EFFECT OF EVAPORATIVE COOLING AND INTERMITTENT SPRAYING ON SWINE PERFORMANCE

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Abdul Khalique
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FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a Master's thesis entitled: Effect of Evaporative Cooling and Intermittent Spraying on Swine Performance

submitted by Mr. Abdul Khalique

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ABSTRACT

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The effect of evaporative cooling and intermittent spraying on swine performance was investigated at The Glenlea Research Station, using two typical swine feeder barns. Temperature in the control barn was always noted to be above the respective ambient temperature and differences as high as 4.5C were observed. The evaporatively cooled barn operated from 3-5C cooler than the control barn and working conditions were found to be much more pleasant. Evaporatively cooled pigs achieved the highest weight gain performance while intermittently sprayed pigs were observed to be the cleanest, in a six week duration test.

In the second test, conducted for three weeks, two reversible fans with a total air flow capacity of 1525 m^3/minute were installed in the ceiling ducts of the control barn. Increasing the air flow rate in this barn resulted in an improved performance by pigs in the spray and control pens which was attributed to the reduction in barn temperature. The pigs were also observed to be much more active after the air flow rate was increased. A centrifugal humidifier, possessing half the barn design capacity for obtaining adiabatic saturation, was operated in the control barn for the next three weeks. This resulted in the barn temperature being

reduced equal to the ambient temperature or below. The test pigs in the control barn showed approximately 10% better performance than in the evaporatively cooled barn. The working conditions also improved but were still not as good as in the evaporatively cooled barn.

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LIST OF SYMBOLS

U_1 = Area of the Frequency Polygon Leaving Classes 6 and 7.

U_3 = Area of the Frequency Polygon Leaving Classes 7 and 8.

Zone A = Classes 7 and Below.

Zone B = Classes 8 and Above.

A_A = Area of Zone A.

A_B = Area of Zone B.

CHAPTER I

INTRODUCTION

The climate of most of Canada is too severe for successful swine production in open feedlots or cheap open-front buildings as sometimes practiced in warm climates. Winter temperatures in a large part of the swine producing agricultural areas can drop to -35C or colder, and in summer hot periods the temperature can go to a humid 33C. The virtually naked, non-sweating pig needs protection from these climatic extremes. This means environmental control including: temperature, humidity, air flow, light,feed and water as well as protective confinement. It will result in a more profitable operation through higher production, better quality, improved feed conversion, less disease and lower mortality rates. Controlled ventilation and cooling in summer is a major factor in producing a good environment. Summer cooling of hogs is being considered by the hog producers as environmental control becomes more sophisticated and as they are becoming more conscious of the margin of profit or return to labour from their investment.

Increasing recognition for the need of cooler swine buildings in hot weather and profit margins have persuaded swine producers to employ the most economical methods of cooling from direct use of the high evaporative cooling power of water. Pigs instinctively use water in their wallows in hot weather. Confinement facilities might provide three possible evaporative cooling systems: one, an artificial wallow where the pigs would lie partially wet and presumably get out at intervals to dry; two, a fogger whereby the air would be cooled, with, possibly some wetting of the pigs and three, spraying or sprinkling pigs periodically, allowing them to dry between wettings. The last two methods would seem to offer some advantages over the first, for they are easier to adapt to the typical swine barn.

The objectives of this work was to study the hog performance under an intermittent spraying unit, an excelsior pad evaporative cooling unit and a centrifugal humidifier. Temperature drop in the barn and temperature distribution across the barn under the latter two units was also to be studied.

CHAPTER II

REVIEW OF LITERATURE

2.1 Effect of Temperature and Relative Humidity on Swine Performance

Research related to swine performance under warm environments has been of three types: effect of temperature and relative humidity, development of performance predictors and comparative response to various types of cooling systems. Tests conducted by Heitman Kelly and Bond (1951), and Hazen and Mangold (1960) lead to the following conclusions:

a) Optimum environmental temperature for swine is between 18.0C and 22.22C.

b) Optimum termperature for maximum weight gains and maximum feed efficiency depends on the body weight of the hog with higher temperatures being preferred by lighter hogs.

c) Optimum relative humidity for swine is 50%.

Most swine researchers are of the opinion that relative humidity has little effect on weight gains unless accompanied by high temperatures. Heitman and Hughes (1949) reported that the rate of weight gain by hogs weighing over 91 kg. was only slightly affected by a variation in relative humidity from 30% to 90% at 32.22C, except that the respiratory rate was increased at the higher humidity. They further reported that at 35.5C and 94% relative humidity the animals were severely stressed; however, the animals were still under stress when the relative humidity was reduced to 30%.

Brody (1945) reported that with non-sweating animals such as swine, the respiration rate rises rapidly with increasing environmental temperature to compensate for the inability to sweat, and to increase the vaporization rate from the respiratory passages. Morrison, Bond and Heitman (1966) reported that the respiration rate of 90 kg. gilts was almost doubled at a constant temperature of 39.4C when the relative humidity was increased from 30 to 90%. They further reported that the moisture loss from lungs was decreased from 0.87 grams per minute at 30% relative humidity to 0.41 grams per minute at 90% relative humidity. The skin moisture loss in their tests increased from one half of the total loss at 30% relative humidity to two-thirds of the total loss at 90% relative humidity.

Bond (1963) conducted several studies on the effect of humidity on swine health and productivity. He concluded that there is a correlation between humidity, daily weight gain and feed consumption but the effect of humidity is small. He found that within the 50% to 78% relative humidity range there was no humidity effect on productivity at any temperature range; in the 78 to 86% relative humidity range daily gains were below normal for temperatures in the 0.0C to 15C range and at temperatures above 15C the daily gains were slightly increased. With regard to disease control he concluded that the bacterial counts were lowest in houses having high humidity ratios inasmuch as the incidence and degree of pneumonia were lowest in environments typified by high temperature and relative humidity.

2.2 Prediction of Swine Performance

Several investigators have worked towards relating air temperature and relative humidity into a single variable or comfort index. Morrison, Bond and Heitman (1968) derived a semi-theoretical relationship which can be used to predict the effects of various combinations of temperature and relative humidity, on the rate of weight gain of hogs. Using their work, the rate of weight gain of 68 kg. hogs can be predicted for any relative humidity and temperature combination between 22C to 33.33C by using a known rate of weight gain at an optimum level of relative humidity and temperature. This relationship is shown in Figure 2.1 for 68 kg. hogs where the optimum level was chosen as 22C and 50% relative humidity.

Hazen and Mangold (1960) developed a relationship relating the change in average daily weight gain and feed efficiency of hogs to air temperature. This relationship was obtained from the results of feeding trials involving a large number of pigs by plotting the observed rates of weight gain and feed efficiency against the air temerature at which the pigs were housed. Their work, however, has the limitations that relative humidity was not included as a factor in predicting swine response to the environment.

Nelson et al. (1970) conducted several tests to evaluate predictors of swine performance. The experimental results indicated that the gain reduction factor developed by Morrison et al. significantly over-predicts the rate of gain and feed efficiency declines with high temperature; whereas the performance decline curves proposed by Hazen and Mangold adequately predict the performance decline for large number of pigs.

2.3 Comparative Response of Swine to Various Cooling Systems

Tests have been conducted by a number of investigators on various

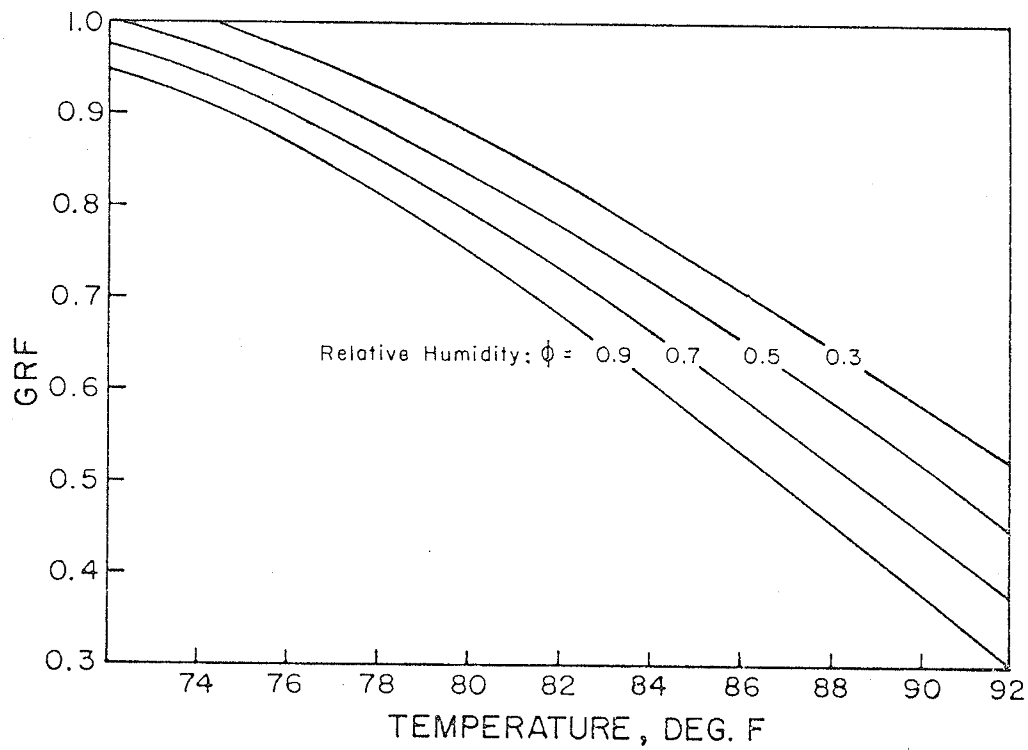


Figure 2.1. Relationship of the gain reduction factor in swine to temperature and humidity as presented by Morrison ~~et al.~~ (1968).

types of cooling systems to determine their feasibility and effect on swine performance. Although zone-air conditioning is used in some farrowing houses; buildings cooled by mechanical air conditioning do not seem to be economically feasible (Read 1969). Most of the work is directed towards the use of evaporative cooling based upon the evidence that relative humidity has little effect on swine performance (Brody 1945; Heitman and Hughes, 1949; Bond, 1963; and Morrison, Bond and Heitman, 1966.)

Tests conducted on swine performance by Nelson, Read, Barfield and Walker (1970) for two summers using four treatments: (1) air conditioning, (2) wetted pad evaporative cooling, (3) natural ventilation, and (4) water mist system; did not give consistent results. They observed that the wet bulb depressions were maximum with air conditioning but weight gains and feed efficiency by hogs did not show any increase over the other treatments. Sprinkling or spraying of pigs periodically allowing them to dry between wettings, was not included in the above study. In most tests under natural weather, weight gains are greater by pigs that have access to sprays (Bracy and Singletary, 1948; Heitman et al., 1959; Culver et al., 1960; Bond, 1963; Hale et al., 1966). Morrison et al. (1968) reported that if pigs were wetted throughly, a sprinkling interval of 80 minutes was sufficient to keep respiratory rate and rectal temperature at a minimum value when the air temperature was 37.77C and dew point was 8.88C to 23.88C; whereas Buchanan (1969) reported improved performance at 30 minute spray intervals. Work of Morrison et al. (1968) does not take into account the weight gain and feed efficiency in determining the response of swine to wetting.

Studies conducted by Buchanan (1969) on swine performance in Manitoba have not been conclusive. The literature indicates that Canadian researchers have directed most of their work towards the use of either natural and forced ventilation or intermittent spraying for hog cooling. Artificial humidification of air has not been given due consideration in the solution of high temperature problems in hog barns in Canada.

CHAPTER III

THEORETICAL CONSIDERATIONS

3.1 Adiabatic Cooling of Air

The most common method of evaporative cooling is to draw ambient air through moistened excelsior pads. Heat in the air is utilized for evaporation of water with a consequent reduction in air temperature. If conduction and radiation losses are assumed negligible, the process is called adiabatic cooling because no heat is added or removed from the air and water-vapour mixture. The process consists of cooling the air by utilizing the sensible heat of air to evaporate water i.e. changing sensible heat to latent heat. The minimum temperature that can be reached is the wet-bulb temperature of the incoming air (Figure 3.1a). As evaporation occurs, cooling occurs with a corresponding increase in relative humidity and humidity ratio. The degree to which saturation is approached is dependent upon the efficiency of the evaporation process. The maximum cooling effect will be obtained in dry geographic regions.

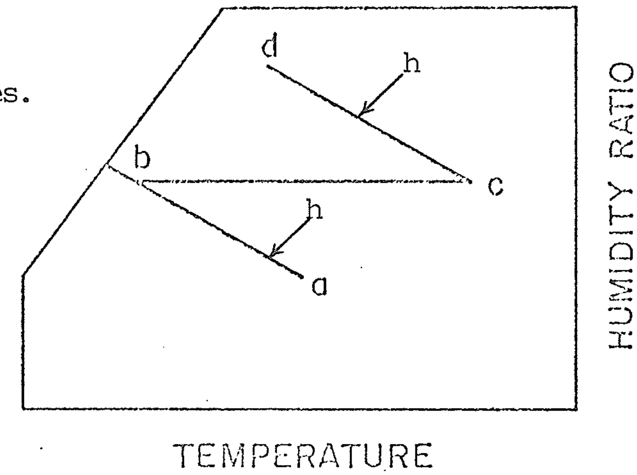
As the incoming air enters the barn, its temperature rises (Figure 3.1a), depending upon the temperature and relative humidity of the barn air. Evaporation of water from wet surfaces in the barn limits a further rise in temperature (Figure 3.1a).

When cooling occurs as a result of evaporation of fine water droplets misted within the barn, the final conditions can be estimated by first considering the rise in the incoming air temperature due to higher temperature a-b. Cooling by pads.

b-c. Heating in the barn.

c-d. Cooling in the barn.

h. Constant enthalpy lines.



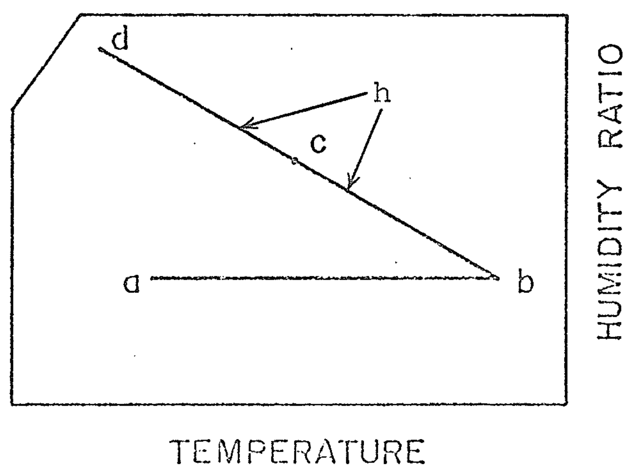
a. Cooling of incoming barn air with evaporative pads.

a-b. Heating in the barn.

b-c. Cooling by mist droplets.

c-d. Cooling due to evaporation of water from wet surfaces in the barn.

h. Constant enthalpy lines.



b. Cooling with fine water droplets misted within the barn.

Figure 3.1 Cooling and heating processes in ventilated swine barns (on a psychrometric chart).

in the barn and then the effect of the misted water (Figure 3.1b). Further reduction in temperature would occure due to evaporation of water from wet surfaces in the barn. If conduction and radiation heat losses are assumed negligible and efficiency of the system is assumed to be equivalent to the pad system, the final conditions within the barn will be slightly cooler and slightly more humid than with the system where the air was cooled by evaporative pads (Figure 3.1). Though an assumed efficiency of 85% is realistic for the design of evaporative pad systems, efficiencies as high as 100% can easily be obtained with fine mist systems. However, to obtain complete efficiency, some undesirable moisture fall-out and barn wetting will occur. With both pad and mist systems, the high humidity conditions would reduce potential evaporation from wet surfaces in the barn.

Final air conditions with spray cooling will not be as cool as with the above two systems, but high relative humidity can be avoided if the water droplets fall directly on the pigs, as in intermittent sprinkling, and heat stresses in pigs will be reduced due to evaporation of water coming in contact with the warm skin surface.

3.2 Physiological Response of Swine to Environmental Changes

Swine productivity is affected by both genetic and environmental factors. It has been said that genetics determines what an animal's potential is whereas environment determines the extent to which he expresses his potential (Heidenreich, 1965).

The pig, like all farm animals, is a homeotherm as it maintains a constant body temperature of 38.88C, irrespective of the environmental temperature. To maintain a constant internal temperature, an animal must continuously adjust and balance heat production (thermogenesis) with heat loss (thermolysis). When this delicate adjustment is upset, body temperature drops (hypothermia) below normal or body temperature increases (hyperthermia).

The animal's first response to a change in ambient temperature is to regulate the rate of heat loss. These adjustments are the animal's attempt to maintain homeothermy and are generally successful if the difference in temperature is not too great. Increased respiration rate is the first response observed in swine under high temperature stress. A dilatation of blood vessels near the skin surface helps dissipate heat in some species. Conscious changes in body position, such as stretching, increases body surface area and thereby dissipating heat. All of these responses originate from the nervous system.

Nervous controlled mechanisms also respond immediately upon exposure to low temperature stress. Pilomotor activity (hair erection), blood vessel constriction and huddling, all reduce heat loss and tend to maintain normal body temperatures. If homeothermy is threatened by excessive body heat loss at low ambient temperatures, shivering commences. Shivering is the only way swine can increase heat production upon initial cold exposure.

Continuous cold exposure gradually increases heat production by altering endocrine secretion rates. The thyroid hormone, thyroxine, and the adrenal hormones are involved in this process. The low temperature acclimatized animal may have lower feed efficiency since more feed is used to produce heat. Rate of body energy reserve depletion is increased by low temperatures and carcass composition may be affected by continuous cold exposure.

Acclimatization to high temperatures has not been experimentally shown or defined in swine. In a climate characterized by rapid weather changes, it may not occur at all. Under continuous high temperature exposure, reduced heat production has not been reported in swine. Reduced feed consumption during periods of high temperature may be a secondary effect caused by increased respiration rates.

From the foregoing discussion on swine physiology, the swine appear to be adapted to low temperatures but have relatively poor tolerance to high environmental temperatures. For example, the uniform distribution of body fat affords an excellent insulation against excessive body heat at high temperatures. The absence of functional sweat glands in swine also increases their susceptibility to hyperthermia. An instinctive behavioural pattern which contributes to apparent low temperature adaptation is huddling. Observations indicate as much as 40% increase in heat production when pigs huddle (Heidenreich, 1965).

Dissipation of body heat by swine has been of great interest to research workers in order to determine an optimum environment for maximum productivity of swine during hot conditions. Swine dissipate heat by conduction, convection, radiation and evaporation. The proportion of heat dissipated by different methods is shown in Fig. 3.2. It appears that the amount of body heat dissipated can be increased by increasing air velocity (by forced convection) at temperatures up to 32.22C, as increasing wind

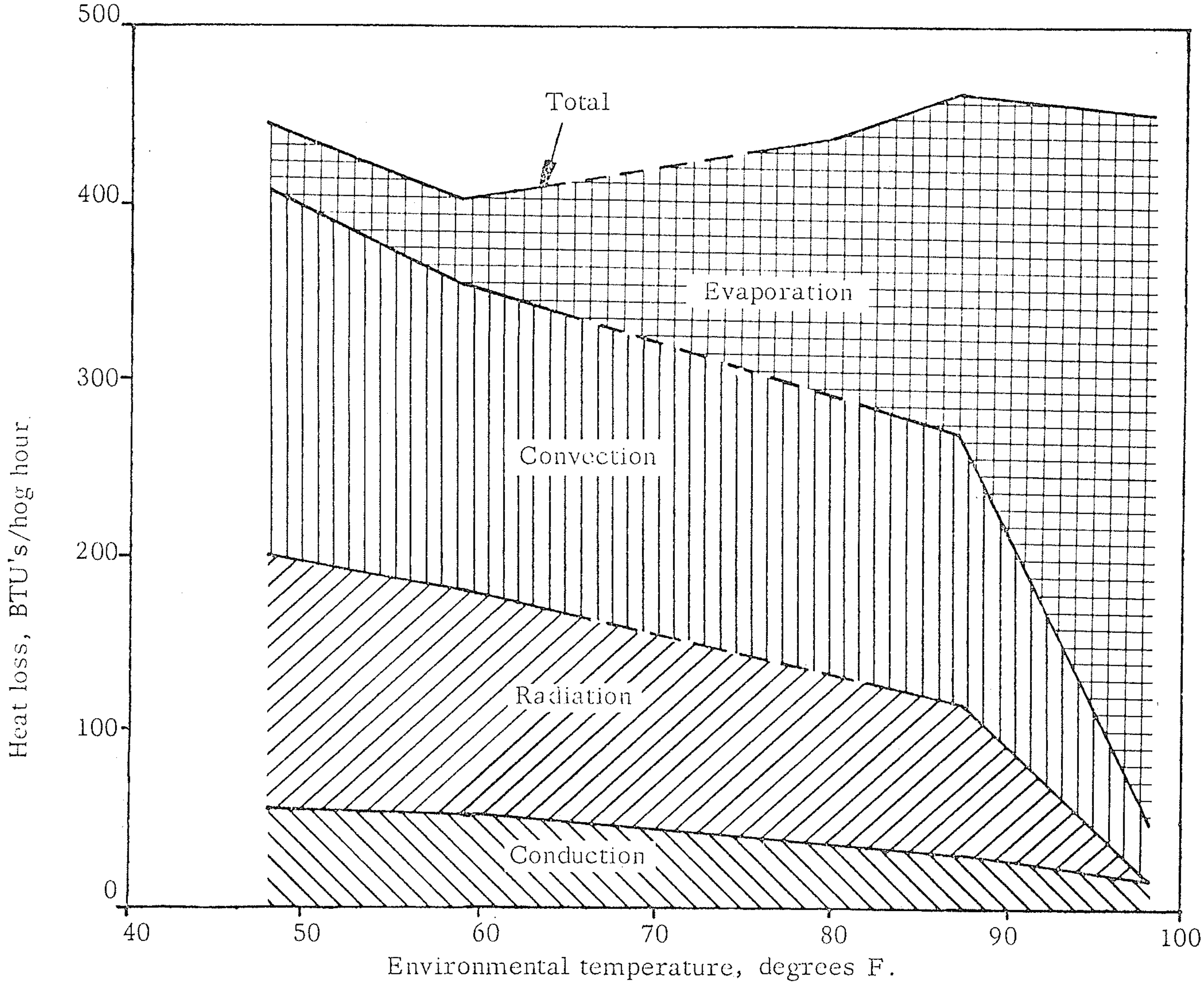


Figure 3.2 Effect of environmental temperature on heat loss for an average hog weighing 75 to 125 pounds (Heidenreich, 1965).

velocity increases convective heat transfer. The heat from the skin of the hog is transferred to the air molecules and these molecules are blown away by the wind and replaced by cool ones which in turn pick up heat. At temperatures above 32.22C, evaporation plays a major role in heat transfer and the process will be limited if high relative humidities are encountered at such temperatures.

CHAPTER IV

METHODS AND MATERIALS

4.1 The Experimental Barns

The experiments were conducted at Glenlea Research Station, University of Manitoba, in two feeder barns with a north-south orientation, located parallel to each other and having the following design features:

Barn 1: Barn dimensions - 38 m. long and 10 m. wide
No. of pens - 25 on each side of the central aisle
Pen dimensions - each 4.27 m. long and 1.52 m. wide

Barn 3: Barn dimensions - 33.55 m. long and 10 m. wide
No. of pens - 18 on each side of the central aisle
Pen dimensions - each 4.27 m. long and 1.83 m. wide

A conventional ventilation system, with a total air flow capacity of 482 cubic metres per minute, existed in barn 1 with fans evenly distributed in the east and west side walls. The ventilation system in barn 3 had a total air flow capacity of 397 cubic metres per minute and was similar to that in barn 1, except that the fans were located only on the east side. In 1968, excelsior pads were installed in the west wall of barn 3 and all the air was exhausted by fans on the east wall. Both barns had similar wall and ceiling construction.

4.2 Experimental Pens

Six pens, two in barn 3 and four in barn 1 were selected for test purposes. The pens in barn 3 were located on the west side adjacent to the excelsior pad installation. Two of the pens in barn 1 were on the east side of the central aisle and the remaining two were located on the west side.

4.3 Experimental Equipment

4.3.1 Excelsior Pads

An excelsior pad, 0.915 m. high, 32.94 m. long and 5.08 cm. thick was installed under the eave on the west side of barn 3. The water distribution system consisted of a perforated 2.54 cm. plastic pipe and a V - trough extending along the full length of the pad. An eave trough was located immediately below the excelsior pad to collect and return the excess water to a reservoir. A submersible pump located in the reservoir recirculated the water in the system and was controlled by a thermostat. The sensing element of the thermostat was located 1.83 m. above the floor in the interior of the barn. A float valve inside the reservoir controlled the water level by replenishing water lost by evaporation. The cooling unit was adapted to the conventional barn ventilation system and utilized the fans on the east side of the barn (Fig. 4.1).

4.3.2 Intermittent Spraying Unit

Due to pen layout and location of the feeders the selection of nozzles required special consideration. In barn 1, the pens measuring 1.52 m. wide and 4.27 m. long contained self-feeders 27.94 cm. wide and 86.36 cm.

Figure 4.1. The excelsior pad unit (barn 3).

long located along the south pen partitions dividing the pen into two equal parts, lenthwise. It was considered desirable to have a spray distribution pattern having the following characteristics:

(a) Water should not drop in the feeders so as to avoid the moistening of feed therein.

(b) Maximum possible pen area should be covered by spray, excluding the feeder area.

(c) The system should be adjustable to create a dry spot in the pen, when desired, for hogs preferring to stay dry.

It was decided not to use nozzles giving circular spray patterns as small, unequal sized nozzles would be required to obtain an acceptable spray pattern in the pen. If two or more large, equal sized nozzles were used, the pen area in front of the feeder would remain dry.

A Nelson Plant and Shrubbery nozzle, manufactured by R.L. Nelson Manufacturing Co., Peoria, Illinois, U.S.A. was tested in the laboratory. This plastic nozzle is being commercially used in U.S.A. and Canada for plant pesticide applications.

The nozzle, when subjected to full available water pressure, ejected a spray pattern at approximately 180° angle. The water wetted an area approximately 4.57 m. long and 91.5 cm. wide. The spray tapered slightly at the ends.

The nozzle was mounted horizontally and it could be easily screwed in and out to bring a relocation of the entire length of spray band.

It was concluded that two such nozzles, mounted on the oppositely directed laterals of a water pipe, would cover the whole pen; each nozzle serving half of the area parallel to the pen partitions. It was also considered possible that the feeder could easily be protected from water by a slight counterclockwise rotation of the nozzle located in the pen half having the feeder. Such a displaced portion of the spray, however, fell on the wall of the barn and was wasted.

The spray unit was assembled in the laboratory and consisted of a main water pipe bifurcated into two lateral 1.27 cm. copper pipes each serving one pen. A filter was installed in the supply line to insure a clean water supply and to prevent the plugging of the nozzle orifices. The pipe was hung over the center of each pen, parallel to the pen partitions. Each pipe had one 12.7 cm. long branch at each end for mounting the nozzle (Fig. 4.2).

The operation of the unit was controlled by a thermostat and a timer connected in series which actuated a solenoid valve in the main supply line.

4.3.3 The Humidifier

Theoretical investigations showed, that 113.6 kg. of water per hour would have to be evaporated to saturate the incoming air of barn 1 during peak summer heat loads. However, due to fund limitations, it was decided to buy a humidifier of half the required design capacity.

A centrifugal humidifier, manufactured by Bahnson Company, Winston-Salem, N.C. U.S.A. was purchased. It was installed 14 m. from the south end of barn 1 above the pen on the west side of the central aisle (Fig. 4.3).

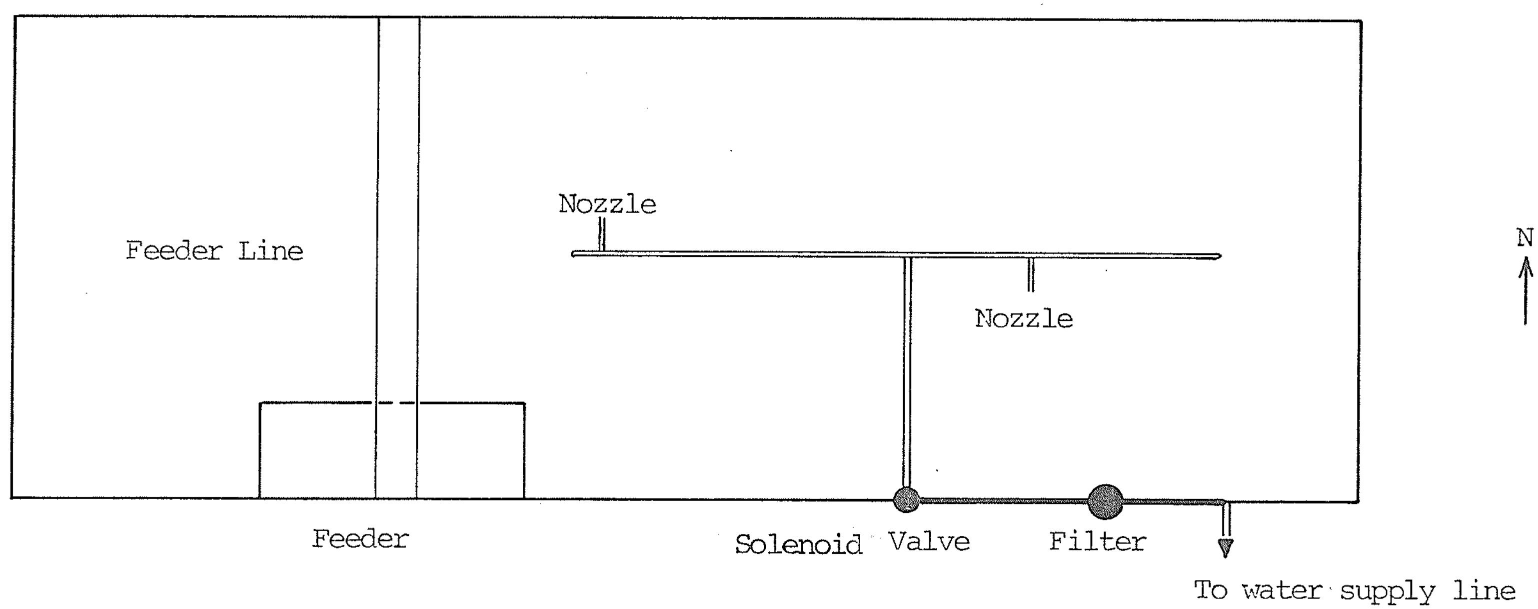


Figure 4.2. Schematic of a pen with spray unit. (Barn 1)

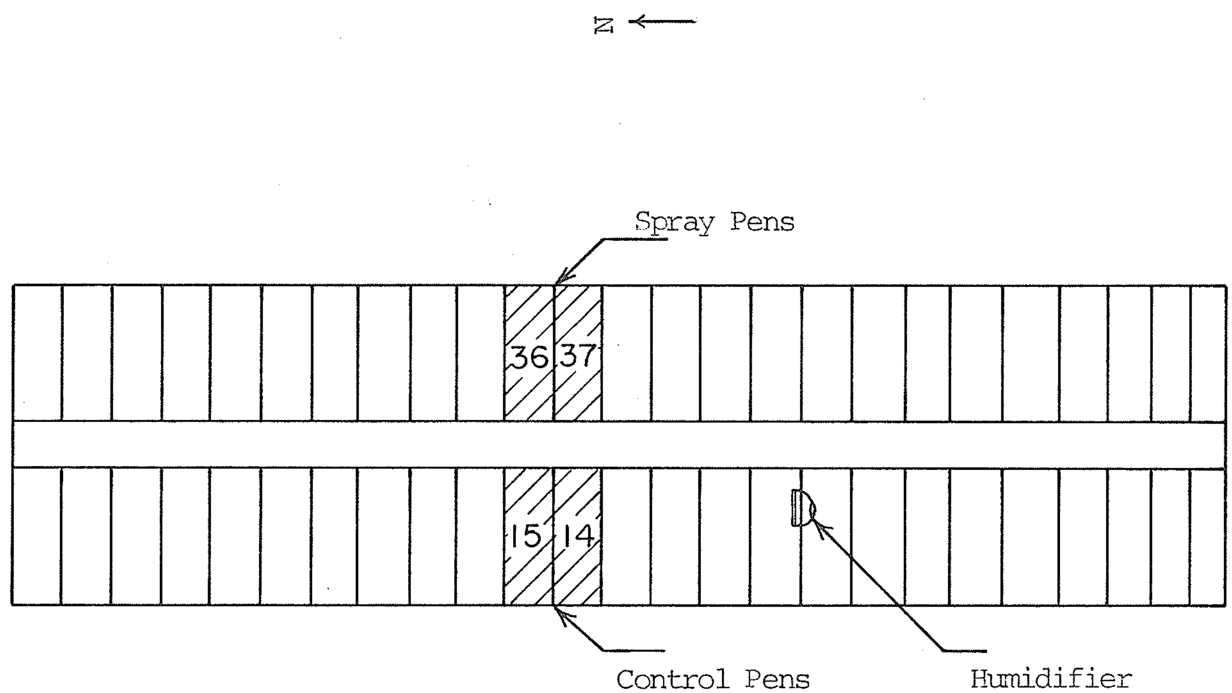


Figure 4.3. Schematic of Barn 1 showing location of test pens and the humidifier.

This site was selected because of an available water supply line and was close to the central alley which made later adjustments easier as well as establishing a free, continuous circulation of air around the barn.

The humidifier was suspended from the barn ceiling (Fig. 4.4) with the axis of the motor shaft parallel to the north-south barn walls. It faced the pens which were chosen for test purposes and was at a sufficient distance to give an average cooling effect. The hanger was positioned such that the drip pan of the humidifier was at least 1.22m. below the ceiling or any other overhead obstruction. This prevented the deposit of spray on these obstructions if they were directly in front of the humidifier.

The recommended water pressure was between 0.70 and 2.46 kg./cm.^{2} but it had to be constant for a satisfactory humidifier operation. The available water pressure was within the above range but it fluctuated appreciably due to the differential in the pressure system control; a pressure reducing valve was installed in the supply line to compensate for this. A strainer in the water line protected the pressure reducing valve and a gauge permitted water pressure readings to be taken.

A 1.27 cm. diameter copper pipe was used as a water feed line whereas the minimum recommended diameter was 0.95 cm. Because of the short period of time available for the completion of the tests, no recirculation system was installed and unused water from the drip pan was allowed to drip into the pen underneath.

The starting switch of the motor equipped with thermal overload protection, was mounted on the ceiling (Fig. 4.4). The motor ran in a clockwise

Figure 4.4. The Humidifier.

direction when viewed from the back or fan end of the humidifier. A thermostat in the electrical branch controlled the operation of the unit.

On one end of the motor shaft of the humidifier was a specially engineered fan, while on the other end was a disc which revolved with the motor shaft. Surrounding the disc were stainless steel teeth. Water was fed at a constant pressure through a small copper tube, onto the back surface of the rapidly spinning disc. Centrifugal force spread the water outward in a thin film. Striking the teeth, the film was broken into a very fine spray. The resulting mist was mixed with the air stream produced by the fan and was almost completely evaporated, leaving a very small amount of water which dripped into the drip pan.

The feed to the humidifier was determined by the water pressure and the size of the orifice in the supply line. As the humidifier capacity was below the design requirements for the barn, the largest sized orifice was used throughout the test and the feed was regulated only by the pressure control valve. Whenever the humidifier was found to be not delivering enough mist, the water pressure was slightly increased.

During operation of the humidifier, a certain amount of dirt from the air deposited on various parts. This dirt was removed periodically, especially from the spinning disc where it could have caused imbalance. The grid teeth and all the wet surfaces of the humidifier were kept clean in order to insure proper atomization of the water. Occasionally, the amount of mist produced decreased appreciably due to clogging of the strainers or the orifice in the water line.

4.3.4 System Controls

The thermostats of the pad system, spray unit and the humidifier were all set at 21.1C so that the systems would start working whenever the respective barn temperatures reached 21.1C.

The spray unit sprayed water for two minutes every half hour, while working.

4.4 Measurement of Variables

4.4.1 Temperature Measurements

Copper-constantan thermocouples were installed at various locations in the barns to determine temperatures at positions shown in Fig. 4.5. Location of thermocouples was as follows:

Thermocouple No.	Location
(1)	Temperature outside barn 3 by recorder box
(2)	Ambient temperature outside north end from barn 3
(3)	Attic space of barn 3
(4)	Fan outside barn 1 (east side)
(5)	Air inlet inside barn 3
(6)	Ceiling high east wall of barn 3
(7)	Pen high west wall of barn 3
(8)	1.5 metres high west side of barn 1
(9)	Pen high central aisle of barn 3
(10)	Attic middle of barn 1

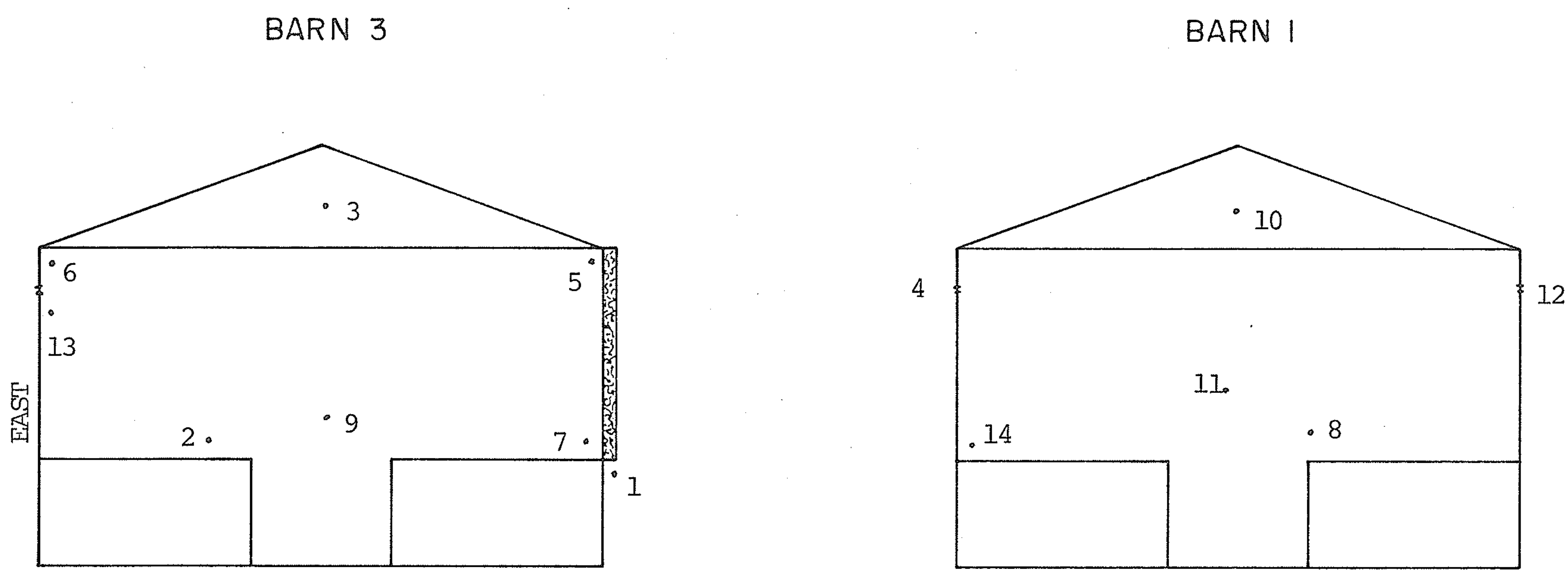


Figure 4.5. Location of thermocouples in the barns.

(11) 1.8 m. high in the middle of barn 1.

(12) Outside barn 1 in front of a fan (west side)

(13) Exhaust outlet inside barn 3.

(14) 1.5 m. high east wall of barn 1, over sprays.

All temperature measurements were taken in Fahrenheit degrees and the Centigrade conversion reflected accuracy greater than the closest one-half degree reading. A 16 point recorder with a potentiometer was used to measure the temperatures registered by the thermocouples. Two potentiometers were available for the readings. It was assumed that exhaust air of the two barns would approximately give respective representative barn temperatures and a sling psychrometer was used to measure these temperatures and the ambient temperature.

4.4.2 Hog Weight

Hogs were weighed by a scale manufactured by Berkel Products Limited, Toronto. This scale had a maximum capacity of 410 kg. and a least count of 0.28 kg.

4.4.3 Feed Weight

Feed put into the test pen feeders was weighed by a scale with a least count of 0.28 kg. Weight of every feeder was taken at the beginning of the experiments. At the end of each test, the feeder along with the feed was weighed. Weight of the feed was determined by substracting the feeder weight from the total weight of the feeder and the feed.

4.4.4 Carcass Composition

All the carcass composition records were obtained from Canada Packers Limited, Winnipeg, where the pigs were shipped and slaughtered.

4.5 Test Procedures

4.5.1 Selection of Hogs

Sixty growing finishing hogs were selected for the tests. They were in the 59 kg. to 72 kg. weight range and were of York, Managra-York, Managra-Lacombe and Managra breeds. All were females. Ten pigs were put into each of the six test pens. At the end of the first test, 5 pigs out of each pen reached market weight and were removed. The subsequent tests were continued with 5 pigs.

4.5.2 Tests

Three tests were conducted during the summer of 1973. Each test consisted of measurement of hog weight gains, feed efficiency, temperature drops inside the barns, temperature distributions inside the barns and visual observation tests.

The first test was conducted for six weeks to compare evaporative and spray cooling systems using hogs in pens 14 and 15 of barn 1 as the control group. Hogs were weighed every Tuesday at 11:00 a.m. Unused feed in the feeders was weighed at the same time. Feeders were filled with fresh feed after finishing the hog weight measurements. Bags were filled with a measured amount of feed sufficient for the next week. Visual observations were made the same day and at least once more every week.

Temperatures were taken on an hourly basis on selected hot days to compare the temperatures of both barns and to determine gradients in average barn temperatures for the day. During peak temperature hours on hot days, measurements were made to obtain temperature distribution inside the barn.

The second test was continued for 3 weeks using the same test pens and hogs. It was similar to test 1 except that two reversible fans of a total airflow capacity of 1525 m^3/minute were installed in the two ceiling ducts of barn 1. The objective was to determine whether blowing air in or out through ceiling ducts would affect swine performance.

Duration of the third test was also 3 weeks using the same hogs. The humidifier was installed in front of the pens 14 and 15 which no longer served as control pens. The spray unit continued to operate to duplicate the effects of spray and misting units. Tests similar in nature and procedure to those in test 1 were conducted.

CHAPTER V

RESULTS AND DISCUSSION

5.1 The First Test

5.1.1 Temperature Distribution and Variations

Exhaust air temperature was assumed to represent the respective average barn temperature. As the barns had more than one exhaust fan, frequent temperature observations of the exhaust air from all fans of both barns were made to determine some method of measuring the average barn temperature. The air temperature from all of the five fans in the same row were more or less equal. During the afternoon hours, the fans on the west side of barn 1 discharged air at a slightly higher temperature than that from the respective fans on the east side. The west side of the barn was directly exposed to the sun at this time; whereas the east side was shadowed. The temperature difference, however, never exceeded ½ C. It was, therefore, concluded that any fan from the barn could be used to determine the respective average barn temperature.

Figure 5.1 shows the comparison of average environmental temperatures in barn 1 and 3 with hourly ambient temperature variations on a typical hot day. It was observed during similar measurements that in the morning, average temperature in both barns were higher than the ambient temperature. As the ambient temperature approached 18.3C, the average temperature of barn 3 tended to reach 2.C; whereas barn 1 had temperatures 0.66 - 2.2C higher than this. As the evaporative cooling unit started working, barn 3 showed insignificant variations in temperature; whereas barn 1 showed a

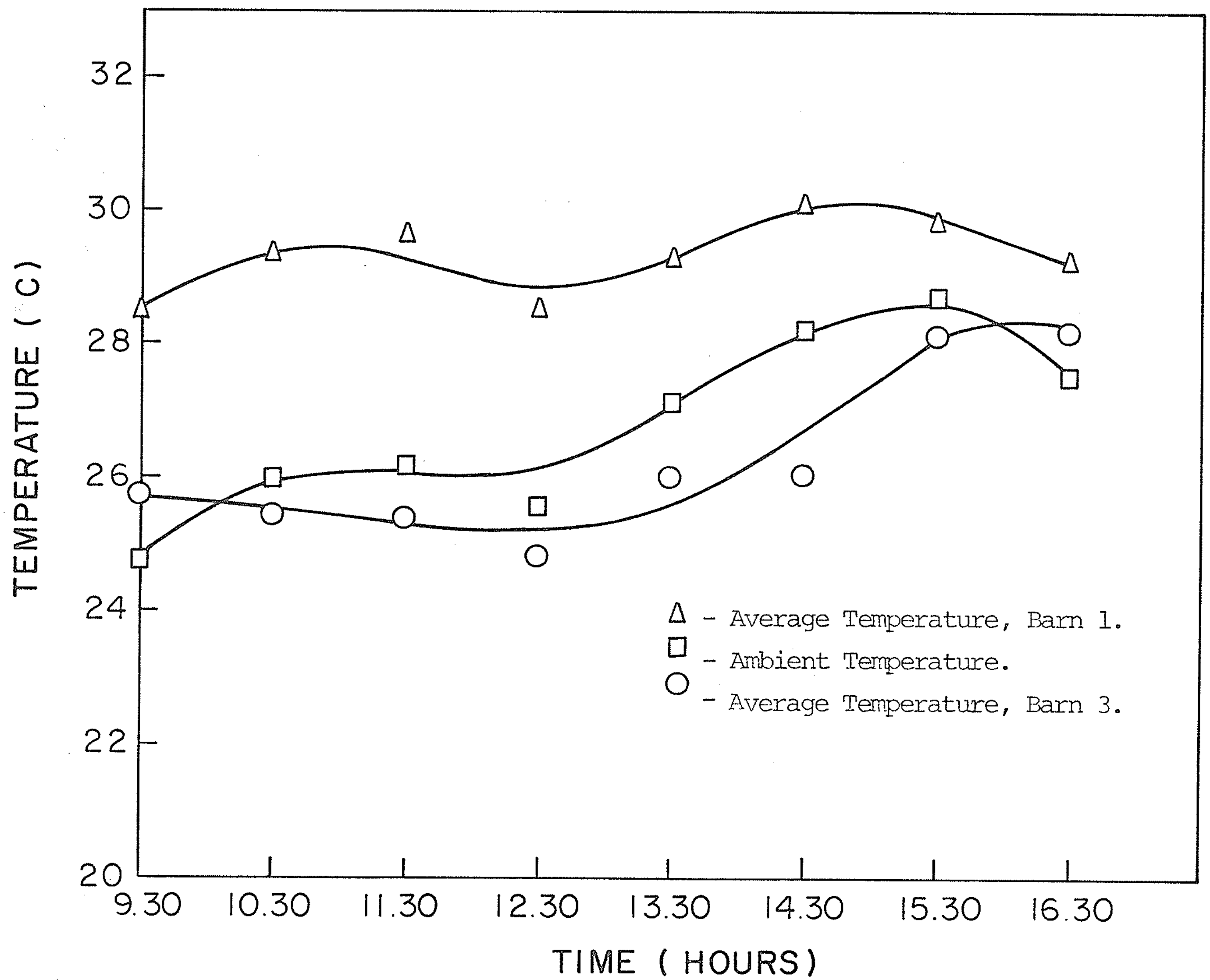


Figure 5.1. Hourly temperature variations in the control barn (barn 1) and the evaporatively cooled barn (barn 3) on July 9, 1973.

continuous increase. Ambient temperature and barn 3 average temperature coincided at approximately 21C.

At ambient temperatures above 21C, barn 3 average temperatures were 0-1C below it and barn 1 average temperatures were obsurved to be as high as 4.5C above the ambient temperature until the peak heat load hours. On normal days, peak heat loads occured between 3-5 p.m. and as this time approached, the ambient and barn 1 temperature difference decreased and subsequently became zero as both temperatures coincided. Afterwards, all the temperatures showed a gradual decrease. The ambient temperature, however, decreased at a faster rate than the barn temperatures.

Figure 5.2 represents a typical temperature distribution across the barns on a hot day. Apparently, the temperatures towards the west side of barn 3 should be lower than on the east side when the cooling unit was working. Figure 5.2, however, shows the reverse. This was possibly due to the west side of the barn being directly exposed to sun at 3:30 p.m. when the observations were made. Temperatures on the east side were higher than temperatures on the west side in the mornings and just the reverse in the evenings. Temperatures in the middle of the attic space of barn 1 were always higher than those at a similar location in barn 3, except around the peak heat load hours when both became almost equal.

5.1.2 Weather Data Analysis

The weather data obtained from Glenlea Research Station for the test duration gave only maximum and minimum daily temperatures. Daily means, weekly means and subsequently the test means were calculated from this data.

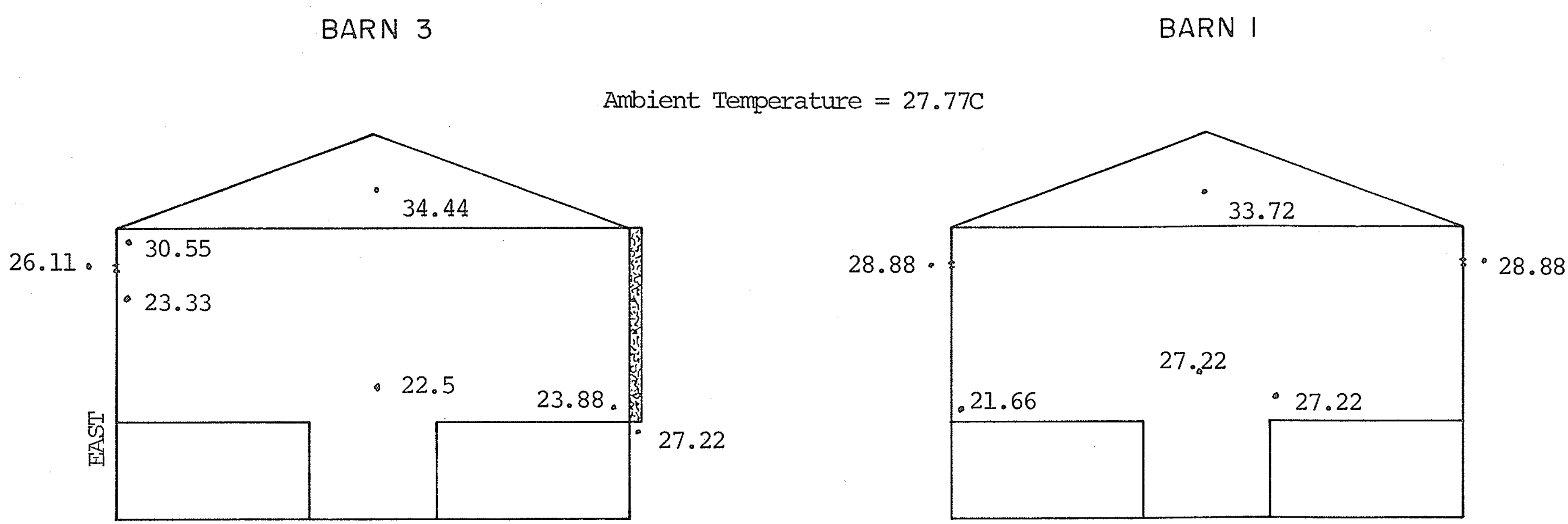


Figure 5.2. A typical temperature distribution (c) across the control barn (barn 1) and the evaporatively cooled barn (barn 3).

This information, however, did not give the necessary daily temperature distribution and it was found difficult to interpret the swine performance results on the basis of this information.

Weather data were obtained for Winnipeg which gave hourly ambient temperatures at Winnipeg International Airport. Weekly averages were calculated from daily maximums and minimums, and the test average was calculated in a similar way. Table 5.1 gives weekly and test averages for Glenlea and Winnipeg. Respective weekly averages for the both places showed a difference of approximately ±0.45C as the sample consisted of only 7 or 14 days. The test averages gave a negligible difference of 0.02C. This occured due to increase in sample points, from 7 or 14 to 41 days. These calculations led to the conclusion that the test temperature distribution for Winnipeg can be safely applied to Glenlea with a very high confidence level. The confidence level will, however, decrease while using the weekly temperature distribution. Due to the nature of tests; this reduction in the confidence level was assumed to have no effect on the interpretation of swine performance results and it was decided to use Winnipeg weather data for Glenlea.

Hourly temperature data of Winnipeg for each week of the test was grouped into the following classes.

Class No.	Class Boundaries (C)
1	1.39-4.17
2	4.17-6.95

TABLE 5.1 WEEKLY MEAN TEMPERATURES FOR GLENLEA AND WEEKLY MEAN, MEDIAN AND MODAL TEMPERATURES FOR WINNIPEG, TEST 1.

Week	Glenlea	Winnipeg			
	*Mean (C)	*Mean (C)	†Mean (C)	Median (C)	Mode (C)
1,2	17.65	17.22	15.97	17.00	14.33
3	20.13	19.81	20.00	20.27	23.87
4	18.45	18.25	18.71	19.01	21.66
5	16.98	17.53	18.10	18.27	18.58
6	17.85	18.25	18.16	18.43	18.61
Whole Test	18.07	18.05	17.8	18.32	18.63

* - (Maximum + Minimum) /2

† - Hourly basis

3	6.95-9.73
4	9.73-12.51
5	12.51-15.29
6	15.29-18.07
7	18.07-20.85
8	20.85-23.63
9	23.63-26.41
10	26.41-29.19
11	29.19-31.97

Frequencies for each class were calculated. The relative frequency for each class, and modes, medians and averages for each week were calculated with the following formulas.

$$\text{Relative Frequency} = \frac{\text{Frequency of each class}}{\text{Total number of observations}}$$

$$\text{Mode} = L_1 + C \left(\frac{d1}{d1+d2} \right)$$

L_1 = Lower boundary of modal class (C).

C = Length of modal class (C).

d1 = Difference in frequencies of modal and premodal classes.

d2 = Difference in frequencies of modal and postmodal classes.

$$\text{Median} = L1 + C \frac{\left(\frac{n}{2} - Fmd \right)}{f_{md}}$$

L1 = Lower boundary of median class (C).

C = Length of median class (C).

F_{md} = Sum of all observations smaller than L1 of median class.

f_{md} = Frequency of median class.

$$\text{Mean} = \frac{1}{n}\sum_{i=1}^{n} U_i F_i$$

F_i = Frequency of the class i.

U_i = Mean of the boundaries of class i (C).

n = Total number of observations in the sample.

Averages, modes and medians were calculated similarly for the whole test. Frequency polygons for every week and the whole period were constructed and are shown in Figure 5.3.

5.1.3 Swine Performance

As suggested in the literature, the ideal temperature range for swine performance is approximately 18.0C to 22.22C. At temperatures above 22.22C, the hogs suffer from heat stresses and eat less feed which may actually give them a relatively better feed efficiency as compared to environmental temperatures below 18.0C. At temperatures below 18.0C, the hogs eat more to develop energy in an effort to keep themselves warm, thus resulting in a relatively poor feed efficiency.

From the observed environmental temperatures in the barns with respect to the ambient temperature, the following approximations were made:

(1) Classes 7 and 8 of the ambient temperature were favourable to the hogs in barn 3, and classes 6 and 7 were favourable to the hogs in barn 1.

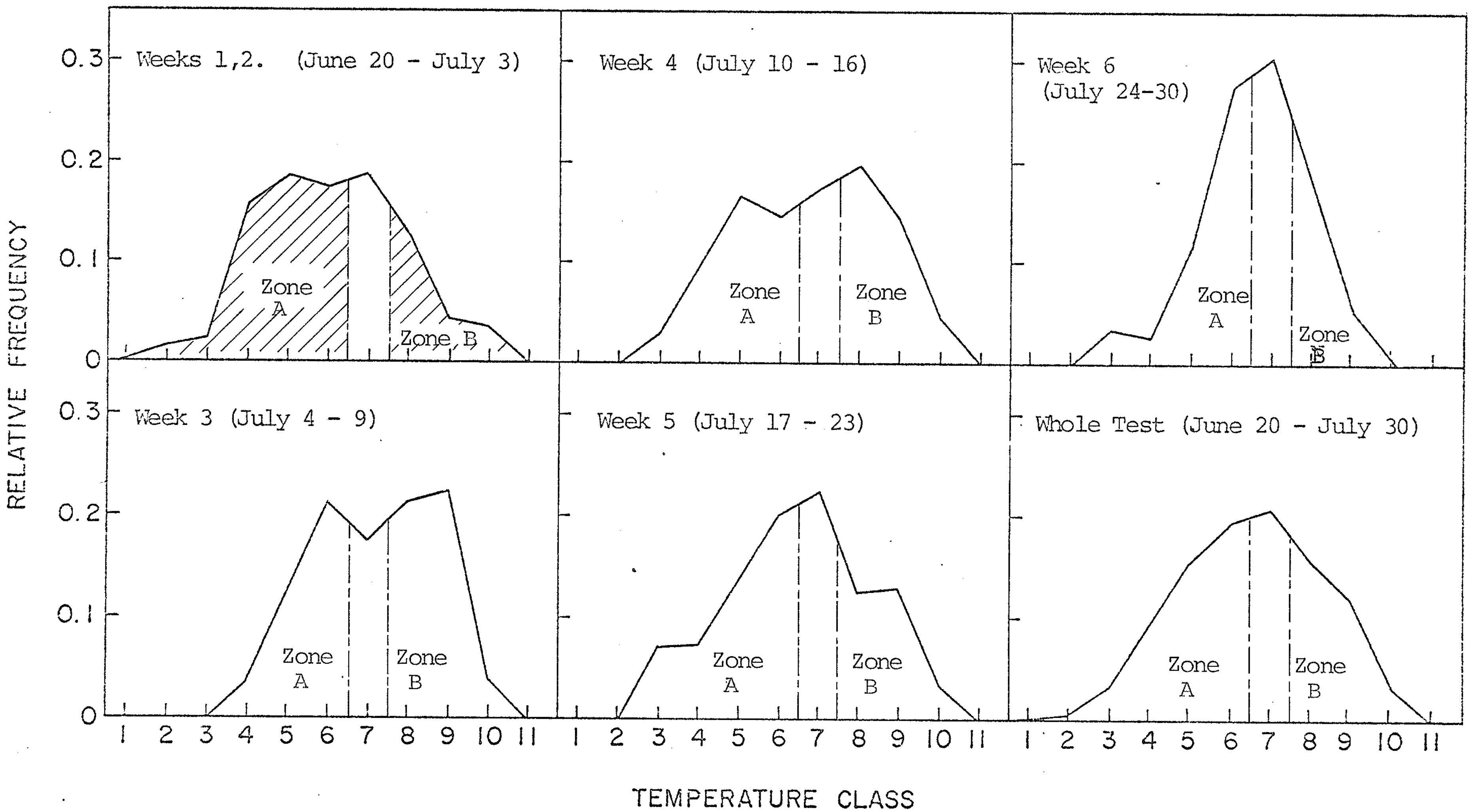


Figure 5.3 Weekly ambient temperature distribution based on hourly weather data for Winnipeg from June 20 - July 30, 1973.

(2) Area of the frequency polygons leaving classes 7 and 8 (U_3) was unfavourable to hogs in barn 3 and the area leaving classes 6 and 7 (U_1) was unfavourable to hogs in barn 1.

(3) Classes 8 and above (zone B with area A_B, Fig. 5.3) were more unfavourable to hogs in barn 1 as compared to hogs in barn 3.

(4) Classes 6 and below (zone A with area A_A, Fig. 5.3) were more unfavourable to hogs in barn 3 as compared to hogs in barn 1.

The following assumptions were made to make use of the above statements in the swine performance analysis:

(1) Swine performance was a function of only the barn dry bulb temperature.

(2) When the ambient temperature was in class 6, temperature in barn 1 remained in the ideal temperature range while temperature in barn 3 remained below 18.0C.

(3) When the ambient temperature was in class 7, temperatures in both barns remained in the ideal temperature range.

(4) When the ambient temperature was in class 8, temperature in barn 3 remained in the ideal temperature range while the temperature in barn 1 remained above 22.22C.

(5) When the ambient temperature was above 23.63C or below 15.29C, temperature in neither of the barns was in the ideal temperature range.

Swine performance results (Table 5.2) were analysed using the frequency polygons (Figure 5.3) and Table 5.3

During the first two weeks of the test, the control group showed better performance than the evaporatively cooled group both in terms of feed efficiency and weight gains. This was substantiated by the polygon for that period when the median temperature was 17C and mean temperature was 15.9C. It implied that the average temperature in the control pens was higher than in the pens of barn 3, which further indicated that the control group was subjected more frequently to temperatures closer to the ideal temperature for hog performance. This was also noted from Table 5.3 where $U_1 < U_3$ and $A_A > A_B$, both of which were more favourable to barn 1 hogs.

During the third week, performance of the evaporatively cooled and control groups was just opposite to that found in the first two weeks, but so was the temperature distribution. During the third week, the ambient temperatures were centred around an approximate temperature of 20C as the mean, with the median temperature almost coinciding and the polygon mound showed a different tilt from the polygon for the first two weeks. U_1 and U_3 were equal which did not explain the performance results. The performance results were, however, explained by the area of Zone B being greater than of zone A.

During the fourth week, weight gains by the control group were better than the evaporatively cooled group, whereas U_1 and U_3 were 67.8% and 63.39% respectively. On the other hand, the area of zone B was greater than Zone A. It means that the performance did not correspond with U_1 and U_3 but

TABLE 5.2 WEEKLY PERFORMANCE OF THE HOGS, TEST 1.

Week	Control Group	Spray Group	Evaporatively Cooled Group
	*ADG/FE	*ADG/FE	*ADG/FE
1,2	0.535/3.625	0.357/6.610	0.415/4.855
3	0.420/6.399	0.715/3.864	0.984/2.65
4	0.568/4.136	0.532/4.721	0.441/3.202
5	0.201/13.200	0.1655/15.35	0.451/6.774
6	1.035/2.281	0.9025/2.698	0.860/3.229
Whole Test.	0.552/4.190	0.500/4.980	0.585/4.360

* - ADG = Average daily gain (kg/hog)

FE = Average feed efficiency (kg feed/kg gain)

TABLE 5.3 AREAS U_1, U_3, A_A, AND A_B IN FREQUENCY POLYGONS OF FIG. 5.3.

Week	U_1	U_3	A_A	A_B
1,2	64.28%	68.75%	55.95%	25.59%
3	62.5%	62.5%	36.11%	46.5%
4	67.8%	63.69%	44.0%	38.69%
5	57.14%	64.88%	48.21%	29.16%
6	42.26%	51.19%	45.8%	23.8%
Whole Test.	59.65%	63.31%	47.96%	31.19%

it did correspond with A_A and A_B. Since $|U_1-U_3| < |A_A-A_B|$, it seems that the performance might have corresponded with A_A and A_B rather than U_1 and U_3.

It was observed during the experimental period that during weeks 5 and 6, all the hog groups gave very low and very high performance respectively. Average Glenlea temperatures were calculated to be 16.98C and 17.85C respectively. This information was not sufficient to explain wide difference in the performance results and thus led to the analysis of hourly weather data for Winnipeg as it was not available for Glenlea.

Polygons for weeks 5 and 6 were the most typical of all and interesting to analyse. The respective mean temperatures were 18.1C and 18.16C; the median temperatures being 18.27C and 18.43C; and the modal temperatures were 18.58C and 18.61C. These measures of central tendency were almost equal for the both weeks. Polygon shapes were, however, quite different from each other and so was the hog performance which was a function of the respective temperature distribution, regardless of the hog group. Standard deviation of the polygon for week 5 will be greater than of the polygon for week 6, if both are calculated. This is noted from higher frequencies observed in the extreme right and the extreme left classes of the polygon for week 5, as compared with the frequencies in similar classes of the polygon for week 6. It was noted that the extreme right and extreme left classes of a temperature distribution largely influence the hog performance as they have similar effects.

(a) Higher frequency densities in these classes, thus producing lower densities for more desirable central classes as the area of the graph should equal unity, are very unfavourable to the performance function because their negative effects are accumulative.

(b) Lower frequency densities in these classes, thus producing higher densities for more desirable central classes, are very favourable to the performance function.

Week 5 corresponded to 'a' above; whereas week 6 corresponded to 'b'. The comparative swine performance during these weeks can be said to be very low and very high respectively. The ideal temperature distribution for hog performance will be the one with the least standard deviation and centred around class 7. The distinct feature of the polygon for week 6 was that it was closer to the above definition than all of the other polygons and so were the performance results for this week.

It was difficult to explain the relative performance of evaporatively cooled and control group hogs during the 5th week. The temperature distribution was more favourable to the control group as $U_1 < U_3$ and $A_A > A_B$, but the performance results were just the reverse of this. The performance during the 6th week corresponded to its temperature distribution as $U_1 < U_3$ and $A_A > A_B$ which made it more favourable to evaporatively cooled hogs.

For the whole test, daily weight gains per hog in the evaporatively cooled group were better than the control group. It did not correspond with the temperature distribution which was more favourable to the hogs in barn 1 as $U_1 < U_3$ and $A_A > A_B$. The feed efficiency, however, was in accordance with the temperature distribution.

The spray group showed the poorest performance in this test. Some work done in previous years was examined when hollow core nozzles were used for similar tests and it was found that the spray system never resulted in as poor a performance as this year. During the trials this year, the spray system thermostat was found not working properly after two weeks. It might have resulted in water spray every thirty minutes, regardless of the barn temperature, until the thermostat was replaced. This could possibly have substantially affected the performance of the spray group hogs.

5.1.4 Visual Observations

During the visual observations, physical comfort of the hogs was studied. At 3.15 p.m. on July 4, a windy day with normal temperature, when the temperature in barn 1 was 25C and 20.83C in barn 3; control group hogs were found less comfortable as compared with evaporatively cooled hogs, some of which were seen lying on the floor, huddling and others taking water and feed. Spray group hogs were seen gathering in drier areas of the pens, although apparently it should not be so at such temperatures. Hogs were found to be all wet. This was why the thermostat was checked and replaced.

At 3:30 p.m. on July 9, a sunny day with clear skies, barn 1 temperature was 26.11C. Control group hogs seemed very uncomfortable and not one was eating; whereas evaporatively cooled hogs were seen huddling, eating and drinking. It was very uncomfortable in barn 1 but much better in barn 3. Spray group hogs were eating and lying over each other to get under the shower.

At 3:30 p.m. on July 17, a cloudy day, when temperature in barn 1 was 25C and 21.11C in barn 3, no difference between the behaviour of evaporatively cooled and control group hogs was noted. Spray group hogs were all standing, some eating and some trying to avoid the water spray.

Apparently, the respective barn 1 and barn 3 temperatures were similar on July 4 and July 17 but the swine response was quite different. This might have been so because July 17 was a cloudy day and relative humidity was higher than on July 4. These and similar observations on various days led to the following conclusions:

(1) Hogs eat less at higher temperatures and eat more at lower temperatures (both temperatures being outside the ideal temperature range).

(2) Hogs feel more uncomfortable at higher temperatures than at lower temperatures (both temperatures being outside the ideal temperature range).

(3) Hogs under water spray feel more comfortable at low barn humidities that at high barn humidities.

(4) Water spray keeps hogs cleaner than evaporative cooling.

The temperature referred to above are in the zones encountered during the experiments.

5.1.5 Carcass Weight Composition

Fat average was the highest in the control group (Figure 5.4) which

TABLE 5.4 CARCASS COMPOSITION OF THE HOGS, TEST 1.

Hog Treatment	Fat Average (cm)	Predicted Yield (%)	Age (days)	Carcass Weight (kg)	Carcass Index
Control	9.52	70.57	191	71.36	101.9
Spray	9.34	70.19	194	70.63	102.8
Evaporatively Cooled	9.04	70.85	197	71.09	103.5

implies that hogs in this group could have been the laziest. Predicted yield was higher in the evaporatively cooled group than in the other groups, although the difference was not significant and average age of hogs in this group was also higher. The carcass index of evaporatively cooled spray groups was higher than of the control group. It can be said that meat quality as well as the predicted yield was the highest in evaporatively cooled hogs. The spray group gave better quality meat than the control group, but predicted yield of the latter was better than the former.

5.2 The Second Test

5.2.1 Temperature Distribution and Variations

Barn 3 temperature response to changes in ambient temperature (Fig.5.4) during test 2 was almost similar to test 1. It was anticipated as no change in the cooling system of this barn was made. Barn 1, however, showed a different response due to the two fans installed in the ceiling ducts.

At 11:30 a.m. on August 2, when the ambient temperature was 25.55C, barn 1 average temperature was 27.5C. On July 9, at 10:30 a.m., barn 1 average temperature was 28.33C whereas the ambient temperature was only 25C. The ambient temperature and barn 1 average temperature approached each other more rapidly on August 2 than on July 9. These temperatures coincided at 3:30 p.m. on August 2; whereas they showed a difference of 1.11C at a similar time on July 9. On the average, the difference between the ambient temperature and barn 1 average temperature on August 2 was

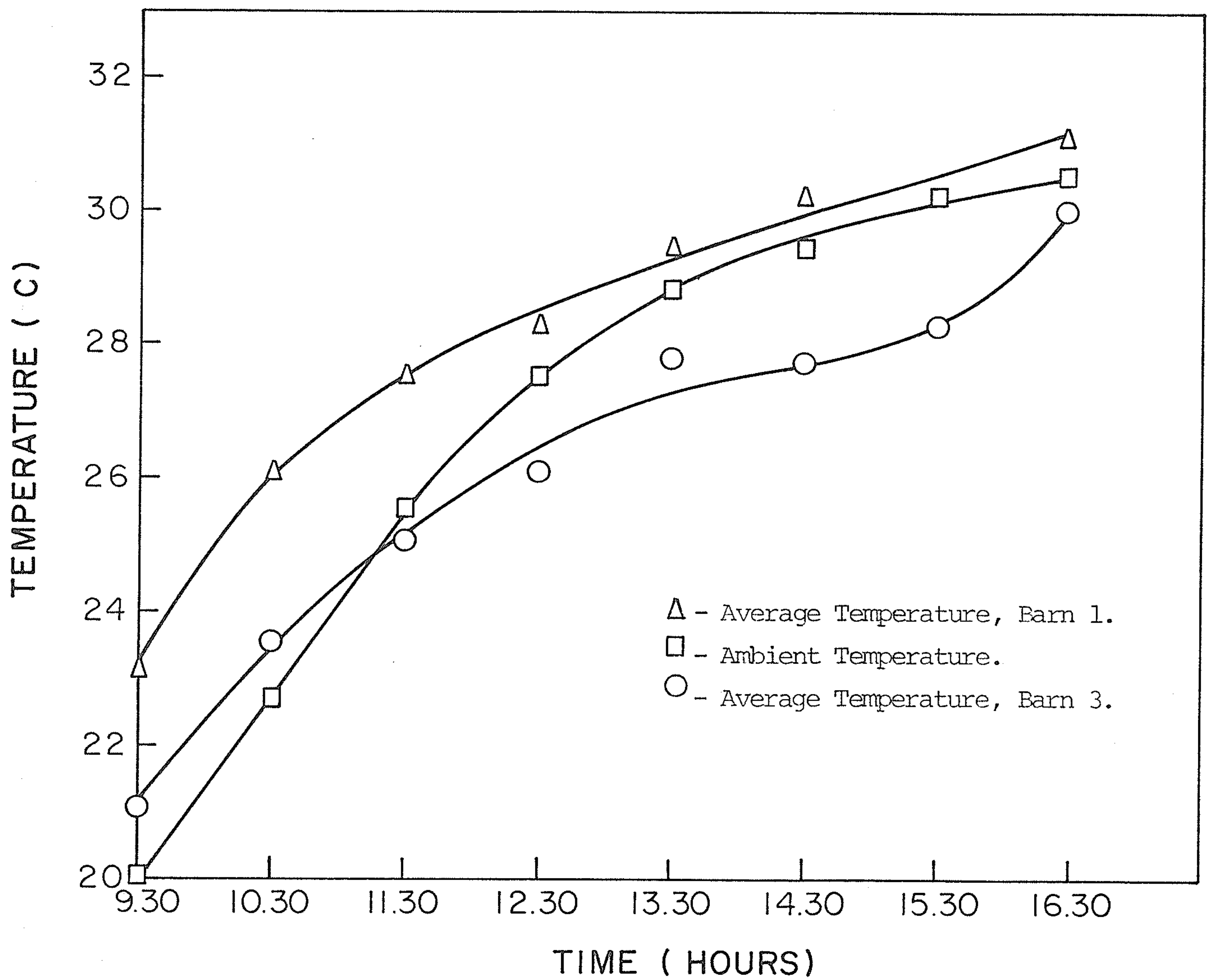


Figure 5.4. Hourly temperature variations in the control barn using two ceiling duct fans (barn 1) and the evaporatively cooled barn (barn 3) on Aug. 2, 1973.

less than on July 9. It appears that better cooling was obtained in barn 1 by installing the ceiling duct fans.

No significant difference in the temperature distribution across the barns from test 1 was observed during test 2, except in the attic space temperatures of the barns (Figure 5.5). During the first test, attic space temperature of barn 1 was always higher than or equal to the temperature at a similar spot in barn 3. During test 2, however, it was just the reverse when the attic temperature of barn 3 was always higher than or equal to the attic temperature of barn 1. Temperature differences of up to 1.11C were observed. It seems to be the result of passing air through the ceiling ducts of barn 1. This drop in the attic space temperature of barn 1 could have contributed to the changes in average temperature of this barn as attic space temperature affects, by heat infiltration, the temperature of air entering the barn through the perimeter inlet slot, (Buchanan 1968).

5.2.2 Hog Performance

Weather data for Winnipeg was analysed in a similar way to that used for the first test (Table 5.5). The frequency polygons thus constructed are shown in Fig. 5.6.

Since no change in the cooling system of barn 3 was made, zone classification made in test 1 still applied to this barn. Barn 1 average temperature was, however, brought down and the difference between the ambient temperature and barn 1 temperature was never greater than 2.77C

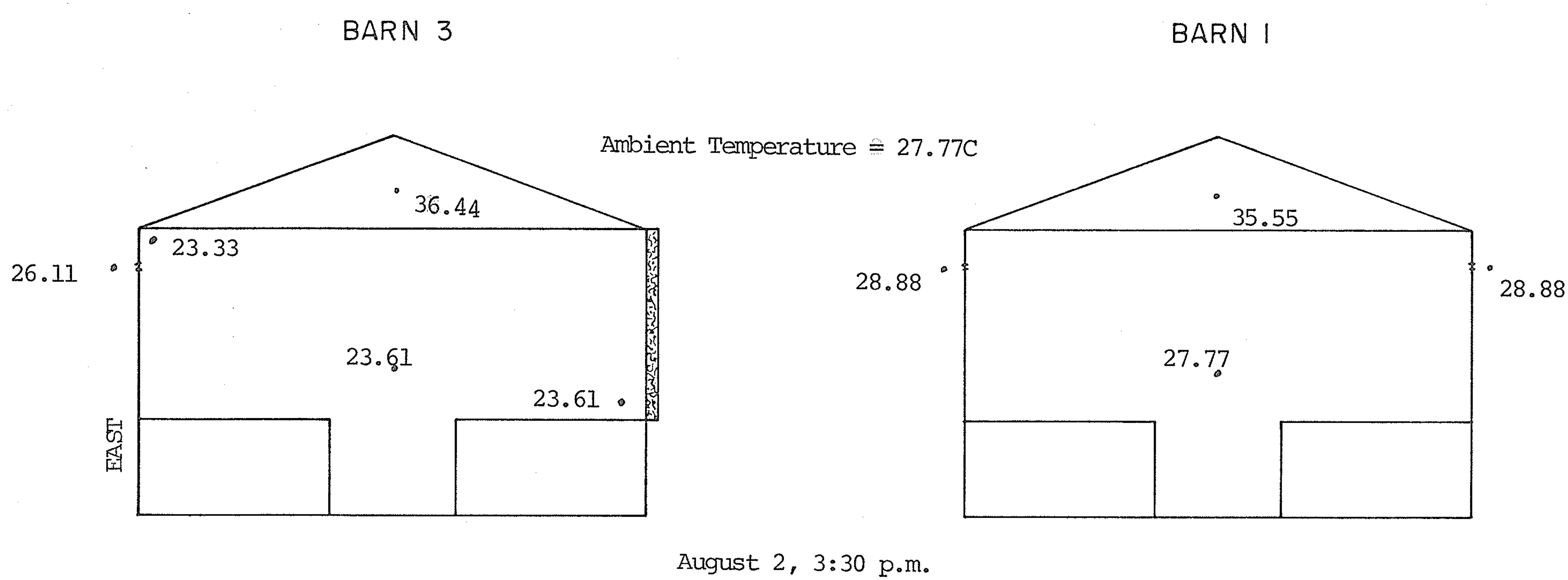


Figure 5.5. A typical temperature distribution (c) across the control barn using two ceiling duct fans (barn 1) and the evaporatively cooled barn (barn 3).

TABLE 5.5 WEEKLY MEAN TEMPERATURES FOR GLENLEA AND WEEKLY MEAN, MEDIAN AND MODAL TEMPERATURES FOR WINNIPEG, TEST 2.

Week	Glenlea	Winnipeg			
	*Mean (C)	*Mean (C)	†Mean (C)	Median (C)	Mode (C)
1	19.67	19.62	20.72	23.98	21.94
2	18.96	19.36	19.27	15.61	16.63
3	20.95	20.73	21.13	20.14	18.86
Whole Test.	19.87	19.85	20.35	20.03	17.52

* - (Maximum + Minimum) /2

† - Hourly basis

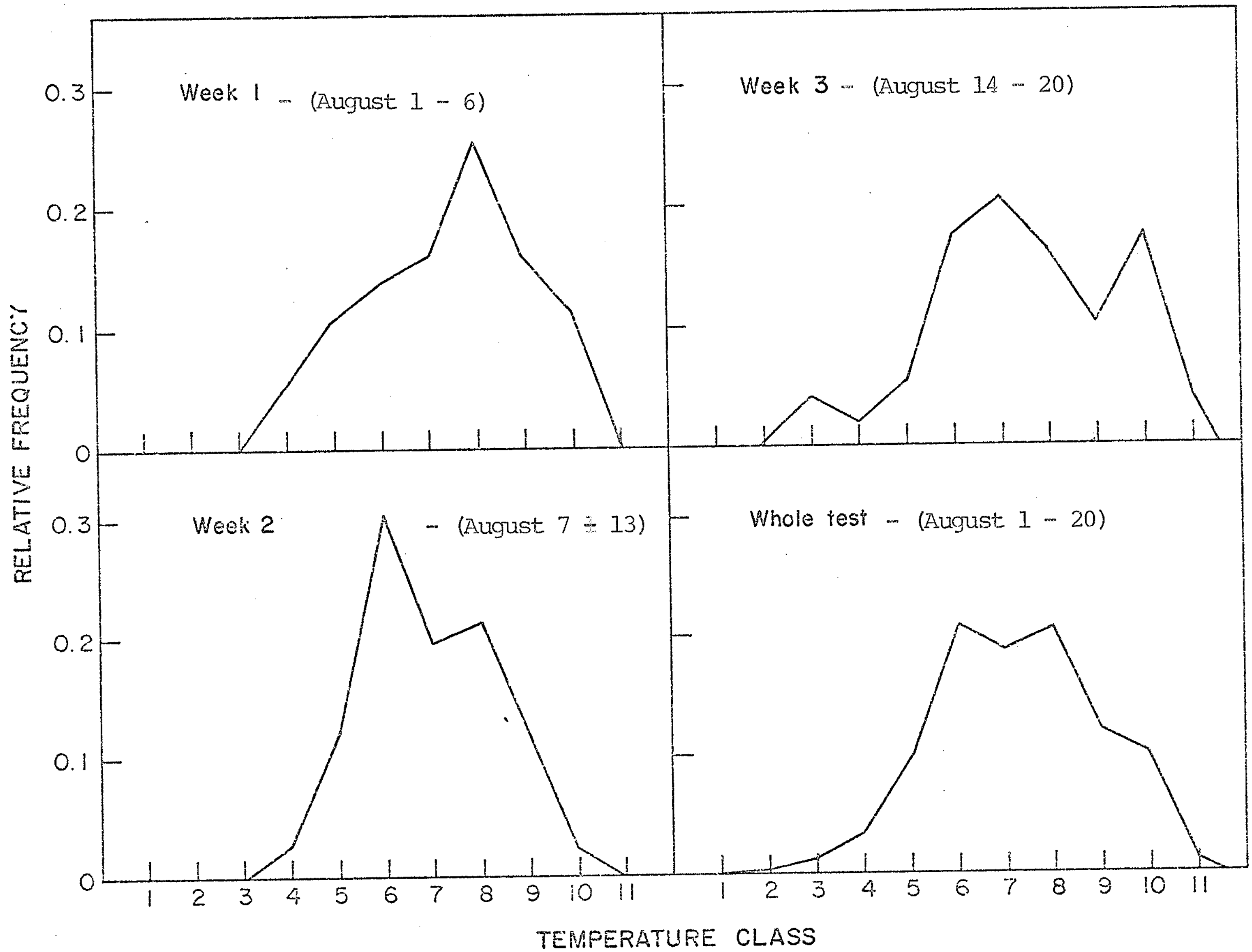


Figure 5.6. Weekly ambient temperature distribution based on hourly weather for Winnipeg from August 1 - 20, 1973.

throughout the observation hours during the test period. This implies that zone B of the frequency polygons in test 2 was not as unfavourable to barn 1 hogs as it was in test 1, and obviously zone A was not as favourable as it was in test 1. Areas unfavourable to both barns and areas of zones A and B were calculated as in test 1 and are shown in Table 5.6.

During the first week, the temperature distribution seemed to be more favourable to barn 3 than barn 1 as it appears from U_1, U_3, A_A, and A_B. The performance results, however, did not correspond with this (Table 5.7). The cooling effect produced by the ceiling fans might have reversed the results.

The temperature distribution of week 2 was favourable to barn 1 as $U_1 < U_3$ and $A_A > A_B$ which was indicated by the better hog performance of the control group than the evaporatively cooled group. The weight gains by the control group were better than the evaporatively cooled group during the 3rd week which was substantiated by the temperature distribution. Better feed efficiency of the evaporatively cooled group, however, was difficult to interpret. The polygon of this week will possibly have the maximum standard deviation of all the polygons in this test; because the dispersion away from the mean is high due to distribution of temperature in all the eleven classes. Its effects were reflected in the feed efficiencies for this week as the relative feed efficiency of each group was very poor.

The frequency distribution for the whole test appeared to be more favourable to barn 3 hogs as U_1 and U_3 were 59% and 60% respectively, and $A_B > A_A$. The performance of the control group, however, was better than the evaporatively cooled group both in terms of feed efficiency and weight

TABLE 5.6 AREAS U_1, U_3, A_A and A_B IN FREQUENCY POLYGONS OF FIG. 5.6.

Week	U_1	U_2	A_A	A_B
1	69.44%	56.94%	30.55%	52.7%
2	47.6%	58.92%	47%	33.33%
3	61.9%	63.69%	30.95%	48.8%
Whole Test.	59.1%	60%	36.45%	44.58%

TABLE 5.7 WEEKLY PERFORMANCE OF THE HOGS, TEST 2.

Week	Control Group	Spray Group	Evaporatively Cooled Group
	*ADG/FE	*ADG/FE	*ADG/FE
1	0.621/4.507	0.772/4.550	0.194/5.35
2	0.553/2.366	0.824/2.768	0.4025/5.795
3	0.6136/15.25	0.603/7.167	0.259/9.24
Whole Test.	0.525/4.93	0.595/4.31	0.486/6.27

* - ADG = Average daily gain (kg/hog)

FE = Average feed efficiency (kg feed/kg gain)

gains. It appears that this was due to the cooling effect produced by the ceiling fans in barn 1.

The spray system in this test has given the best performance results whereas it gave the poorest performance in the first test. It thus appears that there is a tentative preference by the hogs towards a better circulation of air when they are subjected to water spray. This circulation of air may be helpful to reduce their breathing problems resulting from spray, particularly if the spray is very fine.

5.2.3 Visual Observations

The ceiling fans in barn 1 were installed on August 1 at 3:30 p.m. The ambiant temperature at that time was 25C and the temperature inside the barn was 28.88C. It was very uncomfortable in the barn and very few hogs were eating or drinking. As the fans started blowing fresh air in, it gradually began to be felt cooler; especially directly under the fans. The temperature in the barn dropped 1.11C during a period of 20 minutes whereas the ambient temperature remained the same. The barn temperature, however, did not show any subsequent decrease. The hog comfort appeared to be inversely proportional to the pen distance from a point directly under the fan, that is, the hogs closer to fans appeared to be more alert than those away from the fans. On the whole, the hogs tried to gather in a spot of the pen with the least distance from the fan. Some hogs were even seen trying to jump the pen wall towards the fan in an effort to get as close as possible to the fan.

On other days, the hog response was observed to be similar to that described above but, of course, depending upon the ambient temperature. Hog response could not be noted at very low temperatures as no observations were made at night and such temperatures were not encountered during the observations hours. Spray group hogs were again observed to be the cleanest of all.

5.3 The Third Test

5.3.1 Temperature Distribution and Variations.

During test 3, a humidifier was operated in conjunction with two ceiling duct fans in barn 1; while no changes in the cooling system of barn 3 were made. It can be noted (Figure 5.7) that the barn 1 average temperature was brought below the ambient temperature by the humidifier. During the first two tests, barn 1 average temperature was seldom observed to be below the respective ambient temperature (Figure 5.1 and 5.4). On the other hand, in test 3, barn 1 average temperature was rarely above the respective ambient temperature as long as the humidifier was working. For instance, on July 9, barn 1 average temperature was 29.16C when the ambient temperature was 26.66C; whereas on August 30, barn 1 average temperature was 26.11C while the ambient temperature was still 26.66C. The difference between barn 1 average temperature and the ambient temperature in test 3 varied from -1.11C to +0.25C at barn 1 temperatures above 21.11C; whereas in test 1 this difference was always greater than zero.

The temperature distribution across the barns in test 3 (Figure 5.8)

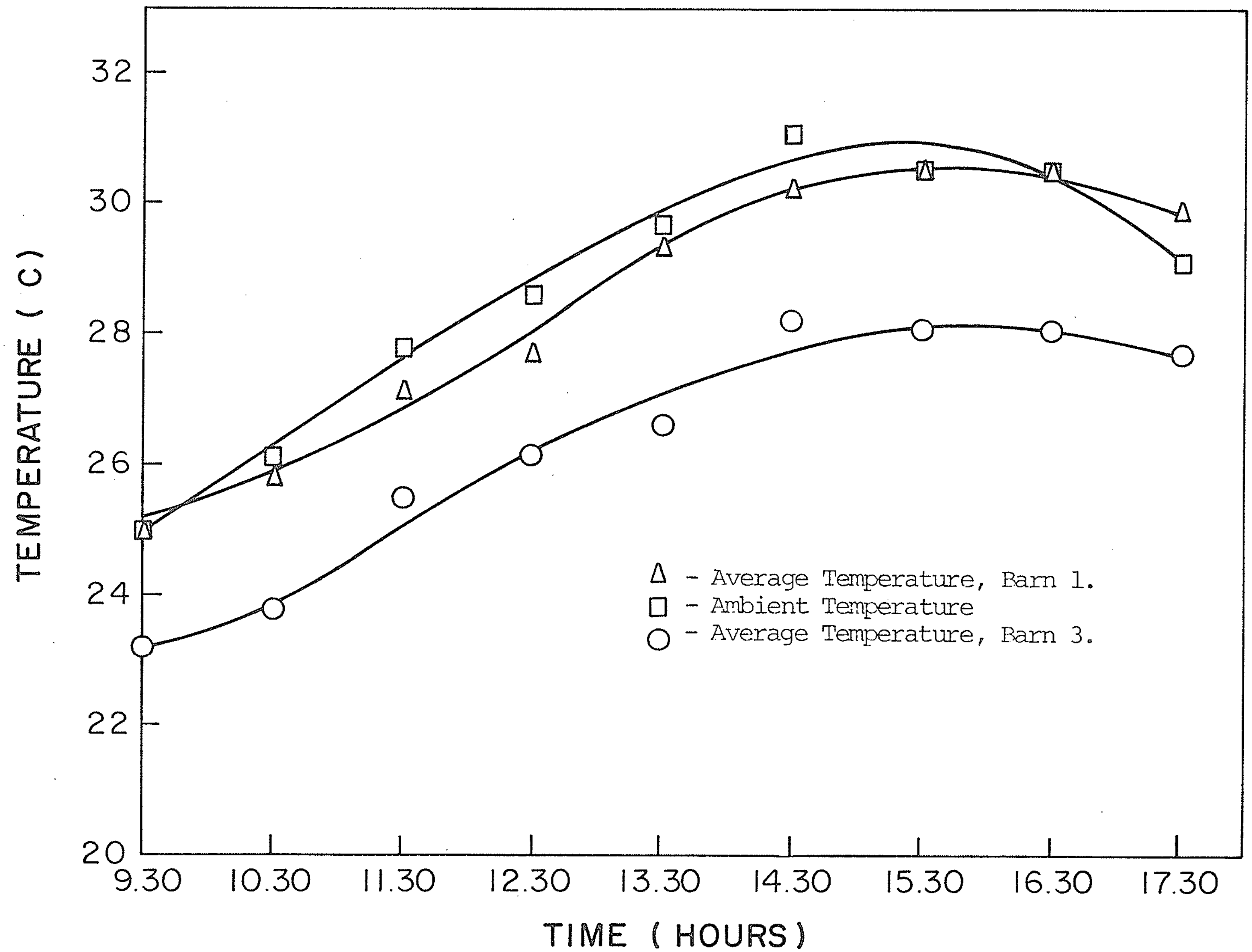
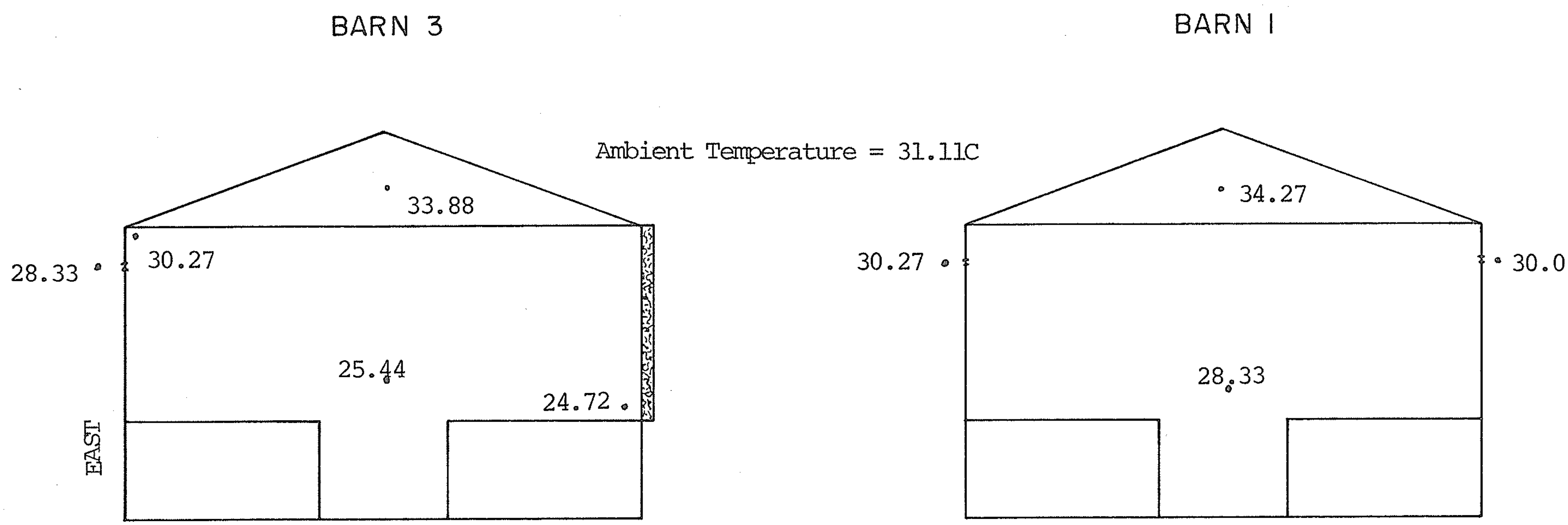


Figure 5.7. Hourly temperature variations in the control barn using a centrifugal humidifier (barn 1) and the evaporatively cooled barn (barn 3) on August 30, 1973.



August 30, 3:30 p.m.

Figure 5.8. A typical temperature distribution (c) across the control barn using humidifier (barn 1) and the evaporatively cooled barn (barn 3).

was almost similar to test 2; except that, in test 3, the exhaust air temperatures on the west side of barn 1 were about 0.27 C. lower on the average than the exhaust air temperatures along the east wall of this barn. This might be due to the humidifier being located a little off the central aisle towards the west wall.

5.3.2 Hog Performance

Substantial changes in the areas, unfavourable to barn 1 hogs, presented by the temperature polygons of test 3 occured due to operation of the humidifier. When the ambient temperature was in class 6, the temperature in barn 1 did not always reach 18.33C as the ceiling fans were still working; particularly when the ambient temperature was in the lower range of class 6. It implies that class 6 became partly unfavourable to hogs of barn 1. On the other hand, barn 1 temperatures were below the ambient temperature when the humidifier was working (at barn temperatures above 21.11C). This in turn implied that class 8 became favourable to barn 1 hogs. As no change in the cooling system of barn 3 was made, the ambient temperature analysis applied to this barn as in the first two tests.

Test 3 was conducted from August 21 to September 10. At that time, the ambient temperatures started dropping (Table 5.8) and frequencies in the upper classes of polygons were reduced resulting in an increase in frequencies of lower classes, particularly classes 5 and 6 (Fig. 5.9). Areas unfavourable to the hogs in both barns were calculated as in the previous tests and are shown in Table 5.9. All frequency polygons for this test appeared to be more favourable to hogs of barn 1.

TABLE 5.8. WEEKLY MEAN TEMPERATURES FOR GLENLEA AND WEEKLY MEAN, MEDIAN AND MODAL TEMPERATURES FOR WINNIPEG, TEST 3.

Week	Glenlea	Winnipeg			
	*Mean (C)	*Mean (C)	†Mean (C)	Median (C)	Mode (C)
1	19.63	19.60	20.03	19.13	18.20
2	20.55	19.91	20.26	19.32	16.06
3	15.10	15.47	15.76	15.75	16.55
whole test.	18.43	18.32	18.68	17.93	16.98

* - (Maximum + Minimum) /2

† - Hourly basis

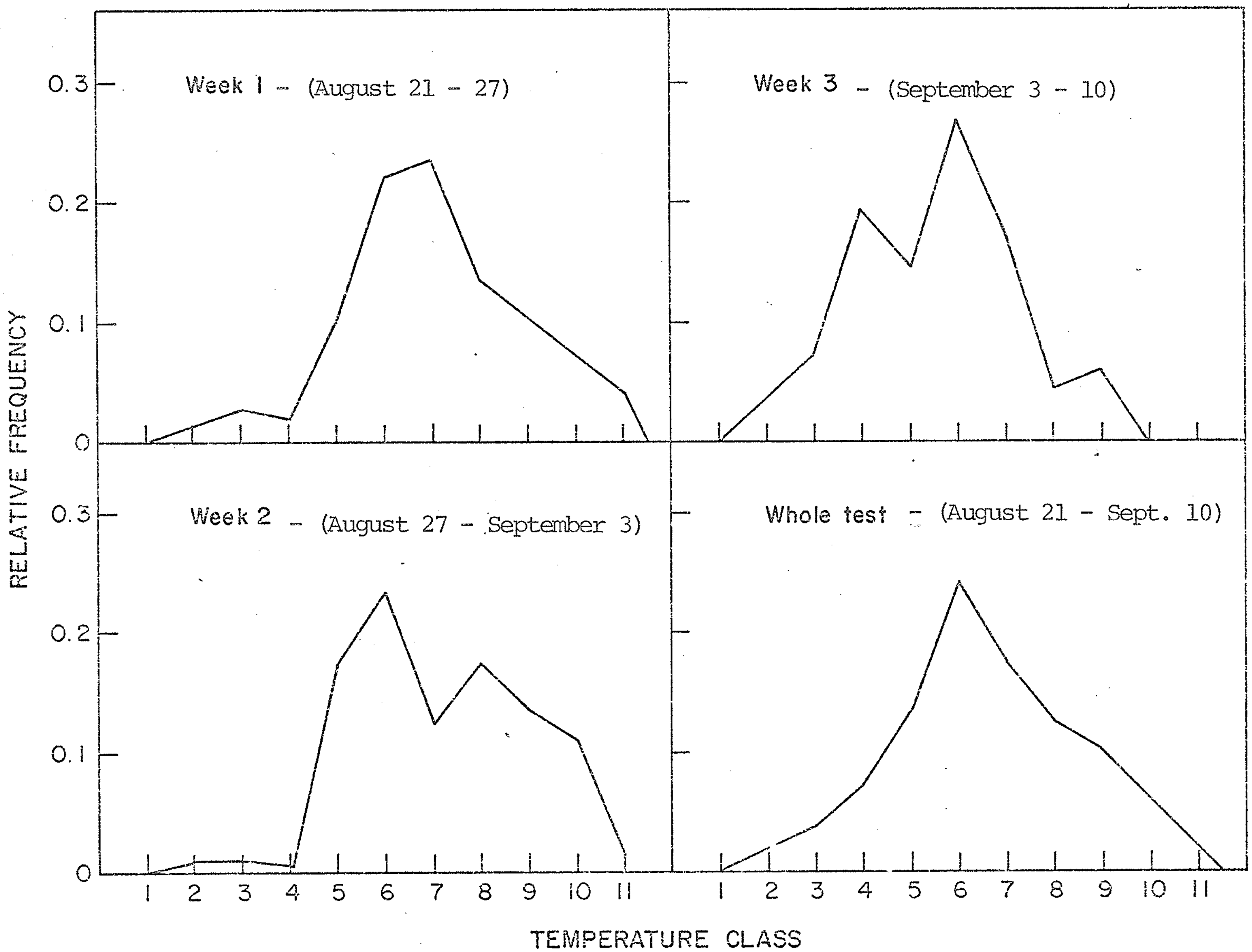


Figure 5.9. Weekly ambient temperature distribution based on hourly weather data for Winnipeg from August 21 - September 10, 1973.

TABLE 5.9 AREAS U_1, U_3, A_A and A_B IN FREQUENCY POLYGONS OF FIGURE 5.9.

Week	U_1	U_2	A_A	A_B
1	54.16%	61.90%	38.69%	38.00%
2	64.28%	69.64%	42.85%	44.64%
3	54.76%	77.97%	71.42%	10.71%
Whole Test.	57.73%	69.84%	50.90%	31.15%

Increase in the area of the polygon unfavourable to barn 1 due to reduction in the barn temperature when the ambient temperature was in class 6, appears to be considerably less than the reduction in this area due to operation of the humidifier. If it is assumed that the above mentioned increase is negligible, areas in class 8 of the polygons could be substracted from the respective U_1. Thus a reduction in U_1 will occur. Based on this analysis, it appeared that the performance of hogs in the mist group would be better than the evaporatively cooled hogs. Performance results of the first and third weeks did not correspond with the above inference (Table 5.10). The average performance of the mist group on the whole was, however, better than the evaporatively cooled hogs.

The temperature analysis for this test suggested a considerable difference between the performance of hogs in the evaporatively cooled and the mist groups, as U_1 and U_2 differed from each other substantially. This, however, was not reflected by the performance results. One possible reason for this could be that at this stage of the experiment, most of the hogs weighed above 91 kg. and the favourable temperature range (18.00 to 22.22C) might not be as applicable as to the hogs with weights below 91 kg. It was observed during the experiment that the weekly weight gains of hogs were lower than the previous tests regardless of the cooling system to which they were subjected. This appears to have caused a lower feed efficiency for each hog group in this test than in the previous tests.

The spray group in this test was subjected to the mist from the humidifier as well. This resulted in a better feed efficiency for this group than the other two groups. The average weight gain for the spray

TABLE 5.10 WEEKLY PERFORMANCE OF HOGS, TEST 3.

Week	Mist Group	Spray and Mist Group	Evaporatively Cooled Group
	*ADG/FE	*ADG/FE	*ADG/FE
1	0.597/5.045	0.5649/4.663	0.597/4.973
2	0.461/5.577	0.381/5.518	2.272/9.638
3	0.4155/6.256	0.4805/5.797	0.441/5.280
Whole Test.	0.4913/5.553	0.476/5.380	0.437/6.050

* - ADG = Average daily gain (kg/hog)

FE = Average feed efficiency (kg feed/kg gain)

TABLE 5.11 SUMMARY OF HOG PERFORMANCE

	*Weight Gain	*Feed Efficiency
Test 1		
Control Group	5.58% decrease	3.89% increase
Spray Group	14.57% decrease	14.22% decrease
Test 2		
Control Group	7.95% increase	21.37% increase
Spray Group	22.43% increase	31.25% increase
Test 3		
Mist Group	12.37% increase	8.21% increase
Mist & Spray Group	8.89% increase	11% increase

* - Based on evaporative cooling (assumed as 100%)

Overall 12 Week Weight Gain Performance

	ADG†
Control Group	0.47
Spray Group	0.46
Evaporatively Cooled Group	0.50

†ADG = Average Daily Gain (kg/hog)

Figure 5.10. The spray and the control pigs.

group, however, was lower than mist group; but it was still higher than evaporatively cooled group.

5.3.3 Visual Observations

As the humidifier evaporated up to 5.45 kg. per hour of water in barn 1, it resulted in a higher relative humidity in this barn. It was not as uncomfortable in the barn as in the first and second tests and the relative comfort was much better at very high ambient temperatures (above 26.66C). The hogs also appeared to feel better, were actively eating and drinking; but they still appeared to be less active than the hogs in barn 3. The hogs in the spray group continued to be the cleanest of all.

5.4 Limitations of the Cooling Systems

Some problems were encountered in the operation of every cooling unit; thus each unit appeared to have advantage over the others in certain respects.

The maintenance of a uniform distribution of water over the excelsior pads was observed to be the greatest limitation of the evaporative cooling unit. Most of the time the problem was due to plugging of the holes, in the overhead pipe, by rust particles or the excelsior pad straws which circulated in water. This problem could not be fully overcome even by putting a wire mesh screen in the pipe of the circulation pump and resulted in frequent dry patches in pads throughout the barn length. Frequently water could not reach the end of the overhead pipe at low water pressures.

Although the initial cost of this unit was the least of the three units, its maintenance was the most difficult. Even if a uniform distribution of water was obtained, a uniform cooling effect in the barn could not be obtained as temperatures in the pens closer to the unit were lower than in the pens away from the unit.

In spite of the use of a filter in the spray unit, occasionally the spray nozzles were found plugged by rust particles. The rusting process was further enhanced due to the use of brackish water in the barn. The rust, and dust particles from the feed in the barn, deposited around the periphery of the nozzle hole which interfered with the spread of the spray. The water pipes over the pens appeared to create obstructions and were a hindrance to the workmen.

Of the desirable features of the humidifier, the most important was the regulation of the water feed. It was obtained by changing the water pressure through the pressure control valve, according to the temperature in the barn. This important feature is difficult to obtain in the other units and even if obtained, it cannot have the precision and immediate effect as with the humidifier. The initial cost of the humidifier was greatest of all the units, its maintenance was limited and the operation costs were minimal. It occupied a very small space in the barn, thus practically offering no obstructions to the workmen.

CHAPTER VI

CONCLUSIONS

1. Water spray cooling keeps the hogs cleaner than evaporative cooling.
2. A humidifier of half the capacity required for bringing adiabatic saturation in a barn with a hog confinement density of 74 kg. per square meter of barn can reduce the average barn temperature equal to ambient temperature or below.
3. Hogs cooled by evaporative pads give better performance than with conventional ventilation system.
4. Performance of the hogs under spray cooling can be improved by increasing the air flow rate in the barn.
5. Performance of the hogs under conventional ventilation system can be improved by using a humidifier of only half the design capacity required for bringing adiabatic saturation in the barn.
6. Ambient temperature distribution for Winnipeg is such that any cooling method will be more effective in improving hog performance in a barn with naturally high temperatures (due to barn construction, its orientation, higher hog weight per unit area of the barn or the ventilation) than in a barn with naturally low temperatures. Hog performance in a barn of the latter type can be improved by decreasing the ventilation rate at barn temperatures below 18.00C and using a cooling system at barn temperatures above 22.22C.

CHAPTER VII

FURTHER SUGGESTIONS

1. Studies on hog performance should be conducted using a humidifier of the full design capacity for obtaining adiabatic saturation in the barn.

2. Controls of the humidifier should modulate the amount of water fed to the humidifier in direct proportion to the barn temperature; and the performance studies be continued.

3. Summer weather data at various locations for at least ten years should be analysed and grouped into classes. It will eventually help in determining the size of cooling units required for typical hog barns at the particular location.

4. Studies should be conducted on the use of plastic pipes for the water spray unit.

5. To achieve better validity of the performance results under various cooling systems, barns with similar construction, orientation and equal hog weights per unit area of the barn should be used.

6. Hygrothermographs or other temperature recording devices should be used in barns which will eventually help in analysis of the performance results.

7. Some better method of weighing the hogs and feed should be employed

to minimize the labour requirements.

8. The effect of humidifier location on the temperature distribution across the barn should be determined.

9. Performance studies should be broadened to include the effect of summer cooling relative to various hog breeds.

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