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To the Graduate Council:

I am submitting herewith a thesis written by William Robert Fox entitled "Temperature and Humidity Conditions in Three Types of Broiler Houses." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agricultural Engineering.

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22
33

TEMPERATURE AND HUMIDITY CONDITIONS IN
THREE TYPES OF BROILER HOUSES

A THESIS

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The Graduate Council
of
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for the degree of
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by
William Robert Fox
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CHAPTER I

THE PROBLEM OF BROILER HOUSING

Those persons acquainted with agriculture realize that vast and varied changes have occurred in this field during the last two or three decades. Science and technology have moved from the drawing board and laboratory to everyday use on the American farm. Production has more than kept pace with the growth of population. This is especially true of grain and fiber production which has created surpluses of these staple commodities. More emphasis has been placed on animal production, and the nature of animal enterprises have experienced considerable change.

One of the most dramatic changes in animal production during this period has occurred in the broiler enterprise. This segment of the poultry industry has developed from a back-yard enterprise to a multi-million dollar industry. During the past twenty-five years the national production has increased fifty-four times from 18,700,000 to 1,002,000 dollars (4).^{*} In thirteen Southeastern states, the percentage increase was even more significant. Since 1934, the production has increased approximately 126 times to the figure of 593,200,000 dollars (4). With the present rate of production, broilers will continue to supply about three-fourths of the United States chicken meat supply (12). The United States broiler producers now have a new and important market for frozen, ready to cook broiler meat. In 1958, 22.5 million pounds of United States

^{*} Numbers in parenthesis refer to appended references.

broilers went to Western Europe where shipments were virtually non-existent five years ago (17).

The Southeast region leads the nation in broiler production and has continued to increase production every year along with the rest of the nation (7). This increase in broiler production is excellent from the standpoint of farm income, but it has brought about housing problems. Instead of having a small inexpensive broiler house in the backyard, it is now necessary to invest several thousand dollars in a broiler house if commercial production is desired. In the past the farmer has built the type of house that was common in his community. This building was generally a simple frame type structure. However, as the price per pound of broilers began to decline, he needed a more efficient house if he were to continue his progress in the broiler industry. The producer desired a house that would give the best lighting conditions, the most desirable temperature and humidity, relatively dry litter, the least amount of dust, and the proper amount of ventilation.

During the past several years, the type of house common on most farms was the conventional type house previously mentioned. However, in the last few years, solar houses and windowless houses have been used on a few farms. Broiler producers generally asked two questions: Which house would give the optimum environmental conditions; and which house would be the most economical? When agricultural engineers were confronted with these questions, it soon became apparent that there was a definite need for basic information on the environmental conditions in the respective types of broiler houses. The agricultural engineers needed this information before they could make specific and reliable recommendations

on which type of house would be the most efficient.

Statement of the Problem

The purpose of this study was to determine, for comparative purposes, the respective temperature and humidity conditions of a Solar, Windowless, and Conventional type broiler house. As previously mentioned, there are many environmental factors, such as light, temperature, humidity, and ventilation which probably could affect the growth of broilers; however, it is commonly thought by poultrymen that temperature and humidity affect the growth of broilers more than the other factors stated. For this reason, those concerned with this research project were of the opinion that temperature and humidity conditions should be studied first. Investigations and studies of the other factors will more than likely be conducted at a later date.

So far as the author was able to determine, this experiment is the initial attempt at determining the respective temperature and humidity conditions of all three type houses - Solar, Windowless, and Conventional - on a comparative basis. The information derived from this investigation should be of considerable value to those concerned with designing broiler houses, and also those concerned with the management of broiler houses. This experiment was conducted under climatic conditions of Eastern Tennessee. The conditions are somewhat parallel and typical of those found in regions of intensive broiler production in the Southeast (4). The magnitude of temperatures at various locations in the Southeast would vary to some extent, but the daily and seasonal fluctuation would be quite

similar to those of this experiment (2).

Proposed Solution of the Problem

The proposed solution of this problem was; first, to investigate literature related to solar, windowless, and conventional type houses; second, to select a feasible method of approaching the problem; third, to construct the respective houses according to recommended plans; fourth, to secure, construct, or adapt equipment to be used in obtaining and recording temperatures and humidities; fifth, to compile and analyze the data in order to compare the temperature and humidity conditions of the respective houses.

Review of Related Studies

To properly design a poultry house, it is important for one to know what temperature and humidity is desired for the most efficient production of broiler growth. Mitchell and Haines found that the average critical temperature for Rhode Island Red Hens was 62° Fahrenheit (10). The critical temperature is the environmental temperature at and below which the heat production of the fasting-resting animal will increase to prevent a lowering of body temperature. Recent unpublished tests by Prince and others seem to support this theory (9). A study at the University of Connecticut was performed using four cabinets (four feet high by four feet wide by eight feet long) of twenty birds each. Temperatures of 45°, 55°, 65°, and 75° Fahrenheit were used in this experiment. There was no significant difference in weight gain and mortality caused by the

different temperatures. However, there was a significant difference in feed consumption and feed efficiency. The results showed a decrease in feed consumption as the temperature was increased. More of the feed consumed by the bird was needed for heat production in the bird for the lower temperatures.

Low humidities were reported as having no adverse effects on broilers but the same is not true for high humidities (16). This becomes even more important when the high humidities are coupled with high temperatures. At high temperatures, chickens have to breathe rapidly to eliminate water; but this panting in turn creates more energy that must be dissipated. If the relative humidity becomes extremely high for a particular temperature, the bird will not be able to dissipate enough heat by vaporization to prevent heat prostration and death.

Various studies have been made in regard to ventilation of poultry houses (11). Promersberger and Bryant found that there is no significant difference between natural or forced ventilation in regard to average daily temperatures or daily fluctuation in temperature (13). However, in the Connecticut study previously cited, the ventilation effects of three-fourths cubic feet per minute per bird on the feed conversion efficiency by the bird was significantly greater than that of two cubic feet per minute per bird (9).

A report on a poultry house built to use the sun as a source of heat was published in October 1958 by Walton and Bressler of the Pennsylvania State Agricultural Experiment Station (20). In cold weather, particularly in the Northeast, poultry houses are generally inadequately supplied with heat. Heat is needed to make up for losses through walls,

windows, doors, and ceilings. Heat is needed to warm the air exchanged by ventilation. Heat is needed to evaporate excess moisture. By incorporating the heat gain from the sun and using thermostatically controlled fans, the Pennsylvania State Experiment Station personnel were able to maintain house temperatures above 50° Fahrenheit inside the Solar House during the winter. To combat high temperatures during the summer months, the house was initially operated with a large sliding door at each end opened, with small doors in the back opened, and with ventilation fans above the windows forcing air into the house. Then, to determine the effect of summer temperatures on an enclosed house, the large doors at each end of the house were kept closed. However, a large fan was installed in each end door, and all small doors were closed except one to provide an exhaust opening. This system moved about 10,000 cubic feet per minute of air into the house in addition to the air supplied by the original ventilating system. Temperature control during periods of hot weather was no more effective with the building closed and all fans operating than with the end doors open and only the original fans operating.

Since November of 1956, the West Virginia University Agricultural Experiment Station has been conducting studies comparing windowless and solar housing (3). Each house has the same construction except the Solar House which has "Thermopane" windows. During the period of November 21, 1956 to January 31, 1957, the Solar House had a maximum temperature of 86° Fahrenheit and a minimum temperature of 50° Fahrenheit. During the same period, the Windowless House had a maximum temperature of 78° Fahrenheit and a minimum of 49° Fahrenheit. There was no significant difference in feed conversion efficiency by the birds.

Further reports of research pertaining to solar and windowless housing could not be found. However, there has been several solar houses installed at Duluth, Georgia by commercial poultry producers (8).

Organization of the Remainder of the Thesis

The remainder of this thesis includes an explanation of how the experiment was planned and conducted; the location of the experiment; the description of the houses; a description of the equipment used in obtaining and recording data; the presentation and discussion of the data; and the summary and conclusions.

CHAPTER II

METHOD OF APPROACH

Once the problem was defined, the next step was to determine the method for obtaining data. As stated previously, the problem was limited to the environmental conditions of temperature and humidity, since these two factors are considered to be very pertinent to the efficiency of bird growth. Since it is logical and convenient to do so, temperature and humidity conditions were investigated together.

Before proceeding any further the following terms and definitions are given since they are used frequently throughout this thesis. The 1955 edition of Heating, Ventilation, and Air Conditioning Guide defines the following terms in this manner (5):

Dry-Bulb Temperature. The temperature indicated by any type of thermometer or thermocouple not affected by the water vapor content of the air or by radiation.

Wet-Bulb Temperature. Wet-bulb temperature is the temperature at which liquid or solid water, by evaporating into air, can bring the air to saturation adiabatically at the same temperature. Wet-bulb temperature (without qualification) is the temperature indicated by a wet-bulb psychrometer constructed and used according to specifications.

Humidity. Water vapor within a given space.

Absolute Humidity. The weight of water per unit volume.

Relative Humidity. Ratio of the mole fraction of water vapor in the actual mixture to the mole fraction of water vapor in saturated air at the same dry-bulb temperature and barometric pressure.

Relative humidity may also be thought of as the ratio of the actual moisture content of air to its saturation content at the same dry-bulb temperature. When air is heated its relative humidity decreases, because

the saturation content at the higher temperature is greater while the actual quantity of moisture remains the same. For example, one cubic foot of air at 20° F. and containing approximately 1.08 grains of moisture would have a relative humidity of ninety per cent. If heated to 70° F. it would have a relative humidity of 12.2 per cent, although its actual moisture content, or absolute humidity, would be unchanged. This would greatly increase the drying effects of the air.

Since the temperatures of each broiler house would not be the same, the relative humidity would not give a specific comparison of the houses. Also, the absolute humidity would not give a specific comparison, because the moisture content of the air in each house could be affected by over-filled watering cups, by different rates of air infiltration, and possibly by other factors. Allen, Walker and Jones state that the total heat of different mixtures of air and water vapor having the same wet-bulb temperature will be equal. The term total heat refers to the heat in the air plus the heat of vaporization of water vapor. Since the wet-bulb temperature is a measure of total heat, this would give a specific comparison. If relative humidity and/or absolute humidity is desired, it would be a simple matter to determine these from a psychrometric chart when the dry-bulb and wet-bulb temperatures are known. Therefore, it was decided to use dry-bulb and wet-bulb readings for obtaining temperature and humidity conditions of the solar, windowless and conventional type houses.

It was decided to collect continuous data for four nine-weeks periods of broiler growth. These periods were Fall of 1958, Winter of 1958-1959, Spring of 1959, and Summer of 1959. The wet-bulb and dry-bulb temperatures in the solar, windowless and conventional type houses could

then be determined and compared.

Description of Test Set Up

Location and orientation of experimental houses. The three broiler houses used for this experiment were located on the Cherokee Farm of the Agricultural Experiment Station in Knoxville adjacent to the main agricultural campus. The houses were located along the crest of a hill. The houses used were existing structures which were remodeled for this experiment. A discussion of the details of remodeling will be presented later in this chapter.

The orientation of the three existing buildings were such that the buildings faced South 38° East. The most desired orientation for a Solar House is when the large glass area faces true South. However, under the particular circumstances, it was impossible to orient the Solar House in this direction. Nevertheless, all three buildings were facing the same direction which gave a consistent and comparative orientation.

To determine the difference in the Sun pattern on the front of the existing Solar House and a Solar House facing due South, two model houses were constructed with one house oriented South 38° East and the other true South. The models were constructed to scale from the existing Solar House. Figure 1 shows a picture of one of the models used to determine the difference in the Sun pattern. Figure 2 shows the Sun patterns on the models for the date of September 21, 1959. The lines drawn across the front of the house indicate the bottom of the shade pattern projected by the overhang of the roof. On the model facing South 38° East the Sun's rays

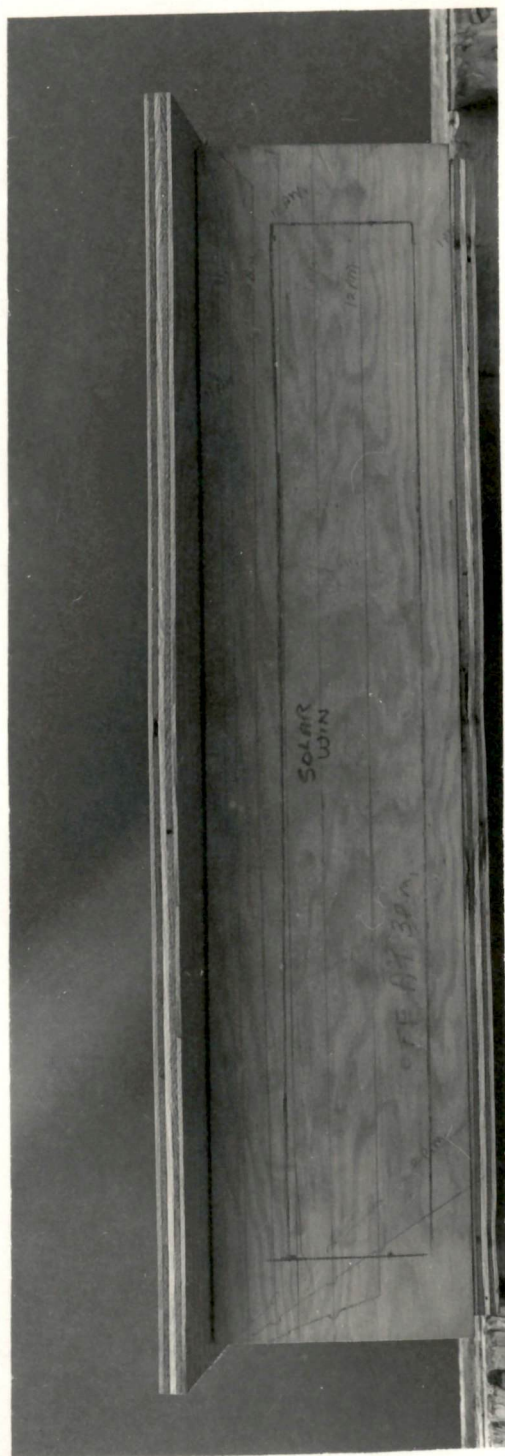
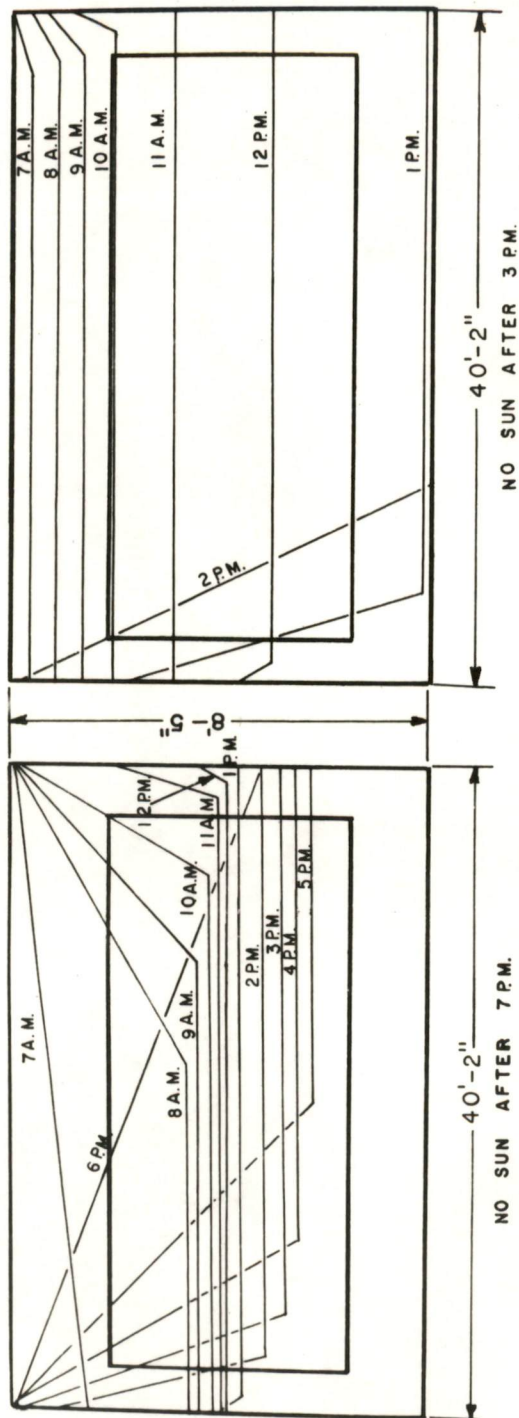


Figure 1. Front view of a model Solar House.



FACING SOUTH

FACING S38°E

SCALE 1" = 40"

NOTE: LENGTH OF HOUSE IS NOT TO SCALE.

LINES WITH TIME NOTED INDICATES BOTTOM OF SHADE PATTERN ON HOUSE AT THE TIME STATED.

Figure 2. Shade patterns on front of model Solar Houses.

continued to pass through the entire window area until ten o'clock in the morning. After ten o'clock, the shade pattern began to move down the front of the building. By three o'clock in the afternoon, the entire glass area was shaded by the roof projection. On the model facing due South, the Sun's rays passed through the bottom half of the window most of the day. The shade pattern began to move down at a much slower rate than it did on the model facing South 38° East. Relative hourly positions of the shade patterns of the two orientations is shown by Figure 2. These relative comparisons of the orientations of the Solar House were for the day of September 21st.; these comparisons would also apply for the day of March 21st.

To determine the relative comparison of the two orientations for the day of June 21st. and the day of December 21st., a Sun angle calculator (developed by Libby - Owens - Ford Glass Company) was used in conjunction with a scale drawing of the Solar House. For the day of June 21st., the window would be completely shaded for a house facing due South. For the house facing South 38° East, the Sun's rays would pass through the window until 9:00 a.m. After 9:00 a.m., the window would be completely shaded. This is the day in the year that the window would receive the least amount of solar radiation. Figure 3 shows a view of the Solar House taken at 10:00 a.m. the day of June 10, 1959. Notice the shade pattern on the ground in front of the house.

For the day of December 21st., the Sun's rays would pass through the window of a house facing south throughout the day. For a house facing South 38° East, the shade pattern would begin to move down the front of the house at 12:00 p.m. At 4:00 p.m., the window would be completely



Figure 3. Front view of Solar House used to indicate shade pattern.

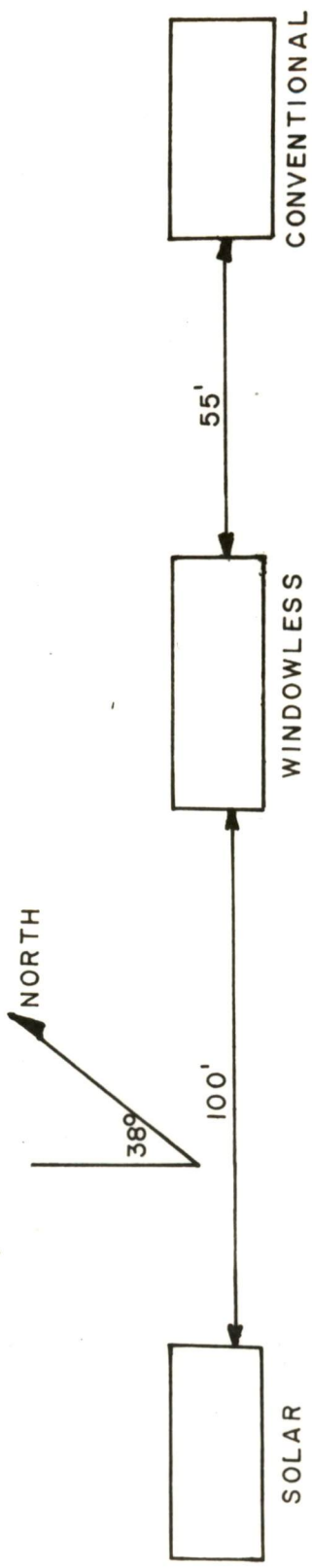
shaded. However, the Sun usually sets about 4:30 p.m. in the southeastern region of the United States.

The difference in a Solar House facing South and a house facing toward the East is that the house oriented South receives the maximum solar heat gain at 12:00 noon Sun time. But, the house facing toward the East receives the maximum solar heat gain earlier in the morning (1). The time of day is directly related to the degree of orientation toward the East. The affects of the different orientations and construction of houses on temperatures will be found in Chapter III.

The location of the houses relating to one another is shown in Figure 4. The houses were located beside a farm road, and there were several trees located near the houses as shown in Figures 5 and 6. The shade patterns of the trees on the roofs would not affect the houses during the spring, fall, and winter periods. However, the author was not sure if the shade of the tree would affect the temperature pattern during the summer period. Any difference in the temperature patterns of the summer period from the other periods will be noted later in this thesis. For an ideal experiment, the trees should be eliminated. However, as stated previously, the three houses were existing structure; and it was not desirable to remove the trees.

The instrument house for the potentiometers was located near the west corner of the Windowless House (Figure 6). This was the central location of the three houses, and also the most convenient.

Construction and Equipment of the Solar House. The Solar House (Figure 7) is eighteen feet wide and forty feet long. The front of the house is eight and one-half feet high, and the roof has a one-twelfth pitch.



LOCATION OF HOUSES

Figure 4. Location and orientation of the experimental houses.



Figure 5. Front view of the Solar, Windowless and Conventional Houses (showing position and alignment).



Figure 6. Rear view of the Windowless and Conventional Houses. Also shown is the instrument house.



Figure 7. Front view of the Solar House (note ventilation fans).

The inside of the house is divided with poultry mesh partitions into four pens each designed to hold one hundred broilers. This was done by the poultry department for the research relating to the broilers.

A partial cross-section of the house is shown in Figure 8. Note the exterior surface is three-fourth inch tongued and grooved wood sheathing, and the interior surface is three-sixteenths inch cement-asbestos board. Insulation was placed in the stud spacings between the interior and exterior surfaces. The insulating material was commercial "Fiberglas" blankets. The roof blankets were encased with aluminum foil, and the sidewall blankets were encased with heavy brown paper. All blankets were approximately three and one-half inches thick. The front of the Solar House has eleven "Thermopane" windows which are thirty-six inches wide by fifty-eight inches high. The term "Thermopane" applies to a type of window manufactured commercially. It is made by mounting two plate glass panes one-half inch apart with a "dead air" space between them. The function of the air space is to act as an insulator, reduce heat loss, and provide a better means for retaining the solar heat gain during the winter. The floor of the Solar House was a concrete slab four inches thick. This was covered with three to four inches of litter. The litter was wood shavings except for the winter period when peat moss was used.

The roof projection extended fifty inches beyond the front of the house. The design of this roof projection and insulation of the walls was recommended by engineers of an industrial firm. This was done prior to the time that the author or his advisor were concerned with this research project. The design of the roof projection was based on the assumption that the house faced true South, and the workmen constructed it to this

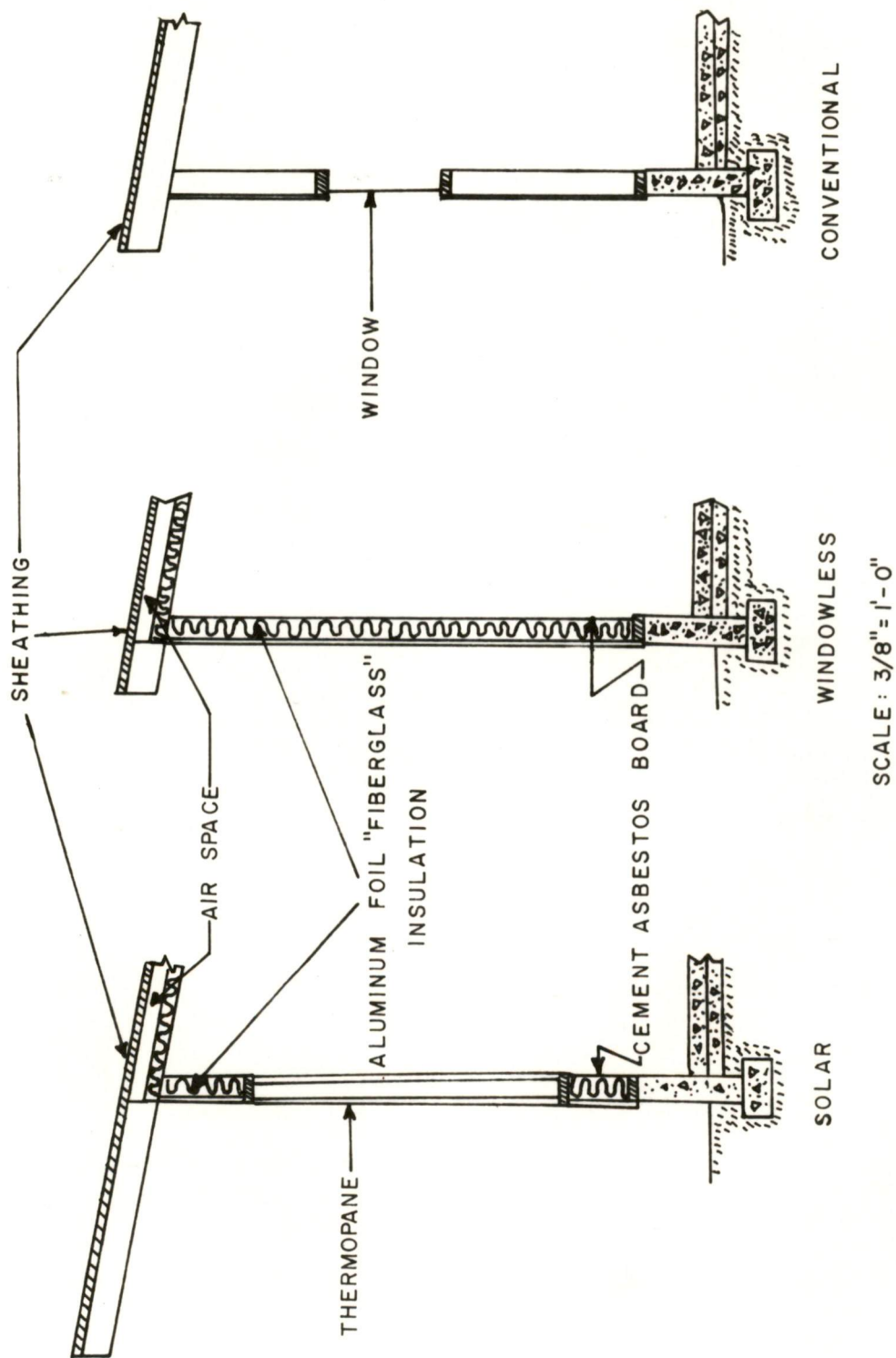


Figure 8. Partial cross-sections of experimental houses showing typical construction features. 28

design. However, at a later date, the orientation of this house was questioned and found to be South 38° East. To keep seasonal comparisons consistent, the projection was not altered. The data of this particular study is presented on the basis of the fifty inch roof projection. The author does not imply that this is necessarily the most desirable projection for a Solar House with a South 38° East orientation.

The house was heated by four Oakes-hover-type 600 watt electric brooders. The brooders were thermostatically controlled, and the thermostat settings were regulated periodically. The first week the thermostats were set at 95° F., and the thermostat setting was reduced 5° F. each week until a setting of 70° F. was reached. The brooders were then operated on this setting for the rest of the nine-week period.

The lighting system of the house provided fourteen hours of light for the broilers. This light consisted of both artificial and natural sunlight. The artificial light was obtained by using eight 40-watt incandescent light bulbs controlled by a time clock. The time clock settings were such that the incandescent lights came on at 6:00 a.m. and off at 9:00 a.m. and also came on at 4:00 p.m. and off at 8:00 p.m.

The ventilation system of the house consisted of two intake fans and one exhaust louver. Each fan had a nominal capacity of 700 cubic feet-per-minute. The location of the fans in the house may be seen in Figure 7. One fan was operated by a thermostat set to start the fan when the temperature in the house reached 75° Fahrenheit. This same thermostat opened and closed the exhaust louver. When the temperature was below 75° Fahrenheit, a time clock in this fan circuit operated the fan and exhaust louver for two minutes of every ten minute interval. This two minute

interval of ventilation was provided to remove fumes and odors from the building. When the temperature was above 80° Fahrenheit, another thermostat started the second fan. The nominal output of the fans was 1400 cubic feet per minute of air movement. The same ventilation, lighting, heating, and construction details apply to the Windowless and Conventional Houses. Differences will be noted under the respective house descriptions.

Construction and Equipment of the Windowless House. The Windowless House (Figure 9) is eighteen feet wide by forty-six feet long. The front of the house is eight and one-half feet high, and the roof has a pitch of one-twelfth. The inside of the house is like that of the Solar House. The insulation of the Windowless House is the same as the insulation of the Solar House. Also the outside and inside sheathing is similar to that of the Solar House (Figure 8).

This house had no windows; therefore, no sunlight could enter the building. Fourteen hours of artificial lighting was provided for the broilers. The artificial lighting was provided by eight 40-watt incandescent bulbs which were turned on at 6:00 a.m. and off at 8:00 p.m. by a time clock.

The heating system, like the Solar House, was four 600-watt Oakes hover-type brooders. The brooders were thermostatically controlled like those in the Solar House.

The ventilation system was the same as the Solar House. That is, it had two 700 cubic feet-per-minute capacity fans and an exhaust louver. The fans were controlled with two thermostats and a time clock with the same temperature and time settings as those used in the Solar House.

Construction and equipment of the Conventional House. The Con-

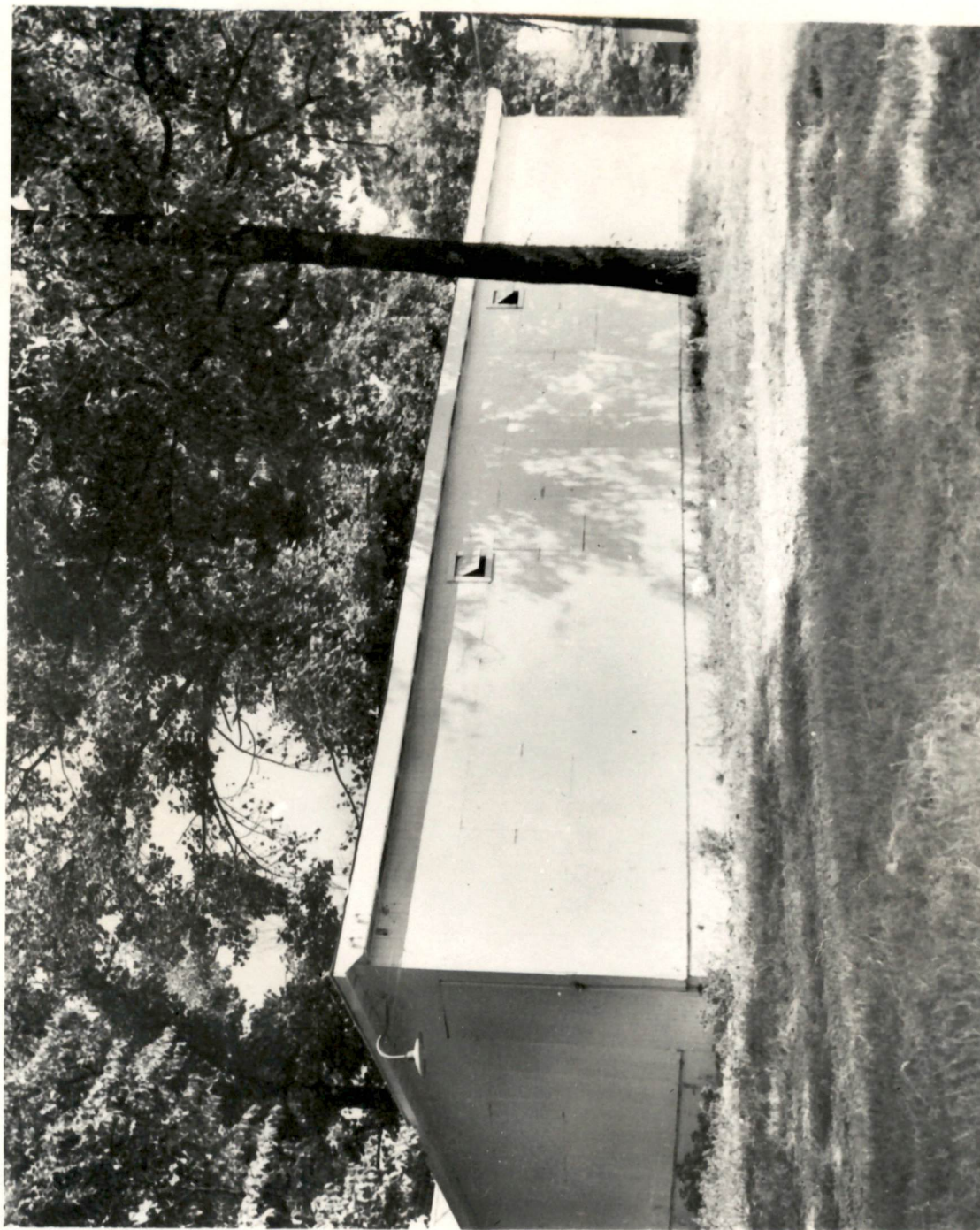


Figure 9. Front view of the Windowless House.

ventional type house (Figure 10) is similar to the type of houses commonly in use by poultrymen throughout the Southeast. It is twenty feet wide and forty feet long. The front height of the house is eight and one-half feet, and the roof pitch is one-twelfth. The inside is divided similar to the other two houses.

The Conventional House was not insulated with the "Fiberglas" insulation. The partial cross-section of the house in Figure 8 shows that the sidewall construction consists only of three-fourths inch wood sheathing. The front of the house includes eight twenty-six inches by forty-eight inches corrugated rigid plastic windows, and the back includes four, twenty-six inch by thirty inch windows. The floor and litter is similar to that in the other two houses.

The house was heated similar to the other houses. That is, four 600-watt Oakes hover-type brooders were used to supply heat to the building. The brooders were thermostatically controlled like the other two houses. During the winter period, supplemental heat was supplied to the building with a small oil heater for one short period of about five days. This was due to an extreme cold period which occurred when the birds were only a few days old. However, only five-gallons of kerosene were used during this period.

The lighting system was the same as the Solar House. Fourteen hours of light were supplied by a combination of sunlight and incandescent lighting. The artificial lighting was controlled in the same manner as that of the Solar House. That is, time clock settings were such that the incandescent lights came on at 6:00 a.m. and off at 9:00 a.m. and also came on at 4:00 p.m. and off at 8:00 p.m.

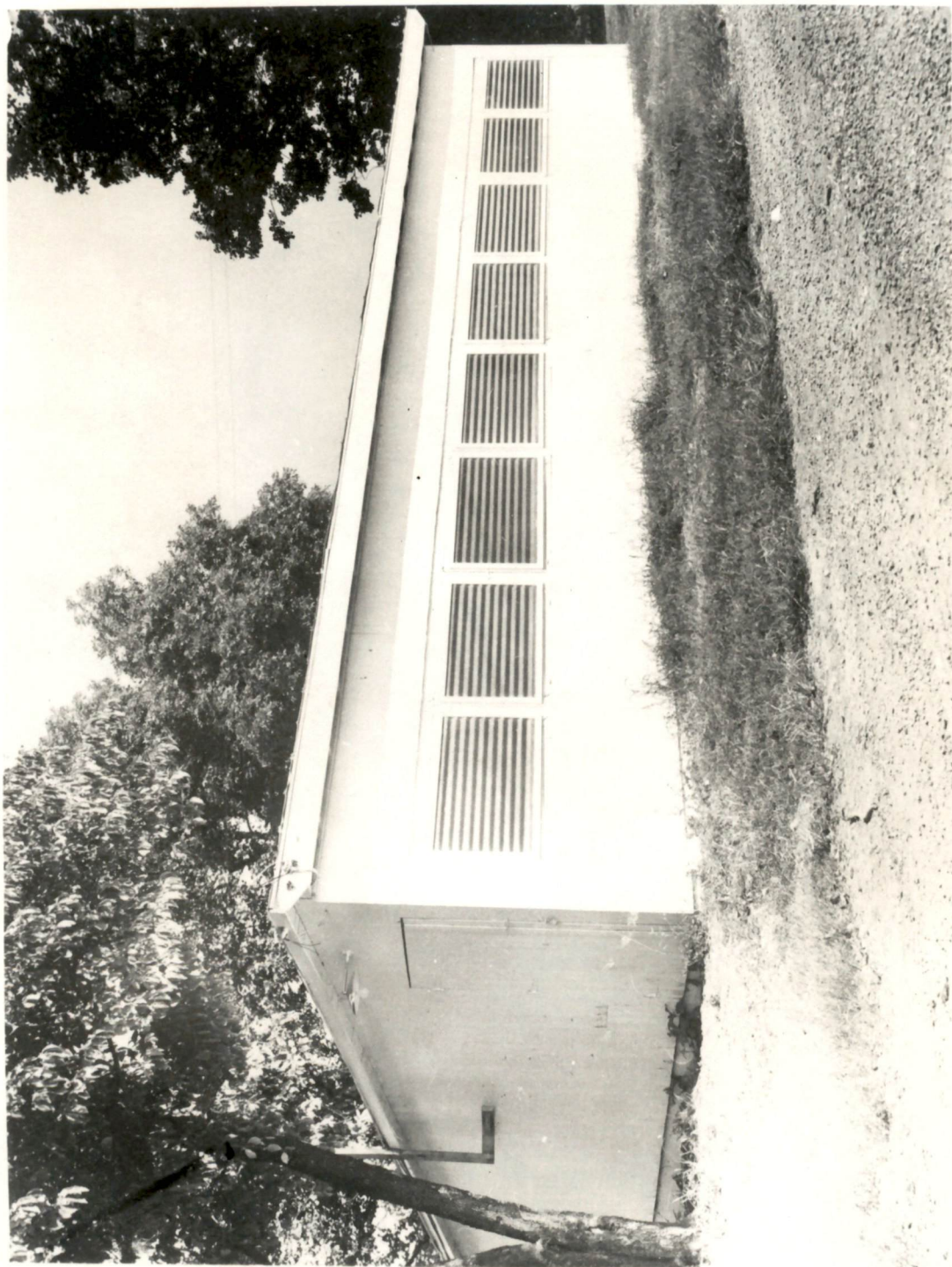


Figure 10. Front view of the Conventional House.

The ventilation of the Conventional House was by natural ventilation only. During the late spring, summer, and early fall, the windows in the front and the small windows in the back were removed to provide natural air-movement through the houses. During the winter months, ammonia fumes were somewhat bothersome due to inadequate ventilation of the closed building.

The broilers and the management of the houses. The broilers for this research were furnished by the University of Tennessee Poultry Department. The growing period during each season for each group of broilers in the three types of houses was nine weeks. The broilers were always placed in each house on the same day, and after nine weeks removed on the same day. The poultry department staff was responsible for the feeding of the broilers and the management of the houses. The birds in each house were fed the same rations, and the water was supplied with automatic watering cups. The management of the broilers included such things as debeaking chicks, setting brooder thermostats, supplying feed, cleaning houses at the end of the nine-weeks period, supplying fresh litter, and other routine matters. The author of this thesis was responsible only for the instrumentation involved in determining the temperature and humidity conditions of the respective houses.

Methods of Obtaining Data

The equipment used. For obtaining a continuous record of wet-bulb and dry-bulb temperatures one needs a sensing element that would require the least calibration and attention. After careful analysis of literature

on various temperature and humidity sensing elements, it was decided to use thermocouples for two reasons: First, the calibration of thermocouples remain fixed indefinitely; second, the wet-bulb thermocouple requires less ventilation and uses less water than any other type of wet-bulb sensing element of equal ruggedness (14).

After deciding to use thermocouples, the next step was to secure a recording potentiometer to be used in conjunction with the thermocouples for obtaining temperature readings. A Leeds and Northrup six-point recording potentiometer (Figure 11) and a Brown twelve-point recording potentiometer (Figure 12) were available for use. By using these two instruments, it was possible to have two dry-bulb and two wet-bulb thermocouples inside each house and one wet-bulb and one dry-bulb thermocouple outside each house. These two potentiometers were placed in the instrument house and lead wires run from there to the respective locations of the thermocouples.

The Brown recorder was used to record the inside and outside temperatures of the Solar and Conventional Houses. The thermocouples for this instrument were made of size twenty-four copper wire and size twenty-four constantan wire. Both wires were insulated with a thermoplastic cover. The lead wires from the thermocouples were size sixteen copper wire and size sixteen constantan wire insulated with thermoplastic. The lead wires were suspended from mounting poles which were placed at selected locations. Figure 13 shows the terminal board for the Brown recorder.

The Leeds and Northrup recorder was used to record the inside and outside temperatures of the Windowless House. The thermocouples for this

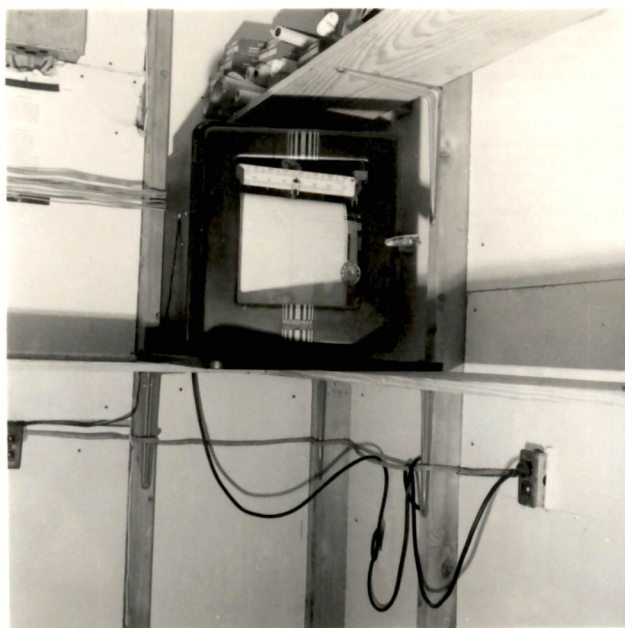


Figure 11. Front view of the Leeds and Northrup recording potentiometer.

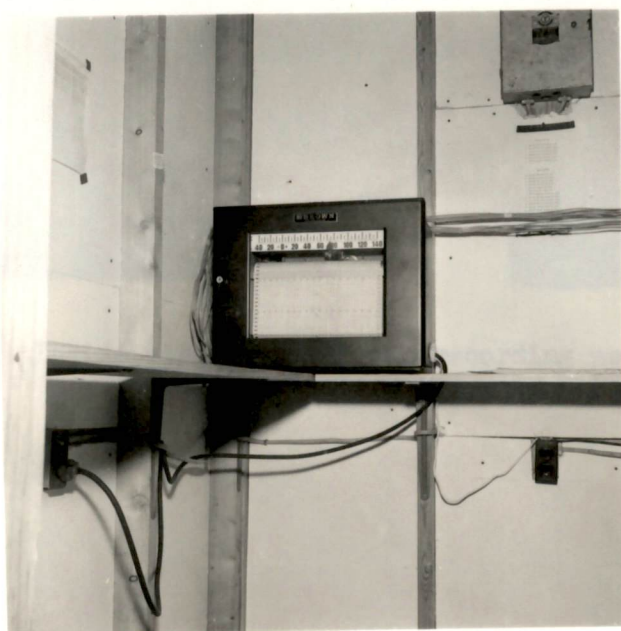


Figure 12. Front view of the Brown recording potentiometer.



Figure 13. Inside view of the Brown recording potentiometer.

machine were made of enamel covered size sixteen iron and constantan wires. The lead wires were made of the same type wire as the thermocouples. Since the lead wires were not weatherproof, they were mounted on the wall and ceiling surfaces of the Windowless House, and extended through a conduit into the instrument house which was located nearby (Figure 6). The terminal board of the Leeds and Northrup is similar to that of the Brown recorder.

To obtain a correct wet-bulb temperature, it is necessary to have air moving across the wet-bulb thermocouple. As the moisture from the wet-bulb evaporates, the air surrounding the sensing element becomes more humid, causing the rate of evaporation to decrease and the indicated wet-bulb temperature to rise (6).

Normally during the evaporation process, the temperature decreases. However, when the air in a small space is not removed, its humidity rises as the evaporation continues. This increase in humidity causes an increase in the wet-bulb temperature. Therefore, in order to measure the correct wet-bulb temperature, a continuous movement of air must pass around the wet-bulb thermocouple. Experimental tests prove that 1000 feet per minute air velocity is sufficient for accurate wet-bulb temperature readings (6). An electric fan with a rated capacity of eighty cubic feet per minute through a two inch diameter opening was used. When the intake opening was reduced to one and one-half inches the air velocity through the intake was 3000 feet per minute which is adequate for correct wet-bulb readings. The air velocity of the intake was measured by a Hasting Air-Meter.

The fan unit used to mount the thermocouples may be seen in Figure 14. The basic item for this unit was a Redmond squirrel cage type fan.



Figure 14. The fan unit used to obtain the air velocity across the thermocouples (note how the plastic pipe is fastened to the fan housing).

To obtain a proper air velocity a one and one-half inch intake had to be installed. An eight inch section of one and one-half inch diameter plastic pipe was chosen for this intake. The piece of plastic pipe was fitted to a five inch diameter brass plate which was fastened to the fan. Between the fan and the brass plate was placed a one-fourth inch thick cork gasket to limit conduction of heat from the fan motor. The pipe elbow was used to prevent direct radiation of the fan motor from striking the thermocouples. The thermocouples were mounted so that they would project into the intake airstream. The dry-bulb thermocouple (Figure 14 and 15) was placed at the end of the intake pipe and the wet-bulb thermocouple was inserted through a hole one inch from the end of the intake pipe. The wick completely covered the end of the wet-bulb thermocouple and extended directly below the opening in the intake to a plastic cup which served as a water reservoir. The wicks were replaced whenever they became covered with dust.

Due to dusty conditions inside the house, the air passing over the thermocouples had to be filtered. To accomplish this, the author constructed a fourteen inch by twenty-one inch by ten and one-half inch plywood box and placed the fan unit inside the box. The fan was bolted to the side of the box with the intake opening located inside the box and the exhaust opening extending to the outside (Figures 14 and 15). This was done in order to prevent the heat of the motor from affecting the thermocouples. The filtering system was obtained by placing "Fiberglas" filters in one end and one side of the box instead of plywood panels. These filters may be seen in Figures 14 and 15. A thin woven cotton cloth with seventy-two meshes was placed on the outside of the "Fiberglas"



Figure 15. A view of the fan unit showing how the thermocouples were mounted (note wet-bulb wick and container for water).

filters (Figure 16). This system was quite effective in filtering the dust from the intake air. Comparison of temperatures as obtained simultaneously by thermocouple readings and psychrometer readings were made at random. This was done to determine if the dust collected on the outside of the cloth or other factors were affecting the thermocouple readings. The comparison of thermocouple and psychrometer readings is given in Table I. The differences between the readings were minor and were probably due to the inability to read the thermometer precisely.

The two filter boxes containing the fan units were placed in the houses ten feet from each end. The boxes were fastened to the studding of the dividing partitions of the pens, approximately three feet above the floor level (Figure 16). They were placed at this height mainly to prevent the birds from damaging the filters. However, this location also gave a good representative temperature of the houses. The author occasionally checked temperatures near the floor, three feet above the floor, and near the roof to see if a temperature gradient existed. There was never any detectable difference in either wet-bulb or dry-bulb temperature at the three levels. The fan units and filter boxes were fastened to the outside of the houses as shown in Figures 17 and 18. The boxes were made as shown to prevent water from entering. Note in Figure 18 the opening in the bottom of the shelter allowing the air to be drawn up and through the "Fiberglas" filters. When in operation, the lid of the filter box is closed leaving only the "Fiberglas" filter as an air intake. The previously described method of filtering the air of dust was very effective for this experiment.

During the winter, the outside wet-bulb reservoirs and wicks were



Figure 16. A view of the fan unit filter box mounted inside the house (note the cloth used for filtering purposes).

TABLE I
THERMOCOUPLE TEMPERATURE READINGS COMPARED
WITH PSYCHROMETER TEMPERATURE READINGS

Date	Temperature Readings *																	
	Outside House						Solar House						Windowless House					
	Thermocouple Psychrometer						Thermocouple Psychrometer						Thermocouple Psychrometer					
	Dry Bulb	Wet Bulb	Dry Bulb	Wet Bulb	Dry Bulb	Wet Bulb	Dry Bulb	Wet Bulb	Dry Bulb	Wet Bulb	Dry Bulb	Wet Bulb	Dry Bulb	Wet Bulb	Dry Bulb	Wet Bulb	Dry Bulb	Wet Bulb
10-28-58	60	49	60	49	73	60	71	58	74	63	73	61	66	56	67	54		
12-2-58	45	41	45	41	65	56	65	55	65	57	65	56	51	45	51	45		
1-13-59	58	52	58	52	75	65	74	64	70	60	69	59	68	63	67	61		
1-27-59	46	45	47	46	72	63	72	62	68	61	68	60	52	48	52	48		
3-18-59	40	33	41	33	83	62	82	62	63	53	63	52	57	47	58	47		
4-7-59	71	59	72	59	83	70	82	69	78	68	77	67	77	63	77	62		
5-27-59	74	65	74	65	80	69	80	68	80	72	80	72	74	65	74	65		
6-26-59	90	77	89	76	92	80	91	79	89	79	89	78	91	78	90	76		
7-24-59	84	77	83	76	88	81	86	80	86	78	85	78	85	79	84	78		

*The temperature readings are in degrees Fahrenheit and were taken at random during the four periods of broiler growth.

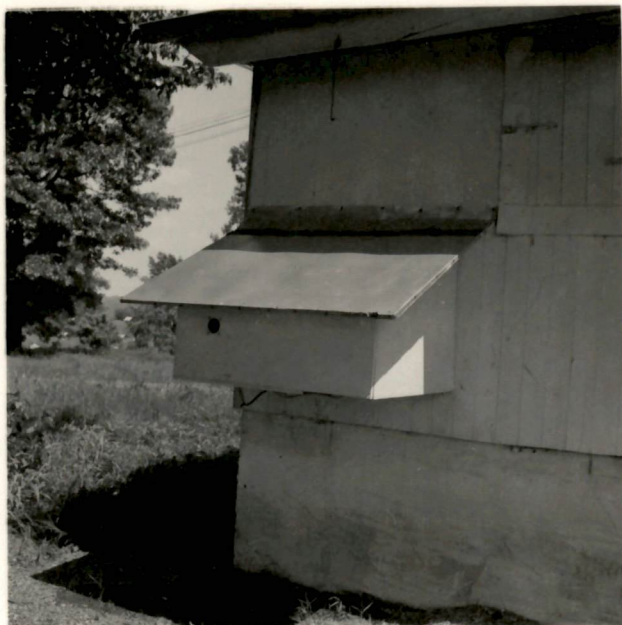


Figure 17. View of outside installation of filter box with cover closed.



Figure 18. View of outside installation of filter box with cover open.

frozen frequently. To check the wet-bulb readings, a Friez Hygro-Thermograph (Figure 19) was installed in the filter box outside the Windowless House. This hygro-thermograph was calibrated for low temperatures. The wet-bulb temperature was then determined by use of a psychrometric chart. This method of determining the wet-bulb temperature was relatively accurate (19). There was no difference in wet bulb temperatures determined by the thermocouples or the hygro-thermograph and psychrometric charts.

Method of recording and data obtained. The temperature readings were recorded by the potentiometer on strips of chart paper designed for the particular machine. Samples of the chart paper used may be found in appendix A. The thermocouples were identified by the numbers printed on the chart. Each number referred to a thermocouple at the respective locations.

The length of the charts for the two potentiometers totaled over 6,000 feet for the four periods. Therefore, for convenience of analysis the author extracted from the charts the data that was necessary. This data was tabulated on forms designed for this experiment. Samples of these forms are shown in appendix B. Explanations will be given in the next chapter as to why the data was tabulated in this manner.

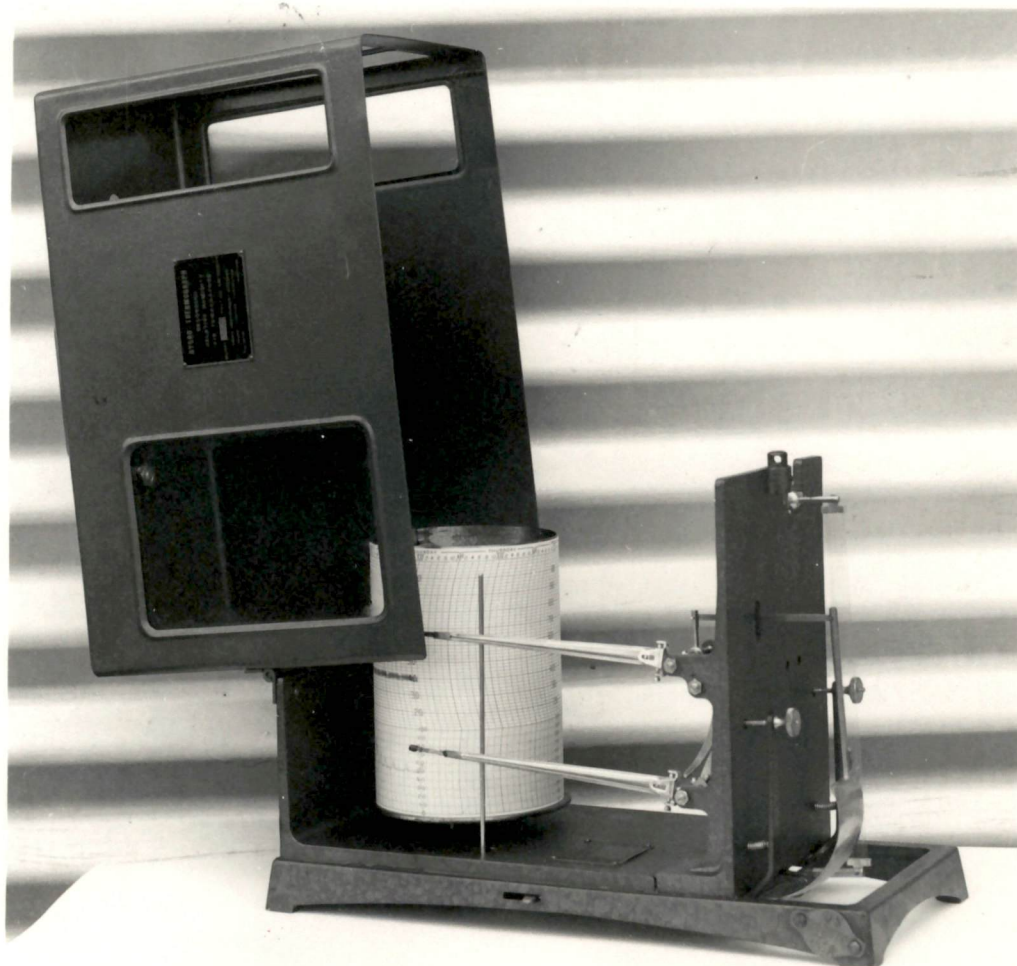


Figure 19. View of Friez Hygro-Thermograph.

CHAPTER III

PRESENTATION AND DISCUSSION OF DATA

The maximum and minimum temperatures of the houses were recorded on forms similar to those found in appendix B. The temperature readings were then plotted on graphs to give a visual comparison of the temperatures inside and outside the houses. These graphs of maximum and minimum temperatures would not only show the comparison among the houses; but, also the seasonal fluctuation of temperatures during the nine-week period. Generally speaking, the outside and inside maximum dry-bulb temperature occurs at 6:00 p.m., and the minimum temperature occurred at 6:00 a.m. during the day. Also, the wet-bulb maximum and minimum temperatures generally occurred at the same respective time as the maximum and minimum dry-bulb temperatures. Of course, there are a few exceptions to this statement. The author found no difference in the temperature pattern of the Solar House and the temperature pattern outside except that the Solar House minimum temperature did not drop as low as the outside minimum temperature. However, due to the different construction of the houses, there was a time lag of the temperature peak in the Windowless House. This is because of the lower rate of solar heat transmission through the insulated wall of the Windowless House (2). This time lag may be clearly seen on the weekly graphs of each experiment. However as stated previously, the maximum and minimum temperatures will be plotted at the same time for all three houses.

To clearly show the daily fluctuations of dry-bulb and wet-bulb temperatures, a one week period of temperatures were plotted by the hour. The week chosen for these temperature readings was the fifth week of broiler

growth. The reason for choosing this week was because it was the middle week of the nine-week period and perhaps would give the most representative sample. During the one week period, a bright sunny day and a relatively cloudy day appeared at least once. These graphs then gave some indication of what kind of temperature one could expect to find in similar houses on a cloudy day or a sunny day. Generally speaking, the temperatures on a cloudy day did not fluctuate in magnitude as much as the temperatures on a sunny day.

The discussion of the data is presented according to the periods of broiler growth. The discussions and graphs of wet-bulb and dry-bulb temperatures of each experiment will be found later in this chapter. Both the discussions and comparisons of the four experiments are given.

Since these experiments were very much alike, the discussions, graphs, and comparisons of each experiment will be somewhat repetitious.

Experiment I - Fall 1958

This period of broiler growth was for the dates of September 3, 1958 to November 4, 1958. Daily records of dry-bulb and wet-bulb temperatures were kept for this period.

The maximum and minimum temperatures of each house was plotted along with the outside maximum and minimum dry-bulb and wet-bulb temperatures. The maximum or minimum temperature for a particular day can be determined from the graphs very easily. However, intermediate temperatures during the day cannot be determined. If all the temperature curves were plotted on one graph, it would be rather confusing and difficult to interpret. There-

fore, the data of each house was placed on separate graphs. The outside maximum and minimum dry-bulb and wet-bulb temperatures were the same for all three houses; therefore, each graph has a common comparison namely the outside temperatures. This, in turn, gives a comparison among the houses.

Conventional House. Figure 20 shows the maximum and minimum dry-bulb and wet-bulb temperatures of the inside and outside the Conventional House. Note that the difference between the maximum and minimum curves is the daily fluctuation of temperatures. The fluctuation of the curves gives the seasonal change of the temperatures. As would be expected the inside temperatures of the Conventional House followed the same general pattern as the outside temperature. However, the inside temperatures were generally 6° to 10° higher than the outside temperatures.

The wet-bulb maximum and minimum curves were closer together than the dry-bulb curves. As the dry-bulb temperatures increase the relative humidity decreases; therefore, the wet-bulb temperatures do not increase simultaneously with the dry-bulb temperatures. The humidity of the inside of the house tends to follow the same general pattern as the outside. Also, as the difference between the maximum and minimum wet-bulb temperature decreases, the total heat content of the house tends to become constant. Throughout the rest of this thesis the term total heat refers to the heat in the air plus the heat of vaporization of water vapor (1).

Solar House. Figure 21 shows the maximum and minimum dry-bulb and wet-bulb temperatures of the inside and outside the Solar House. The inside maximum curve follows the same general pattern as the outside; but it is 6° to 10° F. greater in magnitude than the outside maximum curve.

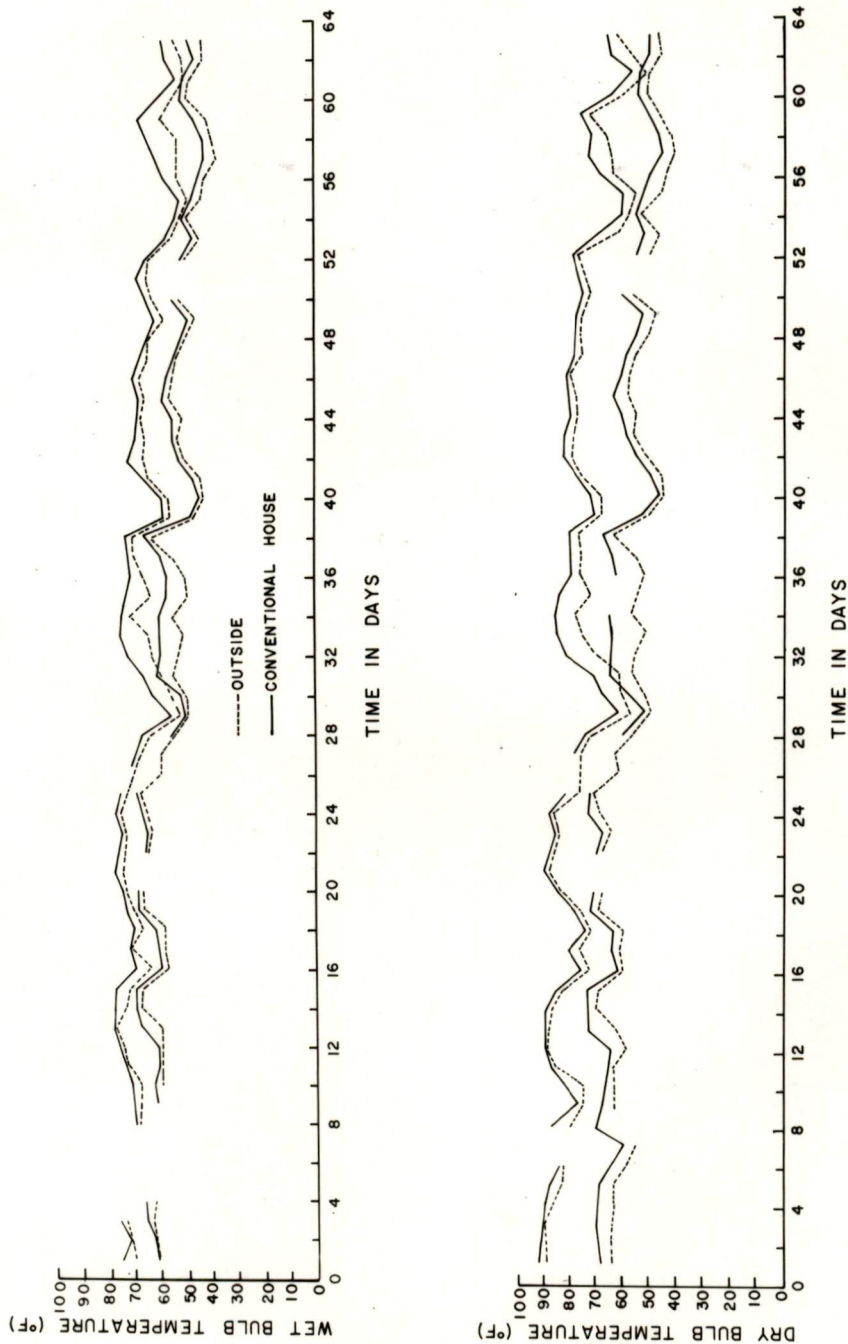


Figure 20. Maximum and minimum dry-bulb and wet-bulb temperatures for the inside and outside condition of the Conventional House during the nine-week period of 9-3-58 to 11-4-58.

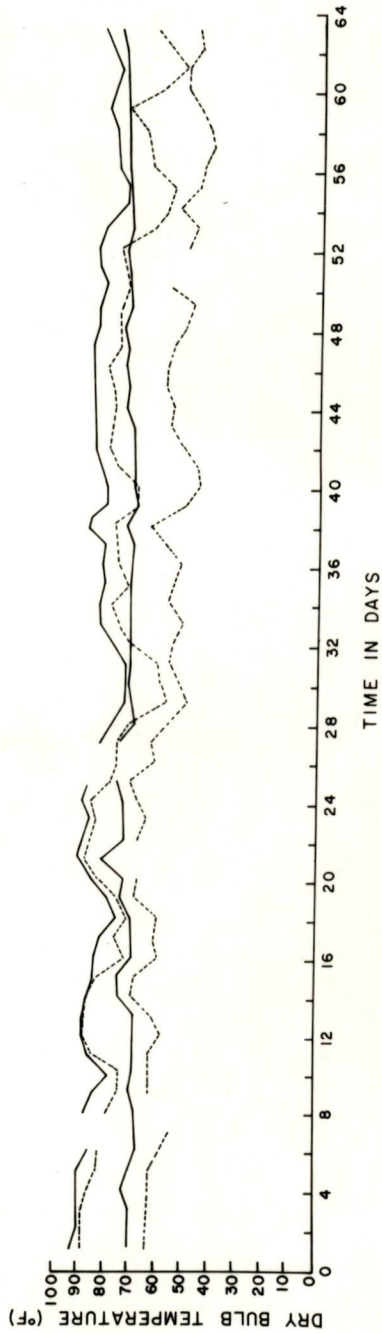
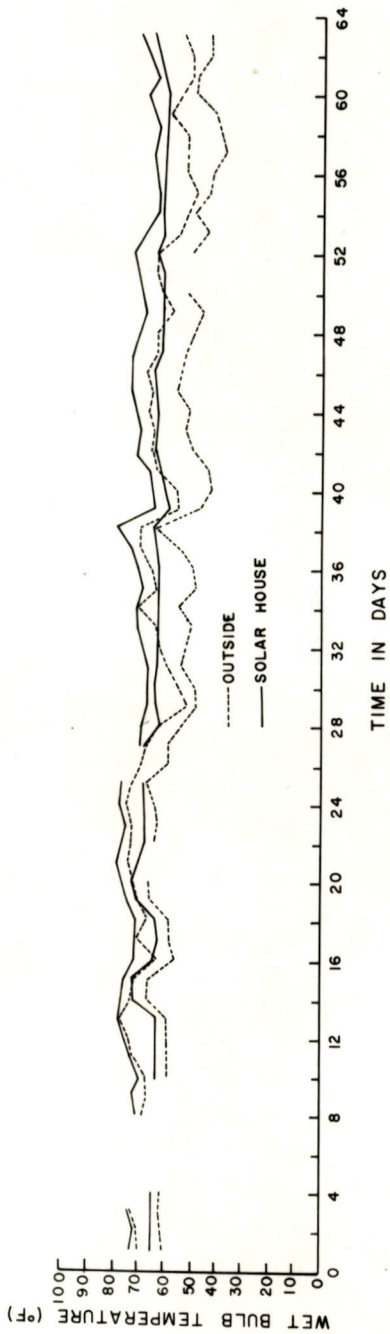


Figure 21. Maximum and minimum dry-bulb and wet-bulb temperatures for the inside and outside condition of the Solar House during the nine-week period of 9-3-58 to 11-4-58.

The inside minimum curve tends to "flatten out" showing a more constant minimum temperature. The daily fluctuation of temperatures were somewhat less than that of the Conventional House. The reason for this is the heat gain during the day and the small amount of heat loss during the night through the "Thermopane" windows. Also in the Solar House, the total heat content tends to be more constant than in the Conventional House. The humidity of the Solar House is less than that of the Conventional House.

Windowless House. Figure 22 shows the maximum and minimum dry-bulb and wet-bulb temperatures inside and outside the Windowless House. The temperatures inside the Windowless House did not follow the general pattern of the outside conditions but formed a pattern of its own. The maximum and minimum temperatures, of course, occurred at (approximately) the same time as the other houses. However, the difference between the maximum and minimum temperatures was much less than that of the other houses; and the daily fluctuation of temperatures was the least. The temperatures in the Windowless House were more constant throughout the nine-week period. Also, the total heat content of the house varied less than the heat content of the other two houses. The humidity inside the Windowless House was relatively constant.

Comparison of Solar, Windowless, and Conventional Houses. Figure 23 clearly shows the daily fluctuations of dry-bulb and wet-bulb temperatures inside all three houses and outside the houses. Notice the Conventional House temperature pattern tends to follow the outside temperature pattern. The Solar House temperatures follow the outside pattern somewhat, but they do not reach as low a minimum temperature as the outside. The Windowless House temperatures are practically constant throughout the day. Note the

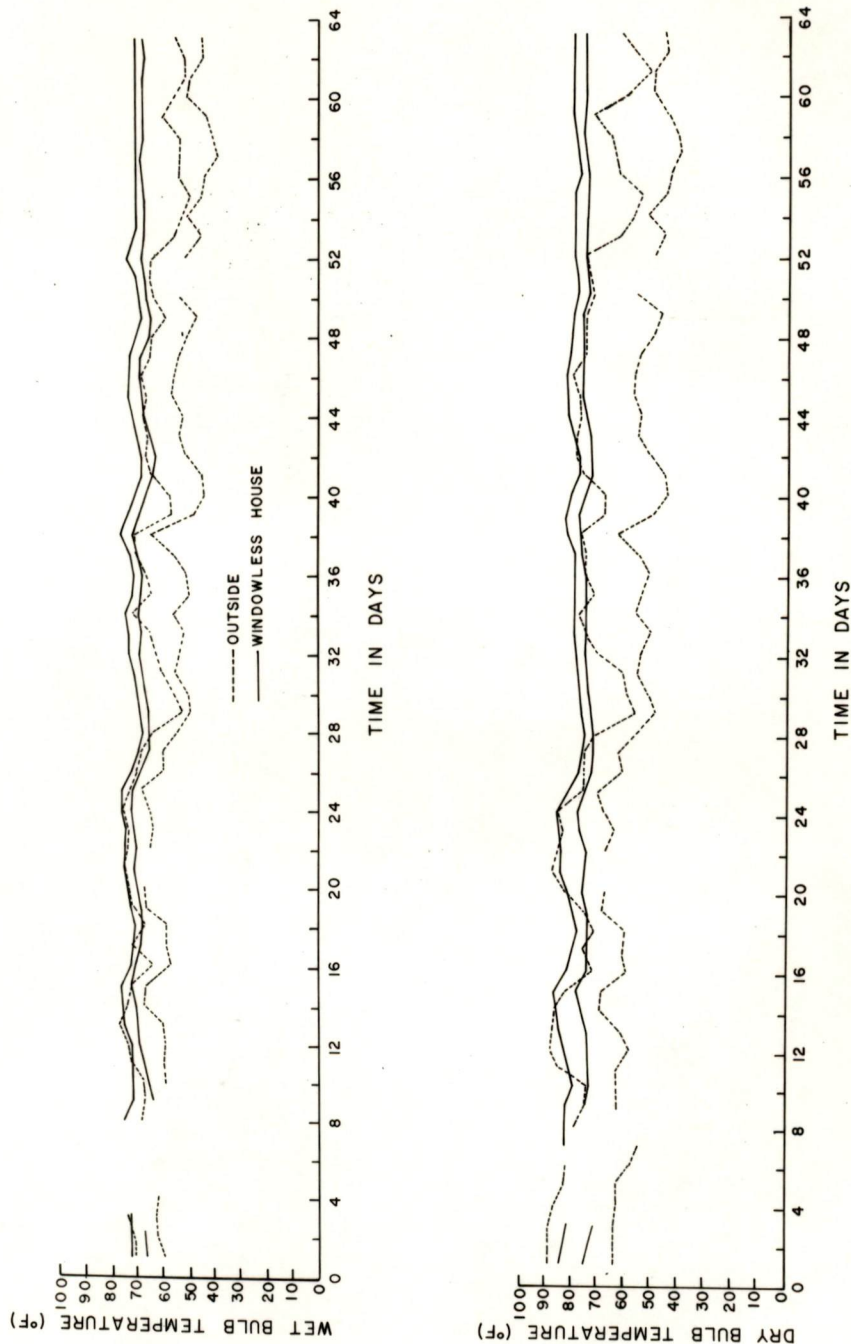


Figure 22. Maximum and minimum dry-bulb and wet-bulb temperatures for the inside and outside condition of the Windowless House during the nine-week period of 9-3-58 to 11-4-58.

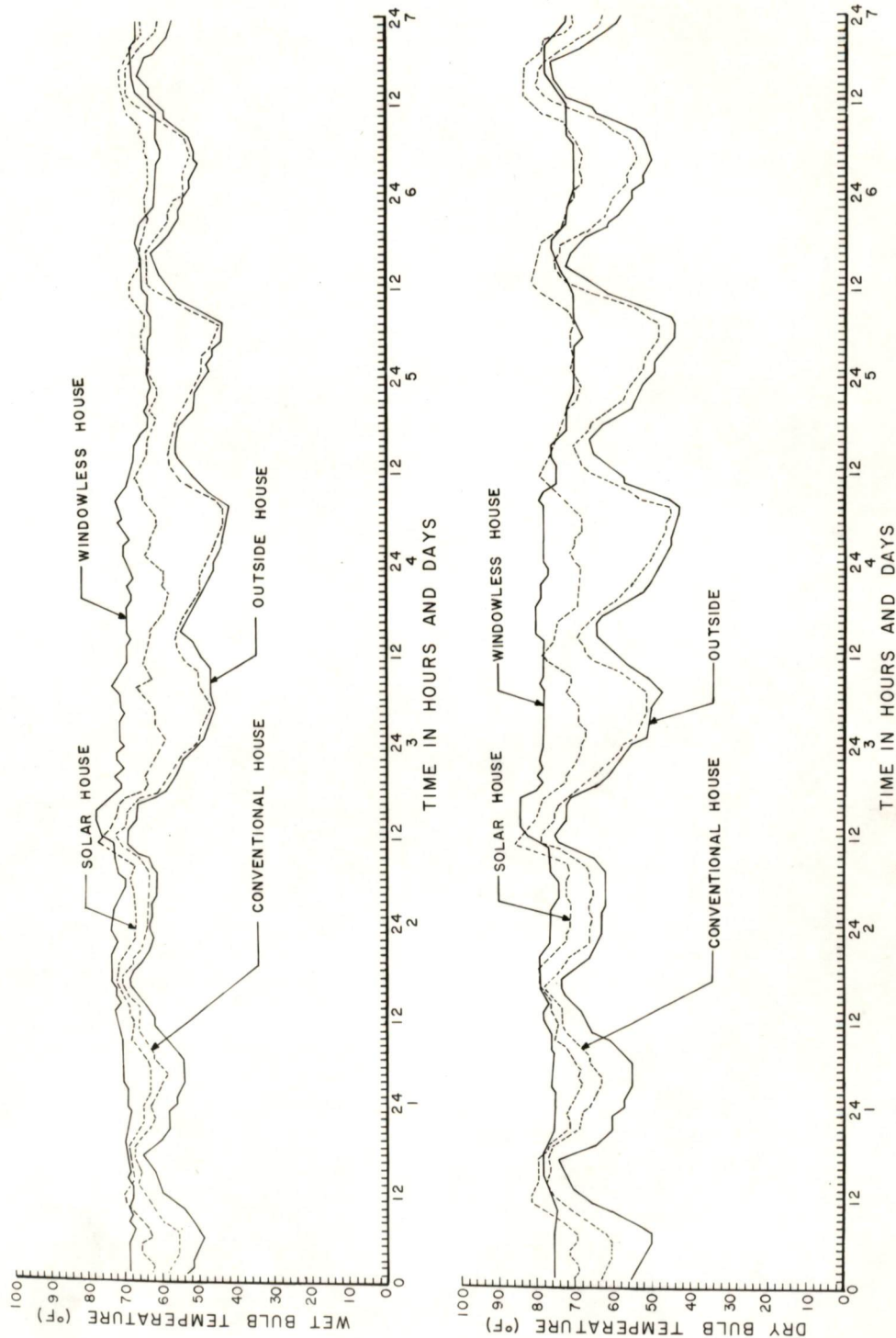


Figure 23. Dry-bulb and wet-bulb temperatures for the inside and outside conditions of the Solar, Windowless, and Conventional Houses during the week of 10-8-58 to 10-15-58.

difference in the pattern of the second and third days from that of the fifty and sixth days. The second and third days were relatively cloudy days; but the fifty and sixth days were bright sunny days (18). The temperatures on the cloudy days did not fluctuate as much as the temperatures on the sunny days.

The dry-bulb temperatures of the inside and outside the three houses during the Fall period are shown in Table II. The mean temperatures of the three houses are approximately equal. But the difference between the maximum and minimum temperatures of the Windowless House was considerably less than that of the other two houses.

The humidity pattern of the Conventional House was like that of the outside; but the humidity inside the Solar House was generally less than the outside. The Windowless House humidity tended to be the most constant throughout this period as indicated by Figure 23.

During this nine-week period, there was no significant difference in the average bird gain in the Conventional or Windowless House (15). However, the Solar House bird gain was significantly less than the bird gain of the other two houses. This significance is based on the 95 per cent level unless indicated otherwise.

Experiment II - Winter 1958-59

This period of broiler growth was for the dates of December 3, 1958 to February 3, 1959. Daily records of wet-bulb and dry-bulb temperatures were kept similar to that of the fall period 1958.

Conventional House. Figure 24 shows the maximum and minimum dry-

TABLE II

DRY-BULB TEMPERATURES DURING EXPERIMENT I

	Temperature Readings*			
	Outside	Conventional House	Windowless House	Solar House
Maximum	89	92	85	93
Minimum	42	46	73	66
Mean	70	75	75	78

*The temperature readings are in degrees Fahrenheit.

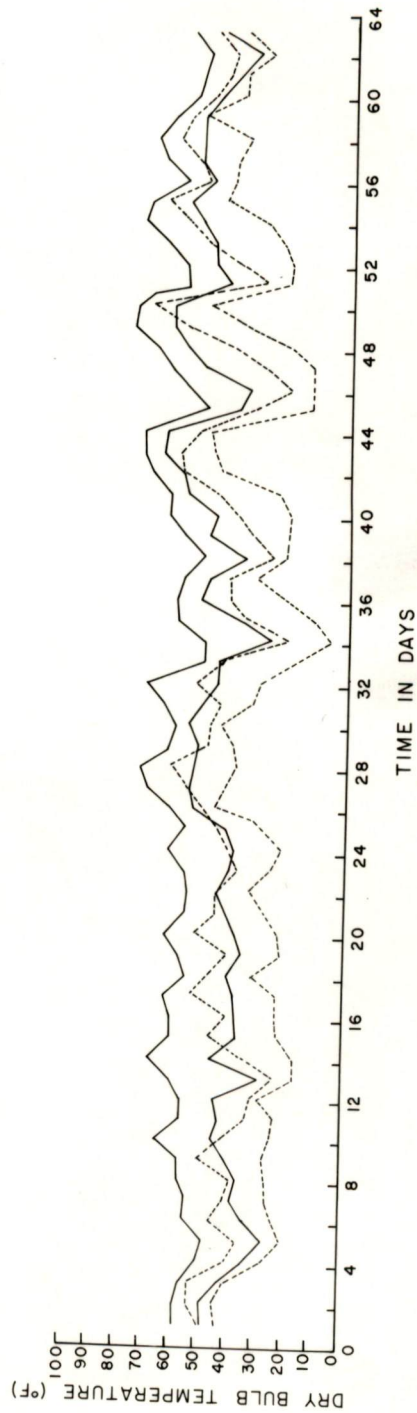
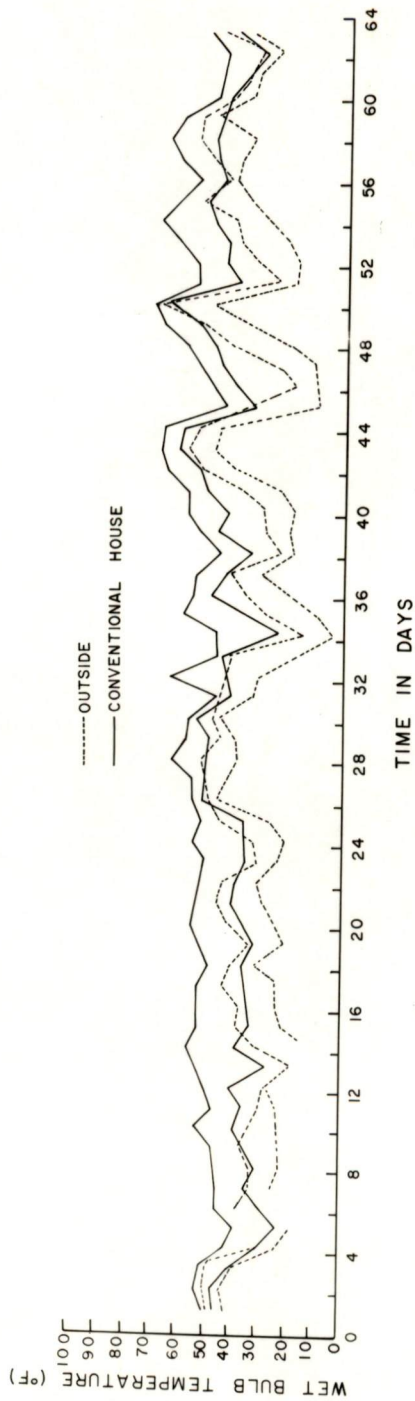


Figure 24. Maximum and minimum dry-bulb and wet-bulb temperatures for the inside and outside condition of the Conventional House during the nine-week period of 12-3-58 to 2-3-59.

bulb and wet-bulb temperatures of the inside and outside conditions of the Conventional House. The inside temperatures of the Conventional House fluctuate like that of the outside; however, the temperatures are of a higher magnitude. Observe the rapid changes in the daily maximum and minimum temperatures. During this period of growth the outside temperature dropped 35° F. in an eight hour interval on the seventeenth day. The humidity conditions inside the house were very much like those outside.

Solar House. Figure 25 shows the maximum and minimum dry-bulb and wet-bulb temperatures of the inside and outside conditions of the Solar House. During this period of broiler growth, the inside temperatures of the Solar House tended to be more constant than the Conventional House from day to day. However, the daily fluctuations were still somewhat noticeable. The inside temperatures of the Solar House were affected by the outside temperatures, but not nearly as much as the Conventional House. The humidity inside the Solar House tended to be more constant and of a smaller magnitude than the humidity inside the Conventional House.

Windowless House. Figure 26 shows the maximum and minimum dry-bulb and wet-bulb temperature of the inside and outside conditions of the Windowless House. As can be seen, the temperatures of the Windowless House were relatively constant throughout this period. There was less fluctuation in both seasonal and daily temperatures in the Windowless House than inside the Solar House and Conventional House. The inside temperatures of the Windowless House tended to be the least affected by the outside temperatures. The humidity of the house was relatively constant.

Comparison of Solar, Windowless and Conventional Houses. Figure 27 shows the daily fluctuation of the dry-bulb and wet-bulb temperatures inside

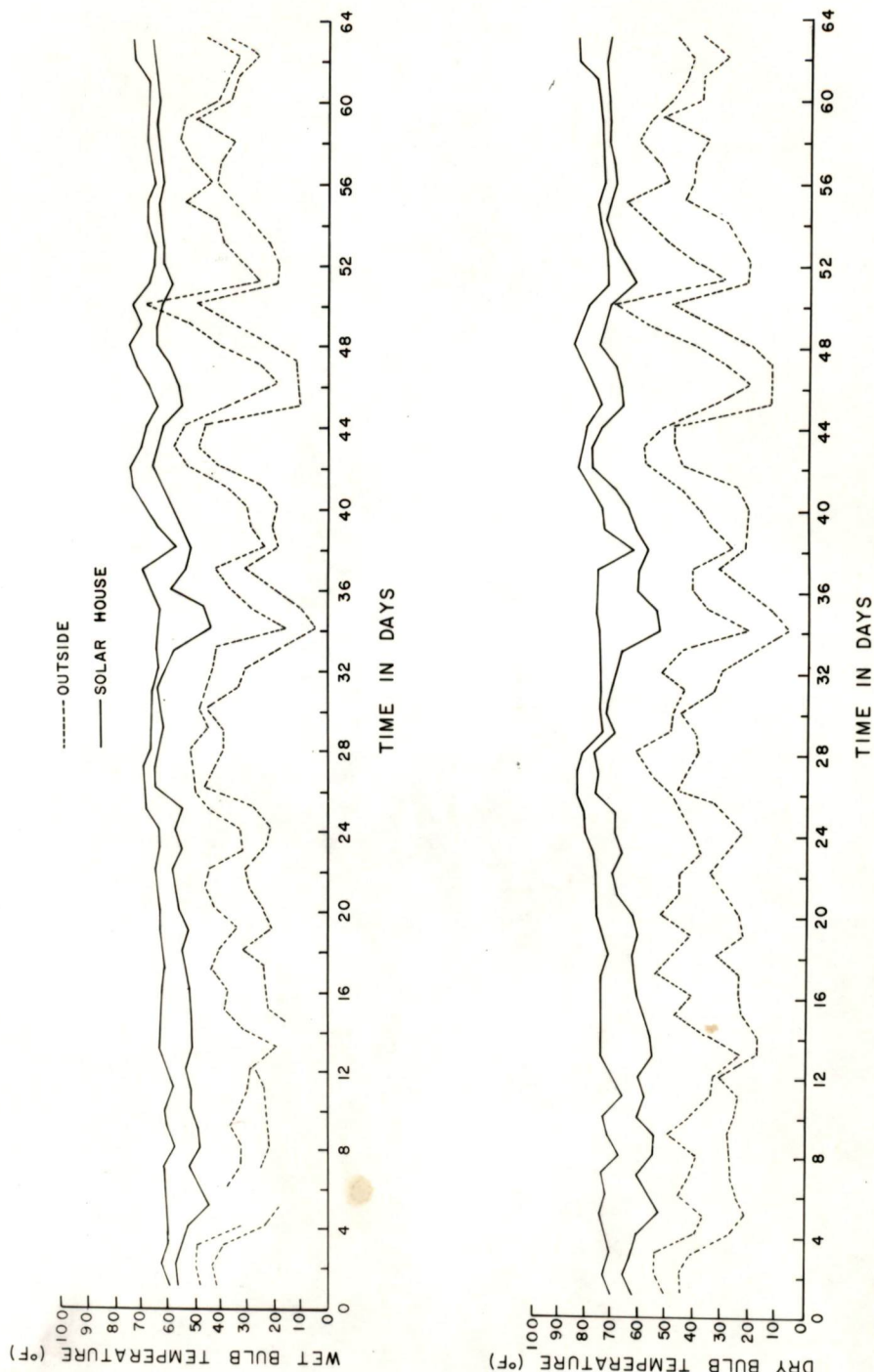


Figure 25. Maximum and minimum dry-bulb and wet-bulb temperatures for the inside and outside condition of the Solar House during the nine-week period of 12-3-58 to 2-3-59.

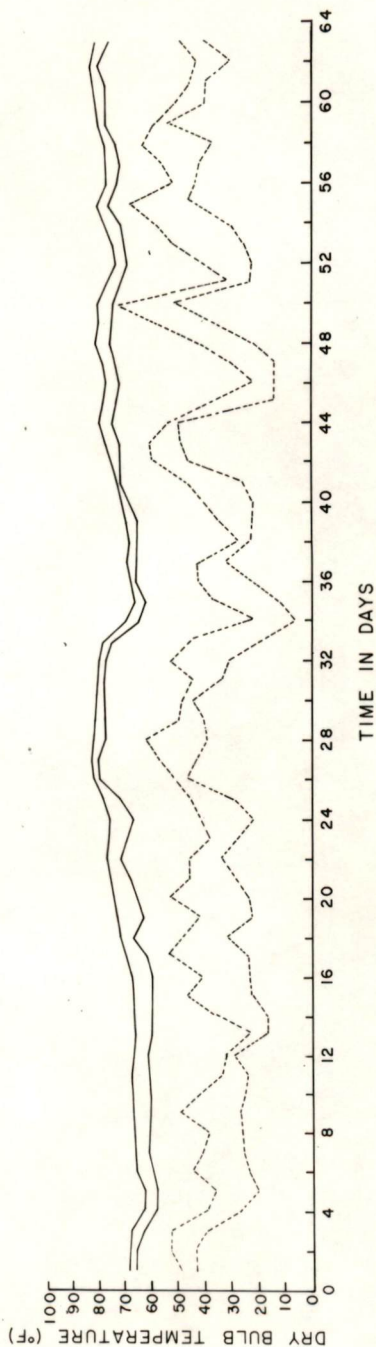
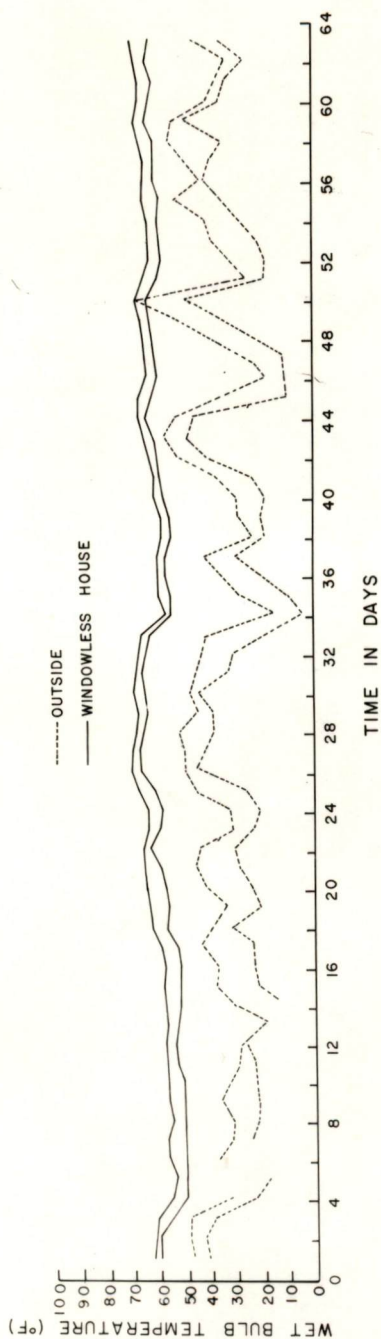


Figure 26. Maximum and minimum dry-bulb and wet-bulb temperatures for the inside and outside condition of the Windowless House during the nine-week period of 12-3-58 to 2-3-59.

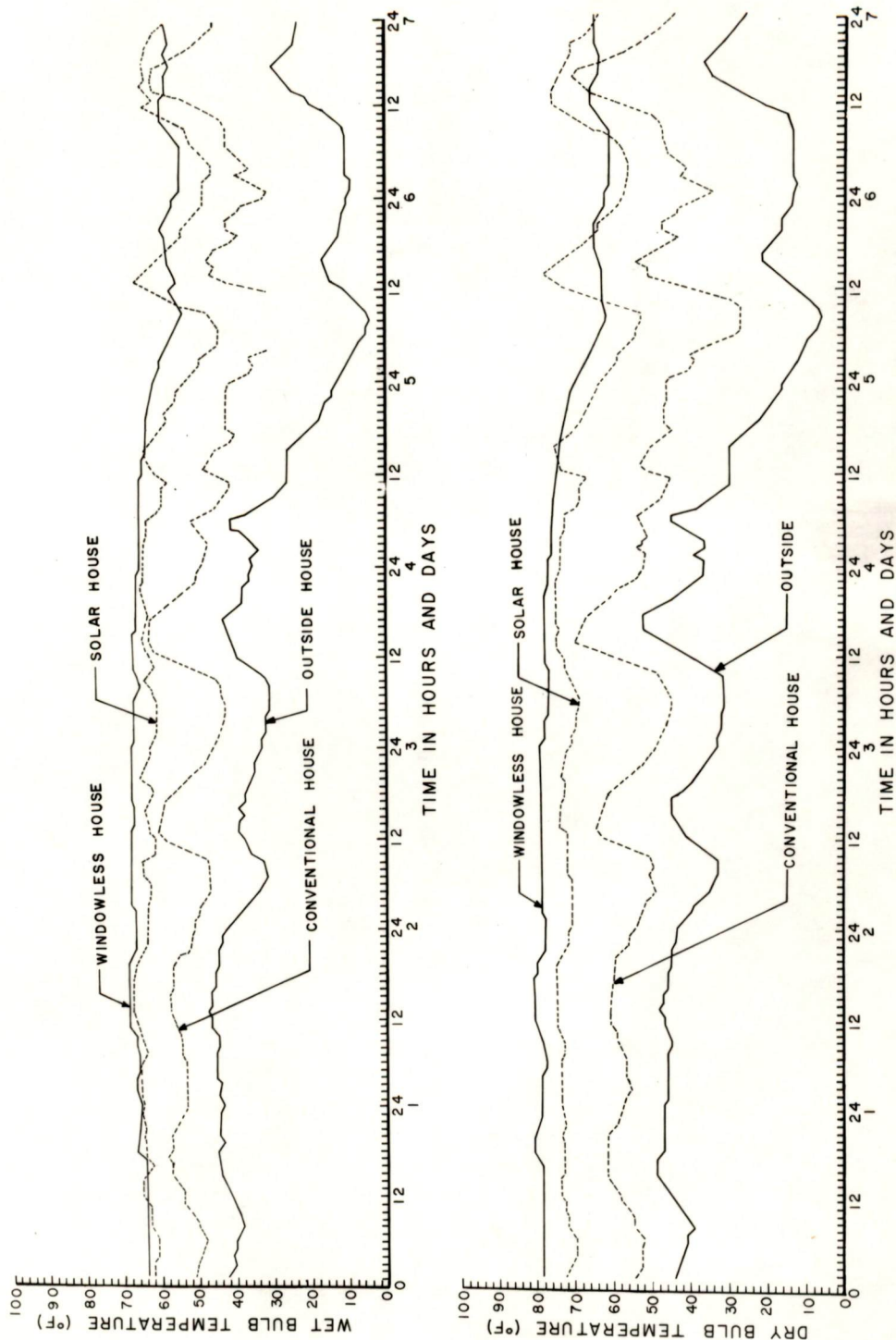


Figure 27. Dry-bulb and wet-bulb temperatures for the inside and outside conditions of the Solar, Windowless and Conventional Houses during the week of 12-31-58 to 1-6-59.

and outside the houses. The Conventional House and Solar House temperatures tend to follow the outside pattern of the temperatures, but they are of a higher magnitude. The temperatures of the Windowless House are practically constant; that is, they do not fluctuate like the outside temperatures. Notice how the temperatures are different on the fifth and sixth days. These two days are an exception to the general statement that the maximum temperature occurred about 6:00 p.m. and the minimum temperature about 6:00 a.m. This occurred during the extreme cold wave in this region.

The first day during this weekly period had no sunshine; whereas, the seventh day had 100 per cent of the possible sunshine (18). Notice that the first day temperatures are more constant than the sixth day temperatures.

The inside and outside dry-bulb temperatures of the houses during the winter period are shown in Table III. During this period, the mean temperatures of the Windowless House and the Solar House were approximately equal. But the mean temperature of the Conventional House was much less than that of the other two houses.

The humidity conditions of the Conventional House were very similar to the outside conditions; but the humidity of the Solar House was considerably less than the Conventional House. The humidity of the Windowless House for this period was relatively constant.

During this nine-week period, there was no significant difference between the bird gain of the Windowless House and the Conventional House (15). However, as in Experiment I, the Solar House bird gain was significantly less than the bird gain of the other two houses.

TABLE III

DRY-BULB TEMPERATURES DURING EXPERIMENT II

	Temperature Readings*			
	Outside	Conventional House	Windowless House	Solar House
Maximum	71	80	82	88
Minimum	5	27	58	52
Mean	36	52	72	70

*The temperature readings are in degrees Fahrenheit.

Experiment III - Spring 1959

This period of broiler growth was for the dates of March 10, 1959 to May 12, 1959. Daily records of temperatures were kept similar to the other two experiments.

Conventional House. Figure 28 shows the maximum and minimum dry-bulb and wet-bulb temperatures of the inside and outside conditions of the Conventional House. The inside temperatures of the Conventional House followed a pattern similar to outside temperatures. The daily and seasonal fluctuations of the temperatures were the same magnitude inside as they were outside the house. The inside temperatures were on the average 6° to 10° F. higher than that outside. As in the previous experiments, the humidity conditions inside the Conventional House were similar to the outside conditions.

Solar House. Figure 29 shows the maximum and minimum dry-bulb and wet-bulb temperatures of the inside and outside conditions of the Solar House. The maximum temperatures of the inside followed the same pattern as the outside conditions, but at a higher magnitude. However the minimum temperatures of the inside did not fluctuate like that of the outside. The daily fluctuation of the Solar House during this period was less than the fluctuation of the Conventional House. This apparently was due to the insulation and "Thermopane" window effects. The humidity of the Solar House tended to be more constant but somewhat less than the humidity of the Conventional House.

Windowless House. Figure 30 shows the maximum and minimum dry-bulb and wet-bulb temperatures of the inside and outside conditions of the

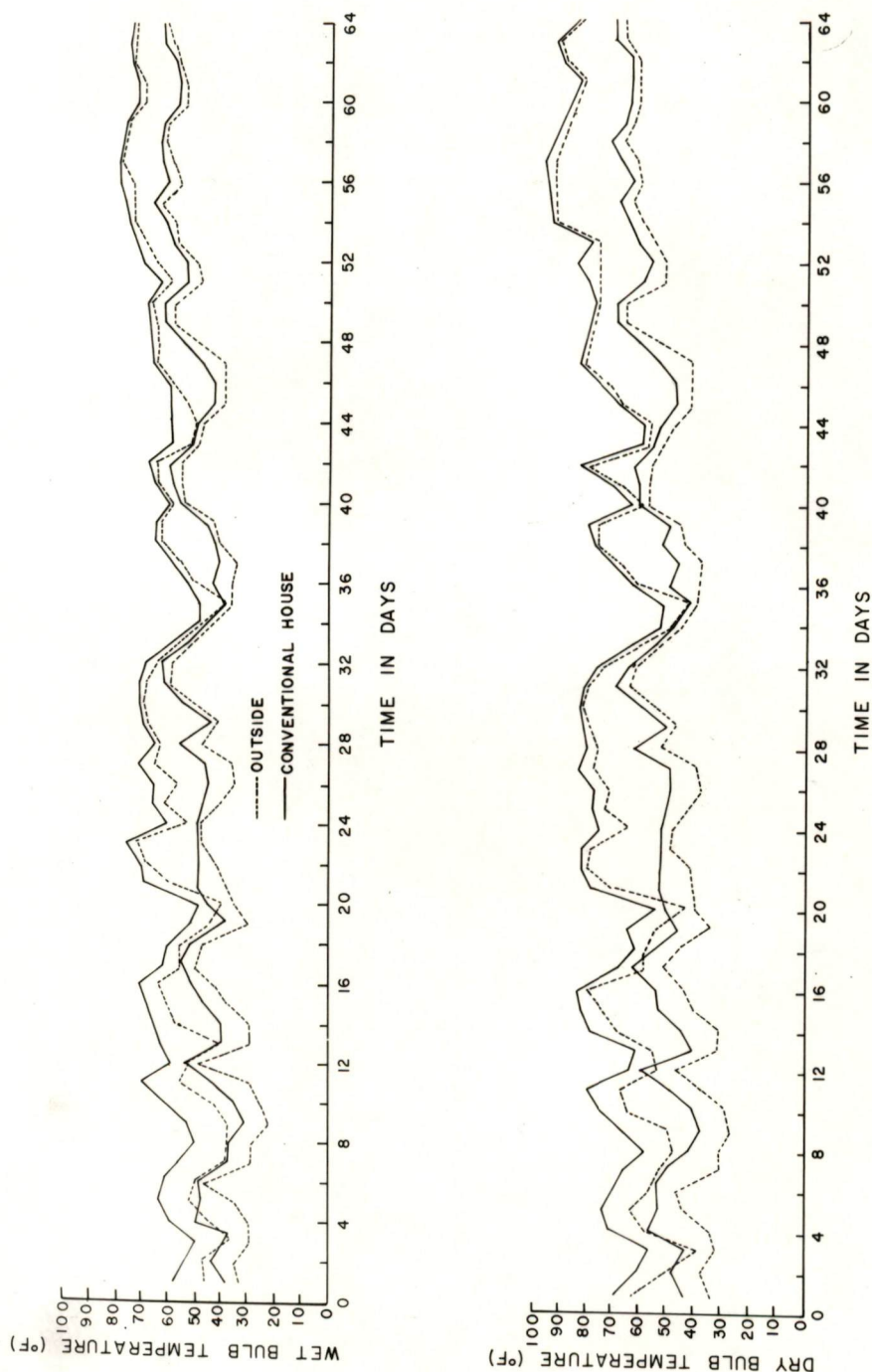


Figure 28. Maximum and minimum dry-bulb and wet-bulb temperatures for the inside and outside condition of the Conventional House during the nine-week period of 3-10-59 to 5-12-59.

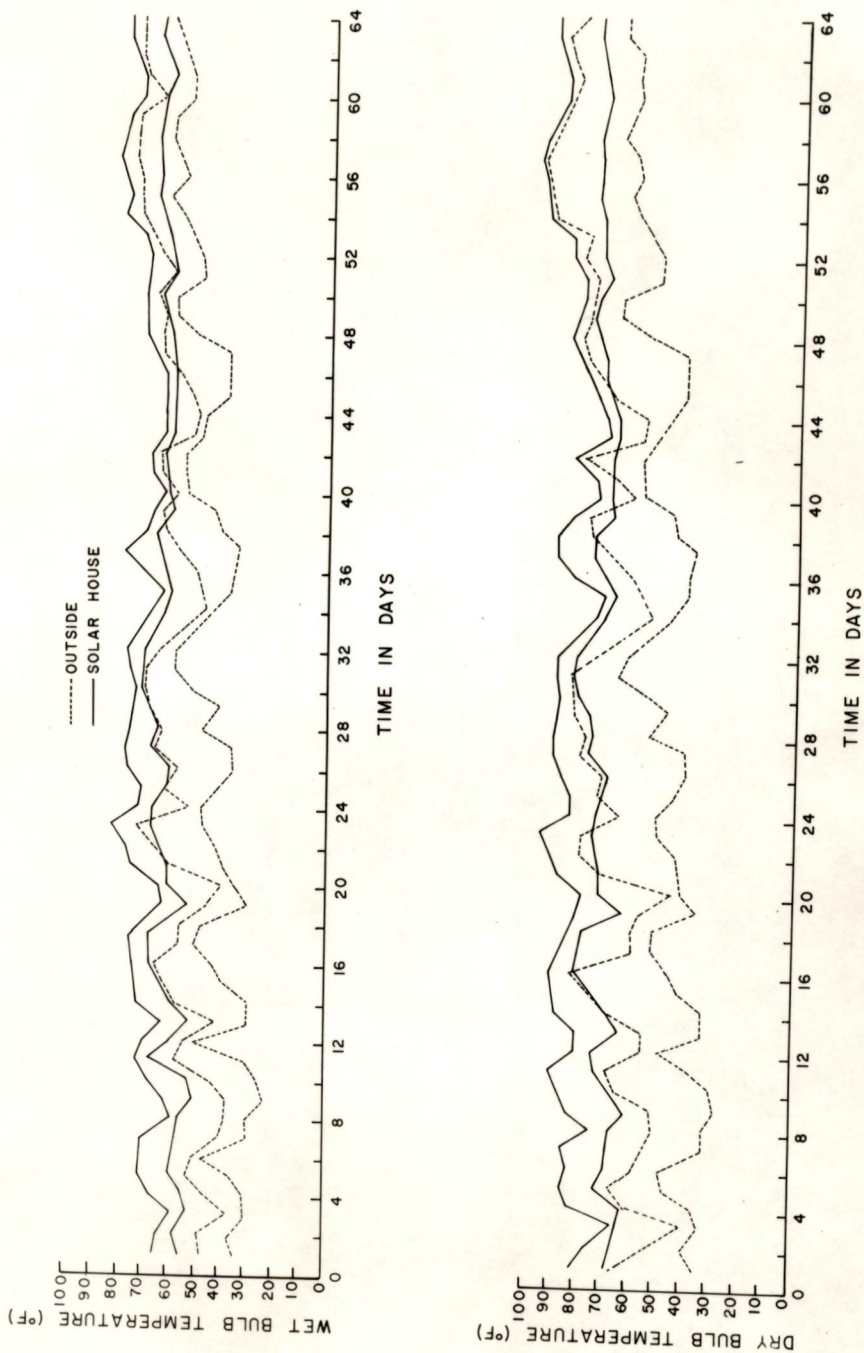


Figure 29. Maximum and minimum dry-bulb and wet-bulb temperatures for the inside and outside condition of the Solar House during the nine-week period of 3-10-59 to 5-12-59.

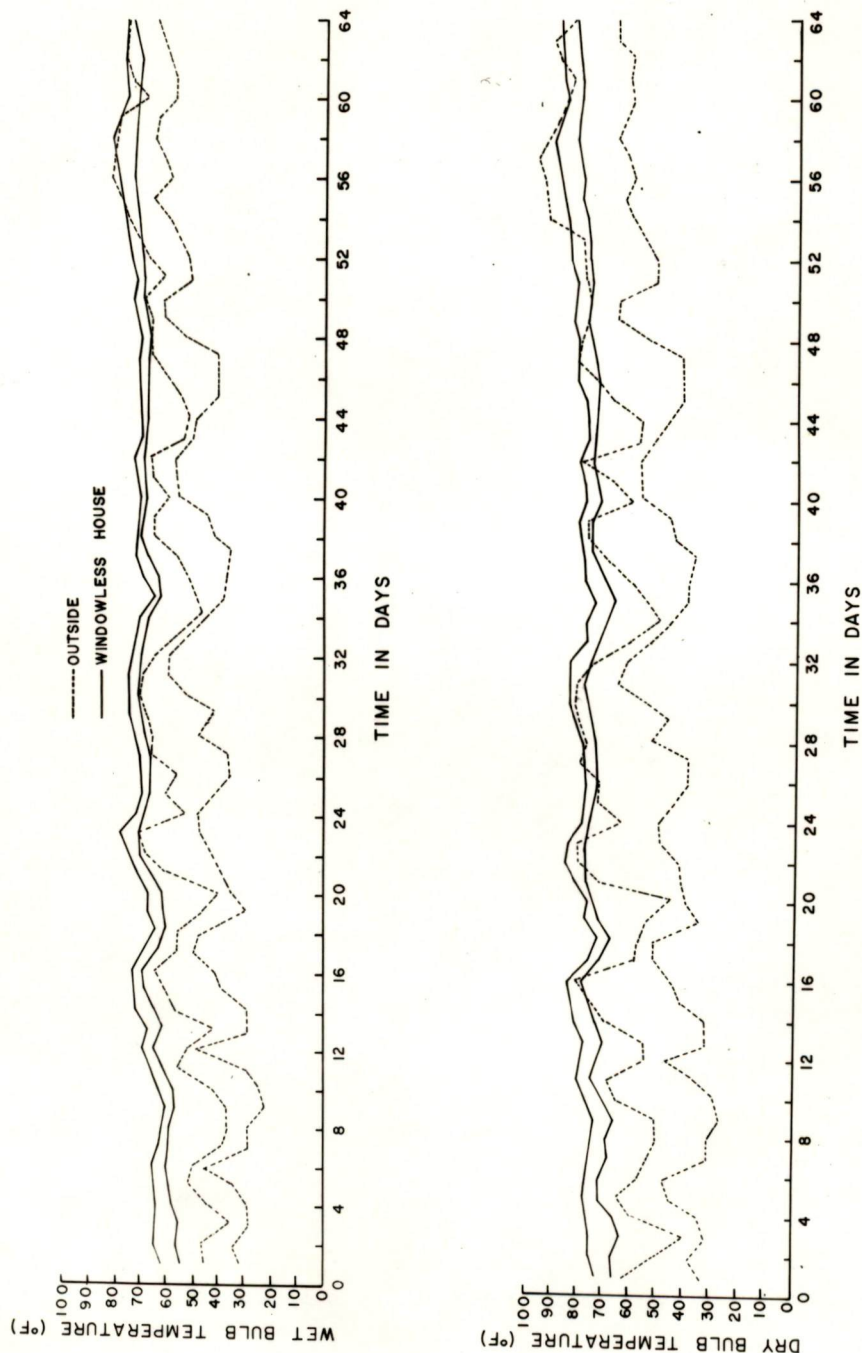


Figure 30. Maximum and minimum dry-bulb and wet-bulb temperatures for the inside and outside condition of the Windowless House during the nine-week period of 3-10-59 to 5-12-59.

Windowless House. The temperatures in the Windowless House were practically constant for this period of broiler growth. Both the daily and seasonal fluctuations of temperatures in the Windowless House were considerably less than those in the other two houses. The outside temperature seemed to have less effect on the inside temperatures of the Windowless House than the Solar House and Conventional House. The humidity was relatively constant for this nine-week period.

Comparison of Solar, Windowless and Conventional houses. Figure 31 shows the daily fluctuations of dry-bulb and wet-bulb temperatures inside and outside the houses plotted on an hourly basis. The temperature of the Conventional House follow the same pattern as the outside temperature. Also, the Solar House temperatures follow the outside pattern to some extent; but the temperatures do not range as low in magnitude as those of the Conventional House. Notice that the Windowless House temperatures fluctuate some but considerably less than the other two houses.

The first three days during this week's period were relatively sunny, but the last four days were mostly cloudy (18). The difference in the temperature pattern due to this is easily seen on the graph.

The dry-bulb temperatures of the inside and outside of the three houses during the Spring period are shown in Table IV. The mean temperature of the Windowless House was greater than the Conventional House and less than the Solar House. Also, the difference between the maximum and minimum temperatures of the Windowless House was less than the other two houses.

As in the previous experiments, the humidity of the Conventional House was similar to the outside humidity. The humidity of the Solar

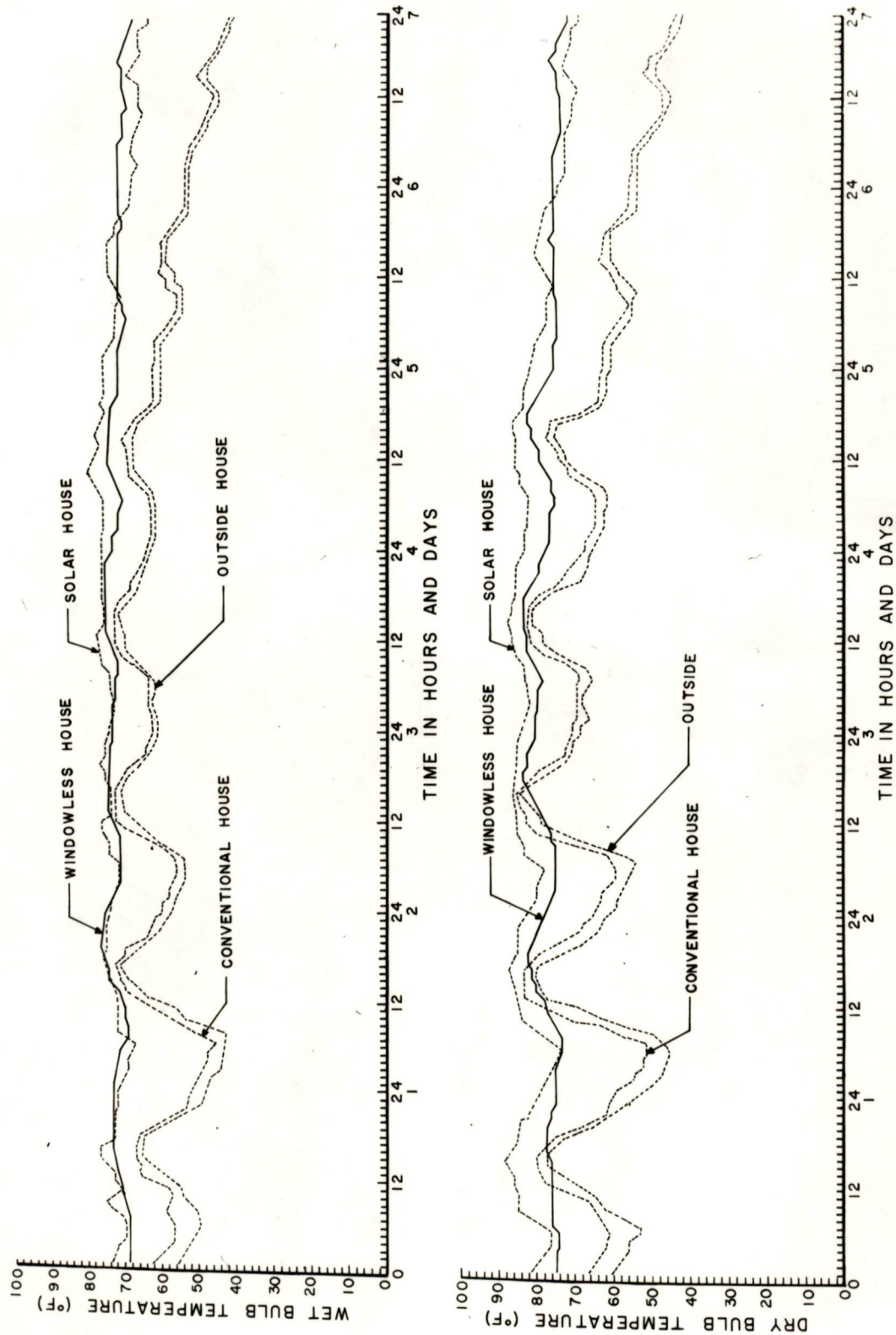


Figure 31. Dry-bulb and wet-bulb temperatures for the inside and outside conditions of the Solar, Windowless and Conventional Houses during the week of 4-6-59 to 4-13-59.

TABLE IV
 DRY-BULB TEMPERATURES DURING EXPERIMENT III

	Temperature Readings*			
	Outside	Conventional House	Windowless House	Solar House
Maximum	95	96	88	99
Minimum	27	38	64	61
Mean	60	68	75	80

*The temperature readings are in degrees Fahrenheit.

House in most cases was less than the Conventional House humidity. However, the humidity inside the Windowless House was nearly constant throughout this nine-week period.

During this nine-week period, there was no significant difference between the bird gain of the Solar House and the Windowless House (15). However, the Conventional House bird gain was significantly greater than the bird gain of the other two houses.

Experiment IV - Summer 1958-59

This period of broiler growth was for the dates of May 26, 1958 to July 26, 1959. Daily records were kept for this period like those of the other three experiments.

Conventional House. Figure 32 shows the maximum and minimum dry-bulb and wet-bulb temperature for the inside and outside conditions of the Conventional House. This experiment was conducted during the summer when the house had all the windows removed. As one would expect, and the graph shows, the temperatures inside the Conventional House were 2° to 4° F. above the temperature outside the house. The temperature patterns inside and outside the house were identical. The humidity inside the house was very much like the humidity outside the house.

Solar House. Figure 33 shows the maximum and minimum dry-bulb and wet-bulb temperatures for the inside and outside conditions of the Solar House. The maximum temperatures inside the house were 2° to 4° F. above the outside of the house, but the temperature patterns were identical. However, as shown in previous graphs of the Solar House, the minimum inside

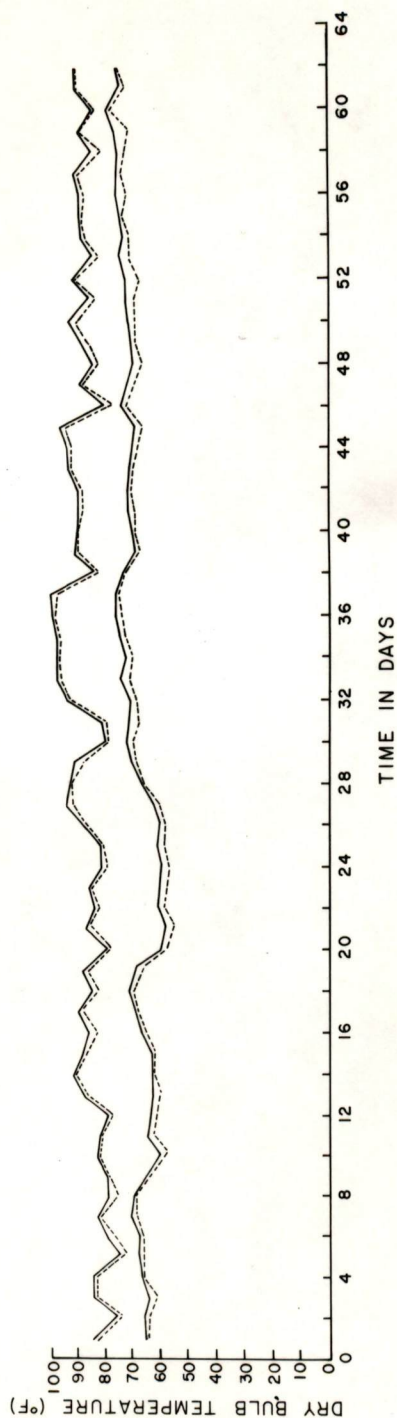
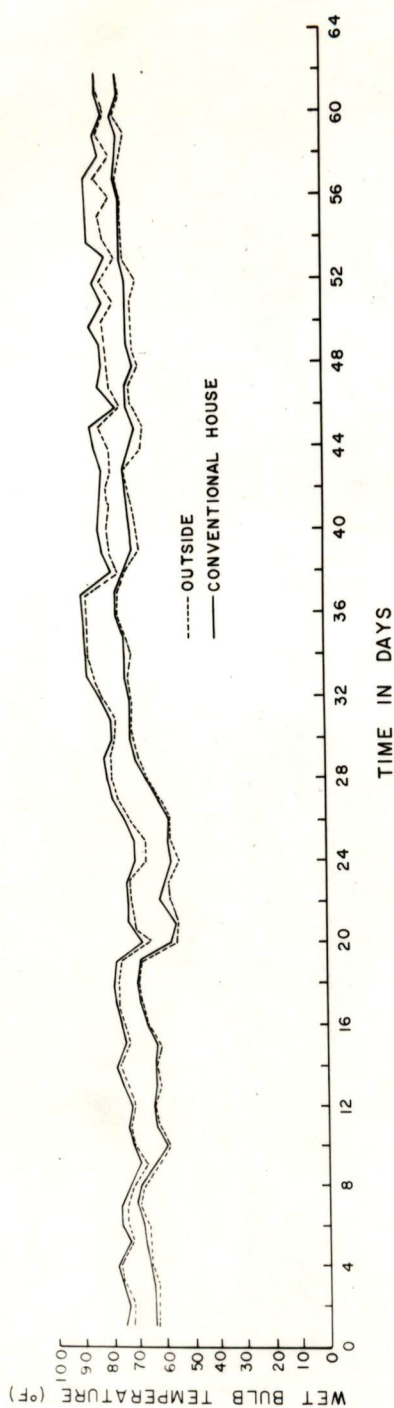


Figure 32. Maximum and minimum dry-bulb and wet-bulb temperatures for the inside and outside condition of the Conventional House during the nine-week period of 5-26-59 to 7-26-59.

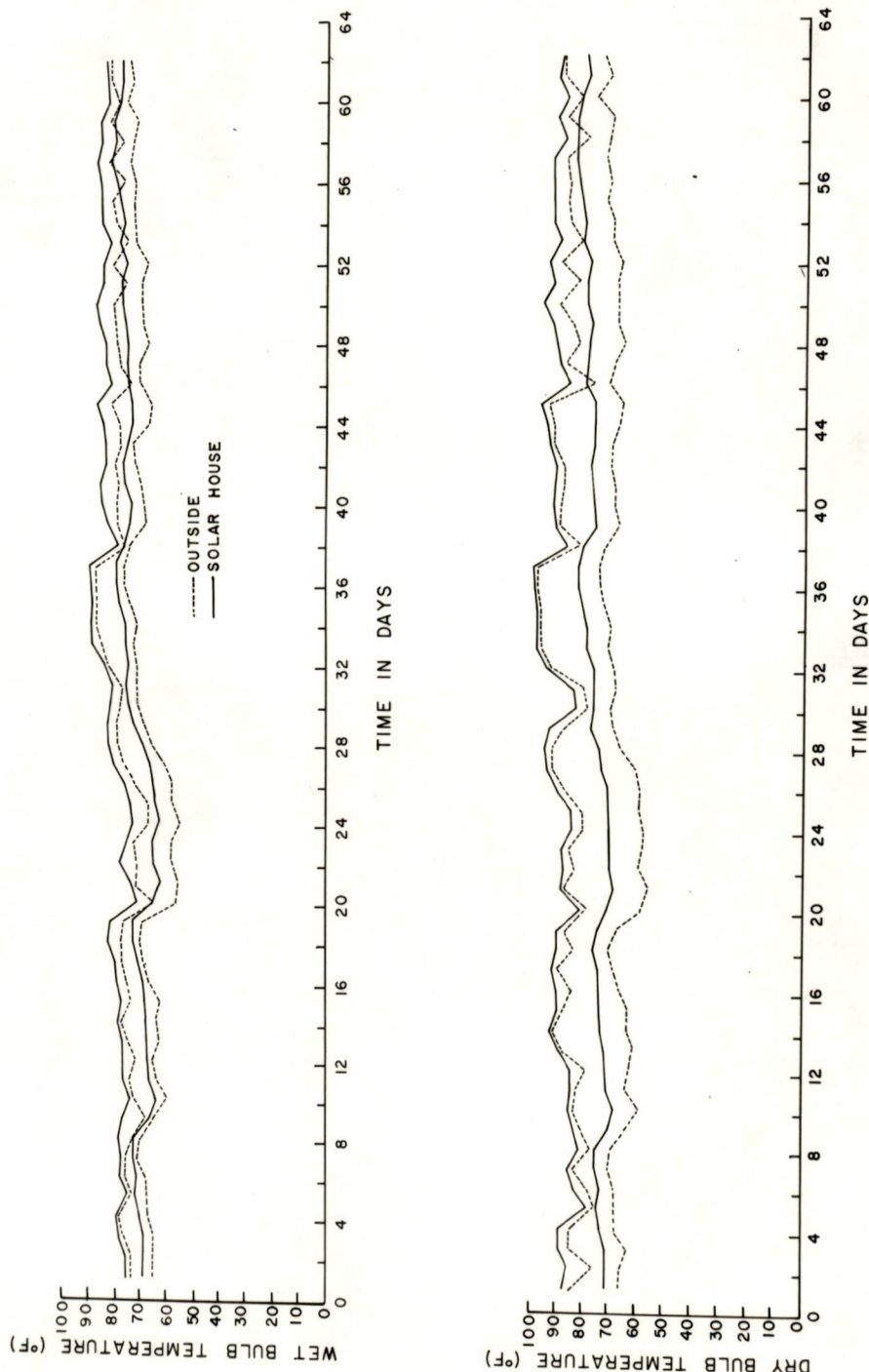


Figure 33. Maximum and minimum dry-bulb and wet-bulb temperatures for the inside and outside condition of the Solar House during the nine-week period of 5-26-59 to 7-26-59.

temperature tended to be higher than the minimum outside temperature. This means that there is less daily fluctuation inside the Solar House than inside the Conventional House. Likewise, the humidity did not fluctuate as much as the Conventional House.

Windowless House. Figure 34 shows the maximum and minimum dry-bulb and wet-bulb temperatures of the Windowless House. As the previous experiments have shown, the temperatures inside the Windowless House have shown less fluctuation than the Solar and Conventional houses. The temperatures inside the house for this nine-week period were practically constant. Even though the outside temperatures ranged rather high during the day and comparatively low at night, the inside temperatures showed little variation throughout this experiment.

Comparison of Solar, Windowless and Conventional houses. Figure 35 shows the daily fluctuation of dry-bulb and wet-bulb temperatures of all houses for a one-week period. Notice that the Conventional House and Solar House temperatures follow the same general pattern as the outside temperatures. But the Windowless House temperatures stay relatively constant.

Notice the difference in the temperature patterns of the first, fourth, fifth, sixth, and seventh days from the second and third days. The second and third days received practically no sun whereas the other days received nearly all sunshine possible throughout the day (18).

The dry-bulb temperatures during the summer period of the inside and outside of the three houses are shown in Table V. During this period, the mean temperatures of the Solar House and the Windowless House were approximately equal. But the mean temperature of the Conventional House was less than the other two houses.

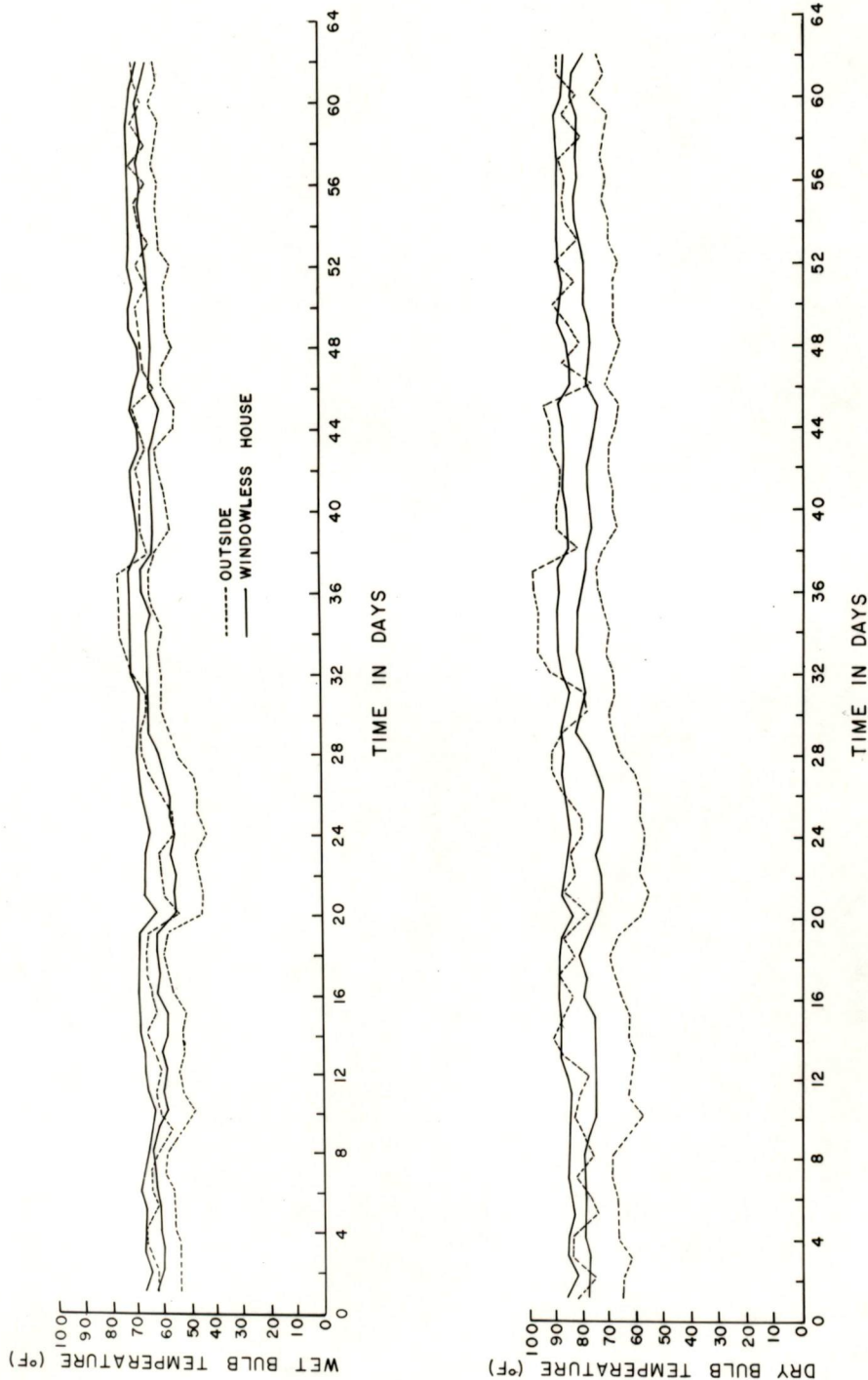


Figure 34. Maximum and minimum dry-bulb and wet-bulb temperatures for the inside and outside condition of the Windowless House during the nine-week period of 5-26-59 to 7-26-59.

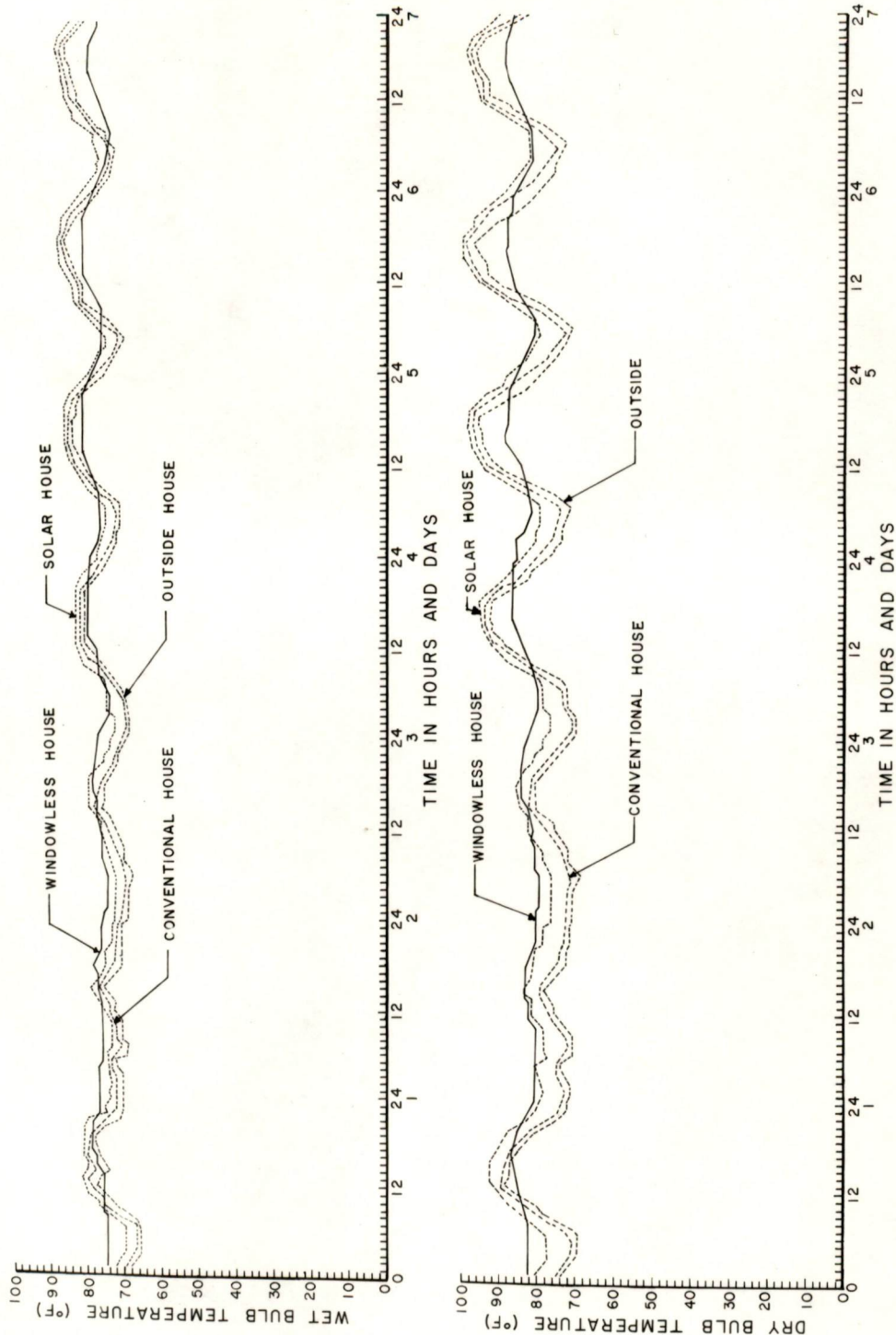


Figure 35. Dry-bulb and wet-bulb temperatures for the inside and outside conditions of the Solar, Windowless and Conventional Houses during the week of 6-23-59 to 6-30-59.

TABLE V
DRY-BULB TEMPERATURES DURING EXPERIMENT IV

	Temperature Readings*			
	Outside	Conventional House	Windowless House	Solar House
Maximum	98	99	88	100
Minimum	54	58	74	68
Mean	73	75	81	82

*The temperature readings are in degrees Fahrenheit.

Throughout the four experiments, the humidity of the Conventional House was very much like the outside humidity. The humidity of the Solar House was generally less in magnitude and more constant than the Conventional House humidity. The humidity of the Windowless House had the least variation of the three houses.

During this period the bird weight gain of the Windowless House was significantly higher than the other two houses (15). As in the previous experiments, the bird weight gain of the Solar House was significantly less than the other two houses.

Results and Discussions of Four Seasonal Experiments

Generally speaking, there was very little difference in the weight gain of the birds of the Windowless House and the Conventional House for these four experiments. However there was a significant difference in the bird weight gain of the Solar and the other two houses. Throughout this study, the weight gain of the birds in the Solar House was less than the other two houses. The difference of weight gain may be due to the following characteristics of the Solar House environment: the Solar House gave more pronounced temperature peaks, and it gave a wide range of temperature fluctuations continually. Of course, there may be other factors and variables which could have produced this result. To definitely determine why the Solar House gave the poorest weight gains, would require additional investigation.

The author noticed that the relative cloudiness of the sky affects the temperature patterns of the houses very much. As the cloudiness of

the sky increases the temperature curves tend to "flatten out." This means there is less daily fluctuation in temperatures on a cloudy day than there is on a sunny day. This is because there is less radiant energy received from the sun on a cloudy day.

From this study definite patterns of the temperature and humidity conditions inside the three houses were determined. Throughout all four experiments, the inside temperatures of the Conventional House followed the same general pattern as the outside temperatures. During the Fall and Spring experiments the inside temperatures on the average were 6° to 10° F. higher than the outside temperatures. During the winter period the temperatures ranged as much as 15° to 20° F. above the outside temperatures. However during the Summer period, the temperatures were practically identical to the outside temperatures. Generally speaking, one may expect the dry-bulb temperature, relative humidity, and the total heat of the Conventional House to be similar to the conditions outside the house.

The temperatures inside the Solar House followed the outside temperature pattern to some extent. The temperatures inside the Solar House tended to peak slightly above the outside temperatures; however, they did not range as low as the outside dry-bulb temperatures. This was noticed quite readily during the winter period. Generally speaking the dry-bulb temperatures, relative humidity, and total heat tended to be more constant for the Solar House and were on an average much higher than the outside or the Conventional House. The relative humidity was generally lower than the Conventional House.

The temperatures in the Windowless House were by far the most constant temperatures. The daily fluctuations were very much less than

the other two houses. Also, the seasonal fluctuations were considerably smaller, as may be seen in Figure 36. Only the maximum temperatures for the four experiments were plotted. The minimum temperatures would follow the same pattern but they would be 8° to 10° lower than the maximum. Notice that the temperatures were around 75° F. throughout the four experiments. Generally speaking, one may expect the dry-bulb temperatures, the relative humidity, and the total heat content of the Windowless House to be relatively constant from day to day during any season in the Southeast. However, the magnitude of these three factors will vary somewhat from season to season.

Limitations of this Study and Suggestions for Future Research

As stated previously, this study was limited to temperature and humidity condition of the three respective houses. Since these are the only factors determined, a recommendation of the most practical house could not be made at this time. However, the economical analysis of the three houses will probably be presented in a thesis by another author. Once this cost analysis is determined, a recommendation of the most practical house could probably be given.

There is need for future research on the following related aspects of this study:

1. A more extensive study on the present research houses in regard to weight gain of the bird and profit per bird is needed.
2. More basic information on the effects of light on broiler production is desirable.

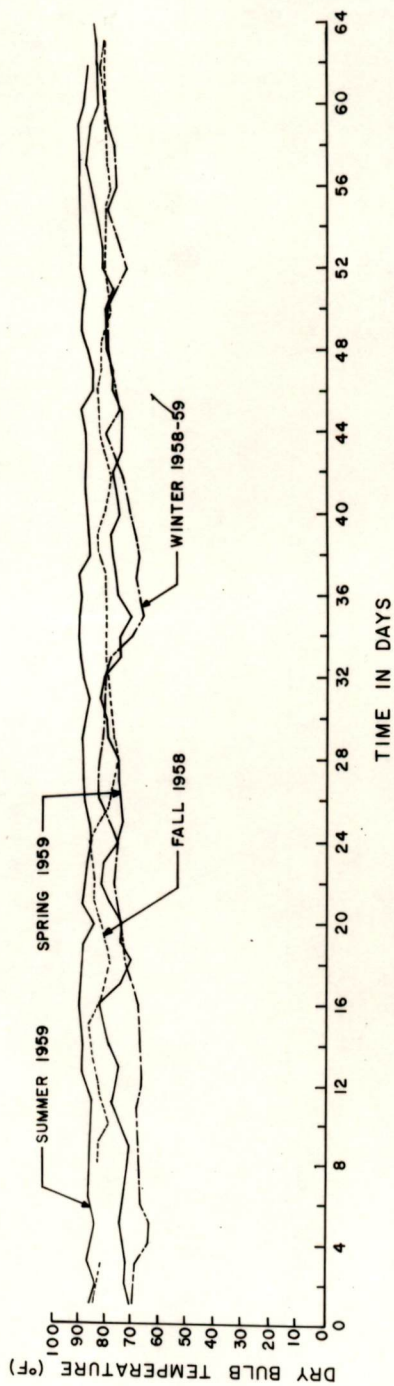
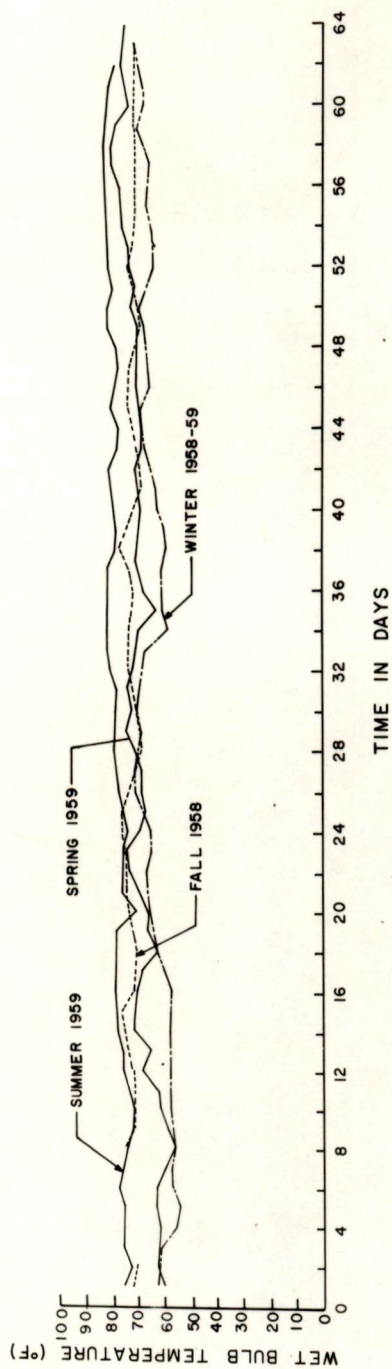


Figure 36. Maximum dry-bulb and wet-bulb temperatures for the inside conditions of the Windowless House for the fall, winter, spring, and summer experiments.

3. More basic information on the effects of ventilation on broiler production is needed.
4. A study to determine if a Windowless House could be built at a cheaper cost is desirable.
5. A study to determine if a Solar House could be improved for use in the Southeast would be desirable.
6. A study of different solar heat collectors for use in furnishing heat for broiler houses is desirable.

CHAPTER IV

SUMMARY AND CONCLUSIONS

The purpose of this study was to determine the temperature and humidity conditions of a solar, windowless, and conventional type broiler house. Recently, there has been a demand for more efficient broiler houses since the broiler enterprise has developed into a mass production industry with a narrow margin of profit. For the average producer, this requires an investment of several thousand dollars of which the largest amount is for housing. However, when Agricultural Engineers were confronted with the problem of designing efficient broiler houses, they soon become aware of the need for basic information on the environmental conditions of different types of houses.

In this study the temperature and humidity conditions of a solar, a windowless, and a conventional type house were determined. These environmental conditions of the three houses were determined for the Fall 1958, Winter 1958-59, Spring 1959, and the Summer 1959 periods. Every effort was made to collect and record accurate and continuous data. The data included the dry-bulb and wet-bulb temperatures for the inside and the outside conditions of each house. Sensing units were selected and installed to obtain the dry-bulb and wet-bulb temperatures. This data was obtained by recording potentiometers, and then tabulated for the respective houses. Graphs were then drawn to represent the temperature and humidity conditions inside and outside each house for the four nine-week periods.

These experiments showed the following:

1. The temperature and humidity conditions inside the Conventional House are quite similar to those outside the house. The inside conditions follow the same general pattern as the outside conditions but at a larger magnitude.
2. The temperature and humidity conditions inside the Solar House were more constant than the Conventional House. The dry-bulb temperatures peaked with the outside dry-bulb temperatures, but they did not drop as low as the outside temperatures during the night. The humidity inside the Solar House was slightly less than that of the Conventional House.
3. The temperature and humidity conditions inside the Windowless House were relatively constant throughout the four experiments. The dry-bulb temperatures inside the Windowless House were around 75° F. at all times. Likewise, the humidity was relatively constant. It was generally higher than the humidity inside the Solar House and less than the humidity inside the Conventional House or the humidity outside.

This information derived from the study should be of considerable value to those concerned with designing broiler houses; those concerned with the management of broiler houses; and, also, the broiler industry in general.

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APPENDIX A

Samples of the Chart Paper

NO. 581

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DEGREES FAHRENHEIT

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DEGREES FAHRENHEIT

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10

DEGREES FAHRENHEIT

20 10 0 10 20 30 40 50 60 70 80 90 100 110 120 130 140

9

APPENDIX B

Samples of Tabulation Sheets

CONVENTIONAL HOUSE

Wet & Dry Bulb Temperature °F

85

DAY O	DATE	DRY BULB						WET BULB						DB--WB		
		MAX		MIN		MEAN	DIFF	MAX		MIN		MEAN	DIFF	MAX	MIN	MEAN
		MAG.	TIME	MAG.	TIME			MAG.	TIME	MAG.	TIME					
3-59	31	82	6 pm	53	7 am	67.5	29	70	6 pm	49	7 am	59.5	21	12	4	8
4-59	1	82	5 pm	52	7 am	67	30	75	5 pm	49	7 am	62	26	7	3	5
	2	76	6 pm	52	8 am	64	24	61	6 pm	50	8 am	55.5	11	15	2	8.5
	3	78	3 pm	51	5 am	64.5	27	66	3 pm	48	5 am	57	18	12	3	7.5
	4	77	4 pm	48	5 am	62.5	29	66	4 pm	45	5 am	55.5	21	11	3	7
	5	84	5 pm	49	6 am	66.5	35	72	5 pm	46	6 am	59	26	12	3	7.5
	6	80	4 pm	61	6 am	70.5	19	65	4 pm	56	6 am	60.5	9	15	5	10
	7	83	4 pm	51	6 am	67	32	70	4 pm	45	6 am	57.5	25	13	6	9.5
	8	85	4 pm	59	5 am	65.5	13	71	4 pm	55	5 am	63	16	14	4	9
	9	83	2 pm	68	7 am	75.5	15	71	2 pm	62	7 am	66.5	9	12	6	9
	10	77	3 pm	64	6 am	70.5	13	69	3 pm	61	6 am	65	8	8	3	5.5
	11	63	2 pm	54	10 am	58.5	9	59	2 pm	53	10 am	56	6	4	1	2.5
	12	51	3 pm	46	10 am	48.5	5	49	3 pm	45	10 am	47	4	2	1	1.5
	13	51	5 pm	38	6 am	44.5	13	48	5 pm	38	6 am	43	10	3	0	1.5
	14	62	5 pm	48	6 am	55	14	53	5 pm	45	6 am	49	8	9	3	6
	15	70	6 pm	45	6 am	57.5	25	60	6 pm	41	6 am	50.5	19	10	4	7
	16	75	5 pm	51	6 am	63	24	65	5 pm	47	6 am	56	18	10	4	7
	17	79	4 pm	47	6 am	63	32	66	4 pm	45	6 am	55.5	21	13	2	7.5
	18	62	6 pm	60	7 am	61	2	58	6 pm	56	7 am	57	2	4	4	4
	19	70	2 pm	60	6 am	65	10	66	2 pm	58	6 am	62	8	4	2	3
	20	80	5 pm	62	6 am	71	18	66	5 pm	60	6 am	63	6	14	2	8

TEMPERATURE

Conventional House

86

Date	Time	OUTSIDE				INSIDE			
		Dry Bulb	Wet Bulb	Diff.	% Rel. Hum.	Dry Bulb	Wet Bulb	Diff.	% Rel. Hum.
6-23	12 am	75	70	5	78	76	71	5	77
	1 am	73	69	4	81	73	69	4	81
	2 am	72	68	4	81	72	68	4	81
	3 am	70	66	4	81	71	67	4	81
	4 am	69	66	3	85	70	67	3	86
	5 am	69	66	3	85	70	67	3	86
	6 am	69	66	3	85	70	67	3	86
	7 am	70	67	3	86	73	69	4	81
	8 am	74	69	5	77	77	72	5	78
	9 am	78	71	7	70	80	75	5	79
	10 am	80	73	7	71	82	76	6	76
	11 am	84	76	8	69	87	78	9	67
	12 pm	87	78	9	67	89	80	9	67
	1 pm	88	77	11	61	91	80	11	62
	2 pm	87	75	12	57	88	78	10	64
	3 pm	86	76	10	63	89	80	9	68
	4 pm	87	77	10	64	89	80	9	67
	5 pm	85	77	8	69	85	78	7	73
	6 pm	84	79	5	80	85	79	6	77
	7 pm	82	78	4	84	83	78	5	80
	8 pm	80	76	4	83	82	77	5	79
	9 pm	76	71	5	78	77	72	5	78
	10 pm	73	70	3	85	75	72	3	86
	11 pm	72	70	2	90	74	72	2	90
6-24	12 am	72	70	2	90	74	71	3	85
	1 am	71	70	1	95	73	71	2	90
	2 am	71	70	1	95	73	70	3	85
	3 am	72	71	1	95	73	71	2	90
	4 am	73	72	1	95	75	72	3	86
	5 am	74	73	1	95	75	72	3	86
	6 am	70	69	1	95	72	69	3	86
	7 am	70	69	1	95	72	69	3	86
	8 am	70	70	0	100	72	69	3	86
	9 am	70	70	0	100	72	69	3	86
	10 am	71	70	1	95	73	71	2	90
	11 am	73	71	2	91	75	73	2	91
	12 pm	75	72	3	86	77	74	3	78
	1 pm	75	72	3	86	77	74	3	78
	2 pm	76	74	2	91	76	74	2	91
	3 pm	78	76	2	91	79	76	3	87
	4 pm	75	73	2	91	78	75	3	87
	5 pm	74	72	2	91	76	74	2	91
	6 pm	72	70	2	90	74	72	2	90
	7 pm	72	70	2	90	74	72	2	90
	8 pm	72	70	2	90	73	71	2	90
	9 pm	71	70	1	95	73	71	2	90
	10 pm	71	70	1	95	73	71	2	90
	11 pm	71	70	1	95	73	71	2	90