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# Limiting Swine Stress with Evaporative Cooling in the Southeast

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## ABSTRACT

**T**HREE-HOURLY weather data for 7 locations in the Southeast and Central United States were used to evaluate the feasibility of evaporative cooling for reducing swine stress. Stress was defined as a relationship between dry and wet bulb temperatures which exceeded a stress index of 85. This analysis indicates that properly installed evaporative coolers could reduce the number of hours that stress would occur in swine facilities from 89.6 to 96.4% depending on location.

## INTRODUCTION

During the summer, temperatures in swine buildings often rise to levels that adversely affect animal performance and the profitability of these operations. Heat stress reduces reproductive efficiency in the breeding herd, affecting both the boar and sow. During extended hot weather periods, death of farrowing sows may result.

Evaporative cooling systems have been used in the less humid parts of the United States to reduce heat stress because of low initial and operating costs. However, their use in the warm humid region of the mid-South has been limited because of their reported reduced effectiveness. Nevertheless, due to their inherent advantages, many producers who desire cooling in their swine facilities remain interested in these systems.

## OBJECTIVES

1. Develop a stress index for uncooled and evaporatively cooled swine facilities.
2. Evaluate the effectiveness of evaporative cooling on limiting the hours of occurrence of thermal stress in swine in the Southeast.

## LITERATURE REVIEW

Swine lose heat by four different modes: radiation, convection, conduction, and evaporation. Pig size has little effect on the percentage of total heat lost by each method; however, according to Bond et al. (1959) ambient air temperature has a significant effect. Cooling of the body surface and lungs by evaporation becomes much more important in the control of body temperature

as the environmental temperature increases above 26 °C. If the environmental temperature is the same as the body temperature, the animal cannot lose heat by convection, or conduction and must lose all body heat by evaporation. When a pig attempts to increase its heat loss by increasing the evaporation rate from the lungs, its respiration rate is increased.

Heitman and Hughes (1949) investigated the effects of high humidity and high temperature on the performance of swine. At 32 °C there was little difference in the response of 90.72 kg hogs to relative humidities of 30 and 94% except that the respiration rate increased at the higher humidity. At 35 °C and 30% relative humidity the hogs lost weight but were able to survive over a long period of time. When the relative humidity was increased to 94%, with an ambient temperature of 35 °C, the pigs were severely stressed. The body temperature increased 1.4 °C and the respiration rate more than doubled.

Roller et al. (1967) reported the effects of dry bulb and dew point temperatures on the reproductive performance of 240 gilts. Average daily gain and daily feed consumption were significantly influenced by the dry bulb temperature, dew point temperature, and the interaction of these two parameters. The rectal temperature and ovulation rate were influenced only by the dry bulb temperature.

Several investigators have worked toward relating air temperature and relative humidity into a single variable or comfort index. To evaluate how effective evaporative cooling is on reducing swine stress some stress index must be used. Many different environmental stress indicators have been used with animals such as respiration rate, respiratory volume, pulse rate, skin temperature, body temperature, activity level, hair coat characteristics, and other physiological characteristics. Body temperature, respiration rate, and respiratory volume are most commonly used, either separately or in combination.

Beckett (1965) developed an "effective temperature" for hogs based on the assumption that the amount of air breathed per unit of time is an exact indication of discomfort, and, therefore, can be used to predict animal performance. Later work by Morrison et al. (1967) indicated that the respiratory volume actually decreased as the environmental stress increased above a certain level.

Suggs (1966) developed a linear relationship between the enthalpy of the ambient air and heat loss. Rate of heart beat was used to indicate the level of environmental stress. The experiments to prove that the level of stress was constant at constant enthalpy, regardless of temperature, were not completely satisfactory. The difficulties were attributed to individual differences in sweat rates and skin temperatures and to the possibility that heat loss by convection creates less stress on an

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animal than heat loss by evaporation.

Roller and Goldman (1969) proposed the use of wet bulb, dry bulb index as a single indicator of the effect of the thermal environment imposed on swine. Equation [1] is the formula that was considered most precise from their data:

$$WD = 0.45 TWB + 1.35 TDB + 32 \dots\dots\dots [1]$$

where

- WD = wet bulb—dry bulb index
- TWB = wet bulb temperature, °C
- TDB = dry bulb temperature, °C.

The figures presented by Roller and Goldman (1969) would indicate that their wet bulb, dry bulb index has no effect on swine rectal temperature, respiration rate, and pulse rate when the index is below 80. In addition, their data would indicate little effect on swine with an index of 85.

A field study conducted during extreme dry bulb temperatures, 36 to 39 °C, showed that an evaporative pad cooling system could reduce inlet air temperatures to 27 °C or lower, McNeill et al. (1980). The data also showed that the time of occurrence of high dry bulb temperature was associated with the lowest relative humidity of the day. This resulted in an increased evaporative pad cooling potential during the extreme dry bulb temperatures.

An evaluation of long-term weather data has been made to develop an average hours of occurrence per year of any dry bulb temperature (Fehr, unpublished data, 1978). As a part of that evaluation the average relative humidity that occurred with any dry bulb temperature was also determined. When these average relative humidities are converted to wet bulb depression it indicates that evaporative cooling potentials exist when extreme dry bulb temperatures occur, Fig. 1.

### PROCEDURE

Weather data was evaluated using a stress index reflecting conditions inside a swine facility to determine

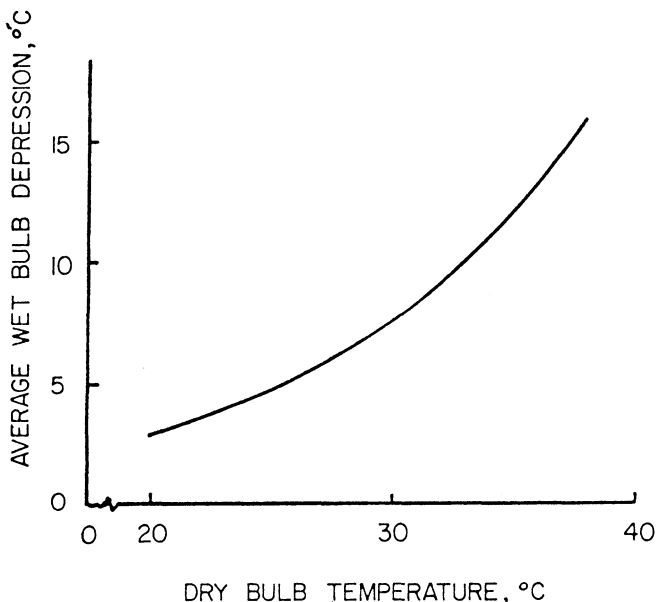


Fig. 1—The average wet bulb depression for dry bulb temperatures above 20 °C for Lexington, KY.

the hour's a stress index of 85 would be exceeded with and without evaporative cooling. A stress index of 85 was chosen because it allows for swine to show some response to thermal stress but at a level where other possible adverse effects should be limited.

A stress index equation must reflect the actual wet bulb and dry bulb temperatures surrounding the animal, in a facility. In a swine facility the wet bulb and dry bulb temperatures increase due to sensible and latent heat production of the animals. The amount of wet and dry bulb temperature rise will be affected by the size of animals, animal density, type of floor, and most importantly the ventilation rate. Temperature rises of 2 °C dry bulb and 1 °C wet bulb were chosen because they reflect conditions which should be obtainable in swine facilities with proper ventilation. Equation [1] was modified to reflect these increases in dry bulb and wet bulb temperatures,

$$WD = 0.45 TWB + 1.35 TDB + 31.15 \dots\dots\dots [2]$$

While equation [2] can be used to determine a stress index in a ventilated swine facility it can be combined with equation [3] to develop an equation for a swine facility with an 80% efficient evaporative cooling system, equation [4].

$$TDBEC = TDB - EFF(TDB - TWB) \dots\dots\dots [3]$$

where

- TDBEC = dry bulb temperature after evaporative cooling, °C; and
- EFF = evaporative cooling efficiency, decimal;

$$WD = 1.35 TWB + 0.27 TDB + 34.07 \dots\dots\dots [4]$$

An 80% efficient evaporative cooling system was chosen because it is easily obtainable in swine facilities using commercially available equipment.

Data were obtained from the National Climatic Center (1963) which gave the hours occurrence of dry bulb temperatures in 2.2 °C increments divided into six relative humidity ranges; under 30%, 30 to 49%, 50 to 69%, 70 to 79%, 80 to 89%, and 90 to 100%, for a ten-year period from 1951 to 1960. Although these data have the limitation that a range of conditions is contained in each group it did provide a method of evaluating several sites using data in which the dry bulb temperatures and relative humidities were measured at the same time. Seven sites were chosen; Des Moines, IA; Lexington, KY; Raleigh, NC; Jacksonville, FL; Jackson, MS; San Antonio, TX, and Tulsa, OK. The sites were chosen to include areas where evaporative cooling is being used and where it is generally not considered effective.

The climate data for the ten-year period were tabularized for each site as shown in Table 1. The table gives an example of the average hours of occurrence of each temperature and humidity range shown for the ten-year period of observation.

Using a constant stress index of 85 without, equation [2], and with, equation [4], evaporative cooling curves were plotted on a psychrometric chart to determine the percentage of the area of each dry bulb temperature and relative humidity range during which a stress index of 85 would be exceeded with and without evaporative cooling,

**TABLE 1. AVERAGE HOURS PER YEAR\* OF TEMPERATURE AND HUMIDITY OCCURRENCES FOR LEXINGTON, KENTUCKY (KY), JACKSON, MISSISSIPPI (MS), AND SAN ANTONIO, TEXAS (TX)**

Temperature	Site	Under					
		30-49%	50-69%	70-79%	80-89%	90-100%	
40.0/37.7	KY						
	MS	4	10				
	TX	18	3				
37.2/35.0	KY	1	1				
	MS	8	89	12			
	TX	68	161	†			
34.4/35.0	KY	2	45	15			
	MS	15	186	139†			
	TX	45	388	37			
31.7/29.4	KY	5	108	147†	4		
	MS	21	166	346	23		
	TX	48	252	317	3		
28.9/26.7	KY	6	141	244	66	6	
	MS	21	128	284	202	55	2
	TX	54	155	457	175	30	

\*Average hours per year are calculated by dividing the total number of hours observed at a condition by number of years observations were made.

†The range which contains the normal daily maximum temperature, and average afternoon relative humidity for July for a given site.

**TABLE 2. PERCENTAGE OF TEMPERATURE AND HUMIDITY RANGES ABOVE A STRESS INDEX OF 85 WITHOUT AND (WITH) EVAPORATIVE COOLING**

Temperature °C	Relative humidity					
	Under 30%	30-49%	50-69%	70-79%	80-89%	90-100%
45.5 - 43.3	100. (34.)	100. (100.)*				
42.8 - 40.5	100. (10.)	100. ( 99.)	100. (100.)*			
40.0 - 37.7	100. ( 0.)	100. ( 77.)	100. (100.)*			
37.2 - 35.0	100. ( 0.)	100. ( 18.)	100. ( 97.)	100. (100.)*		
34.4 - 32.2	94. ( 0.)	100. ( 0.)	100. ( 39.)	100. (100.)*		
31.7 - 29.4	15. ( 0.)	67. ( 0.)	97. ( 0.)	100. ( 28.)	100. (77.)	100. (100.)*
28.9 - 26.7	0. ( 0.)	0. ( 0.)	5. ( 0.)	22. ( 0.)	34. ( 0.)	51. ( 24.)

\*No data was recorded for any site in the study for this temperature at this or any higher humidity range.

Table 2. Then assuming a uniform distribution of temperature and humidity occurrences in each range. The number of hours per year a stress index of 85 is exceeded with and without evaporative cooling was determined using Tables 1 and 2.

### RESULTS

Table 3 shows the number of hours per year a stress index of 85 is exceeded with and without evaporative cooling using the procedure described previously. Although there is a wide range in both the hours without evaporative cooling, 1320 to 313 and with evaporative cooling, 102 to 15, between sites, the minimum reduction in hours exceeding a stress index of 85 with evaporative

cooling was 89.6%. In most of the sites the percentage reduction in hours the stress index exceeded 85 was over 91%. Although evaporative cooling did not eliminate all the hours that the stress index exceeded 85, as calculated with equation [4], it did reduce their frequency of occurrence.

At the extreme levels of temperature and humidity ranges, shown in Table 1, the stress index could approach 100 without evaporative cooling, equation [2]. With evaporative cooling the index could be reduced by 6 to 10%. Stress index levels of 90 to 93 were calculated at the extremes with evaporative cooling, equation [3]. Although the reduction in the stress index does not provide conditions in which no stress may occur, any reduction in the stress index at these extremes may be valuable to the animal.

This method was compared to the use of normal daily high temperatures and afternoon humidities to determine if evaporative cooling is effective at that site (National Climate Center, 1979). At all the sites evaluated, use of normal averaged data resulted in selection of a temperature-humidity range near the extreme of the conditions, as shown in Table 1. Normal averaged data does not generally reflect the occurrence of relative humidity or wet bulb temperature at given dry bulb temperatures.

Use of long-term weather data would provide a more

**TABLE 3. HOURS A STRESS INDEX OF 85 IS EXCEEDED PER YEAR WITH AND WITHOUT EVAPORATIVE COOLING**

Location	Hours exceeding a stress index of 85		Percent reduction
	w/o Evaporative cooling	w/Evaporative cooling	
San Antonio, TX	1320	48	96.4
Jackson, FL	1077	92	91.5
Jackson, MS	1015	102	89.6
Tulsa, OK	987	82	91.7
Raleigh, NC	544	36	93.4
Des Moines, IA	391	23	94.1
Lexington, KY	313	15	95.2

accurate method of determining the frequency of occurrence of a stress index exceeding specific values. If the economic impact of a stress index on the sow herd's performance could be determined, an analysis using long-term weather data would be useful.

### CONCLUSIONS

1. Evaporative cooling is effective at reducing the number of hours a swine will be in thermal stress.
2. Evaporative cooling can be used in the southeast to reduce thermal stress in swine facilities.
3. Average daily weather data does not provide an accurate method of evaluating evaporative cooling potentials.
4. Peak stress index levels may be reduced only 6 to 10% at temperature and humidity extremes with evaporative cooling.

### References

1. Beckett, F. E. 1965. Effective temperature for evaluating or designing hog environment. *TRANSACTIONS of the ASAE*

8(2):163-166.

2. Bond, T. E., C. E. Kelly and H. Heitman, Jr. 1959. Hog house air conditioning and ventilation data. *TRANSACTIONS of the ASAE* 2(1):1-4.

3. Heitman, H., Jr. and E. H. Hughes. 1949. Effect of temperature and relative humidity on the physiological well being of swine. *J. Animal Sci.* 8:171.

4. McNeill, S. G., R. L. Fehr and J. N. Walker. 1980. Performance of evaporative coolers for gestation housing. *ASAE Paper No. 80-4558*, ASAE, St. Joseph, MI 49085.

5. National Climatic Center. 1963. Decennial Census of United States Climate-Summary of Hourly Observations. *Climatology of the United States*, Numbers 82-15, 82-13, 82-31, 82-8, 82-22. Superintendent of Documents, U.S. Government Printing Office, Washington.

6. National Climatic Center. 1979. Comparative climatic data for the United States through 1978. National Climatic Center, Federal Building, Asheville, NC.

7. Roller, W. L. and R. F. Goldman. 1969. Response of swine to acute heat exposure. *TRANSACTIONS of the ASAE* 12(2):164-169.

8. Roller, W. L., H. S. Teague and A. P. Grifo, Jr. 1967. Reproductive performance of swine in controlled warm environment. *TRANSACTIONS of the ASAE* 10(4):517-518, 522.

9. Suggs, C. W. 1966. Role of enthalpy in heat loss. *TRANSACTIONS of the ASAE* 9(3):322-325.