



## Dairy Cooling in Arid and Semi-Arid Climates

Ian Atkins (PhD student) and Christopher Choi (Professor)  
University of Wisconsin-Madison Dept. of Biological Systems Engineering

This guide is a climate-specific extension of the summary article “Dairy Cooling: The Benefits and Strategies,” which describes heat stress, its costs and consequences, and strategies for its mitigation. Herein, we focus on the unique challenges of mitigating heat stress in regions with hot and dry summers by discussing the pros and cons and costs of the ventilation and cooling options for dairy operations in these climates.

### Climate

The American Southwest (as well as parts of Africa, Asia, and the Middle East) is dominated by a type of climate classified as “arid” or “semi-arid,” which is characterized by extremely hot and dry summers. The dairy cows raised in such a climate are, on average, more greatly affected by heat stress than cows raised in cooler climates. However, because of the low relative humidity (RH), evaporative cooling is very effective. For example, at 100 °F and 15% RH, an evaporative cooling system operating at 75% evaporation efficiency will reduce the temperature by almost 25 °F and the THI by about 8.3 units.

Due to its effectiveness, evaporative cooling often also makes sense economically. An economic analysis showed that implementing high-pressure misters mounted on fans can reduce the overall costs of heat stress by well over 45% (including the annualized capital and operating costs of cooling systems).<sup>[1]</sup> Table 1 presents the typical number of heat-stress hours in three arid to semi-arid US states and the estimated costs of heat stress under minimal heat stress abatement as compared to with high-pressure misters mounted on fans.

Table 1. Hours of heat stress, estimated costs of heat stress under minimal heat stress abatement and with high-pressure misters and fans, and percent savings achieved at three arid to semi-arid locations.<sup>[1]</sup>

	Typical heat stress hours <sup>1</sup>	Costs under minimal heat stress abatement <sup>2</sup> (\$/head/year)	Costs with high-pressure misters and fans (\$/head/year)	Percent Savings (%)
Arizona	3536	\$265	\$105	60
New Mexico	1706	\$168	\$87	48
Texas	4078	\$698	\$376	46

1. Heat stress hours from weather data in Tucson, AZ; Albuquerque, NM; and Fort Worth, TX when THI > 68.<sup>[2]</sup>

2. Minimal heat stress abatement assumes access to shade and good air exchange, but no additional cooling.

### Common Facilities

In hot and dry climates, shade is necessary in the summer. In many locations, however, the winters are warm enough that additional shelter is not required. Also, because annual rainfall is scant and the ground seldom muddy, earthen floors are acceptable. For these reasons, dry lots, “Saudi barns” (also known as “desert barns” or “loose barns”), and covered freestalls are all viable options.

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The least expensive housing system is the dry lot with simple shade structures. Saudi and freestall barns are considerably more expensive. The capitals costs of constructing dry lots with shade structures for a new, 2,400-cow dairy with modern equipment were estimated to be \$8.41 million, whereas constructing Saudi barns for the same dairy would cost an estimated \$9.25 million, and freestalls would cost an estimated \$9.56 million.<sup>[3]</sup> Despite the higher costs, confinement freestall housing is sometimes chosen if the winters in the area where the dairy is located are harsh or the environmental regulations are very stringent.

### Choosing a Ventilation and Cooling System

The decision-making process begins with first deciding what type of system to implement and then selecting the specifics of its design in accordance with the steps shown in this diagram:

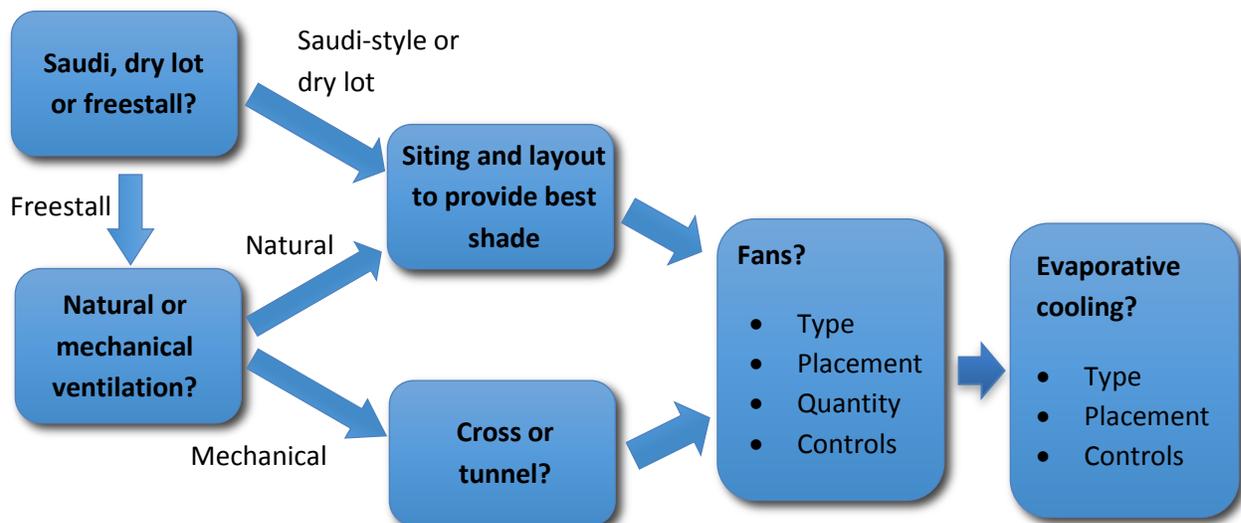


FIG. 1. Decision-making diagram outlining major steps for providing adequate ventilation and heat stress abatement.

When combined with evaporative cooling pads, mechanical ventilation can be effective in hot and dry weather. Mistlers are more common, however, because they do not require the barn to be totally enclosed, as is the case with fans and evaporative cooling pads. If a freestall barn with mechanical-cross, mechanical-tunnel, or fans and low-pressure sprinklers is chosen, please refer to either Dairy Cooling in Humid Continental Climates or Dairy Cooling in Humid Subtropical Climates.

## Cooling in Saudi barns and dry-lot shades

### **Basic structure and layout**

#### *Dry-lot shades*

In dry lots, 45 to 50 square feet of shade should be provided per cow. Dry-lot shades are typically oriented North-South to maximize the distance their shadow moves during the day so that, as the animals move with the shade, the manure and urine they produce will be spread over a wider area and the abandoned ground can dry.<sup>[4]</sup> The recommended height for dry-lot shades is 11 to 14 feet.<sup>[5]</sup>

#### *Saudi barns*

Saudi barns are also constructed in dry lots and are typically around 105 feet wide, with 11- to 14-foot eaves and a 2/12 to 4/12 roof slope. They feature a central drive-through feed alley and feedlines that can be underlain by a concrete slab, but elsewhere typically have dirt floors (see figure 2). One advantage these structures have over basic dry-lot shades is that the cows do not have to leave the shade to access the feedline.

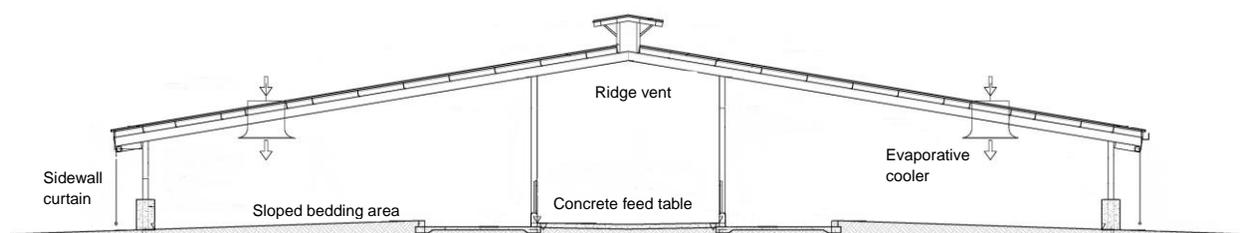


FIG. 2. Example Saudi-barn cross section (Courtesy of JGM III Dairy Design Team).

In extremely hot locations, the bedding area is cooled with high-pressure (200 – 500 psi) misters, and sidewall curtains can be used to somewhat contain the cooled air and provide shade. In this case, a North-South orientation may be advantageous to help keep both sides of the barn dry. In milder climates, some producers have chosen to forego the installation of evaporative cooling and curtains. In this case, an East-West orientation provides better shade.<sup>[4]</sup>

### **High-pressure misters and circulation fans**

Because high-pressure misters mounted on fans have proven to be especially effective in hot and dry weather, several companies now market fan/mister assemblies. We will consider these combination systems as they are sold, as opposed to discussing fans and misters as separate units. The combination systems are often mounted below a structure's eaves to blow in fresh air from outside. Alternatively, through-the-roof fan/mister assemblies pull in fresh air through an opening in the structure's roof. If mist is injected into recirculated air, very good ventilation is necessary. Too much mist without inlet air does not lower the temperature and can lead to unhealthy wet conditions.

### Eave-mounted evaporative coolers

Mounting fans and misters below a structure's eave is especially compatible with dry-lot shades (see figure 3). Some systems, such as FlipFan (Schaefer Ventilation Equipment Corp., Sauk Rapids, MN) are also shade tracking. Shade-tracking systems offer the advantage of supplying cooling to the shaded area as it moves throughout the day. Besides providing the cows more comfort, this feature spreads manure and urine over a greater area and eliminates the need for a curtain to block afternoon sun. In addition, the FlipFan can be adjusted to blow mist into the loafing area, where cows often rest at night. Recommended spacing varies by specific product. As an example, the recommended number of fans per truss, depending on its length, is shown for the FlipFan system in Table 2 below.



FIG. 3. FlipFan system cooling cows under a dry-lot shade.

Table 2. Recommended FlipFans per truss by length of truss.<sup>[6]</sup>

Truss Length (Feet)	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
Fans/Truss		1	1	1	1										
					2	2	2	2	2	2					
Recommended # of fans								3	3	3	3	3	3	3	3
Minimum # of fans/truss (for modest heat applications)											4	4	4	4	4
Maximum # of fans/truss (for extreme heat applications)															5

### Through-the-roof coolers

Through-the-roof coolers, such as the SuperCooler (Schaefer Ventilation Equipment Corp., Sauk Rapids, MN) and the Korral Kool (Korral Kool Inc., Mesa, AZ) pull fresh air through the roof and inject a high-pressure mist into it, cooling the air before it is blown onto the cows. These systems have the advantage of bringing fresh air into the central areas of the barn and are ideal for Saudi barns, but they can also be used in conjunction with naturally ventilated freestalls and dry-lot shades. Although recommendations vary by specific product, these units are typically placed about every 20 feet on either side of the central feed table.<sup>[7]</sup>



FIG. 4. SuperCooler in UAE dairy.<sup>[6]</sup>

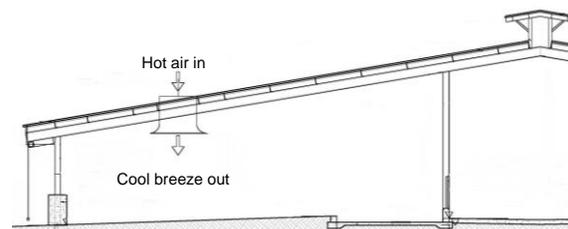


FIG. 5. Saudi barn with through-the-roof evaporative coolers. (Courtesy of JGM III Dairy Design Team).

## *Controls*

Combined fan/mister assemblies usually rely heavily on a control system to function optimally. The control system measures parameters such as sun angle, wind speed, wind direction, temperature, and relative humidity. These measurements help the cooling system focus cooling on the areas where the cows are most likely to be. In addition, the control system can regulate the flow rate of water leaving the nozzle. This enables the misters to inject just the right amount of water to maximize evaporative cooling without wetting the bedding. Some cooling should be provided as the THI exceeds 68. However, in an arid climate, setting the system to turn on at 68 °F may cause the system to operate many more hours than necessary. For example, at 20% RH, a THI of 68 corresponds to a temperature of 76 °F (see figure 1 in the companion summary article <sup>[8]</sup>).

## *Holding pens and feedlines*

In the holding pen and along feedlines, cooling can be provided by fans and low-pressure sprinklers. In well-ventilated feed and holding areas mister/fan assemblies are also an option. Refer to the companion summary article <sup>[8]</sup> for guidelines on using fans and low-pressure sprinklers in these areas. In Saudi barns, care must be taken so that water applied at the feedline does not flow into the lying areas.

## *Priority*

When available funds will not cover the costs of heat stress abatement in all desired locations, the funds should be applied according to the following priority: <sup>[5]</sup>

1. Shade for all milking and dry cows
2. Holding pen cooling
3. Exit lane cooling
4. Corral shade cooling
5. Feedline cooling
6. Covered feed line

## **Estimating Resource Use**

In a recent study conducted at a commercial dairy in Saudi Arabia from June to August 2013, the FlipFan consumed an average of 98.0 gallons of water and 4.0 kWh of electricity per cow per day and the Korral Kool consumed an average of 98.7 gallons of water and 4.6 kWh of electricity per cow per day. <sup>[9]</sup> Resource consumption, which will vary according to how the system is operated, will generally be less in areas of less extreme heat.

The amount of electricity used by the fans can be estimated by multiplying the power consumption of the fans' motors by the typical number of hours per year the fans operate. When estimating electrical costs, note that motor hp is given in mechanical output and that the electrical input is always greater. A typical 1 hp motor requires around 1 kW of electrical power. <sup>[10]</sup> The water used by a

sprinkler system can be estimated in a similar manner. Simply multiply the system's flow rate at its setpoint by the typical number of hours per year within each setpoint range (see example 1 in appendix).

## **Conclusions**

Implementing cow cooling has been shown to provide clear economic benefits in arid and semi-arid climates. However, determining the practices that will optimize the combination of air velocity and evaporative cooling in terms of milk production, animal health, and resource efficiency will require more studies. This notwithstanding, current research has shown that high-pressure misters mounted on fans are very effective at reducing heat stress in open structures. Mechanically ventilated systems with evaporative pads can also lower the temperature, but require totally enclosed barns. While freestalls are more expensive than dry-lot shade pens, they may become more common with increasingly strict environmental regulations and in regions where the risk of severe winter storms is high.

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**Appendix:**

**Example 1: Estimating the annual water use of a sprinkler system operating in a holding area in Tucson, AZ**

**Assumptions:**

- Holding area is 400 square feet
  - Water is applied at a rate of 0.025 gal per sq. ft. per cycle
  - System uses valved nozzles, so water is not wasted between cycles
  - Cycles are set to operate 1 minute in: 15 minutes at temperature 68 – 78 °F, 10 minute cycles at temperatures 79 – 88 °F, and 5 minute cycles at temperatures above 88 °F
  - Typical meteorological year has 1,924 hours from 68 – 78 °F, 1,214 hours from 79 – 88 °F, and 1,289 hours > 88 °F
- Water per cycle [gal] = square feet \* application per square foot = 400 square feet \* 0.025 gal per square foot per cycle = 10 gal per cycle
- Number of cycles is found by dividing the number of hours by the cycle duration

<b>Range</b>	<b>Number of hours/yr</b>	<b>Number of cycles/yr</b>	<b>Gallons of water/yr</b>
68 – 78 °F	1,924	7,696	76,960
79 – 88 °F	1,214	7,284	72,840
> 88 °F	1,289	15,468	154,680
<b>Annual water use in holding area:</b>			<b>304,480</b>

(note: water can be saved in the holding area by staging sprinklers so they do not operate in the empty portion (or only installing sprinklers in the 75% closest to the parlor, which is occupied a higher percentage of the time). Significant water could also be saved by staging the sprinklers to turn on at THI setpoints instead of temperature setpoints).

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