AN INVESTIGATION OF THE EFFECTS OF COOL DRY BREATHING AIR ON THE RESPIRATION RATE AND RECTAL TEMPERATURES OF FARROWING SOWS

by

RALPH JERRY McGINTY

B. S., Kansas State University
of Agriculture and Applied Science, 1959

A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agricultural Engineering

KANSAS STATE UNIVERSITY
OF AGRICULTURE AND APPLIED SCIENCE

1960

TABLE OF CONTENTS

INTRODUCTION

Environmental control is becoming an important factor in modern livestock production systems. Quality of breeds and quality of management in many cases have advanced to the point that environmental factors become the limiting factor in increased production.

Farmers have long practiced partial control of environment to lessen the effects of weather extremes. In the case of swine, sows have been sheltered during winter farrowings, and during the hot summer weather, open shelters provide protection from the sun while water holes or "wallows" give the hog an additional means of losing heat.

In modern times it has been recognized that hogs are essentially nonsweating animals. Thus they lack, to a large degree, the ability to keep cool by the evaporation of moisture from the skin unless an external source of moisture is supplied. In modern pork production systems this is done by providing a concrete "wallow" or wading pool, or by providing water sprinklers which release a fine mist in the air. The hog can wet its body surface and then experience cooling by evaporation much the same as man does by sweating.

This method has proven satisfactory in most cases; however, problems arise when sows are moved from open pens to farrowing houses prior to farrowing. Farrowing houses are usually crowded as the operator desires to use its facilities to the fullest extent. Sows are often placed in crates, or small pens side by side with only a small space between them for the operator to work or to serve as a creep for the baby pigs. In these crowded conditions the removal of moisture from urine, spilled drinking water, and water used for cleaning may become a problem without adding more moisture by spraying the sows. The resulting dampness is conducive to bacteria growth and spreading of disease. "Wallows" also present a health problem especially if the sow's udders are not cleaned before nursing.

Air conditioning has been considered as a means of controlling the farrowing house temperatures. In hot dry climates evaporative coolers have been used with some success. However, in hot humid weather little cooling can be accomplished, and the resulting high humidity in the barn is undesirable. Refrigerative air conditioning has been tried, but the high latent heat load from the animals plus the sensible heat load from the animals, ventilation air, and building requires a large refrigerative capacity to lower the inside ambient temperature to the desired conditions. In order to reduce the size of the system and the resulting expense, attempts have been made to lower the ventilation rate and recirculate a large portion of the air. This presents a problem of accumulation of ammonia fumes in the building and clogging of the cooling coil filters with dust.

At this point Agricultural Engineers from the Agricultural Research Service and Purdue University designed a system making use of the large heat loss from swine by evaporation of moisture from the lungs. They reasoned that if dry air were supplied for breathing, more moisture could be absorbed by the air while in the lungs thus substantially aiding heat loss from the sows. The system as built used refrigerative cooling to lower the fresh outside air to below the dew point. This caused moisture to condense from the air. The resulting cool dry air was blown through a duct system with individual outlets provided for each sow. No attempt was made to control the ambient temperature of the building. Ventilation was provided by allowing outside air to move freely through the building. The required refrigeration capacity was greatly reduced since only enough air for breathing purposes was cooled.

The Purdue tests conducted at Conner Prairie Farms near Noblesville, Indiana, were reported to indicate less stress in the test sows receiving dry breathing air than in the check sows; however, there was not enough data available to make recommendations for such a system.

In the spring of 1959 there was some local interest in air conditioning of farrowing houses. Max Porter, a farmer from Glen Elder, Kansas, in particular desired advice in designing a system similar to the one at Conner Prairie Farms. It was decided that some applied research should be done on such a system to determine if it were practical. This was done during the summer of 1959 by the Department of Agricultural Engineering of K.S.U. in cooperation with Max Porter of Glen Elder, Kansas.

PURPOSE

The purpose of this investigation was to determine the effects under North Central Kansas summer conditions, of cool dry breathing air on the rectal temperatures and respiration rates of sows during the period of confinement immediately preceeding and following farrowing.

REVIEW OF LITERATURE

Considerable research has been done under laboratory conditions on the effects of environment on swine growth and feed efficiency. In the majority of the work, respiration rate and rectal temperature are used as indications of heat stress. According to McDowell (15) and Brody (5), (6) changes in respiration rate and rectal temperature are the most frequently used indications of heat stress. Body temperature is a direct measure of a change in heat balance. McDowell (15) concludes in the absence of other evidence the individual with the lower respiration rate under hot conditions is most likely to be the cooler one. It is generally reported that hogs weighing over 100 pounds do best in ambient temperatures between 60 and 70 degrees Fahrenheit with daily gain and feed efficiency falling off at ambient temperatures above 80 degrees Fahrenheit (5), (8), (11), (13), (17). Tidwell (19) investigated the effects of exposure of swine to sunlight. Heitman et al. (13), (11), (10), and Bond et al. (3), (4), subjected swine to relatively high ambient temperatures in order to observe their reactions and develop corrective measures.

Although much work has been done on the effects of hot weather on growing and fattening swine the author found that only recently has there been much investigation on the effects of hot weather on pregnant sows and their resulting litters. As Bond (1) states

> There have been only a few investigations concerning the effect of environment on gestating and lactating sows. However, there is a recent increase of interest in this problem, and undoubtedly greater emphasis will be placed on the environment of the sow, particularly during the latter weeks of gestation and during the first days after farrowing.

Heitman et al. (12) subjected 14 sows to ambient temperatures as high as 99 degrees Fahrenheit. Of the sows 13 were 85 or more days pregnant and one was open. These high ambient temperatures caused increased respiration rates and rectal temperatures. Feed and water consumption was lowered and weight was lost. The open sow responded in a similar fashion, but to a lesser degree. At high ambient temperatures the sows showed great stress and in some cases the ambient temperature had to be lowered to prevent death.

Investigations of means of relieving heat stress have shown many possibilities, some of which have been long practiced, others of which are new. Tidwell's work (19) indicates the value of shade as rectal temperatures and respiration rates of the swine increased after exposures to sunlight of 15 and 30 minutes duration. Brody (5) pg. 296 states "Overheating in nonsweating animals is due to lack of skin moisture. An obvious solution is external application of moisture." He concludes that the use of wallows may not be practical in commercial swine production, that air conditioning is expensive, and that fans alone do no good since they only circulate hot air over the dry body surface.

Heitman and Hughes (11) found high relative humidity at high ambient temperatures caused great distress in swine. They also reported that test swine withstood higher temperatures if the floors were wet and considerable air movement existed. Air movement over dry floors provided no relief. Heitman et al. (10) used 48 growing-finishing pigs confined under California summer conditions to test various means of cooling. The tests involved were a control lot, a wallow in the sunlight, a wallow in the shade, a wallow combined with increased air movement, access to a small air conditioned house, and confinement to a pen inside a large hog barn. Over the 70 day test period all of the treated groups gained weight more rapidly and utilized their feed better than the control group. However, there was no significant difference between the treated groups. Whatley et al. (20) compared the litters of 17 sows confined and sprinkled with water during gestation to the litters of 17 sows similarly confined but not sprinkled. Under the summer conditions of Oklahoma where the tests were conducted the sprinkled sows farrowed 2.35 more live pigs per litter, their average body temperature was 2.8 degrees Fahrenheit lower, and their litters averaged 85 pounds heavier at 56 days than those of the 17 check sows. Taylor (18) and Johnson and Taylor (14) described an experiment where they supplied cool dry air for breathing through air ducts to individual sows. They reported that the sows supplied the conditioned air appeared to be more comfortable than sows serving as controls.

From these tests it becomes apparent that there are several means to relieve heat stress in swine thus the problem becomes one of finding the one best suited for adaptability to a given situation.

Special problems arise in providing cooling for pregnant or lactating sows while confined in farrowing houses. Ideally, a stress free environment should exist in which the sow will eat well, produce an adequate supply of milk for her litter, and rest quietly to reduce the possibility of crushing pigs. According to Fontaine et al. (8) and Sibbitt et al. (17) these conditions would exist, for swine weighing more than 150 lbs., at an ambient temperature of about 60 degrees Fahrenheit. Recommendations for swine housing (2), (1) specify a dry environment to aid in control of disease causing organisms. Baby pigs have a higher optimum temperature for growth than do sows (11), (16) and Bond (1) reports the desirability of a separate sow pig environment. Johnson and Taylor (14) discuss the advantages of raising pigs under conditions not extremely different from those which will exist when they are turned out of the farrowing house to avoid setbacks due to environmental changes.

Thus it would appear that ideally the farrowing house should be dry, the sows cool, and the pigs relatively warm. This would rule out sprinkling water in the house or using air conditioners to cool the building to optimum conditions for the sows.

Initially the Conner Prairie Farms, Noblesville, Indiana, farrowing house where Johnson and Taylor (14), (18) did their work was cooled by means of a 5-ton heat pump. In order to reduce the large heat load encountered, ventilation rates were reduced and air was recirculated from the building back to the heat pump. This resulted in an accumulation of ammonia in the atmosphere, and caused a problem of dust from the recirculated air clogging the cooling coils of the heat pump. Johnson and Taylor tried the method mentioned earlier of supplying the sows individually with cool dehumidified air for breathing. They calculated that under Indiana summer conditions to maintain conditions of 65 degrees Fahrenheit and 75 cubic feet of fresh ventilation air per sow per minute it would require 0.28 tons of refrigeration for each sow exclusive of the building heat load. Taylor (18), and others (1), (5), (8), (14), (17), state that at an ambient temperature of 80 degrees Fahrenheit, 40 per cent of the total heat loss of swine is by evaporation of moisture from the lungs and at 100 degrees Fahrenheit, 90 per cent of the total heat is lost in this fashion. Brody (7) found air exhaled by swine to be about 98 degrees Fahrenheit and 90 per cent relative humidity. Therefore, theoretically the introduction of cool dehumidified air should aid in the transfer of heat from the lungs. Assuming ambient conditions of 90 degrees Fahrenheit and 50 per cent relative humidity and air exhaled at 98 degrees Fahrenheit and 90 per cent relative humidity, Taylor and Johnson (14), (18) calculated that 24 British Thermal Units could be lost in the same fashion per pound of air breathed. This would allow a decrease of 48 per cent in the lung ventilation rate to dissipate the same amount of heat. At ambient conditions of 90 degrees Fahrenheit and 50 per cent relative humidity, a sow theoretically would require 5.7 cubic feet per minute to dissipate heat produced (3), (9). With the cooled air under the assumed conditions, the sow would need 2.8 cubic feet per minute. Assuming equal time to exhale as to inhale, 5.6 cubic feet per minute would be required. Realizing this was a theoretical value, an actual supply of 8 cubic feet per minute per sow was provided. This additional air would probably provide extra cooling as it flowed over the sow's body surface forming an "envelope" of cool air. Using this method the only heat load is the sensible and latent heat in the breathing air and would amount to about 0.1 ton of refrigeration per sow. Thus the system requires less refrigeration capacity than air conditioning the entire house; moisture can be removed by conventional ventilation; and an approach is made toward a separate environment for sow and pigs.

In the search of the literature many articles of a "popular" nature were encountered which, while containing little useful information, did indicate the growing interest in sow-pig environment.

PROCEDURE

The farrowing house at the Max Porter farm was already equipped with a system of air ducts to distribute heated air for warming the pig creep areas. The south room in which farrowing crates were located had air delivered from two overhead, 9-inch diameter, ducts through individual, 6-inch diameter down spouts which directed the air flow over the creep areas. The middle room which contained farrowing pens had two, 9-inch diameter, ducts (one on each side of the center aisle) which passed under the creep areas, warming the floor by conduction. Provisions were made on these under floor ducts for 6-inch diameter elbows to be attached with which to direct air into the pens. The north room served as a nursery and did not enter into the test. The air intake for the ducts was from the furnace room located between the south and the middle room. The air was drawn from the furnace room by a fan located in the furnace and blown through the duct system.

For summer cooling consideration was given to passing fresh outside air over an evaporator coil and through the duct system. It was decided that it would be impractical to acquire such a coil, which might require special design, in time for the experiment. Since the purpose of the experiment was to determine the effects of dehumidified air, the method of dehumidifying the air was of secondary importance. Upon inspection it was decided to use the furnace room as a recirculation chamber for cooling the outside air by successive passes over an evaporator coil. This was done by using an auxiliary fan in the furnace room to blow air continuously over the coil to maintain the room at the temperature desired for the cooling air. The air used for cooling was then drawn through the furnace duct system by the furnace fan in the usual manner and delivered to the sows.

The compressor unit was located outside of the barn and was both air and water cooled. Copper tubes carrying refrigerant ran through a hole in the wall to the evaporator coil. The compressor, controlled by a thermostat located in the furnace room, ran continuously at room temperatures above 40 degrees Fahrenheit. The evaporator coil was mounted horizontally over a drip pan which caught the water condensed from the air. The pan was drained by a hose leading to outside the building.

The climatic conditions were essentially the same as those that the Conner Prairie Farm system was designed for. Using the same assumptions for calculations of air flow requirements, the value of 8 cubic feet of air per minute per sow was confirmed; however, limitations of the delivery system made it more practical to deliver 12 c.f.m. of air per sow. With lower air flows it was discovered that the supply was intermittent. This was believed to be due to changes in room pressure during periods of gusty winds.

The furnace room was insulated with 2 inches of balsam wool with aluminum foil on both sides. Air leaks between the furnace room and the rest of the barn were stopped as much as was possible. Outside air was allowed to enter through openings in an outside door on the west side of the barn. The air ducts, except those buried in the floor, were insulated with a fibre glass material to prevent condensation in the barn.

Elbows were placed on each down spout in the south room and on each floor opening in the middle room to direct the air flow towards the test sows. The openings to the check sows were capped each day in addition to the closing of valves to insure positive shutoff. Air temperatures at the outlets were measured with thermocouples. A Brown Recording Potentiometer calibrated in degrees Fahrenheit was used to record all thermocouple measurements.

Outside ambient temperatures were measured by sheltered mercury thermometers. Relative humidity, both inside and outside, was measured by a sling psychrometer and a bellows operated psychrometer for comparison. Inside ambient temperatures were measured by both thermocouples and mercury thermometers. The state of the air in the furnace room and in the air ducts was measured by wet and dry bulb temperatures. Air flow to the sows was determined by measuring the pressure drop through a standard 3-inch air nozzle placed in the opening leading to the furnace fan. Barometric pressures were measured with a mercury barometer.

After consultation with Dr. H. C. Fryer of the Kansas State University Statistical Department, it was decided to supply half of the sows with dehumidified air one day using the other half as checks and reverse the process the following day. The sows on the west side of the south room and east side of the middle room would serve as test sows on the same days. The group of sows, east side of south room and west side of middle room or west side of south room and east side of middle room serving as test sows the first day was determined by the toss of a coin and the resulting order was maintained throughout the test. The sows in the crates were turned out each evening at about 5:00 pm for feeding. At that time the doors and windows were all opened and the supply of dehumidified air to the sows was shut off. The sows were shut back into their crates between 7:00 and 8:00 pm. They were again turned out in the morning from about 6:00 am to 8:00 am after which time they were shut into their crates for the remainder of the day. The sows in the pens remained in their pens from the time they were initially brought into the barn until about a week after farrowing when they were removed to the nursery area.

Because of the management practices, the tests ran from 9:00 am till 5:00 pm each day. The compressor unit and circulating fan in the furnace room were turned on each morning around 6:00 or 7:00 am. The time from 7:00 am until 9:00 am when the sows usually had quieted down was spent servicing equipment. At 9:00 am the initial measurements of rectal temperatures and respiration rates were made along with the corresponding ambient temperatures and relative humidity. Rectal temperatures were measured with clinical, mercury thermometers. Respiration rates were determined by counting the breaths taken for a period of two minutes during the time the thermometer was reaching equilibrium.

The temperature in the furnace room usually reached 40 degrees Fahrenheit by 10:00 am. The air supply to the test sows was turned on about 10:30 am. Subsequent measurements of sow temperatures, respiration rates, air temperatures and relative humidities were taken at 11:30 am, 2:00 pm and 4:00 pm. At 5:00 pm the test period ended, data was summarized, and equipment serviced for the following day.

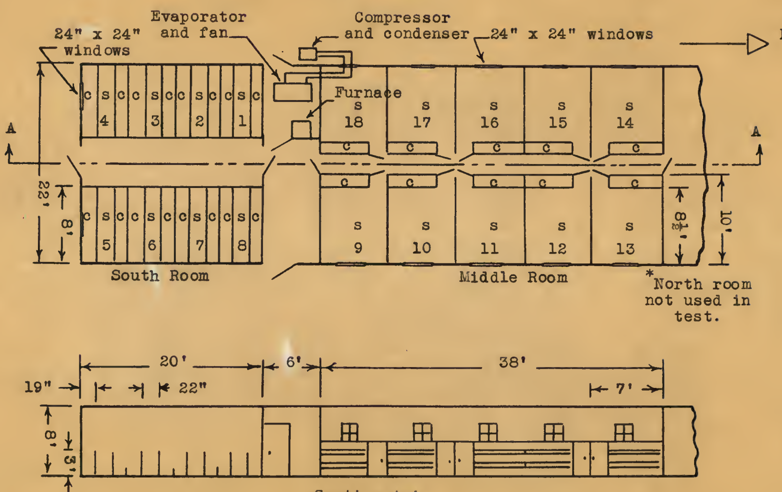
Some sows became sick from an unidentified infection resembling some type of "milk fever". All data from such sows were discarded. Also when sows had any other type of special stress, such as getting out and being chased, their data for that day was discarded.

ILLUSTRATIONS

EXPLANATION OF PLATE I

Floor plan and longitudinal cross section of farrowing house with pertinent dimensions. Pen numbers show locations of sows. The letter "s" designates area occupied by sow; "c" designates creep area for pigs. The north room is not shown since it was not used in the experiment.

PLATE I



Section A-A

Scale: 3/32" = 1'-0"

EXPLANATION OF PLATE II

Fig. 1. The farrowing house as viewed from the southwest corner.

Fig. 2. Some of the farrowing crates located in the south room.

Fig. 3. Some of the pens located in the middle room.

PLATE II

Fig. 1

Fig. 2

Fig. 3

EXPLANATION OF PLATE III

Fig. 1. Method of air delivery to a sow in a farrowing crate. Dehumidified air comes from the downspout and is directed by the elbow connection towards the sow's head.

Fig. 2. Method of air delivery to the farrowing pens. Dehumidified air is transported by a 9-inch diameter duct located under the creep area and is directed into the sow's pen by elbow connection.

PLATE III

Fig. 1

Fig. 2

EXPLANATION OF PLATE IV

Fig. 1. A sow located in a farrowing pen lying directly in front of the opening from which the dehumidified air is flowing.

Fig. 2. A sow in a farrowing pen lying with her head about 3 feet from the air spout and with the major portion of her body entirely out of the air flow.

Fig. 3. A sow lying on the opposite side of the pen from the air spout with her entire body out of the air flow.

PLATE IV

Fig. 1

Fig. 2

Fig. 3

STATISTICAL ANALYSIS OF TEST RESULTS

The data consisting of rectal temperatures, respiration rates, ambient temperatures at sow level, and relative humidity at sow level obtained from the experiment were analyzed statistically to determine the significance of the results obtained. The detailed data for each day are included in tables 8 through 19 in the appendix. During the days the experiment was conducted the average ambient temperature at sow level was 86 degrees Fahrenheit, the average relative humidity at sow level was 55 per cent, the average outside ambient temperature was 88 degrees Fahrenheit, the maximum ambient temperature at sow level was 92 degrees Fahrenheit, the maximum relative humidity was 83 per cent, and the maximum outdoor ambient temperature was 104 degrees Fahrenheit.

For rectal temperatures and respiration rates it was decided to use the difference between the initial measurement in the morning and the final measurement of the day which was taken just before the sows in the farrowing stalls were turned out for the day. This final measurement usually contained the peak respiration rate and rectal temperature of the majority of the sows. This also put all measurement on an equal time basis. These differences were labeled delta rectal temperature and delta respiration rate and were used as the comparison of the reactions of the test sows to the reactions of the check sows. The ambient temperature and relative humidity, both taken at sow level, which best represented the conditions existing during the test period were selected for each day. These were labeled delta ambient temperature and delta relative humidity respectively to signify that they accompanied the delta rectal temperature and delta respiration rate for that day.

Since there was a wide range of initial rectal temperatures and respiration rates between sows on any given day and from day to day for any given sow, it was necessary to determine if the change in rectal temperature or respiration rate depended on the value of the initial measurement of rectal temperature or respiration rate. This was accomplished by plotting delta respiration rate versus initial respiration rate, and plotting delta rectal temperature versus initial rectal temperature for each sow. The plots were separated into two groups--test sows and check sows to detect any difference because of treatment.

Table 1. Correlation between the initial and final values of rectal temperature as measured during each daily test.

Check sows	group 1=	t = -0.9274,	36 d.f.	n.s.
	group 2	t = +0.1524,	13 d.f.	n.s.
Test sows	group 1	t = +0.373,	34 d.f.	n.s.
	group 2	t = -0.834,	16 d.f.	n.s.

Test sows received dehumidified air.
Check sows did not receive dehumidified air.
Degrees of freedom d.f.
Nonsignificant n.s.
Group 1 consists of data from test periods during August 8, 9, 13, 24, and 25, 1959.
Group 2 consists of data from test periods during August 18, 20, and 21, 1959.
Group 1 and group 2 were separated on the basis of relative humidity.

Table 2. Correlation between initial and final values of respiration rate as measured during each daily test.

Check sows	group 1	t = -1.012	30 d.f.	n.s.
	group 2	t = +0.3188	13 d.f.	n.s.
Test sows	group 1	t = -5.400	33 d.f.	sig.at 0.1%
	group 2	t = -1.287	16 d.f.	n.s.

The sample regression coefficient was calculated by standard methods and tested on the hypothesis that the slope of the regression curve was zero. The test indicated that only one group of data for delta respiration rates versus initial respiration rates had a regression coefficient significantly different from zero. This being the case it was concluded that within the range that the experimental data covered it could be assumed that initial rectal temperature or respiration rate did not affect the delta rectal temperature or respiration rate.

The tests were run so that each sow was cooled on alternate days. Thus, each sow could be paired against herself on alternate days. This was intended to eliminate differences because of individual reactions to heat stress. The sows were paired against themselves by comparing each sow's delta rectal temperature and delta respiration rate for days when she served as a test sow against days she served as a check sow.

By these methods four variables were defined. There were the differences between the delta rectal temperatures of a sow on alternate days, the difference between delta respiration rates of a sow on alternate days, the difference between delta ambient temperature at sow level on alternate days, and the difference between delta relative humidity on alternate days. These were designated Y, Y', X_1, and X_2, respectively

To determine the relation, if any, among Y, X_1, X_2 and among Y', X_1, X_2, freed of sow differences, pooled product-moment coefficients of linear correlation were computed. Statistical tests indicated no significant correlation existed between any of the variables except X_1 and X_2.

Thus it could be concluded that the test variables, difference in delta rectal temperature Y and difference in delta respiration rate Y', were not related to the environmental variables, difference in delta ambient temperature X_1 and difference in delta relative humidity X_2.

Also a partial correlation test was made for the relation between Y and X_1 with X_2 held constant, between Y and X_2 with X_1 held constant, between Y' and X_1 with X_2 held constant and between Y' and X_2 with X_1 held constant. These correlations were all non-significant which reaffirmed the results of the previous simple correlation tests.

Table 3. Correlation between the difference of delta rectal temperature (Y) and the difference of delta ambient temperature (X_1), or the difference of delta relative humidity (X_2).

Sows in Pens

	Simple Correlation	Partial Correlation
Ambient Temperature, (X_1)	0.039	0.265
Relative Humidity, (X_2)	0.105	0.281

Multiple Ry_{12} = 0.284

Sows in Crates

	Simple Correlation	Partial Correlation
Ambient Temperature, (X_1)	-0.190	-0.205
Relative Humidity, (X_2)	-0.218	-0.230

Multiple Ry_{12} = 0.296

Table 4. Correlation between the difference of delta respiration rate (Y') and the difference of delta ambient temperature (X_1), or the difference of delta relative humidity (X_2).

	Simple Correlation	Partial Correlation
Sows in Pens		
Ambient Temperature, (X_1)	0.174	0.687
Relative Humidity (X_2)	0.184	0.689
Multiple $R_{y'12}$ = 0.700		
Sows in Crates		
Ambient Temperature, (X_1)	0.0595	0.0473
Relative Humidity, (X_2)	-0.328	-0.327
Multiple $R_{y'12}$ = 0.331		

An analysis of variance was done to determine the variance between sows as compared to variance of an individual sow. The results were non-significant, and indicated the effects of cooling, if any, did not vary more from sow to sow than in the same sow.

Table 5. Analysis of variance.

Sows in Crates

Differences of delta rectal temperature (Y)

	degrees of freedom	sum of squares	mean square	F	significance
Sows	7	1.40	0.20	0.24	N.S.
Same sow	27	22.87	0.85		
Total	34	24.27			

Differences of delta respiration rate (Y')

	degrees of freedom	sum of squares	mean square	F	significance
Sows	7	5622.21	803.17	0.27	N.S.
Same sow	27	81402.08	3014.89		
Total	34	87024.29			

Sows in Pens

Differences of delta rectal temperature (Y)

	degrees of freedom	sum of squares	mean square	F	significance
Sows	9	3.78	0.42	0.81	N.S.
Same sow	23	11.93	0.52		
Total	32	15.69			

Differences of delta respiration rate (Y')

	degrees of freedom	sum of squares	mean square	F	significance
Sows	9	2036.74	226.30	0.12	N.S.
Same sow	23	43137.51	1875.54		
Total	32	45174.24			

The previous tests indicated that a test for paired differences could be made using individual sows compared against themselves on alternate days. The test for paired differences was done separately for the sows in crates and the sows in pens since the data indicated that there was a difference in the effect of the dehumidified air in the two rooms. This was believed to be due to the difference in degree of confinement of the crates compared to the pens. The sows in the crates were almost constantly in the air flow while those in the pens were often completely out of range of the air flow.

Table 6. Paired differences of delta rectal temperatures of individual sows on test days compared to check days.

Sows in Crates

Summation d = 20; N = 35, $\bar{d}$ = 0.5714

Summation $(d - \bar{d})^2 = 24.27$

$$S = \left[\frac{24.27}{35(34)}\right]^{\frac{1}{2}} = 0.1428$$

$$t = \frac{\bar{d} - ho}{S_{\bar{d}}}$$, where $ho(U_1 - U_2 = 0)$ versus $ha(U_1 - U_2 \neq 0)$

$$t = \frac{0.5714}{0.1428} = 4.001^{***}$$, 34 d.f. significant, P less than 0.001

Sows in Pens

Summation d = -3.2 N = 33 $\bar{d}$ = 0.0970

Summation $(d - \bar{d})^2 = 15.69$

$$S_{\bar{d}} = \left[\frac{15.69}{33(32)}\right]^{\frac{1}{2}} = 0.1221$$

$$t = \frac{-0.0970}{0.1221} = -0.794$$, 32 d.f. non-significant

Table 7. Paired differences of delta respiration rates for individual sows on test days compared to check days.

Sows in Crates

Summation d = 1045, N = 35, $\bar{d}$ = 29.8571

Summation $(d - \bar{d})^2$ = 87024.29

$$S_{\bar{d}} = \left[\frac{87024.29}{(35)(34)}\right]^{\frac{1}{2}} = 8.5516$$

$$t = \frac{\bar{d} - ho}{S_{\bar{d}}},$$ where ho $(U_1 - U_2 = 0)$ versus ha $(U_1 - U_2 \neq 0)$

$$t = \frac{29.8571}{8.5516} = 3.491^{**},$$ 34 d.f. significant, P less than 0.005

Sows in Pens

Summation d = 335, N = 33, $\bar{d}$ = 10.1515

Summation $(d - \bar{d})^2$ = 45174.24

$$S = \left[\frac{45,174.24}{33(32)}\right]^{\frac{1}{2}} = 6.5406$$

$$t = \frac{10.1515}{6.5406} = 1.552,$$ 32 d.f. non-significant

The results of this analysis indicated a significant difference in the delta rectal temperatures and delta respiration rates of the sows in farrowing crates for the days that they served as test sows compared to the days they served as checks. There was no significant differences in the delta rectal temperatures and delta respiration rates of the test sows and check sows in the farrowing pens.

CONCLUSIONS

From the results of the statistical analysis it could be stated that on the average, under the conditions of the experiment, the increase in rectal temperature and respiration rate of the sows located in the farrowing crates was less when they received cool dehumidified breathing air than when they did not. Apparently there was no effect, on the average, on the corresponding changes for the sows located in the farrowing pens.

If this daily increase of rectal temperature and respiration rate is a valid indication of heat stress, then it could be concluded that, on the average, the treatment resulted in decreased heat stress for the sows confined in crates.

RECOMMENDATIONS FOR FURTHER STUDY

From the results of the experiment it appears that the best use of such a system for cooling would be with sows confined in crates where they are forced to lie in the air stream. Further study would be desirable to determine design criteria for quantity of air flow and the desirable physical state of the air when delivered to the sows. It would be useful to know how much of the cooling actually takes place by evaporation of moisture from the lungs and the effect the envelope of cool air surrounding the sow.

To determine whether or not the system is economically justified, the number of pigs raised and their weight should be compared for sows cooled by such a system against a similar group not cooled. The value of the difference, if any, in number and weight of the pigs could be equated to the cost of providing the cooling to determine if the cooling is profitable. Such information is necessary in order to provide a sound basis for recommending the system.

ACKNOWLEDGMENTS

Appreciation is given to Associate Professor R. I. Lipper for his cooperation and advice in this investigation.

Indebtedness is also acknowledged to Professor H. C. Fryer for assistance in the experimental design and statistical analysis.

Acknowledgment is given to Instructor Gerald Zachariah for technical assistance, to Max Porter for his extensive cooperation, to Miss Arlis Gaines for preparation of the thesis, and to my wife for her patience and assistance.

Appreciation is given to the Kansas Committee on the Relation of Electricity to Agriculture for making an assistantship available and for financing this investigation.

REFERENCES

1. Bond, T. E.
   Environmental studies with swine. Agr. Engg. 40:544-49. 1959.

2. Bond, T. E.
   Hog houses. U. S. Dept. of Agr. Misc. Pub. 744. 1958.

3. Bond, T. E., C. F. Kelly, and Hubert Heitman Jr.
   Hog house air conditioning and ventilation data. Amer. Soc. Agr. Eng. Transactions 2:1-4. 1959.

4. Bond, T. E., C. F. Kelly, and Hubert Heitman Jr.
   Heat and moisture loss from swine. Agr. Engg. 33:148-52. 1952.

5. Brody, Samuel.
   Bioenergetics and growth. New York: Reinhold Corp. 1945.

6. Brody, Samuel.
   Environmental physiology. University of Missouri Agr. Expt. Sta. Res. Bul. 423. 1948.

7. Brody, Samuel.
   Resting energy metabolism and pulmonary ventilation in growing swine. University of Missouri Agr. Expt. Sta. Res. Bul. 380. 1944.

8. Fontaine, W. E., F. N. Andrews, and W. L. Sibbett.
   Are hogs prospects for comfort cooling? Paper presented at annual meeting of Amer. Soc. of Refrig. Eng. in Washington D. C. Dec. 6 to 9, 1953.

9. Hahn, LeRoy, T. E. Bond, C. F. Kelly, and Hubert Heitman Jr.
   Estimating cooling loads for air conditioning swine housing. U. S. Dept. of Agr. Tech. Bul. A.R.S. 42-32. 1959.

10. Heitman,Hubert Jr., T. E. Bond, C. F. Kelly, and LeRoy Hahn.
    Effects of modified summer environment on swine performance. Jour. Anim. Sci. 18:1367-72. 1959.

11. Heitman, Hubert Jr., and E. H. Hughes.
    The effects of air temperatures and relative humidity on the physiological well being of swine. Jour. of Anim. Sci. 8:171-81. 1949.

12. Heitman, Hubert Jr., E. H. Hughes, and C. F. Kelly.
    Effects of elevated temperatures on pregnant sows. Jour. of Anim. Sci. 17:62-67. 1958.

13. Heitman, Hubert Jr., C. F. Kelly, and T. E. Bond.
Ambient air temperatures and weight gain in swine. Jour. of Anim. Sci. 17:62-67. 1958.

14. Johnson, Ernest A., and John G. Taylor.
Individual air conditioning for farrowing sows. Paper 58-714 presented at the winter meeting of the Amer. Soc. of Agr. Eng. Chicago, Ill. Dec. 19, 1958.

15. McDowell, R. E.
Heat control indices. Paper 59-825 presented at the 1959 meeting of Amer. Soc. of Agr. Eng. Chicago, Ill. Dec. 15-18, 1959.

16. Newland, H. W., W. N. McMillen, and E. P. Reineke.
Temperature adaptation in the baby pig. Jour. of Anim. Sci. 11:118-133. 1952.

17. Sibbitt, W. L., W. E. Fontaine, and F. N. Andrews.
Comfort cooling livestock may boost rural load. Electric Light and Power pg. 82-85. March, 1955.

18. Taylor, John G.
Individual air conditioning for farrowing sows. U. S. Dept. of Agr. Tech. Bul. A.R.S. 42-19. 1958.

19. Tidwell, A. L., and J. L. Fletcher
The effect of summer environment on the body temperature and respiration rate of swine. Jour. of Anim. Sci. 10:523-32. 1951.

20. Whatley, J. A., J. B. Palmer, Doyle Chamber, and D. F. Stevens.
The value of water sprinklers for cooling pregnant sows during the summer. Oklahoma Agr. Expt. Sta. Bul. M.P. -48. 1957.

APPENDIX

Table 8. Daily test results for individual sows.

Date	Aug. 8, 1959	9:00 am A.T. 85°F	R.H. 50%	11:30 am A.T. -	R.H. -	2:00 pm A.T. 87°F	R.H. 43%	4:00 pm A.T. 89°F	R.H. 44%
Test Sow No.	Check Sow No.	Rectal Temp. °F	Resp. Rate breaths/min.	Rectal Temp. °F	Resp. Rate breaths/min.	Rectal Temp. °F	Resp. Rate breaths/min.	Rectal Temp. °F	Resp. Rate breaths/min.
	1a	103.9	-	-	-	104.2	-	103.1	-
	2a	102.7	-	-	-	103.1	-	103.4	-
	3a	102.6	25	-	-	102.9	-	103.1	30
	4a	99.9	40	-	-	100.1	60	100.9	80
5a		-	-	-	-	-	-	-	-
6a		102.5	30	-	-	103.5	-	104.3	80
7a		100.5	40	-	-	101.0	-	101.6	100
8a		-	-	-	-	-	-	-	-
	9a	102.5	30	-	-	103.6	-	104.0	80
	10a	102.3	-	-	-	103.7	-	103.6	-
	11a	102.4	20	-	-	102.7	-	103.5	60
	12a	101.7	25	-	-	102.1	40	102.6	40
	13a	102.5	20	-	-	103.9	40	104.3	40
14a		101.9	20	-	-	102.7	-	103.0	50
15a		100.2	20	-	-	101.2	30	101.2	60
16a		102.6	45	-	-	104.0	40	104.5	55
17a		100.9	20	-	-	101.8	30	101.3	30
18a		-	-	-	-	-	-	-	-

A.T. stands for ambient room temperature °F at sow level
R.H. stands for percent relative humidity at sow level

Table 9. Daily test results for individual sows.

Date	Aug. 9, 1959	9:00 am		11:30 am		2:00 pm		4:00 pm	
		A.T. 75°F	R.H. 62%	A.T. -	R.H. -	A.T. 87°F	R.H. 40%	A.T. 90°F	R.H. 40%
Test Sow No.	Check Sow No.	Rectal Temp. °F	Resp. Rate breaths/min.	Rectal Temp. °F	Resp. Rate breaths/min.	Rectal Temp. °F	Resp. Rate breaths/min.	Rectal Temp. °F	Resp. Rate breaths/min.
1a	1	102.5	35	-	-	103.5	20	103.7	40
2a		102.7	35	-	-	103.2	35	103.0	30
3a		102.7	25	-	-	103.0	25	103.3	25
4a		100.6	135	-	-	101.3	40	100.1	70
	5b	103.2	60	-	-	103.0	120	102.9	120
	6a	102.4	-	-	-	103.5	-	104.0	-
	7a	100.7	50	-	-	100.4	65	101.9	65
	8b	100.8	60	-	-	100.3	45	101.0	80
9a		103.2	40	-	-	103.0	70	103.2	60
10a		101.9	40	-	-	102.7	60	103.5	50
11a		102.1	70	-	-	103.2	40	103.2	50
12a		101.9	30	-	-	102.6	30	103.0	60
13a		103.8	-	-	-	103.5	-	103.5	-
	14a	102.9	40	-	-	102.7	25	103.3	40
	15a	100.9	35	-	-	101.2	100	102.0	100
	16b	-	-	-	-	-	-	-	-
	17a	100.6	50	-	-	101.1	40	101.5	40
	18a	104.2	30	-	-	104.8	80	104.7	70

A.T. stands for ambient room temperature °F at sow level
R.H. stands for percent relative humidity at sow level

Table 10. Daily test results for individual sows.

Date	Aug. 12, 1959	9:00 am A.T. -	R.H. -	11:30 am A.T. 88°F	R.H. 47%	2:00 pm A.T. 92°F	R.H. 45%	4:00 pm A.T. 92°F	R.H. 43%
Test Sow No.	Check Sow No.	Rectal Temp. °F	Resp. Rate breaths/min.	Rectal Temp. °F	Resp. Rate breaths/min.	Rectal Temp. °F	Resp. Rate breaths/min.	Rectal Temp. °F	Resp. Rate breaths/min.
	1a	-	-	103.3	40	103.5	40	104.1	20
	2a	-	-	103.4	40	103.6	60	104.2	100
	3a	-	-	103.8	25	104.3	85	105.1	100
	4a	-	-	102.6	100	103.2	160	105.1	100
5b		-	-	102.7	40	103.0	30	103.3	35
6a		-	-	-	-	-	-	-	-
7a		-	-	101.4	80	101.3	60	101.8	70
8b		-	-	100.6	50	101.0	50	101.2	140
	9a	-	-	102.6	40	102.8	80	103.0	60
	10a	-	-	102.9	20	102.2	60	103.4	35
	11a	-	-	103.0	140	103.1	100	103.8	100
	12a	-	-	102.5	40	103.1	60	103.4	40
	13a	-	-	102.9	55	103.2	75	103.5	80
14a		-	-	102.2	40	103.1	40	103.8	40
15a		-	-	102.2	45	102.3	30	102.4	25
16b		-	-	102.2	25	102.5	45	103.2	140
17a		-	-	100.5	100	100.0	35	101.8	140
18a		-	-	-	-	-	-	-	-

A.T. stands for ambient room temperature °F at sow level
R.H. stands for percent relative humidity at sow level

Table 11. Daily test results for individual sows.

Date Aug. 13, 1959		9:00 am A.T. $80^{\circ}F$	R.H. 58%	11:30 am A.T. $87^{\circ}F$	R.H. 49%	2:00 pm A.T. $90^{\circ}F$	R.H. 48%	4:00 pm A.T. $91^{\circ}F$	R.H. 43%
Test Sow No.	Check Sow No.	Rectal Temp. $^{\circ}F$	Resp. Rate breaths/min.	Rectal Temp. $^{\circ}F$	Resp. Rate breaths/min.	Rectal Temp. $^{\circ}F$	Resp. Rate breaths/min.	Rectal Temp. $^{\circ}F$	Resp. Rate breaths/min.
1b		100.4	60	100.4	20	100.2	20	100.0	30
2a		102.7	40	103.8	40	103.7	40	104.4	35
3b		101.3	20	100.5	40	100.9	20	100.8	20
4a		101.7	25	101.9	40	102.4	40	103.3	35
	5b	102.0	30	103.0	50	104.0	100	105.0	100
	6b	101.8	30	102.3	40	103.7	80	104.0	120
	7a	102.3	25	103.1	35	104.0	80	104.4	115
	8b	100.4	50	100.9	30	101.2	70	100.5	70
9a		102.9	40	103.4	40	104.1	80	104.5	50
10a		103.6	70	103.0	25	103.8	90	104.3	25
11a		102.2	50	102.2	20	102.8	20	103.4	55
12a		102.5	20	102.7	35	103.3	60	103.0	70
13a		102.4	30	102.6	20	103.2	60	103.5	60
	14a	105.3	80	103.7	60	103.4	45	104.3	100
	15a	102.3	35	102.8	75	103.0	40	103.7	110
	16b	102.0	20	102.9	90	103.0	35	104.2	120
	17b	103.4	40	103.5	40	104.6	40	104.9	160
	18a	104.0	45	104.4	60	104.9	80	105.5	160

A.T. stands for ambient room temperature $^{\circ}F$ at sow level
R.H. stands for percent relative humidity at sow level

Table 12. Daily test results for individual sows.

Date	Aug. 14, 1959	9:00 am A.T. 81°F	R.H. 73%	11:30 am A.T. 78°F	R.H. 80%	2:00 pm A.T. 78°F	R.H. 80%	4:00 pm A.T. 77°F	R.H. 80%
Test Sow No.	Check Sow No.	Rectal Temp. °F	Resp. Rate breaths/min.	Rectal Temp. °F	Resp. Rate breaths/min.	Rectal Temp. °F	Resp. Rate breaths/min.	Rectal Temp. °F	Resp. Rate breaths/min.
	1b	101.6	70	102.4	25	103.4	25	103.9	20
	2a	102.9	60	103.6	70	103.8	30	103.5	50
	3b	101.9	100	100.9	25	101.1	90	100.9	50
	4a	101.2	80	102.4	30	103.0	40	102.8	35
5b		102.6	40	102.8	20	103.0	35	102.6	20
6b		102.6	35	102.8	20	102.5	20	102.5	20
7a		102.2	20	102.8	25	102.4	20	102.9	20
8b		102.4	70	100.5	25	99.0	35	100.9	60
	9a	102.9	40	102.7	30	102.9	40	103.1	40
	10a	101.8	40	102.6	30	103.0	20	103.4	60
	11a	102.5	20	102.1	25	103.0	40	102.8	60
	12a	102.0	25	102.2	25	102.2	20	102.2	50
	13a	102.9	30	103.2	25	103.0	30	103.5	50
14a		104.0	50	102.6	30	102.7	20	103.2	40
15a		102.1	30	101.9	55	102.0	30	101.8	30
16b		103.0	120	102.7	80	103.3	60	103.0	50
17b		102.8	35	102.8	40	103.8	60	103.5	60
18a		103.0	40	103.0	40	103.4	30	103.7	40

A.T. stands for ambient room temperature °F at sow level
R.H. stands for percent relative humidity at sow level

Table 13. Daily test results for individual sows.

Date Aug. 15, 1959		9:00 am A.T. 76°F	R.H. 83%	11:30 am A.T. 78°F	R.H. 80%	2:00 pm A.T. 78°F	R.H. 80%	4:00 pm A.T. 78°F	R.H. 80%
Test Sow No.	Check Sow No.	Rectal Temp. °F	Resp. Rate breaths/min.	Rectal Temp. °F	Resp. Rate breaths/min.	Rectal Temp. °F	Resp. Rate breaths/min.	Rectal Temp. °F	Resp. Rate breaths/min.
1b		103.2	20	103.1	20	102.9	20	102.9	20
2a		102.5	25	102.9	20	103.0	20	102.8	40
3b		101.4	100	101.4	30	102.1	25	101.4	40
4a		102.8	30	102.9	30	103.1	35	102.8	20
	5b	103.0	20	103.0	30	103.3	20	103.4	40
	6b	102.5	20	102.5	20	103.1	20	102.9	20
	7a	102.3	20	102.6	25	103.2	20	103.5	35
	8b	100.8	45	101.4	80	101.4	100	101.2	100
9a		103.4	20	102.8	20	103.6	20	103.4	40
10a		102.5	30	102.8	20	102.7	25	103.1	20
11a		102.0	60	102.4	20	102.4	40	102.8	50
12a		102.2	20	102.3	20	102.2	20	102.0	20
13a		102.5	40	102.9	25	103.2	25	103.4	30
	14a	104.9	40	103.2	30	103.0	20	103.8	30
	15a	102.9	30	102.8	30	102.4	25	102.8	40
	16b	102.8	60	102.6	35	103.0	25	103.0	50
	17b	103.4	30	103.2	25	103.6	20	103.5	40
	18a	103.6	30	102.8	20	102.7	30	102.6	20

A.T. stands for ambient room temperature °F at sow level
R.H. stands for percent relative humidity at sow level

Table 14. Daily test results for individual sows.

Date Aug. 18, 1959		9:00 am A.T. 84 °F	R.H. 62%	11:30 am A.T. 88 °F	R.H. 52%	2:00 pm A.T. 89 °F	R.H. 56%	4:00 pm A.T. 89 °F	R.H. 55%
Test Sow No.	Check Sow No.	Rectal Temp. °F	Resp. Rate breaths/min.	Rectal Temp. °F	Resp. Rate breaths/min.	Rectal Temp. °F	Resp. Rate breaths/min.	Rectal Temp. °F	Resp. Rate breaths/min.
	1b	103.7	40	104.1	40	104.1	110	104.6	80
	2a	-	-	-	-	-	-	-	-
	3b	-	-	-	-	-	-	-	-
	4a	102.0	60	103.3	70	104.8	100	104.3	140
5b		102.8	25	104.0	40	104.2	40	104.8	75
6b		103.1	40	104.6	100	105.6	160	105.2	160
7a		102.0	25	103.6	80	103.5	30	103.3	40
8b		-	-	-	-	-	-	-	-
	9a	103.4	80	103.8	70	104.3	120	104.8	100
	10a	103.1	60	103.8	90	104.5	100	104.4	70
	11a	101.7	30	102.5	30	103.0	110	103.0	90
	12a	101.8	60	102.3	40	103.0	60	103.4	110
	13a	102.3	20	103.5	100	104.4	140	104.8	100
14a		104.4	70	104.8	100	105.6	140	106.0	150
15a		103.1	20	103.4	25	104.0	100	104.4	60
16b		102.1	100	103.0	60	103.1	130	104.0	110
17b		103.4	60	103.7	40	104.4	45	104.7	60
18a		101.8	40	101.8	20	102.0	60	102.4	70

A.T. stands for ambient room temperature °F at sow level
R.H. stands for percent relative humidity at sow level

Table 15. Daily test results for individual sows.

Date	Aug. 19, 1959	9:00 am		11:30 am		2:00 pm		4:00 pm	
		A.T. -	R.H. -	A.T. 87°F	R.H. 58%	A.T. 87°F	R.H. 58%	A.T. 89°F	R.H. 40%
Test Sow No.	Check Sow No.	Rectal Temp. °F	Resp. Rate breaths/min.	Rectal Temp. °F	Resp. Rate breaths/min.	Rectal Temp. °F	Resp. Rate breaths/min.	Rectal Temp. °F	Resp. Rate breaths/min.
1b		-	-	103.5	30	103.4	50	104.0	40
2a		-	-	-	-	-	-	-	-
3b		-	-	-	-	-	-	-	-
4a		-	-	102.5	65	103.9	40	103.9	40
	5b	-	-	104.3	90	104.8	95	105.2	100
	6b	-	-	-	-	-	-	-	-
	7a	-	-	103.4	20	104.0	100	104.2	105
	8b	-	-	-	-	-	-	-	-
9a		-	-	103.7	70	104.2	35	104.4	50
10a		-	-	102.3	60	103.6	70	104.2	70
11a		-	-	102.0	20	102.5	30	102.7	70
12a		-	-	101.8	65	102.2	50	102.2	30
13a		-	-	103.4	100	104.3	90	104.2	100
	14a	-	-	105.7	110	106.6	135	106.4	120
	15a	-	-	103.6	20	104.1	50	105.1	60
	16b	-	-	102.7	60	102.7	125	104.1	100
	17b	-	-	104.0	90	105.1	140	104.6	40
	18a	-	-	102.8	60	102.2	45	102.3	50

A.T. stands for ambient room temperature °F at sow level
R.H. stands for percent relative humidity at sow level

Table 16. Daily test results for individual sows.

Date Aug. 20, 1959		9:00 am A.T. 84°F	R.H. 57%	11:30 am A.T. 91°F	R.H. 48%	2:00 pm A.T. 92°F	R.H. 51%	4:00 pm A.T. -	R.H. -
Test Sow No.	Check Sow No.	Rectal Temp. °F	Resp. Rate breaths/min.	Rectal Temp. °F	Resp. Rate breaths/min.	Rectal Temp. °F	Resp. Rate breaths/min.	Rectal Temp. °F	Resp. Rate breaths/min.
	1b	103.7	45	104.0	45	104.6	100	-	-
	2a	-	-	-	-	-	-	-	-
	3b	-	-	-	-	-	-	-	-
	4a	101.4	60	103.7	60	102.6	150	-	-
5b		103.0	35	104.9	50	105.8	60	-	-
6b		102.9	50	104.4	55	105.2	50	-	-
7a		102.4	30	104.0	35	104.0	50	-	-
8b		103.9	35	104.2	40	104.5	60	-	-
	9a	102.3	40	103.4	80	103.5	100	-	-
	10a	-	-	-	-	-	-	-	-
	11a	-	-	-	-	-	-	-	-
	12a	101.7	25	102.0	25	102.4	50	-	-
	13a	-	-	-	-	-	-	-	-
14a		-	-	-	-	-	-	-	-
15a		-	-	-	-	-	-	-	-
16b		102.0	70	103.4	120	103.8	65	-	-
17b		103.2	45	103.6	25	103.6	50	-	-
18a		102.7	40	102.8	45	103.1	70	-	-

A.T. stands for ambient room temperature °F at sow level
R.H. stands for percent relative humidity at sow level

Table 17. Daily test results for individual sows.

Date	Aug. 21, 1959	9:00 am		11:30 am		2:00 pm		4:00 pm	
		A.T. 87°F	R.H. 52%	A.T. 90°F	R.H. 50%	A.T. 91°F	R.H. 50%	A.T. 92°F	R.H. 47%
Test Sow No.	Check Sow No.	Rectal Temp. °F	Resp. Rate breaths/min.	Rectal Temp. °F	Resp. Rate breaths/min.	Rectal Temp. °F	Resp. Rate breaths/min.	Rectal Temp. °F	Resp. Rate breaths/min.
1b		103.3	45	103.8-	35	103.9	80	103.8	40
2a		103.1	90	102.9	45	103.1	70	103.6	70
3b		-	-	-	-	-	-	-	-
4a		102.1	55	103.5	40	104.0	80	104.2	80
	5b	102.9	25	104.1	20	104.1	60	104.7	90
	6b	103.0	80	104.4	80	105.5	200	105.7	200
	7a	101.9	35	103.0	45	103.6	40	104.2	100
	8b	102.8	65-	104.4	70	104.9	120	105.1	120
*									

A.T. stands for ambient room temperature °F at sow level
R.H. stands for percent relative humidity at sow level

*Note: Remaining sows moved to pasture.

Table 18. Daily test results for individual sows.

Date Aug. 24, 1959		9:00 am A.T. 84°F	R.H. 57%	11:30 am A.T. 86°F	R.H. 55%	2:00 pm A.T. 88°F	R.H. 50%	4:00 pm A.T. 90°F	R.H. 43%
Test Sow No.	Check Sow No.	Rectal Temp. °F	Resp. Rate breaths/min.	Rectal Temp. °F	Resp. Rate breaths/min.	Rectal Temp. °F	Resp. Rate breaths/min.	Rectal Temp. °F	Resp. Rate breaths/min.
	1b	102.9	25	103.4	65	104.3	120	104.2	100
	2b	103.8	30	104.2	60	105.2	90	105.0	100
	3c	101.8	20	102.2	50	102.6	30	102.8	25
	4a	102.7	60	103.6	80	104.5	130	105.1	120
5b		103.2	45	104.1	60	104.2	65	104.0	60
6b		102.3	35	103.2	25	104.1	35	102.8	40
7a		101.4	30	102.2	35	102.5	45	102.4	40
8b *		102.6	45	102.6	40	102.6	30	102.5	35

A.T. stands for ambient room temperature °F at sow level
R.H. stands for percent relative humidity at sow level

*Note: Remaining sows removed to pasture.

Table 19. Daily test results for individual sows.

Date	Aug. 25, 1959	9:00 am A.T. 83°F	R.H. 52%	11:30 am A.T. 87°F	R.H. 48%	2:00 pm A.T. 88°F	R.H. 40%	4:00 pm A.T. 88°F	R.H. 40%
Test Sow No.	Check Sow No.	Rectal Temp. °F	Resp. Rate breaths/min.	Rectal Temp. °F	Resp. Rate breaths/min.	Rectal Temp. °F	Resp. Rate breaths/min.	Rectal Temp. °F	Resp. Rate breaths/min.
1b		102.7	50	103.3	30	102.8	80	103.6	60
2b		103.4	30	103.7	25	104.4	40	104.4	40
3c		101.9	20	102.6	20	103.0	20	102.9	20
4a		101.6	40	102.2	25	103.1	60	103.2	100
	5b	102.6	40	103.6	50	103.6	60	104.1	110
	6b	101.6	20	102.4	30	103.7	90	104.1	80
	7a	101.4	20	101.7	35	102.6	70	102.8	60
	8b	101.9	25	102.2	30	102.9	25	102.4	50
	*								

A.T. stands for ambient room temperature °F at sow level
R.H. stands for percent relative humidity at sow level

*Note: Remaining sows moved to pasture.

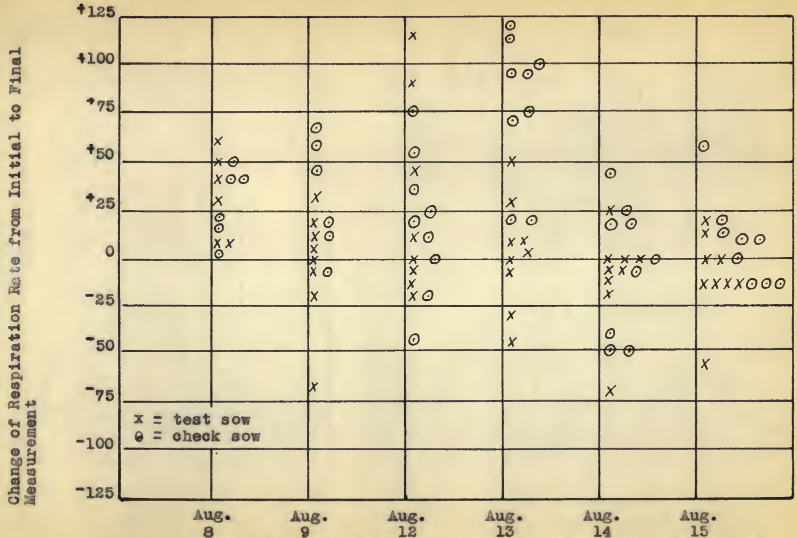


Fig. 1. Plot of changes of respiration rates from initial to final measurement for test sows and check sows during each daily test period of Max Porter Farm, Glen Elder, Kansas, during August 1959.

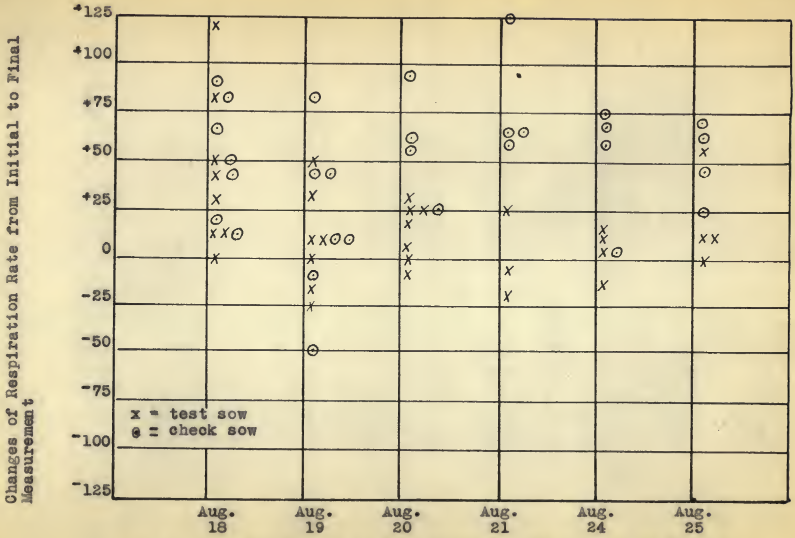


Fig. 2. Conclusion of plot of changes of respiration rates from initial to final measurement for test sows and check sows during each daily test period at Max Porter Farm, Glen Elder, Kansas, during August 1959.

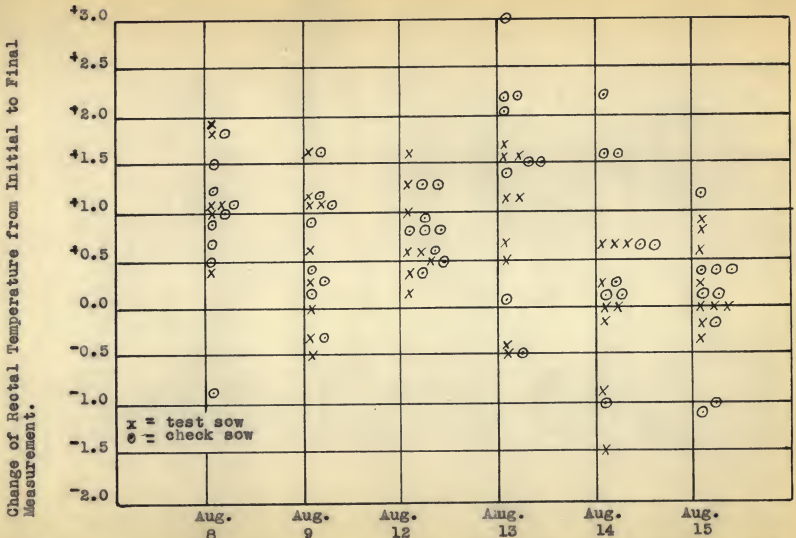


Fig. 3. Plot of changes of rectal temperatures from initial to final measurement for test sows and check sows during each daily test period at Max Porter Farm, Glen Elder, Kansas, August, 1959.

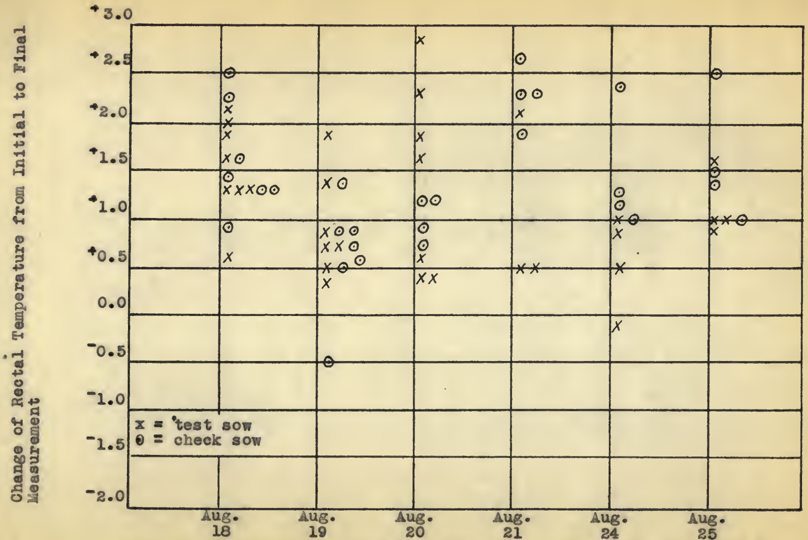


Fig. 4. Conclusion of plot of rectal temperatures from initial to final measurement for test sows and check sows during each daily test period at Max Porter Farm, Glen Elder, Kansas, during August, 1959.

AN INVESTIGATION OF THE EFFECTS OF COOL DRY
BREATHING AIR ON THE RESPIRATION
RATE AND RECTAL TEMPERATURES OF
FARROWING SOWS

by

RALPH JERRY McGINTY

B. S., Kansas State University
of Agriculture and Applied Science, 1959

AN ABSTRACT OF
A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agricultural Engineering

KANSAS STATE UNIVERSITY
OF AGRICULTURE AND APPLIED SCIENCE

1960

High ambient temperatures have long been recognized as being detrimental to swine production. The resulting loss in efficiency has become increasingly important in the modern "mass production" swine raising systems.

Swine are essentially non-sweating animals. As a result of their relatively dry skin, they lose little heat by means of evaporation from the skin unless moisture is artifically applied. In hot summer climates this is usually done by means of concrete wading pools, "wallows", or with water sprayed from nozzles.

In modern farrowing houses where conditions are crowded, and sanitation is of prime importance the presence of excess moisture, as from sprays or wallows, is objectionable. During periods of high humidity, evaporative coolers do not work well and may retard the evaporation of moisture from urine and the water used for cleaning. Cooling the entire farrowing house by refrigerative air conditioning is expensive and may not result in optimum conditions for the baby pigs.

A method has been used by agricultural engineers from Purdue University in which it was attempted to aid heat transfer from the sow's lungs. At high ambient temperatures a large portion of the total heat loss from swine is by evaporation of moisture from the lungs. It was proposed to increase this heat loss by supplying relatively cool dehumidified air for breathing.

The purpose of this research was to investigate the effects of cool dry breathing air on the respiration rate and rectal temperature of farrowing sows. The respiration rate and rectal temperature were used as indicators of heat stress.

A farrowing house owned by Max Porter of Glen Elder, Kansas, was used in this investigation. The house contained 8 farrowing crates in one room and 10 farrowing pens in another.

Outside air was introduced to the furnace room of the farrowing house. The air in the furnace room was recirculated through the evaporator coil of a refrigerative air conditioning system. The air was cooled to below the dew point temperature and the resulting condensed moisture was drained from the room. The cooled dehumidified air was drawn from the furnace room and directed by means of air ducts to the individual pens and crates.

Records were kept of inside and outside temperature, relative humidity, the state of the breathing air, and each sow's rectal temperature and respiration rate.

The data consisting of ambient temperature, relative humidity, rectal temperatures, and respiration rates were analyzed statistically. In the final analysis the sows were compared against themselves on days they served as test sows as compared to the days they served as check sows. This was intended to eliminate differences between sows. The statistical analysis indicated that on the average, for the conditions tested, the supplying of cool dehumidified air resulted in less daily increase in rectal temperature and respiration rate for sows contained in crates, but did not affect the corresponding daily increase for sows in pens.