John F. Smith, age 51, of Oro Valley, Arizona, died March 29, 2013, at his home after a courageous battle with cancer.

John was born on February 2, 1962, in Nevada, Iowa, the son of John and Karen Smith. He grew up in Jefferson, Iowa, where he graduated from high school in 1980. John completed his B.S. in Animal Science in 1984 and his M.S. in 1986 at Northwest Missouri State University in Maryville, Missouri. In 1989, he completed his Ph.D. in Dairy Science at the University of Missouri.

From 1989 to 1995, John was an Extension Dairy Specialist, Associate Professor, at New Mexico State University in Las Cruces, New Mexico. He then continued his career at Kansas State University in Manhattan, Kansas, as an Extension Dairy Specialist, Professor, from 1995 to 2011. In 2011, John moved to Arizona to finish out his career at the University of Arizona in Tucson, Arizona.

In 1993 and 1994, John was awarded the Salt of the Earth Award from the Dairy Producers of New Mexico, In 2000 he was awarded the Midwest Outstanding Young Extension Specialist Award, in 2002 the DeLaval Dairy Extension award, in 2008 he was selected as Western Dairy Business Magazine’s Outstanding Dairy Educator/Researcher, and in 2010 John was recognized with the Jefferson Iowa Bell Tower of Fame Award for his efforts in dairy education and research.

John’s professional interests and research centered around cow comfort, heat stress, milking parlor performance, and management of expanding dairies. He was a Co-Founder of the Western Dairy Management Conference and High Plains Dairy Management Conference. John worked throughout the United States and internationally assisting producers with the development of efficient dairy operations.

John was a lifelong hunter and fisherman. He experienced hunting or fishing trips with dear friends in Alaska, Canada, South Africa, and many other unique and interesting places. One of his favorite passions was hunting with friends in Missouri, Iowa, and Kansas. John was an avid fan of the Northwest Missouri State University Bearcats and the Kansas State University Wildcats. His greatest love, however, was spending time with his two beautiful daughters.

On August 10, 1985, John married Debbie Schieber. She survives him of the home. Additional survivors include their two daughters: Jordan Smith of Corvallis, Oregon, and Hope Smith of the home; his parents, John and Karen Smith of Jefferson, Iowa; three sisters, Rhonda (Joe) Coffman of Carroll, Iowa, Debbie (Bob) Sees of Lee’s Summit, MO, and Diane Smith of Wichita, KS, many dear in-laws, nieces, and nephews.

A scholarship for Animal Science majors at Northwest Missouri State University has been established in memory of John. Memorial contributions may be made to “Northwest Foundation - John F. Smith Memorial Scholarship” and mailed to the Northwest Foundation, 800 University Dr., Maryville, MO 64468.

John Smith Memorial Lecture: New Technologies in Heat Stress Abatement

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With Mike Brouk and J. Zulovich

The impacts of heat stress on milk production, feed efficiency, breeding and cow health have been researched and studied since the 1950's. Numerous studies whether based on environmental chambers or field scale pen studies have demonstrated the economic benefits of reducing heat stress. The payback of fixed and variable cost is minimal however, the long term sustainability of current heat stress recommendations must be considered. Horner and Zulovich (2008) economic analysis of heat abatement show the larger economic incentive producers have to install and manage a cooling system for the dairy herd. Even with increased feed, marketing, utility, and ownership costs of the equipment, the investment in a properly operating cooling system that provides the herd with relief from heat stress is profitable. Their economic analysis did not consider the possible improved animal health with improved milk quality and lower illness and/or death loss.

Nearly all current recommendations are based on utilizing electrical energy for increasing air velocity across the cows back and water either for low pressure feed line sprinkler systems or evaporative cooling rings or pads. As new technologies are explored, systems using less electrical energy and lower water consumption should be explored and considered.

Temperature humidity index (THI) is the most common index used to measure heat stress in dairy cows. The index is calculated using the dry bulb temperature and dew point temperature or relative humidity. The impact of wind velocity or shade is not components of the THI index. Zulovich et al (2008) concept of Cow Heat Stress Hours (CHSH) which quantifies the intensity and duration of heat stress conditions. The CHSH are used to calculate a Cow Heat Balance over 24 hours or other time interval to estimate the effectiveness of heat abatement systems. The Cow Heat Balance considers THI, heat abatement from air movement and direct cooling and air exchanges. L. Zimbelman et al (2006) studied the impact of THI on high performing cows since the origin research was conducted more than 50 year ago. They results showed the physiological and production parameters indicate a new THI threshold for lactating dairy cows producing more than 77 lbs/day should be 68. Buffington et al. (1981) concluded with the Black Globe Humidity Index BGHI there was an increase in the correlations to rectal temperature increases and milk yield decreases compared to THI (Buffington et al., 1981). However, Zimbelman et al (2006) concluded there was no advantage of replacing THI with Black Globe Humidity Index.

Introduction

Hourly weather data was obtained for 21 cities from 1994 to 2013 to evaluate the impact of heat stress. The cities or regions selected are shown in Figure 1. Hourly data (annually 8,760 observations/site) were utilized to calculate hours and days of heat stress. The hourly temperature humidity index (THI) was then calculated to evaluate the impact of annual heat stress. Figure 2 shows the annual days per year when the minimum THI was equal to or greater than 65 and or the average daily THI were greater than or equal to 68. Cities located along the southern tier of states had 140 to 190 days when the THI was above 65 or 68. Cites along the 40 degree latitude had between 89 and 140 days of heat stress and northern regions tend to have less than 80 days of heat stress.

Figure 1. Regions across the US where 20 year average hourly weather data was use to evaluate heat stress.

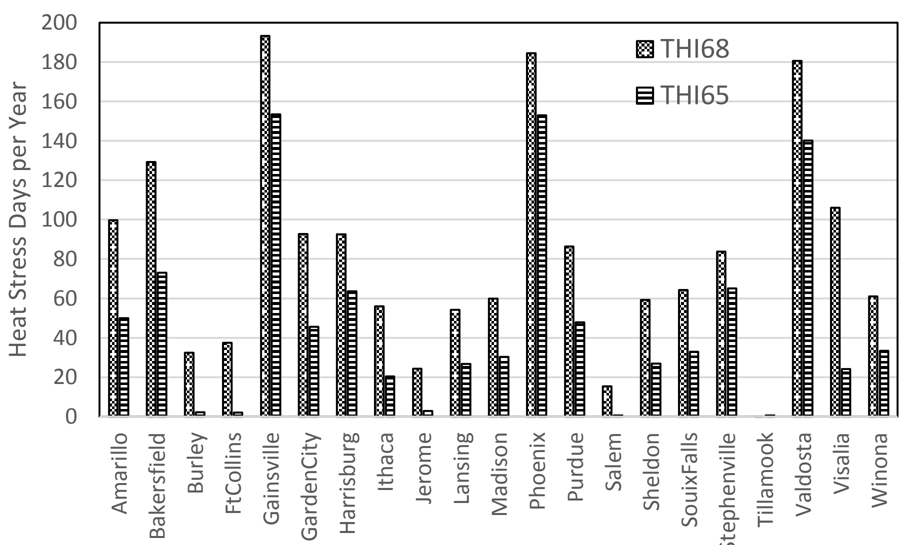

Figure 2. Comparison of days per year when the temperature humidity index averaged 68 for the day or the minimum THI for the day was 65.

Figure 3 plots the average THI and temperature for each of the data sets. Hourly THI or temperature readings of less than 65 or 65 F were excluded from the data set. Across on the United States, the average THI value is 73 to 75 and average temperature is 75 to 78 F.

Figure 4 plots average temperature vs the difference between average temperature and average THI. In general, the THI is 5 to 6 units lower than the average temperature in dry climates with low rainfalls and humidity. This indicates in drier climates the actual THI value could be estimated by assuming the THI value is 5 units below the temperature or if temperatures average is 75, the THI would equal 70 (75 – 5). In wetter climates with higher relative humidity, the difference between average temperature and THI is only 2 to 3 units.

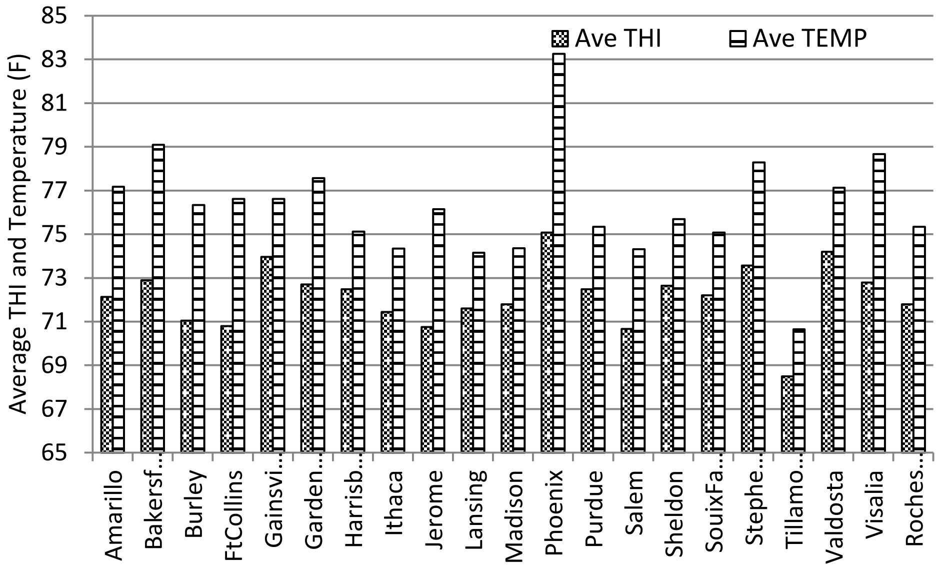

Figure 3. Comparison of the average temperature and temperature humidity index.

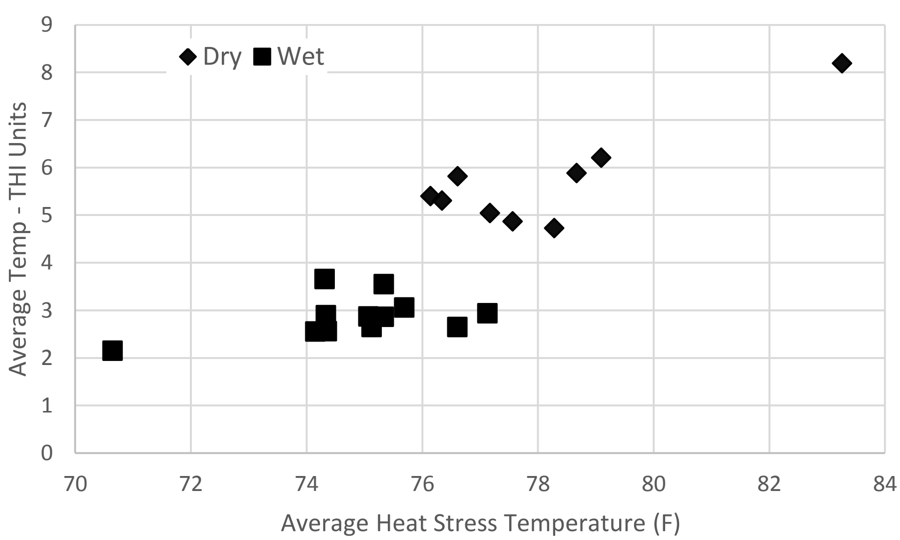

Figure 4. Comparison of average temperature and temperature humidity index in wet and dry areas.

The data sets were used to estimate the number of sprinkler cycles anticipated when using a fence line soaker system based on current recommendations and assuming the soaker systems is turned on either when THI equals to or exceeds 68 or temperature equals or exceeds 68. Figure 5 shows the cycles range from less than 5,000 to more than 40,000 depending on the location of the dairy.

Using 1 gpm nozzles, spaced 8 feet on center, Figure 6 shows the estimated annual water requirements per dairy cow for heat stress abatement. In most regions of the US annual water requirements are between 1,500 and 2,000 gallons per cow. However, in the extremely hot regions and areas where dry lot dairies are utilized the water requirement exceeds 4,000 gallons per cow. These are the regions during the 2009 to 2014 have experienced some of the greatest drought and face water availability issues. Current heat stress abatement is based on temperature controllers; however, as shown in Figure 7 an estimated 30 to 50 % water savings could occur if technology was available to operate the controllers on THI rather than temperature. Development of reliable relative humidity sensors that are accurate in a dusty environment is critical for a THI controller to be accurate.

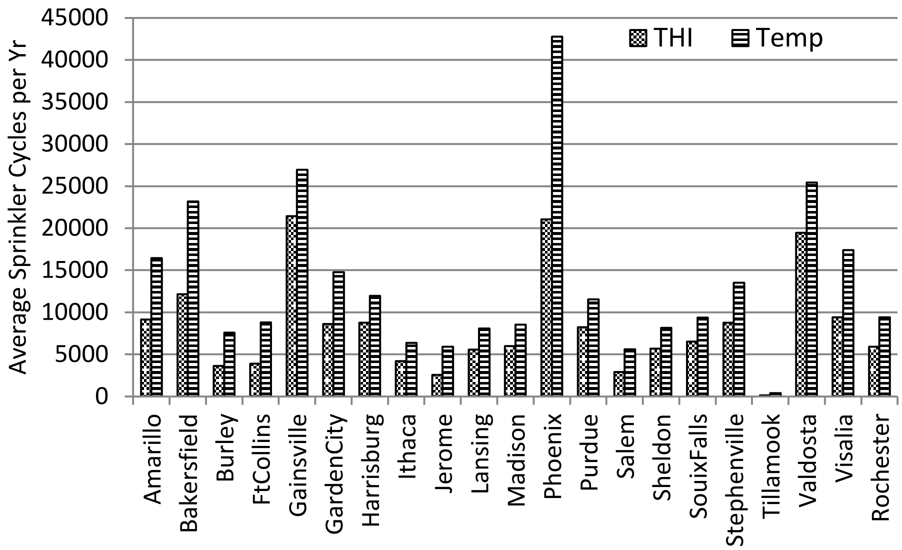

Figure 5. Estimate of the annual on cycles based on current recommendations for low pressure soaker feedline systems.

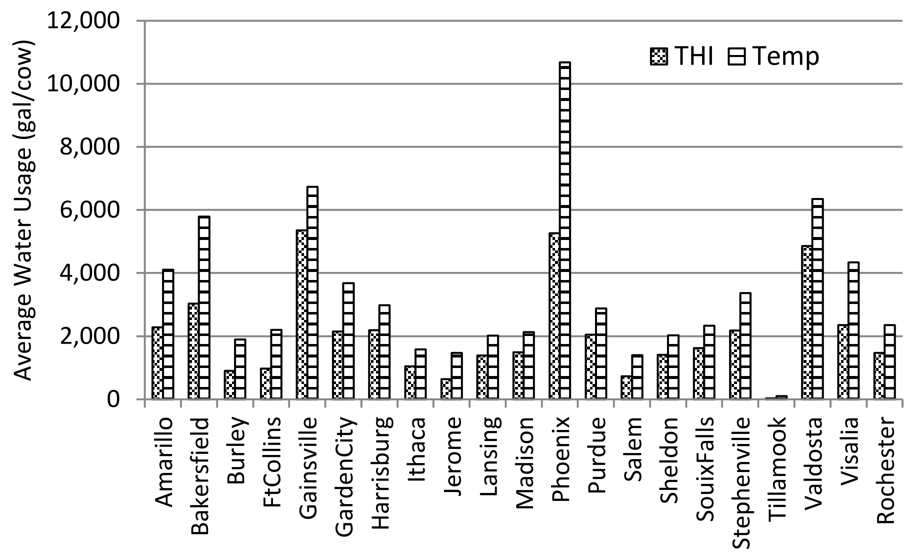

Figure 6. Estimate of the annual water requirements per cow for cooling using a feedline soaker system with 1 gallon per minute nozzle and spaced 8 feet on center.

On option for measuring relative humidity in dusty livestock environments is an aspirated psychrometer. This device raises a wet bulb sensor from a reservoir and into the airstream during aspiration and measures the wet bulb temperature. Use psychometric equations, the dry bulb and wet bulb temperatures can be used to calculate the relative humidity. Costello et al. (1991) reported "in laboratory tests over a wide range of vapor pressures, the root-mean-squared-difference (RMSD) between relative humidity from the psychrometer and a chilled mirror hygrometer was 0.3%. In tests in a commercial broiler house, differences between three psychrometers (RMSD=2.0%) could be traced to experimental uncertainty in temperature measurement. Tests in broiler houses have shown the psychrometer mechanisms to be reliable with minor maintenance required every five to ten days." Barber and Gu (1989) early reported the accuracy and reliability of a shop-built aspirated psychrometer were comparable to a saturated-salt dew point hygrometer, and a mechanical hygrothermograph. The measured relative humidity measurements were within ±5% relative humidity of a reference psychrometer. Dust accumulations did not affect the accuracy of the sensors as much as was expected during an eight week test in a dairy barn.

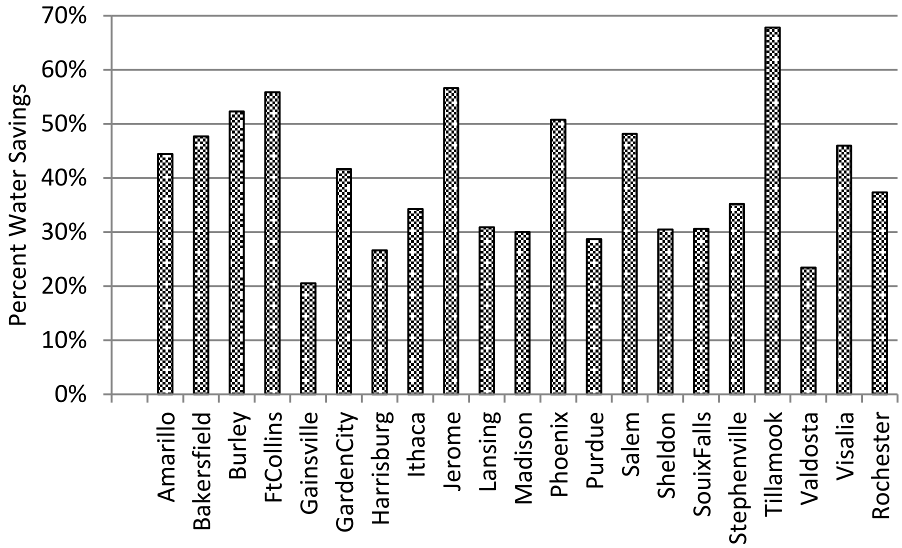

Figure 7. Estimated annual water savings if feedline soaker system was controlled based on THI rather than temperature.

Figure 8 compares the annual electrical energy requirements for heat stress abatement per cow. The estimates assume 1 hp (0.75 kW) of fan capacity per 12 dairy cows which is the common recommendations in a 4-row freestall building with 2-rows of fans per pen. Electrical requirements range from 100 to 250 kWh per cow per year regardless of whether the fans operated based on temperature or THI.

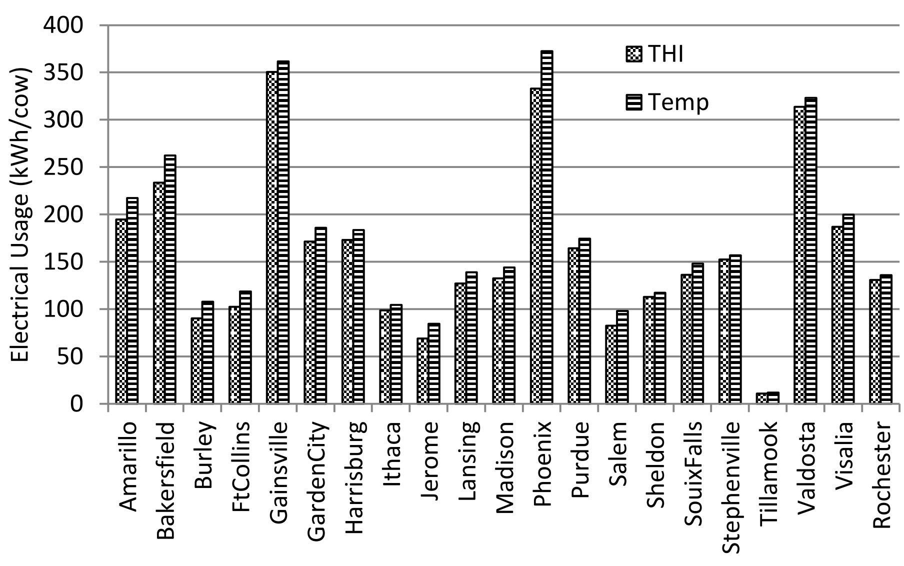

Figure 8. Estimate of electrical energy requirements utilized for heat stress abatement

Figure 9 shows the electrical energy savings if heat abatement were based on THI rather than temperature. Energy savings are 1/3 to 1/5 of the water savings, however, there would still be economical benefits to managing heat stress based on THI.

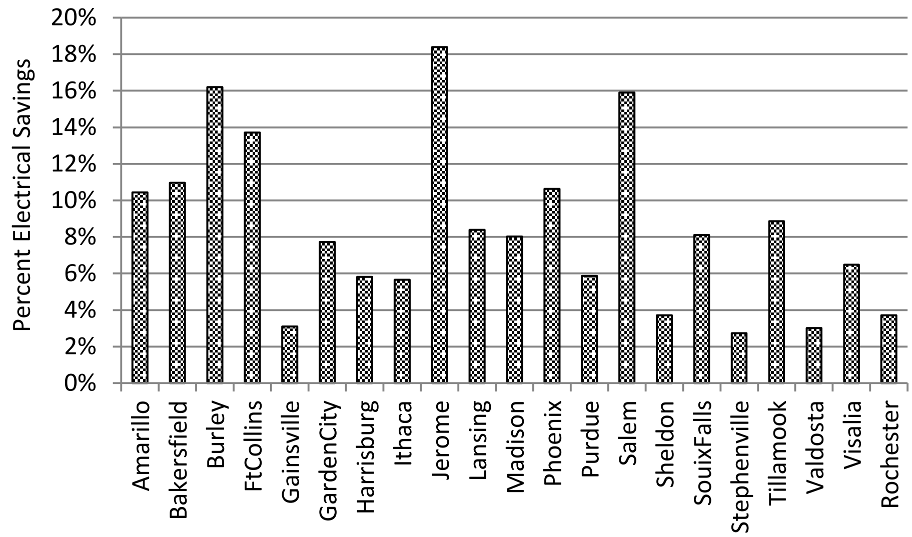

Figure 9. Electrical energy savings if heat abatement ventilation systems were controlled based on temperature humidity index rather than temperature

Figure 10 shows the percent hours of the heat stress period when the THI is between 70 and 74. With the exception of Phoenix, 60 % of the heat stress abatement occurs during periods when the THI is between 70 and 74. Since much of the heat stress in the US occurs with the THI range of 70 to 74 understanding and developing control strategies in this heat stress range is critical in reducing the energy and water footprints necessary to abate heat stress.

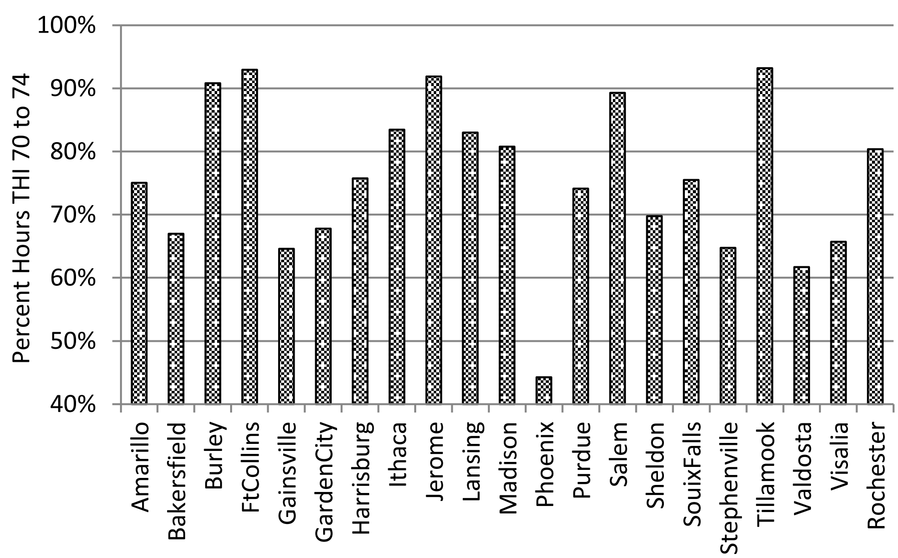

Figure 10. Percent of heat stress occurring between temperature humidity indices of 70 and 74

Energy Ratings of Fans

The fan manufacturing industry has taken the leadership in developing energy efficient fans. Most companies have their fans independently test to verify their performance at Bioenvironmental and Structural Systems Laboratory (BESS Lab at http://bess.illinois.edu/) located at the University of Illinois. This lab independently verifies the performance of ventilation fans used in the livestock industry similar to the test procedures used by the Underwriter's Laboratory. Figure 12 shows the energy efficiency rating(cfm/watt) for five 54 inch diameter and 1.5 hp fans. Tunnel and low profile dairy housing systems often operate at 0.15 inches of static pressure. In viewing Figure 11 at 0.15 inches static pressure the energy efficiency ranges from 15 to 17.8 cfm/watt of electricity. The kWh of electricity utilized per hour for tunnel ventilation of a barn requiring 1,000,000 cfm of air ranges from 56 to 67 kWh. This equates to an 11 kW difference in demand charges and 11 kWh difference in electrical energy charges.

According to the Department of Energy over half of all electrical energy consumed in the United States is used by electric motors. Motors may be classified as standard or energy efficient. Motor efficiency is the ratio of mechanical power output to the electrical power input, usually expressed as a percentage. Dairies with mechanically ventilated housing systems such as tunnel or cross ventilated should consider energy efficient motors. While the initial cost may be higher, there may be energy tax credits available, energy savings and reduced operating costs. Energy-efficient motors are better constructed so they usually have higher service factors, longer insulation and bearing lives, lower waste heat output, and less vibration, all of which increase reliability.

Munter-Aerotech (this is not an endorsement by the authors or the Western Dairy Management Conference of their fans or products) has developed and patented a direct-drive "M" fans. Figure 12 compares the energy efficiency rating of four of Munter-Aerotech 55 inch fans. The 1.5 and 2 hp fans have belt drives and the M drive fans are high efficiency or high output. Using the same example as above, the difference in electrical requirements at 0.15 inches static pressure is from 70 to 92 kW per hour of fan operations. These energy efficient fans do have a higher initial cost but in mechanically ventilated buildings the savings in the electrical demand and electrical energy charges may result in a quick payback. Direct drive fans also result in less maintenance cost since belts do not have to be periodically replaced or tightened. Cleaning of the fans and shutters is required with both types of fans. The test results of the BESS lab are based on a clean environment. Energy efficient declines if dust or dirt accumulates on the fan blades.

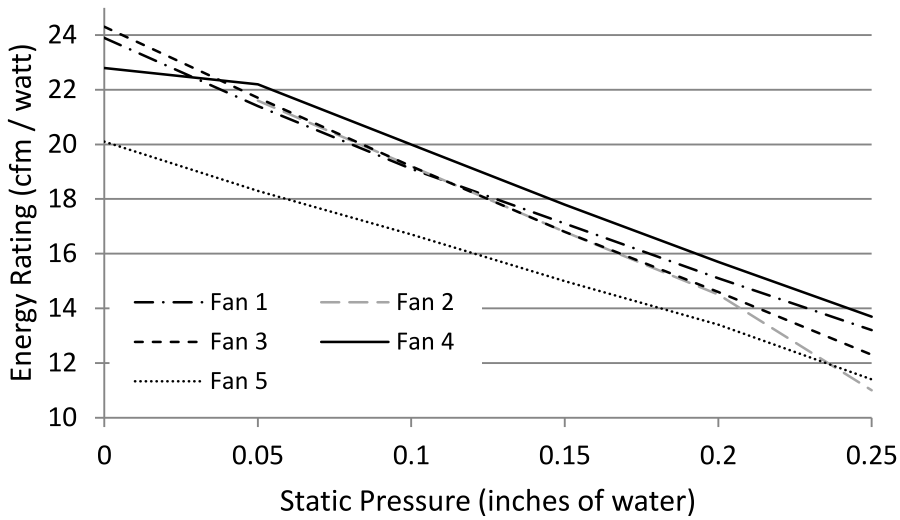

Figure 11. Comparison of energy rating of five different 54 inch fans tested by the BESS Lab

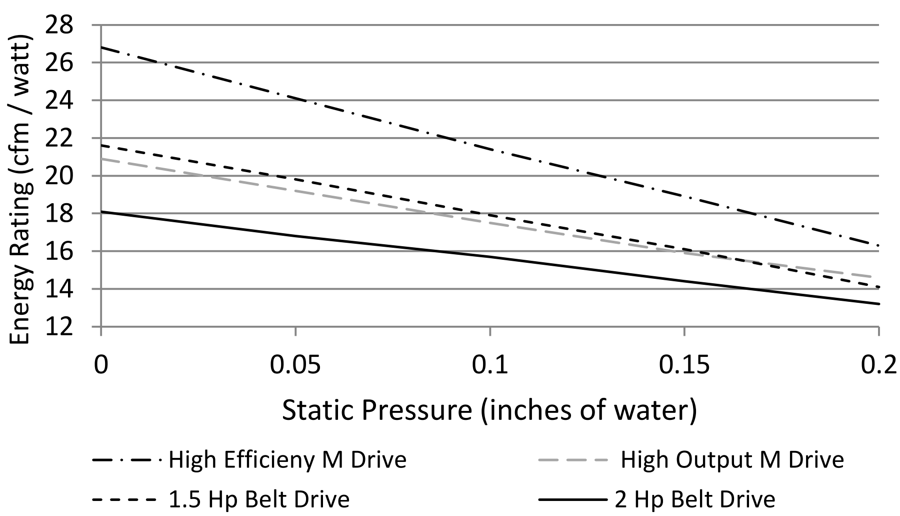

Figure 12. Comparison of Munter-Aerotech's 55 inch direct and belt drive fans

Directional Fans

Manufacturers are increasingly focusing on directional control of the air flow and velocity. Air tends to follow the path of less resistance resulting in higher air velocities in alleys, traffic lanes and head space of freestall. This is occurs in mechanically ventilated buildings such as tunnel or cross ventilated freestall houses. Direction all fans move air that stratifies above the cows back or near the top of the building direct the air back into the cow space. Since the fans are operating at low to zero static pressure, they can direct air at high velocities into the cow space very energy efficient. Most of these fans may be equipped with a high pressure mist or fogging unit and can re-cool the air as the moves the length of the building assuming the air is not saturated with moisture. In tunnel freestalls, the end walls fans are used to create the desired air exchange inside the building and the directional control fans are used to create the velocity in the cow space. This results in a much more energy efficient ventilation system. Other manufacturers are changing the fan blades to increase the throw of cage or basket fans utilized in naturally ventilated freestalls. A 36 inch (~1 m) fan that is normally mounted 24 ft (8 m) on center with redesigned blades the mounting increases to 36 to 40 ft (13 m) since higher velocities can be maintained further distances from the fan.

Water Savings

The authors have received inquiries about turning of the feed line soaker during various portions of the day. Current recommendation is to leave the soaker system on 24 hours per day however cow time budgets indicate cows only spend 5 to 6 hours per day at the bunk or about 25 % of the time. There has been discussion on placing motion or thermal sensors on feedline sprinkler nozzles. The complexity of the system increases and a power source is required at individual nozzle or a bank of nozzles for the sensor and the solenoid. A simpler solution for dairies to experiment with is adding a 2nd soaker line controlled by a 24 hour time in series with the main controller (Figure 13). The main soaker line would remain in place and a timer would turn on the soaker system 30 minutes after the cows were at the milk center and remain on for the next 2 hours. Any time feed was pushed up the main line would be operational for 1 hour. Therefore, when most of the cows were at the feedline, 100 % of the nozzle would be operational. During the other periods of the day the secondary line would be operational. The secondary line would per shorter and only a few nozzles would be turned on. The recommendation is the secondary line length equal 10 % of the number of nozzles along the main line if a 2-row pen and 20 % if a 3-row pen. The nozzle spacing recommended 2x of main line nozzle spacing in order to distribute the cows along the feed line. Assuming the main line is 400 feet long and the pen is 2-row, the secondary line would have 5 nozzles (10% of main line nozzles - 400 ft / 8 ft spacing). The secondary line would be located at the center of the feedline with only 5 nozzles spaced at 16 ft. The potential water savings will vary but using the following assumptions:

- the pen is milked 3X
- feed is pushed once per milking interval
- 4 sprinkler on cycles per hour
- 0.25 gallons per cow per sprinkler on cycle, and
- 16 hours of heat stress
- Nozzle Spacing is 8 ft

The water usage with current recommendations equals 16 gallons per day per cow and installation of a secondary line reduces water usage to 7 gallons per day per cow.

Geo Thermal Heat Exchangers

The University of Arizona and GEA ((mention of trade names is not an endorsement by the authors or the Western Dairy Management Conference of their fans or products) are evaluating the use of heat exchangers placed beneath the bedding in freestall. Cold water passes through the heat exchanger and cools the bedding resulting in heat transferring from the cow as she is resting on the bedding. Oritz et al (2014) reported the results of this study using geo thermal heat exchangers buried 10 inches below the surface as components in a conductive system for cooling cows. Their studies conducted in an environmental chamber with 10 inches of either sand or dried manure between the cows and the heat exchangers. The water temperature through the exchanger was 45 ˚F and three different climates (hot and dry, thermo- neutral, and hot and humid) were evaluated. This studied showed sand bedding remained cooler than dried manure bedding regardless of climate. The cooler beds resulted in a reduction of core body temperatures, respiration rates, rectal temperatures, and skin temperatures for cows housed in the stalls with sand bedding and the heat exchanger operating. They also observed feed intake and milk yield numerically increasing during the bed treatment with sand and water on for all climates. There were no major changes in the lying time of cows or milk protein or fat. They “conclude that use of heat exchangers is a viable adjunct to systems that employ fans, misters, and evaporative cooling methods to mitigate effects of heat stress on dairy cows. Sand was superior to dried manure as a bedding material in combination with heat exchangers.”

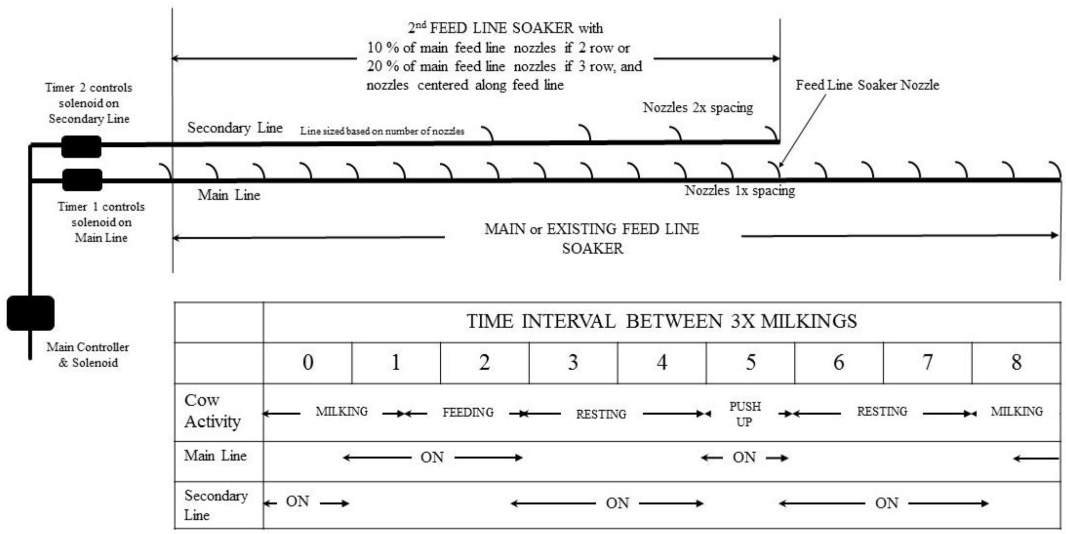

Figure 13. Conceptual idea of adding a secondary soaker line along the feed line and operating schedule

Summary

Technologies are being developed to reduce the energy and water requirements for heat abatement. Electrical energy savings of the fans and energy efficient fans are currently available from equipment suppliers. The geo thermal cooling mats are being evaluated through research trials and efforts are being made to improve the performance. Technologies available for reducing water consumption are currently lacking. There is much interest in water saving technologies utilizing timers, cameras, motion detectors or infrared sensors to determine when cows are at the feed line. Significant electrical and water savings are possible by operating the heat abatement system based on the temperature humidity index rather than temperatures.

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Notes: