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Partial Cooling of the Environment in Free Stalls for Sows During Farrowing and Lactation

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PARTIAL COOLING OF THE ENVIRONMENT IN FREE STALLS FOR SOWS DURING FARROWING AND LACTATION

BY

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PARTIAL COOLING OF THE ENVIRONMENT IN FREE STALLS FOR SOWS DURING FARROWING AND LACTATION

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Advisor Date

Head of Major Department Date

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INTRODUCTION

The swine industry generates an income of 100 million dollars per year for South Dakota farmers, amounting to 15 percent of the total farm income, which ranks swine production second only to the beef industry as a source of farm income in South Dakota, Aanderud (1)[1]. Over the last ten years, swine production has averaged 2.9 million hogs annually which is 3.2 percent of the production in the United States, ranking South Dakota ninth nationally. To keep pace with production in other areas of the country, South Dakota farmers must learn and employ the most advanced production techniques. Agricultural engineers must continue to improve the total environment, as it relates to animal performance, to parallel advances in genetics and nutrition being made by animal scientists.

The total environment depends on several factors which can be divided into three general areas: thermal, physical and social. Thermal factors include air temperature, relative humidity, air movement, and temperature of the radiant and conductive surfaces. Light, sound, space and equipment are examples of physical factors. Social factors include the number of animals per pen, social behavior and "pecking order."

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[1]Numbers in parenthesis refer to literature cited.

The importance of thermal factors has been emphasized by the number of investigators who have studied hog reaction to various temperature conditions. Kelly, Heitman and Morris (16) summarized many of the basic reactions in the following statement:

> As much as 30 percent of the gross energy of the feed may be dissipated as heat. Four avenues of heat dissipation are available to the animal for cooling itself--conduction, convection, radiation and evaporation. The first three depend on the difference between the surface temperature of the animal and the temperature of the air and of the surroundings to control the heat loss rate. As the environmental temperature increases the animal surface temperature also increases, but at a slower rate. The difference between the animal's surface temperature and the temperature of the air and the surroundings then becomes less and less, and it becomes more difficult for the animal to lose, through the skin, the amount of heat necessary to retain normal body temperature. In an effort to keep a normal temperature, the animal then cuts down on its feed intake and increases its rate of respiration. Finally because the hog is unable to dissipate all the heat, a part of it must be stored, with a consequent increase in body temperature.

Technological advances have improved methods of rearing pigs during cold weather. Many systems have been developed to provide heating and ventilation levels that are adequate in most swine housing systems. However, air distribution systems in farrowing houses need improvement since the amount of air required to keep sows comfortable in summer could result in a draft on pigs. Ross (25) reported that facilities and equipment for cold weather were developed to the extent that -20 F weather is preferable to 95 F for farrowing, indicating a need to investigate performance and cost of cooling systems for warm weather operations.

Many of the technological advances in the swine industry have resulted in increased capital requirements for buildings and equipment. This has made multiple farrowing, including summer farrowing, a near necessity. Hog farmers recognize the problem of sow mortality due to severe heat stress during periods of high ambient temperatures, and hog producers utilizing the free stall farrowing system recognize yet another problem, that of poor stall occupancy. Sows in this type of system tend to seek relief by leaving their stalls and lying in moist or breezy areas. This decreased stall occupancy has resulted in pigs being severely neglected, reduced weight gains and starvation in extreme cases.

A need to modify the thermal environment in the free stalls to provide sows with thermal relief is desired. Preliminary work has indicated that cooling the entire environment is very expensive. Therefore, an alternate system of partial modification of the environment using a stream of cooled air directed on sows was investigated. The objectives of this research were the following:

1. Determine the effects of cooled air directed

toward the sow on swine performance as indicated by pig weight gain, mortality and weight change of the sow.

2. Evaluate sow response in terms of respiration rate and pen occupancy.
3. Describe the environmental conditions of temperature and relative humidity within the farrowing building.
4. Determine the electric energy use of the environmental control equipment.

REVIEW OF LITERATURE

Environment has been recognized as a factor which influences swine performance and physiological response. Heitman and Hughes (12) cited an 1883 Kansas publication by Shelton which stated that pigs kept outside during winter required 25 percent more feed than pigs housed in the basement of a warm barn. More recently, studies were designed to investigate performance and physiological response of hogs with respect to varying environmental conditions. Major conditions investigated were temperature, air velocity and relative humidity.

Bond, Kelly and Heitman (6) reported that pigs gained weight much faster when subjected to an optimum air temperature which was found to be 73.5 F for a 100-lb pig and 64.0 F for a 350-lb hog. Bond, Kelly and Heitman (5) found that sows gained weight during lactation at 60 and 70 F temperature, while a sow at 80 F lost weight but raised the largest and heaviest litter. Mangold, Hazen and Hays (18) concluded that swine fed "ad libitum" and raised in a range of air temperatures from 50 to 75 F exhibited similar levels of performance. Also, pigs exposed to temperatures above 75 F consumed less feed and had a better feed efficiency but a poorer growth rate than pigs raised at 60 F. Below 50 F, the pigs consumed more feed but had a poorer rate of gain and feed efficiency than the 60 F group. Bond, Kelly and Heitman (5) found that baby pigs seemed comfortable at 80 F, light hogs huddled for warmth below 70 F and heavy hogs began to huddle near 60 F. Heitman and Hughes (12) noted that respiration rates varied directly with temperature for groups of pigs averaging 200-lb and 100-lb (Figure 1). Respiration rates of 20 breaths per minute were recorded for 200-lb pigs at 40 F air temperature, while 100-lb pigs breathed 25 times per minute. The effect of temperature was more severe for larger hogs as respiration rates at 95 F doubled the rates of the smaller pigs (160 versus 80 breaths per minute). Morrison, Bond and Heitman (21) found that respiration rates of 90-kg pigs increased from 15 breaths per minute at 60 F dry-bulb temperature and 50 F dew-point temperature to 86 breaths per minute at 85 F dry-bulb temperature and 50 F dew-point temperature.

Investigators have concluded that humidity affects swine response. Morrison, Bond and Heitman (22) reported that hogs raised at their maximum gain temperatures and at a temperature 10 F above maximum gain temperature showed a decrease in growth rate as relative humidity was raised from 30 to 95 percent. Morrison, Bond and Heitman (21) noted that respiration rates increased from 86 to 143 breaths per minute at a temperature of 85 F dry bulb when dew-point temperature was raised from 50 to 82 F.

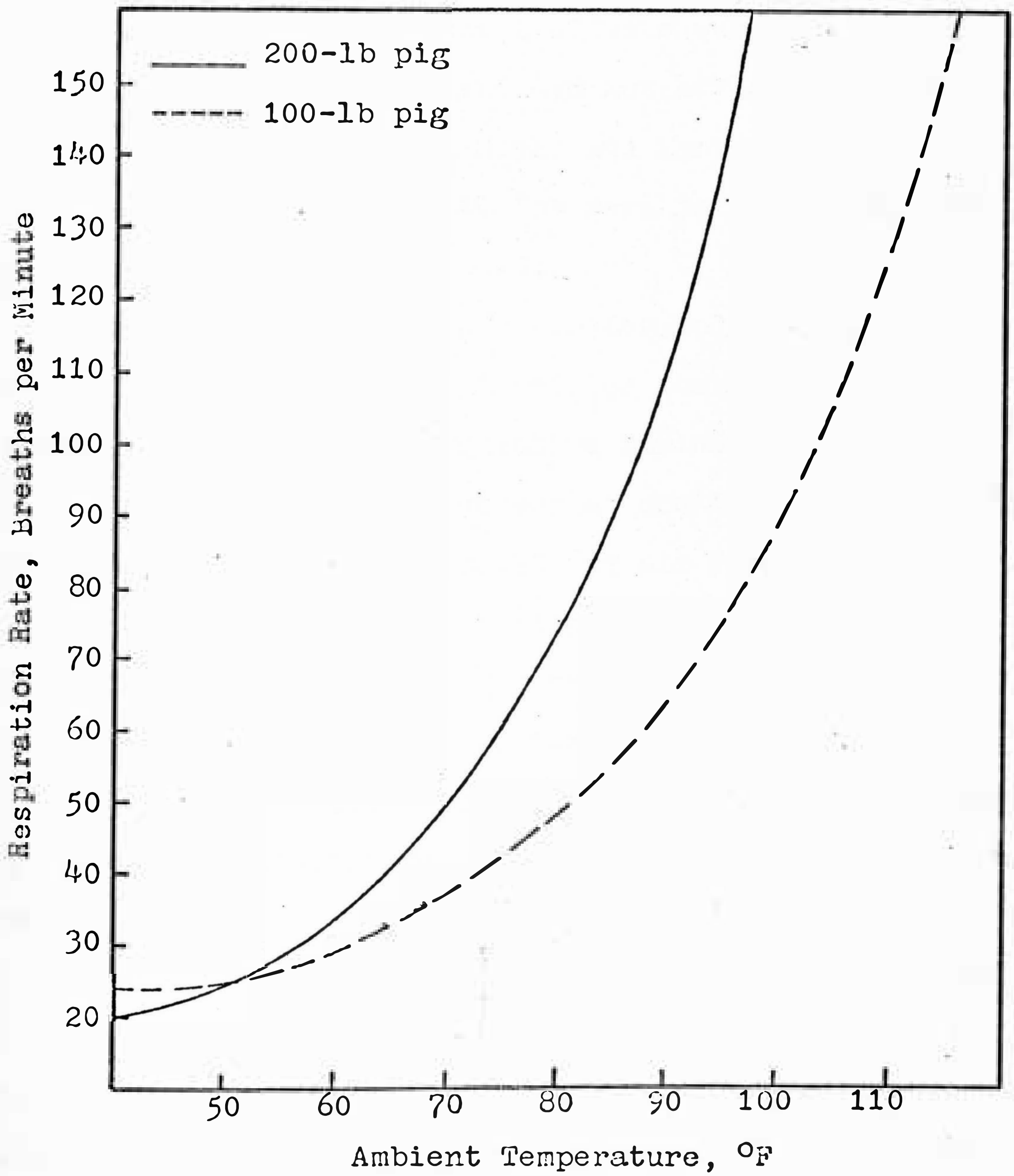

Figure 1. Effect of Temperature on Respiration Rate of Swine, Heitman and Hughes (12)

Bond, Heitman and Kelly (4) determined that increasing air velocities in the range of 35 to 300 fpm improved feed conversion and rate of gain of growing and finishing pigs at temperatures of 95 to 100 F. However, at lower temperatures adverse effects were frequently noted. Rate of air movement did not affect pulse or respiration rates. Nave, Olver and Shove (24) observed that air velocities over 40 fpm were not desirable for pigs under three weeks of age.

Beckett (2) devised a parameter called swine effective temperature which relates combinations of ambient temperatures and relative humidity to dry-bulb temperature of equal pig stress at conditions of 50 percent relative humidity and 20 to 30 fpm air velocity (Figure 2). A major assumption was that respiration rate is an indicator of discomfort. The validity of this assumption was confirmed by Esmay (9). Air at 95 F and 50 percent relative humidity would have a swine effective temperature of 95 F. If moisture were added adiabatically until the relative humidity were 75 percent, the dry-bulb temperature would be 86 F, yielding a swine effective temperature of 87 F, thus the swine effective temperature could be lowered 8 F by evaporative cooling. A change in relative humidity from 30 to 94 percent at an ambient temperature of 90 F would increase swine effective temperature from

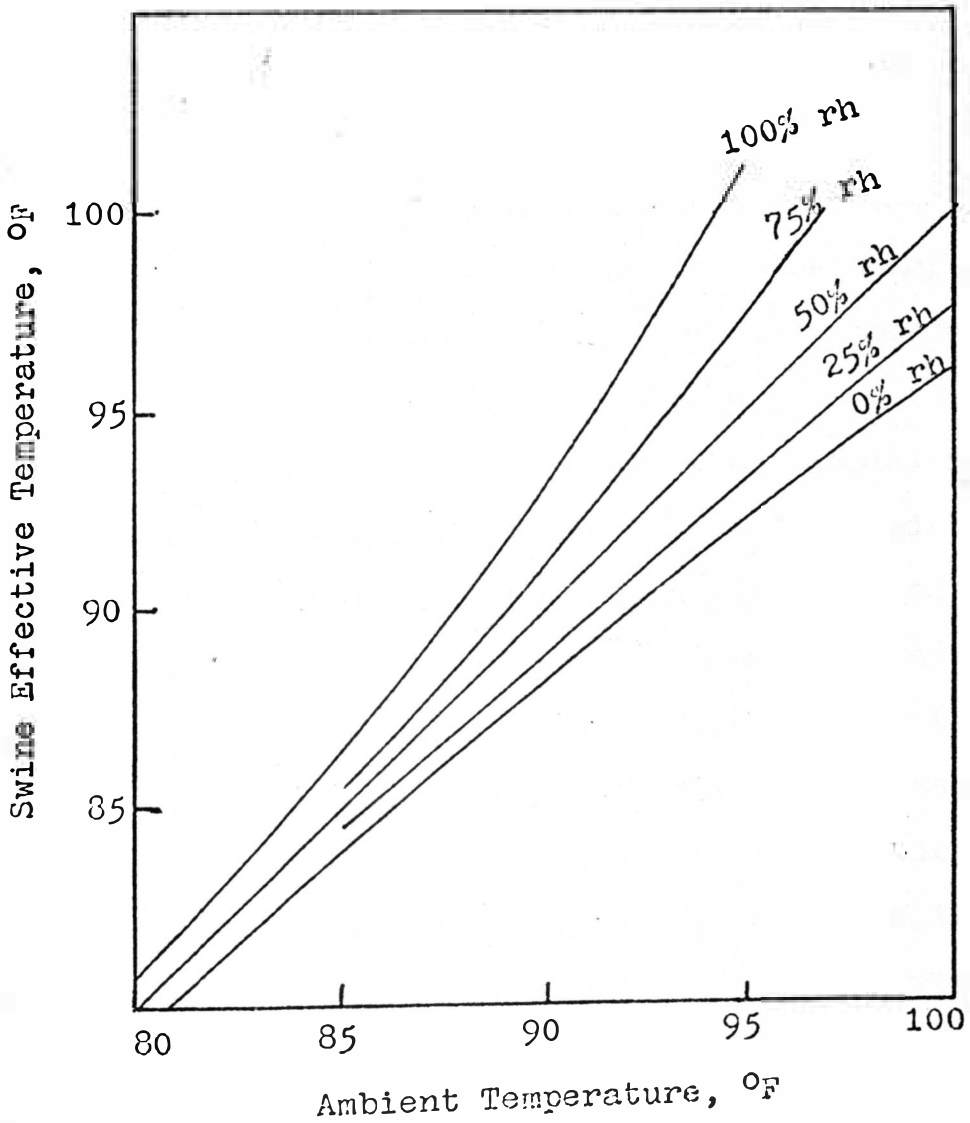

Figure 2. Swine Effective Temperature, Beckett (2)

89.4 to 92.6 F, but a change in relative humidity from 30 to 94 percent at an ambient temperature of 96 F would increase swine effective temperature from 93.8 F to above 100 F. This indicates the greater effect of moisture at higher temperatures. Beckett and Vidrine (3) expanded the concept of swine effective temperature to include the reductions in swine effective temperature caused by higher air velocities, pigs breathing cooled air, radiant temperatures below ambient temperature and numerous factors of lesser importance.

Heat loss from swine and other warm blooded animals, including influencing factors, have been studied by various investigators. Animals have physiological compensation mechanisms which can control both heat loss and heat production to maintain body temperature at the same level under varying environmental conditions. Esmay (9) indicated that animals can reduce heat loss by decreasing skin temperature, maximizing the arrangement of the body covering (hair, feathers, or fur), minimizing evaporative losses and minimizing surface area exposed to the environment. Heat production, thermogenesis, is regulated by mechanisms such as shivering, changes in muscle tonus and secretion from endocrine glands which increases the metabolic heat production. Brody (7) found the period immediately following birth was frequently a critical time in the life of many animals since homeothermic mechanisms are not highly developed; Mount (23) reported that in a cold environment rectal temperature of newborn pigs dropped despite a marked increase in heat production due to shivering. Under the same conditions, rectal temperatures did not fall when the pig was one week old. He also found that thermal conductivity of newborn pigs was greater than hairy animals of similar weight. Butchbaker and Shanklin (8) found respiration rates of newborn pigs remained relatively constant for varying environmental temperatures as low as 75 F. According to Esmay (9), Holub, Forman and Jezkova found the pilomotor (hair raising) and vasomotor (changing blood vessel size) reactions for pigs could be noted at approximately 6 days of age, even though metabolism rate did not change. Maturity of the thermoregulatory system was reached 20 days after birth.

Investigators have observed that pigs in areas of high temperatures tend to behave in a manner facilitating heat loss. Mangold, Hazen and Hays (18) reported growing-finishing pigs at 80 F remained prone and away from others much of the time and kept the floor wet with liquid from body waste and waterers. Brody (7) stated that pigs wallowed in mud or water pools to increase heat loss. Heitman and Hughes (12) found that during warm weather pigs wallowed in the urine from other hogs and turned from side to side which exposed the moist skin surface and increased evaporative heat loss.

Total heat loss has been divided into the following components: conduction, convection, radiation and evaporation. Bond, Kelly and Heitman (6) reported the percentage of heat lost by conduction, convection and radiation decreased from 13, 38 and 35 percent of the total, respectively at 40 F to 3, 5 and 2 percent, respectively at 100 F, while evaporation heat loss markedly increased from 14 to 90 percent (Figure 3). Beckett and Vidrine (3) modeled heat flow in a 150-lb pig and presented partitioned heat loss, BTU per hr per sq ft of hog surface area, versus temperature. This illustrated that total heat loss for swine decreased from 51 to 33 BTU per hr per sq ft when temperature increased from 10 to 100 F (Figure 4). The model was verified with swine heat loss data for temperatures ranging from 40 to 100 F. Total heat loss for a pig of any size can be calculated using the Brody-Comfort formula for the surface area of a pig, which was presented by Esmay (9). Esmay (9) indicated that normally 80 percent of the surface area of a hog is exposed for convection, 75 percent for radiation and 20 percent for conduction. However, when pigs were huddled, the surface area of the

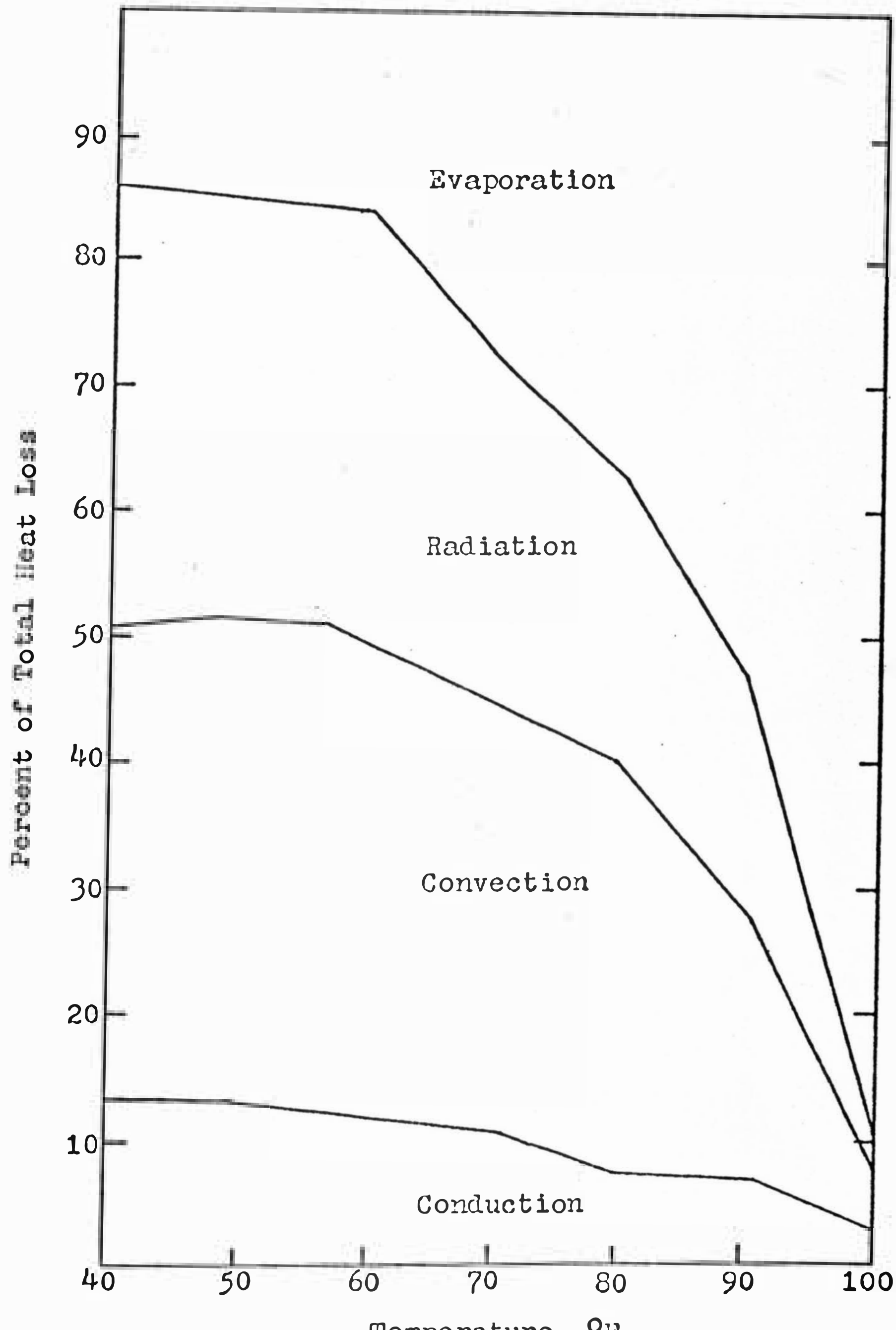

Figure 3. Partitional Heat Loss of Swine, Bond, Kelly and Heitman (6)

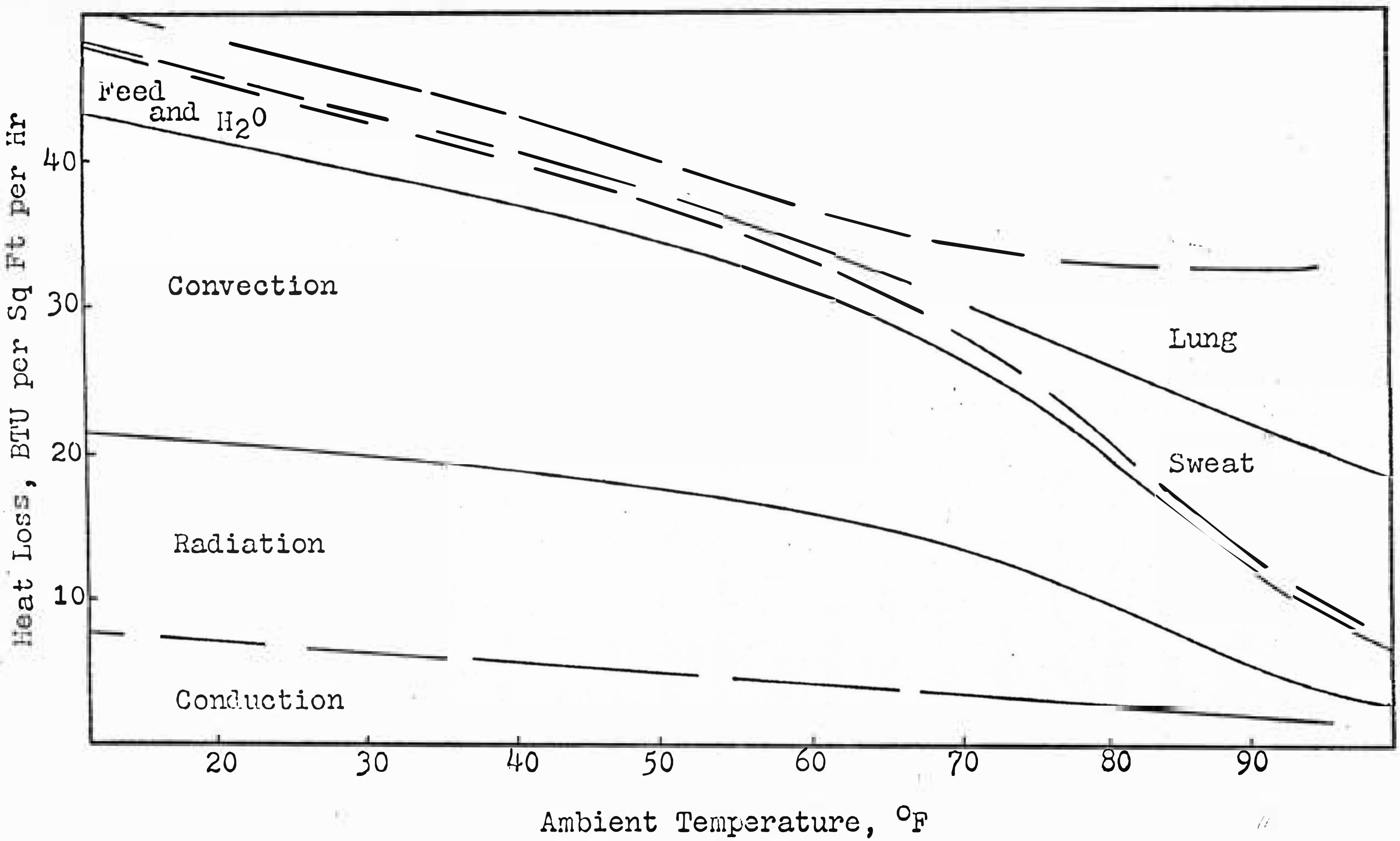

Figure 4. Partitional Heat Loss, Theoretical Model of a 150-lb Pig, Beckett and Vidrine (3)

inner pigs exposed for convection and radiation was reduced to 40 and 35 percent, respectively. Butchbaker and Shanklin (8) stated the total heat loss of huddled pigs approximates the heat loss of an individual pig of equal mass. Also, they concluded that the amount of latent heat lost was relatively uninfluenced by temperature, but ranged from 8 to 100 percent of the total heat loss at 55 and 100 F, respectively. Latent heat loss was a small portion of the total heat loss in the 70 to 90 F range with two-thirds of the remaining heat loss attributed to radiation and one-third to convection.

Many investigators have studied environmental factors which influence heat loss. Bond, Heitman and Kelly (4) found total heat loss varied directly with air velocity, and convective and evaporative heat losses increased from 60 to 80 percent of the total heat loss when air velocity was increased from 35 to 300 fpm at air temperatures up to 100 F. Beckett and Vidrine (3) reported that radiant heat loss remained near 30 percent of the total from 10 F to 70 F but decreased to near zero at 100 F (Figure 4). Evaporative losses through lungs and skin rapidly increased above 70 F. Brody (7) concluded exhaled air may be assumed to be 3.5 F below body temperature and at 90 percent relative humidity. Also, the tidal volume and difference in enthalpy of the incoming and outgoing respiration air determined lung heat loss. Esmay (9) reported that skin evaporation heat loss varies even though pigs are classified as nonsweating animals and that vaporization may take place below the surface of the skin with vapor diffusion dependent on convective air velocities and vapor pressure. Morrison, Bond and Heitman (21) showed skin evaporation doubled and lung heat loss tripled for 90-kg pigs when temperature was increased from 60 to 80 F with dew-point temperature constant at 50 F.

Studies to evaluate methods of increasing heat loss have been performed. Kelly, Bond and Garret (15) reported cooled slabs increased conductive heat loss from 11 to 28 percent of the total heat loss of growing-finishing pigs at an air temperature of 100 F. However, an optimum slab temperature was reached and lower slab temperatures caused less heat loss from pigs to the conductive surface. They concluded that the conductive capacity of the skin surface of pigs limited heat flow at the lower slab temperatures. Spillman and Hinkle (27) found growing and finishing pigs lost the most heat, 130 BTU per sq ft per hr, at an air temperature of 92 F with floor temperature at 75 F. They studied air temperatures ranging from 72 to 92 F and slab temperatures ranging from 70 to 85 F. The average heat loss at air temperatures of 72 and 82 F ranged from 37 to 58 BTU per hr per sq ft regardless of floor temperatures. The Midwest Plan Service (20) recommended intermittent sprinkling to increase heat loss of swine.

Taylor (28) furnished 8 cfm of cooled air directed in the area of the snout of sows to reduce the enthalpy of the respiration air. He concluded that "snout cooled" sows in Indiana exhibited less stress than other sows. The most noticeable indicator was the change in respiration rates. Merkel and Hazen (19) found sows in Iowa receiving 80 cfm of 65 F air were more comfortable than sows receiving 80 cfm of 90 F ambient air, but no significant difference due to treatment was observed in weight gain of the litters.

DESCRIPTION OF RESEARCH FACILITIES

The Curtis Nelson farm eight miles southeast of Brookings, South Dakota, was selected to evaluate environmental conditions and swine performance in a free stall farrowing operation.

The farrowing unit (Figure 5) is an "L" shaped portion of a converted barn. The research facility, which bounds a large open barn area, measures 59.2 ft long on the west side by 15.4 ft wide and 55.2 ft long on the south side by 13.3 ft wide and has a ceiling height of 7.4 ft. Figure 5 includes the dimensions and location of the 19 free stalls, doors, windows and environmental control equipment. The eight single pane windows are 22.5 in. wide by 28 in. high. Access is gained through four hinged doors and one 9-ft long by 7.3-ft high sliding, wooden door of double thick construction. The southwest access door opens to a concrete feeding floor and is divided into upper and lower sections 43 and 35 in. high, respectively. The walls are insulated with 3 5/8 in. of fiberglass, sealed on the inside with a polyethylene vapor barrier and covered with 3/8-in. plywood. The exterior is sheathed with 6-in. drop siding. Grain and hay storage in the loft plus the flooring boards provide the insulation in the ceiling.

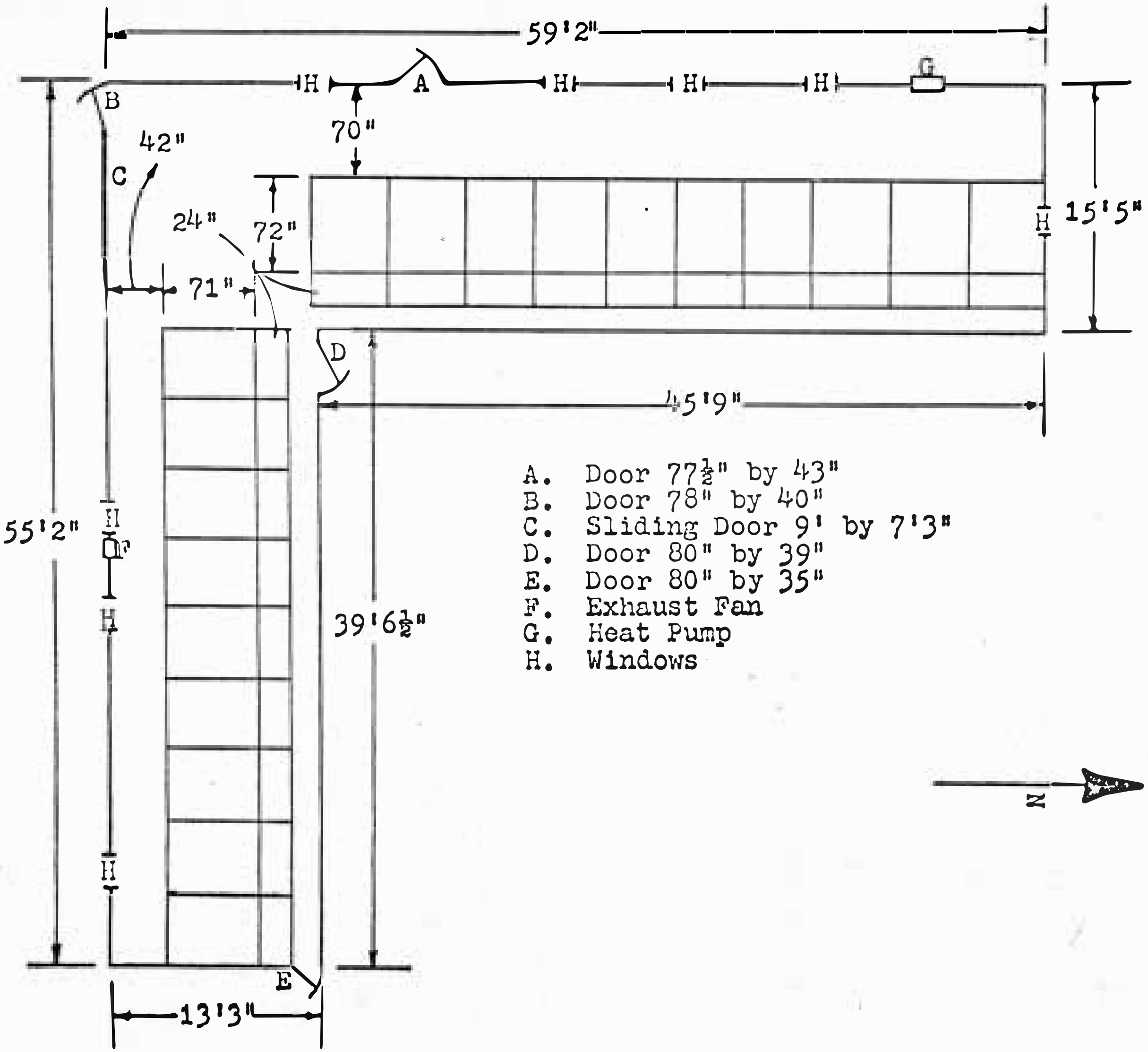

Figure 5. Physical Description of the Research Facility

The free stalls were fabricated from 3/4-in. exterior plywood and were placed on a solid concrete floor. The west and south stalls were constructed with 48 in. and 39 in. high sides, respectively. Stall widths varied from 51 to 59 in. to conform to existing structural components.

A two-ton heat pump furnished conditioned air which was delivered to the free stalls through a square, 1-ft by 1-ft plywood duct which was suspended from the ceiling joists. This air was directed to the individual stalls through 3-in. inside diameter flexible steel tubing and was controlled with adjustable sliding baffles located at the main air duct directly over the stalls receiving the conditioned air. The heat pump was controlled for summer use by a thermostat (single pole, single throw) located 2 ft above floor level at mid-length along the north side of the stall designated as treatment 1 of block 1 (Figure 6). A 1776 cfm exhaust fan, located on the south wall and controlled by a time clock, provided supplemental ventilation. The time clock was adjusted to run 40 percent of the time when the temperature was above the thermostat setting.

Kilowatt hour meters were installed to monitor the amount of electrical energy consumed by the heat pump. Cycling of the compressor was monitored by sensing the

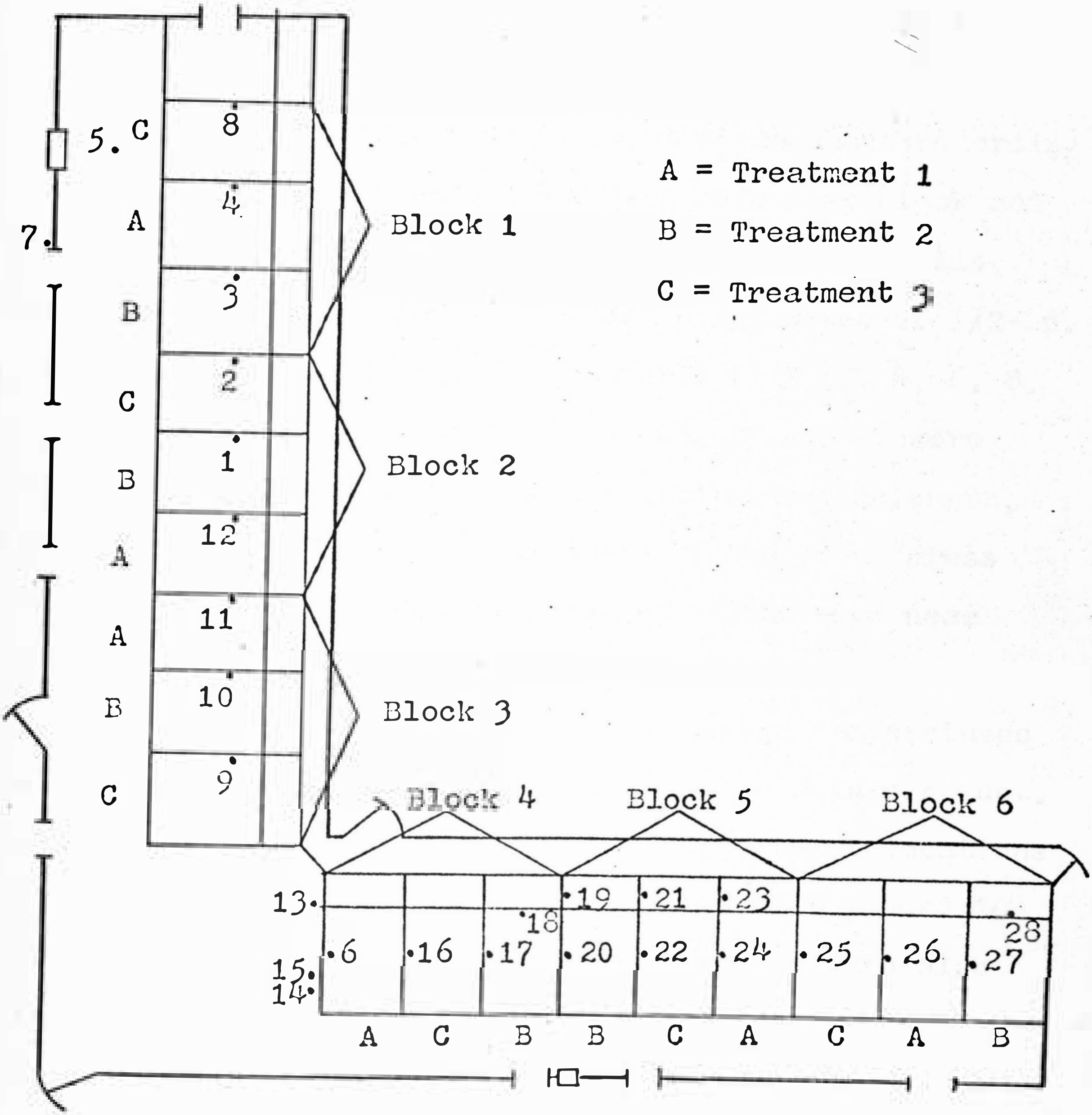

Figure 6. Temperature Sensing Locations (1-28), Block and Treatment Identification

main air duct temperature with a single channel continuous recording thermometer.

Temperatures at 28 selected locations (Figure 6) were sensed by 26-gauge copper constantan thermocouples and were recorded on two multi-point strip chart recording potentiometers which were controlled by a time clock and time delay relay system. Thermocouples in the stalls were inserted in thermocouple wells constructed of 1/2-in. copper tubing. Thermocouples numbered 1, 2, 3, 4, 6, 8, 9, 10, 11, 12, 16, 17, 20, 22, 24, 25, 26 and 27 were located at the edge of the free stalls near mid-length, 2 ft above the floor. Temperatures of the creep areas (points 19, 21 and 13) were measured at the edge near mid-length of the creep area, 6 in. above the floor. Thermocouples at points 5, 13 and 28 sensed temperatures at three locations along the length of the main air duct. Wet- and dry-bulb temperatures were measured at locations 14 and 15 with a motor aspirated psychrometer placed 10 in. below the joists. Wet-bulb temperatures were also investigated in the air stream of the 3-in., air delivery tube. Outside temperature, point 7, was measured at a shaded location on the west side of the barn.

RESEARCH PROCEDURE

Environmental conditions and swine performance in a farrowing house provided with minimal cooling were studied from July 17, 1970 to September 4, 1970. A randomized complete block design was utilized to evaluate performance of 15 sows and their litters as affected by selected levels of cooled air directed in the area of the snout of sows. The selected levels were 100 cfm for treatment 1, 50 cfm for treatment 2 and no air for treatment 3. The air supplied by a heat pump was adjusted employing sliding baffles and a vane anemometer.

The heat pump controls were adjusted to keep the heat pump fan running continuously and to activate the compressor when the temperature in the stall designated treatment 1 of block 1 was above 65 F. The fan was manually interrupted on extremely cool nights.

Temperatures were recorded at midnight, 0600, 1000, 1200, 1300, 1400, 1500 and 1600 hr at the points designated 1 through 28 in Figure 6. Hourly temperature observations in the afternoons were selected to better describe environmental conditions during periods of high outside temperatures. Electrical energy consumed by the heat pump was manually recorded between 0700 and 0900 hr each day.

The sows were brought into the farrowing house several days before farrowing. Farrowing commenced

July 16, 1970, and was completed August 10, 1970. The stalls were filled by block to keep litter age within blocks nearly equal. Sows choosing a stall in a block other than the one being filled were allowed to farrow in that stall but were moved to the correct location as soon as practical.

The sows were fed on the concrete feeding floor twice daily by farm personnel. Water was continuously available, since the lower portion of the southwest door was open allowing access to the feeding floor and an automatic waterer.

Treatment of the sows and baby pigs (performed by farm personnel) was consistent with standard recommended management practices. Water and creep feed were available continuously after the pigs were two to three days old. Pigs were fostered when litter size varied greatly among litters of equal age.

Pigs were weighed within 24 hours after birth. Initial sow weights were recorded the first morning or evening the sow left the stall after she had given birth. From farrowing to weaning, the pigs and sows were weighed each Friday morning. Smaller pigs were weighed with a balance scale, larger pigs were weighed with a dairy-type scale and the sows were weighed with a portable large animal scale. Respiration rate and pen occupancies were recorded by visual observation.

RESULTS AND DISCUSSION

Environmental Conditions

Maximum, minimum and average daily temperatures were obtained with a digital computer. Daily averages were computed from temperatures recorded at midnight, 0600, 1200 and 1800 hr. Weekly block and treatment averages were calculated from daily average temperatures of individual stalls within each block and treatment.

Weekly outside temperatures, sensed at a shaded position along the west wall, ranged from 2 F below to 5 F above and averaged 3 F above weekly averages for Brookings, South Dakota, based on data from 1898 to 1965. However, maximum daily temperatures did not exceed 90 F as frequently as expected. Weekly average main air duct temperatures at a location near the heat pump, point 5, ranged from 55.7 to 62.9 F and averaged 58.7 F for the total test period. This average was 15 F below the average outside temperature. Figure 7 shows the average daily temperatures, which closely correspond with average weekly relationships, for positions outside, in the duct near the heat pump, in the duct at mid-length and in the duct at the far end.

The horizontal temperature profile of the main air duct described the temperature of the conditioned air

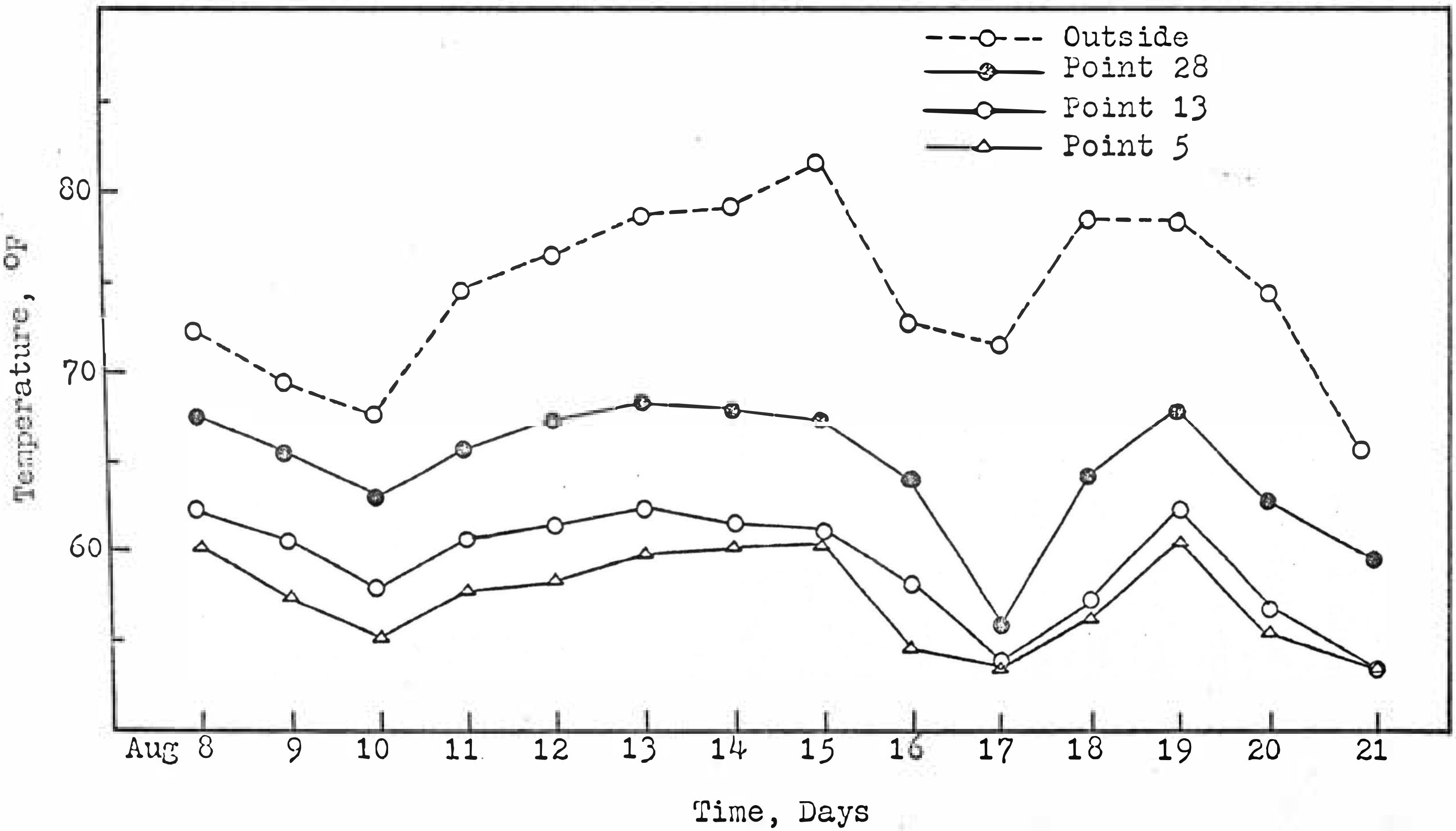

Figure 7. Average Daily Outside Temperature and the Temperature Profile in the Main Air Duct at the Heat Pump (5), Mid-Length (13) and the Far End (28)

delivered to stalls with respect to location within the farrowing facility. This temperature profile, averaged over the two-week period, indicated temperature increased 2 F from the heat pump to the mid-length of the duct and 5 F from mid-length to the far end. The temperature difference from the heat pump to the far end averaged 8 F for the entire period compared with 7 F for the two weeks illustrated in Figure 7. The cross-sectional area of the main air duct was uniform which caused decreasing air velocities in the duct as distance from the heat pump increased. The decreased velocities were primarily responsible for the 3 F larger temperature increase in the portion of the duct from mid-length to the far end as compared with that portion of the duct from the heat pump to mid-length.

Average weekly relative humidities at Brookings, in the research unit and in the main air duct near the ell, are shown in Figure 8. The humidity data in the farrowing facility were calculated from average daily wet- and dry-bulb temperatures. Averages at Brookings were obtained from observations at 0800, 1200 and 1600 hr. Average weekly relative humidity in the duct was nearly constant at 60 percent, while average weekly relative humidity in the building ranged from 64 to 80 percent and averaged 12 percent higher than the relative humidity in the main air

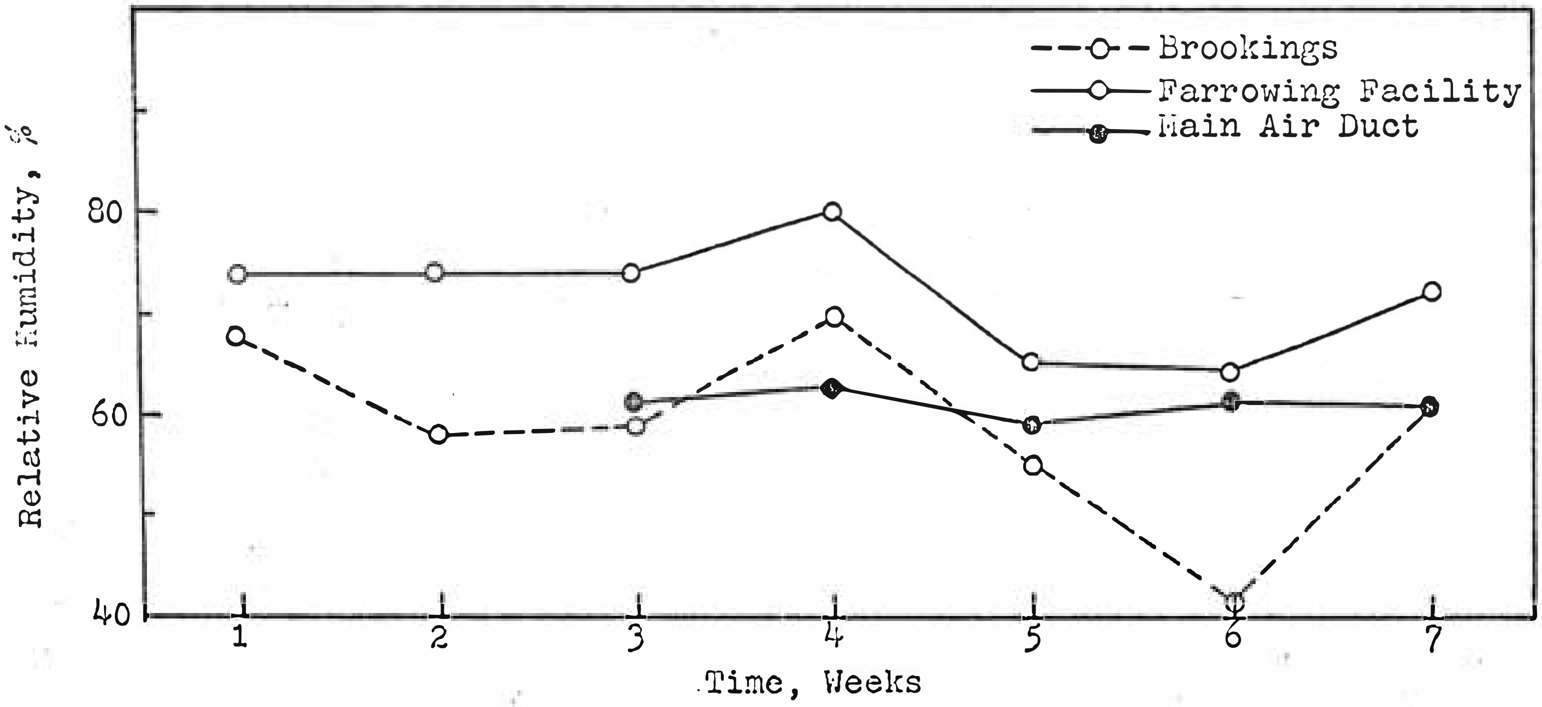

Figure 8. Average Weekly Relative Humidity in the Main Air Duct, the Farrowing Facility and at Brookings

duct for the period. Because moisture was added by the sows and litters, relative humidity in the farrowing facility was consistently higher than it was at Brookings. Duct dew-point temperatures averaged 8.6 F below the dew-point for the period in the farrowing facility and was also below the dew-point of the outside air due to the moisture removed by the cooling coil of the heat pump (Figure 9).

Treatment and Block Temperatures

Treatments of 100 cfm of conditioned air, 50 cfm of conditioned air and no ventilation air directed into individual stalls caused minimal variation in stall temperatures (Figure 10). Averages for the entire period were 72.8, 73.4 and 74.0 F for treatments 1, 2 and 3, respectively. Daily treatment averages were similar to weekly treatment averages and also indicated the expected time lag response of stall temperatures compared with outside temperatures (Figure 11). To further examine extreme stress conditions, daily maximum temperatures recorded by treatment in a single block are illustrated in Figure 12. The maximum temperature was 88 F and occurred in treatments 1 and 3 on August 13, 1970. Average maximum temperatures for the two weeks shown were 80.8, 81.0 and 82.3 F for treatments 1, 2 and 3,

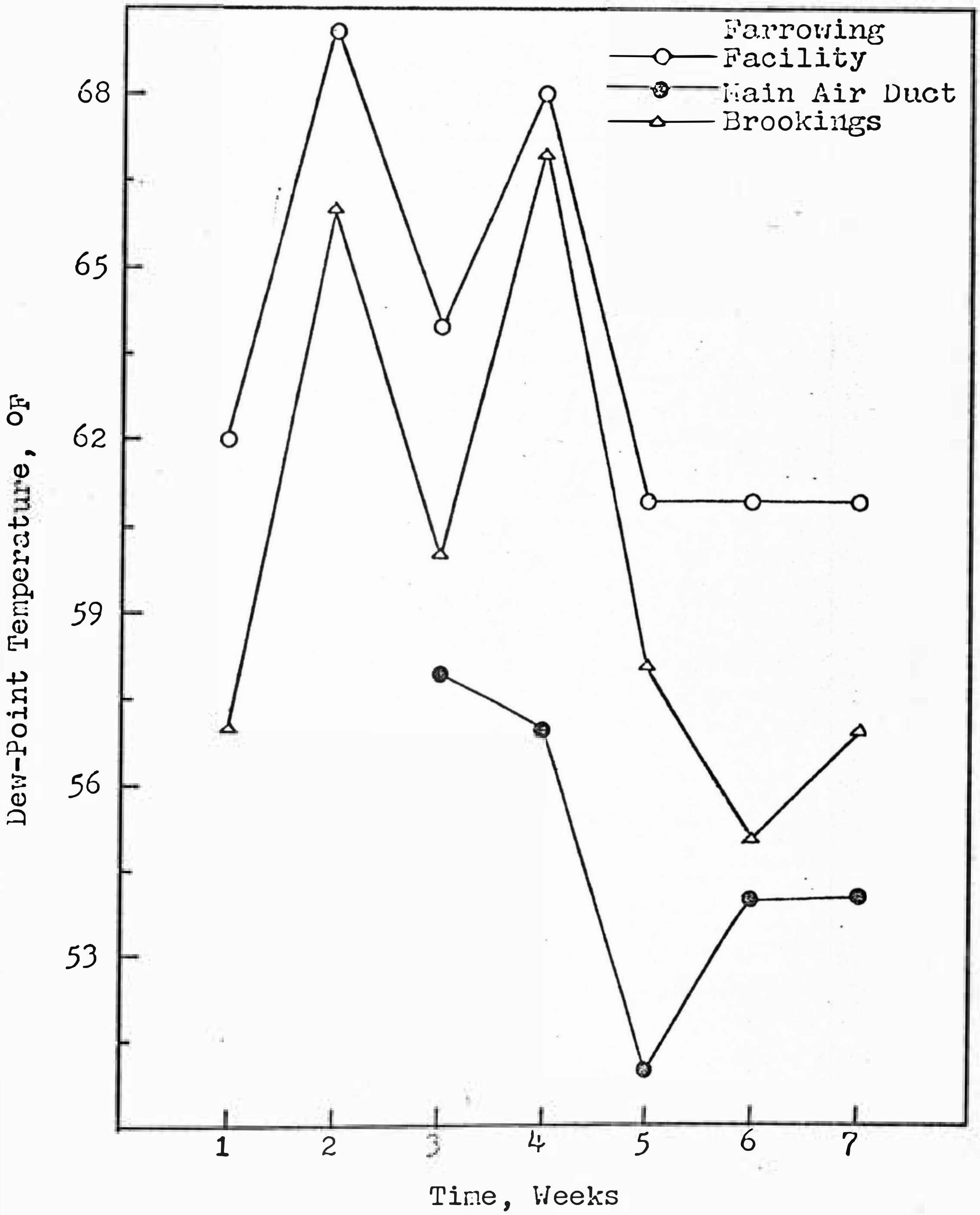

Figure 9. Average Weekly Dew-Point Temperature in the Farrowing Facility, in the Main Air Duct and at Brookings

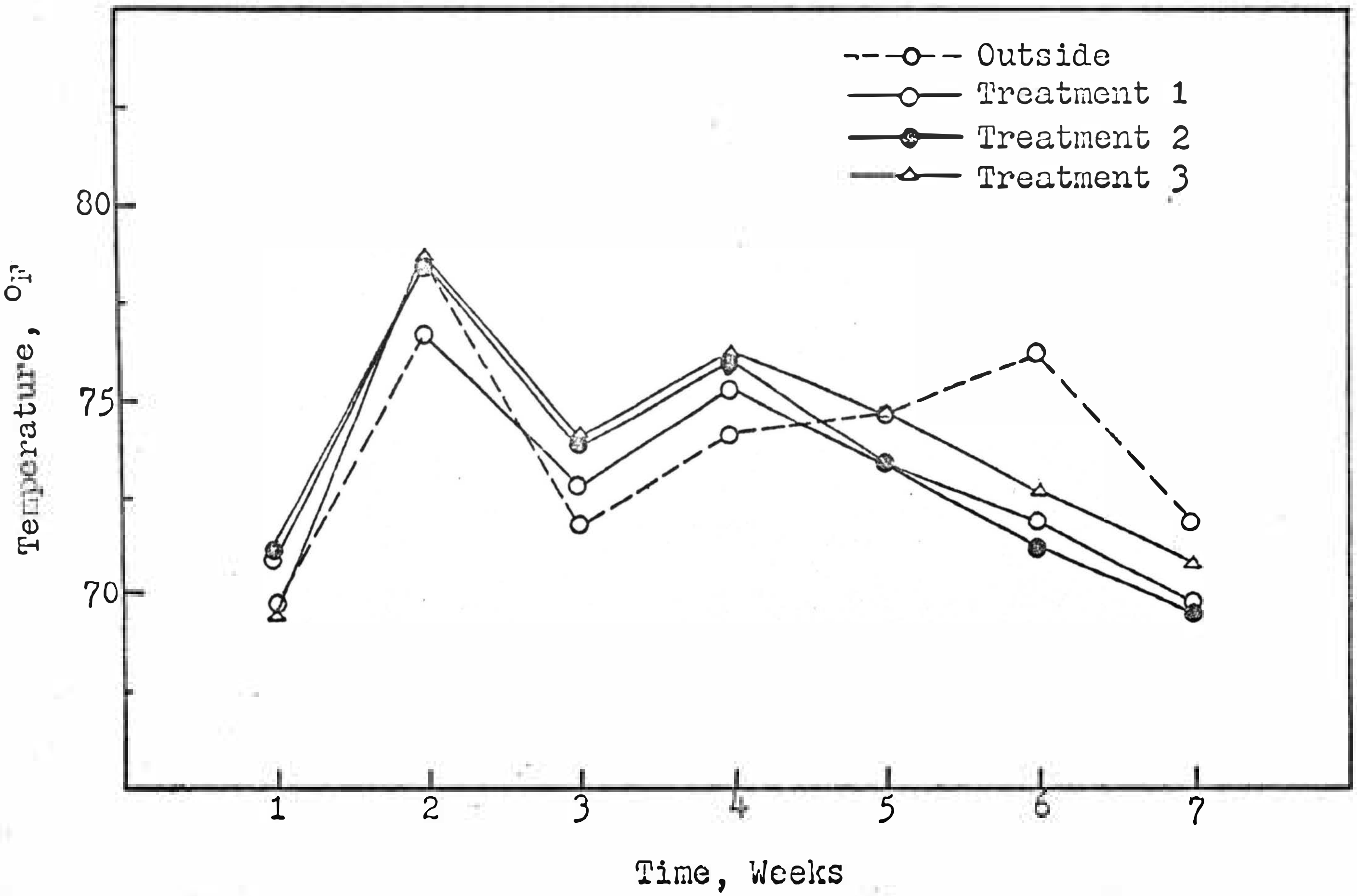

Figure 10. Average Weekly Treatment and Outside Temperatures

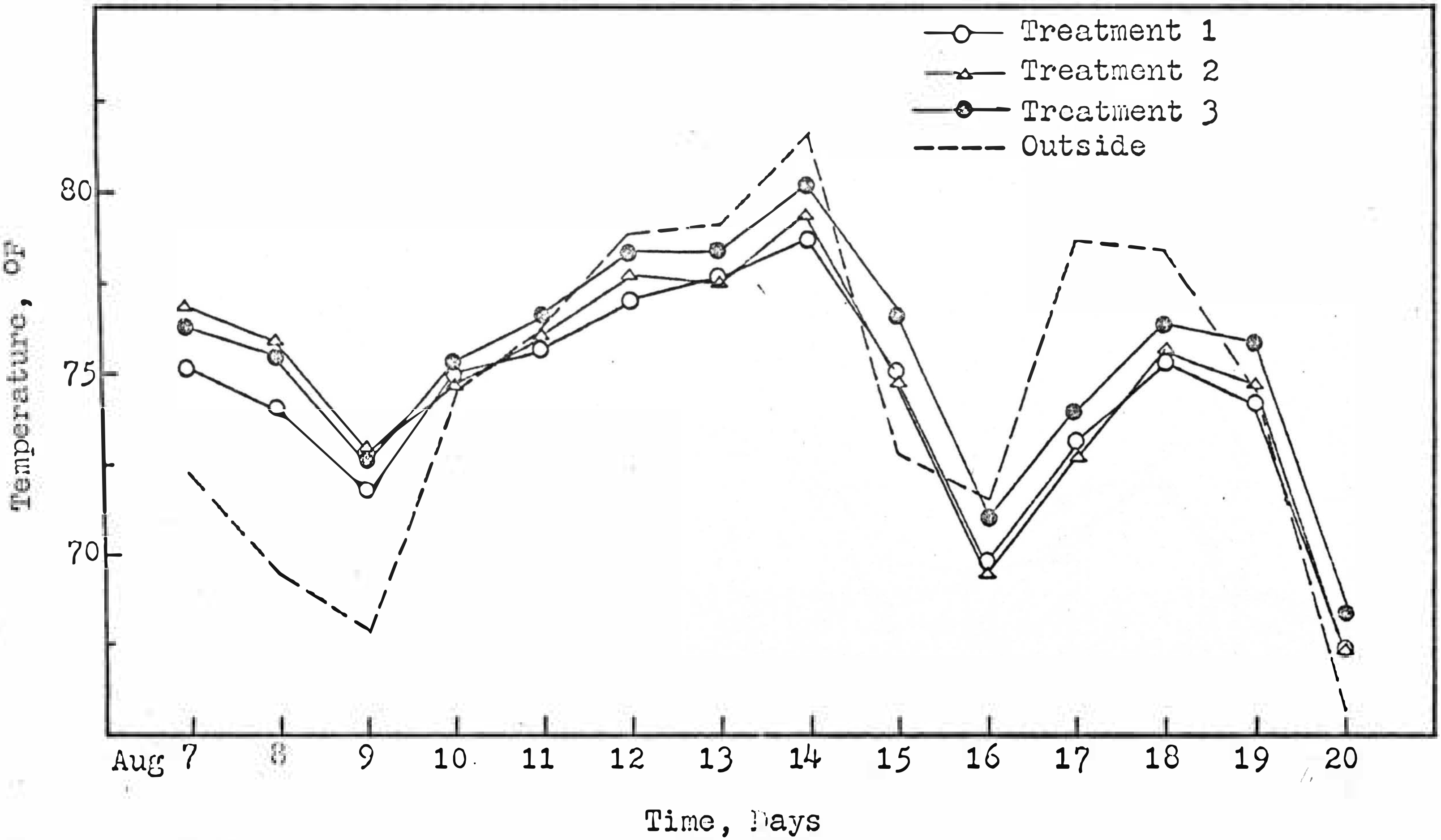

Figure 11. Average Daily Treatment and Outside Temperatures

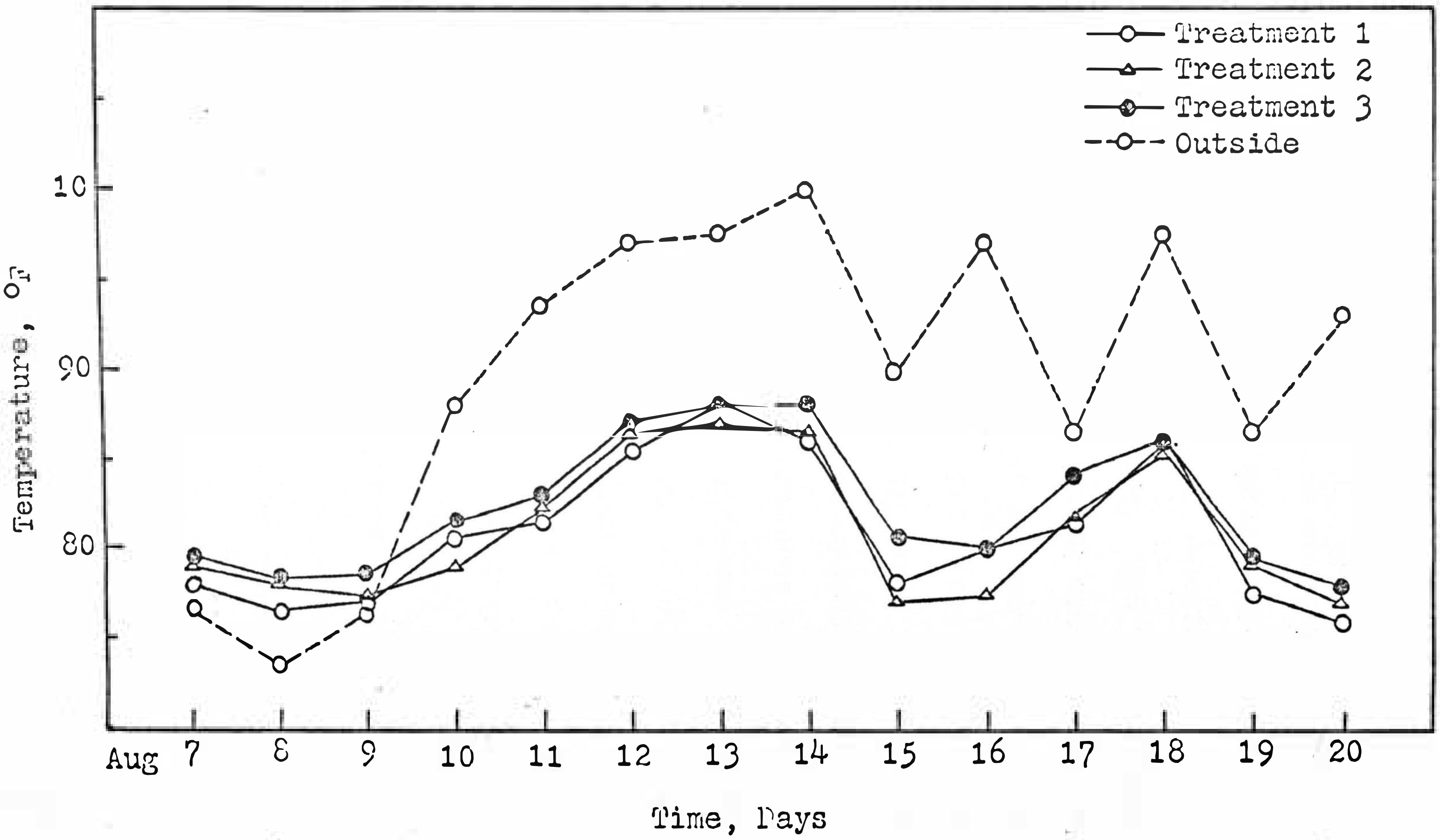

Figure 12. Maximum Daily Temperature Outside and in the Treatments, Block 2

respectively, which indicates variations in extreme stall temperatures were also minimal.

Temperature averages by block were calculated to determine the influence of the horizontal temperature profile in the main air duct and southerly versus westerly wall exposure on block temperature. The temperature averages of the blocks for the second week of the test exhibited the expected pattern of warmer stall temperatures in positions further from the heat pump (Figure 13). However, a comparison of farrowing dates with corresponding block temperatures showed stall occupancy exhibited greater influence on stall temperatures than did location within the building. This was evidenced by the rise in temperature of block 1 in week four which corresponded with the introduction of sows. Sows occupied blocks 2 and 4 by the end of the first week and farrowed in blocks 3 and 5 during week two. The comparative lowering of temperature in blocks 2, 3 and 4 in week six corresponded with the removal of sows and litters. When averaged over the entire period, minimal temperature differences between blocks were observed. Period averages were 72.9, 73.4, 73.2, 72.9 and 74.5 F for blocks 1 through 5, respectively.

No logical explanation was found for the 7 F difference in daily block temperatures on August 18, 1970

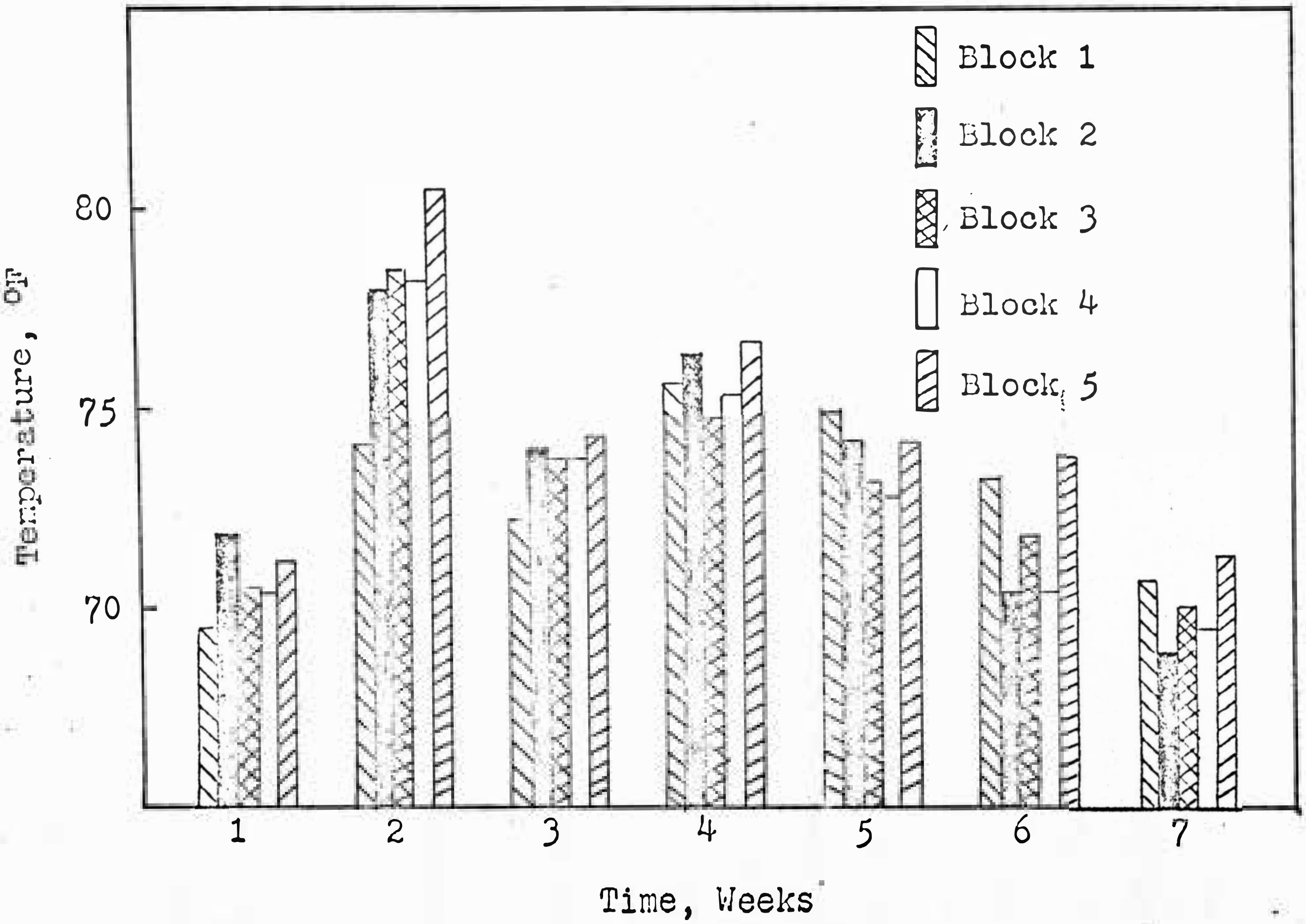

Figure 13. Average Weekly Block Temperature

as shown in Figure 14. However, a comparison of average block temperatures for the two-week period, shown in Figure 14, corresponds closely with the entire period averages.

Creep Areas

The average weekly temperatures observed in the creep areas in block 5 for each of the three treatments revealed that maximum temperature differences between treatments were less than 6 F with the highest temperatures observed in the creep area of the stall receiving the 100 cfm treatment (Figure 15). Highest creep temperatures were noted in week two and corresponded with the early life of the pigs and the operation of the 250-watt heat lamps. Minimum average weekly temperature, during the time of pen occupancy, was 71.2 F. Note the drop in creep temperature in week seven (Figure 15) which was immediately after weaning. Daily average creep temperatures for the three treatments (dotted lines represent the creep temperatures prior to the date the sow farrowed) are shown in Figure 16. Temperatures for the first week averaged 78 F for treatment 2, and temperatures in treatments 1 and 3 averaged 79 F. Figures 17 and 18 show maximum and minimum daily temperatures were not greatly affected by treatment and ranged from 73 to 91 F for all treatments.

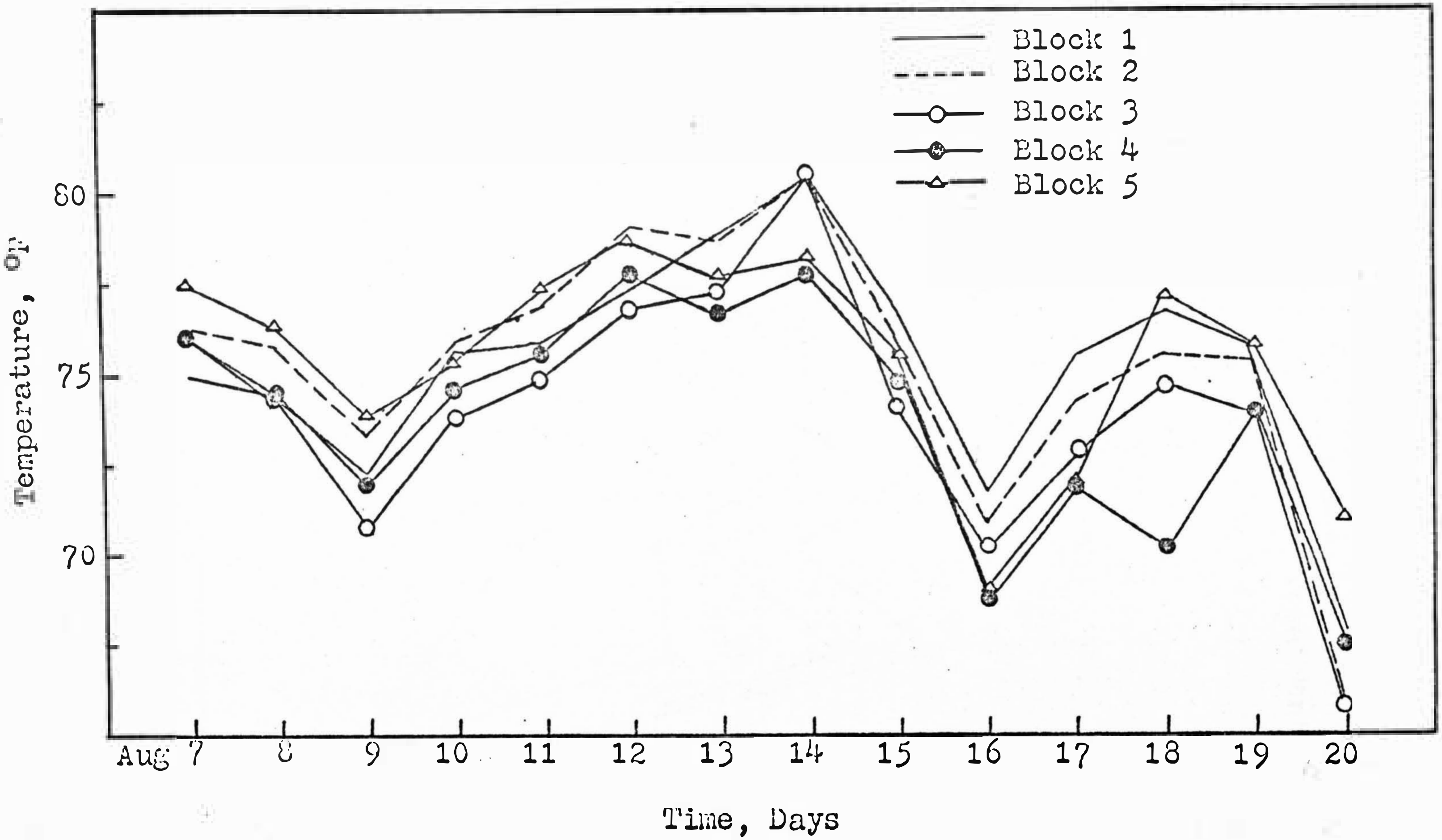

Figure 14. Average Daily Block Temperature

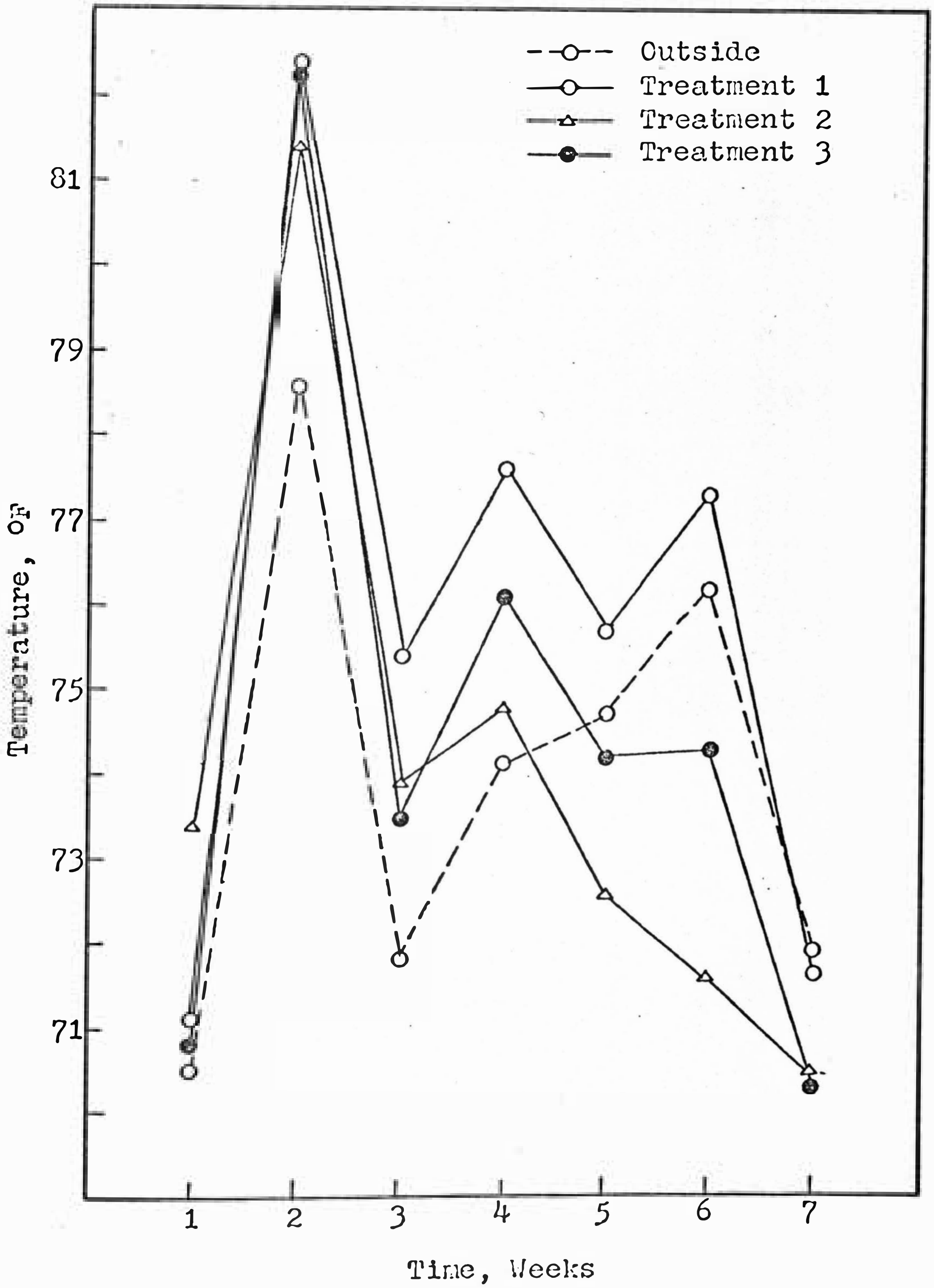

Figure 15. Average Weekly Creep Temperatures, Block 5, and Average Weekly Outside Temperature

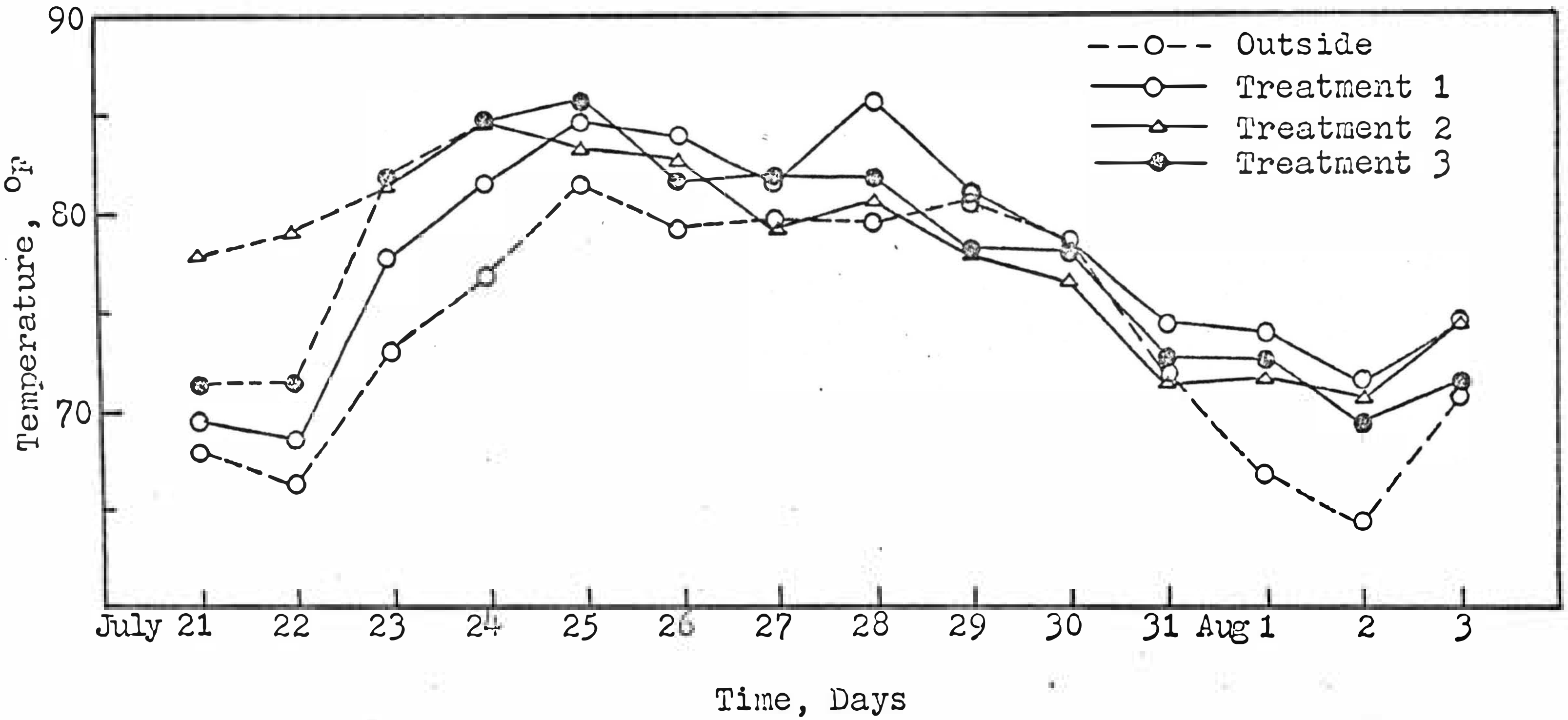

Figure 16. Average Daily Creep Temperature, Block 5, Dotted Lines Represent Creep Temperatures Prior to Farrowing

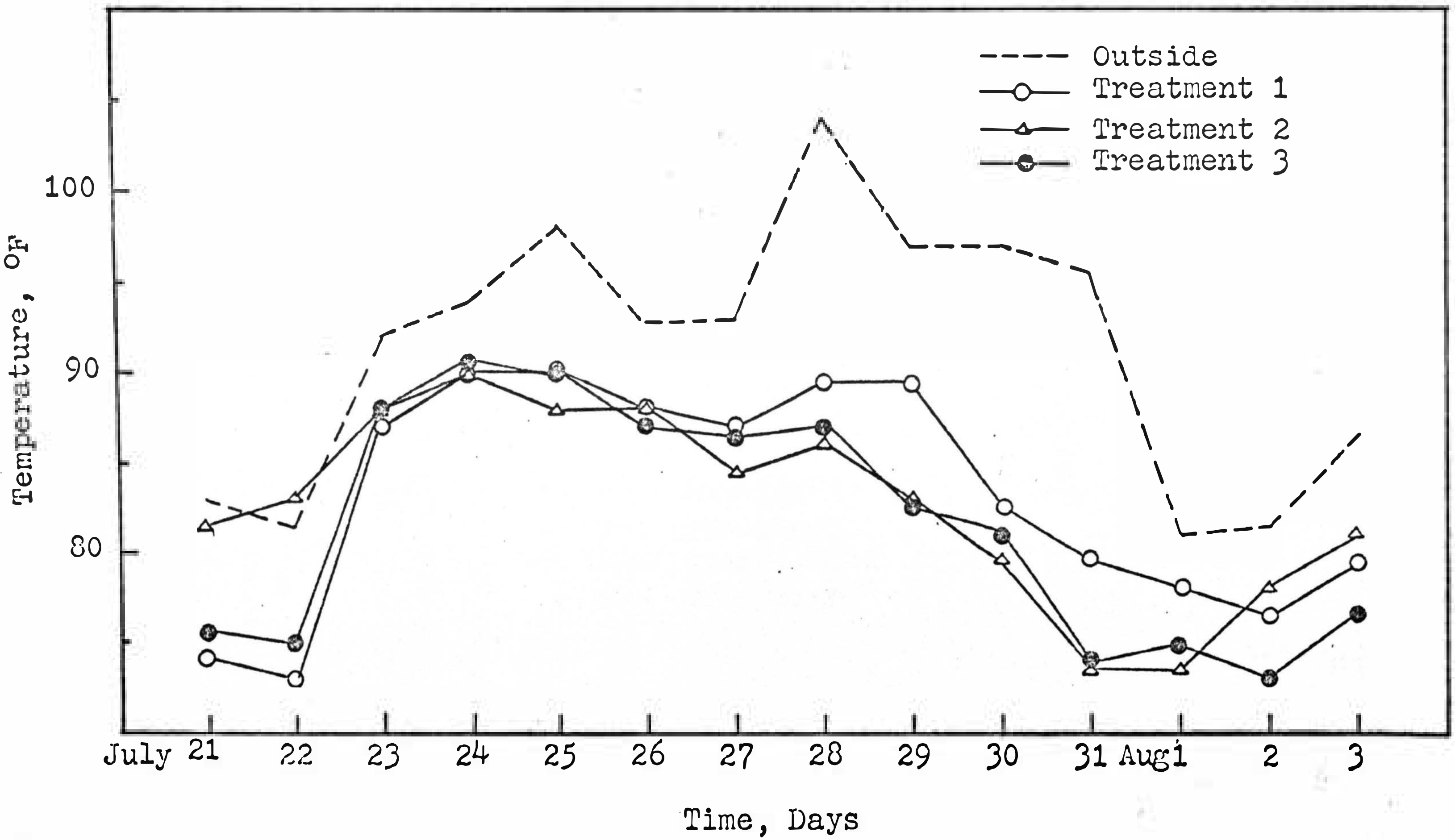

Figure 17. Maximum Daily Outside and Creep Temperatures, Block 5, for Two Weeks Following Farrowing

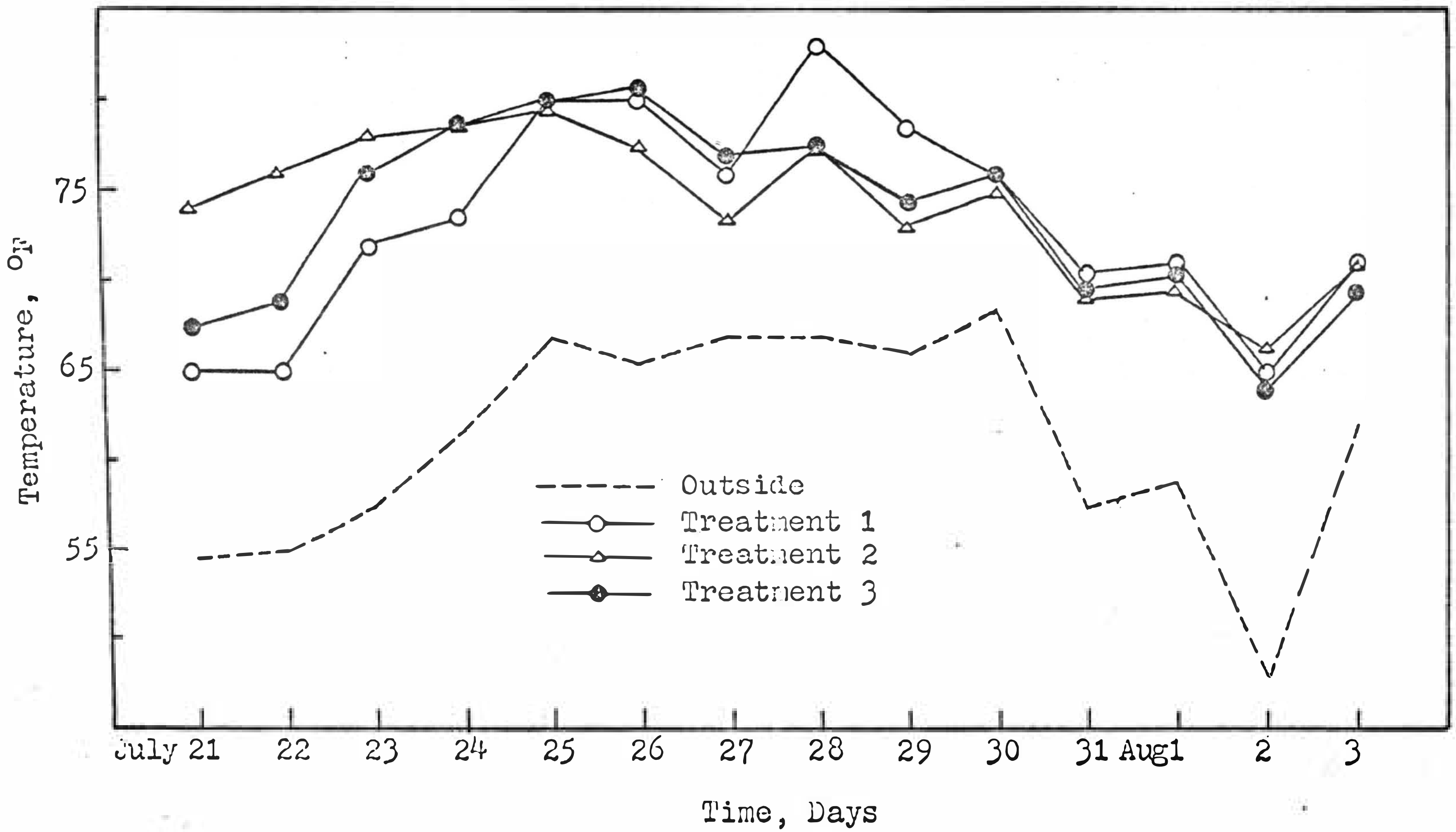

Figure 18. Minimum Daily Outside and Creep Temperatures, Block 5, for Two Weeks Following Farrowing

Heat Pump Operation

The energy used by the heat pump was recorded in increments of 10 kw-hr between 0700 and 0900 hr daily from July 27, 1970, to September 4, 1970. Table 1 (Appendix A) lists the kw-hr used each day and the corresponding average daily outside temperatures. The maximum daily energy use of 90 kw-hr was recorded on August 12, 1970. Energy use did not correlate well with outside temperatures, since relative humidity and the number of animals in the facility were major confounding factors.

Energy use of 80 kw-hr was recorded on 12 of the 39 days studied; most were days of continuous or nearly continuous heat pump operation as determined by analysis of continuous main air duct temperature data. Investigation of the data revealed that the compressor was in continuous operation on August 11 and 12 with energy use readings of 70 and 90 kw-hr, respectively. Therefore, it was assumed the time of observation introduced a 10 kw-hr error in these two readings and that 80 kw-hr of energy were used each of these two days. The minimum one-day energy requirement was 40 kw-hr and the average energy requirement was 68.7 kw-hr per day for the period.

The continuous main air duct temperature data from August 25, 1970, to September 4, 1970 (Figure 19) was

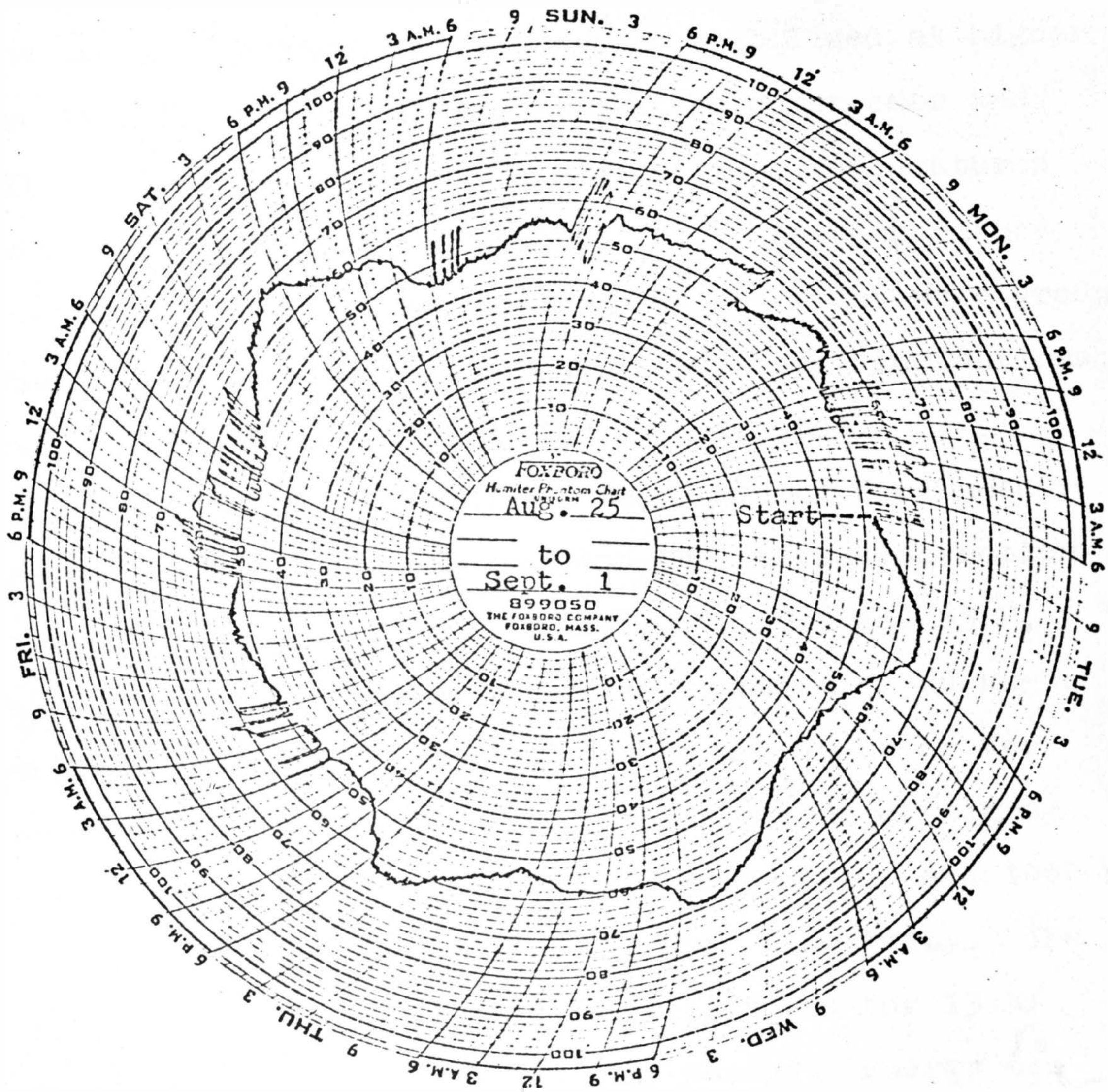

Figure 19. Continuous Main Air Duct Temperature Data Illustrating On and Off Cycles of the Heat Pump

chosen as representative of compressor operation during the study. Temperature traces that stabilized at higher levels after a rapid change denote the compressor was idle while those that stabilized at lower temperatures indicated compressor operation. Note, the temperature changes from 0900 hr Tuesday to 0300 hr Friday were gradual changes and were due to diurnal temperature fluctuations; continuous compressor operation is indicated.

The average daily outside temperatures for Tuesday through Friday (the heat pump was in constant operation until 0300 hr Friday) were 78.6, 80.0, 79.1 and 65 F, respectively and correspond to energy usage of 80 kw-hr per day for Tuesday through Thursday and 70 kw-hr for Friday (Figure 19). The seven brief periods of higher temperatures in the main air duct between 0300 and 1000 hr Friday indicated periods of compressor inactivity. The longest period of compressor inactivity was for 13 hr between 2030 hr Sunday and 0930 hr Monday. Energy use from Sunday to Monday morning was 40 kw-hr with an average outside temperature of 67 F.

The percent of the time that the compressor operated was determined by dividing the 68.7 kw-hr average daily energy use for the entire period by 80 (kw-hr use for a continuous day's operation). This indicated the heat pump was in operation 86 percent of the period.

Swine Performance

Pig weight data were analyzed statistically with no adjustments for litter size. Linear, second order and third order least squares regression equations were fitted to the weight data for the sum of each treatment and the sum of all treatments. Second order regression equations yielded a significantly better fit than linear (based on a smaller error term), but no improvement was realized with third order equations. No significant difference in pig weight gain between treatments was found. However, a plot of the pig weight regression equations indicated a trend towards higher pig weight gain in fully air-conditioned stalls (Figure 20). The regression equations for each treatment are as follows:

$$Y_1 = 3.19 + 0.30X + 0.0033X^2$$

$$Y_2 = 3.38 + 0.21X + 0.0034X^2$$

$$Y_3 = 3.07 + 0.25X + 0.0022X^2$$

Y_1, Y_2 and Y_3 represent the pig weights for treatments 1, 2 and 3, respectively, and X represents pig age in days. Variation within treatments was large as shown by the scatter of data along the regression lines in Figure 20. This variation caused a large error term in the analysis of variance. Average daily gains for treatments 1, 2 and 3 were 0.417, 0.345 and 0.301 lb per day, respectively.

Analysis revealed that air flow had little influence

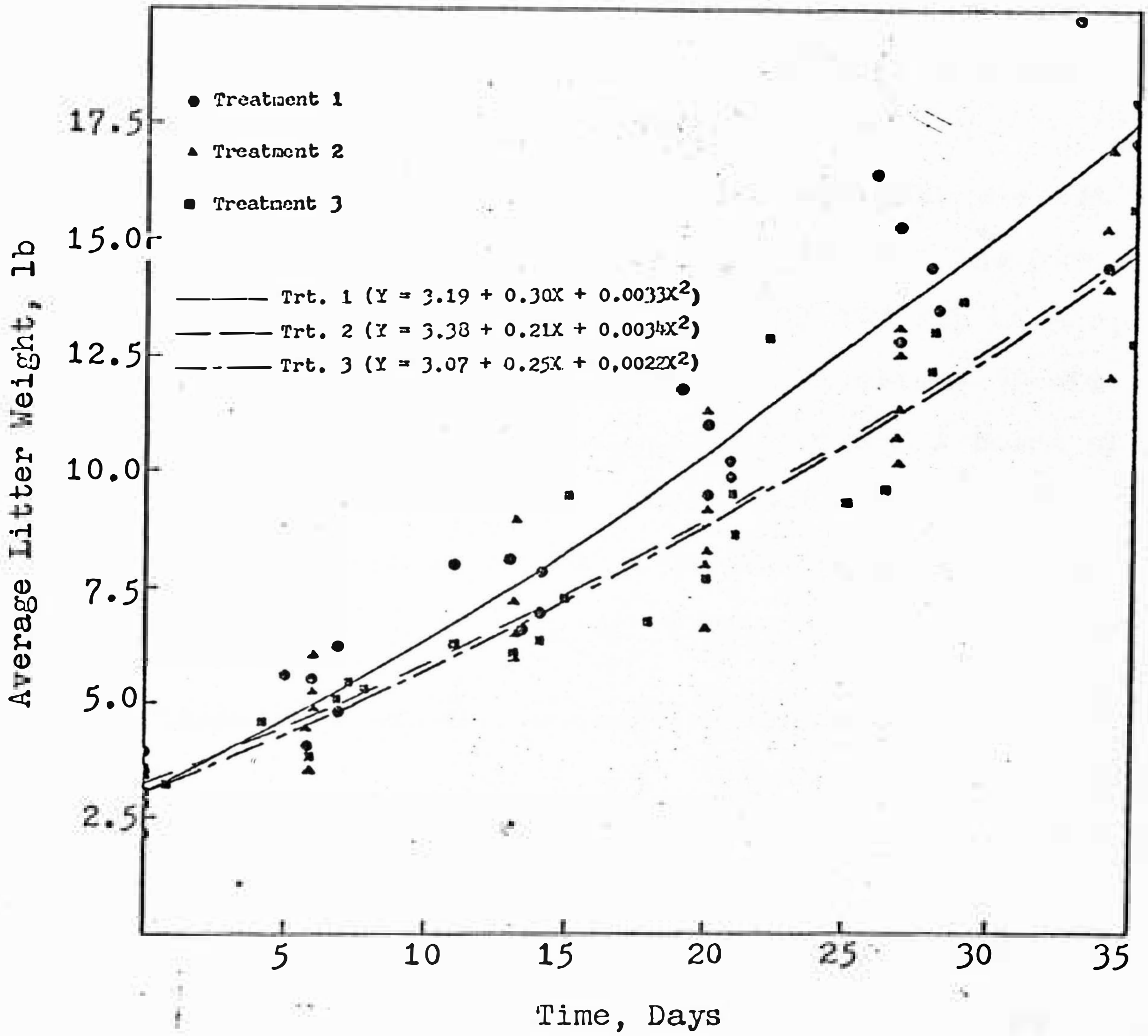

Figure 20. Average Pig Weight Gain by Litters as Affected by Treatment

on sow weight, although sow weights tended to decrease for a period of time after farrowing and then increase near the end of the lactation period.

Mortality data revealed no clear trend with respect to air flow. Twenty-two out of a total of 146 pigs died; 4 out of 44 pigs died in stalls receiving 100 cfm of air, and 9 pigs per treatment died in stalls receiving 50 cfm and no air. Sows in these treatments farrowed a total of 53 and 49 pigs, respectively. Individual sows, one in treatment 2 and one in treatment 3, were responsible for five and six dead pigs, respectively.

Respiration Rate and Pen Occupancy Comparisons

Based on the average of data observed on July 27, 28, August 5, 12 and 18 between 1400 and 1600 hr, significantly reduced respiration rates were noted in stalls receiving cooled air, as contrasted to those sows not provided cooled air. Average treatment temperatures and average respiration rates for each treatment and date are presented in Table 2 (Appendix B). Variation in stall temperatures were small as previously reported. Mean respiration rates for the total of all days observed were 36.8, 54.8 and 64.6 breaths per minute for treatments 1, 2 and 3, respectively. No significant difference was noted because of date or the interaction between date and treatment. The plot of average respiration rates by treatment on the Heitman and Hughes (12) respiration versus temperature graph (Figure 21) shows the swine effective temperatures were 62, 72 and 78.5 F for treatments 1, 2 and 3, respectively, as compared with actual stall temperatures from 78 to 83 F for all treatments and observations.[2] This indicates that the 100 cfm of 69.6 F conditioned air reduced the effective temperature sensed by the sows 16.5 F, while the 50 cfm of the conditioned air reduced the effective temperature sensed by the swine 6.5 F.

Stall occupancy data were obtained from July 18, 1970, to August 14, 1970, to determine the influence of cooled air delivered to the stalls on the amount of time the sows spent with their pigs. Sows in treatment 1 exhibited 3 percent more occupancies than the no air treatment and 7 percent more occupancies than the 50 cfm treatment. The cooperating farmer reported an overall increase in the time sows spent in the stalls as compared with summer farrowings before the introduction of conditioned air. Stall occupancy levels were calculated on the basis of number of times the sows were in the stalls compared to

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[2]Beckett and Vidrine (3) reported that respiration rate data collected for a sow compared closely with that of the 200-lb Heitman and Hughes (12) pigs and indicated that comparisons between sows and 200-lb pigs could be made.

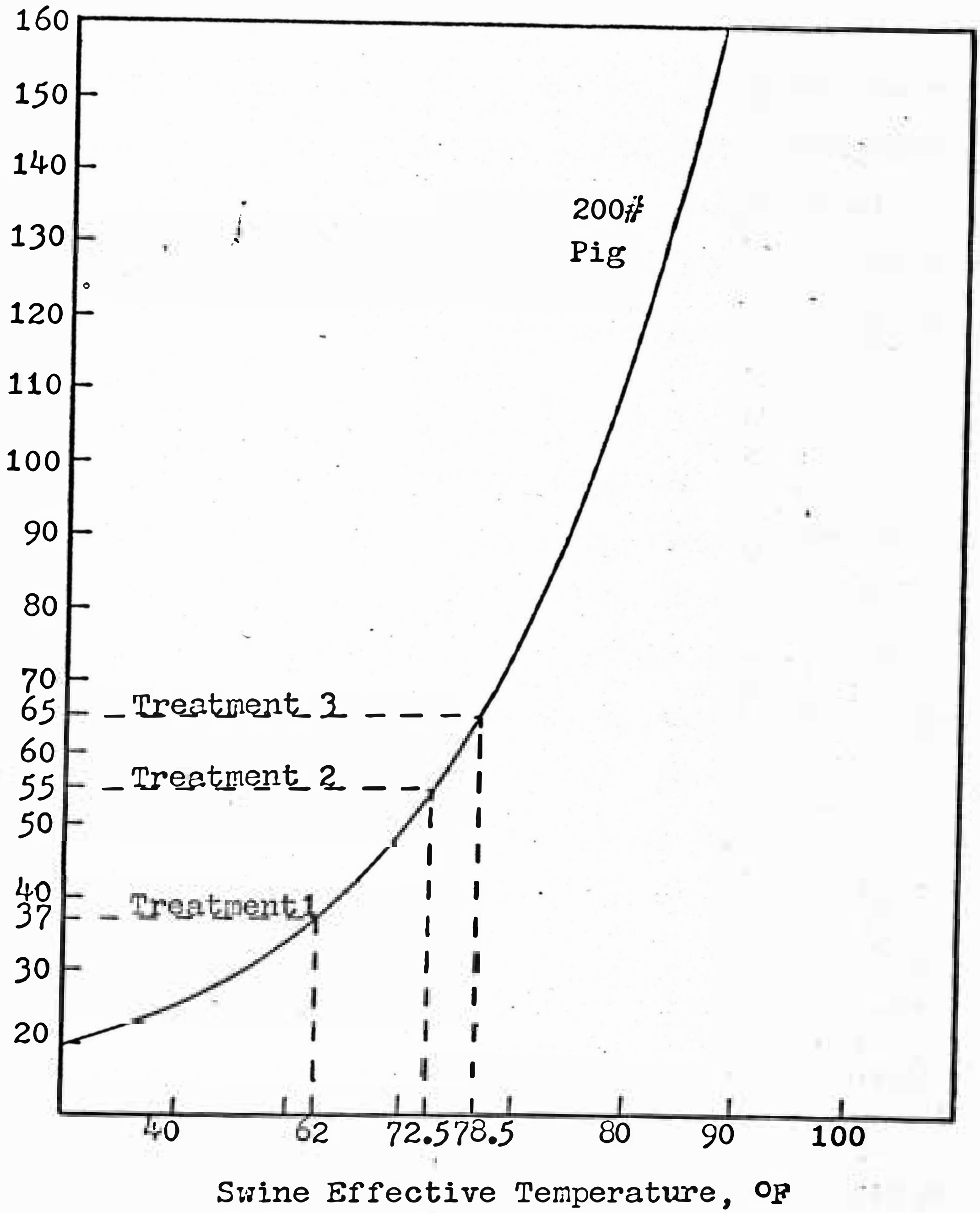

Figure 21. Swine Effective Temperature by Treatment as Indicated by Respiration Rates Based on the Data of Heitman and Hughes (12) 200-lb Pigs

total observations. This data revealed that treatment 1 had 175 occupancies out of a possible 236 or 74 percent occupancy rate, 157 occupancies out of 234 observations or an occupancy rate of 67 percent was observed in treatment 2, and treatment 3 exhibited 156 occupancies out of a possible 217 which gave an occupancy rate of 71 percent.

Economic Analysis of Heat Pump Operation

At retail values the heat pump, wiring, control and installation costs were approximately 1250 dollars, including the construction of the duct. Based on an interest rate of 6 percent and an estimated life of ten years, the annual recovery costs are 170 dollars.

The benefits received by summer farrowing based on the indicated increased average daily gain of 0.116 lb per pig would be 159 dollars above an annual electrical energy cost of 48 dollars. This is based on 2 farrowings each summer with 10 sows averaging 8 pigs per litter, a weaning age of 28 days and a price of 40 cents per lb. This suggests a contribution in excess of 90 percent of the annual recovery costs leaving only 10 percent to be allocated to the potential income from increased number of pigs weaned, minimized sow mortality and value added during spring, fall and winter farrowings.

CONCLUSIONS

The following conclusions were indicated by this investigation:

1. Treatment had less effect on stall and creep temperatures than did stall occupancy.
2. Average daily energy consumption of the heat pump was 68.7 kw-hr during the period which averaged 3 F above normal temperature for the Brookings, South Dakota area.
3. The 100 cfm level of air reduced swine effective temperature 16.5 F, and the 50 cfm level reduced it 6.5 F as indicated by decreased sow respiration rates.
4. Average daily pig weight gains were 0.417, 0.345 and 0.321 lb per day for treatments 1, 2 and 3, respectively. Pig weight gain was not significantly affected by level of air flow.
5. Sow respiration rate decreased significantly with increasing air flow and averaged 36.8, 54.8 and 64.6 breaths per minute for the treatments.
6. Greatest stall occupancy was noted in the stalls receiving 100 cfm of conditioned air.

7. Indications were that the value of the added weight gain of the pigs from two farrowings per summer season would contribute 90 percent of the annual recovery costs of the heat pump, based on a ten-year useful life.

SUMMARY

Sow mortality and poor litter performance have been attributed to heat stress during the farrowing and lactation period. Since cooling an entire swine building has been shown to be cost prohibitive in many cases, an alternate system of partial environmental modification was studied.

The effect of selected levels of air flow, conditioned by a heat pump and directed to the snout area of sows, on the performance of sows and litters housed in a free stall farrowing barn and the performance of the environmental control equipment were studied during a summer farrowing period in east central South Dakota. Five replications of the following three treatments were studied using a randomized complete block design: 100 cfm of conditioned air, 50 cfm of conditioned air and no air.

Analysis of the environmental conditions indicated that treatment had less effect on stall and creep temperatures than did stall occupancy. Outside temperature averaged 73.7 F, farrowing barn temperature 73.5 F, and conditioned air temperature delivered by the heat pump averaged 58.7 F for the period. Swine effective temperature was reduced 16.5 F and 6.5 F by the 100 cfm and the 50 cfm of conditioned air, respectively. Level of conditioned air had no significant effect on piglet

weight gain and change in sow weight, but sow respiration rate decreased significantly with increasing levels of conditioned air. Sow stall occupancy was greatest for the 100 cfm treatment. The economic value of the added weight gain of the pigs was in excess of 90 percent of the annual recovery cost of heat pump, assuming two farrowings per summer season.

REFERENCES

1 Aanderud, W. G. Hog production and management. Practical Hog Production and Marketing for South Dakota Farmers. South Dakota Cooperative Extension Service EC649, Brookings, South Dakota 57006, 1969.

2 Beckett, F. E. Effective temperature for evaluating or designing hog environments. Transactions of the ASAE 8:(2)163-166, 1965.

3 Beckett, F. E. and Vidrine, C. G. A mathematical model of heat transfer in a pig. ASAE Paper No. 69-437, ASAE St Joseph, Mich. 49085, 1969.

4 Bond, T. E., Heitman, H., and Kelly, C. F. Effects of increased air velocities on heat and moisture loss and growth of swine. Transactions of the ASAE 8:(2)167-169, 174, 1969.

5 Bond, T. E., Kelly, C. F., and Heitman, H. Jr. Heat and moisture loss from swine. Agricultural Engineering 33:(3)148-152, 1952.

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

7 Brody, S. Bioenergetics and Growth. Reinhold Publishing Corporation, New York, 1945.

8 Butchbaker, A. F. and Shanklin, M. D. Partitional heat loss of newborn pigs as affected by air temperature, absolute humidity, age and body weight. Transactions of the ASAE 7:(4)380-384, 1964.

9 Esmay, M. L. Principles of Animal Environment. The AVI Publishing Company, Westport, Connecticut, 1969.

10 Gunnarson, H. F., Butchbaker, A. F., Witz, R. L., and Dinusson, W. E. Effect of air velocity, air temperature and mean radiant temperature on performance of growing-finishing swine. Transactions of the ASAE 10:(6)715-718, 1967.

11 Hegg, J. Personal interview. 1970.

12 Heitman, H. Jr. and Hughes, E. H. The effect of air temperature and relative humidity on the physiological well being of swine. Journal of Animal Science 8:(2)171-181, 1949.

13 Heitman, H. Jr., Kelly, C. F. and Bond, T. E. Ambient air temperature and weight gain in swine. Journal of Animal Science 17:(1)62-67, 1958.

14 Karhnak, J. M. and Aldrich, R. A. Environmental control in a farrow-to-finish facility. ASAE Paper No. 69-443, ASAE St. Joseph, Mich. 49085, 1969.

15 Kelly, C. F., Bond, T. E. and Garrett, W. Heat transfer from swine to a cold slab. Transactions of the ASAE 7:(1)34-35, 1964.

16 Kelly, C. F., Heitman, H. Jr. and Morris, J. R. Effect of environment on heat loss from swine. Agricultural Engineering 29:(12)525-529, 1948.

17 Mahoney, G. W. A., Omtvedt, I. T., Edwards, R. L., Stephens, D. F. and Turman, E. J. Heat-stress effects on reproduction in gilts. ASAE Paper No. 69-457, ASAE St. Joseph, Mich. 49085, 1969.

18 Mangold, D. W., Hazen, T. E. and Hays, V. W. Effect of air temperature on performance of growing and finishing swine. Transactions of the ASAE 10:(3)370-377, 1967.

19 Merkel, J. A. and Hazen, T. E. Zone cooling for lactating sows. Transactions of the ASAE 10:(4)444-447, 1967.

20 Midwest Plan Service. Structures and environment handbook. 1969.

21 Morrison, S. R., Bond, T. E. and Heitman, H. Jr. Skin and lung moisture loss from swine. Transactions of the ASAE 10:(5)691, 692 and 696, 1967.

22 Morrison, S. T., Bond, T. E. and Heitman, H. Jr. Effect of humidity on swine at high temperatures. Transactions of the ASAE 11:(4)526-529, 1968.

23 Mount, L. E. Metabolic rate of the newborn pig in relation to environmental temperature and age. Journal of Physiology 147:(2)333-345, 1959.

24 Nave, W. R., Olver, E. F. and Shove, G. C. Effects of floor temperature and ventilation on swine in confinement. Transactions of the ASAE 7:(2)108-110, 1964.

25 Ross, O. B. Swine housing. Agricultural Engineering 41:(9)584, 1960.

26 Shanklin, M. D. and Stewart, R. E. Radiant cooling of dairy cattle. Transactions of the ASAE 3:(1)52-56, 1960.

27 Spillman, C. K. and Hinkle, C. N. Conduction heat transfer from swine to controlled temperature floors. ASAE Paper No. 69-441, ASAE St. Joseph, Mich. 49085, 1969.

28 Taylor, J. G. Technical progress report on individual air conditioning for farrowing sows. United States Department of Agriculture, ARS Series 42-19, May, 1958.

APPENDIX

APPENDIX A. Daily Electrical Energy Use of the Heat Pump and Average Daily Temperature, July 27, 1970, to September 3, 1970

Table 1. Daily Electrical Energy Use of the Heat Pump and Average Daily Temperature, July 27, 1970, to September 3, 1970

Date	Kw-hr	Avg. Temp. °F	Date	Kw-hr	Avg. Temp. °F
727	60	79.1	816	70	71.5
728	70	79.6	817	70	78.6
729	80	79.6	818	80	78.4
730	70	80.6	819	50	74.4
731	50	78.9	820	60	65.8
801	40	71.9	821	40	74.1
802	50	66.8	822	60	75.6
803	40	64.3	823	60	68.8
804	60	70.9	824	30	76.9
805	80	74.5	825	60	78.6
806	80	71.3	826	80	80.0
807	80	72.3	827	80	79.1
808	80	69.5	828	70	65.0
809	70	67.8	829	60	76.9
810	80	76.6	830	40	68.1
811	70	76.3	831	50	66.0
812	90	78.9	901	80	76.9
813	70	79.1	902	70	75.9
814	80	81.6	903	50	74.3
815	80	72.8			

APPENDIX B. Respiration Rates and Temperatures by Treatment at Sampling Time

Table 2. Treatment Respiration Rates and Temperature at Sampling Time

Date	Temp °F	Treatment 1	Temp °F	Treatment 2	Temp °F	Treatment 3
		Respiration Rate, Breaths/Minute				
1	81.5	25.2	82.2	62.3	83.1	93.0
2	81.5	23.5	82.2	67.3	83.1	76.3
3	82.6	44.5	82.3	38.0	83.8	49.5
4	78.1	26.2	78.5	58.2	78.3	49.2
5	78.1	37.2	78.5	40.6	78.3	47.2
6	82.7	45.0	83.5	60.0	83.8	78.6
7	82.6	55.8	83.0	57.8	83.0	58.0

APPENDIX C. Temperature Data

Table 3. Maximum, Minimum and Average Temperatures at Point 1 from July 17, 1970, to September 3, 1970

Date	Max. °F	Min. °F	Avg. °F	Date	Max. °F	Min. °F	Avg. °F
717	82.0	69.5	75.0	811	82.5	72.0	76.9
718	85.5	70.0	77.9	812	86.5	71.5	77.8
719	77.5	69.0	74.0	813	87.0	70.5	77.5
720	79.5	62.5	70.1	814	86.5	75.0	80.5
721	76.0	63.5	70.3	815	77.0	73.0	75.0
722	76.0	61.5	69.6	816	77.5	63.5	69.0
723	76.0	62.5	69.8	817	82.0	65.5	73.1
724	83.0	67.0	73.9	818	85.5	70.0	75.9
725	86.0	69.5	77.4	819	79.5	72.0	76.1
726	86.5	72.5	79.3	820	77.0	62.5	67.0
727	84.0	75.0	79.3	821	69.0	61.5	66.1
728	84.0	74.0	79.3	822	76.0	61.5	68.8
729	87.5	74.5	79.5	823	72.0	62.5	67.5
730	84.0	76.0	80.0	824	78.0	65.5	72.1
731	79.0	73.5	75.9	825	78.0	67.0	71.0
801	76.5	68.5	71.8	826	83.0	65.5	72.3
802	77.5	70.0	73.3	827	76.0	69.5	72.8
803	75.5	67.5	71.1	828	67.0	63.5	65.0
804	77.5	69.5	73.3	829	74.5	63.0	67.4
805	81.5	72.0	75.4	830	70.0	64.0	67.0
806	77.5	72.5	75.1	831	73.5	62.5	64.9
807	79.0	73.5	76.3	901	81.5	65.5	71.5
808	78.0	73.5	75.9	902	81.0	70.5	74.0
809	77.5	69.5	74.1	903	73.5	56.5	70.1
810	79.0	71.5	74.5				

Table 4. Maximum, Minimum and Average Temperatures at Point 2 from July 17, 1970, to September 3, 1970

Date	Max. °F	Min. °F	Avg. °F
717	82.5	70.5	76.4
718	82.0	71.0	76.9
719	74.5	66.5	70.9
720	77.0	61.5	68.1
721	74.0	60.0	67.3
722	73.5	60.0	67.0
723	74.0	60.5	67.8
724	82.0	67.0	73.8
725	86.0	69.5	77.9
726	86.0	72.0	79.3
727	83.5	72.0	77.8
728	85.5	72.0	78.0
729	86.5	76.0	79.9
730	84.0	75.0	79.1
731	80.0	75.0	77.1
801	78.5	70.0	73.3
802	77.5	71.0	74.0
803	77.0	67.5	72.1
804	80.5	70.5	75.0
805	83.0	71.5	76.5
806	77.5	74.5	75.9
807	79.5	75.5	77.0
808	78.5	76.0	77.0
809	78.5	73.0	74.4
810	81.5	74.0	77.1
811	83.0	74.0	78.5
812	87.0	74.5	79.9
813	88.0	72.5	79.9
814	88.0	77.0	82.0
815	80.5	75.0	78.0
816	80.0	65.5	72.3
817	84.0	70.0	76.1
818	86.0	72.0	76.6
819	79.5	72.5	76.3
820	78.0	60.0	66.9
821	70.0	61.5	67.6
822	79.0	61.5	70.0
823	74.5	62.5	68.1
824	80.0	68.0	74.1
825	80.0	68.5	73.1
826	84.0	67.5	74.0
827	77.5	71.5	75.0
828	69.0	66.0	67.6
829	76.5	65.0	69.3
830	73.0	66.0	68.6
831	73.5	64.0	67.3
901	83.5	67.5	73.6
902	81.5	72.5	76.3
903	74.0	57.5	70.8

Table 5. Maximum, Minimum and Average Temperatures at Point 3 from July 17, 1970, to September 3, 1970

Date	Max. °F	Min. °F	Avg. °F	Date	Max. °F	Min. °F	Avg. °F
717	83.0	69.5	75.6	811	81.0	72.5	76.8
718	81.5	71.5	75.9	812	86.0	71.5	77.8
719	73.5	66.0	69.8	813	86.0	70.0	78.3
720	75.0	61.5	67.1	814	87.0	74.0	79.9
721	72.0	60.0	66.1	815	79.0	73.5	76.3
722	70.5	60.0	66.4	816	80.0	64.5	71.4
723	70.0	60.0	66.0	817	82.5	68.5	74.9
724	76.5	64.0	69.6	818	85.0	72.0	75.6
725	82.0	66.0	73.9	819	80.0	71.5	75.6
726	80.5	67.5	74.6	820	77.0	58.5	66.4
727	80.0	68.5	73.8	821	70.5	61.5	69.0
728	79.5	68.5	74.0	822	76.0	60.5	69.3
729	83.0	72.0	76.8	823	77.5	64.5	69.9
730	81.5	72.0	75.9	824	81.0	68.5	75.5
731	78.0	73.0	75.3	825	82.5	67.0	73.8
801	78.5	68.5	71.9	826	86.0	67.0	74.1
802	76.0	71.0	74.3	827	79.5	70.0	75.0
803	76.0	67.0	71.5	828	69.5	64.5	67.1
804	79.5	69.5	74.1	829	78.5	63.5	69.4
805	81.5	70.5	75.8	830	72.0	65.0	68.0
806	77.0	74.5	75.8	831	74.5	63.0	66.9
807	78.5	75.5	76.4	901	84.0	66.0	73.1
808	77.5	74.5	76.1	902	83.0	72.5	75.3
809	77.5	70.5	73.1	903	74.0	59.0	70.0
810	80.0	74.5	76.6				

Table 6. Maximum, Minimum and Average Temperatures at Point 4 from July 17, 1970, to September 3, 1970

Date	Max. °F	Min. °F	Avg. °F	Date	Max. °F	Min. °F	Avg. °F
717	81.0	69.0	74.5	811	81.5	72.0	76.4
718	80.5	70.0	74.6	812	85.5	72.5	77.8
719	73.0	59.0	69.0	813	86.0	74.0	79.4
720	73.0	60.5	66.6	814	85.5	76.0	80.3
721	70.5	59.5	65.6	815	78.5	72.5	76.4
722	72.0	60.0	66.8	816	80.0	67.0	71.5
723	71.0	60.0	66.1	817	82.0	70.0	76.0
724	77.5	64.0	69.9	818	86.8	71.0	77.2
725	81.5	65.5	73.3	819	80.0	68.5	74.4
726	81.5	67.0	74.4	820	76.0	64.0	68.8
727	79.0	67.0	72.1	821	72.5	66.0	71.3
728	80.5	69.0	74.3	822	76.5	64.5	72.5
729	82.5	70.5	75.5	823	77.5	66.5	71.1
730	80.0	70.5	75.3	824	80.5	67.5	75.5
731	76.0	69.5	73.1	825	81.5	69.0	74.8
801	74.5	61.5	68.3	826	86.0	70.0	75.3
802	73.5	69.5	70.6	827	80.0	72.5	76.8
803	72.0	64.5	68.5	828	73.5	67.0	69.5
804	73.5	69.0	71.0	829	79.0	66.0	70.9
805	77.5	70.0	72.9	830	77.5	67.5	72.1
806	74.0	71.5	73.1	831	74.0	64.0	67.3
807	77.5	70.0	74.9	901	83.0	68.5	73.8
808	75.5	72.0	74.0	902	82.0	73.0	76.1
809	77.0	72.0	73.1	903	75.0	59.0	71.6
810	79.5	73.5	76.4				

Table 7. Maximum, Minimum and Average Temperatures at Point 5 from July 17, 1970, to September 3, 1970

Date	Max. °F	Min. °F	Avg. °F	Date	Max. °F	Min. °F	Avg. °F
717	69.0	54.0	63.4	811	64.5	53.0	58.3
718	72.0	58.0	65.3	812	68.0	53.0	59.9
719	68.0	59.0	65.0	813	68.5	53.0	60.3
720	77.5	56.5	67.8	814	69.0	53.5	60.4
721	76.0	55.0	61.1	815	59.0	50.5	54.5
722	74.0	53.0	61.8	816	62.5	45.0	53.4
723	70.0	52.5	56.3	817	64.0	48.0	56.1
724	66.0	58.5	61.5	818	69.0	56.0	60.6
725	66.0	54.5	59.3	819	62.0	49.5	55.5
726	69.0	53.5	60.8	820	58.5	49.0	53.3
727	68.0	54.0	61.6	821	60.5	49.0	52.4
728	68.0	54.5	61.6	822	59.0	52.0	53.4
729	72.0	61.0	67.3	823	74.0	53.5	62.3
730	71.0	57.0	65.3	824	69.0	46.5	58.9
731	64.5	57.0	59.3	825	65.5	49.0	56.1
801	70.0	51.0	58.8	826	68.0	50.5	58.1
802	67.0	53.0	60.3	827	63.0	54.0	57.6
803	69.0	47.5	50.3	828	54.5	46.5	49.6
804	68.5	53.5	64.4	829	68.0	51.5	58.0
805	66.0	50.5	58.5	830	57.5	46.0	51.4
806	61.0	56.0	58.4	831	57.5	51.0	54.6
807	63.5	58.0	60.3	901	68.5	52.5	60.5
808	60.0	56.5	57.4	902	65.0	57.5	59.8
809	60.0	51.5	55.1	903	61.0	41.5	56.3
810	63.5	53.0	57.8				

Table 8. Maximum, Minimum and Average Temperatures at Point 6 from July 17, 1970, to September 3, 1970

Date	Max. °F	Min. °F	Avg. °F	Date	Max. °F	Min. °F	Avg. °F
717	69.0	53.5	63.0	811	79.0	68.0	73.3
718	72.0	58.0	65.1	812	86.0	69.5	76.3
719	68.0	58.5	65.0	813	85.5	69.5	76.3
720	77.0	60.5	68.3	814	84.5	70.0	77.8
721	75.5	52.0	64.6	815	77.5	70.0	75.0
722	74.5	64.0	69.8	816	77.0	63.5	68.9
723	74.0	63.0	69.0	817	81.5	65.0	72.4
724	77.5	59.0	65.1	818	83.5	70.5	74.5
725	83.0	54.0	72.8	819	77.0	69.0	73.9
726	84.5	70.0	77.5	820	75.5	61.5	66.3
727	83.5	73.0	77.8	821	69.0	62.0	67.3
728	85.5	71.0	76.8	822	75.0	62.5	68.5
729	85.5	75.5	79.6	823	74.5	62.5	68.4
730	85.5	73.5	78.4	824	77.5	66.5	72.3
731	81.5	74.5	78.6	825	79.0	66.0	71.4
801	80.0	62.0	73.8	826	83.0	67.0	73.4
802	75.5	69.5	72.0	827	77.5	70.0	74.3
803	73.5	65.0	68.5	828	68.0	64.5	66.1
804	77.0	68.5	71.5	829	77.5	63.5	71.1
805	79.0	66.5	72.9	830	70.5	64.0	67.6
806	76.0	71.5	72.6	831	70.0	61.5	64.1
807	75.0	70.5	73.1	901	80.0	66.5	71.4
808	73.0	70.0	71.5	902	79.0	70.0	72.9
809	74.0	67.5	69.8	903	74.0	57.0	69.8
810	79.5	68.0	73.4				

Table 9. Maximum, Minimum and Average Temperatures at Point 7 from July 17, 1970, to September 3, 1970

Date	Max. °F	Min. °F	Avg. °F	Date	Max. °F	Min. °F	Avg. °F
717	98.5	66.5	80.4	811	93.5	63.0	76.3
718	97.0	66.0	77.8	812	97.0	66.0	78.9
719	71.5	60.0	64.4	813	97.5	64.0	79.1
720	84.0	49.5	64.1	814	100.0	73.0	81.6
721	82.5	52.0	65.6	815	90.0	62.5	72.8
722	83.0	54.5	68.0	816	97.0	54.5	71.5
723	81.5	55.0	66.1	817	87.5	61.5	78.6
724	92.0	57.5	73.0	818	97.5	68.5	78.4
725	94.0	61.5	76.8	819	86.5	65.5	74.4
726	98.0	67.0	81.3	820	93.0	49.0	65.8
727	92.5	65.5	79.1	821	81.0	52.5	74.1
728	93.0	67.0	79.6	822	93.5	55.0	75.6
729	104.0	67.0	79.6	823	96.0	43.0	68.8
730	97.0	66.0	80.6	824	97.0	61.5	76.9
731	97.0	68.5	78.9	825	99.0	66.0	78.6
801	95.5	57.5	71.9	826	99.5	64.0	80.0
802	81.0	59.0	66.8	827	98.0	68.5	79.1
803	81.5	48.0	64.3	828	69.5	60.5	65.0
804	86.5	62.0	70.9	829	103.5	60.0	76.9
805	86.5	61.5	74.5	830	81.5	57.5	68.1
806	75.5	68.0	71.3	831	87.5	54.5	66.0
807	76.5	70.0	72.3	901	98.5	64.0	76.9
808	73.5	67.5	69.5	902	90.5	72.5	75.9
809	76.5	63.5	67.8	903	88.5	62.0	74.3
810	88.0	64.0	74.6				

Table 10. Maximum, Minimum and Average Temperatures at Point 8 from July 17, 1970, to September 3, 1970

Date	Max. °F	Min. °F	Avg. °F	Date	Max. °F	Min. °F	Avg. °F
717	82.0	71.5	75.5	811	79.0	70.0	74.1
718	81.5	71.0	76.4	812	85.5	69.5	76.8
719	74.0	66.5	70.1	813	87.5	72.0	79.1
720	72.5	60.5	66.6	814	87.0	75.0	81.3
721	72.0	59.0	65.9	815	80.0	74.5	78.1
722	73.0	60.0	67.3	816	80.0	66.5	72.3
723	74.0	60.5	67.5	817	83.5	67.0	75.8
724	77.5	64.0	70.8	818	85.5	72.0	77.1
725	81.5	66.5	73.9	819	80.5	74.0	77.4
726	83.0	69.0	76.4	820	77.5	62.5	68.4
727	79.0	69.0	73.6	821	72.5	63.0	70.1
728	81.5	70.0	75.5	822	77.0	62.5	72.5
729	83.0	73.5	77.3	823	76.0	64.5	69.9
730	80.0	72.0	75.9	824	81.5	69.5	75.8
731	79.0	72.0	75.1	825	81.5	70.0	74.9
801	75.5	67.5	70.9	826	86.0	69.0	75.1
802	72.5	61.5	67.9	827	79.5	72.5	76.6
803	72.5	63.0	68.3	828	70.0	63.0	67.3
804	77.0	67.0	71.5	829	78.5	65.5	70.3
805	79.0	69.5	74.0	830	72.5	66.5	69.6
806	74.0	72.0	73.0	831	73.5	64.0	67.0
807	75.5	72.5	73.6	901	84.0	67.5	73.4
808	74.5	72.5	73.5	902	82.0	74.0	75.9
809	74.0	69.0	70.6	903	75.5	58.5	71.3
810	77.5	70.5	73.9				

Table 11. Maximum, Minimum and Average Temperatures at Point 9 from July 17, 1970, to September 3, 1970

Date	Max. °F	Min. °F	Avg. °F	Date	Max. °F	Min. °F	Avg. °F
717	84.0	71.5	76.6	811	82.5	70.5	75.3
718	84.5	69.5	77.1	812	86.5	71.5	77.6
719	74.5	66.5	70.8	813	88.0	69.5	78.0
720	73.5	61.5	67.5	814	88.0	75.0	81.1
721	73.5	60.0	67.3	815	79.0	73.0	76.0
722	74.5	60.0	67.4	816	80.0	66.0	72.0
723	73.5	60.5	67.4	817	82.5	67.0	74.3
724	81.0	63.5	71.8	818	86.0	70.0	75.1
725	87.0	68.5	77.8	819	79.5	70.5	75.4
726	88.5	73.5	81.1	820	76.5	61.5	67.6
727	86.0	75.0	80.5	821	70.5	61.5	69.3
728	86.5	75.5	81.0	822	76.5	61.5	70.9
729	89.5	78.0	82.6	823	76.5	64.5	70.3
730	86.5	76.0	81.4	824	82.5	68.0	75.5
731	83.0	77.5	79.9	825	83.0	68.0	73.9
801	79.5	70.0	73.1	826	87.0	68.0	75.3
802	76.0	71.5	74.1	827	80.5	72.5	76.8
803	75.5	70.0	71.6	828	70.0	67.0	68.9
804	80.0	70.5	73.9	829	79.0	66.0	70.9
805	82.0	70.0	75.1	830	74.0	67.5	70.8
806	74.5	72.0	73.4	831	74.5	64.5	67.5
807	77.0	74.0	76.0	901	84.0	68.0	74.0
808	75.5	72.5	74.1	902	82.0	73.5	76.5
809	77.0	69.5	70.9	903	76.0	60.0	71.6
810	79.5	70.5	74.0				

Table 12. Maximum, Minimum and Average Temperatures at Point 10 from July 17, 1970, to September 3, 1970

Date	Max. °F	Min. °F	Avg. °F	Date	Max. °F	Min. °F	Avg. °F
717	83.5	69.5	75.1	811	83.0	68.0	73.4
718	84.5	69.0	76.5	812	86.5	69.0	75.8
719	74.5	66.5	70.6	813	89.0	68.0	77.5
720	73.5	60.5	66.9	814	89.0	76.0	80.8
721	73.5	60.0	66.8	815	79.0	70.0	72.9
722	74.0	59.5	67.0	816	79.0	65.0	69.6
723	73.0	60.0	66.9	817	81.0	64.0	72.5
724	81.0	63.5	71.8	818	86.0	69.5	74.5
725	86.5	69.5	78.4	819	77.0	68.0	73.0
726	86.5	72.0	79.4	820	74.5	59.0	64.5
727	85.0	74.0	78.6	821	70.0	61.0	66.6
728	85.5	73.5	79.9	822	73.5	59.0	70.0
729	88.0	77.5	81.4	823	74.0	62.5	68.3
730	86.0	76.0	80.6	824	82.5	65.0	73.9
731	82.0	76.0	78.4	825	81.5	66.0	72.3
801	79.5	70.5	73.1	826	87.5	66.0	74.6
802	75.5	69.0	71.9	827	78.0	69.5	73.9
803	75.5	63.0	68.9	828	69.0	62.5	65.4
804	79.0	69.0	72.9	829	79.5	63.5	69.9
805	81.5	67.5	72.9	830	74.0	64.0	68.0
806	74.0	70.5	72.3	831	73.5	62.5	65.8
807	78.0	73.0	76.4	901	86.5	65.0	72.9
808	77.0	71.5	74.3	902	81.5	70.5	73.9
809	78.5	68.5	70.0	903	72.0	54.0	69.4
810	79.5	68.5	72.8				

Table 13. Maximum, Minimum and Average Temperatures at Point 11 from July 17, 1970, to September 3, 1970

Date	Max. °F	Min. °F	Avg. °F	Date	Max. °F	Min. °F	Avg. °F
717	84.5	70.0	76.1	811	82.5	71.5	76.0
718	84.0	70.0	77.0	812	85.5	70.0	76.8
719	75.0	67.5	71.8	813	86.0	68.0	76.3
720	75.0	62.5	68.8	814	87.5	73.5	79.5
721	74.0	61.0	67.6	815	76.5	70.0	73.5
722	74.0	61.0	68.0	816	78.0	64.0	68.9
723	73.0	61.0	67.4	817	81.0	64.0	72.0
724	82.5	64.5	72.1	818	85.5	69.0	74.1
725	85.5	66.5	76.4	819	77.0	69.0	73.4
726	86.5	69.0	78.1	820	74.5	59.5	64.8
727	83.0	72.5	77.3	821	70.0	61.0	66.3
728	86.5	69.5	77.6	822	74.0	59.0	69.9
729	88.0	75.0	80.3	823	73.0	62.5	68.1
730	85.0	76.0	80.1	824	81.5	63.5	73.1
731	78.5	73.5	76.1	825	81.0	65.5	71.8
801	78.0	70.5	73.4	826	86.5	65.0	73.6
802	75.5	70.0	73.1	827	77.5	69.0	73.5
803	74.0	67.0	69.0	828	68.0	62.5	64.9
804	79.5	70.5	74.4	829	79.0	63.0	69.6
805	81.0	72.0	76.0	830	73.5	63.0	67.3
806	75.5	70.5	74.0	831	73.5	62.0	65.4
807	78.0	73.5	75.6	901	86.0	64.5	72.6
808	77.0	72.0	75.1	902	81.0	70.5	73.5
809	75.5	70.0	71.4	903	72.0	54.0	69.3
810	79.5	70.5	74.5				

Table 14. Maximum, Minimum and Average Temperatures at Point 12 from July 17, 1970, to September 3, 1970

Date	Max. °F	Min. °F	Avg. °F	Date	Max. °F	Min. °F	Avg. °F
717	83.0	69.5	76.4	811	81.5	68.0	75.4
718	86.5	70.0	78.8	812	85.5	70.5	76.6
719	78.5	71.0	75.0	813	88.0	72.0	78.5
720	78.5	62.5	71.0	814	86.0	74.0	78.9
721	76.5	62.5	69.5	815	78.0	73.5	75.4
722	75.5	63.0	69.5	816	80.0	64.5	71.8
723	75.0	61.0	68.4	817	81.5	66.0	73.6
724	79.5	66.0	72.9	818	86.0	68.5	73.9
725	84.5	69.0	76.5	819	77.5	70.0	73.9
726	85.5	70.0	78.3	820	76.0	60.0	65.1
727	83.0	71.5	77.6	821	68.5	61.5	65.8
728	84.0	70.5	78.1	822	74.0	62.5	68.6
729	88.0	76.0	80.9	823	72.0	62.5	67.6
730	85.0	75.0	79.0	824	78.0	63.5	71.1
731	79.5	74.0	75.5	825	77.5	64.5	69.9
801	77.5	68.5	72.6	826	83.0	64.0	71.5
802	75.0	70.0	73.0	827	74.5	68.0	71.4
803	75.0	67.5	69.8	828	65.5	61.5	63.4
804	78.0	69.5	73.8	829	75.5	61.0	66.6
805	82.0	69.0	74.9	830	69.0	61.5	64.9
806	77.0	72.0	74.8	831	70.0	61.5	64.0
807	78.0	73.5	75.5	901	81.0	64.0	70.8
808	76.5	72.5	74.5	902	79.0	69.5	72.6
809	77.0	69.0	71.6	903	73.0	56.5	69.1
810	80.5	70.5	75.8				

Table 15. Maximum, Minimum and Average Temperatures at Point 13 from July 17, 1970, to September 3, 1970

Date	Max. °F	Min. °F	Avg. °F	Date	Max. °F	Min. °F	Avg. °F
717	68.0	58.0	61.3	811	67.0	56.0	61.3
718	73.0	60.0	65.1	812	70.0	57.0	62.3
719	68.5	58.0	63.0	813	68.5	55.0	61.5
720	72.5	64.0	66.6	814	67.0	56.5	61.1
721	74.5	59.0	63.4	815	65.0	53.5	58.1
722	67.0	56.0	62.9	816	61.5	49.0	53.9
723	73.5	57.5	61.4	817	66.0	50.5	57.3
724	67.5	60.0	63.9	818	70.0	58.5	62.4
725	71.0	59.0	64.1	819	61.5	52.0	56.9
726	73.0	62.5	66.6	820	60.0	48.0	53.5
727	76.5	58.0	65.4	821	63.0	51.0	54.6
728	76.5	64.0	71.4	822	59.5	54.0	54.5
729	74.0	63.0	68.3	823	75.0	61.0	65.6
730	73.5	63.0	67.0	824	67.0	59.0	62.4
731	66.0	59.0	61.4	825	66.0	52.5	59.1
801	67.0	57.0	60.6	826	70.0	52.0	58.8
802	63.0	58.0	60.1	827	65.0	57.0	59.9
803	63.0	50.5	54.1	828	56.0	50.0	52.3
804	65.0	55.0	59.8	829	69.0	61.0	64.1
805	67.5	53.0	59.9	830	59.0	50.0	54.4
806	64.0	60.0	61.6	831	60.0	53.0	56.6
807	66.0	61.0	62.3	901	70.5	61.0	65.1
808	62.0	60.0	60.6	902	68.0	61.0	62.8
809	63.0	55.0	57.9	903	63.5	57.5	60.6
810	66.0	56.5	60.6				

Table 16. Maximum, Minimum and Average Temperatures at Point 14 from July 17, 1970, to September 3, 1970

Date	Max. °F	Min. °F	Avg. °F	Date	Max. °F	Min. °F	Avg. °F
717	80.5	62.5	69.0	811	78.5	65.5	70.3
718	76.5	64.0	68.8	812	79.0	68.5	73.1
719	71.5	64.0	68.8	813	80.0	63.0	70.0
720	68.0	60.0	64.4	814	77.0	67.5	71.3
721	70.5	55.0	60.3	815	76.0	62.0	67.3
722	79.5	51.0	63.3	816	65.0	56.0	60.3
723	72.5	58.5	60.9	817	71.0	57.0	63.3
724	76.5	63.0	69.0	818	75.0	60.5	67.1
725	76.0	60.0	68.9	819	69.5	61.0	65.4
726	73.0	66.0	70.0	820	70.0	56.0	60.4
727	83.0	65.5	71.5	821	65.5	58.5	63.1
728	79.0	66.5	75.3	822	74.0	54.0	64.3
729	78.0	70.0	74.1	823	71.0	60.0	64.5
730	84.0	67.5	73.5	824	70.0	60.0	63.1
731	80.0	66.0	70.9	825	69.0	61.5	64.4
801	65.5	59.0	62.1	826	80.0	61.0	64.3
802	68.5	62.0	66.3	827	78.0	64.0	68.3
803	65.0	54.5	62.0	828	64.0	57.5	59.6
804	74.0	60.0	64.3	829	78.0	66.5	69.5
805	74.5	65.5	69.4	830	67.0	59.0	63.9
806	71.5	68.0	70.8	831	66.0	59.5	62.5
807	73.5	70.0	70.6	901	73.0	61.5	65.5
808	72.5	66.5	68.8	902	71.0	67.5	68.5
809	72.0	63.0	66.3	903	71.5	63.5	66.3
810	72.0	66.5	69.5				

Table 17. Maximum, Minimum and Average Temperatures at Point 15 from July 17, 1970, to September 3, 1970

Date	Max. °F	Min. °F	Avg. °F	Date	Max. °F	Min. °F	Avg. °F
717	82.5	70.0	75.1	811	81.0	72.5	76.4
718	85.5	72.5	77.4	812	85.0	70.0	76.8
719	76.0	70.5	74.3	813	88.5	68.0	75.8
720	73.0	63.5	68.0	814	85.0	73.0	77.6
721	73.5	61.5	67.1	815	82.5	71.0	75.5
722	73.0	62.0	66.4	816	78.5	66.5	71.8
723	75.0	63.0	67.4	817	79.5	63.5	70.4
724	82.5	66.0	74.0	818	83.0	70.0	74.5
725	85.0	67.5	76.9	819	78.0	71.0	74.6
726	87.0	72.0	78.5	820	78.5	64.0	69.8
727	87.5	70.5	78.3	821	74.5	63.0	70.5
728	83.5	75.0	79.3	822	76.5	61.0	70.4
729	88.0	75.0	79.3	823	82.0	64.5	72.4
730	87.5	75.0	79.8	824	82.5	65.0	73.6
731	83.0	74.0	77.0	825	83.5	67.5	75.3
801	75.0	67.0	71.4	826	86.0	67.5	74.0
802	76.0	69.0	72.5	827	83.0	70.5	75.9
803	72.5	64.5	68.9	828	71.0	66.5	67.9
804	77.0	69.0	71.9	829	83.0	67.5	74.0
805	79.0	67.5	72.8	830	74.0	66.5	70.3
806	74.5	72.0	73.3	831	74.5	68.0	72.3
807	77.0	73.5	74.6	901	84.5	66.5	72.9
808	74.5	72.0	73.6	902	82.0	72.5	74.5
809	75.0	69.5	71.4	903	79.0	69.0	73.3
810	80.0	71.0	74.3				

Table 18. Maximum, Minimum and Average Temperatures at Point 16 from July 17, 1970, to September 3, 1970

Date	Max. °F	Min. °F	Avg. °F	Date	Max. °F	Min. °F	Avg. °F
717	80.5	69.5	73.8	811	82.0	74.0	77.3
718	84.5	72.0	78.0	812	84.0	74.5	78.4
719	77.5	74.0	75.9	813	85.5	71.0	76.9
720	75.0	65.5	69.0	814	82.5	75.0	77.6
721	76.5	65.0	70.0	815	81.5	70.5	74.8
722	75.5	66.5	70.0	816	75.5	63.5	68.8
723	77.0	66.0	70.9	817	80.0	64.0	71.5
724	83.0	71.5	76.8	818	83.0	71.5	75.3
725	86.0	72.5	79.6	819	76.5	70.0	73.6
726	87.0	75.5	80.8	820	75.5	63.5	67.8
727	86.0	77.5	81.4	821	69.5	62.5	67.9
728	84.5	74.5	79.8	822	73.5	62.5	68.1
729	86.0	76.5	80.6	823	74.5	63.0	68.9
730	85.5	74.5	79.8	824	76.5	64.5	69.9
731	82.0	77.0	78.8	825	77.5	68.0	71.8
801	76.0	70.5	73.1	826	80.5	68.0	72.3
802	76.5	70.5	73.1	827	78.0	71.0	74.3
803	74.0	65.0	70.6	828	69.0	66.0	67.1
804	78.0	70.0	73.4	829	76.0	66.5	71.0
805	81.0	69.5	74.9	830	69.5	63.5	67.3
806	78.0	74.0	75.4	831	71.0	65.5	69.5
807	78.5	75.5	77.4	901	78.5	67.0	71.3
808	77.5	74.0	76.3	902	78.0	72.0	73.8
809	76.0	70.5	72.9	903	74.0	68.0	70.8
810	81.0	72.5	75.6				

Table 19. Maximum, Minimum and Average Temperatures at Point 17 from July 17, 1970, to September 3, 1970

Date	Max. °F	Min. °F	Avg. °F	Date	Max. °F	Min. °F	Avg. °F
717	77.0	68.0	71.5	811	82.0	73.0	76.3
718	80.0	69.0	74.5	812	84.0	75.5	78.6
719	75.5	71.0	74.0	813	85.0	70.5	77.0
720	77.0	67.0	70.5	814	81.5	75.5	77.9
721	76.5	67.0	70.5	815	80.5	70.5	74.6
722	75.0	68.5	71.4	816	75.0	63.0	68.6
723	77.5	68.5	72.3	817	79.0	64.5	71.4
724	82.5	72.5	77.0	818	83.0	72.5	75.5
725	85.5	73.0	79.3	819	77.0	70.5	74.1
726	85.0	75.5	80.0	820	75.0	65.0	68.4
727	84.0	75.5	80.0	821	69.5	64.0	67.8
728	82.0	74.0	78.5	822	73.5	62.5	67.9
729	86.0	78.5	81.6	823	74.5	65.0	69.6
730	83.0	75.5	79.1	824	75.5	65.5	70.0
731	82.0	77.0	78.6	825	76.0	65.5	70.1
801	76.5	69.5	73.8	826	79.0	67.5	71.5
802	77.5	69.5	72.9	827	77.5	70.5	73.6
803	73.5	65.0	69.8	828	68.0	65.5	66.6
804	79.0	69.5	73.1	829	75.5	66.5	71.0
805	82.0	69.5	75.3	830	70.0	62.5	66.6
806	77.5	74.0	75.8	831	70.0	65.0	68.6
807	78.5	75.0	77.4	901	77.0	67.0	70.6
808	77.5	74.5	76.1	902	77.0	71.5	73.0
809	77.0	70.0	73.5	903	73.0	68.0	70.4
810	81.0	71.0	75.1				

Table 20. Maximum, Minimum and Average Temperatures at Point 18 from July 17, 1970, to September 3, 1970

Date	Max. °F	Min. °F	Avg. °F	Date	Max. °F	Min. °F	Avg. °F
717	76.5	67.0	71.0	811	67.0	55.0	60.3
718	80.0	68.5	73.6	812	69.0	56.5	60.9
719	74.5	70.0	72.9	813	66.0	53.0	59.9
720	74.5	62.5	68.0	814	65.0	54.0	58.9
721	76.5	65.5	69.8	815	64.0	51.0	57.0
722	67.0	54.0	59.6	816	59.0	47.0	51.8
723	64.0	55.5	59.0	817	65.0	49.0	55.3
724	76.0	57.5	65.5	818	68.0	57.0	60.5
725	79.0	60.5	71.6	819	59.0	50.0	54.8
726	79.0	65.0	69.8	820	58.0	46.5	52.0
727	76.5	63.0	67.8	821	61.0	49.0	51.8
728	71.5	61.0	66.9	822	57.5	52.0	52.5
729	71.5	62.5	68.1	823	73.0	60.0	63.4
730	78.0	60.0	66.9	824	65.0	57.5	60.3
731	73.5	68.0	69.4	825	63.0	50.0	56.4
801	62.0	55.0	58.1	826	68.0	50.0	56.6
802	61.5	55.0	57.6	827	63.0	55.0	57.9
803	57.5	48.0	53.0	828	54.0	48.0	50.1
804	63.5	54.0	58.3	829	67.0	60.0	62.3
805	65.5	54.0	60.3	830	57.0	48.0	52.3
806	63.0	57.5	60.0	831	56.5	52.5	54.8
807	64.0	59.0	60.5	901	68.5	56.0	61.3
808	61.5	59.0	60.1	902	66.5	59.0	60.5
809	62.0	55.0	57.5	903	61.0	54.0	58.0
810	67.0	55.0	59.9				

Table 21. Maximum, Minimum and Average Temperatures at Point 19 from July 17, 1970, to September 3, 1970

Date	Max. °F	Min. °F	Avg. °F	Date	Max. °F	Min. °F	Avg. °F
717	75.0	68.5	71.1	811	81.0	71.0	74.5
718	78.5	68.0	73.4	812	83.5	68.0	77.3
719	74.5	70.5	73.1	813	83.5	70.5	75.1
720	72.5	61.0	67.4	814	79.0	73.5	76.5
721	81.0	64.0	72.3	815	79.0	69.0	73.5
722	81.5	74.0	77.8	816	73.5	61.5	67.0
723	83.0	76.0	79.0	817	81.0	64.5	70.8
724	88.0	78.0	81.4	818	83.0	74.0	76.0
725	90.0	78.5	84.9	819	80.0	70.0	75.8
726	88.0	79.5	83.1	820	78.5	65.5	69.0
727	88.0	77.5	82.8	821	69.5	64.0	67.9
728	84.5	73.5	79.6	822	77.0	64.5	69.4
729	86.0	77.5	80.4	823	79.0	64.5	70.9
730	83.0	73.0	77.8	824	76.5	69.0	71.6
731	79.5	75.0	76.5	825	78.0	68.0	71.1
801	73.5	69.0	71.5	826	82.0	67.5	72.6
802	73.5	69.5	71.9	827	79.5	71.0	75.0
803	78.0	66.0	70.8	828	68.0	66.5	67.1
804	81.0	71.0	74.5	829	75.5	66.5	70.8
805	82.0	73.0	77.0	830	70.0	63.0	66.8
806	82.0	67.5	75.5	831	69.0	64.0	68.0
807	79.0	76.0	76.6	901	75.0	67.5	70.3
808	76.5	73.0	74.8	902	75.0	71.5	72.6
809	76.0	69.0	72.1	903	72.0	68.5	70.1
810	78.0	70.5	73.4				

Table 22. Maximum, Minimum and Average Temperatures at Point 20 from July 17, 1970, to September 3, 1970

Date	Max. °F	Min. °F	Avg. °F	Date	Max. °F	Min. °F	Avg. °F
717	77.5	68.5	72.5	811	82.5	73.5	76.8
718	81.0	67.5	74.3	812	85.0	75.5	78.8
719	75.0	71.0	73.6	813	86.0	71.0	77.1
720	73.5	62.0	68.3	814	81.5	73.0	78.1
721	76.5	64.5	69.6	815	81.0	71.5	75.5
722	76.0	68.5	71.9	816	75.5	63.0	68.6
723	77.0	69.0	72.1	817	79.5	65.5	72.0
724	83.0	74.0	78.5	818	84.0	74.0	76.6
725	86.0	74.5	80.4	819	79.0	70.5	75.3
726	87.0	77.0	80.9	820	77.5	66.0	70.3
727	85.0	78.0	81.4	821	72.0	65.0	69.8
728	83.5	75.5	79.8	822	75.5	65.0	69.9
729	85.5	78.5	81.4	823	78.0	66.0	71.4
730	87.0	80.5	84.6	824	78.5	67.5	72.4
731	81.0	77.5	78.8	825	78.5	69.0	72.9
801	75.5	70.5	73.1	826	82.0	69.5	73.6
802	75.5	68.0	72.1	827	80.0	72.5	75.8
803	74.5	66.0	70.5	828	69.5	67.5	68.4
804	79.5	70.0	73.6	829	77.5	67.5	72.3
805	81.5	73.0	76.6	830	77.5	63.5	67.8
806	78.0	75.0	76.1	831	71.0	66.0	70.1
807	79.5	76.5	78.1	901	78.5	68.0	71.8
808	78.0	75.0	76.5	902	78.0	72.5	73.9
809	78.0	72.5	74.0	903	75.0	69.0	71.0
810	80.0	71.5	75.3				

Table 23. Maximum, Minimum and Average Temperatures at Point 21 from July 17, 1970, to September 3, 1970

Date	Max. °F	Min. °F	Avg. °F	Date	Max. °F	Min. °F	Avg. °F
717	74.0	68.5	70.9	811	87.0	75.5	76.9
718	78.5	69.0	74.0	812	85.0	78.0	80.1
719	75.5	71.0	73.6	813	85.0	72.0	76.4
720	70.5	63.0	65.9	814	82.0	75.0	77.9
721	75.5	63.0	68.4	815	80.0	70.0	75.8
722	75.5	67.5	71.3	816	75.0	63.5	69.1
723	75.0	69.0	71.4	817	82.0	68.5	74.0
724	88.0	76.0	81.6	818	86.0	74.0	77.4
725	90.5	78.5	84.5	819	79.0	71.0	75.8
726	90.0	80.0	85.4	820	77.0	66.6	69.8
727	87.0	80.5	82.8	821	74.0	66.5	70.5
728	86.5	77.0	81.6	822	75.5	63.0	70.4
729	87.0	77.5	81.8	823	81.5	65.5	71.4
730	82.5	74.5	78.1	824	81.0	69.5	75.1
731	81.0	76.0	78.0	825	82.0	71.0	76.0
801	74.0	69.5	72.4	826	83.0	75.5	78.8
802	75.0	70.5	72.6	827	81.0	75.0	77.9
803	73.0	64.0	69.3	828	72.5	68.0	70.4
804	76.5	69.5	71.5	829	75.5	67.0	71.0
805	81.5	73.0	75.8	830	77.0	63.0	67.1
806	77.0	74.0	75.3	831	69.5	65.5	68.8
807	78.0	75.5	76.8	901	75.5	68.0	70.8
808	77.0	73.0	75.8	902	75.5	72.0	73.3
809	78.0	70.5	72.6	903	73.5	69.0	71.0
810	82.5	70.0	76.0				

Table 24. Maximum, Minimum and Average Temperatures at Point 22 from July 17, 1970, to September 3, 1970

Date	Max. °F	Min. °F	Avg. °F	Date	Max. °F	Min. °F	Avg. °F
717	77.0	68.5	72.3	811	83.0	75.5	77.9
718	81.0	68.5	74.8	812	85.0	76.0	79.4
719	75.0	71.0	73.6	813	85.5	73.0	78.1
720	72.0	63.0	66.4	814	82.5	76.5	78.9
721	75.5	63.0	68.3	815	81.0	72.0	76.4
722	74.5	66.0	71.3	816	75.5	65.0	69.8
723	75.0	67.5	70.4	817	80.5	67.0	72.6
724	85.0	73.5	78.8	818	84.0	75.0	77.8
725	87.5	75.0	81.4	819	80.0	72.5	76.3
726	88.0	78.0	82.4	820	78.0	67.5	71.6
727	86.0	79.5	82.3	821	75.5	66.0	72.3
728	85.0	76.0	81.0	822	76.5	66.0	71.6
729	86.5	79.5	82.5	823	81.0	68.0	73.6
730	85.0	76.0	79.6	824	80.5	69.0	74.6
731	82.0	78.5	79.5	825	80.5	70.0	74.3
801	76.5	71.5	74.3	826	83.0	71.5	75.4
802	77.0	73.0	75.5	827	82.0	75.0	77.6
803	74.0	67.0	70.3	828	70.5	68.0	69.4
804	78.5	70.0	73.5	829	77.5	68.0	72.6
805	82.0	74.0	76.8	830	78.0	65.0	68.8
806	79.0	75.0	76.3	831	71.5	66.5	70.6
807	79.5	77.0	78.1	901	78.0	68.5	71.9
808	78.0	75.0	76.8	902	77.5	73.0	74.3
809	78.0	72.5	74.6	903	75.0	69.5	72.1
810	81.0	72.0	75.9				

Table 25. Maximum, Minimum and Average Temperatures at Point 23 from July 17, 1970, to September 3, 1970

Date	Max. °F	Min. °F	Avg. °F	Date	Max. °F	Min. °F	Avg. °F
717	75.5	68.5	71.4	811	84.0	74.0	78.1
718	84.0	69.5	76.8	812	85.0	77.0	79.3
719	79.5	75.0	77.6	813	84.5	73.0	78.3
720	72.0	63.0	66.5	814	82.5	76.5	78.9
721	74.0	63.0	67.1	815	80.5	72.0	76.3
722	74.0	65.0	69.8	816	78.0	65.0	70.6
723	73.0	65.0	68.4	817	83.0	67.5	73.6
724	87.0	72.0	77.9	818	84.0	76.0	79.1
725	90.0	73.5	81.6	819	81.5	74.0	78.1
726	90.0	80.0	84.6	820	78.0	70.0	73.6
727	88.0	80.0	84.0	821	79.0	69.0	75.4
728	87.0	76.0	81.8	822	81.0	65.5	74.4
729	89.5	83.0	85.9	823	82.5	68.0	75.3
730	89.5	78.5	80.8	824	83.0	74.5	77.9
731	82.5	76.0	78.5	825	84.5	76.0	79.1
801	79.5	70.5	74.4	826	86.0	75.0	79.1
802	78.0	71.0	74.0	827	84.5	76.5	80.0
803	76.5	65.0	71.5	828	75.0	68.5	71.8
804	79.5	71.0	74.6	829	77.0	69.0	72.6
805	82.0	74.0	77.3	830	72.0	64.0	68.3
806	80.0	75.5	77.4	831	70.5	66.0	69.6
807	83.5	77.0	78.3	901	79.0	68.5	72.1
808	84.0	75.5	78.0	902	77.0	73.0	74.0
809	78.5	74.0	75.0	903	75.0	70.5	72.8
810	79.5	70.5	74.0				

Table 26. Maximum, Minimum and Average Temperatures at Point 24 from July 17, 1970, to September 3, 1970

Date	Max. °F	Min. °F	Avg. °F	Date	Max. °F	Min. °F	Avg. °F
717	77.5	68.0	72.0	811	81.0	74.0	77.3
718	83.0	69.0	75.6	812	84.5	73.0	77.8
719	76.5	72.5	74.9	813	85.5	71.0	77.5
720	72.0	62.5	66.1	814	81.5	75.5	77.6
721	74.0	63.0	67.9	815	80.5	71.0	74.6
722	74.0	60.5	68.4	816	76.0	62.0	68.4
723	73.0	65.5	68.6	817	80.0	65.0	71.8
724	83.0	70.5	75.5	818	83.5	74.0	76.9
725	86.5	71.5	79.1	819	79.5	72.0	75.5
726	87.0	77.0	81.1	820	78.0	67.0	71.4
727	85.5	76.0	80.6	821	75.5	66.5	73.1
728	84.5	75.5	80.1	822	77.5	65.5	72.3
729	86.5	78.5	81.4	823	81.0	68.0	74.8
730	84.0	74.5	78.4	824	81.5	70.0	75.1
731	80.5	76.5	77.6	825	83.5	70.0	74.5
801	75.0	70.0	73.0	826	84.5	71.5	75.6
802	75.0	69.0	72.3	827	82.5	74.0	77.3
803	74.0	65.0	68.8	828	70.0	68.0	68.9
804	77.0	69.5	72.8	829	78.0	68.5	73.0
805	80.5	71.0	74.9	830	73.0	65.0	69.0
806	77.5	73.5	74.5	831	71.5	66.5	70.6
807	78.5	76.0	76.3	901	80.5	68.0	72.6
808	76.0	74.5	75.5	902	78.5	72.5	74.1
809	76.5	71.5	73.0	903	75.5	70.0	72.9
810	80.0	71.0	75.1				

Table 27. Maximum, Minimum and Average Temperatures at Point 25 from July 17, 1970, to September 3, 1970

Date	Max. °F	Min. °F	Avg. °F	Date	Max. °F	Min. °F	Avg. °F
717	78.0	68.0	72.3	811	79.0	71.0	75.1
718	82.0	69.0	75.5	812	82.5	70.5	76.4
719	76.0	71.5	74.3	813	83.5	71.0	76.8
720	72.5	62.0	65.6	814	81.0	75.0	77.4
721	74.5	63.0	67.6	815	80.5	71.0	74.6
722	73.0	65.0	69.4	816	74.5	62.0	67.4
723	75.0	65.5	68.8	817	80.0	65.0	72.1
724	81.0	68.5	74.1	818	82.5	73.5	76.5
725	85.0	70.0	77.5	819	79.0	71.5	75.4
726	86.5	73.5	78.6	820	81.0	65.0	71.3
727	84.5	76.0	79.9	821	77.0	67.5	75.3
728	83.5	73.0	78.9	822	78.0	68.0	74.8
729	86.0	78.5	81.1	823	83.5	70.5	76.6
730	83.5	76.5	79.1	824	83.5	70.5	76.6
731	80.0	76.5	77.6	825	82.0	73.0	76.6
801	74.0	68.5	71.6	826	85.5	74.0	77.1
802	74.0	69.0	71.6	827	83.5	76.5	78.9
803	72.0	64.0	68.6	828	73.5	69.5	71.3
804	76.5	69.5	72.0	829	81.0	70.5	75.8
805	79.0	71.0	74.5	830	75.5	66.5	71.0
806	76.0	73.0	74.4	831	75.0	68.5	72.8
807	77.0	74.5	75.3	901	82.0	71.5	74.8
808	76.0	73.5	74.4	902	80.0	75.0	76.6
809	75.0	70.0	71.8	903	77.0	72.0	74.5
810	79.0	71.5	74.6				

Table 28. Maximum, Minimum and Average Temperatures at Point 26 from July 17, 1970, to September 3, 1970

Date	Max. °F	Min. °F	Avg. °F	Date	Max. °F	Min. °F	Avg. °F
717	78.0	68.0	72.1	811	80.0	72.0	75.6
718	81.0	69.0	74.9	812	80.0	72.0	75.4
719	76.5	70.5	74.3	813	81.5	67.0	73.5
720	71.5	61.0	65.3	814	78.5	69.5	73.5
721	74.5	62.5	67.1	815	79.0	65.5	70.6
722	73.5	65.0	69.3	816	71.0	60.0	64.9
723	73.5	64.5	68.3	817	80.5	61.5	70.4
724	79.0	68.0	71.8	818	82.0	73.5	76.1
725	84.0	68.5	76.5	819	78.0	72.0	74.9
726	85.5	74.5	79.0	820	79.0	68.5	73.3
727	84.0	73.5	78.4	821	76.5	68.5	74.1
728	83.0	74.0	78.8	822	78.0	66.0	72.9
729	86.0	77.0	80.6	823	82.5	69.5	75.9
730	83.0	75.0	78.4	824	83.5	70.0	76.3
731	80.0	76.0	77.0	825	82.0	71.0	76.0
801	73.0	67.5	70.8	826	86.0	72.5	77.3
802	74.0	69.0	71.6	827	83.5	77.5	78.8
803	70.5	63.0	66.9	828	74.0	69.5	71.5
804	75.5	68.0	70.6	829	82.0	73.0	77.4
805	78.0	69.0	72.6	830	77.0	68.0	72.8
806	75.0	72.5	73.5	831	76.5	70.0	72.9
807	77.0	72.0	73.3	901	83.0	72.5	75.6
808	73.5	71.0	71.9	902	81.0	75.0	77.0
809	72.5	67.5	69.8	903	79.0	72.0	74.4
810	78.0	68.5	72.4				

Table 29. Maximum, Minimum and Average Temperatures at Point 27 from July 17, 1970, to September 3, 1970

Date	Max. °F	Min. °F	Avg. °F	Date	Max. °F	Min. °F	Avg. °F
717	77.0	68.0	72.3	811	78.0	72.5	74.8
718	82.0	72.0	76.9	812	80.5	70.5	74.6
719	77.0	70.5	74.3	813	82.0	68.5	74.4
720	72.0	61.0	65.5	814	79.0	71.0	74.1
721	73.0	62.0	66.9	815	77.0	68.0	72.6
722	72.5	64.5	68.9	816	72.0	62.0	66.6
723	73.0	62.5	68.0	817	79.0	63.0	70.3
724	79.0	68.0	71.8	818	81.5	72.0	76.0
725	86.0	68.5	77.1	819	79.0	72.0	76.0
726	87.0	76.0	80.8	820	80.0	68.5	73.1
727	86.0	78.0	81.4	821	77.5	26.0	75.3
728	85.5	75.5	80.8	822	79.0	68.5	74.4
729	88.0	80.0	82.5	823	82.5	71.0	76.5
730	85.0	70.0	77.6	824	82.5	51.0	70.3
731	82.0	76.0	78.9	825	82.0	71.5	76.0
801	76.0	71.5	73.8	826	86.0	72.0	77.3
802	76.5	71.0	73.3	827	84.0	78.0	80.0
803	74.0	66.0	70.0	828	74.5	71.5	72.4
804	78.5	70.5	72.9	829	84.0	74.0	78.6
805	80.5	72.5	75.5	830	78.5	69.0	73.8
806	78.0	74.0	75.3	831	77.0	71.5	75.0
807	75.0	73.0	73.6	901	83.5	72.5	76.6
808	73.5	71.0	71.9	902	83.0	77.0	78.5
809	72.5	67.5	69.8	903	80.5	74.5	77.1
810	76.5	69.0	72.1				

Table 30. Maximum, Minimum and Average Temperatures at Point 28 from July 17, 1970, to September 3, 1970

Date	Max. °F	Min. °F	Avg. °F	Date	Max. °F	Min. °F	Avg. °F
717	71.5	61.0	66.6	811	72.0	63.0	67.4
718	76.0	64.0	69.8	812	75.0	63.5	68.3
719	71.0	62.0	66.1	813	76.5	61.0	68.0
720	72.5	63.5	66.8	814	73.0	63.0	67.3
721	73.5	63.0	66.8	815	71.5	60.0	64.0
722	73.0	63.0	67.3	816	64.5	50.0	56.0
723	71.5	61.5	66.4	817	71.5	58.5	64.3
724	73.0	64.0	68.1	818	74.5	65.0	68.0
725	76.5	67.0	70.3	819	67.0	58.5	62.9
726	86.0	65.0	72.6	820	66.5	56.5	59.9
727	77.0	66.0	70.9	821	69.0	57.5	61.3
728	75.0	66.0	71.1	822	65.5	59.0	61.0
729	79.0	70.0	73.6	823	79.0	64.5	72.1
730	77.0	67.5	70.8	824	72.0	59.5	65.6
731	71.0	66.5	67.8	825	79.5	59.5	67.3
801	68.0	61.5	65.8	826	75.5	60.5	65.4
802	68.0	64.0	66.1	827	71.0	63.5	66.6
803	73.5	55.0	59.0	828	62.0	58.5	59.8
804	69.0	60.0	63.5	829	72.5	62.5	67.6
805	71.0	59.0	65.5	830	65.0	56.5	60.6
806	68.5	65.0	66.6	831	65.5	59.0	62.6
807	70.0	65.5	67.4	901	74.5	65.5	68.8
808	67.0	65.0	65.6	902	73.0	66.5	68.1
809	67.0	61.0	63.0	903	70.0	63.0	65.8
810	71.0	62.0	65.9				

APPENDIX D. Sow and Litter Data

Table 31. Sow and Litter Data

BLOCK 1

Treatment 1			Treatment 2			Treatment 3		
August 2, 1970			August 1, 1970			August 10, 1970		
Days from Birth	Litter Avg. Wt. Lbs.	Sow Wt. Lbs.	Days from Birth	Litter Avg. Wt. Lbs.	Sow Wt. Lbs.	Days from Birth	Litter Avg. Wt. Lbs.	Sow Wt. Lbs.
0	3.9	460	0	3.39	455	0	3.50	500
5	5.59	455	6	3.67	445	4	4.50	---
12	7.91	455	13	5.97	440	11	6.38	470
19	11.81	---	20	8.03	435	18	6.81	455
26	16.57	440	27	10.3	440	25	9.36	460
33	19.81	445	34	13.84	455			

BLOCK 2

Treatment 1			Treatment 2			Treatment 3		
July 17, 1970			July 18, 1970			July 23, 1970		
Days from Birth	Litter Avg. Wt. Lbs.	Sow Wt. Lbs.	Days from Birth	Litter Avg. Wt. Lbs.	Sow Wt. Lbs.	Days from Birth	Litter Avg. Wt. Lbs.	Sow Wt. Lbs.
0	2.96	500	0	3.33	480	0	2.96	480
7	4.85	485	6	4.17	475	1	3.07	480
14	6.96	485	13	6.50	480	8	5.17	460
21	9.93	495	20	8.19	470	15	9.46	455
28	13.99	490	27	11.49	475	22	12.91	445
35	17.61	495	34	15.32	---	29	13.76	455

Table 31. Continued

BLOCK 3

Treatment 1 July 24, 1970			Treatment 2 July 25, 1970			Treatment 3 July 25, 1970		
Days from Birth	Litter Avg. Wt. Lbs.	Sow Wt. Lbs.	Days from Birth	Litter Avg. Wt. Lbs.	Sow Wt. Lbs.	Days from Birth	Litter Avg. Wt. Lbs.	Sow Wt. Lbs.
0	3.87	525	0	3.44	620	0	2.74	535
6	5.52	505	6	5.23	570	6	3.76	525
13	8.22	515	13	7.46	565	13	5.93	515
20	11.08	500	20	9.30	550	20	7.62	515
27	15.29	495	27	12.68	550	27	9.71	515

BLOCK 4

Treatment 1 July 16, 1970			Treatment 2 July 18, 1970			Treatment 3 July 17, 1970		
Days from Birth	Litter Avg. Wt. Lbs.	Sow Wt. Lbs.	Days from Birth	Litter Avg. Wt. Lbs.	Sow Wt. Lbs.	Days from Birth	Litter Avg. Wt. Lbs.	Sow Wt. Lbs.
0	3.54	575	0	3.00	460	0	3.40	418
7	6.16	565	6	4.95	453	7	5.01	418
14	7.85	565	13	5.9	450	14	7.18	355
21	10.15	580	20	6.8	460	21	9.52	325
28	13.11	575	27	10.80	460	28	13.06	320
35	17.26	570	34	12.08	465	35	15.84	325

Table 31. Continued

BLOCK 5

Treatment 1 July 25, 1970			Treatment 2 July 25, 1970			Treatment 3 July 23, 1970		
Days from Birth	Litter Avg. Wt. Lbs.	Sow Wt. Lbs.	Days from Birth	Litter Avg. Wt. Lbs.	Sow Wt. Lbs.	Days from Birth	Litter Avg. Wt. Lbs.	Sow Wt. Lbs.
0	2.24	525	0	3.65	480	0	3.05	420
6	3.66	495	6	6.03	470	7	5.38	405
13	6.50	495	13	9.03	450	14	6.41	400
20	9.58	475	20	11.35	440	21	8.84	380
27	12.66	465	27	13.42	440	28	12.25	395
34	14.62	460	34	17.14	455	35	12.84	405

APPENDIX E. Respiration Rates

Table 32. Respiration Rates

Observation	1	2	3	4	5	6	7
Sow Number							
11				20		44	98
12				25		58	34
13						56	47
21	19	26	27	18	33	51	55
22	70	95	38	88	26	75	47
23	81	65	65	69	50	92	62
31	26	21	62	51	70	55	48
32	51	51		19	19	40	35
33	80	68	34	21	34	42	42
41	37			19	28		41
42				84	77	35	92
43	129			67	58	99	49
51	24			17	18	30	37
52	66	56			75	92	72
53	84	96		40	47	104	90