baseline/control group for the duration of the study.

Pen 2 was equipped with fans over stalls with similar configuration as Pen 1. In addition, Pen 2 had five 52-in fans installed over the feeding area, spaced 40-ft apart and ~10 ft above the floor. Pen 2 was equipped with 31 soaker heads (Edstrom C440S, Waterford, WI) located over the feed area, spaced 6-ft apart and 7-ft above the alley floor. The Edstrom soakers had two settings: Low setting – soakers came on at 78°F for two minutes, expelling one gallon of water per minute with a 15-minute interval; High setting – above 90°F, soakers came on for three minutes expelling one gallon of water per min, with an interval of 9 min.

The CowKühlerZ system was also installed in Pen 2 with one solenoid operating spray nozzles attached to fans over the feedbunk line and a second solenoid controlling spray nozzles attached to fans over the free stalls. Both solenoids were controlled by an Edstrom Controller with two settings for each solenoid. The feedbunk line solenoid settings were: Low setting – CowKühlerZ came on at 72°F for one minute every three minutes; High setting – CowKühlerZ came on at 90°F for two minutes every three minutes. The freestall solenoid settings were: Low setting - CowKühlerZ came on at 72°F for 30 seconds every three minutes; High setting CowKühlerZ came on at 90°F for one minute every three minutes.

The study was conducted using a quasi-experimental design since it did not meet all requirements necessary for controlling influences of extraneous variables and randomization of treatments was not feasible. Under this assumption, a time-series design with the addition of a comparison group (Pen 1) was used. Four treatment combinations were imposed on Pen 2 and evaluated over 1 week periods from August 6th through September 23rd:

A – Edstrom Soakers/Fans along feedbunk + Fans over the free stalls
B – CowKühlerZ/Fans along feedbunk + CowKühlerZ/Fans over the free stalls
C – Fans only along feedbunk + CowKühlerZ/Fans over the free stalls
D – Edstrom Soakers/Fans along feedbunk + CowKühlerZ/Fans over free stalls

Cows were milked 3 times daily in a double-twelve parallel parlor (Xpressway Parallel Stall System; Bou-Matic, Madison, WI) with fans and soakers located in the holding area. A TMR formulated for 90 lb of milk/d was delivered once daily when cows were removed for 0430 h milking and pushed up approximately 6 times daily. Water troughs were located in the return alley between the free-stall pens and the parlor. Approximate time spent outside the pen was 2.5 h/d for cows in both pens.

Cow selection. Twenty five cows each in Pens 1 and 2 were selected such that the initial groups were balanced for days in milk (DIM), parity and milk production (Table 1). All cows received recombinant bST (Posilac; Elanco Animal Health, Indianapolis, IN) administration subcutaneously every 14 d. Over the course of the study, cows treated for mastitis were removed from the pen until the health issue was resolved. Weekly summarizations did not include data from cows for the week(s) they were removed from study pens. Non-study cows were added to and removed from the pens at weekly intervals.

Measurements:

Characterization of environmental conditions. Temperature and relative humidity were recorded continuously using THI sensors (Onset HOBO, Bourne, MA) placed in the center of pens 1 and 2. The equation used for THI was: THI = (1.8 x td +32) – [(0.55 – 0.0055 x RH)(1.8 x td -26)], where td is the dry bulb temperature in ºC and RH is the percent relative humidity. THI measurements were taken at 15-minute intervals, and averaged hourly over the course of the study. Water usage was measured for each treatment by using water meters installed for each sprinkler/soaker systems. Wind speed was recorded for fans located over freestalls and feedbunk line using a Kestrel 3000 anemometer (Nielsen-Kellerman Co,, Boothwyn, PA).

Effect of ambient conditions on lactation performance and behavior. Milk production was measured 3 times per day (Xpressway Parallel Stall System; Bou-Matic, Madison, WI) and averaged daily. Time spent lying or standing was measured continuously for the duration of the study using leg-mounted data loggers (Onset HOBO, Bourne, MA). Loggers were placed on the back leg, just below the hock joint using vet wrap. Data were downloaded from the loggers once per week, and the logger was switched to the opposite leg to minimize irritation. Placement of loggers was done once per week during milking at approximately 1230 h for Pen 1 and 1330 h for Pen 2 (Krawczel et al., 2012). The data were summarized by week or as needed around heat stress episodes. Activity (movement) and rumination were measured continuously using the HR-tags of the ai24™ system (Semex, Madison, WI). Data from the selected cows were summarized weekly throughout the study.

Water usage and bedding dry matter. Water meters for each system allowed for water usage to be monitored throughout the study. To address concerns about wet bedding when the CowKuhlerZ are used over the stalls, dry matter of the bedding was determined on a day the system was used. For comparison, dry matter of the bedding collected from similar stalls in Pen 1 was also determined. A uniform sample of bedding was collected from the stall and ~80 g was dried for 18 h at 105ºC.

Statistical analysis and presentation of data. Given the preliminary nature of this study, much of the results will be presented as means ± standard error in graphical format. For the data collected during specific heat stress events, the data are presented in two ways: 1) means ± standard error, and 2) a covariate analysis is used in which a non-heat event day from the beginning and end of the study is used to adjust the means prior to statistical analysis using a mixed model procedure with SAS.

RESULTS AND DISCUSSION

THI Conditions during Study

The THI was similar for Pens 1 and 2 throughout the study as shown in Figure 1. Since the study was conducted in late summer and early fall, there were sporadic episodes of heat stress as indicated by THI >68. Recent Arizona research (ex. Zimbelman et al., 2009) has demonstrated that high producing cows, such as the cows used in our study that averaged 111 lb/d of milk at the start of the experiment, experience heat stress at THI lower than previously thought. In these Arizona studies, cows have responded positively in milk production to heat stress abatement beginning at the lower THI.

Time-Series Observational Results for Milk Yield, Lying, and Rumination

For the results presented in Figures 2 through 6 and Table 2, the data are simply reported a means ± standard error with no statistical significance implied. The discussion of these data focuses strictly on numerical trends and relationships. The primary purpose of this preliminary study is to gain a quick assessment of how the heat abatement systems may influence the cow's response to heat stress compared with a minimally cooled pen.

Milk production. The average daily milk production by pen is presented in Figure 2 along with average daily minutes of THI > 68. This graph illustrates the impact of heat events and heat abatement systems on short-term milk production responses. The heat abatement treatments were imposed in one-week cycles and so it becomes complicated to tease out the effect of each cooling system on milk production due to the lag in milk yield reduction that may occur following a heat episode. Also, it is possible that the effect of periodic heat stress is cumulative and that this net effect is reflected in the milk response as the experiment continued. We need to keep this potential confounding in mind as we interpret the data in Figure 2.

Nonetheless, from 8/6/13 to 9/23/13, the milk yield for cows in the baseline pen (Pen 1) and the treatment pen (Pen 2) generally declined. Compared with the baseline pen, cows in Pen 2 with enhanced cooling maintained numerically greater milk production, especially beyond mid-experiment. If we visually examine the periods when the CowKuhlerZ system was being used the cows had numerically greater milk yield than the baseline cows with minimal cooling (fans over stalls only). This positive effect of the CowKuhlerZ system on short-term milk production was especially noticeable from 9/13/13 to 9/21/13 following a bout of severe heat stress. Here we observe both groups of cows begin to lose milk production with the onset of the heat stress event, but the cows with the CowKuhlerZ system recover milk production more rapidly and to a greater extent than the baseline cows. The difference is maintained until the treatment is switched to CowKuhlerZ over the stalls only and then milk yield gradually declines.

Lying and rumination activity. The average lying time by pen is presented in Figure 3 with average daily minutes of THI >68 similar to the layout of Figure 2. As illustrated in this graph, cows housed in Pen 2 with heat abatement systems had numerically higher resting times when compared to cows in Pen 1 with only fans. Similar to milk yield responses in Figure 2, lying time appeared to be improved versus baseline cows during periods when cows were cooled with CowKuhlerZ system over the stalls. Similar to milk production, the effect of greater cooling over the stalls was especially evident for the time period between 9/11/13 to 9/23/13.

It appears that when enhanced cooling is provided over the free stalls, cows will lie down more and this response is associated with greater milk production. Although the design of this study precludes statistical inferences, the observed relationship between greater lying time and better milk production is expected based on many reports in the literature that link improved stall comfort and lying time with greater milk production (Grant, 2012).

The average rumination and activity times recorded by the ai24™ system are presented in Figures 4 and 5. Total minutes that cows spend ruminating appear to be highest for cows housed in Pen 2 where heat abatement systems were employed. Activity of cows was highest in Pen 1 where only fans were used. These data agree with the reduced resting time shown for Pen 1 cows.

Overall, these data illustrate the relationships between effective cow cooling, less activity (i.e. standing and walking) in the pen, greater lying in the stall, greater rumination activity, and better milk production versus minimal cow cooling. These effects were observed even under conditions of mid-summer to late fall when heat stress events in northern New York State are typically not that severe. It is important to bear in mind that these relationships are observational only and that, except for the standard error bars indicating the degree of variability, there is no statistical comparisons being made among the treatments or between the pens.

Water Usage and Bedding Moisture Content

Total water used by these heat abatement systems during these heat events is also presented. The Edstrom soakers used the most water compared to the CowKuhlerZ system. This may have been because more extreme temperatures were realized during the heat events. According to the data in Table 2, the CowKuhlerZ System only used ~18% as much water as the Edstrom System.

The dry matter of bedding collected from stalls after two consecutive days of water usage was similar to bedding dry matter in Pen 1 where only fans were used for heat abatement (84.9% vs. 86.2% DM, respectively).

While it appears the use of KuhlerZ over stalls does not affect dry matter of bedding, future studies should continue to evaluate bedding dry matter when longer heat events resulting in greater water usage occur.

Heat Stress Events

There were only four significant heat events during the course of this study on August 9th, August 22nd, September 1st and September 11th. Interestingly, all four of the heat abatement treatments were employed during one of the heat events: Edstrom soakers over feedbunk, CowKuhlerZ over stalls only, Edstrom soakers at feedbunk and Cow KuhlerZ at stalls, and Cow KuhlerZ at feedbunk and stalls, respectively. This study illustrates the potential benefits of cooling cows even during periodic heat stress events.

Figures 6 and 7 illustrate the percentage of study cows within a pen ruminating or active during each of these heat-stress event days. Total time that cows spent ruminating and resting on these dates is presented in Table 2. In addition, activity and standing bouts are also presented in Table 2. Generally, enhanced cow cooling numerically increased the rumination, and decreased the standing time, throughout the day compared with minimal cooling.

Table 3 shows the covariately adjusted total rumination, standing bouts and lying time on the four heat-event days when various cooling systems were employed in Pen 2. Although there are numerical differences with these adjusted means, there are no statistically significant effects.

These data were analyzed as a single heat event day within each treatment week. The covariate period was when minimal heat stress occurred prior to and after the study. The limitation when using this approach is that the covariate assumes that pen 1 and pen 2 are equal even though pen 2 cows have experienced greater heat abatement throughout the summer. Consequently, this statistical approach may put the treatments in pen 2 at a disadvantage compared with pen 1. In the study planned for summer of 2014, two major changes in design and analysis will be used compared with 2013:

1) Only two comparisons will be made (minimal heat abatement versus CowKuhlerZ System) so that constant switching from one treatment to another will not confound the data.
2) THI will be used as a covariate (rather than simply identifying non-heat stress days prior/after the heat event) which should provide a more meaningful basis for statistical comparison between pen 1 (minimal cooling) and pen 2 (Cow KuhlerZ System).

LIMITATIONS

Limitations of this study include the experimental design and the reliance on heat events to fully evaluate the efficacy of the different heat abatement strategies. Since the study began in mid-summer and continued into early fall, earlier and more severe heat stress events were not included in this preliminary study. It is expected that the study planned for summer of 2014 should address the major limitations of this observational study.

CONCLUSIONS

This was a preliminary experiment with cow cooling treatments imposed in short periods during mid-summer to early fall. During this time, four primary episodes of heat stress occurred. Consequently, there is a potential danger of over-interpreting and inferring the results of this preliminary study. The only statistically analyzed data are in Table 3 and these results show no statistical significance for lying, rumination, or standing bouts.

But, the basic numerical responses hold together well and can serve as the hypotheses for the longer term study planned for 2014:

- ✓ enhanced cow cooling during these episodes of heat stress appeared to improve lying time, and consequently reduced activity within the pen.
- ✓ enhanced cooling appeared to visually increase milk yield (this will remain the most difficult measure to assess even with the 2014 study.)
- ✓ enhanced cooling improved rumination overall. Rumination was especially improved during the hottest parts of the day.
- ✓ Most notably during the fourth heat stress episode, the CowKuhlerZ system provided benefits in terms of greater stall lying time, less activity, more rumination particularly during the hottest part of the day, and more milk yield.

REFERENCES

Armstrong, D. V. 1994. Heat stress interactions with shade and cooling. J. Dairy Sci. 77:2044-2050.

Brouk, M., J. F. Smith, and J. P. Harner. 2001. Fan placement and heat stress abatement in four-row freestall barns. EP-110. Kansas State Univ. Agric. Exp. Sta., Manhattan.

Cook, N. B., R. L. Mentink, T. B. Bennett, and K. Burgi. 2007. The effect of heat stress and lameness on time budgets of lactating dairy cows. J. Dairy Sci. 90:1674-1682.

DeVries, A. 2012. Economics of heat stress: implications for management. eXtension. http://www.extension.org/pages/63287. Accessed May 1, 2012.

Harner, J. P., J. F. Smith, M. Brouk, and J. P. Murphy. 1999. Sprinkler systems for cooling cows at a feed line. MF-2401. Kansas State Univ. Agric. Exp. Sta. Manhattan.

Hillman, P. E., C. N. Lee, and S. T. Willard. 2005. Thermoregulatory responses associated with lying and standing in heat-stressed dairy cows. Trans. ASAE. 48:795-801.

St-Pierre, N. 2001. Economics of heat stress. Dairy Fact Sheet. Ohio State Univ. Columbus.

Tapki, I., and A. Sahin. 2006. Comparison of the thermoregulatory behaviours of low and high producing dairy cows in a hot environment. Appl. Anim. Behav. Sci. 99:1-11.

Thom, E. C. 1958. Cooling degree days. Air conditioning, heating and ventilating. 55:65-69.

West, J. W. 2003. Effects of heat-stress on production in dairy cattle. J. Dairy sci. 86:2131-2144.

Wildman, E. E., G. M. Jones, P. E. Wagner, R. L. Boman, H. F. Troutt, Jr., and T. N. Lesch. 1982. A dairy cow body condition scoring system and its relationship to selected production characteristics. J. Dairy Sci. 65:495-501.

Wilson, S. J., R. S. Marion, J. N. Spain, D. E. Spiers, D. H. Keisler, and M. C. Lucy. 1998. Effects of controlled heat stress on ovarian function of dairy cattle. 1. Lactating cows. J. Dairy Sci. 81:2124-2131.

Table 1. Initial parity, stage of lactation, and daily milk yield by pen.

Item	Pen 1 (Control)	Pen 2 (cooling treatments)
n	25	25
Parity	2.2±0.9	2.5±1.1
Days in milk	175±37	158±112
Milk yield (lb/d)	111±11	111±6

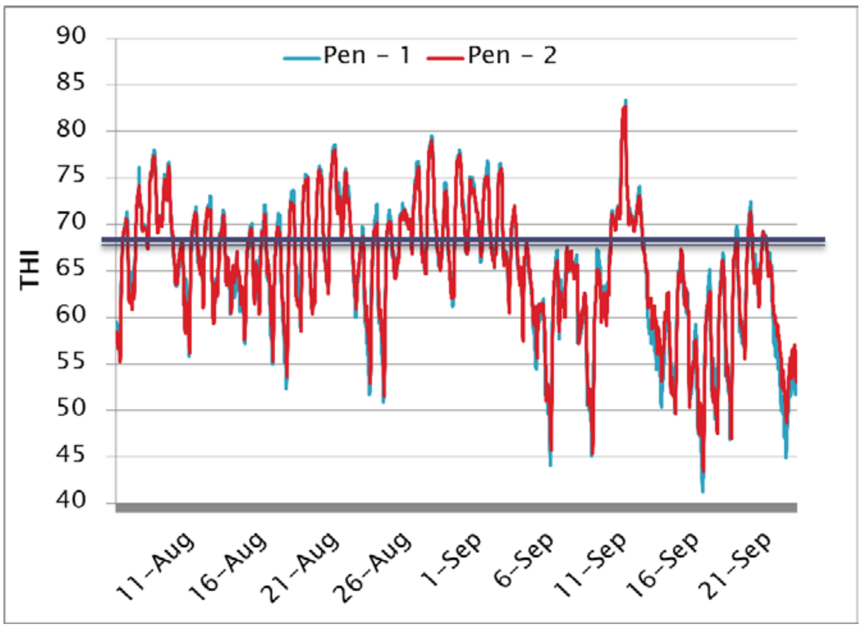

Figure 1. Temperature Humidity Index of Pens 1 and 2.

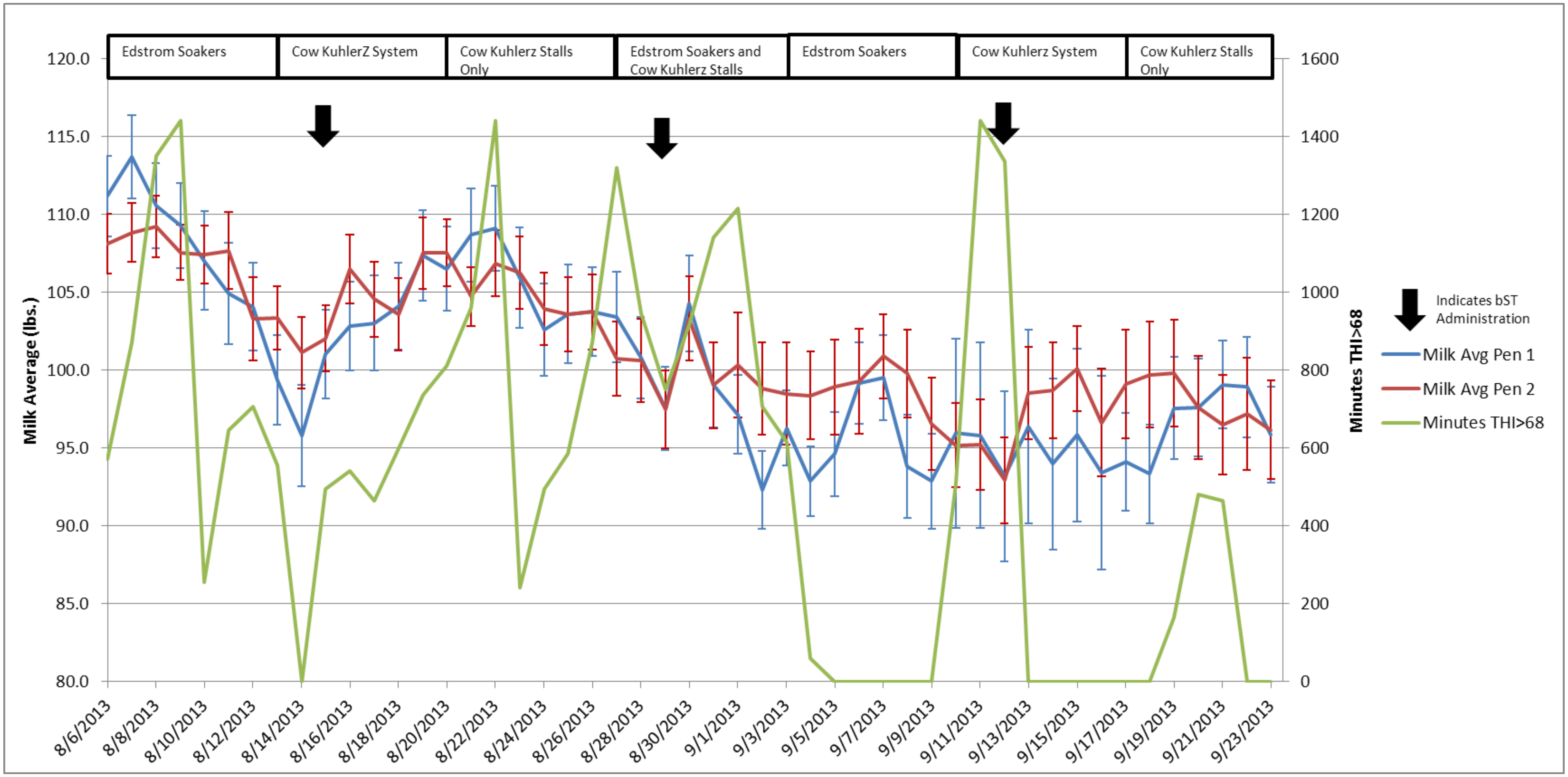

Figure 2. Daily milk production by pen and daily minutes THI >68 (mean±se).

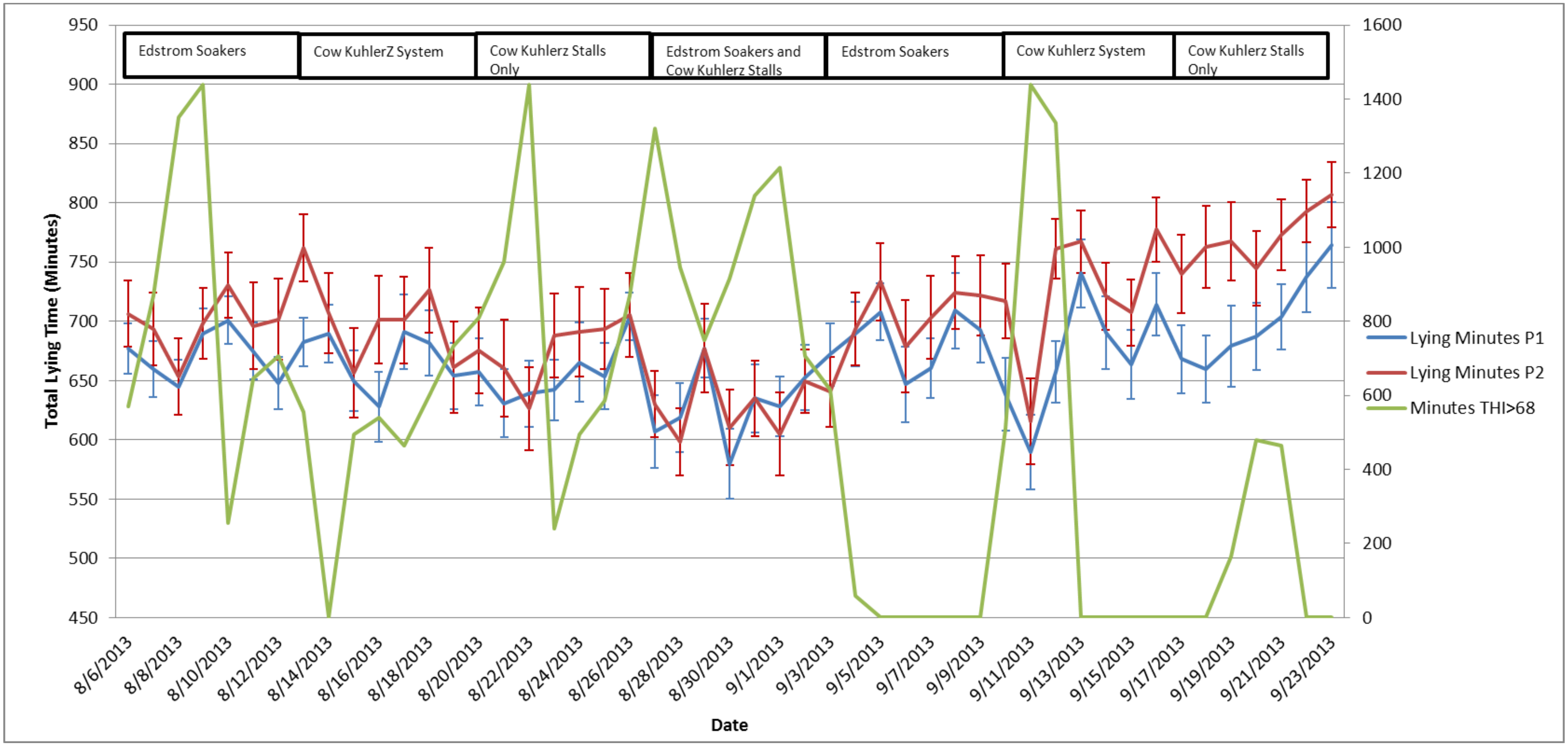

Figure 3. Total daily lying time by pen and daily minutes THI >68 (mean±se).

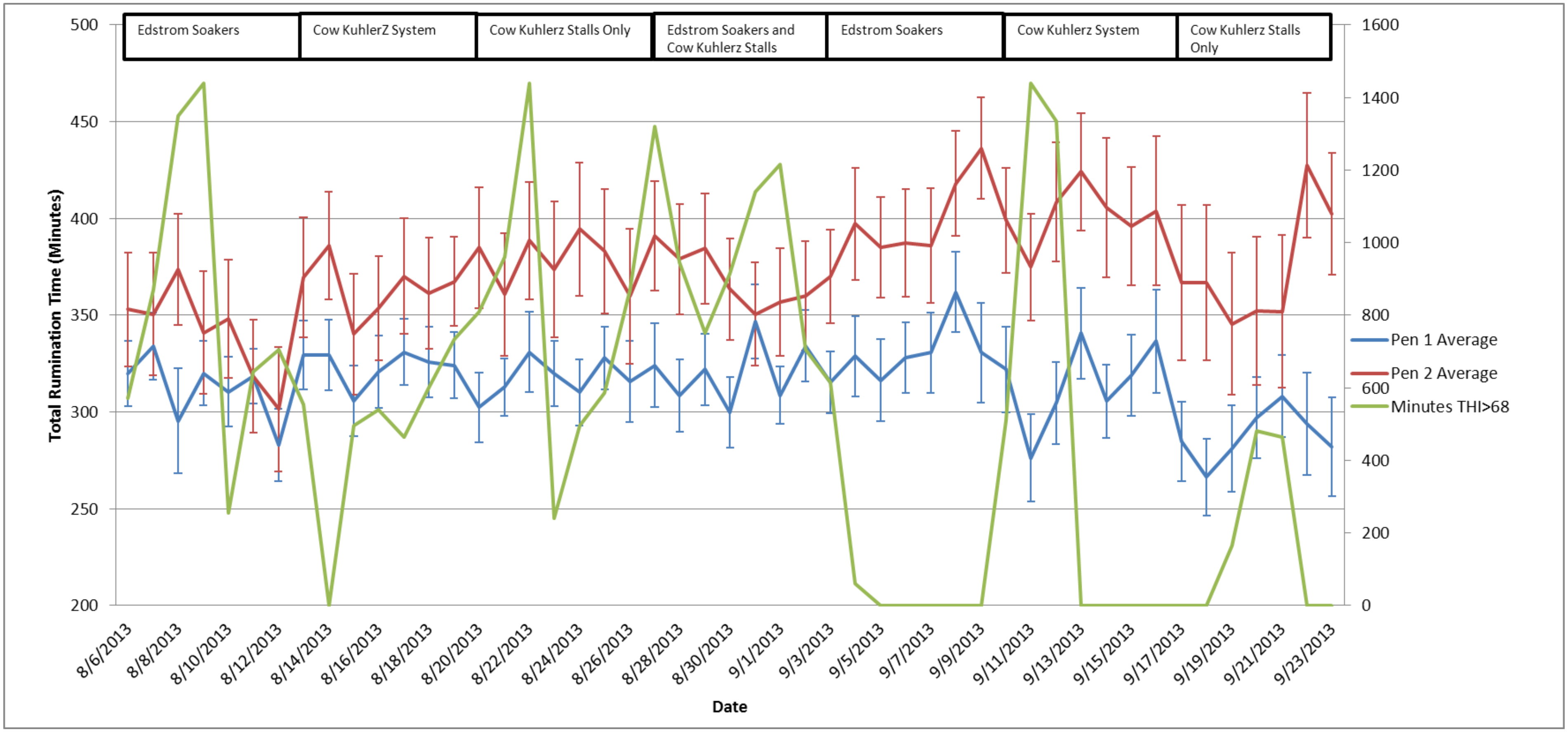

Figure 4. Total daily rumination time by pen and daily minutes THI >68 (mean±se).

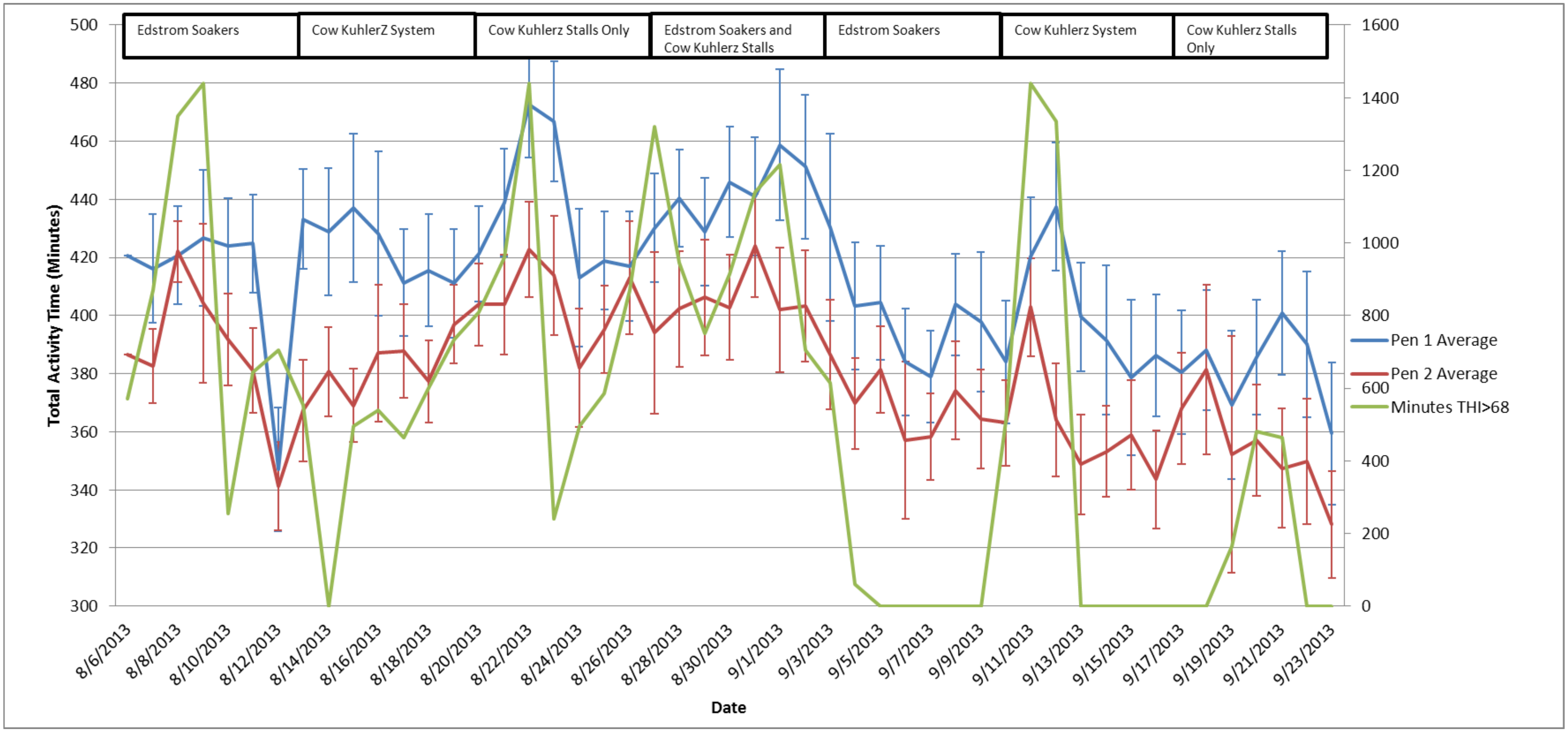

Figure 5. Total daily activity time by pen and daily minutes THI >68 (mean±se).

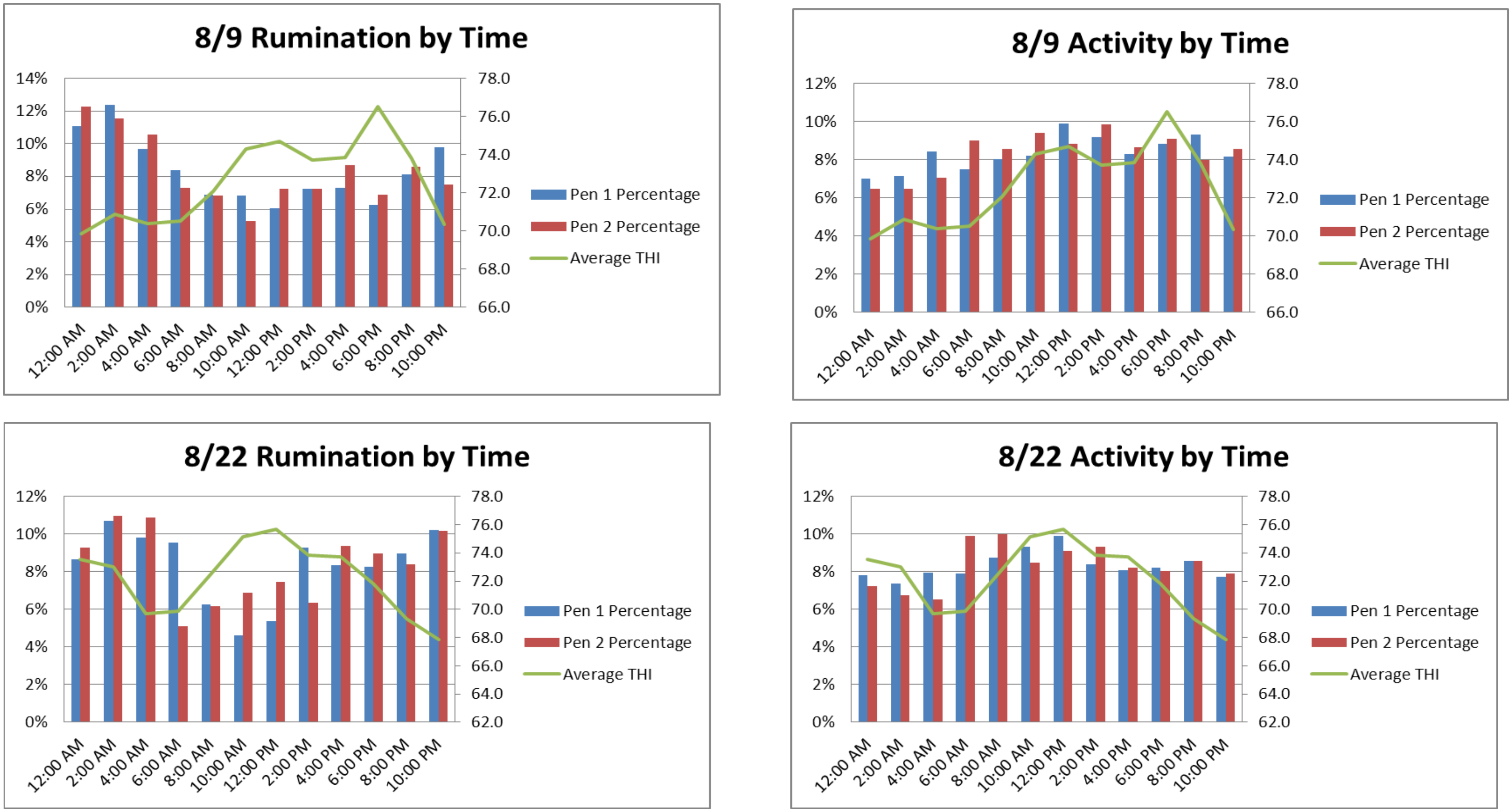

Figure 6. Percent of study cows within pen ruminating or active over the course of the day during heat events on August 9th and 22nd.

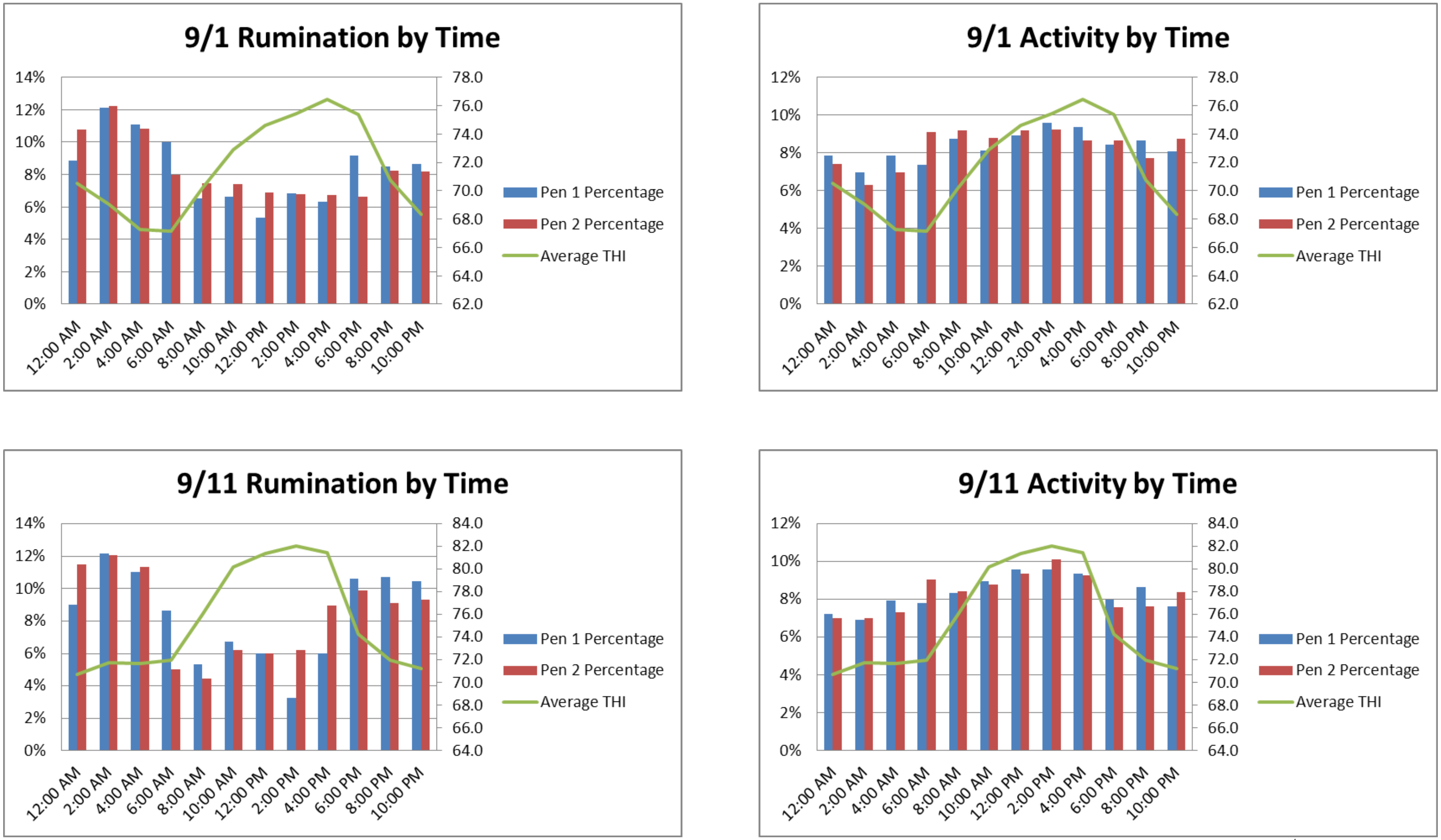

Figure 7. Percent of study cows within pen ruminating or active over the course of the day during heat events on September 1st and 11th.

Table 2. Average total rumination, activity, standing bouts and lying time on four heat event days when various cooling systems were employed in Pen 2.

	Edstrom Soakers	**Cow KuhlerZ Stalls Only**	**Edstrom KuhlerZ**	**Cow KuhlerZ**
Rumination Time	**8/9/2013**	**8/22/2013**	**9/1/2013**	**9/11/2013**
Pen 1	319.9	330.9	308.6	276.1
SE	16.7	20.8	14.8	22.6
Pen 2	341.0	388.5	356.9	374.8
SE	31.6	30.5	27.8	27.4
Activity Time	**8/9/2013**	**8/22/2013**	**9/1/2013**	**9/11/2013**
Pen 1	426.6	472.7	458.8	420.3
SE	16.5	20.8	24.9	22.0
Pen 2	404.2	422.8	401.9	402.9
SE	15.8	20.5	19.2	19.4
Standing Bouts	**8/9/2013**	**8/22/2013**	**9/1/2013**	**9/11/2013**
Pen 1	12.4	12.6	12.0	12.1
SE	0.8	0.8	0.8	0.8
Pen 2	11.4	11.4	10.3	13.0
SE	1.0	0.9	0.9	1.1
Lying Time	**8/9/2013**	**8/22/2013**	**9/1/2013**	**9/11/2013**
Pen 1	689.6	639.0	628.0	589.7
SE	21.3	27.9	25.0	31.4
Pen 2	698.5	626.2	604.9	615.6
SE	30.0	35.4	35.2	36.3
Water Usage (gallons)	17	5	22	3

Table 3. Covariately adjusted total rumination, standing bouts and lying time on four heat event days when various cooling systems were employed in Pen 2.

	Edstrom Soakers	**Cow KuhlerZ Stalls Only**	**Edstrom KuhlerZ**	**Cow KuhlerZ**
Rumination Time	**8/9/2013**	**8/22/2013**	**9/1/2013**	**9/11/2013**
Pen 1	345.5	357.3	334.3	306.4
SE	13.8	18.7	17.9	21.6
Pen 2	340.2	372.6	327.9	345.9
SE	15.6	20.5	17.3	21.6
P-value	0.81	0.58	0.81	0.21
Standing Bouts	**8/9/2013**	**8/22/2013**	**9/1/2013**	**9/11/2013**
Pen 1	10.5	10.1	10.3	10.8
SE	0.6	0.6	0.7	0.6
Pen 2	10.2	10.4	10.3	9.7
SE	0.7	0.7	0.8	0.6
P-value	0.72	0.75	0.99	0.27
Lying Time	**8/9/2013**	**8/22/2013**	**9/1/2013**	**9/11/2013**
Pen 1	699.0	637.5	623.9	587.4
SE	21.5	29.1	35.4	33.4
Pen 2	691.9	611.7	586.5	622.0
SE	24.9	33.1	39.3	40.1
P-value	0.83	0.56	0.48	0.51