THE EFFECTS OF HEAT STRESS ON RECTAL TEMPERATURES AND RESPIRATION RATES IN GILTS

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Bachelor of Science

Oklahoma State University

Stillwater, Oklahoma

1969

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
May, 1971

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TEMPERATURES AND RESPIRATION

RATES IN GILTS

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ACKNOWLEDGMENTS

The author expresses his sincere appreciation to Dr. I. T. Omtvedt, Professor of Animal Science, and Dr. R. A. Battaglia, Assistant Professor of Animal Science, for their instruction, guidance and counseling during the course of this study and in the preparation of this thesis. The author is also indebted to Dr. E. J. Turman, Professor of Animal Science, for his contributions to this thesis.

Further appreciation is extended to Paul Ellis, Maintenance Engineer at the Veterinary Science Building, and to G. W. A. Mahoney, Assistant Professor of Agriculture Engineering for their cooperation in making this study possible.

A special vote of thanks is extended to Steve Welty and Dennis Gerken for their help in transporting and in caring for the experimental animals, in equipment construction and for their assistance with collection of the data.

Appreciation is extended to fellow graduate students of Oklahoma State University for their assistance over the duration of this study.

Special recognition is extended to the author's wife Gayle for her patience, encouragement and understanding during the course of this study.

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INTRODUCTION

The effects of temperature stress on the physiological well-being and on the performance of swine is of greater importance today than in the past as a result of confinement rearing. Most of the heat stress research has been conducted in outside experiments or in climatic rooms that are equipped to control only temperature and lighting. Due to lack of adequate environmental facilities there is limited data on the effects of constant high temperature, relative humidity and wind velocity.

Numerous reports suggest that animals will exhibit increases in rectal temperature and respiration rate upon initial exposure to high ambient temperature with humidity only affecting body temperature at the higher environmental temperatures. It appears that swine will adapt to heat stress as evidenced by a decreased body temperature over long periods of exposure. This adaptation is thought to be associated with a decrease in feed consumption and metabolic rate.

This study was initiated on April 6, 1970 with the following objectives:

1. To determine the effects of constant high chamber temperature on rectal temperature and respiration rate of gilts.
2. To determine the extent of adaptation for gilts exposed to constant high temperature, humidity and wind velocity.

3. To determine the practical limitations and capabilities of the environmental chambers and equipment located in the Veterinary Science Building.

LITERATURE REVIEW

Normal Body Temperature

Hafez (1968a) stated that the normal body temperature of mammals will range from 96.8° to 104°F. but can be influenced by many factors. Feeding, muscular exercise, estrus and late pregnancy all result in elevated temperatures, while aging, starvation and the ingestion of large amounts of cold water tend to cause a depressing effect. Deighton (1935) reported body temperature of mature swine to be 101.7°F. However, Dukes (1955) considered the normal body temperature for swine to be 102.5°F. Brody (1945) reported that the normal body temperature for all breeds of cattle is considered to be 101°F. with deviations due to age, reproductive state and stage of lactation. Hafez (1968a) stated that sheep maintain an average daytime rectal temperature of 102.2°F. with a normal range from 99.5° to 104.9°F.

Factors Affecting Homeothermic Regulation

High Ambient Temperature

Heitman and Hughes (1949) reported that as air temperature rises above 40°F. the pig's body temperature and respiration rate increases. They also found that lightweight pigs (under 150 lb.) could survive at an approximate air temperature of 115°F. and that with heavy weight pigs (over 150 lb.) it was not possible to exceed 100°F. Heitman *et al.* (1951) studied the effects of elevated ambient temperature on 13 pregnant sows and observed marked increases in respiration rate at 88^{o}F. and in body temperature at 94^{o}F. Ingram (1964) exposed seven 18 to 28 kg. Landrace male pigs to a climatic room at dry-bulb temperatures of 23^{o}, 50^{o}, 86^{o} and 95^{o}F. He reported that rectal temperatures of all animals increased at 95^{o}F., but the rate of increase decreased with exposure time and from 77^{o} to 95^{o}F. skin temperature increased 0.97^{o}F. for every 1.8^{o}F. rise in chamber dry-bulb temperature. Respiration frequency was reported to increase from 12 to 18 per minute to 181 per minute between 86^{o} and 95^{o}F. Sanders _et al_. (1964) measured rectal temperature for 56 consecutive days on four, seven-month old Berkshire gilts housed in a psychrometric chamber at temperatures of 70^{o} and 85^{o} F. with 50 percent relative humidity. The mean body temperature of each gilt was higher at 85^{o}F. than at 70^{o}F. and the analysis of variance indicated that the mean rectal temperatures of the gilts, irrespective of ambient temperature, were significantly different ($P<0.01$). They concluded that there exists individual biological variation among gilts in ability to alter thermogenesis or thermolysis. Butchbaker and Shanklin (1965) studying new-born pigs also found that a wide biological variation existed in the rate of change of rectal temperature due to step changes in environmental temperature between pigs of the same age and weight. Tonks and Smith (1965) kept gilts and male pigs in a hot environment (83^{o}F. and 90 to 96 percent relative humidity) and compared them to litter mates conventionally housed (70^{o}F. and 70 to 76 percent relative humidity). They found that the pigs exposed to the hot humid environment exhibited slightly higher rectal temperatures, average skin temperatures were 2^{o}F. higher, and respiration rates were higher than for pigs conventionally housed. Beckett (1965) also reported that the respiration rate of swine increases with air temperatures above 70°F. Bond et al. (1967) found at a constant temperature of 69.8°F. there is an expected variation in rectal temperature of 0.67° and 0.45° F. for heavy and light weight hogs, respectively. Edwards et al. (1968) in two trials at the Fort Reno Livestock Experiment Station exposed gilts to a continuous cool chamber (74°F.) or a hot chamber (17 hours at 100°F. and 7 hours at 90°F. daily) prior to breeding and in early pregnancy. Rectal temperatures were taken at 7 a.m. before temperature elevation, at noon and at 4 p.m. before lowering temperature each day. They found that average rectal temperature for heat stressed gilts in both trials tended to decrease until about the sixth or eighth day of exposure and then tended to level off and remain relatively constant. However, rectal temperature was still above normal (102.5°F.).

In another study at Fort Reno Nelson et al. (1970) subjected 126 gilts at various stages of pregnancy to a control chamber (74°F.) or a hot chamber (100°F. for 17 hours and 90°F. for 7 hours). Rectal temperatures were taken at 4 p.m. before temperature elevation and at 8 p.m. four hours later. They reported that the average control rectal temperatures were slightly below normal (102.5°F.) for all stages of gestation. The heat stress maximum rectal temperatures were higher than normal at all times with a tendency for rectal temperature to decrease during late confinement. After 6 days exposure they found that there was no significant difference for 4 p.m. cool and hot gilt rectal temperatures except for those gilts confined during late pregnancy.

In cattle air temperature was shown to have a marked effect on body temperature (Branton et al., 1953; Robinson and Klemm, 1953; and Quazi and Shrode, 1954). In studies under field conditions with

European breeds of cattle Bonsma *et al.* (1940), Seath and Miller (1946) and Branton *et al.* (1953) showed that body temperature increases with environmental temperatures above 70°F. with a marked increase occurring above 80°F. Rate of increase in respiration frequency is most pronounced at 85°F. in dairy cattle. Gaztambide *et al.* (1952), Benezra (1954), and Beakley and Findlay (1955).

Lee (1950) reported that agitation of sheep occurs when rectal temperature reaches 107.6°F. with gasping and staggering occurring around 109.4°F. The effects of temperature with constant vapor pressure on four adult female goats was studied by Appleman and Delouche (1958). The warm chamber temperatures were 68°, 86°, 95° and 104°F. with 12 mm Hg. vapor pressure. Their results indicated that the increase in body temperature associated with ambient temperatures of 86°F. or higher occurred during the initial 4 to 8 hour exposure and after this initial increase body temperature leveled off and remained relatively constant during the remaining period of exposure. Respiration rate also rose rapidly with an increase in environmental temperature. However, when environmental temperature was increased from 95° to 104°F. a sharp decrease in respiration frequency was observed. Fletcher and Reid (1953) in a field trial investigated the effect of shearing lambs at high environmental temperature. The atmospheric temperature was 90° F. at 10:30 a.m. and 96°F. at 3:00 p.m. At both times average body temperature was higher than normal with the average temperature of shorn sheep 0.8°F. less than unshorn sheep.

Humidity

Heitman and Hughes (1949) reported that at air temperatures of

90° and 96°F. there was little difference in the response of 200 lb. pigs to relative humidities of 30 and 94 percent except that respiration rate increased at the higher humidity. When two month old pigs were exposed to 77°F. dry-bulb temperature, an increase in wet-bulb temperature from 66.2° to 75.2°F. had no effect on body temperature or respiration frequency, but four month old pigs experienced a slight rise in respiration rate. At 86°F. an increase in wet-bulb temperature was always accompanied by an increase in respiratory frequency, but there was little effect on body temperature (Ingram, 1965b). Hafez (1968a) reported that high relative humidity does not distress the pig unless the environmental temperature begins to approach body temperature or unless it is below 30 or above 80 percent. D'Arche et al. (1970) exposed gilts to a constant temperature (91.9°F.) and dew point temperatures (84.0° and 60.0°F.) and found that the highest respiration rates (140 and 150 per minute) occurred in the high humidity chamber compared to 90 to 100 per minute for the gilts in the low humidity chamber. They also reported that relative humidity had a highly significant effect on rectal temperature. The mean rectal temperature for high humidity exposed gilts was $102.38^{\circ} \pm .018^{\circ}$F. vs. $101.84^{\circ} \pm .018^{\circ}$F. for those exposed to low humidity.

Seath and Miller (1945) studying dairy cows found that increasing air temperature by 1°F. caused an increase in body temperature 13 to 15 times and respiration rate 41 to 43 times more than a one percent change in humidity. Reik and Lee (1948) concluded from hot room experiments with Jersey cows that an increment in humidity of 0.4 grains/ft.^{3} had the same effect on body temperature as an increase in ambient temperature of 1°F. Arrillage et al. (1952) reported that relative humidity appears to be secondary to environmental temperature in affecting the physiological well being of cattle. In a study with Aryshire calves at air temperatures of 86° and 95°F. at high humidity, Beakley and Findlay (1955) found these two temperatures to be equivalent in effect to air temperatures of 91.4° and 114.8°F. at low humidity. McDowell (1958) also reported that at high temperature a condition of high humidity is a factor in the distress of cattle.

Wind Velocity

Heitman and Hughes (1949) increased air motion over a wet chamber floor on three hogs weighing about 200 lb. and in 30 minutes observed a 60 percent decrease in respiration rate and an average of 2.5°F. decrease in body temperature. When air temperature was 90°F. growing swine exhibited only a small reduction in gain due to increased wind, but at temperatures of 95° and 100°F. there was a substantial increase in gain with increased air movement (Bond *et al.*, 1965). From these results it was concluded that 90° to 104°F. is the range of ambient temperatures at which any benefits might be realized from additional wind velocity. Neither respiration rate nor pulse rate has been shown to be affected by wind velocity.

In California beef cattle studies, Bond *et al.* (1957) reported that increased air movement during hot weather promotes increased weight gain and feed utilization. Joyce and Blaxter (1964) studied the effect of air movement and fleece length with two sheep at an ambient temperature of 41°F. and reported that increasing wind velocity had a greater affect on heat production of short fleece sheep.

Age

Hafez (1968a) reported that normal body temperature decreases from 104° to 102.2°F., 103.82° to 102.38°F. and 102.38° to 100.94°F. for young and adult pigs, sheep, and cattle, respectively. Casady et al. (1956) exposed the same bulls at different ages to air temperatures of 60°, 70°, 80°, 85°, 90° and 95°F. In the first experiment the bulls were 8½ months old and a marked increase in rectal temperature and respiration rate occurred from 70° to 80°F. but when the bulls were 17½ to 19 months old this response did not occur until chamber temperature reached 90°F. They concluded that thermoregulation is not as efficient in young as in older animals.

Feed Consumption

Deighton (1935) fasted pigs two to five days and found an average reduction in body temperature of 1.7°F. Heitman et al. (1951) and Edwards et al. (1968) found weight losses in sows kept at high ambient temperatures due to lowered feed consumption. Bond et al. (1952) observed an increase in pig total heat loss soon after feeding and Bond et al. (1964) reported that less than 15 minutes after pigs were fed rectal temperatures increased. In six experiments with 612 pigs Mangold et al. (1963) reported a decline in daily feed intake and a decrease in daily weight gain of 0.005, 0.010, and 0.015 lb. per degree increase in air temperature above approximately 72°F. for 30, 75 and 140 lb. pigs, respectively. Teaque et al. (1968) studied the effects of high temperature on gilts and found that increased dry-bulb and dew-point temperature significantly ($P < .01$) decreased feed consumption and rate of gain.

Water Consumption

Heitman *et al.* (1951) reported a general weight loss in pregnant sows at high ambient temperatures due to lowered feed and water intake. However, Tonks and Smith (1965) found that daily water intake was not affected in pigs kept in a hot house environment of 83°F. as compared to those housed at 70°F. Voluntary water intake in groups of pigs increased by about 40 percent when environmental temperature was elevated from 68° to 86°F. (Holmes and Mount, 1967). They also found the mean daily water intake for swine to be approximately 0.1 liter per kg. body weight or 3 liters per kg. of feed consumed.

Bianca (1966) studied the heat tolerance of six steers deprived of water for four days and kept in an environment of 59°F. The steers responded to the treatment with a decrease in appetite resulting in a ten percent reduction in body weight. When these steers were watered normally and subjected for four hour periods to high temperature they had higher rectal and skin temperatures than normally watered steers. These observations were associated with a slower initial rise and a lower final value of respiration rate than non-dehydrated steers. This reduction in heat tolerance was considered to be the result of a reduced rate of evaporation.

Estrus

Sanders *et al.* (1964) reported that increased muscular activity at the time of estrus undoubtedly contributes to increased body temperature. Teaque *et al.* (1968) found that increasing dry-bulb temperature had a greater adverse effect on estrual behavior of gilts than increases in dew-point temperature. They also reported that gilts which were not cycling in the hot chambers, when placed in a cooler environment, were observed in estrus after 4 to 17 days which suggested that normal cycle length was interrupted by high temperature. Edwards et al. (1968) exposed 8 gilts to a cool chamber (74°F.) and 10 gilts to a hot chamber (100°F. for 17 hours and 90°F. for 7 hours) each day for one estrous cycle prior to breeding. They reported a significant ($P < .05$) increase in estrous cycle length for heat chamber gilts when compared to their average length of estrous before confinement. However, the difference between estrous cycle lengths for those confined to the hot chamber and those in the control chamber was not significantly different. D'Arche et al. (1970) reported that rectal temperatures of some gilts tended to be highest on the day of estrus or on the day prior to estrus, but estrus had no significant affect on rectal temperature.

Wrenn et al. (1958) reported that the body temperature of the cow is lowest prior to estrus, high on the day of estrus, low at the time of ovulation and high during the luteal phase of the cycle.

Activity

Heitman and Hughes (1949) found that at an air temperature of 80°F. 100 lb. pigs were still fairly active but as air temperature increased the animals became increasingly lazy and lay flat on the chamber floor. Teaque et al. (1968) also reported that as air temperature increased the visible activity of gilts decreased.

Hafez (1968a) stated that heat production is ten percent greater during standing in cattle and sheep than during lying.

Heat Loss

Hafez (1968a) reported that heat can be transferred away from the animal body or toward the animal body by radiation, conduction, and convection with evaporative heat loss only occurring away from the body. Kelly et al. (1948) observed that no heat loss occurred by convection or radiation in hogs when the surface temperature and environmental temperatures are equal. Bond et al. (1952) studied the heat losses of 60 to 350 lb. pigs at air temperatures ranging from 40° to 100°F. and from sows and litters at 60°, 70°, and 80°F. They found that at low air velocities the radiation and convective heat loss was about equal and that a higher wind velocity would increase the rate of heat loss by convection. The percentage of heat loss by evaporation for all groups of pigs was observed to decrease from 90 percent at 100°F. to 25 and 35 percent at 75°F. From 60° to 80°F. there was no apparent effect of environment on the heat loss of the sows and litters. Holmes and Mount (1967) reported that the heat loss in the pig from warming consumed water to body temperature is about three percent of the total heat loss. Holmes and Mount (1966) studied the heat loss of young pigs at 48.2°, 68°, and 86°F. and found that heat loss exhibited a 24 hour cycle. Holmes (cited by Mount, 1968) found a significant relation between heat loss and respiratory rate for 20 and 60 kg. pigs at 86°F.

In a study with dairy cows Kibler and Brody (1950) reported that at air temperatures above 80°F. heat loss is mainly by evaporative cooling from the respiratory tract and body surface and as air temperature decreases the major heat loss is through radiation, conduction and convection.

Adaptation to Heat

Hafez (1968a) stated that the animal can defend itself against heat by behavourial means such as reducing body insulation, increasing evaporation, lowering heat production, or increasing the reflectivity of the hair coat to solar radiation. Edwards _et al_. (1968) exposed gilts to high ambient temperature and reported that rectal temperature decreased for the first 6 to 8 days and then leveled off and remained relatively constant, which appeared to indicate adaptation to heat stress. D'Arche (1970) found that average rectal temperature of gilts when exposed to high temperature was at its highest level six hours after initial exposure and then decreased steadily with a highly significant ($P < .01$) effect resulting from length of exposure. Omtvedt _et al_. (1971) exposed 126 gilts at different stages of gestation to a cool or hot chamber and reported that all heat stress gilts exhibited an increase in rectal temperature at initial exposure with a decline after a few days. They also found no close relationship between a gilt's ability to acclimate and her reproductive performance. Rectal temperature was concluded to be inadequate in predicting the effect of high temperature on reproductive performance. Ingram and Mount (1965) reported that the level of food intake for pigs is a great factor in apparent heat adaptation with some evidence of a small independent element of metabolic acclimatization to high temperature. Ingram and Slebodzinski (1965) studied the thyroid secretory activity by the release of ^{131}I and rate of oxygen consumption of pigs housed at 77^{o} and $95^{o}F$. Thyroid secretory activity and oxygen consumption rate was always greater in $77^{o}F$. housed pigs compared to pigs kept at $95^{o}F$. When the thyroid gland was removed from eight day old pigs their metabolic adaptation was impaired.

Bianca (1965) reported when cattle are exposed to mild heat for a long period of time there is a decrease in metabolic heat production. Johnston et al. (1958) in a field study reported that Jersey, Holstein and Red-Sindhi Holstein crossbred cattle showed a decrease in heat production apparently due to adaptation at elevated temperatures and humidities. Thompson et al. (1963) reported that heat production, respiratory rate, and rectal temperatures of 10 Holstein heifers increased following initial heat exposure and then declined on continual exposure. This change was said to be the compensatory adjustments due to altered thyroid and adrenal cortical function. Yousef et al. (1967) also found that after 60 hours of exposure to 100.4^{o}F. Holstein cows exhibited a significant decline in thyroid activity and heat production. They concluded that thyroid function and metabolic rate are involved in acclimatization.

Diurnal Fluctuation

Hafez (1968a) reported that domestic mammals exhibit a 24 hour body temperature cycle with a minimum in early morning and a maximum in late afternoon. This rhythm is caused by activity and feeding during the day and rest at night. In an experiment with three Large White Wessex Saddleback male pigs in a constant temperature and lighting environment Caunice and Pullar (1959) reported that after three week exposure the 24 hour heat production cycle was not diminished. Bond et al. (1967) exposed pigs to either a constant temperature or 24 hour cycling temperature and found that in the constant temperature environment, rectal temperature and respiration rates varied 0.54^{o}F. and 15 breaths per minute, respectively. Hafez (1968a) reported that pigs are diurnal in their habits and become nocturnal in constant high temperature environments. In one of his experiments with six pigs at 68°F. and continuous lighting he measured heat loss from these pigs and found a high heat loss occurred at 3:00 p.m. and a low at 3:00 a.m. He concluded that feeding at 9:00 a.m. and 5:00 p.m. probably reinforced the 24 hour heat loss cycle.

Bligh (1965) studied 24 hour rhythm in different mammalian species and found that body temperature fluctuated between 1.8° to 5.4°F. with thermostability being lowest in the camel and buffalo and highest in the sheep.

MATERIALS AND METHODS

Chamber Description

This study utilized two environmental chambers located in the Veterinary Science Building at Oklahoma State University. The chambers were designed and constructed by Lab-Line Environeers Incorporated, Melrose Park, Illinois. Exterior dimensions are 132" x 156" x 94" and interior dimensions approximately 68" x 102" x 84". The exterior of the chambers is galvannealed steel, with heavy gauge stainless steel interiors. Interior wall corners are interlocking to eliminate air leaks. The walls contain 6" of glass wool insulation to minimize heat loss. The environmental control room showing the environmental chamber equipment and chamber design is presented in Figures 1 and 2, respectively.

Chamber cooling is accomplished with two remote 15 H.P. Copeland Semi-Hermetic, water cooled R502 condensing units. Chamber heating and wind velocity is controlled by the operation of one, two, three or four of the Joy Vaneaxial fans mounted within each chamber. Each fan is rated at 11.3 BHP at 55^{o}C. rise, permitting wind velocity control of 1 to 16 mph. The heat produced by these fans provides for the upper ranges of desired temperatures. Temperature specifications range from -20^{o}F. to $+130^{o}$F. with a control of $\pm 2^{o}$F. at high air flow and $\pm 1^{o}$F. at low air flow with a total uniformity of 4^{o}F.

Each chamber is also furnished with two 4 G.P.H. maximum distilled humidifiers and 2 dehumidifier coils designed to control relative

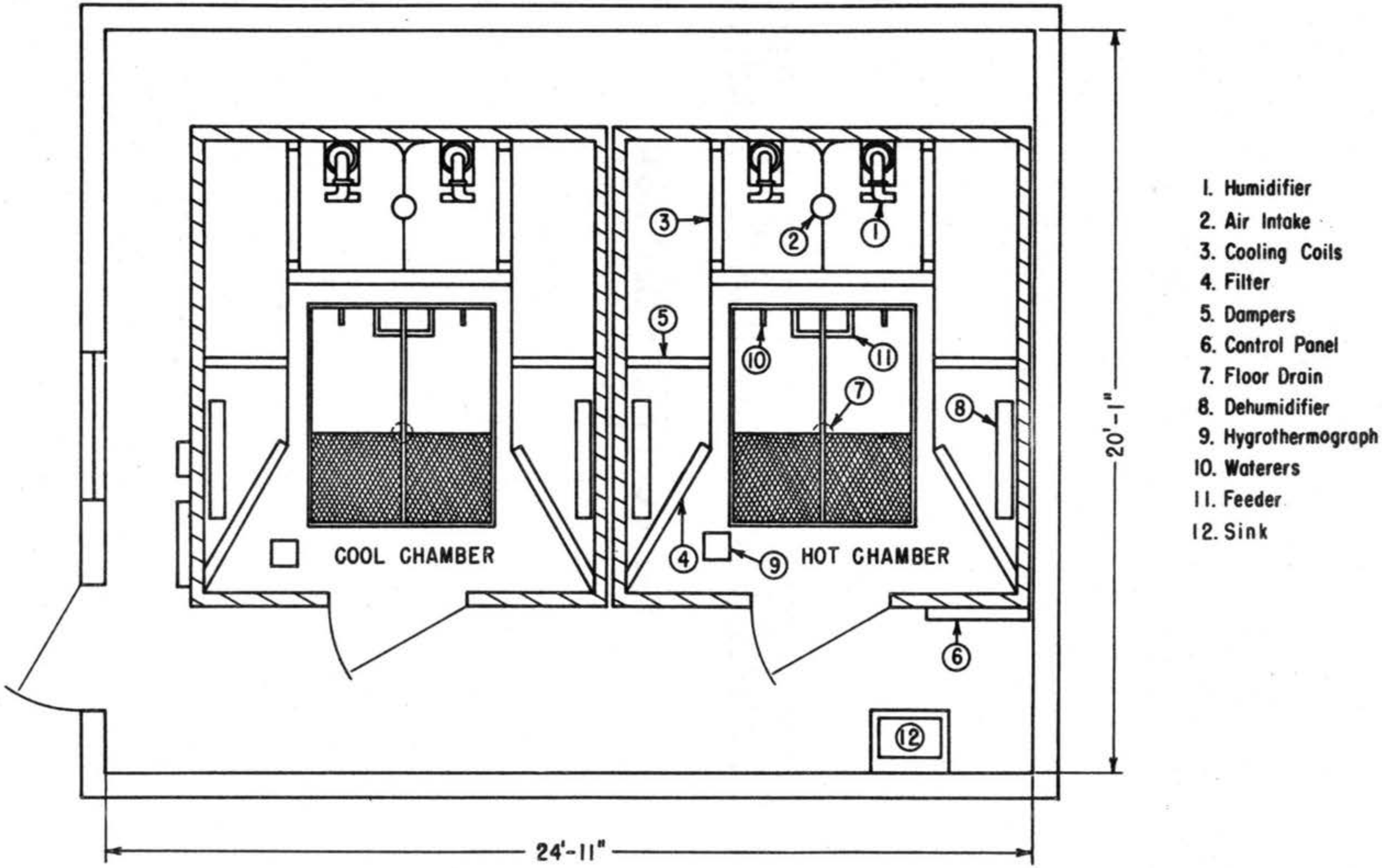

Figure 1. Environmental Control Room Showing Location of Environmental Chambers, Restraining Crate Position and Work Area

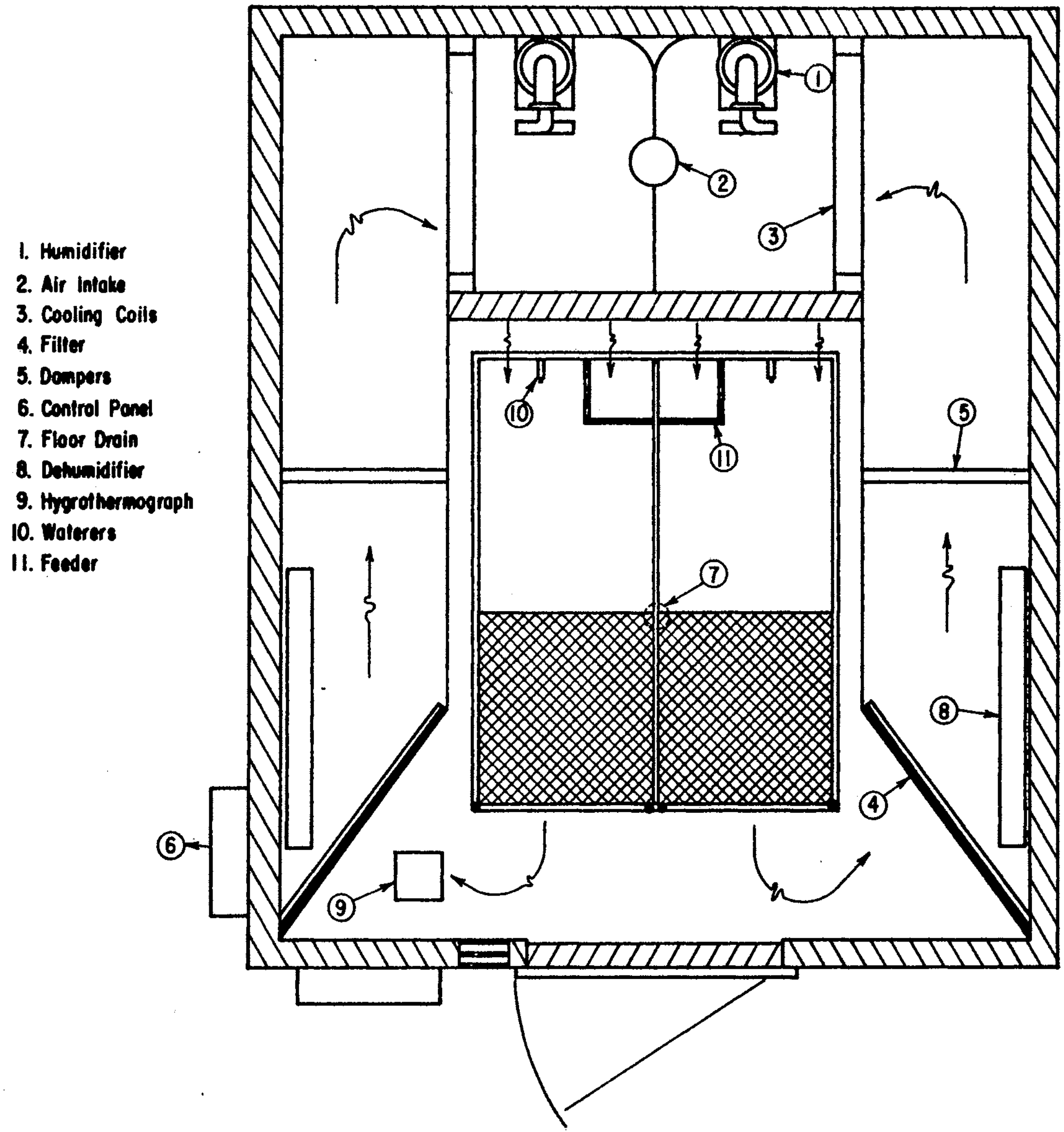

Figure 2. Environmental Chamber Showing Restraining Crate and Environmental Equipment

humidity within a 20 to 90 percent range which is limited by 45°F. minimum and 118°F. maximum chamber temperatures.

A control cabinet located on the exterior wall of each chamber houses all necessary switches, pilot lights, high-low safety thermostats and a transistorized temperature controller with a sensitivity which exceeds $\pm 5^{\circ}$F.

The chamber design also includes a 42" x 78" insulated door, two 100 watt incandescant lights and a 7" x 17" multipane window for visual observation to the room's interior.

Restraining Crate Description

During this study each environmental chamber was equipped with a restraining crate designed to restrict and support two 200 lb. pigs. Crates were utilized in an effort to control feed consumption and animal activity and to prevent unnecessary structural damage to the chamber's interior. Figure 3 shows a cross section of the environmental control chamber and the restraining crate design. The crates had dimensions of 38" x 72" x 36" and consisted of a ¼" welded wire cage constructed over a 38" x 41" plywood floor that was joined at the rear by a 38" x 31" nine gauge expanded metal grate. The grate had 3/4" diamond holes to allow feces, urine and excess water to fall into a collection pan beneath each crate. A 3/4" plastic drain was connected to the collection pan and extended to a disposal drain in the center of each chamber floor to eliminate excess moisture from the chamber atmosphere. The crate floor was elevated 20" in front and 18" behind over two 2" pipe runners with 1" square steel tubing to allow adequate drainage and air movement beneath the crate. Two adjustable hinged gates located in a vertical

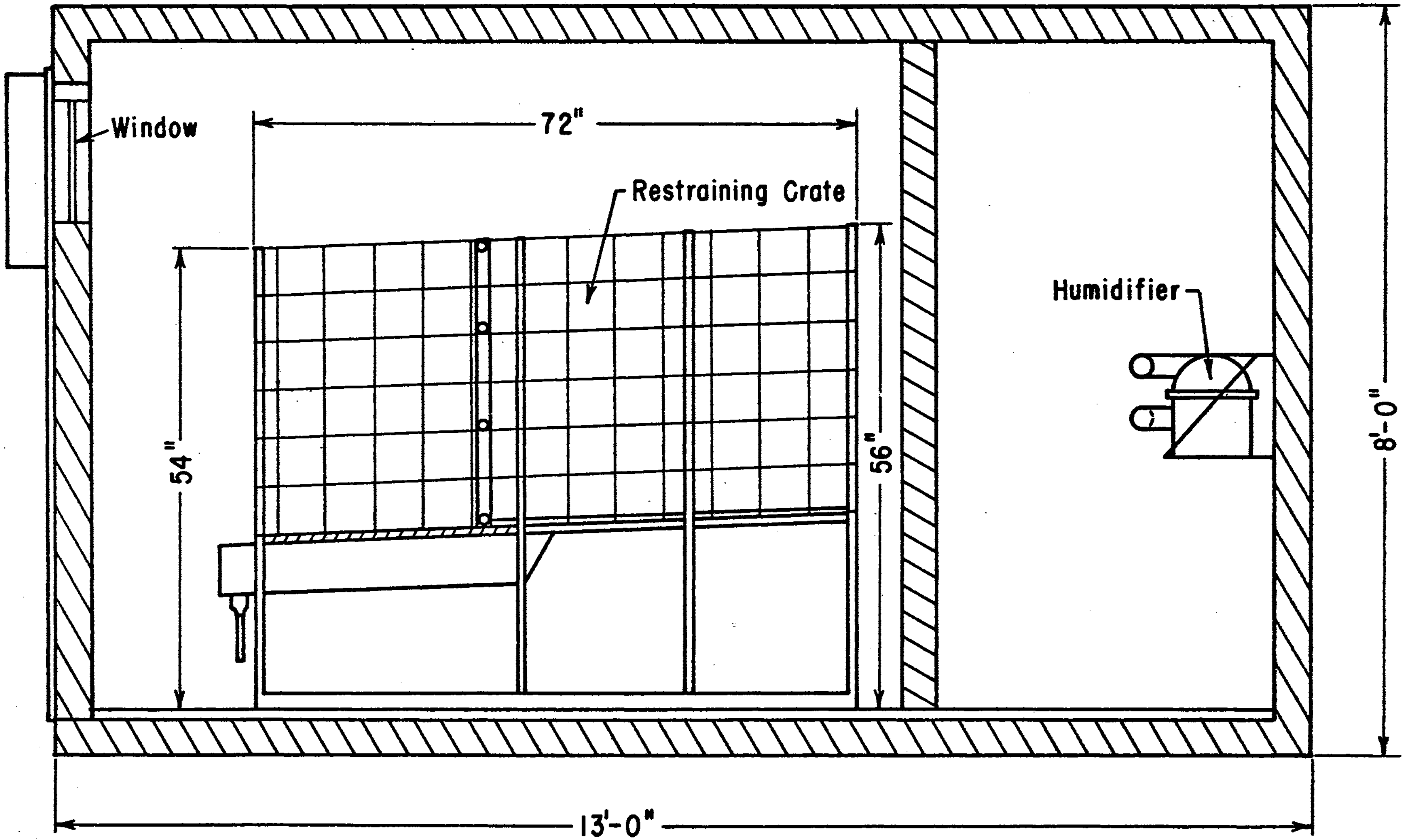

Figure 3. Cross Section of Environmental Chamber Showing Restraining Crate Design

position over the grated floor plus a ¼" welded wire center partition extending from the front to the rear of the crate restricted activity and provided each pig equal confinement space.

Feed and Water Facilities

Two wooden feed boxes 11" x 10" x 4" were attached to the plywood floor at the front of each crate to permit uniform feed distribution throughout this experiment.

Two Arato-Pig-Drinkers were bolted directly to each crate and attached to a 3/4" pressure line. This pig waterer consisted of a 5" long drinking tap mounted horizontally 27" above the crate floor. This type system was used to provide water *ad libitum* to each pig during the confinement period and to eliminate exposure of excess water to the chamber's atmosphere.

General Procedure

Twenty-four purebred Hampshire gilts averaging seven months of age and weighing 208.9 $\pm$ 2.9 pounds were confined to either a cool or hot chamber environment for a period of approximately 120 hours during this study. Gilts were selected from litters farrowed in the fall of 1969 and reared in outside lots at the Experimental Swine Barn on the Oklahoma State University campus. This study was conducted for a 6 week period from April 6 to May 16, 1970. Four gilts were selected on Monday morning of each week and brought to the swine barn to be washed and weighed. The gilts were then randomly allotted to the cool chamber, or the hot chamber, plus a crate position within each chamber and transported to the chamber location.

In the preliminary trial the tentative plan was to operate both chambers at 75°F., 40 percent relative humidity and 2 m.p.h. wind velocity for the first two days of each week, then gradually elevate the hot chamber to 96°F. on the third day. However, at 7:30 p.m. on the third day two gilts exhibited rectal temperatures of 106° and 107°F. and respiration rates of 228 and 232 per minute, respectively, and were found dead 14 hours later. During this trial the dehumidification system was observed to be operating at full capacity, but was unable to decrease the relative humidity to 40 percent in the 75°F. chambers. The 2 m.p.h. wind velocity was also too slow to create adequate air movement through the dehumidification coils, resulting in a solid ice formation.

From these observations the cool chamber control switches and dials in this study were set to produce a constant environment of 70°F., 60 percent relative humidity and 5 m.p.h. wind velocity. An attempt was made to create an identical environment in the hot chamber so the gilts could adjust to the confinement and new watering system prior to temperature elevation. On Tuesday of each week at approximately 6:30 a.m. the hot chamber was increased from 70°F. to 80°F. and again at 10:30 a.m. to 85°F. and held constant the remainder of each week. The two 100 watt incandescant lights located above each restraining crate were on continuously while gilts were in the chambers.

Four pounds of a medicated 15 percent protein grower ration were fed at the time the gilts were placed in the crates and at 6:30 a.m. each day of the remaining confinement period. The ration fed during this study is given in Table I.

TABLE I

GROWER RATION

Ingredient	Amount, lb.
Milo	78.00
Soybean meal (44%)	18.75
Dicalcium phosphate	1.50
Calcium carbonate	.75
Trace mineral salt	.50
Vitamin-mineral premix	.50
Antibiotic (SP250)	.25
	100.25

Rectal Temperature and Respiration Rate Data

Rectal temperatures and respiration rates were routinely obtained from each gilt in this study at the designated intervals illustrated in Table II. The 6:30 a.m. rectal temperatures and respiration rates each day were taken prior to feeding. Rectal temperature was determined by inserting a large animal thermometer approximately 5 inches into the rectum of each gilt for a 3 minute period. Respiration rate was determined by counting flank movements for two 30 second intervals. Each 30 second count was multiplied by 2 to get respirations per minute. These two respiration rates per minute were then averaged to obtain each gilt's respiration rate.

TABLE II

TIME SCHEDULE FOR DETERMINING RECTAL TEMPERATURES AND RESPIRATION RATES[a]

	Day in Chamber					
Time	1	2	3	4	5	6
6:30 A.M.		X	X	X	X	X
10:30 A.M.		X	X	X	X	X
2:30 P.M.		X	X	X	X	
6:30 P.M.	X	X	X	X	X	
10:30 P.M.	X	X	X	X	X	

[a]This schedule was used for the entire 6 week period of this study.

After the last rectal temperature and respiration rate was taken at 10:30 a.m. on day 6 of each week the gilts were removed from the chambers and transported back to the Experimental Swine Barn. The chambers and crates were cleaned and allowed to dry before day 1 of the next week.

Visual Observations

During this experiment it was necessary to observe and record estrual behaviour, activity, visual signs of sickness, eating habits or any visible function which could affect body temperature.

Chamber Temperature and Humidity Data

The stress chambers were equipped with electric hygrothermograph recorders to continuously collect temperature and humidity data. These recorders were located inside the chambers on stands approximately 24" above chamber floor level. The instruments were serviced and calibrated by personnel of the Oklahoma State Agriculture Engineering Department prior to this study. A large thermometer was also positioned inside each chamber for observation from the chamber window to detect temperature fluctuation and to minimize entry into the chamber.

There was a Honeywell Electronic 16 Multipoint Strip Chart recorder attached to the exterior wall of the cool chamber but this was not used in this experiment because preliminary wet and dry-bulb temperature recordings indicated some type of mechanical malfunction in this instrument.

Statistical Analyses

A completely randomized design was utilized for this experiment. The experimental design is shown in Table III.

The cool chamber gilt rectal temperature variables for days 2, 3, 4 and 5 of confinement for weeks 1 through 6 were subjected to an analysis of variance, the components of which are shown in Table IV.

The data were further analyzed by calculating means ($\bar{x}$), standard deviations (s) and standard errors ($s\bar{x}$) for cool and heat stress gilt rectal temperatures, respiration rates and chamber temperatures and relative humidities.

All analyses were performed as illustrated by Snedecor and Cochran (1967). Student's t test was used to test differences between cool and hot rectal temperature means and respiration rate means assuming that the two populations had common variances.

TABLE III

EXPERIMENTAL DESIGN SHOWING NUMBER OF RECTAL TEMPERATURES AND/OR RESPIRATION RATES FOR COOL AND HEAT CHAMBER GILTS[a]

	Time					
Week	6:30 A.M.	10:30 A.M.	2:30 P.M.	6:30 P.M.	10:30 P.M.	Total
1	2	2	2	2	2	10
2	2	2	2	2	2	10
3	2	2	2	2	2	10
4	2	2	2	2	2	10
5	2	2	2	2	2	10
6	2	2	2	2	2	10
	12	12	12	12	12	60

[a]Two rectal temperatures and respiration rates taken per gilt.

TABLE IV

ANALYSIS OF VARIANCE FOR RECTAL TEMPERATURES GILTS IN COOL CHAMBER

Source	df
Total	59
Week	5
Time	4
Week X Time	20
Error[a]	30

[a]Error term used to test week, time and week x time.

With unequal sample numbers and common variance, $s_{\bar{x}_1-\bar{x}_2}$ was determined by the following formula and divided into $\bar{d}$ for the t test.

$$s_{\bar{x}_1-\bar{x}_2} = \sqrt{s^2p \left(\frac{n_1 + n_2}{n_1 n_2}\right)}$$

Where,

$\bar{d}$ = the difference between group means

$s_{\bar{x}_1-\bar{x}_2}$ = standard error of the difference

s^2p = the pooled variance

n_1 = number of observations in group one

n_2 = number of observations in group two

With equal sample numbers and common variance the formula used to compute $s_{\bar{x}_1-\bar{x}_2}$ was as follows.

$$s_{\bar{x}_1-\bar{x}_2} = \sqrt{\frac{2s^2p}{n}}$$

Where,

$s_{\bar{x}_1 - \bar{x}_2}$ = the standard error of the difference

$s^2 p$ = the pool variance

n = the common sample size.

The degrees of freedom for testing were $(n_1-1) + (n_2-1)$.

RESULTS AND DISCUSSION

Chamber Temperature and Relative Humidity

As previously discussed the desired cool and hot chamber environments for this study were 70^{o}F. and 85^{o}F., respectively, with both chambers having 60 percent relative humidity with 5 m.p.h. wind velocity. Chamber temperatures and relative humidities for this study were determined by collecting these data from the hygrothermograph recorder charts at the time periods designated in Table II.

The means and standard deviations for the cool and hot chamber environments are summarized in Table V.

TABLE V

MEANS AND STANDARD DEVIATIONS FOR CHAMBER TEMPERATURE AND RELATIVE HUMIDITY

	Temperature (oF.)		Relative Humidity (%)	
Chamber	Mean	St. Dev.	Mean	St. Dev.
Cool	69.9	0.86	61.5	2.74
Hot	84.8	0.49	60.3	1.41

These results indicate that the cool and hot chamber temperatures and relative humidities were relatively constant during this experiment. However, the hot chamber temperature and humidity was controlled more closely to the desired 85^{o}F. and 60 percent relative humidity than was the cool chamber to 70^{o}F. and 60 percent relative humidity. Humidity was controlled more precisely at the desired level in the hot chamber because the higher temperature (85^{o}F.) was a supplement to the chamber dehumidification system in the evaporation of moisture from the chamber atmosphere. In the cool temperature chamber (70^{o}F.) the dehumidifiers were observed to be operating at full capacity during the entire period of this experiment. This suggests that these environmental facilities would be relatively inefficient to obtain relative humidity levels below 60 percent under the conditions of this experiment.

The mean cool and hot chamber temperatures and relative humidities for designated time periods of this experiment are graphically presented in Figure 4. The actual means and standard deviations for the cool and hot chamber temperature and relative humidity for time periods are presented in Appendix Tables XII and XIII and given by week in Appendix Tables XIV and XV. Figure 4 shows a trend for the chamber temperatures to be controlled more uniformly throughout this experiment than were the chamber humidities. This graph also shows a trend for average cool chamber relative humidity to increase at approximately 2:30 p.m. on day 3 of confinement. This trend resulted from the under-capacity of the dehumidification system in the 70^{o}F. chamber. It was observed during the second and fourth weeks that as the exterior chamber relative humidity increased above 60 percent the interior chamber humidity increased.

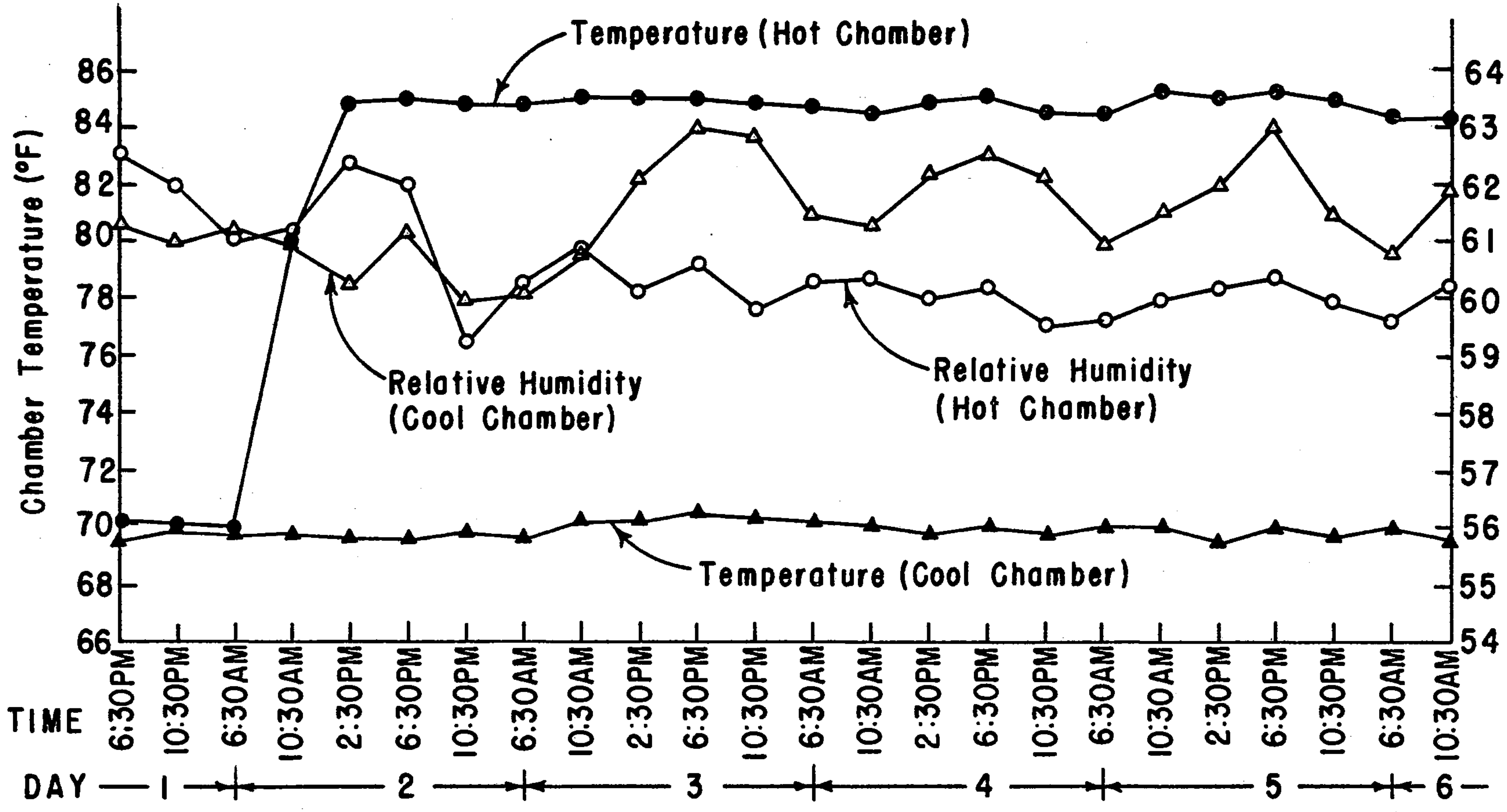

Figure 4. Average Cool and Hot Chamber Temperatures (^{o}F.) and Percent Relative Humidities

Hafez (1968a) stated that high relative humidity does not distress the pig unless environmental temperature begins to approach body temperature or unless it is below 30 or above 80 percent. Assuming this statement to be correct the slightly higher humidities in the constant cool temperature environment should have not affected the comparisons made between hot and cool chamber gilts.

During this study the 5 m.p.h. chamber wind velocity could have been too slow to circulate sufficient air through the dehumidification system in the low temperature chamber. For future trials designed to obtain low humidities at low temperatures it may be desirable to increase chamber air movement or install a larger dehumidification system.

General Comments

One gilt assigned to the 85^{o}F. chamber exhibited abnormally high rectal temperatures and respiration rates during the fourth week of this experiment. The abnormal increase was a direct result of this gilt's increased activity during confinement. Although this gilt was not removed from the chamber, she was not included in the analyses of this trial since her behaviour was considered to be atypical.

Ten of the 24 gilts in this study were observed to be showing signs of estrus on the third or fourth days of confinement. The number of gilts observed to be in estrus, their chamber location, and the week and day that estrus was observed is given in Table VI.

TABLE VI

GILTS OBSERVED TO BE IN ESTRUS

No. Observed	Chamber	Week	Day of Confinement
1	Cool	1	4
1	Hot	1	3
2	Hot	3	4
1	Hot	4	4
1	Cool	4	4
1	Cool	5	4
1	Hot	5	4
1	Cool	6	4
1	Hot	6	3

The limited chamber space and strict confinement of the pig made it impossible to determine estrus by applying pressure to the gilt's back to check for an immobility response. The gilts in this trial were reported to be in estrus only if they had signs of a swollen and/or congested vulva. Very few reports are available concerning the effects of change of environment on the onset of estrus in swine. Hafez (1968b) stated that changes in temperature and light intensity have little influence on the regularity of estrus in swine.

A possible explanation for the gilts showing estrus could have been a result of changing environmental conditions and the physical stress of moving the gilts from the Experimental Swine Barn to the environmental chambers. This action could have caused some of the gilts to synchronize their sexual activity to the day of moving. Nalvandov

(1964) has quoted similar findings and suggested that significantly more pigs when moved will exhibit estrus within 5 to 8 days than would have at their original locale.

Rectal Temperature

Rectal temperatures were routinely taken from gilts exposed to either the cool or hot chamber environment as previously discussed. The average cool and heat stress gilt rectal temperatures for this study were 102.4° and 103.0°F., respectively. This 102.4°F. average cool rectal temperature is in close agreement with the normal 102.5°F. body temperature for swine quoted by Dukes (1955). These data suggest that the gilts maintained in the cool chamber at approximately 70°F., 60 percent relative humidity and 5 m.p.h. wind velocity were at relatively normal atmospheric conditions. The 103°F. average heat stress rectal temperature indicates that these gilts were exposed to an environmental condition above their comfort zone.

The analyses of variance for cool rectal temperatures on days 2, 3, 4 and 5 of confinement are given in Table VII.

This table indicates that differences between weeks were a significant ($P < .01$) source of variation on the second day of confinement. This difference may have been directly associated with the different environmental conditions from which the pigs came to the chambers. If the outside lot temperatures were higher or lower than the 70°F. chamber temperature, the gilts possibly had not adjusted to the chamber conditions by the second day of confinement. Week and time were highly significant ($P < .01$) sources of variation for cool gilt rectal temperature on the fourth day of chamber exposure. The significant differences between weeks on the fourth confinement day possibly resulted from 4 gilts coming into estrus during different weeks, and exhibiting increases in rectal temperature. Sanders et al. (1964) and D'Arche (1970) reported similar results for cycling gilts. Wrenn et al. (1958) found that a cow's body temperature was lowest prior to estrus and highest on the day of estrus. The highly significant ($P < .01$) time on day 4 suggests that the gilts were exhibiting a body temperature fluctuation in approximately constant lighting, temperature, humidity and wind conditions. Hafez (1968a), Bond et al. (1967) and Bligh (1965) have all reported mammals to have a 24-hour body temperature cycle.

TABLE VII

ANALYSES OF VARIANCE FOR RECTAL TEMPERATURES
OF GILTS IN COOL CHAMBER

		Day of Confinement			
		2nd	3rd	4th	5th
Source	d.f.	M.S.	M.S.	M.S.	M.S.
Total	59				
Week	5	0.93**	0.13	0.36**	0.17
Time	4	0.08	0.16	0.68**	0.07
Week X Time	20	0.05	0.17	0.14	0.05
Error[a]	30	0.22	0.09	0.10	0.12

[a]Error term used to test week, time and week x time.

**Significant ($P < .01$).

Actual means and standard errors for cool and hot gilt rectal temperature for designated time intervals are given in Table XVI of the Appendix. These mean cool and heat stress rectal temperatures are illustrated in Figure 5 and the actual mean cool and hot gilt rectal temperatures are compared by times in Table VIII. As chamber temperature was increased to 85°F. in the hot chamber on day 2, average hot gilt rectal temperature became significantly ($P < .01$) higher than average cool gilt rectal temperature. Similar results have been reported by Edwards _et al_. (1968) and Nelson _et al_. (1970). Average heat stress rectal temperature remained significantly higher than average cool rectal temperature until 10:30 a.m. on day 4. Average hot rectal temperature was again significantly ($P < .01$) and ($P < .05$) higher at 2:30 p.m. on day 4 and 6:30 p.m. and 10:30 p.m. on day 5, respectively, than average cool gilt rectal temperature. On day 5 at 10:30 a.m. average cool rectal temperature was 0.06°F. higher than average hot rectal temperature, but this difference was not significant. These data suggest that the heat stressed gilts appeared to adapt to high temperature on approximately the fourth or fifth day of confinement. Edwards _et al_. (1968) reported that gilts appeared to adapt to heat stress after about 6 days exposure. This difference for length of adaptation to heat stress may possibly have been a result of the higher heat stress temperatures used in the latter study.

From Figure 5 it is evident that the cool and hot chamber gilts were exhibiting daytime high rectal temperatures at 2:30 p.m., 6:30 p.m. or 10:30 p.m. for each day of confinement. These rectal temperatures were averaged for days 2, 3, 4 and 5 to obtain daytime high cool and hot rectal temperatures and the comparisons are presented in Figure 6.

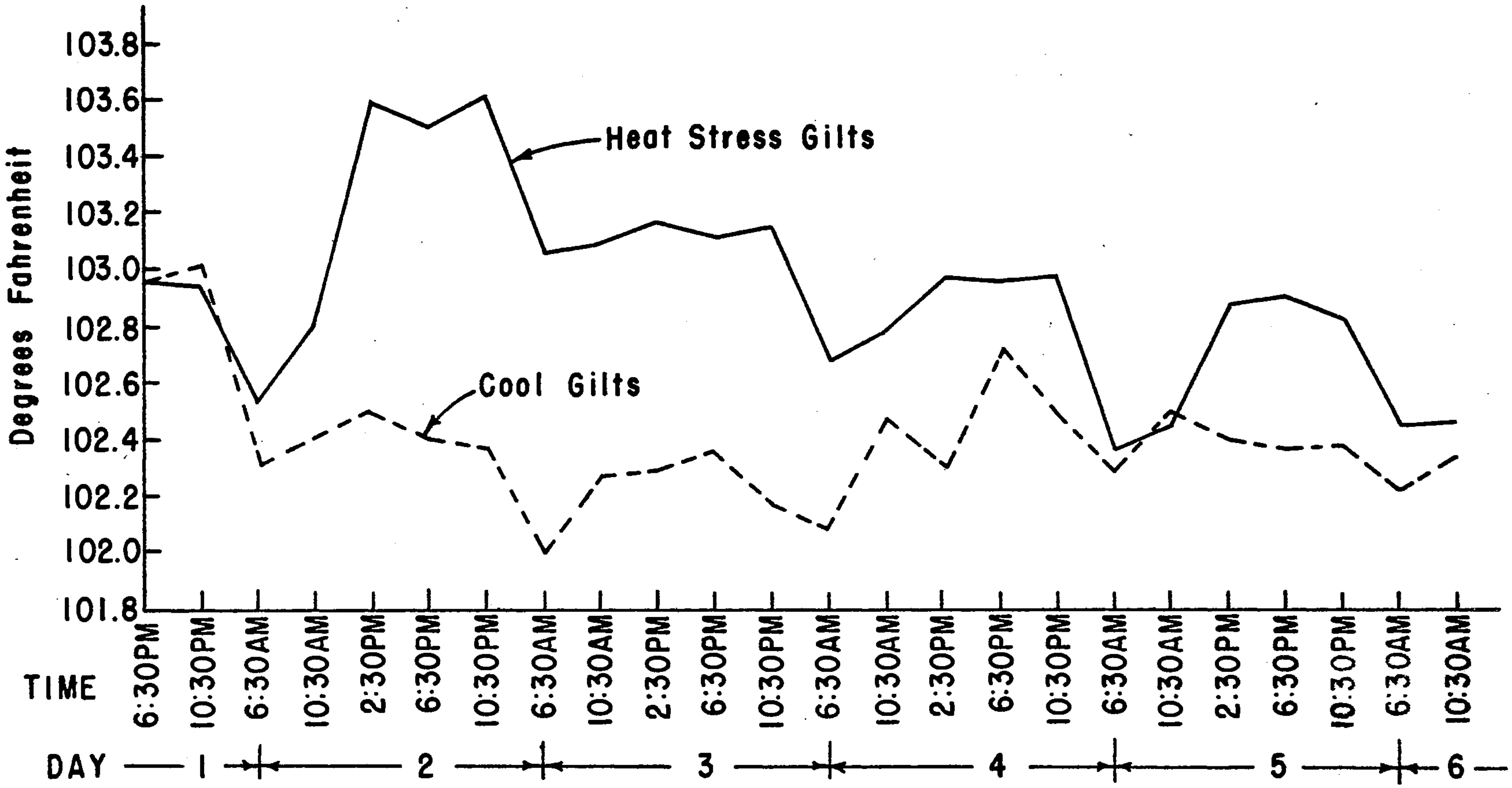

Figure 5. Average Cool and Heat Stress Gilt Rectal Temperature Comparisons at Different Stages of Confinement

TABLE VIII

MEAN RECTAL TEMPERATURE COMPARISONS OF COOL AND HOT CHAMBER GILTS AT DESIGNATED TIME INTERVALS

Day	Time	Cool Chamber Gilt Temperature (°F.)	Hot Chamber Gilt Temperature (°F.)	Difference
1	6:30 P.M.	102.95	102.95	0.00
	10:30 P.M.	103.02	102.95	-.54
2	6:30 A.M.	102.28	102.53	0.25
	10:30 A.M.	102.43	102.80	0.37
	2:30 P.M.	102.50	103.59	1.09**
	6:30 P.M.	102.42	103.51	1.09**
	10:30 P.M.	102.38	103.61	1.23**
3	6:30 A.M.	102.06	103.06	1.00**
	10:30 A.M.	102.27	103.09	0.82**
	2:30 P.M.	102.29	103.17	0.88**
	6:30 P.M.	102.36	103.12	0.76**
	10:30 P.M.	102.18	103.15	0.97**
4	6:30 A.M.	102.09	102.68	0.59*
	10:30 A.M.	102.48	102.78	0.30
	2:30 P.M.	102.29	102.97	0.68**
	6:30 P.M.	102.73	102.96	0.23
	10:30 P.M.	102.49	102.98	0.49
5	6:30 A.M.	102.30	102.36	0.06
	10:30 A.M.	102.51	102.45	-.06
	2:30 P.M.	102.42	102.89	0.47
	6:30 P.M.	102.38	102.91	0.53*
	10:30 P.M.	102.39	102.83	0.44*
6	6:30 A.M.	102.23	102.45	0.22
	10:30 A.M.	102.35	102.46	0.11

*Significant ($P < .05$).

**Significant ($P < .01$).

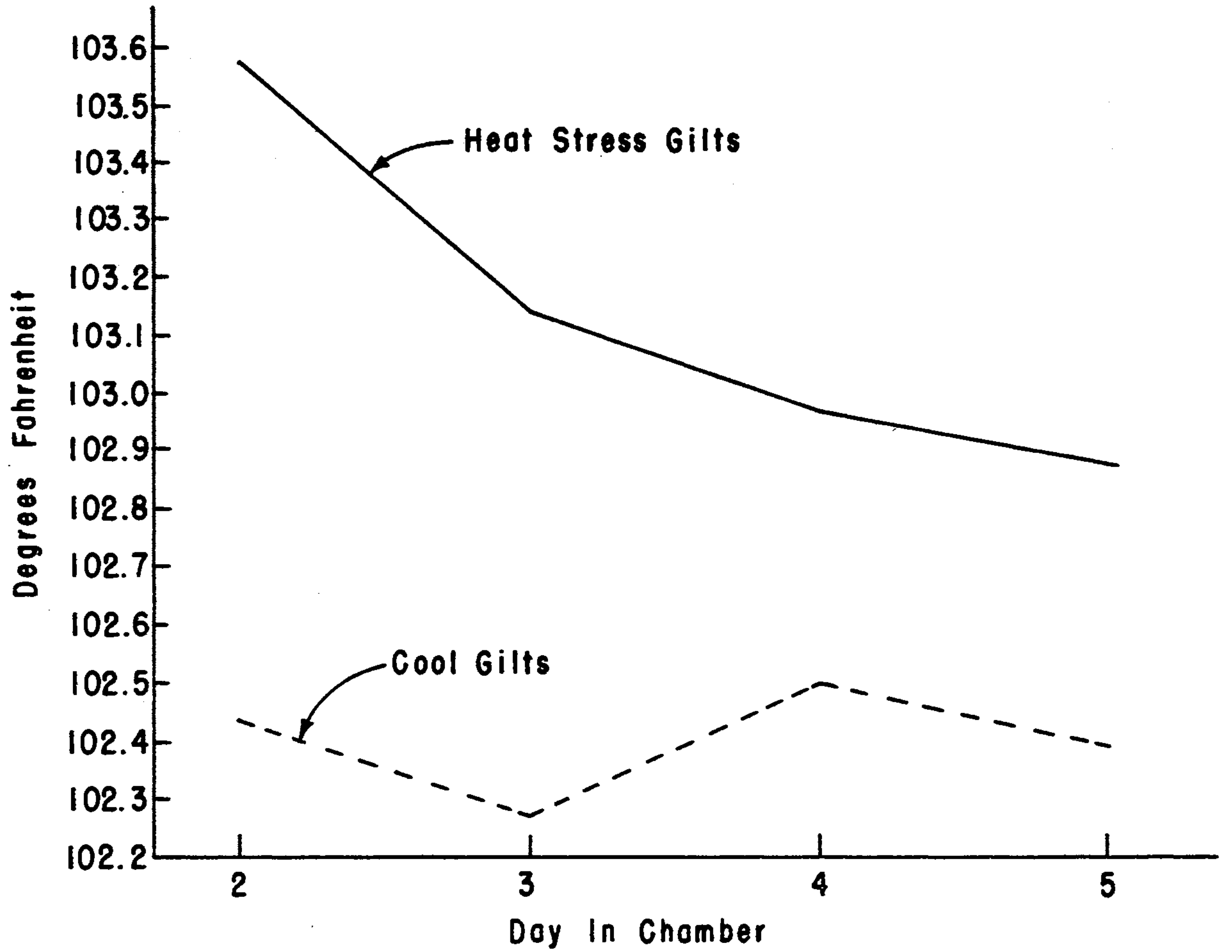

Figure 6. Average Daytime High (2:30 p.m., 6:30 p.m. and 10:30 p.m.) Rectal Temperature Comparisons for Cool and Heat Stress Gilts on Days 2, 3, 4 and 5 of Confinement

Table XVII in the Appendix presents the actual means for daytime high cool and hot gilt rectal temperatures.

Average daytime high hot rectal temperature was significantly ($P < .01$) higher on days 2, 3, 4 and 5 of confinement than average cool rectal temperature. However, there was a tendency for this difference to decrease with length of exposure. Further comparisons were made between days for the average daytime high rectal temperatures within the cool and hot chambers and are presented in Tables IX and X, respectively.

TABLE IX

MEAN DAYTIME HIGH (2:30 P.M., 6:30 P.M. and 10:30 P.M.) COOL GILT RECTAL TEMPERATURE COMPARISONS FOR DAYS 2, 3, 4 AND 5 OF CONFINEMENT

Comparison		Average Daytime High Cool Rectal Temperature (°F.)		Difference
Day 2 vs.:	Day 3	102.4	102.3	-.10*
	Day 4		102.5	0.10
	Day 5		102.4	0.00
Day 3 vs.:	Day 4	102.3	102.5	0.20**
	Day 5		102.4	0.10*
Day 4 vs.:	Day 5	102.5	102.4	-.10*

*Significant ($P < .05$).

**Significant ($P < .01$).

TABLE X

MEAN DAYTIME HIGH (2:30 P.M., 6:30 P.M. AND 10:30 P.M.) HEAT STRESS GILT RECTAL TEMPERATURE COMPARISONS FOR DAYS 2, 3, 4 AND 5 OF CONFINEMENT

Comparison		Average Daytime High Hot Rectal Temperature (°F.)		Difference
Day 2 vs.:	Day 3	103.6	103.2	-.40**
	Day 4		103.0	-.60**
	Day 5		102.9	-.70**
Day 3 vs.:	Day 4	103.2	103.0	-.20
	Day 5		102.9	-.30
Day 4 vs.:	Day 5	103.0	102.9	-.10

**Significant ($P < .01$).

Average daytime high cool rectal temperature on day 3 was significantly ($P < .05$) lower than day 2 with days 4 and 5 being significantly ($P < .01$) and ($P < .05$) higher, respectively, than day 3. This suggests that the gilts were adjusting to the environment up to day 3.

The significant ($P < .01$) increase in average rectal temperature on day 4 may have been the result of 4 cool gilts coming into estrus on this day of confinement. Cool gilt average daytime high rectal temperature was 0.10°F. less on day 5 than day 4 ($P < .05$). This indicates that the gilts were exhibiting a possible decrease in body temperature as they were going out of estrus on the fifth day of confinement.

Average daytime high hot rectal temperature was significantly ($P < .01$) higher on day 2 when compared to days 3, 4 or 5 with a trend for this difference to decrease to day 5 of confinement. The decreases in average daytime high hot gilt rectal temperature from days 2 to 3, days 3 to 4 and days 4 to 5 were $0.40^{o}F.$, $0.20^{o}F.$ and $0.10^{o}F.$, respectively. This indicates that the heat stressed gilts exhibited the greatest rectal temperature reduction from day 2 to 3 of confinement. Although 2 gilts on day 3 and 4 gilts on day 4 were observed to be in estrus in the high temperature chamber, there was no evidence of an increase in average gilt rectal temperature for either day of confinement.

As indicated in Figure 5 there was also a trend for both the cool and hot chamber gilts to have lower rectal temperatures at 6:30 a.m. each day. Figure 7 shows the comparisons for average cool gilt rectal temperatures at 6:30 a.m., 10:30 a.m., 2:30 p.m., 6:30 p.m. and 10:30 p.m. for days 2, 3, 4 and 5 of confinement.

Figure 7 illustrates a trend for the 6:30 a.m. average cool gilt rectal temperature to be lower than any other average rectal temperature for either day 2, 3, 4 or 5 of the confinement period. This suggests that a diurnal body temperature fluctuation was occurring in the gilts under a relatively constant temperature, humidity, wind velocity and lighting environment. Caunice and Pullar (1959) reported that after a three week exposure of pigs to constant temperature and lighting the 24 hour heat production cycle was not diminished. Bligh (1965) studying 24 hour rhythm in different mammalian species reported that body temperature fluctuated between 1.8^{o} and $5.4^{o}F.$ Also illustrated in this figure is a trend for average cool gilt rectal temperature to increase after rectal temperatures were taken and the gilts were fed at 6:30 a.m. each day. Average cool gilt rectal temperature was then observed to decrease at approximately 2:30 p.m. and 6:30 p.m. on days 2

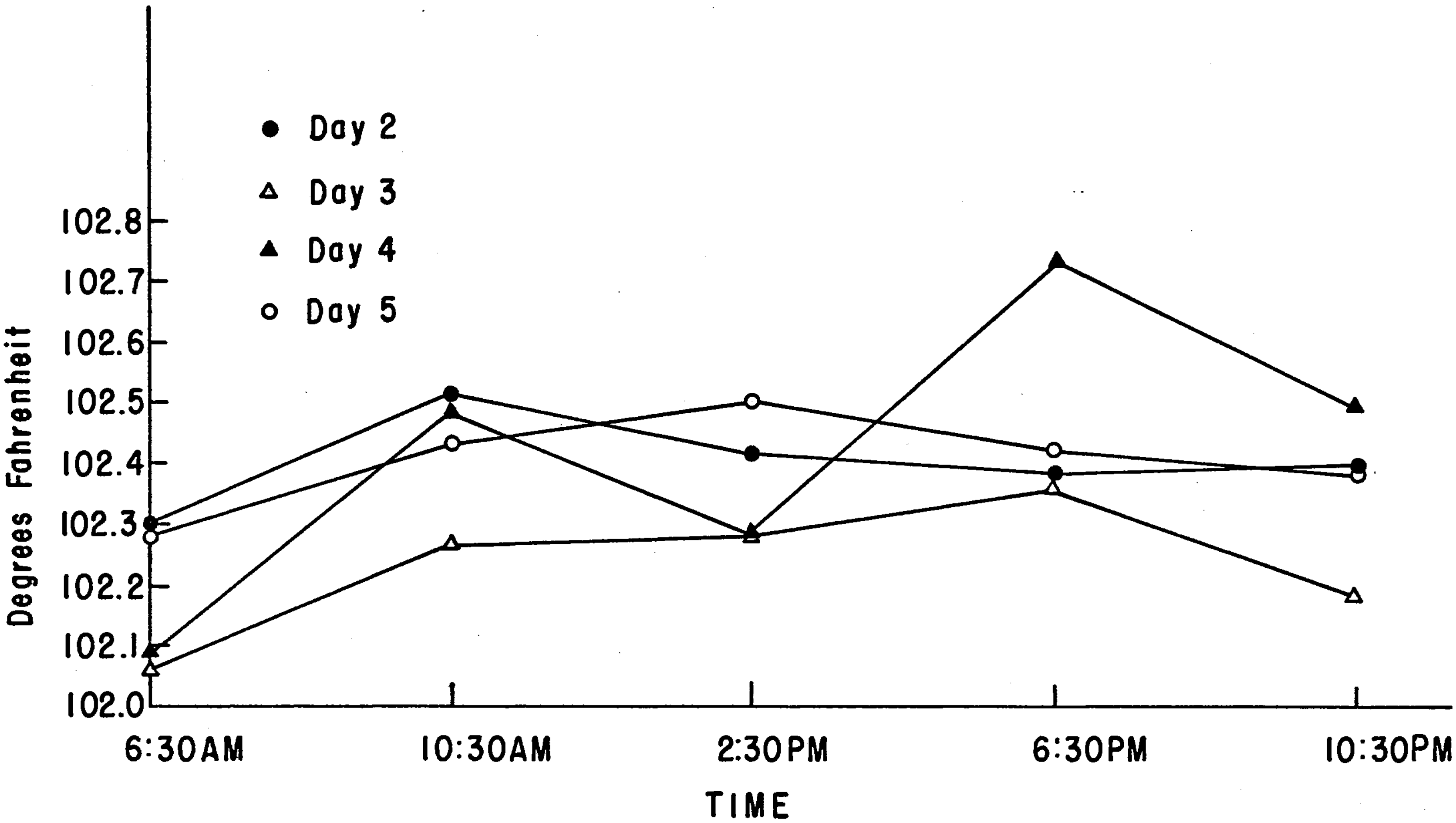

Figure 7. Average Cool Gilt Rectal Temperature Comparisons at Designated Time Intervals

and 3 and 10:30 a.m. on days 4 and 5, respectively. The increased gilt rectal temperature at 6:30 a.m. may have resulted from feed intake and/or increased gilt activity. Bond et al. (1964) reported that less than 15 minutes after pigs were fed, rectal temperature increased. The actual 6:30 a.m. mean cool rectal temperature versus the 10:30 a.m., 2:30 p.m., 6:30 p.m. and 10:30 p.m. temperature comparisons for days 2, 3, 4 and 5 of confinement are presented in Table XVIII of the Appendix.

Comparisons for average hot gilt rectal temperatures at 6:30 a.m., 10:30 a.m., 2:30 p.m., 6:30 p.m. and 10:30 p.m. for days 2, 3, 4 and 5 of confinement are shown in Figure 8. From this graph it is evident that the heat stressed gilts were also exhibiting low daytime rectal temperatures at 6:30 a.m. on each day of confinement. The trend was for the 6:30 a.m. average hot gilt rectal temperature to be lower for each consecutive day of high temperature exposure with the daytime peak rectal temperature occurring at 2:30 p.m. and remaining relatively constant throughout the rest of the day. The increase in average hot gilt rectal temperature after feeding at 6:30 a.m. to 10:30 a.m. tended to be less than the increase observed in the cool chamber gilts. This difference may have been a direct result of the variation in metabolic heat production and increased gilt activity as indicated by the eating habit differences between the cool and hot chamber gilts. The cool chamber gilts tended to be more active and to consume their daily 4 pound feed allottment prior to 10:30 a.m. each day. However, the high temperature gilts were observed to be consuming their feed over a 24 hour period. Ingram and Mount (1965) found that level of food intake by the pig is a great factor in apparent heat adaptation. Lowered feed

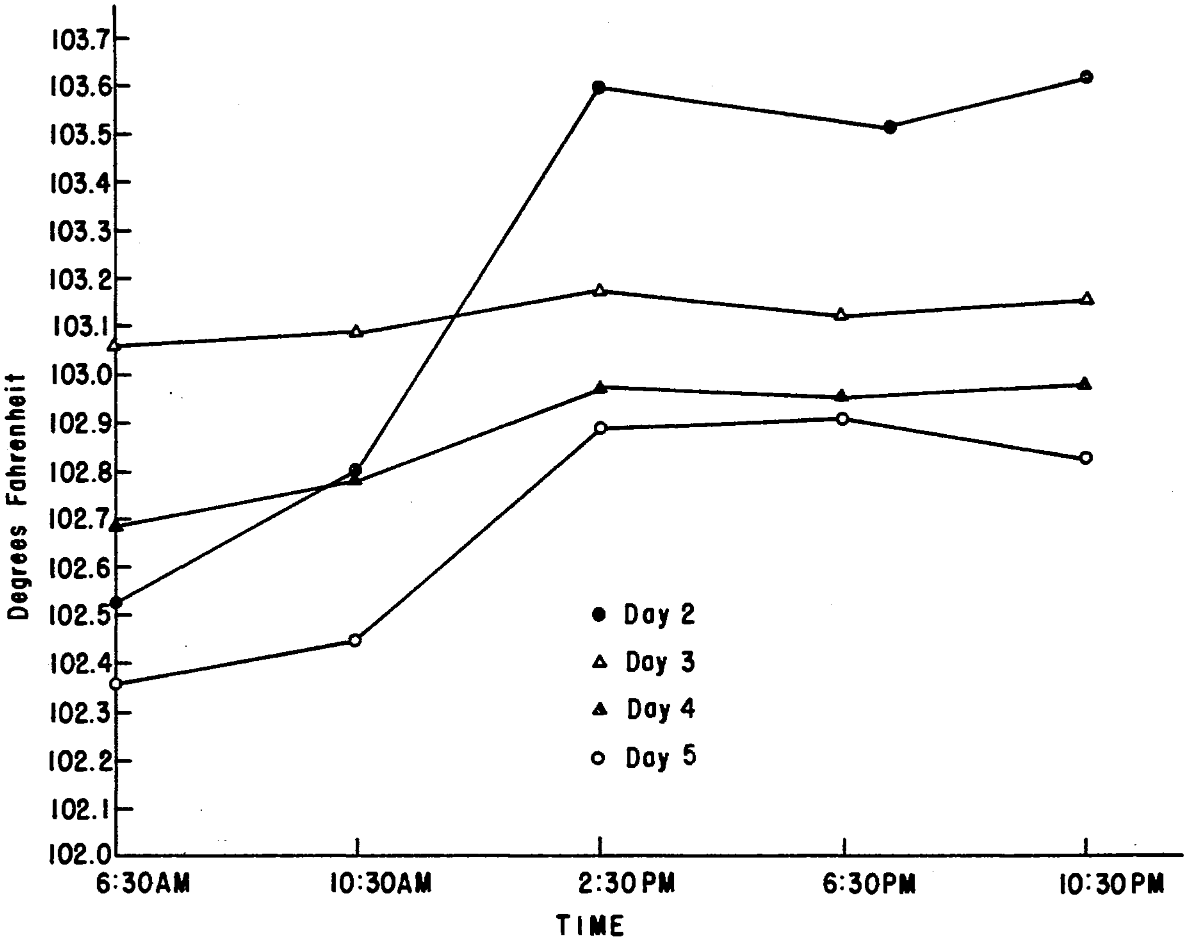

Figure 8. Average Heat Stress Gilt Rectal Temperature Comparisons at Designated Time Intervals

consumption in swine kept at high temperatures has been reported by Edwards _et al_. (1968), Teaque _et al_. (1968) and Mangöld _et al_. (1963). During this study daily feed consumption data were not available.

The actual 6:30 a.m. mean heat stress gilt rectal temperature versus the 10:30 a.m., 2:30 p.m., 6:30 p.m. and 10:30 p.m. temperatures comparisons for days 2, 3, 4 and 5 of confinement are presented in Table XIX of the Appendix.

Respiration Rate

The average cool and heat stress gilt respiration rates are illustrated in Figure 9.

Average respiration frequency for the gilts exposed to high temperature increased when chamber temperature was gradually elevated to 85°F. on day 2 of confinement. This suggests that the gilts were attempting to regulate their body temperature by increasing their rate of evaporative heat loss from the lungs. Heitman and Hughes (1949) also reported that as air temperature increases the respiration rate and body temperature of swine increases. The comparisons between average cool and heat stress gilt respiration rates per minute are given in Table XI.

The actual means and standard errors for cool and hot gilt respiration rates are presented in Table XX of the Appendix. The average respiration rate for heat stressed gilts was significantly higher than average cool gilt respiration frequency from 10:30 a.m. on day 2 following temperature elevation through day 6 of confinement. As also indicated in Figure 9 the hot gilts exhibited peak respiration rates at 6:30 a.m. on day 3 and 6:30 p.m. on days 4 and 5, respectively, with the tendency for this daytime high average respiration to decrease with

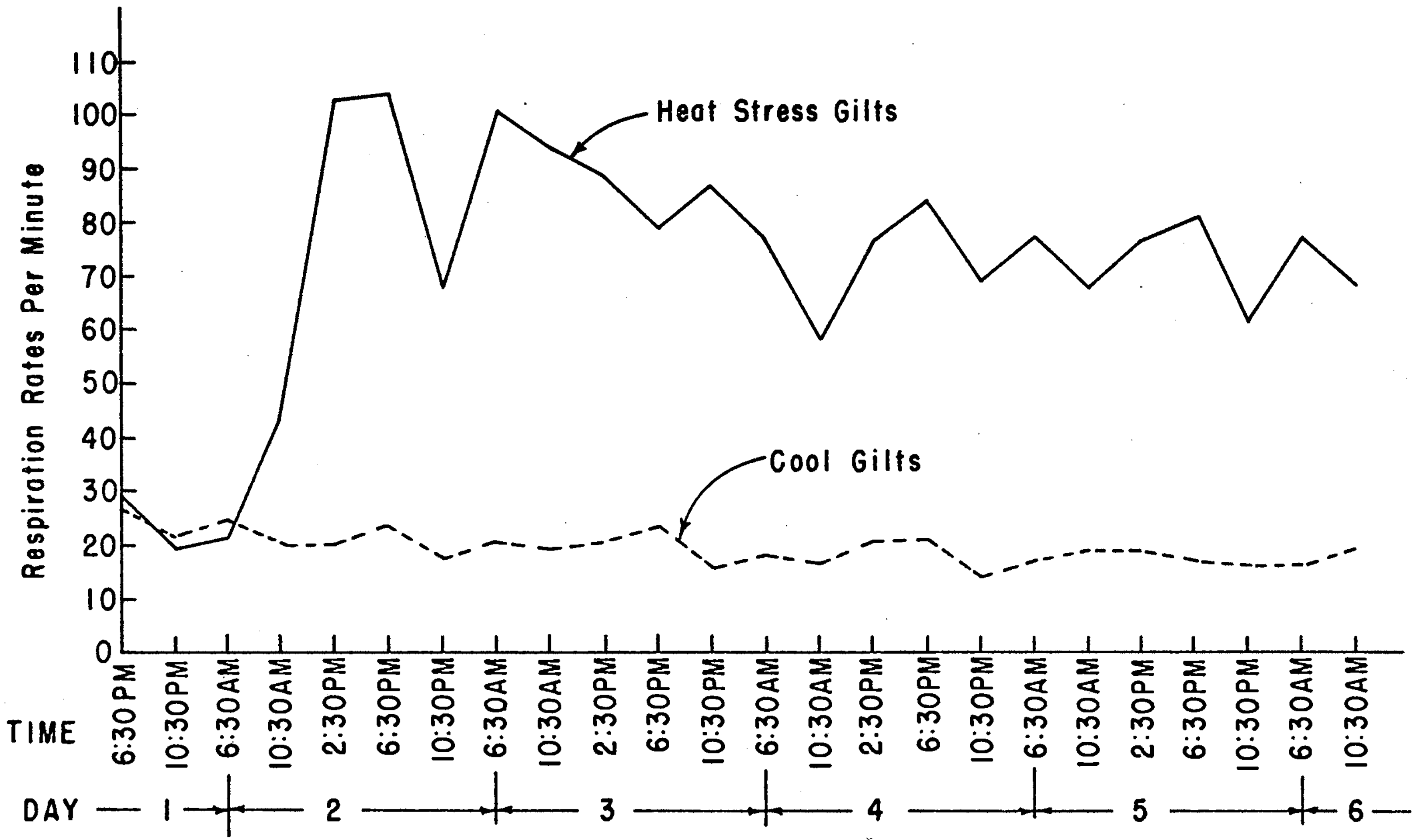

Figure 9. Average Cool and Heat Stress Gilt Respiration Rate Per Minute Comparisons at Different Stages of Confinement

TABLE XI

COMPARISONS BETWEEN AVERAGE COOL AND HOT CHAMBER GILT RESPIRATION RATES AT DESIGNATED TIME INTERVALS

Day	Time	Cool Chamber Gilt Resp. Rate	Hot Chamber Gilt Resp. Rate	Difference
1	6:30 P.M.	26.58	28.46	1.88
	10:30 P.M.	21.50	19.64	-1.86
2	6:30 A.M.	24.75	21.02	-3.73
	10:30 A.M.	20.00	43.56	23.56**
	2:30 P.M.	20.00	103.73	83.73***
	6:30 P.M.	24.00	104.73	80.73***
	10:30 P.M.	17.50	68.46	50.96***
3	6:30 A.M.	20.08	101.36	81.28***
	10:30 A.M.	19.83	94.00	74.17***
	2:30 P.M.	20.17	89.82	69.65***
	6:30 P.M.	23.33	79.18	55.85***
	10:30 P.M.	15.83	87.27	71.44***
4	6:30 A.M.	18.33	77.55	59.22***
	10:30 A.M.	16.92	58.55	41.63***
	2:30 P.M.	20.58	76.73	56.15***
	6:30 P.M.	21.08	84.82	63.74***
	10:30 P.M.	14.92	89.64	74.72***
5	6:30 A.M.	17.25	78.27	61.02***
	10:30 A.M.	19.08	68.00	48.92***
	2:30 P.M.	19.08	77.00	57.92***
	6:30 P.M.	17.67	81.00	63.33***
	10:30 P.M.	16.00	61.00	45.00***
6	6:30 A.M.	16.33	77.64	61.31***
	10:30 A.M.	19.58	68.73	49.15***

**Significant ($P < .01$).

***Significant ($P < .001$).

length of exposure. Thompson (1963) observed the respiration rate in 10 Holstein heifers to increase after initial heat exposure and then decline with continued exposure. The average cool gilt respiration rate tended to be increased from the 10:30 p.m. reading at 6:30 a.m. each day of confinement. These fluctuations in respiration frequencies probably reinforced the diurnal body temperature fluctuation observed during this study. Bond *et al*. (1967) studying Duroc pigs exposed to high temperature found that respiration rates appeared to exhibit a rhythmic diurnal increase between 5:00 p.m. and 7:00 p.m. each day when chamber temperature was constant.

SUMMARY

Two temperature, humidity and wind velocity control chambers were utilized to study the effects of heat stress on the rectal temperature and respiration rate of gilts. Since the chambers had not been operated prior to this study, the investigation was also necessary to determine the limitations and capabilities of the environmental equipment to function as a controlled environment. Each chamber was equipped with a restraining crate designed to confine two 200 pound pigs.

This study was conducted for a 6 week period in the spring of 1970, utilizing 24 purebred Hampshire gilts with an average age of 7 months and weighing 208.9 ± 2.9 lbs. Two gilts were allotted at random to either a cool or hot chamber where each gilt received 4 lbs. of feed at 6:30 a.m. daily and where water was available _ad libitum_.

On Monday of each week both chambers were operated at 70°F., 60 percent relative humidity and 5 m.p.h. wind velocity to allow an adjustment period for the gilts. The temperature in one chamber was elevated to 80°F. and again to 85°F. at 6:30 a.m. and 10:30 a.m., respectively, on Tuesday and were maintained at this level until Saturday of each week.

The gilts were removed from the chambers at approximately 10:30 a.m. on Saturday of each week and transported back to the Experimental Swine Barn.

The average cool and hot chamber temperatures and relative humidities were 69.9°F. and 84.8°F. with 61.5% and 60.3%, respectively. The

cool and hot chamber temperatures and the hot chamber humidities were more controllable to the desired levels than was the cool chamber humidity. The cool chamber dehumidifiers did not cycle during the entire experiment, indicating a lesser degree of humidity control.

Four gilts in the cool chamber and six gilts in the heat chamber were observed to display signs of estrus on either days 3 or 4 of the confinement period.

Week was a highly significant ($P < .01$) source of variation for cool gilt rectal temperatures on day 2. This difference may have resulted from gilts coming from different environments each week to approximately the same environment conditions. There also was a highly significant ($P < .01$) week difference on day 4 which possibly resulted from 4 cool gilts, during different weeks, exhibiting increases in rectal temperature on the day of estrus. A diurnal body temperature rhythm was indicated by a highly significant ($P < .01$) difference for time on day 4.

Average cool and heat stress gilt rectal temperature was 102.5°F. and 103.0°F., respectively. As hot chamber temperature was elevated to 85°F. average gilt rectal temperature and respiration rate increased. The gilts appeared to adapt to heat stress on about the fourth or fifth day of confinement, but average daytime high hot gilt rectal temperature was significantly ($P < .01$) higher than average daytime high cool gilt rectal temperature for days 2, 3, 4 and 5 of confinement. The majority of heat stress gilt reduction in rectal temperature seemed to occur from the second to the third confinement day.

A 24 hour diurnal rectal temperature rhythm was indicated by lower 6:30 a.m. average rectal temperatures each day for both gilt groups. This rhythm was undoubtedly reinforced by feeding and increased gilt activity during the day. The cool chamber gilts were observed to eat faster and to be more active than the heat stressed gilts. There was a trend for average cool and hot chamber gilt respiration rates to fluctuate during each day with a tendency for the hot chamber gilt average daytime high respiration rate to decline with length of exposure.

LITERATURE CITED

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APPENDIX

TABLE XII

MEANS AND STANDARD DEVIATIONS OF COOL CHAMBER TEMPERATURE AND RELATIVE HUMIDITY AT DESIGNATED TIME INTERVALS

Day	Time	Temperature (°F.)	St. Dev.	Relative Humidity (%)	St. Dev.
1	6:30 P.M.	69.5	1.05	61.3	2.66
	10:30 P.M.	70.0	0.00	61.0	2.97
2	6:30 A.M.	69.8	0.41	61.2	3.37
	10:30 A.M.	69.8	1.33	61.0	3.58
	2:30 P.M.	69.7	0.52	60.3	3.83
	6:30 P.M.	69.7	0.82	61.2	3.76
	10:30 P.M.	69.8	0.41	60.0	3.85
3	6:30 A.M.	69.7	0.52	60.2	3.76
	10:30 A.M.	70.2	0.98	60.8	2.79
	2:30 P.M.	70.3	0.82	62.2	2.04
	6:30 P.M.	70.5	1.38	63.0	2.00
	10:30 P.M.	70.3	1.03	62.7	2.25
4	6:30 A.M.	70.2	0.98	61.5	2.51
	10:30 A.M.	70.0	1.10	61.3	2.73
	2:30 P.M.	69.8	0.41	62.2	2.71
	6:30 P.M.	70.0	0.00	62.5	3.02
	10:30 P.M.	69.8	0.41	62.2	2.71
5	6:30 A.M.	70.0	1.10	61.0	2.83
	10:30 A.M.	70.0	1.10	61.5	2.51
	2:30 P.M.	69.5	1.05	62.0	2.61
	6:30 P.M.	70.0	0.00	63.0	2.19
	10:30 P.M.	69.8	1.17	61.5	2.26
6	6:30 A.M.	70.0	1.55	60.8	2.48
	10:30 A.M.	69.5	0.55	61.8	1.90

TABLE XIII

MEANS AND STANDARD DEVIATIONS OF HOT CHAMBER TEMPERATURE AND RELATIVE HUMIDITY AT DESIGNATED TIME INTERVALS

Day	Time	Temperature (°F.)	St. Dev.	Relative Humidity (%)	St. Dev.
1	6:30 P.M.	70.2	0.45	62.6	2.51
	10:30 P.M.	70.0	0.71	62.0	2.12
2	6:30 A.M.	69.8	0.84	61.2	2.59
	10:30 A.M.	81.2	1.79	61.4	3.13
	2:30 P.M.	84.8	0.84	62.4	3.13
	6:30 P.M.	85.0	0.00	62.0	2.53
	10:30 P.M.	84.8	0.41	59.3	1.03
3	6:30 A.M.	84.8	0.41	60.3	1.86
	10:30 A.M.	85.0	0.00	60.8	1.60
	2:30 P.M.	85.0	0.00	60.2	1.17
	6:30 P.M.	85.0	0.00	60.7	0.82
	10:30 P.M.	84.8	0.41	59.8	1.17
4	6:30 A.M.	84.7	0.52	60.3	1.03
	10:30 A.M.	84.5	0.55	60.3	1.03
	2:30 P.M.	84.8	0.45	60.0	0.71
	6:30 P.M.	85.0	0.00	60.2	0.45
	10:30 P.M.	84.5	0.45	59.6	1.14
5	6:30 A.M.	84.5	0.84	59.6	1.14
	10:30 A.M.	85.2	0.45	60.0	0.71
	2:30 P.M.	85.0	0.00	60.2	1.10
	6:30 P.M.	85.2	0.45	60.4	1.52
	10:30 P.M.	85.0	1.00	60.0	1.22
6	6:30 A.M.	84.4	0.55	59.6	0.67
	10:30 A.M.	84.2	0.45	60.2	1.10

TABLE XIV

WEEKLY MEANS AND STANDARD DEVIATIONS OF COOL CHAMBER TEMPERATURE AND RELATIVE HUMIDITY

Week	Temperature ($^oF.$)	St. Dev.	Relative Humidity (%)	St. Dev.
1	70.38	0.92	59.71	1.63
2	70.50	1.18	62.33	2.96
3	69.86	0.46	61.63	1.66
4	69.79	0.51	64.96	2.58
5	69.25	1.53	59.79	2.11
6	69.71	0.46	60.63	1.13

TABLE XV

WEEKLY MEANS AND STANDARD DEVIATIONS OF HOT CHAMBER TEMPERATURES AND RELATIVE HUMIDITY

Week	Temperature (°F.)	St. Dev.	Relative Humidity (%)	St. Dev.
1	85.20	0.44	59.75	0.44
2	85.10	0.32	61.20	0.92
3	84.58	0.51	59.21	0.63
4	84.60	0.50	60.45	2.04
5	84.85	0.49	61.15	1.14
6	84.85	0.37	60.50	1.43

TABLE XVI

MEANS AND STANDARD ERRORS OF COOL AND HOT CHAMBER GILT RECTAL TEMPERATURE AT DESIGNATED TIME INTERVALS

Day	Time	Average Cool Gilt Rectal Temperature (°F.)	Average Heat Stress Gilt Rectal Temperature (°F.)
1	6:30 P.M.	102.95 ± 0.16	102.95 ± 0.10
	10:30 P.M.	102.02 ± 0.26	102.95 ± 0.15
2	6:30 A.M.	102.28 ± 0.16	102.53 ± 0.12
	10:30 A.M.	102.43 ± 0.09	102.80 ± 0.18
	2:30 P.M.	102.50 ± 0.14	103.59 ± 0.20
	6:30 P.M.	102.42 ± 0.14	103.51 ± 0.13
	10:30 P.M.	102.38 ± 0.14	103.61 ± 0.11
3	6:30 A.M.	102.06 ± 0.09	103.06 ± 0.15
	10:30 A.M.	102.27 ± 0.09	103.09 ± 0.20
	2:30 P.M.	102.29 ± 0.07	103.17 ± 0.21
	6:30 P.M.	102.36 ± 0.12	103.12 ± 0.18
	10:30 P.M.	102.18 ± 0.13	103.15 ± 0.16
4	6:30 A.M.	102.09 ± 0.09	102.68 ± 0.21
	10:30 A.M.	102.48 ± 0.12	102.78 ± 0.28
	2:30 P.M.	102.29 ± 0.07	102.97 ± 0.19
	6:30 P.M.	102.73 ± 0.12	102.96 ± 0.20
	10:30 P.M.	102.49 ± 0.12	102.98 ± 0.21
5	6:30 A.M.	102.30 ± 0.09	102.36 ± 0.16
	10:30 A.M.	102.51 ± 0.11	102.45 ± 0.09
	2:30 P.M.	102.42 ± 0.06	102.89 ± 0.23
	6:30 P.M.	102.38 ± 0.07	102.91 ± 0.20
	10:30 P.M.	102.39 ± 0.11	102.83 ± 0.16
6	6:30 A.M.	102.23 ± 0.09	102.45 ± 0.11
	10:30 A.M.	102.35 ± 0.08	102.46 ± 0.18

TABLE XVII

MEAN DAYTIME HIGH (2:30 P.M., 6:30 P.M. AND 10:30 P.M.) COOL AND HEAT STRESS GILT RECTAL TEMPERATURE COMPARISONS FOR DAYS 2, 3, 4 AND 5 OF CONFINEMENT

Day		Mean Cool Gilt Temperature (°F.)	Mean Heat Stress Gilt Temperature (°F.)
2	Actual	102.4	103.6
	Difference		1.2**
3	Actual	102.3	103.2
	Difference		0.9**
4	Actual	102.5	103.0
	Difference		0.5**
5	Actual	102.4	102.9
	Difference		0.5**

**Significant ($P < .01$).

TABLE XVIII

COMPARISONS BETWEEN COOL GILT MEAN RECTAL TEMPERATURES (^{o}F.) FOR 6:30 A.M. VERSUS 10:30 A.M., 2:30 P.M., 6:30 P.M., AND 10:30 P.M. FOR DAYS 2, 3, 4 AND 5 OF CONFINEMENT

		Time				
Day		6:30 A.M. vs	10:30 A.M.-	2:30 P.M.-	6:30 P.M.-	10:30 P.M.
2	Actual	102.3	102.4	102.5	102.4	102.4
	Difference		0.1	0.3	0.1	0.1
3	Actual	102.1	102.3	102.3	102.4	102.2
	Difference		0.2	0.2	0.3	0.1
4	Actual	102.1	102.5	102.3	102.7	102.5
	Difference		0.4*	0.2	0.6**	0.4*
5	Actual	102.3	102.5	102.4	102.4	102.4
	Difference		0.2	0.1	0.1	0.1

*Significant ($P < .05$).

**Significant ($P < .01$).

TABLE XIX

COMPARISON BETWEEN HOT GILT AVERAGE RECTAL TEMPERATURES (°F.) FOR 6:30 A.M. VERSUS 10:30 A.M., 2:30 P.M., 6:30 P.M. AND 10:30 P.M. FOR DAYS 2, 3, 4 AND 5 OF CONFINEMENT

		Time				
Day		6:30 A.M. vs	10:30 A.M.	2:30 P.M.	6:30 P.M.	10:30 P.M.
2	Actual	102.5	102.8	103.6	103.5	103.6
	Difference		0.3	1.1**	1.0**	1.1**
3	Actual	103.1	103.1	103.2	103.1	103.2
	Difference		0.0	0.1	0.0	0.1
4	Actual	102.7	102.8	103.0	103.0	103.0
	Difference		0.1	0.3	0.3	0.3
5	Actual	102.4	102.5	102.9	102.9	102.8
	Difference		0.1	0.5	0.5	0.4

**Significant ($P < .01$).

TABLE XX

MEANS AND STANDARD ERRORS FOR COOL AND HOT CHAMBER GILT RESPIRATION RATE AT DESIGNATED TIME INTERVALS

Day	Time	Average Gilt Respiration Rate (Cool Chamber)	Average Gilt Respiration Rate (Hot Chamber)
1	6:30 P.M.	26.58 ± 3.36	28.46 ± 3.07
	10:30 P.M.	21.50 ± 3.09	19.64 ± 1.87
2	6:30 A.M.	24.75 ± 6.20	21.02 ± 2.90
	10:30 A.M.	20.00 ± 1.86	43.56 ± 6.39
	2:30 P.M.	20.00 ± 1.67	103.73 ±11.65
	6:30 P.M.	24.00 ± 3.61	104.73 ±11.10
	10:30 P.M.	17.50 ± 2.37	68.46 ± 8.81
3	6:30 A.M.	20.08 ± 3.84	101.36 ±11.79
	10:30 A.M.	19.83 ± 1.60	94.00 ±11.94
	2:30 P.M.	20.17 ± 2.50	89.82 ± 9.63
	6:30 P.M.	23.33 ± 4.17	79.18 ± 9.12
	10:30 P.M.	15.83 ± 0.83	87.27 ±10.71
4	6:30 A.M.	18.33 ± 2.22	77.55 ± 9.64
	10:30 A.M.	16.92 ± 1.06	58.55 ±10.23
	2:30 P.M.	20.58 ± 2.39	76.73 ±11.71
	6:30 P.M.	21.08 ± 2.17	84.82 ±12.61
	10:30 P.M.	14.92 ± 0.66	89.64 ± 9.46
5	6:30 A.M.	17.25 ± 2.16	78.27 ± 8.99
	10:30 A.M.	19.08 ± 1.04	68.00 ±11.06
	2:30 P.M.	19.08 ± 1.89	77.00 ± 6.83
	6:30 P.M.	17.67 ± 0.94	81.00 ±10.41
	10:30 P.M.	16.00 ± 1.04	61.00 ± 7.06
6	6:30 A.M.	16.33 ± 0.53	77.64 ±10.32
	10:30 A.M.	19.58 ± 2.24	68.73 ± 9.10

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