1956

Research on a Portable Floor Plate Brooder with Electric Heating Elements for Use in South Dakota

Virgil H. Flesher

RESEARCH ON A PORTABLE FLOOR PLATE BROODER WITH ELECTRIC HEATING ELEMENTS FOR USE IN SOUTH DAKOTA

By

Virgil H. Flesher

A thesis submitted
in partial fulfillment of the requirements for the
degree Master of Science at South Dakota
State College of Agriculture
and Mechanic Arts

December 1956

RESEARCH ON A PORTABLE FLOOR PLATE BROODER WITH ELECTRIC HEATING ELEMENTS FOR USE IN SOUTH DAKOTA

This thesis is approved as a creditable, independent investigation by a candidate for the degree, Master of Science, and acceptable as meeting the thesis requirements for this degree; but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser

Head of the Major Department

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

A reduced profit margin in the poultry business has brought about the demand for more efficient methods of poultry farming. A savings of a few cents per bird on the cost of raising poultry may mean the difference between profit or loss. With this is mind an efficiency study was made of three types of electric brooders. Two of these types of brooders, the infra-red lamp and the conventional electric resistance type heating element and hover, are available commercially. The portable floor plate brooder with electric heating elements was constructed for research purposes in this study.

These three brooder units were tested in portable, wood constructed, shed type brooder houses. No insulation was used in the construction of any of the houses. The floor was uninsulated except for the litter that was used on the floor. Bales of straw were used to bank the outside perimeter.

Inside temperature of the brooder house was therefore subject to variation of the climatic temperature. Temperature variations in South Dakota in early spring may range from as low as minus fifteen degrees to as high as a plus forty degrees Fahrenheit.

Under these conditions the primary purpose of this study was to compare the heat transfer from radiation, conduction, and convection that were recorded in each of the three types of electric brooders. This meant an investigation of materials that will radiate or transfer heat by radiation. Heat changes due to the variation of radiant energy received from the sun were noted.

REVIEW OF LITERATURE

Cost Comparison

A great deal of work has been done in poultry breeding. Egg size has been brought under genetic control, slow feathering has been improved in flocks, and many other characteristics have been improved by selection. Work has been done on the nutritional needs of poultry. Yet there is little basic environmental information concerning the chick during the brooding period. This perhaps is the most critical and difficult period in the management of domestic birds.

Recommended temperatures for chicks can be found from the time they hatch from the egg to the time they are four to five weeks old. However there is no general agreement among poultry men as to what constitutes proper brooding temperatures for chicks just out of the egg or at succeeding ages.

Experienced poultry men regulate brooding temperatures according to chick reaction. Less experienced growers find thermometers helpful.

Tests have shown that for each age of chick there is a temperature at which metabolism was at a minimum. This temperature was 94 to 95 degrees Fahrenheit for day old chicks and decreased about .8 of a degree per day through the thirty-second day. At one year of age, this optimum temperature was found to be 70 degrees Fahrenheit.[1] At temperatures below these optimum temperatures, the chicks need more heat and this is supplied by increased metabolic activity. This increase continues until the chicks are no longer able to produce enough heat to

---

[1] Bywaters. James H. The Physiological Aspects of Chick Brooding. Journal of Ag. Eng. Volume 33. p. 298. 1952.

maintain body temperature and they die from cold. Thus chicks from a day old to two weeks of age are usually unable to survive temperatures below 70 degrees Fahrenheit for twenty-four hours; chicks five to eight weeks of age under similar exposure normally die at temperatures below 50 degrees Fahrenheit. Similar lethal temperatures have not been determined beyond eight weeks of age.[2]

Metabolic activity also increases when the ambient temperature rises above the optimum temperature. This is primarily due to the extra effort required in panting to evaporate extra moisture from the respiratory tract for cooling purposes to maintain body temperature. This process too, has a limit beyond which the bird cannot go and it dies from heat. Thus the exposure of a baby chick to a temperature of about 103 degrees Fahrenheit for twenty-four hours is lethal while a similar exposure of a mature pullet at 90 degrees Fahrenheit is disastrous.[3]

Some research has been conducted on electrically heated brooders. They offer more possibilities than other types such as those heated with oil, coal or gas as far as ease of control is concerned and also in safety from fire hazards. One of the first electric brooders in use was a hover type brooder, a semi-enclosed chamber surrounding a heat unit. This unit provides warmth for the chicks irrespective of the ambient temperature of the brooding room itself. Construction of

[2]Ibid., p. 298.

[3]Ibid., p. 298.

such a brooder is made so chicks can move in and out of the heated area at will. Ventilation under the hover is provided by either natural or forced air flow.

The last few years have brought about a deviation from the conventional, electrically heated brooder. This was caused by a widespread use of the infra-red heat lamp. Elimination of the hover was possible because infra-red rays of these lamps were not converted into heat until coming in contact with the floor or the chick's bodies. In some respects the infra-red heat lamp proved unsatisfactory. The heat requirement proved to be greater since heat from the chicks was dissipated to the surrounding air and not utilized as in the case of the hover type brooder. Another heat loss was from the infra-red rays that did not strike any solid object. Costly controls had to be used for good temperature regulation.

Since the infra-red lamp proved economically disappointing in certain ways, poultry men and researchers turned to other ways of brooding. One method was heating the floor of the brooder house. The chief disadvantage of this method was the lack of portability. Efforts have been made to design a portable heat slab, yet retain the advantages of the permanent type of under floor brooding.

The Department of Agricultural Engineering Research, Agricultural Experiment Station of the Louisiana State University built several portable under heat units. The unit was designed with an insulated layer at the bottom to restrict heat flow downward and a top of materials that would provide a uniform passage of heat. The heat unit which consisted of soil heating cable was placed between the top and

bottom layers. The area of this under floor heat unit was 48 inches by 48 inches, which proved ample room to accommodate 350 chicks through a five-week brooding period under conditions found in the spring in the state of Louisiana.

In the early part of 1954, two units were installed at the North Louisiana Experiment Station, and simple flat top wooden hovers were supported 12 inches above each unit.

At the time these units were in use, four other units, two using butane as a fuel and two using infra-red lamps as the heat sources, were installed in the same building and accurate cost figures were kept. These figures are shown in Table 1.

Table 1. Comparative Cost Figures for Five Brooder Units[a]

Brooder Units	Cost Per Bird	Fuel Consumed Per Bird
1. Premier Butane Brooder	2.88 cents	.19 gals.
2. A. R. Woods Butane Brooder	2.52 cents	.17 gals.
3. Buckeye Infra-red Brooder #1	4.21 cents	2.02 kwhr.
4. Buckeye Infra-red Brooder #2	4.02 cents	1.93 kwhr.
5. Underheat Brooder #1	1.02 cents	.5 kwhr.
6. Underheat Brooder #2	0.85 cents	.4 kwhr.

"Table reproduced from Report on a Portable Underheat Brooder Using Electric Soil Heating Cable, p. 5."

[a]Test run for a five-week brooding period.

The low fuel cost shown in Table 1 was encouraging so another test was run at the Louisiana Agricultural Experiment Station after

Table 2. Comparative Cost Figures for Brooder Units[a]

Brooder Units	Cost Per Bird Test #1	Cost Per Bird Test #2[b]	Fuel Consumption Per Bird Test #3	Fuel Consumption Per Bird Test #4
1. Premier Butane	2.30¢	1.41¢	.16 gals.	.094 gals.
2. A. R. Woods Butane	2.01¢	1.02¢	.14 gals.	.07 gals.
3. Buckeye Infra-red #1	3.37¢	2.14¢	1.62 kwhr.	1.03 kwhr.
4. Buckeye Infra-red #2	3.22¢	2.04¢	1.54 kwhr.	.98 kwhr.
5. Underheat Brooder #1[c]	0.82¢	0.212¢	.40 kwhr.	.102 kwhr.
6. Underheat Brooder #2[d]	0.68¢	0.22¢	.32 kwhr.	.106 kwhr.

"Table reproduced from Report on Portable Underheat Brooder Using Electric Soil Heating Cable, p. 6."

[a]Four week brooding period.

[b]Ambient temperature for Test #2 was higher than for Test #1.

[c]Underheat Brooder #1 had pyramidal aluminum hover.

[d]Underheat Brooder #2 had quonset aluminum hover.

Table 3. Per cent Cost of the Infra-red Brooder

Brooder Units[a]	1st Test % Cost	2nd Test % Cost
1. Infra-red	100.0 %	100.0 %
2. Butane	65.6 %	58.0 %
3. Underheat	22.8 %	10.33 %

"Table reproduced from Report on Portable Underheat Brooder Using Electric Soil Heating Cable, p. 6."

[a]Average of each of the two units tested.

redesigning the two hovers for the underheat brooder. The results are shown in Tables 2 and 3.

The average material costs of all units made with aluminum hovers were $34.00, not including labor. These figures are based on the cost of materials in Louisiana where the study was carried out. It is hoped that this cost will go down as the units are improved.[4]

In the fall of 1949, experimental work on the comparing of the various methods of poultry brooding was started at the State College at Pullman, Washington. All tests were made in a brooding laboratory at the college.

The laboratory was a frame building with two inches of blanket insulation on the wall. Five inches of wood shavings provided insulation for the ceiling. The building was equipped with a heat exchanger and a forced air ventilating system. Inside temperature of the laboratory could be regulated.

Test rooms were equipped for duplication of each brooding method so that with eight rooms, four methods of brooding could be studied at one time.

Brooding methods of this study were the electric hover, under floor electric, underfloor hot water, battle gas hover, and the heat lamp. Results of this study are shown in Table 4.

---

[4]Hough, J. H. Report on a Portable Underheat Brooder Using Electric Soil Heating Cable. Department Circular #20. p. 9. 1955.

Table 4. Comparison of Energy Costs for the Methods used in this Study.[a]

	Brooder Units	Cost Per Bird[b]
1.	Electric Hover	1.90 cents
2.	Under Floor Electric	5.71 cents
3.	Under Floor Hot Water	9.54 cents
4.	Bottle Gas	7.26 cents
5.	Heat Lamp	2.61 cents

"Table reproduced from Report on Comparison of Various Methods of Brooding. Journal of Ag. Eng. Volume 33. p. 558. 1952."

[a]Each test for five week duration

[b]Mean of seven tests.

Heat Transfer

The three methods of transferring heat are by conduction, convection, and radiation. Conduction is the transfer of heat from one part of a body to another part of the same body, or from one body to another which is in physical contact. An example of conduction can be found within a metal rod when one end is being heated. The fast moving molecules in the heated area strike other molecules and heat is transferred to the unheated end of the rod.

Convection is the heat transfer which occurs when warm particles of a fluid mix with cooler particles. The mixing may be accomplished by movement resulting only from temperature differences within a fluid, a process of natural or free convection. Mixing by power operated blowers or pumps is known as a process of forced convection.

The transmission of energy by a process similar to the behavior of light is known as radiation. This energy is not heat until it is absorbed by some object. Radiant heat energy is present in and emitted by all bodies. The rate of transmission depends on the temperature and character of the body. An example of this is heat from the sun. Heat passes through empty space with no apparent medium to carry it. In the electric heater, heat from the glowing element is directed and focused by the reflector and passes as a beam across the room.

For the special case of heat transfer by flat surfaces to air, the heat transmitted per unit area of a heated surface to air by natural convection varies as the 1.25 power of the temperature difference (surface and air) or[5]

---

[5]Stroch, C. Heating & Ventilating's Engineering Databook. 1st Ed. New York, The Industrial Press. p. 5-8. 1940.

$$q_c = bt^{1.25}$$

where t = the temperature difference, surface and air, in degrees F.

q_c = heat transmitted by convection, BTU per hour per square foot of surface, and

b = a constant depending on the position of the surface and the mean temperature involved, and with values (from Fishenden) as follows:

surface vertical	$b = 0.3$
surface facing upward	$b = 0.4$
surface facing downward	$b = 0.2$

Heat transfer by conduction is actually heat transmission through the building material. The unit of heat transmission through materials is calculated by the formula $H = AU(t_i - t_o)$ where H is the total amount of heat in BTU per hour. A is the area of the construction. The temperature of the indoor air is represented by t_i and that of the outdoor temperature by t_o. The value of U can be calculated from the formula:

$$U = \frac{1}{\frac{1}{f_i} + \frac{1}{f_o} + \frac{x}{k} \quad \frac{1}{k_1} + \frac{1}{a_1} + \frac{1}{a_2} + \text{etc.}}$$

where f_i = inner surface conductance usually taken at 1.6 or 1.65

f_o = outer surface conductance usually taken at 6.0

x = thickness of solid material (inches or feet)

k = heat conductivity of solid, BTU per hour per square foot per inch thickness per degree Fahrenheit

a = heat transmitted across air space within construction BTU per square foot per hour per degree Fahrenheit = 1.1

Table 5. Coefficients of Thermal Conductivity of Various Materials
BTU per Square Foot per Hour per °F of Temperature
Difference per Foot of Thickness

Material	Apparent Density Lb. per Cu. Foot	°F	k
Air		32	0.0140
Asbestos - cement boards	120	68	0.43
Asbestos sheets	55.5	124	0.096
Asbestos	36	32	0.090
	36	212	0.111
Aluminum		32	117.0
Aluminum foil, 7 air spaces per 2.5 inches	0.2	100	0.025
Brick, building		68	0.4
Cardboard, corrugated			0.037
Concrete 1:4 dry			0.44
Concrete, stone			0.54
Copper, pure		64	224.0
		212	218.0
Cotton wool	5	86	0.024
Cork, board	10	86	0.025
Cork, ground	9.4	86	0.025
Diatomaceous earth	27.7	399	0.066
	27.7	1600	0.092
Fiber insulating board	14.8	70	0.028
Glass, boro-silicate	139	86-167	0.63
Glass, soda			0.3-0.44
Glass, window			0.3-0.61
Ice	57.5	32	1.3
Iron, wrought		64	34.9
		212	34.6
Iron, cast		129	27.6
		216	26.8
Mill shavings			0.033-0.05
Mineral wool	9.4	86	0.0225
	19.7	86	0.024
Sawdust	12	70	0.03
Snow	34.7	32	0.27
Steel, mild		64	26.2
		212	25.9
Steel, stainless (18-8)		932	12.4
Water		32	0.330
Wood shavings	8.8	86	0.034
Wood, across grain, balsa	7-8	86	0.025-0.3
oak	51.5	59	0.12
white pine	34	59	0.087
Wool, animal	6.9	86	0.021

"Table reproduced from Engineering Elements of Agricultural Processing. p. 114. 1952."

U = heat flow through wall, BTU per hour per square foot per degree Fahrenheit

Values of f, x, k, and a are found in Tables 5 and 6.

Heat transfer by radiation has the characteristics of light. The Stefan-Boltzman law states that radiation from a black body to another body is proportional to the difference of the fourth power of the absolute temperatures of the two bodies.[6] When the radiating body is not a perfect black one, the following formula is used.

$$Q_r = \frac{0.174\ Ae\ (T_h^4 - T_c^4)}{10^8}$$

Q_r = radiation in BTU per hour

A = area in square feet

e = emissivity of radiating body

T_h = absolute temperature of the radiating body

T_c = absolute temperature of receiving body

Table 6. Representative Surface Conductance Coefficients

Service	h_c BTU per (sq ft hr °F)
Evaporating water	400 - 4000
Condensing steam	300 - 5000
Evaporating ammonia	300 - 500
Condensing ammonia	900 - 1600
Air on wall surface, natural convection	1.65*
Air on wall surface, 15 m. p. h. wind	6.00*
Air forced across 1 in. tubes at 10 ft per sec	7
Water at 4 ft per sec in 1 in. pipe	930
Surface cooler, milk flowing over horizontal tubes	200 - 650

"Table reproduced from Engineering Elements of Agricultural Processing, p. 115. 1952."

*Radiant transfer is included in these values

---

[6] Ibid. p. 5-10.

Care should be taken in selecting the value of e since it is dependent on the characteristics of the body surface and its temperature. Temperatures most common in agricultural practices range below 600° Fahrenheit and do not effect emissivity (e) to any great extent.

To help clarify the meaning of emissivity the following definition is used. Emissivity is the ratio of the emissive power of a surface (1 cm^2) other than a black body to the emissive power of a black body under similar conditions. Emissive power is the radiant energy or power going out in all directions within a complete hemisphere.

Values for e in Table 7 are given according to the above definition and at corresponding temperatures. This explanation shows that the angle between two radiating surfaces does not effect the amount of power being emitted and therefore is not taken into consideration in the computations.

Table 7. Normal Total Emissivity of Various Surfaces

Surface	Temp °F	Emissivity
Aluminum, polished plate	73	0.040
Aluminum, oxidized at 1110 °F	390-1110	0.11-0.19
Copper, polished	245	0.023
Copper, heated to 1110 °F	390-1110	0.57
Polished iron	800-1880	0.144-0.377
Ground sheet steel	1720-2010	0.55-0.61
Oxidized iron	212	0.736
Steel plate, rough	100-700	0.94-0.97
Nickel, 98.9% pure, polished	440-620	0.07-0.087
Nickel plate, heated to 1110 °F	390-1110	0.37-0.48
Zinc, 99.1% pure, polished	440-620	0.045-0.053
Galvanized sheet iron, fairly bright	82	0.228
Galvanized sheet iron, gray oxidized	75	0.276
Asbestos, paper	100-700	0.93-0.945
Enamel, white fused on iron	66	0.897
Glass, smooth	72	0.937
Oak, planed	70	0.895
Snow-white enamel varnish on rough iron plate	73	0.906
Flat black lacquer	100-200	0.96-0.98
Oil paints, 16 different, all colors	212	0.92-0.96
Aluminum paint, 10% Al, 22% lacquer body	212	0.52
Aluminum paint, 26% Al, 27% lacquer body	212	0.3
Aluminum paints, varying age and Al content	212	0.27-0.67
Paper	66	0.924-0.944
Porcelain, glazed	72	0.924
Roofing paper	69	0.91
Water	32-212	0.95-0.963

"Table reproduced from Engineering Elements of Agricultural Processing, p. 127. 1952."

Brooding Controls

Controls for electric brooding have been a big problem. The most common control has been the gas filled wafer thermostat.[7] As the element produces heat the wafer is warmed and the gas inside expands, causing the wafer to widen. This action will open a set of contacts which will in turn cut off the current to the elements. With the current cut off the element and wafer cool and the gas contracts and allows the contacts to come together to turn on the current. This wafer thermostat has been used extensively on the farm. In many instances it has good control and its original cost is low. Its application to the infra-red heat lamp has not been very satisfactory.

During the 1952 late winter brooding season, a saturable Core Reactor was built by Westinghouse Electric Corporation.[8] The unit consisted of a reactor and a temperature sensing element. The sensing element regulated the amount of current that was supplied to the core winding of the reactor, which determined the degree of saturation of the core. The degree of saturation regulated the voltage that was supplied to the infra-red load.

This unit has given satisfactory results as far as brooding has been concerned. From an economical point of view, its use will probably be limited to flocks of 5,000 to 10,000 birds and larger.

---

[7] Wright, F. B. Electricity in the Home and on the Farm. New York, John Wiley & Sons. p. 251. 1950.

[8] Stanley, J. M., Baker, Vernon. Control Equipment for Infra-red Poultry Brooding. Journal of Ag. Eng. Volume 34. p.751. 1953.

In many experiments air temperature has to be controlled very accurately. Many commercial thermostats used to control air temperature have too low a sensitivity which brought about the development of the supersensitive thermostat.[9] This thermostat employs the use of two principles to provide on and off control: (1) a spiral bimetal as primary sensing element and (2) the thyrathron relay to switch the working current. These two principles combined give good temperature control and have been applied in the use of curing tobacco.

A differential thermostat[10] is activated by temperature differences. This thermostat, for example, will start ventilating equipment whenever outdoor air temperature is lower than inside air and will stop equipment when favorable temperature differences no longer exist. This type of thermostat may make possible the cooling of farm commodities below average outdoor temperatures. A differential thermostat provided the type of control used in potato storage or other similar applicators.

Another method of temperature control used has been the cyclic temperature regulator.[11] This regulator has been used to simulate some typical temperature conditions. Its construction is such that it can be modified to fit any resulting temperature cycle. One application of this unit was to study the effect of temperature on rate of nitrate

---

[9] Hessler, F. J., Puchett, H. B. Supersensitive Thermostat. Journal of Ag. Eng. Volume 34. p. 841. 1953.

[10] Young, F. D., Soderholm, L. H. Different Thermostats for Agricultural Applications. Journal of Ag. Eng. Volume 33. p. 205. 1952.

[11] Kemp, J. G., Cook, F. D. Cyclic Temperature Regulator. Journal of Ag. Eng. Volume 35. p. 40. 1954.

accumulation in soil.

Commercial temperature controls are now on the market that are accurate to two degrees or less. One such control, known as the Line-Voltage Farm-O-Stat, number T631A, is made by Minneapolis Honeywell.[12] The sensing element is a hydraulic filled copper tube which operates a micro switch within a 2° differential. This and the rugged construction has made it desirable for farm application. Besides this particular thermostat there are many other commercial thermostats that can be applied readily to farm tasks.

---

[12] Honeywell. Catalog of Automatic Controls. p. 86. 1955-56.

ANALYSIS OF THE PROBLEM

The hover type brooder is used mostly by farmers and small operators. Basically, a hover type brooder is a semi-closed chamber surrounding a heating unit which provides a warm shelter for young chickens or poultry. This unit is not effected by the ambient temperature of the brooding room itself. Its construction is such that the chicks have freedom to move in or out of the heated area. The heating element is usually placed in the top of the hover and ventilation is provided by either natural or forced air flow.

This type of hover is produced commercially and is accepted by the small operator. It will provide ample heat for chick brooding in areas of severe climatic conditions, but from the standpoint of profits for the poultry producor it is not very economical.

The last few years have brought about a deviation from the conventional electrically heated brooder because of the increased use of the infra-red heat lamp. The infra-red rays of this lamp have a behavior pattern similar to light; however these rays are not converted into heat until coming into contact with solid bodies. The solid bodies in this case are the chicks. The infra-red heat lamp has been found to be expensive since the rays that do not strike the chick are lost to the surrounding air and floor. Also, costly controls have had to be used to maintain a comfortable brooding zone for the chicks.

Since the use of infra-red lampe proved economically disappointing in some respects due to costly controls and high operating costs, research has been done on a portable floor plate brooder with electric heating elements.

The problems with which this research has been primarily concerned include:

1. The use of an insulated floor plate in a brooder to reduce heat transfer and power costs in that area.

2. The construction of the hover of a brooder from a material which will reduce heat transfer and power costs.

3. The construction of a portable brooder unit that can be moved from house to house.

4. The investigation of radiation reflective characteristics of various building materials to assist in selecting the material to be used in constructing the hover.

A careful study of heat transfer from radiation, conduction, and convection was made on three types of electric brooders. These brooders were the portable floor plate brooder with electric heating elements, the conventional electric brooder, and the infra-red heat lamp. The results of the heat transfer studies were compared. These results will show the effectiveness of the portable floor plate brooder with electric heating elements and will serve as a guide in future construction.

Energy consumption is another factor used as a guide for the construction of the portable floor plate brooder with electric heating elements. Each of the brooders was connected to a separate kilowatt hour meter and the input recorded. On the basis of input, operating costs were compared.

EQUIPMENT AND MATERIALS

The portable unit was visualized as a sandwich with an insulated layer at the bottom to prevent heat flow downward and a top of materials that would provide a uniform passage of heat. The heat unit was placed between the top and bottom layer, molded into the required shape.

The bottom layer consisted of ½" celotex insulating board, mounted on ½" marine type plywood. A sixty foot length of soil heating cable of 400 watt capacity bent to form a flat grid (Figure 1) was secured to the top side of the celotex by wooden spacer strips. To this was added a layer of sand to provide heat retention in case of power failure. The top consisted of 1/8" asbestos board. The entire unit was bound together with edging of sheet metal. (Figure 2) The dimensions of the sandwich were 48" by 48". This area provided room for 200 chicks through a four week brooding period.

The heating cable was controlled by a thermostat which was in contact with the topside of the flexboard and was partially shielded by a sheet of aluminum.

The hover (Figure 3) was made of lightweight aluminum on a frame of angle iron for rigidity. Aluminum was used for the hover because the high reflective power would raise the heating efficiency. One side was hinged so that the chicks could be inspected below the hover. (Figure 4)

The conventional electric brooder was purchased commercially. Its dimensions were 72" by 48" and was used to brood about 200 chicks. The heating element has a 700 watt heating capacity. This unit was

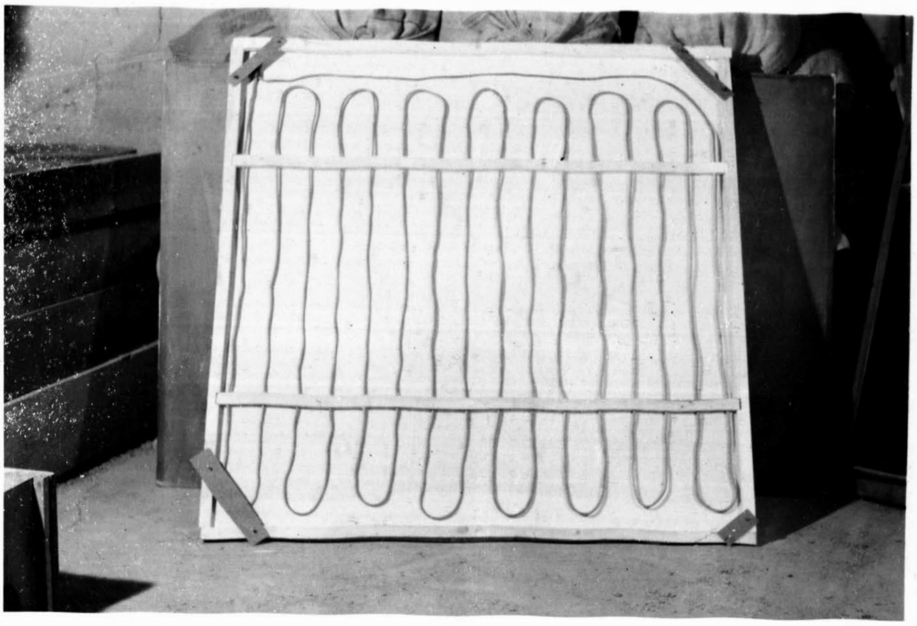


Figure 1. Location, method of fastening, and shape of the heating element for the portable floor plate brooder with electric heating elements.

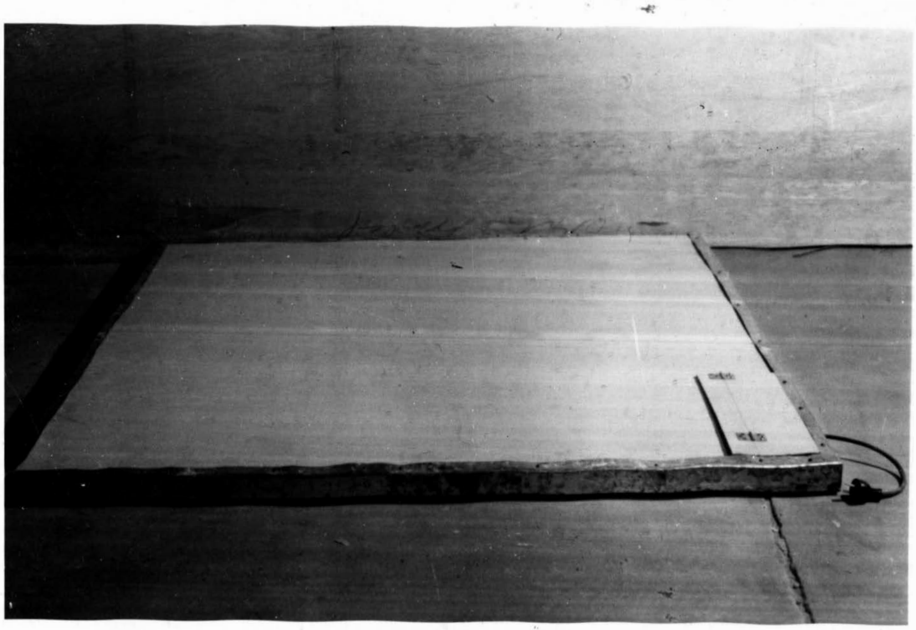


Figure 2. Floor plate of the portable floor plate brooder with electric heating elements showing the edgings of sheet metal

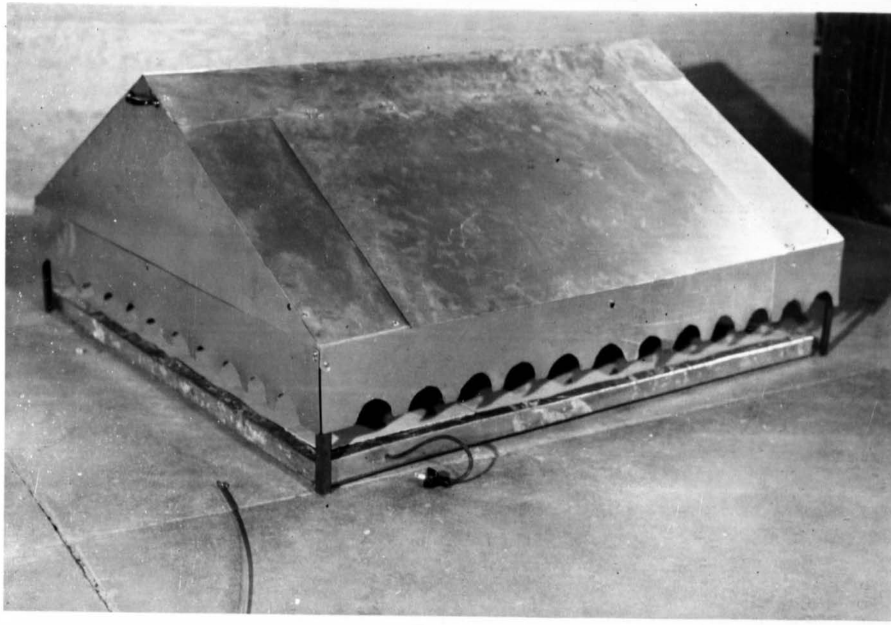


Figure 3. Lightweight aluminum hover on an angle iron frame

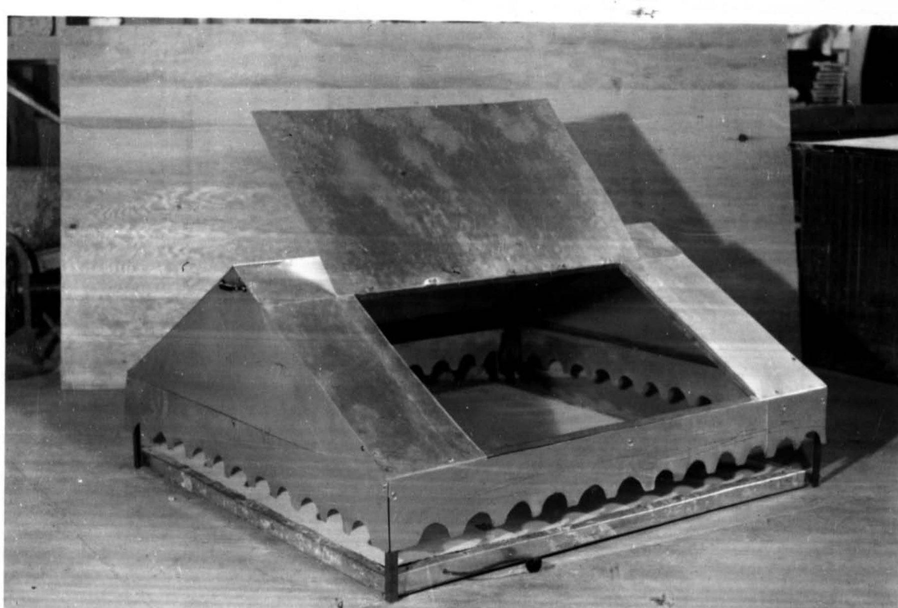


Figure 4. Hover with hinged door for inspection of chicks

equipped with a wafer type thermostat and operated on 110 volts A. C. (Figure 5)

The infra-red heat lamp brooder was also purchased commercially and was used to brood 200 chicks. This unit consisted of four 250 watt infra-red bulbs, two of which were in operation at all times and two that were operated by a wafer type thermostat. (Figure 6)

These types of brooders were placed in separate breeder houses which were of the portable wooden shed type. No insulation was used except for the litter of sawdust on the floor. Bales of straw banked the outside perimeter. (Figure 7)

For temperature measurement a portable Rubicon Temperature Potentiometer (Figure 8) calibrated for copper-constantan thermocouples was used. Along with this potentiometer, some use of mercury thermometers was made. For air flow measurement a Model 60 Anemotherm Air Meter was used. Some quantitative measurements of radiant heat were made by the use of a DW60 radiation meter. The air meter and radiation meter are shown in Figure 9.

Figure 5. Conventional electric brooder

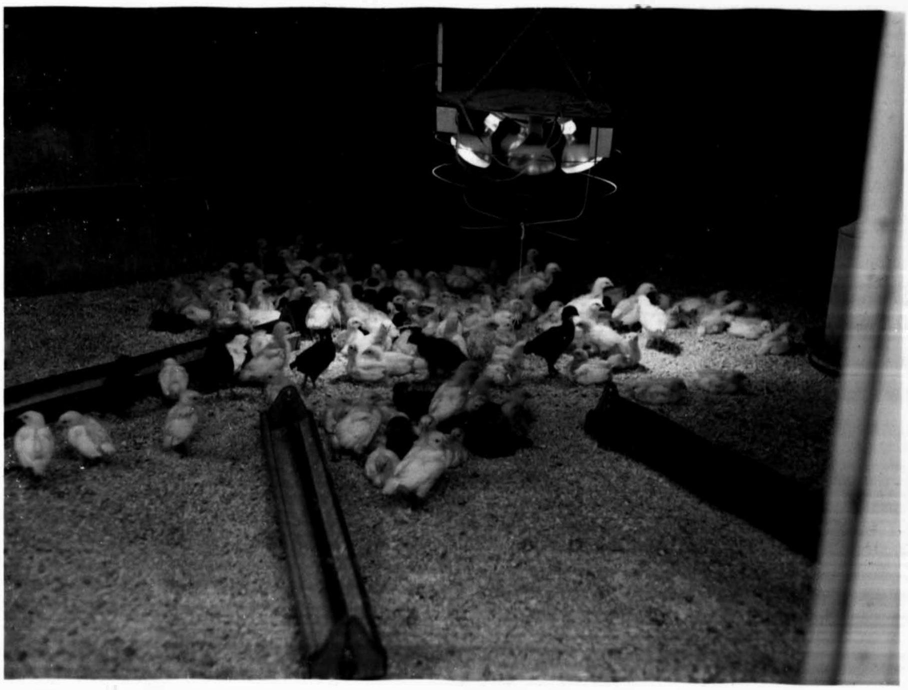


Figure 6. Infra-red heat lamp brooder

Picture Removed

Figure 7. Portable wooden shed type of brooder houses

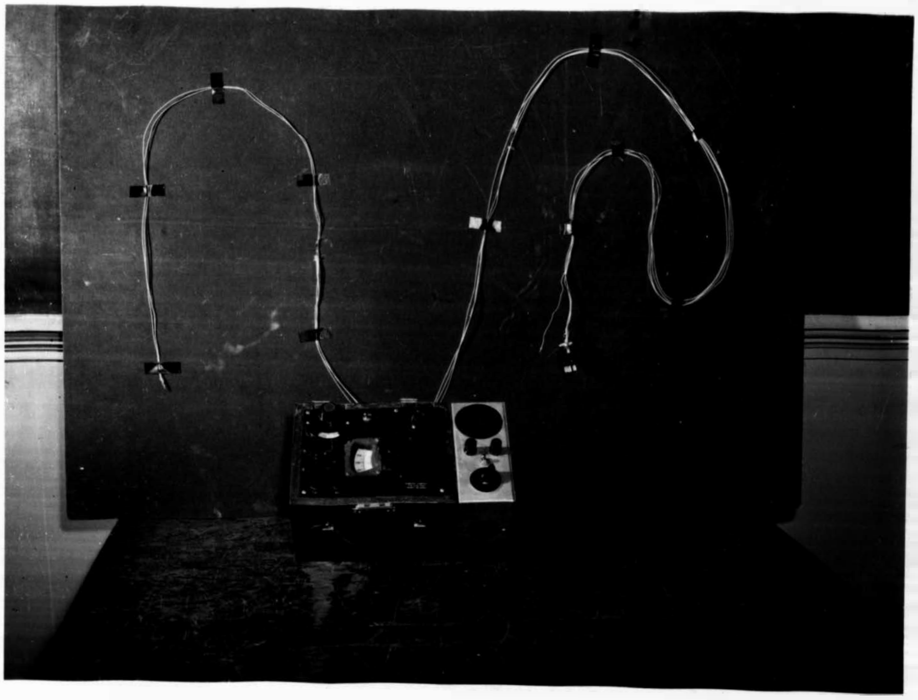


Figure 8. Portable Rubicon temperature potentiometer with thermocouple

EXPERIMENTAL INVESTIGATION

The site selected was located at the poultry farm, Agricultural Experiment Station, South Dakota State College, Brookings, and was chosen partly because of the interest and cooperation of the Poultry Department. Also through that department the brooder houses, the conventional electric brooder, and the infra-red heat lamp brooder were made available. The feeding facilities were another important factor in the choice of the poultry farm as the site for this research project.

The selection of materials and construction of the portable floor plate brooder with electric heating elements were carried on by the author. Kilowatt hour meters were purchased and installed in the three brooder house units. These gave an accurate record of the electric energy input.

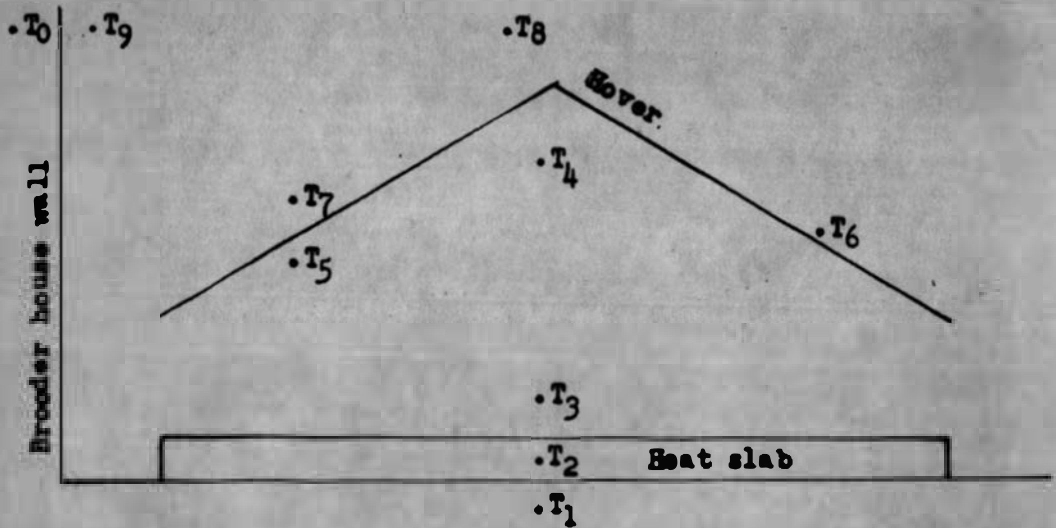
To measure temperatures, thermocouples were installed on each of the brooder units. The thermocouples consisted of from two to five junctions. Temperatures could be measured at each of these junctions. Any large area had a thermocouple with five junctions while a smaller area would have only three junctions per thermocouple. The temperatures at the junctions were averaged to give the temperature of that particular area or surface.

Thermocouples for the portable floor plate brooder with electric heating elements were installed at various locations. Thermocouple number one was located below the plate. Thermocouple number two was located inside the sandwich to give the temperature of the heating element. Thermocouple number three was located at chick height to

give the temperature in the chick brooding zone. The third junction from the end of this thermocouple recorded the thermostat temperature. Thermocouple number four was wrapped around a suspended wood strip to give the temperature of an area six inches below the hover peak. Thermocouple number five was secured to a 3/4 inch wooden strip to give the temperature just below the hover on the inside. Thermocouple number six was fastened directly to the hover surface by means of black electrician's tape. This thermocouple gave the surface temperature of the hover. Thermocouple seven was installed like number five except it was located just above the hover. These two thermocouples gave the temperature difference between the inside and outside surface of the hover.

A mercury thermometer (T_8) was suspended to read air temperature of the brooder house just above the brooder. Another mercury thermometer (T_9) was secured to the wall of the brooder house to give the air temperature near the outside wall. To measure the air temperature outside, a mercury wall thermometer was used. It was installed on the outside wall of the brooder house (T_o). The locations of the above thermocouples can be found in Figure 10. Also some of the thermocouples installed on the outside of the hover can be found in Figure 11.

On the conventional electric brooder, thermocouples were installed at various locations. Thermocouple number one located at chick height gave the temperature of the brooding zone. Thermocouple number two was installed on the ventilator inlet to give the temperature of the air as it entered the fan. Thermocouple number three was fastened to the ceiling of the hover. This ceiling was a piece of fiber board that



(Side view)

T_1............ Thermocouple below heat slab

T_2............ Thermocouple inside heat slab

T_3............ Thermocouple at chick height

T_4............ Thermocouple below hover at the peak (6")

T_5............ Thermocouple below hover surface (3/4")

T_6............ Thermocouple on hover surface

T_7............ Thermocouple above hover surface (3/4")

T_8............ Thermometer suspended near hover

T_9............ Thermometer inside brooder house wall

T_0............ Thermometer outside brooder house wall

Figure 10. Thermocouple and thermometer locations on the portable floor plate brooder with electric heating elements

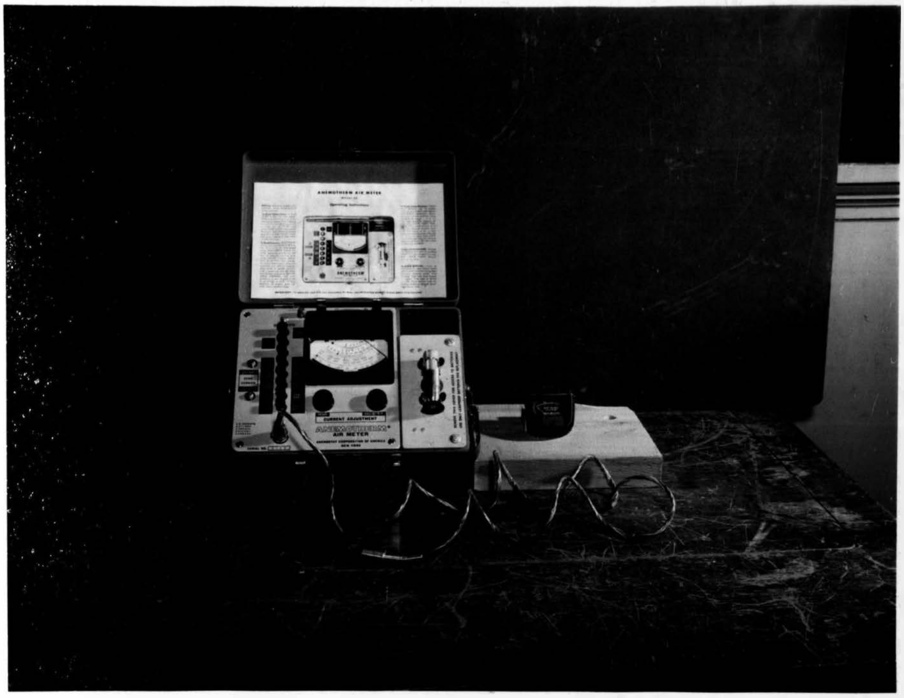


Figure 9. Model 60 Anemotherm air meter on the left and the DW60 radiation meter on the right

Figure 11. Thermocouple and thermometer locations on the outside of the hover of the portable floor plate brooder with electric heating elements

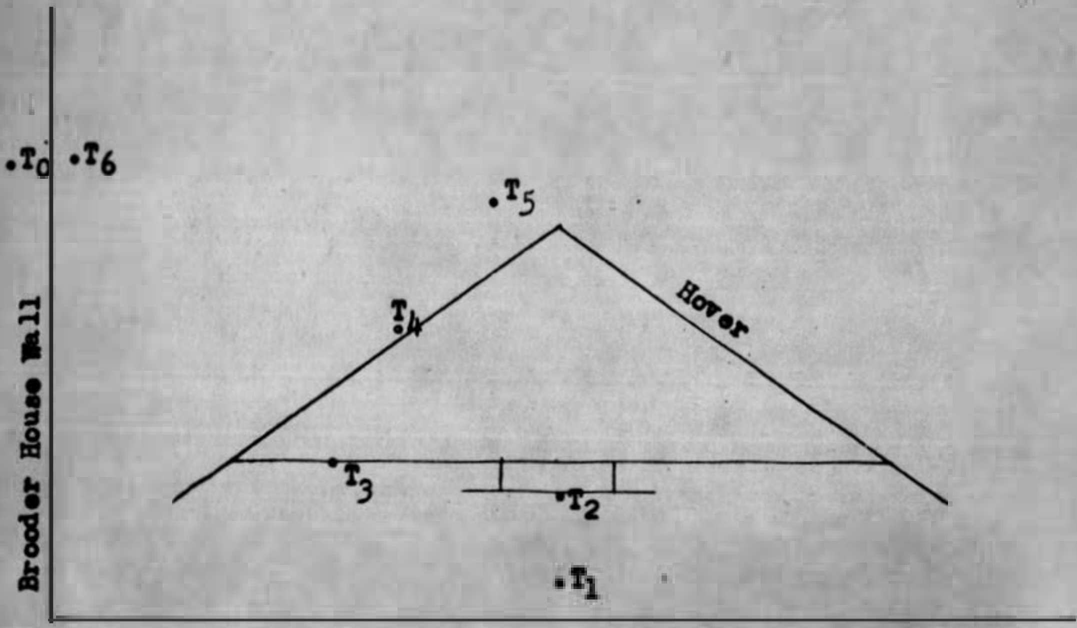
created a loft or air space in the hover for added insulation. Thermocouple number four was fastened to the outside of the hover with black electrician's tape. A temperature difference was obtained between these two thermocouples.

A mercury thermometer was used at the following locations to measure air temperature near the hover (T_5); air temperature near the brooder house wall. (T_6); outside air temperature, (T_o). Location of these thermocouples can be found in Figure 12.

On the infra-red heat lamp, a thermocouple was installed at chick height for recording temperature in the brooding zone. Thermocouple number two was fastened on the under side of the base between the bulb sockets to give temperature readings at that point. Thermocouple number three was installed topside of the base and fastened by means of tape.

Mercury thermometers were located near the base of the infra-red heat lamp brooder, on the inside brooder house wall, and on the outside wall to give air temperatures near the brooder, near the inside wall of the brooder house, and the outside temperature respectively. These thermocouple installations may be seen in Figure 13.

The temperatures of the above thermocouples were read by means of a portable potentiometer and recorder. The temperatures for the portable floor plate brooder with electric heating elements and the time at which they were taken are found in Table 8. The temperatures and the time they were taken for the conventional electric brooder are found in Table 9. Also temperatures and time taken for the infra-red brooder can be found in Table 10.



T_1 ....Thermocouple at chick height

T_2 ....Thermocouple at fan inlet

T_3 ....Thermocouple on inside surface of hover

T_4 ....Thermocouple on outside surface of hover

T_5 ....Thermometer suspended near fan outlet

T_6 ....Thermometer inside brooder house wall

T_0 ....Thermometer outside brooder house wall

Figure 12. Location of the thermocouples and thermometer for the conventional electric brooder.

Figure 13. Location of thermocouples on the infra-red heat lamp brooder

Table 8. Daily temperatures taken for the portable floor plate brooder with electric heating elements

Date	T_1[c] 1	T_1 2	T_1 3	T_2 1	T_2 2	T_2 3	T_3 1	T_3 2	T_3 3[b]	T_4 1	T_4 2	T_4 3	T_5 1	T_5 2	T_5 3	T_6 1	T_6 2	T_6 3	T_6 4	T_6 5	T_7 1	T_7 2	T_7 3	T_8	T_9	T_0	cycle	setting	kilowatts[d]
April																													
20 (4:00pm)	86	83	91	119	112	112	97	101	92	95	95	95	95	93	93	86	87	87	84	87	85	85	85	86	84	71	off	100	263.5
21 (8:00am)	102	96	113	140	133	145	78	92	82	88	87	86	82	82	81	69	71	69	70	70	63	63	63	55	52	44	on	95	268.0
22 (6:30am)	106	106	118	148	140	145	97	100	77	79	79	79	75	75	75	57	62	58	56	60	49	49	51	36	32	28	on	95	274.0
(2:15pm)	88	88	100	123	116	108	96	93	84	82	82	82	79	79	77	68	68	68	67	67				66	64	38	off	95	276.5
23 (5:00pm)	88	88	94	127	127	141	92	91	86	86	89	85	84	84	84	73	73.	73	69	74	68	68	66	66	64	44	on	95	285.0
24 (7:30am)	99	99	119	137	139	143	75	73	70	77	78	77	72	72	75	58	61	57	60	60	51	51	52	42	38	32	on	95	291.0
(3:30pm)	98	106	111	138	130	145	79	79	81	85	85	85	80	82	82	69	72	67	67	67	62	62	62	56	54	44	on	95	293.5
25 (7:15am)	100	106	122	137	140	144	79	78	78	82	82	82	76	76	76	61	65	62	62	62	55	55	56	48	46	36	on	95	298.0
(2:00pm)	86	92	97	108	108	100	95	95	89	87	87	87	86	86	84	79	82	79	79	79	61	61	61	78	76	51	off	95	301.0
26 (8:15am)	99	100	114	140	133	145	81	107	78	84	84	82	79	79	77	63	68	63	63	65	57	57	58	50	47	41	on	95	305.0
(4:00pm)	86	86	94	100	100	95	90	92	86	85	85	83	84	82	81	78	78	77	77	79	72	74	74	76	75	63	off	95	307.0
27 (8:15am)	106	110	122	143	140	148	87	105	85	85	85	83	80	79	79	63	67	64	62	65	55	59	56	48	45	31	on	95	313.0
(10:30am)	92	96	106	131	121	131	76	97	71	72	73	73	68	68	69	51	57	52	52	53	47	47	46	46	43	29	on	95	313.5
(1:30pm)	89	95	103	130	122	135	78	105	72	76	76	75	71	73	69	52	57	55	52	55	48	48	48	45	42	27	on	95	313.5
(3:45pm)	83	89	97	129	120	132	72	102	68	72	72	71	66	68	66	49	53	51	49	52	45	46	44	44	42	27	on	95	314.0
28 (8:00am)	92	91	106	136	128	144	75	107	68	72	74	72	68	68	68	52	57	53	53	55	44	45	45	36	33	25	on	95	321.0
(4:15pm)	93	92	102	130	124	142	78	93	74	81	81	80	75	76	76	58	64	61	58	60	53	55	55	46	43	31	on	95	323.5
29 (7:00am)	102	101	119	143	138	143	87	98	82	82	82	82	76	77	77	61	66	63	62	64	52	54	54	40	37	27	on	95	327.5
30 (8:00am)	90	89	107	128	123	133	59	82	64	70	71	71	65	67	67	50	54	51	51	51	45	45	46	46	43	36	on	95	335.0
(4:15pm)	105	102	114	142	138	152	89	104	95	94	94	94	88	89	88	77	79	78	77	78	71	71	72	64	62	43	on	95	337.5
May																													
1 (7:15am)	94	98	113	141	132	136	70	89	72	74	77	74	70	72	72	52	57	54	53	55	48	48	49	49	47	37	on	95	343.5
(4:15pm)	102	104	114	143	137	148	92	104	92	90	91	91	83	86	86	70	72	69	69	70	63	64	63	56	55	41	on	95	345.5
2 (8:15am)	103	103	121	141	144	146	84	95	83	85	86	84	79	81	80	65	67	65	64	65	57	59	58	50	48	35	on	95	352.5
(4:15pm)	86	85	95	103	100	97	91	95	92	89	89	89	88	87	87	82	83	83	81	81	80	80	79	78	77	52	off	95	353.5
3 (7:15am)	98	112	112	137	137	145	73	89	74	76	79	77	72	72	74	56	59	56	56	57	49	49	51	50	49	38	on	90	357.0
(4:00pm)	80	78	90	96	98	101	88	92	88	86	86	85	84	83	83	78	79	79	77	77	75	75	75	76	74	50	off	90	360.5
4 (8:15am)	100	98	118	138	138	144	87	92	78	85	86	85	79	81	81	69	69	67	68	68	62	62	63	55	53	38	on	90	364.0
(4:15pm)	85	80	93	11	114	134	87	88	81	85	86	87	84	85	84	80	78	76	78	76	72	73	72	71	69	51	on	90	365.5

[a]Numbers for each individual column of number under a T heading indicate thermocouple junctions

[b]Thermostat temperatures

[c]Refer to Figure 10 for the thermocouple locations

[d]Electric energy consumption in kilowatt hours

Table 8. "(Continued)"

Date	T_1			T_2			T_3			T_4			T_5			T_6					T_7			T_8	T_9	T_{10}	cy-cle	set-ting	kilo-watts
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	4	5	1	2	3						
May																													
5 (7:30am)	102	103	120	130	143	112	86	96	85	84	85	85	80	80	80	67	70	67	67	72	60	60	60	56	53	42	off	90	371.0
(4:00pm)	98	100	113	135	139	145	83	92	83	86	87	86	81	81	82	68	71	68	68	70	62	62	63	57	55	44	on	90	373.0
6 (7:00am)	96	96	111	134	136	142	79	91	77	77	78	77	73	73	74	59	62	60	60	61	52	52	53	56	54	42	on	90	376.0
7 (8:30am)	100	101	116	128	132	141	89	96	86	88	88	89	85	85	86	75	75	74	74	74	70	70	71	65	63	55	on	90	381.5
(4:00pm)	78	78	81	87	88	85	89	85	87	86	85	85	86	85	85	84	84	86	84	83	82	82	80	82	81	66	off	85	382.0
8 (8:15am)	96	99	111	135	132	141	86	92	80	84	85	85	80	80	83	70	70	70	70	70	65	65	66	60	59	54	on	85	383.5
(4:30pm)	90	92	100	118	116	137	89	100	80	87	88	88	83	84	85	76	76	75	75	75	70	69	70	67	66	60	on	85	384.5
9 (8:30am)	82	81	91	105	108	130	96	90	79	83	84	84	81	81	82	72	72	70	71	71	69	69	69	68	66	58	on	85	386.5
(4:00pm)	71	70	75	78	80	78	82	80	80	81	81	81	82	80	80	78	79	79	78	78	78	78	78	81	80	61	off	85	387.0
10 (8:30am)	90	93	107	135	130	136	80	96	78	83	85	83	78	79	79	66	66	65	65	67	59	59	61	56	54	46	on	85	391.0
(4:00pm)	84	84	92	112	111	129	85	87	78	84	84	83	80	80	80	69	70	69	68	69	65	65	65	64	62	55	on	85	392.5
11 (8:30am)	95	95	109	118	120	100	86	88	84	86	86	84	83	83	84	77	77	77	77	76	72	72	74	68	66	57	off	85	393.5
(3:30pm)	77	74	80	82	84	82	87	89	85	86	86	86	87	85	85	83	83	85	83	84	83	83	82	83	82	74	off	85	394.0
12 (8:30am)	79	79	87	89	95	85	80	85	79	83	84	84	81	81	83	77	77	77	77	77	75	75	77	76	74	68	off	80	394.5
13 (6:45am)	85	87	92	111	112	131	82	87	82	84	84	84	81	81	80	69	69	69	67	70	65	65	65	58	56	50	on	80	395.0
14 (8:30am)	82	83	94	101	104	105	74	80	83	75	76	76	73	73	73	68	68	68	68	68	64	64	66	67	64	49	off	80	398.5
(1:45pm)	72	70	78	84	87	82	83	86	81	82	83	83	82	81	81	81	80	80	79	79	78	78	78	79	78	64	off	80	400.0
15 (2:30pm)	75	74	83	92	95	109	76	79	75	80	81	81	80	80	80	75	75	73	73	73	70	71	71	71	70	51	on	80	402.0
16 (8:30am)	93	94	109	127	127	131	73	104	78	82	82	80	77	77	78	67	68	68	67	68	63	63	63	59	57	52	on	80	403.5
17 (2:00pm)	70	69	74	78	81	76	80	81	80	83	83	83	84	82	82	81	82	82	81	81	79	79	79	81	80	70	off	80	404.5
18 (8:30am)	82	84	90	104	101	93	76	83	78	80	80	81	79	79	79	72	73	73	73	73	70	70	70	69	67	62	off	80	405.5
(4:00pm)	70	69	72	80	79	79	82	83	83	85	85	84	86	84	84	82	84	85	83	83	83	83	83	87	86	76	off	80	405.5

Table 9. Daily temperatures taken for the conventional electric brooder[a]

Date	T_1[b]		T_2		T_3					T_4					T_5	T6	To	cycle	kilowatts[c]
	1	2	1	2	1	2	3	4	5	1	2	3	4	5					
April																			
20 (4:00pm)	82	82	94	95	84	83	89	86	87	87	88	88	88	88	88	89	72	on	837.5
21 (8:00am)	97	79	102	100	94	99	109	100	98	76	77	79	76	80	60	58	48	on	845.0
22 (6:30am)	100	75	106	100	92	92	108	105	99	65	71	69	68	73	40	37	32	on	855.0
(2:15pm)	88	78	89	89	88	87	99	97	93	69	71	73	70	74	65	64	41	on	859.0
23 (5:00pm)	89	85	95	95	91	89	99	98	96	77	80	80	77	81	68	66	48	off	873.5
24 (7:30am)	90	74	101	99	87	87	102	99	93	62	66	66	65	70	47	44	37		
(3:30pm)	91	80	98	98	91	91	102	100	97	72	77	77	74	76	59	56	45	on	882.0
25 (7:15am)	94	79	108	104	93	99	106	104	100	70	74	74	70	74	51	49	39		893.0
(2:00pm)	90	90	95	94	91	91	97	96	96	82	82	82	83	84	79	78	54	off	894.0
26 (8:15am)	98	87	108	104	95	95	106	104	102	71	73	73	73	77	56	53	45	on	903.5
(4:00pm)	94	89	96	96	92	92	99	97	97	82	83	83	82	84	78	78	64	off	905.0
27 (8:00am)	96	87	108	105	93	93	108	106	103	66	70	71	70	75	48	46	33	on	912.5
(10:30am)	87	78	101	98	86	85	100	100	95	58	63	64	62	66	46	44	31	on	913.5
(1:30pm)	90	82	105	100	90	89	104	103	101	61	65	67	64	70	45	43	29	on	914.0
(3:45pm)	84	76	98	95	84	82	98	97	95	55	59	61	58	64	44	42	28	on	915.5
28 (8:00am)	88	78	102	100	87	86	102	100	97	59	63	66	61	66	39	36	28	on	925.0
(4:15pm)	94	89	107	105	93	92	108	106	104	63	66	69	67	73	46	45	34	on	931.0
29 (7:00am)	100	92	113	110	96	96	111	110	107	65	69	69	68	76	45	40	90	on	938.0
30 (8:00am)	87	75	97	95	83	84	97	94	92	58	61	61	60	65	55	52	37	on	951.0
(4:15pm)	103	97	108	108	96	96	104	109	102	77	80	80	79	84	67	66	46	on	953.5
May																			
1 (7:15am)	90	78	96	96	85	85	98	97	95	57	62	62	61	67	53	50	40	on	962.0
(4:15pm)	101	90	110	108	94	95	106	103	102	70	73	72	72	77	58	55	41	on	965.0
2 (8:15am)	98	82	110	107	96	96	111	108	105	69	73	73	71	71	54	50	37	off	973.5
(4:15pm)	89	89	100	100	93	93	100	97	98	83	83	84	84	86	80	80	54	on	975.5
3 (7:15am)	69	64	97	96	85	85	98	95	94	60	64	64	61	67	54	52	40	on	983.0
(4:00pm)	86	88	96	96	91	91	98	96	96	80	80	81	81	84	76	76	52	off	985.0
4 (8:15am)	75	70	100	100	93	93	104	101	99	73	75	75	74	77	61	60	43	on	993.5
(4:15pm)	82	89	93	96	92	92	102	99	100	77	78	77	78	82	72	72	52	on	995.5

[a]Numbers for each individual column under a T heading indicates thermocouple junctions

[b]Refer to Figure 12 for the thermocouple locations

[c]Electric energy consumption in kilowatt hours

Table 9. "(Continued)"

Date		T_1		T_2		T_3					T_4					T_5	T_6	T_0	cy-cle	kilo-watts
		1	2	1	2	1	2	3	4	5	1	2	3	4	5					
May																				
5	(7:30am)	80	80	107	107	95	95	108	106	105	70	71	71	72	77	57	55	44	on	1003.0
	(4:00pm)	82	80	99	99	93	92	104	101	69	71	71	71	71	78	60	58	46	on	1005.0
6	(7:00am)	69	68	94	94	86	86	97	94	93	62	65	63	63	69	59	57	45	on	1012.0
7	(8:30am)	99	88	98	98	93	93	100	99	98	78	78	79	79	82	71	70	59	off	1020.0
	(4:00pm)	91	87	94	96	92	91	97	95	95	83	84	85	85	88	81	82	69	on	1022.0
8	(8:15am)	97	83	99	97	90	90	98	98	97	74	74	74	74	78	63	69	57	on	1026.0
	(4:30pm)	94	84	95	93	89	90	97	96	96	76	76	76	77	80	68	68	62	on	1030.0
9	(8:30am)	95	78	98	96	90	90	96	95	94	74	74	74	74	78	70	70	60	on	1034.0
	(4:00pm)	96	90	97	97	95	100	100	99	98	87	86	87	88	92	81	82	62	off	1036.0
10	(8:30am)	73	74	96	96	87	87	97	96	94	65	68	68	67	73	58	56	48	on	1043.5
	(4:00pm)	77	83	94	94	92	92	101	99	98	72	74	74	74	79	65	64	58	off	1044.5
11	(8:30am)	82	79	99	99	92	93	97	97	94	82	82	82	81	83	73	72	60	off	1051.5
	(3:30pm)		84	91	91	92	92	96	95	95	85	85	85	85	87	84	85	76	on	1052.5
12	(8:30am)	82	87	92	95	86	88	96	90	88	83	89	83	83	82	82	82	72	off	1055.0
13	(6:45am)	84	92	94	92	87	88	97	96	96	71	73	72	73	78	60	58	52	off	1061.5
14	(8:30am)	74	74	86	86	85	86	94	93	94	74	74	74	73	76	68	68	52	off	1071.0
	(1:45pm)	82	82	90	90	89	89	95	93	94	84	83	83	84	84	83	83	67	off	1072.5
15	(2:30pm)	89	85	87	87	88	90	95	94	95	77	77	76	76	78	72	72	54	off	1078.5
16	(8:30am)	76	91	93	93	88	90	97	96	96	71	72	71	71	75	61	60	55	off	1085.5
17	(2:00pm)			92	92	90	90	95	94	96	85	84	84	85	85	82	83	71	on	1093.5
18	(8:30am)			91	94	87	88	95	92	92	77	77	77	76	78	71	70	66	on	1101.0
	(4:00pm)			89	92	91	90	93	92	93	85	85	86	87	87	88	88	77	on	1102.0

Table 10. Daily temperatures taken for the infra-red heat lamp brooder[a]

Date	T_1		T_2		T_3		T_4	T_5	T_o	kilo-watts[c]
	1	2	1	2	1	2				
April										
20 (4:00pm)	103	95	120	125	103	104	96	94	72	877.0
21 (8:00am)	71	68	94	97	74	77	62	60	48	886.0
22 (6:30am)	93	65	119	120	87	78	50	44	28	902.0
(2:15pm)	79	72	101	105	78	80	68	66	39	906.0
23 (5:00pm)	83	78	107	110	85	85	72	69	45	925.5
24 (7:30am)	92	65	121	118	87	80	56	51	35	937.0
(3:30pm)	86	74	119	124	92	83	62	60	43	943.5
25 (7:15am)	97	73	126	126	93	83		60	55	956.0
(2:00pm)	90	86	107	114	92	92	82	79	51	961.5
26 (8:15am)	97	77	122	127	93	82	64	59	46	974.0
(4:00pm)	91	90	111	115	92	93	83	80	63	978.0
27 (8:15am)	96	73	117	119	89	77	54	49	30	992.0
(10:30am)	85	62	107	109	80	69	52	46	28	993.5
(1:30pm)	90	67	109	111	82	70	52	45	26	994.5
(3:45pm)	83	59	103	107	76	65	50	44	26	996.0
28 (8:00am)	90	63	105	107	78	67	46	40	26	1012.0
(4:15pm)	94	89	119	124	89	76	54	49	31	1017.0
29 (7:00am)	91	81	116	119	84	74	52	45	28	1031.5
30 (8:00am)	75	67	110	114	81	73	62	57	36	1048.0
(4:15pm)	93	87	119	121	92	89	72	69	44	1054.0
May										
1 (7:15am)	80	66	110	112	82	71	59	54	38	1066.0
(4:15pm)	90	79	124	125	93	83	64	58	38	1073.5
2 (8:15am)	86	70	122	125	89	79	60	55	34	1087.5
(4:15pm)	93	89	111	116	94	95	84	80	52	1093.5
3 (7:15am)	73	53	116	120	83	71	64	58	38	1104.0
(4:00pm)	86	86	108	114	92	92	80	77	48	1111.0
4 (8:15am)	91	77	126	128	97	93	70	66	41	1123.5
(4:15pm)	87	80	108	111	88	89	76	74	49	1126.0

[a] Numbers for each individual column under a T heading indicates thermocouple junctions

[b] Refer to Figure 13 for the thermocouple locations

[c] Electric energy consumption in kilowatt hours

Table 10. "(Continued)"

Date		T_1		T_2		T_3		T_4	T_5	T_0	kilo-wattd
		1	2	1	2	1	2				
May											
5	(7:30am)	91	80	127	129	97	86	61	67	42	1137.0
	(4:00pm)	92	88	115	113	87	87	69	63	44	1144.0
6	(7:00am)	81	70	117	118	87	80	70	63	44	1155.0
7	(8:30am)	84	83	112	116	92	92	76	73	57	1173.0
	(4:00pm)	85	96	111	118	96	96	85	83	67	1175.0
8	(8:15am)	78	87	113	113	87	87	70	67	55	1186.5
	(4:30pm)	77	91	113	113	88	90	74	72	60	1193.0
9	(8:30am)	81	93	117	120	92	89	76	72	58	1203.0
	(4:00pm)	88	107	112	119	97	97	84	81	60	1205.0
10	(8:30am)	78	82	114	110	87	77	66	60	46	1218.0
	(4:00pm)	77	77	121	126	97	86	71	67	55	1223.5
11	(8:30am)	87	82	130	131	106	96	78	78	58	1235.0
	(3:30pm)	89	88	114	120	98	98	88	88	73	1238.0
12	(8:30am)	80	78	91	88	95	84	81	80	70	1245.5
13	(6:45am)	73	70	108	106	95	78	63	58	50	1253.5
14	(8:30am)	67	70	112	106	97	78	72	69	50	1264.0
	(1:45pm)	82	82	101	95	90	92	84	83	63	1266.0
15	(2:30pm)	81	73	119	113	104	89	74	71	53	1276.5
16	(8:30am)	73	66	109	105	94	79	67	63	54	1284.5
17	(2:00pm)	81	79	120	119	110	96	84	82	69	1296.0
18	(8:30am)	80	85	114	105	98	84	75	73	66	1304.0
	(4:00pm)	87	85	104	106	102	90	87	87	74	1306.0

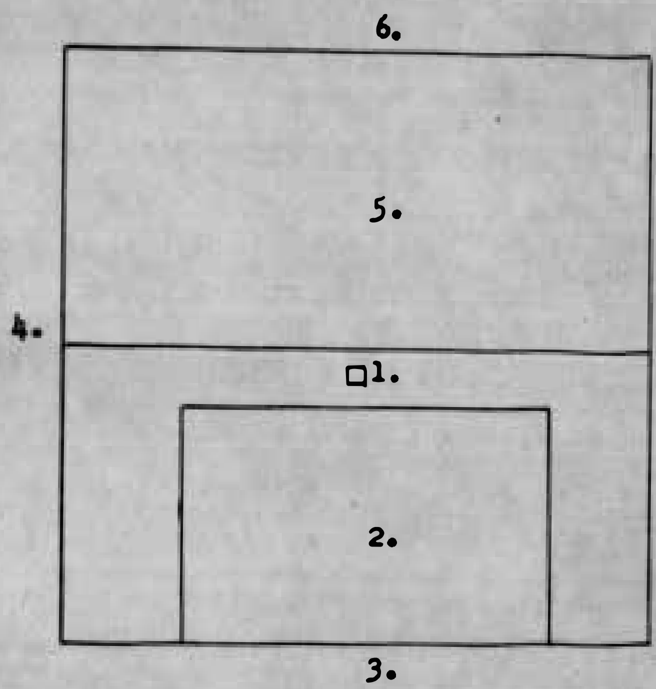
Each time that the temperatures were taken, measurements of the air velocity about each hover were also taken. These measurements were taken by a Model 60 Anemotherm air meter and recorded. Air velocities of the portable floor plate brooder with electric heating elements were taken at point one which is the ventilator opening. Points two and five were air velocity measurements to check the convection air currents near the hover surface. Points three, four and six are air velocity measurements around the hover edge. Location of these points can be found in Figure 14.

Much the same air velocity measurements were taken for the conventional electric brooder. Location of these points of measurement are shown in Figure 15.

To check convection air currents around the base of the infra-red heat lamp, four measurements were made. The location of the points of measurement are shown in Figure 16.

The purpose of these air velocity measurements was to estimate a surface conductance value. In heat transfer through building material, this value is 1.6 or 1.65 for an inner surface. The outside surface conductance is usually taken to be 6.0 assuming a 15 mph wind.

The radiation intensity of each brooder unit was checked by means of a DW60 radiation meter. It was found that the radiation intensity for the portable floor plate brooder with electric heating elements and conventional electric brooder was too low to be measured with the meter. Another means was used for calculating heat transfer by radiation. On the infra-red heat lamp brooder, the radiation intensity could be easily read with this meter. Radiation intensity



1.......Air velocity at the ventilator opening

2.......Air velocity at the outside hover surface

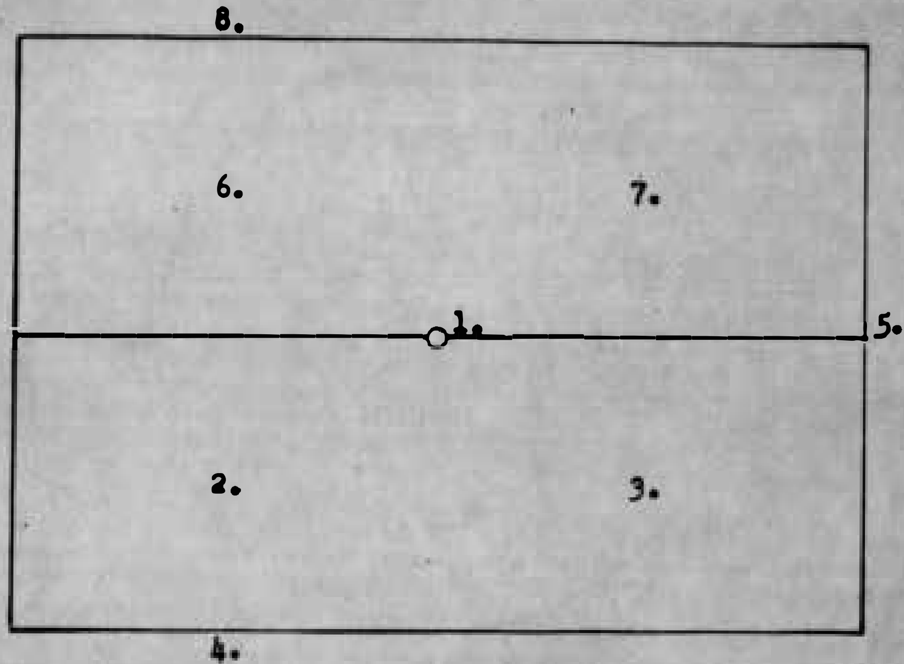
3.......Air velocity moving below hover at the outer edge

4.......Air velocity moving below hover at the outer edge

5.......Air velocity at the outside hover surface

6.......Air velocity moving below hover at the outer edge

Figure 14. Location of the air velocity measurements for the portable floor plate brooder with electric heating elements



(top view)

1........Air velocity at the ventilator opening

2.......Air velocity at the outside hover surface

3.......Air velocity at the outside hover surface

4.......Air velocity moving below hover at the outer edge

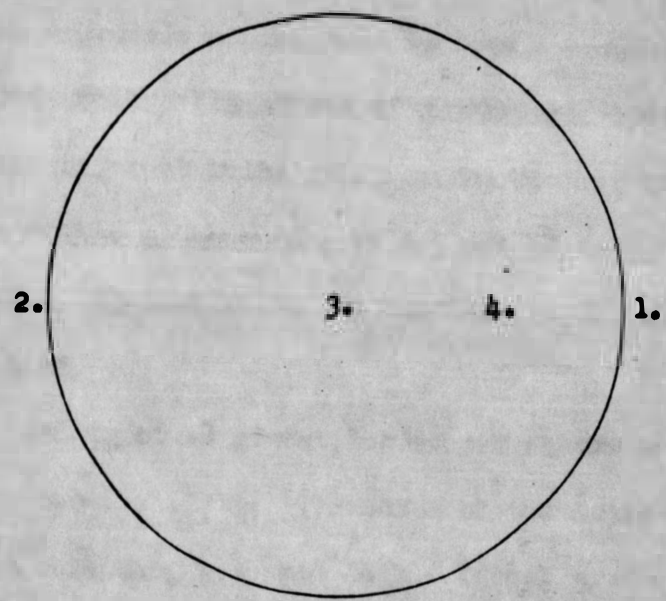
5.......Air velocity moving below hover at the outer edge

6.......Air velocity at the outside hover surface

7.......Air velocity at the outside hover surface

8.......Air velocity moving below hover at the outer edge

Figure 15. Location of air velocity measurements for the conventional electric brooder



(top view)

1.......Air velocity at the base edge

2.......Air velocity at the base edge

3.......Air velocity at a central location near the top surface of the base

4.......Air velocity at a point near the top surface midway between the center of the base and the edge

Figure 16. Location of air velocity measurements on the infrared heat lamp brooder

(gram-calories per square centimeter per minute) was measured at eight locations around the base of the infra-red heat lamp. Four bulbs were located at intervals on the base to form a square. Point number one was located arbitrarily at one of the bulbs. Point two was located between two adjacent bulbs going in the counter clockwise direction. This same method of measuring at a point directly opposite a bulb and then between adjacent bulbs was continued until point number one was again reached.

A reading of .1 gram-calories per square centimeter per minute was chosen because of the graduation of the scale on the radiation meter. This reading was next to the lowest graduation and was considered in the fringe area of the brooding zone where the chicks were most comfortable. At each point at chick height the meter was placed so that this reading was reached. The distance of the meter from the center of the base was measured and recorded. (Table 11) These distances were then averaged weekly and used to plot a heat pattern to show the radiant intensity. These average weekly values are found in Table 12.

For the portable floor plate brooder with electric heating elements the following calculations of heat transfer by conduction, convection, and radiation were made. For heat transmission through the hover the formula $H = AU (t_1 - t_o)$ was used where H is the total amount of heat in BTU per hour passing through a construction of area A. The temperature of the air inside the hover is represented by t_1 and that of the outside air by t_o. (Table 13) Heat flow through the wall is represented by U.

Table 11. Daily radiation intensity measurements for the infra-red heat lamp brooder[a]

Date	Inches[b]							
	1	2	3	4	5	6	7	8
April								
20 (4:00pm)	36	26	8*	24	29	25	25*	26
21 (8:00am)	35	22	7*	24	34	21	8*	25
22 (6:30am)	36	33	35	28	33	30	33	33
(2:15pm)	37	28	8*	29	36	22	7*	28
23 (5:00pm)	36	26	5*	23	30	24	7*	25
24 (7:30am)	35	35	32	25	31	31	32	33
(3:30pm)	36	33	34	25	31	31	34	33
25 (7:15am)	37	33	36	26	31	33	33	32
(2:00pm)	35	22	0*	21	30	25	0*	27
26 (8:15am)	36	34	33	26	29	32	30	32
(4:00pm)	36	26	0*	23	30	26	0*	26
27 (8:15am)	36	35	36	25	30	31	33	33
(10:30am)	36	35	34	25	32	32	31	34
(1:30pm)	35	34	34	25	31	31	30	31
(3:45pm)	35	34	33	26	32	32	29	30
28 (8:00am)	36	34	34	26	30	30	30	30
(4:15pm)	35	36	36	28	32	32	31	33
29 (7:00am)	38	36	36	28	33	32	32	36
30 (8:00am)	37	38	38	27	33	34	34	34
(4:15pm)	33	23	0*	24	31	24	0*	24
May								
1 (7:15am)	36	37	34	20	31	32	33	31
(4:15pm)	36	34	34	30	33	31	34	33
2 (8:15am)	35	34	34	28	32	31	32	33
(4:15pm)	35	24	5*	23	35	24	6*	25
3 (7:15am)	36	36	36	32	31	32	33	31
(4:00pm)	35	21	7*	28	31	28	13*	32
4 (8:15am)	36	27	8*	22	33	24	9*	25
(4:15pm)	36	28	9*	26	34	25	10*	21

[a]Numbers with an asterisk indicate bulbs not burning

[b]Distance from the base center to the radiation meter when a reading of .1 gram calorie per square centimeter per minute is reached. All readings at chick height

Table 11. "(Continued)"

Date		Inches							
		1	2	3	4	5	6	7	8
May									
5	(7:30am)	34	34	34	28	33	32	30	31
	(4:00pm)	38	36	34	31	35	32	34	35
6	(7:00am)	38	27	10*	21	35	18	9*	26
7	(8:30am)	36	24	8*	22	33	26	9*	25
	(4:00pm)	41	20	11*	28	35	27	32*	25
8	(8:15am)	41	33	36	28	36	32	33	33
	(4:30pm)	36	18	13*	18	35	23	13*	23
9	(8:30am)	35	11	11*	19	32	17	12*	23
	(4:00pm)	38	18	13*	21	36	30	32*	26
10	(8:30am)	36	12	12*	17	32	18	13*	23
	(4:00pm)	38	31	35	30	35	31	33	32
11	(8:30am)	38	11	9*	17	32	20	12*	20
	(3:30pm)	40	19	12*	20	36	24	14*	26
12	(8:30am)	8*	16	32	14	9*	14	32	16
13	(6:45am)	10*	15	31	12	11*	18	28	10
14	(8:30am)	13*	20	31	14	9*	17	29	14
	(1:45pm)								
15	(2:30pm)	17*	24	32	17	9*	18	32	20
16	(8:30am)	15*	21	32	14	13*	17	28	16
17	(2:00pm)								
18	(8:30am)	11*	21	29	15	12*	18	30	13
	(4:00pm)								

Table 12. Average weekly radiation intensity measurements for the infra-red heat lamp brooder[a]

Week	Inches							
	1	2	3	4	5	6	7	8
1	38.5	34.0	34.1	25.7	31.1	31.4	31.7	32.3
1	35.8	25.0	4.7	24.0	31.5	23.8	7.8	26.2
2	36.1	35.6	35.3	27.4	31.9	31.8	32.4	32.6
2	35.0	24.6	5.8	24.6	32.8	25.0	7.6	25.4
3	37.8	33.5	34.8	29.3	34.8	31.8	32.5	32.8
3	37.6	17.8	11.0	20.3	34.0	22.6	16.2	24.1
4[b]								
4	12.3	19.5	31.2	14.3	10.5	17.0	29.8	14.8

[a]The first row of numbers for each week indicate that these values were taken with all bulbs burning. The second row of numbers for each week indicate that these values were taken with two bulbs burning.

[b]Only two bulbs were used for the entire fourth week.

The value of U is determined by the following formula.

$$U = \frac{1}{\frac{1}{f_i} + \frac{1}{f_o} + \frac{x}{k} + \frac{x}{k_1} + \frac{1}{a_1} + \frac{1}{a_2} + \text{etc.}}$$

where f_i = inner surface conductance usually taken at 1.6 or 1.65

f_o = outer surface conductance usually taken as 6.0 (15 mph wind)

x = thickness of solid material, inches

k = heat conductivity of solid, BTU per hour per square foot per inch thickness per degree Fahrenheit

a = heat transmitted across air space within construction BTU per square foot per hour per degree Fahrenheit = 1.1

U = heat flow through wall, BTU per hour per square foot per degree Fahrenheit (an overall coefficient)

The following is a sample calculation of heat transmission through the aluminum hover of the portable floor plate brooder with electric heating elements. In this calculation only the surface conductance coefficient was used. Air velocity was checked outside the hover as well as inside and was found to be low. This low value of air velocity corresponds to the surface conductance coefficient of 1.65 which is used for inside surfaces. This surface conductance value was used for the inside and outside surface of the hover.

The thickness of the aluminum hover was .030 inches and had a conductivity of 1393 BTU per hour per square foot per degree Fahrenheit difference per inch of thickness. In the U calculation this has an almost negligible value and was omitted.

$$U = \frac{1}{\frac{1}{1.65} + \frac{1}{1.65}} = \frac{1}{1.21} = .826 \text{ BTU per hr per sq ft per } ^{\circ}F$$

A = area of hover, 29.7 square feet

$H = AU (t_1 - t_o)$

$= 29.7 \times .826 (78.3 - 58.7)$

$= 29.7 \times .826 \times 19.6$

= 481 BTU/hour

= 80,600 BTU lost by conduction and radiation the first week.

Heat transfer by convection was not calculated separately but was taken into account by the surface conductance coefficient. Heat transfer by radiation was calculated from Table 14. This table gives the unit radiation from the hot body to absolute zero and the unit radiation of the receiving or cold body to absolute zero. By subtracting to find the difference which is the unit radiation when the emmissivity is 1.0, the heat transfer by radiation is found. Values for emmissivity of various materials can be found in Table 7.

The following is a sample calculation of heat transfer by radiation for the portable floor plate brooder with electric heating elements. The average temperature for the surface of the hover (hot body) for week one is taken as 65.9 degrees Fahrenheit. The average air temperature for the first week is 54.9 degrees Fahrenheit. The unit radiation of the hot body at the given temperature in relation to absolute zero and the unit radiation of the receiving body at the given temperature in relation to absolute zero are found in Table 14. By subtraction, the difference or unit radiation between the two bodies is found.

65.9 °F -- 131.7

54.9 °F -- <u>121.0</u>

10.7 BTU per sq ft per hr
or unit radiation

167.76 number hours for week one

29.7 hover area in square feet

10.7 x 167.75 x 29.7 = 53,400 BTU heat transfer for week one
for an emissivity of one.

The emissivity of polished aluminum was found in Table 7 as .04.

53,400 x .04 = 2,144 BTU heat transfer for week one by radiation.

Table 13. Average weekly temperatures for the portable floor plate brooder with electric heating elements

Week	T_1[a]	T_2[b]	T_4[c]	T_5[d]	T_6[e]	T_7[f]	T_9[g]	T_8[h] & T_9	Hours by weeks
1	98.9	128.9	82.2	78.3	65.9	58.7	53.6	54.9	167.75
2	99.2	131.2	82.6	78.4	66.0	59.8	53.1	54.1	168.50
3	93.1	117.3	84.5	81.5	72.8	68.3	64.7	65.5	167.25
4	81.3	97.7	81.8	80.0	74.7	72.1	70.2	71.1	168.50

[a] Temperatures below heat slab.

[b] Temperatures inside heat slab.

[c] Temperatures below hover peak (6").

[d] Temperatures below hover surface (3/4").

[e] Surface temperature of hover.

[f] Temperatures above hover surface (3/4").

[g] Inside temperature of brooder house wall.

[h] Combined air temperature inside brooder house wall and air temperature near hover.

Table 14. Radiation from surfaces to surroundings at absolute zero when emissivity 1.0

Surface Temperature F	Radiation BTU per Sq. Ft./Hr.	Surface Temperature F	Radiation BTU per Sq. Ft./Hr.	Surface Temperature F	Radiation BTU per Sq. Ft./Hr.
30	99.3	66	131.8	102	172.2
31	100.0	67	132.8	103	173.3
32	101.0	68	133.9	104	174.4
33	101.7	69	134.8	105	175.5
34	102.3	70	135.9	106	176.6
35	103.3	71	136.8	107	176.9
36	104.2	72	137.9	108	179.3
37	105.0	73	139.0	109	180.6
38	105.9	74	140.0	110	182.0
39	106.7	75	141.1	111	183.3
40	107.6	76	142.2	112	184.7
41	108.3	77	143.3	113	186.0
42	109.3	78	144.4	114	186.9
43	110.1	79	145.4	115	188.5
44	111.1	80	146.5	116	189.9
45	112.2	81	147.6	117	191.2
46	113.1	82	148.6	118	192.5
47	113.9	83	149.6	119	193.9
48	114.7	84	150.8	120	194.6
49	115.5	85	151.9	121	195.9
50	116.6	86	153.1	122	197.3
51	117.6	87	154.1	123	198.8
52	118.4	88	155.4	124	200.0
53	119.4	89	156.5	125	201.4
54	120.2	90	157.7	126	202.8
55	121.1	91	159.0	127	204.2
56	122.2	92	160.0	128	205.5
57	123.0	93	161.2	129	206.9
58	124.0	94	162.4	130	208.4
59	125.1	95	163.5	135	215.3
60	125.9	96	164.6	140	222.8
61	126.9	97	165.8	145	230.4
62	127.7	98	167.0	150	238.1
63	128.8	99	168.5	175	279.6
64	130.0	100	169.7	200	326.3
65	130.8	101	170.9		

"Table reproduced from Heating and Ventilating's Engineering Databook. p. 5-10. 1st Ed. 1948."

Heat transfer through the ventilator of the portable floor plate brooder with electric heating elements was calculated from the following formula.

Z = specific heat x density x $Q\ (t_i - t_o)$

$= 0.24 \times .075\ Q\ (t_i - t_o)$

where Z = heat production in BTU per minute

Q = air flow in CFM

$t_i - t_o$ = temperature difference inside minus outside in degrees F

0.24 = specific heat of air (BTU per lb per degree F)

.075 = density of air at 70 degrees F (lbs/cubic foot)

The following is a sample calculation of heat transfer through the ventilator of the portable floor plate brooder with electric heating elements. The temperatures (t_i) were averaged weekly and were inside hover temperatures. The temperatures (t_o) were averaged weekly and are air temperatures outside the ventilator opening. The average weekly temperatures are found in Table 13.

Also in order to calculate heat transfer through the ventilator the size of the ventilator opening had to be taken into account. The opening was one square inch, which in terms of square feet is .00695. This value multiplied by the air velocity in feet per minute is the value for Q (air flow CFM). The average air velocity for week one, found in Table 15, was 95.1 feet per minute.

$Q = 95.1 \times .00695$

$= .661$ CFM

$Z = 0.24 \times .075\ Q\ (t_i - t_o)$

$= 0.24 \times .075 \times .661\ (82.2 - 54.9)$

Table 15. Average weekly air velocity (FPM) measurements for the portable floor plate brooder with electric heating elements

Week	Points		
	2 & 5[b]	1[c]	3, 4, & 6[d]
1	24.2	95.1	26.9
2	21.6	107.8	27.9
3[a]	22.2	93.2	26.3
4[a]	21.4	75.9	24.4

[a]Windows were open the third and fourth weeks.

[b]Air velocity by natural convection near top of hover.

[c]Air velocity through one square inch ventilator.

[d]Air velocity moving under hover edge.

$$= 0.24 \times .075 \times .661 \times 27.3$$

$$= .326 \text{ BTU per minute}$$

This value multiplied by 60 minutes in an hour and the number of hours in week one gives the total heat transfer for the week in BTU.

$.326 \times 60 \times 167.75 = 3,280$ BTU heat transfer through the ventilator for week one.

Heat transfer by conduction through the plate for the portable floor plate brooder with electric heating elements was calculated in much the same pattern as for the hover. The same formula $H = AU\ (t_1 - T_o)$ was used except that for different materials a new U value had to be calculated. Using the same formulas as before the U value of the materials in the plate was found to be .324. The area of the plate was 16 square feet and the average weekly temperature for the heating element

and the outside average weekly temperature were found to be 128.9 and 98.9 degrees F respectively. These values are found in Table 13. A sample calculation follows.

$$H = AU\,(t_i - t_o)$$
$$= 16 \times .324\,(128.9 - 98.9)$$
$$= 16 \times .324 \times 30$$
$$= 155.7 \text{ BTU per hour}$$

This value multiplied by the number of hours in the first week gives 26,100 as the total heat transfer (BTU) by conduction and radiation through the plate.

To find the energy consumption of the portable floor plate brooder with electric heating elements, a kilowatt hour meter was used. This meter was read at the end of week one. One kilowatt hour is equal to 3,415 BTU. This value times the meter reading gives the energy consumption for week one in BTU. For example, the number of kilowatt hours used was 50.5.

$$50.5 \times 3415 = 172{,}000 \text{ BTU energy consumption for week one}$$

Heat transfer by conduction for the conventional electric brooder was calculated in much the same way. However the hover had a ceiling of fiber board that created a loft or air space for added insulation, so that a different method had to be used for the calculation of the U value. The following formula was used.

$$U_c = \frac{(U_r)(U_{ce})}{U_r + (U_{ce/n})}$$

where U_c = combined coefficient to be applied to the ceiling area

U_r = transmission coefficient for roof

U_{ce} = transmission coefficient for ceiling

n = ratio of roof area to ceiling area

The value of U_c given by the above equation is then applicable to the ceiling area for purposes of estimating heat flow through ceiling and roof combined. This combined coefficient of heat transfer to be applied to the ceiling was found to be .424. The rest of the surface below the ceiling had a U value or coefficient of .826. To find the heat transfer by conduction and radiation, each of the above values had to be used separately in the formula $H = AU (t_1 - t_o)$.

Heat transfer by radiation for the conventional electric brooder was calculated in the same manner as for the portable floor plate brooder with electric heating elements. Heat transfer by convection was taken into account by the surface conductance coefficient.

Due to the fact that the infra-red heat lamp brooder did not utilize a hover, calculation of heat transfer in this area was unnecessary. To calculate heat transfer through the base, the formula $H = AU (t_1 - t_o)$ was used. The area of the base was 2.25 square feet. U value was calculated as .827. The values of the average weekly temperatures t_1 and t_o are found in Table 16.

The calculation is as follows.

$$H = AU (t_1 - t_o)$$
$$= 2.25 \times .827 \ (113.7 - 84.0)$$
$$= 2.25 \times .827 \times 29.7$$
$$= 55.25 \text{ BTU per hour}$$

This value times the number of hours in week one gives 9,260 BTU heat transfer by conduction and radiation. Heat transfer by convection

Table 16. Average weekly temperatures for the infra-red heat lamp brooder

Week	T_2[a]	T_3[b]	T_4 & T_5[c]
1	113.7	84.0	62.4
2	116.5	84.4	62.5
3	117.8	91.2	73.2
4	106.7	92.2	75.2

[a]Lower surface and socket temperature of base.

[b]Top surface temperature of base.

[c]Combined air temperature inside brooder house wall and air temperature near hover.

was again taken into account by the surface conductance coefficient. To determine this coefficient the air velocity above and below the hover was checked. This surface conductance coefficient was used in the calculation of the U value in the heat transfer formula $H = AU\,(t_i - t_o)$.

A study of the ability of various materials to reflect radiant energy was made. These materials were set perpendicular to the radiation of a 250 watt infra-red bulb. All these materials were alternately inserted in a holder one foot from the center of the bulb and each had a surface area of one square foot.

The surface of each material had a different characteristic. Some were unpainted and some were coated with either white, black or

aluminum paint. At the distance specified, a quantitative measurement of the amount of radiation intensity reflected was taken by a DW60 radiation meter. This meter was in a fixed position to give a comparative reading of the various materials. Also a measurement of the direct radiation intensity of the infra-red bulb was made at various intervals.

To help in the selection of material for the construction of the portable floor plate brooder with electric heating elements a study of the ability of various materials to reflect radiation was made. Twelve materials that could be used in the construction of this portable brooder were selected. These materials included aluminum, iron, masonite with several different surfaces as well as others. For a complete descriptive list of these materials see Table 25. Some of the materials were the same except that the characteristics of the surface were changed by painting. The source of radiation was a 250 watt infra-red heat lamp bulb. The intensity of the radiation that was reflected was measured by the radiation meter.

To keep the conditions of the test the same, each material had a surface area of one square foot. The position of the meter, the material, and the bulb were fixed. Radiation for each material tested had to travel the same distance and be reflected back to the meter at the same angle. The only variable that affected the intensity of the reflected radiation was the surface characteristic of the material.

RESULTS

Temperature readings, air velocity measurements, and radiant intensity measurements were taken daily. Daily temperature readings for the portable floor plate brooder with electric heating elements, conventional electric brooder, and the infra-red heat lamp brooder are shown in Tables 8, 9, and 10 respectively. The daily air velocity measurements for these brooders are shown in Tables 17, 18, and 19 respectively. Daily radiation intensity could not be measured directly for the portable floor plate brooder with electric heating elements and conventional electric brooder. The daily radiant intensity measurements for the infra-red heat lamp brooder are shown in Table 11.

The numerous daily temperature readings, daily air velocity measurements, and daily radiant intensity measurements were condensed into average weekly readings and measurements. The average weekly temperatures for the brooders are shown in Tables 13, 16, and 20. Tables 15, 21, and 22 show the average weekly air velocity measurements for the brooders.

The average weekly temperatures were used in calculation of heat transfer by conduction. This is shown in the form of bar graphs for easy comparison. (Figures 17, 18, and 19) The average weekly temperatures were also used in the calculation of heat transfer through the ventilator. The graphs showing heat transfer through the ventilator for the portable floor plate brooder with electric heating elements and the conventional electric brooder are shown in Figures 20 and 21.

Heat transfer by radiation for the portable floor plate brooder with electric heating elements, through the hover of the conventional

electric brooder, and through the base of the infra-red heat lamp brooder could not be measured directly. The average weekly temperatures could again be used for this calculation of heat transfer. The results are shown in bar graphs. (Figures 22,23,and 24) Heat transfer by radiation from the bulbs of the infra-red heat lamp had to be handled in a different manner. Radiant intensity was measured in different areas of the brooding zone. From this, a pattern of radiant intensity was made. These patterns are shown in Figures 25, 26, 27, 28, 29, 30, and 31 for the infra-red heat lamp brooder.

Electric input for each brooder was measured through separate watt hour meters. This input was calculated in BTU and the results shown in Figures 32, 33, and 34. On the basis of two cents per kilowatt hour, the cost of brooding a chick for a period of four weeks was computed. Comparative operation costs are found in Tables 23 and 24.

This rate of two cents per kilowatt hour was chosen as a figure with which to calculate brooding costs. The basis for this choice was that a farm in South Dakota not using an electric hot water heater but using over 300 kilowatt hours per month would be charged at the rate of two cents per kilowatt hour.

The difference between heat input and the total heat transfer by conduction, convection, and radiation was considered as unaccountable heat transfer. This unaccountable heat transfer for the portable floor plate brooder with electric heating elements and the conventional electric brooder is shown in Figures 35 and 36.

The investigation of the radiation reflective characteristics of

Table 17. Daily air velocity (FPM) measurements for the portable floor plate brooder with electric heating elements

Date			1	2	3	4	5	6
April	20	(3:30pm)	55	25	25	24	25	20-23
	21	(8:00am)	91	25		25	25	30-31
	22	(6:30am)	100	33	28-33	31	19	28
		(2:15pm)	75	32	32	26	22	25
	23	(5:00pm)	118	37	31	28	22	25
	24	(7:30am)	110	20	27	27	28	25
		(3:30pm)	101	27	35	24	21	33
	25	(7:15am)	95	30-35	28	20	16	29
		(2:00pm)	86	22	22	25	16	24
	26	(8:15am)	110	18	30	25	15	38
		(4:00pm)	71	15	22	25	25	26
	27	(8:15am)	105	31	23	21	25	27
		(10:15am)	85	12	25	25	30	31
		(1:30pm)	110	27	28	25	30	27
		(3:45pm)	115	23	27	28	26	29
	28	(8:00am)	118	21	28	24	25	28
		(4:15pm)	110	21	28	30	31	27
	29	(7:00am)	110	26	32	30	20	30
	30	(8:00am)	100	20	27	25	21	27
		(4:15am)	83	25	32	25	27	26
May	1	(7:15am)	130	23	30	25	23	28
		(4:15pm)	130	16	27	25	23	25
	2	(8:15am)	145	23	33	25	23	28
		(4:15pm)	100	23	27	27	16	30
	3	(7:15am)	100	24	34	31	20	27
		(4:00pm)	62	22	27	25	21	31
	4	(8:15am)	130	15	33	20	15	25
		(4:15pm)	83	15	27	36	23	25

[a]Refer to Figure 14 for locations of the air velocity measurements

Table 17. "(Continued)"

Date			1	2	3	4	5	6
May	5	(7:30am)	130	16	27	22	22	26
		(4:00pm)	111	16	27	21	21	28
	6	(7:00am)	110	21	29	22	16	26
	7	(8:30am)	108	20	26	20	15	26
		(4:00pm)	51	27	25	35	23	25
	8	(8:15am)	100	41	45	38	32	26
		(4:30pm)	120	33	25	29	23	29
	9	(8:30am)	109	21	24	28	12	25
		(4:00pm)	47	17	23	21	21	21
	10	(8:30am)	108	23	31	29	26	30
		(4:00pm)	102	28	26	27	20	23
	11	(8:30am)	68	18	30	23	23	25
		(3:30pm)	48	20	16	23	21	24
	12	(8:30am)	30	19	26	21	16	27
	13	(6:45am)	101	22	24	26	31	27
	14	(8:30am)	73	22	22	21	18	26
		(1:45pm)	44	20	21	23	18	24
	15	(2:30pm)	95	27	25	30	18	26
	16	(8:30am)	100	17	21	22	23	23
	17	(2:00pm)	60	22	27	27	16	25
	18	(8:30am)	110	25	29	26	25	24
		(4:00pm)	70	26	26	20	22	21

Table 18. Daily air velocity (FPM) measurements for the conventional electric brooder[a]

Date	1	2	3	4	5	6	7	8
April								
20 (4:00pm)	135	20	20-22	30	38	24	24	28
21 (8:00am)	80	26	33	21	31	19	32	30
22 (6:30am)	102	60	27	26	32	15	44	40
(2:15pm)	90	32	32	25	26	25	32	27
23 (5:00pm)	120	17	16	17	26	27	35	20
24 (7:30am)	100	35	30	21	31	18	26	37
(3:30pm)	95	26	38	40	30	15	21	40
25 (7:15am)	100	35	31	26		22	32	25
(2:00pm)	120	23	21	25	21	25	25	23
26 (8:15am)	100	34	20	27	22	25	38	24
(4:00pm)	120	25	22	28	31	26	26	22
27 (8:15am)	90	38	25	30	38	29	44	15
(10:30am)	105	34	40	35	25	31	47	26
(1:30pm)	109	41	40	33	35	23	32	32
(3:45pm)	100	36	24	28	38	30	33	26
28 (8:00am)	100	40	20	33	33	51	64	22
(4:15pm)	90	50	25	29	33	56	60	31
29 (7:00am)	100	40	35	27	28	46	46	32
30 (8:00am)	80	25	19	27	31	21	47	24
(4:15pm)	112	30	19	29	26	34	43	27
May								
1 (7:15am)	100	40	26	29	23	32	32	29
(4:15pm)	130	33	26	28	34	28	41	30
2 (8:15am)	101	21	22	27	33	19	30	27
(4:15pm)	160	25	20	35	25	11	27	27
3 (7:15am)	110	22	20	30	25	20	20	29
(4:00pm)	120	22	21	27	20	17	25	27
4 (8:15am)	145	20	24	27	33	10	31	26
(4:15pm)	100	29	21	27	28	10	30	23

[a]Refer to Figure 15 for location of the air velocity measurements

Table 18. "(Continued)"

Date		1	2	3	4	5	6	7	8
May									
5	(7:30am)	130	38	17	20	20	10	36	26
	(4:00pm)	135	30	20	28	28	25	48	22
6	(7:00pm)	106	38	34	35	33	24	38	21
7	(8:30am)	150	21	21	25	38	22	24	26
	(4:00pm)	140	20	23	31	27	22	23	41
8	(8:15am)	111	33	22	32	36	18	31	31
	(4:30pm)	120	25	23	25	23	25	28	27
9	(8:30am)	125	33	22	26	25	30	35	28
	(4:00pm)	138	27	20	28	32	22	21	32
10	(8:30am)	110	32	27	36	37	24	22	25
	(4:00pm)	125	22	22	27	26	21	26	23
11	(8:30am)	120	32	24	28	42	17	29	28
	(3:30pm)	150	15	16	30	50	26	25	29
12	(8:30am)	140	19	21	25	45	25	23	26
13	(6:45am)	140	47	27	33	30	21	35	30
14	(8:30am)	115	23	33	34	27	17	25	30
	(1:45pm)	120	20	22	27	30	22	25	26
15	(2:30pm)	100	40	22	29	28	20	24	25
16	(8:30am)	110	27	30	36	30	24	34	24
17	(2:00pm)	130	15	20	27	30	25	25	36
18	(8:30am)	160	20	23	29	38	15	26	30
	(4:00pm)	105	46	22	35	32	22	22	28

Table 19. Daily air velocity (FPM) measurements for the infra-red heat lamp brooder[a]

Date			1	2	3	4
April	20	(4:00pm)	20	21	20	21
	21	(8:00am)	15	32	25	30
	22	(6:30am)	21	62	22-25	35
		(2:15pm)	11	13	21	21
	23	(5:00pm)	21	19	23	17
	24	(7:30am)	26	37	28	21
		(3:30pm)	55	75	24	20
	25	(7:15am)	32	29	24	24
		(2:00pm)	31	50	25	23
	26	(8:15am)	21	23	18	25
		(4:00pm)	18	38	26	20
	27	(8:15am)	29	70	53	48
		(10:30am)	43	55-85	55	50
		(1:30pm)	13	36	34	35
		(3:45pm)	42	44	46	34
	28	(8:00am)	32	28	30	27
		(4:15pm)	37	46	41	41
	29	(7:00am)	33	33	36	37
	30	(8:00am)	13	21	20	26
		(4:15pm)	26	20	24	49
May	1	(7:15am)	34	33	20	24
		(4:15pm)	33	25	48	45
	2	(8:15am)	27	23	28	30
		(4:15pm)	23	20	20	25
	3	(7:15am)	25	23	23	32
		(4:00pm)	18	13	24	31
	4	(8:15am)	14	20	24	15
		(4:15pm)	19	20	23	25

[a]Refer to Figure 16 for location of the air velocity measurements

Table 19 "(Continued)"

Date			1	2	3	4
May	5	(7:30am)	26	22	30	48
		(4:00pm)	17	26	33	33
	6	(7:00am)	52	14	35	58
	7	(8:30am)	20	25	17	27
		(4:00pm)	21	21	22	25
	8	(8:15am)	25	26	16	21
		(4:30pm)	26	31	26	20
	9	(8:30am)	27	42	24	22
		(4:00pm)	16	18	29	20
	10	(8:30am)	28	23	33	49
		(4:00pm)	25	20	25	20
	11	(8:30am)	25	27	22	26
		(3:30pm)	30	26	22	21
	12	(8:30am)	19	22	15	
	13	(6:45am)	22	25	30	25
	14	(8:30am)	15	27	40	37
		(1:45pm)	22	23	15	20
	15	(2:30pm)	24	25	20	20
	16	(8:30am)	21	25	20	21
	17	(2:00pm)	20	26	29	25
	18	(8:30am)	25	26	30	29
		(4:00pm)	23	28	23	21

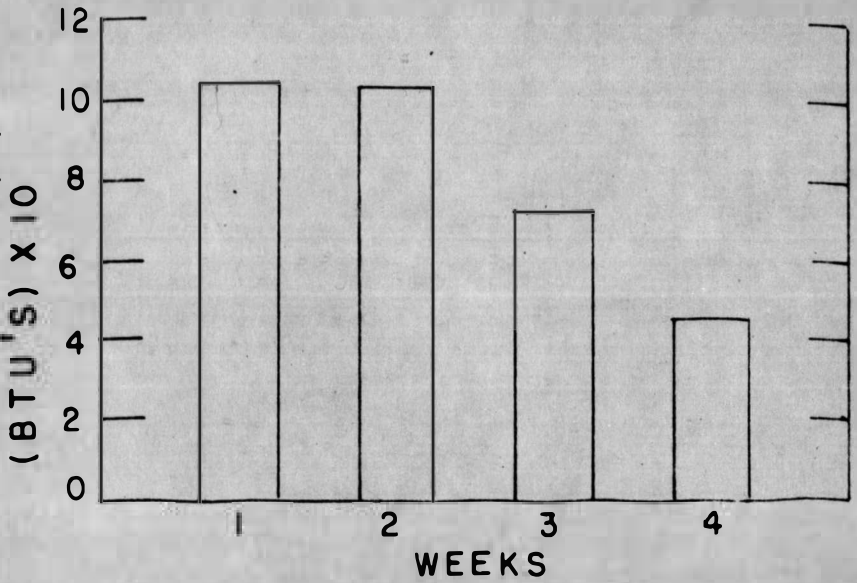


Figure 17. Heat transfer (BTU) by conduction through the hover and plate for the portable floor plate brooder with electric heating elements (includes heat transfer by radiation through the plate)

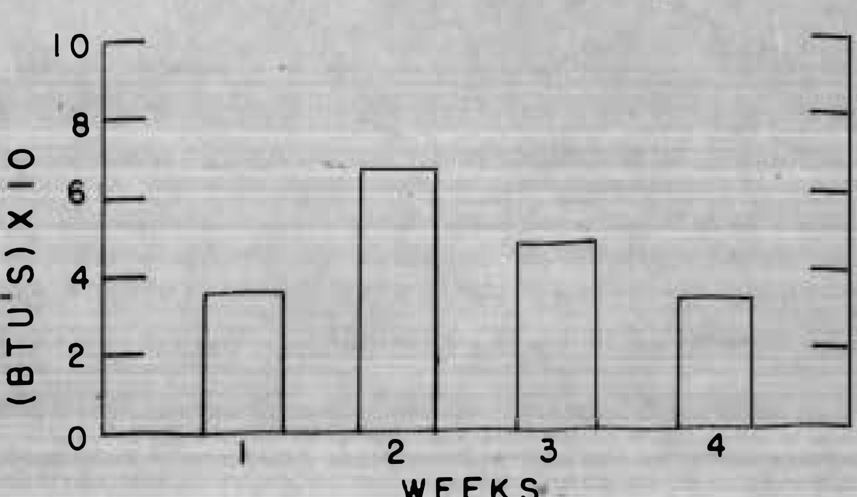


Figure 18. Heat transfer (BTU) by conduction through the hover for the conventional electric brooder

Figure 19. Heat transfer (BTU) by conduction through the base of the infra-red heat lamp brooder (week 4 includes heat transfer by radiation)

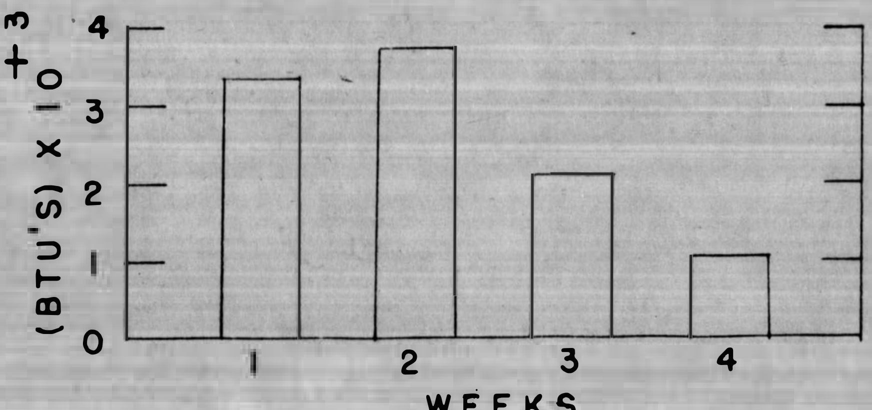


Figure 20. Heat transfer (BTU) through the ventilator of the portable floor plate brooder with electric heating elements

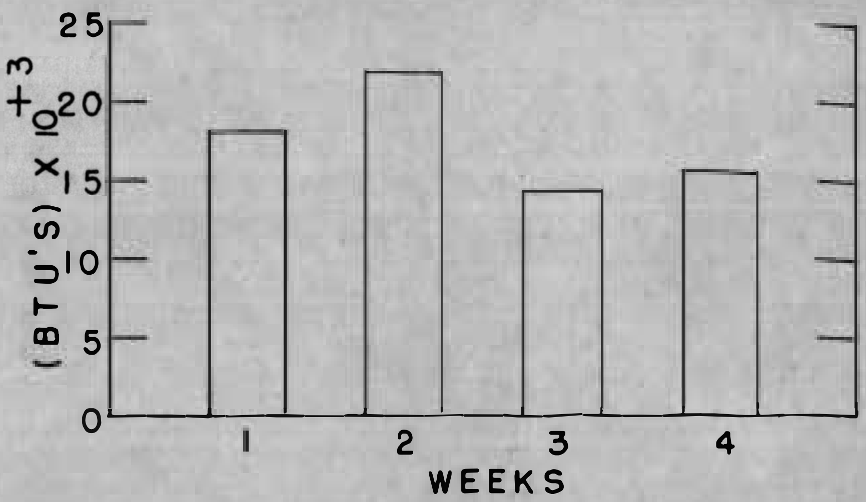


Figure 21. Heat transfer (BTU) through the ventilator of the conventional electric broder

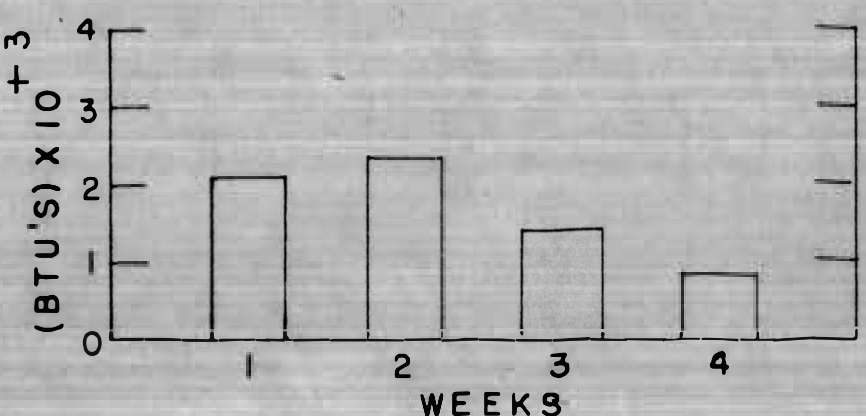


Figure 22. Heat transfer (BTU) by radiation for the portable floor plate brooder with electric heating elements

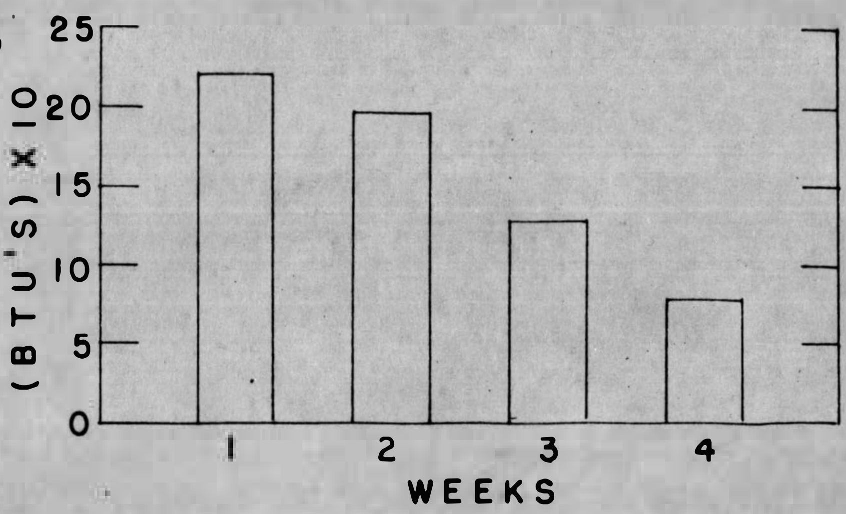


Figure 23 Heat transfer (BTU) by radiation for the conventional electric brooder

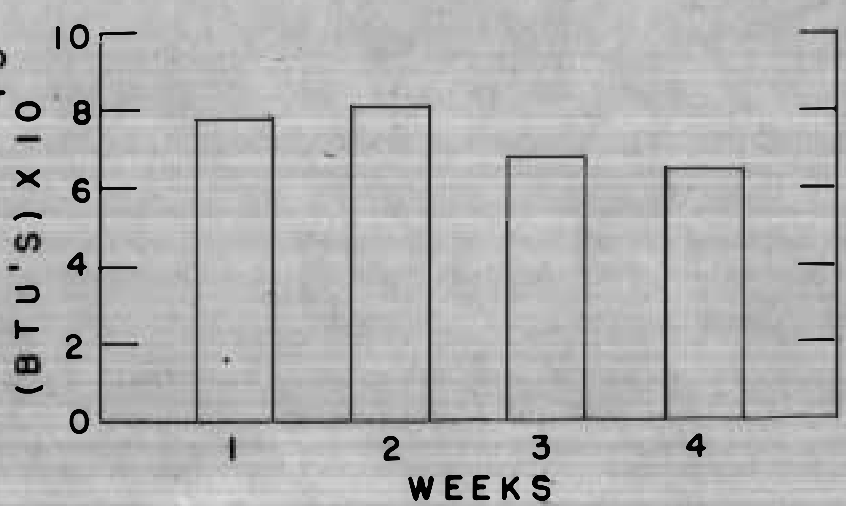
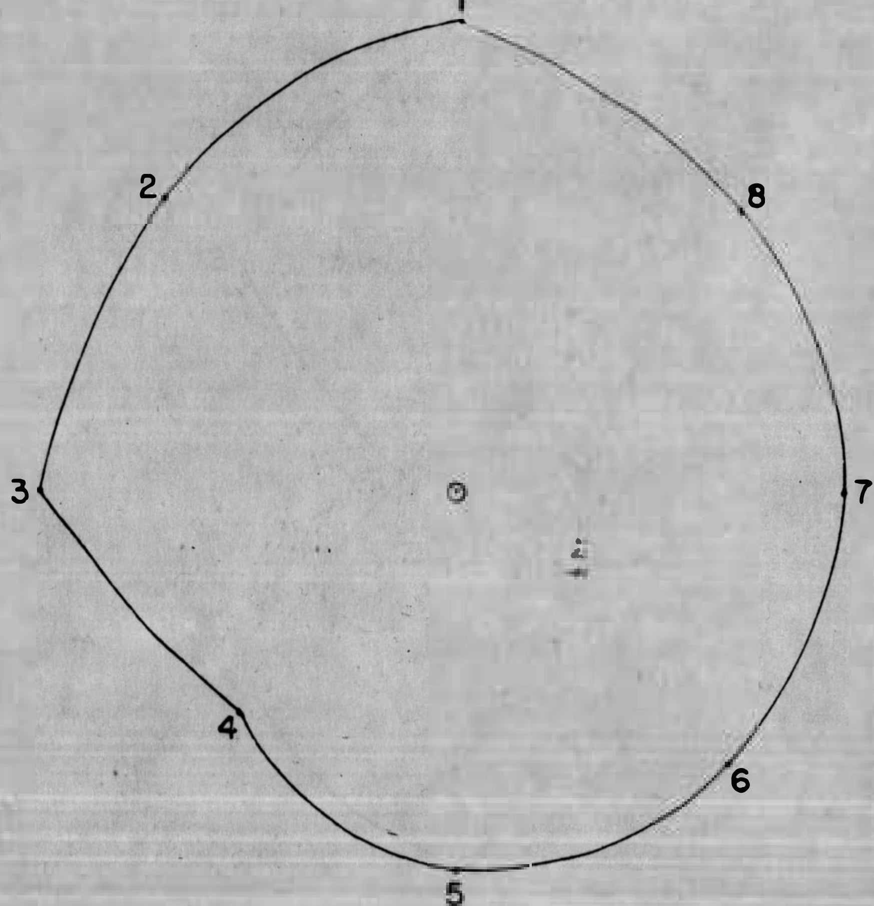
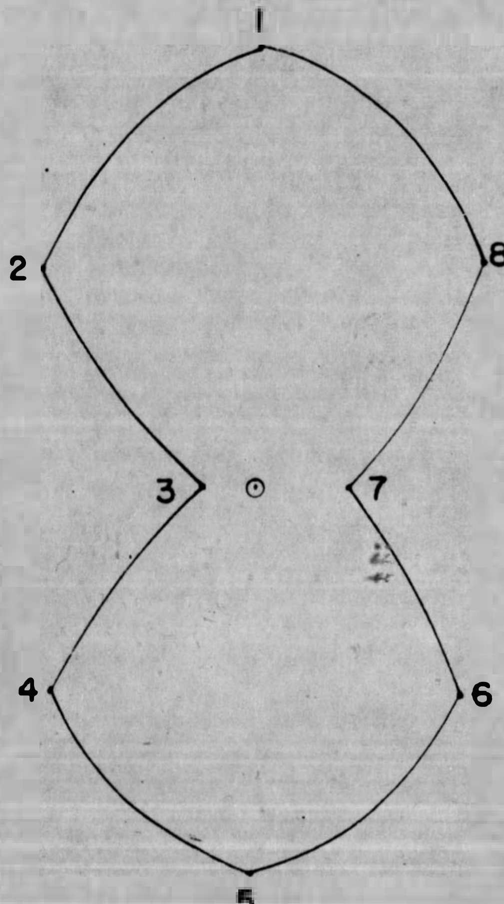


Figure 24 Heat transfer (BTU) by radiation from the top surface of the infra-red heat lamp brooder



SCALE 1/16"=1"

Figure 25 Radiant heat pattern for the infra-red heat lamp brooder (All lamps burning for week one)



SCALE 1/16" = 1"

Figure 26 Radiant heat pattern for the infra-red heat lamp brooder (Two lamps burning for week one)

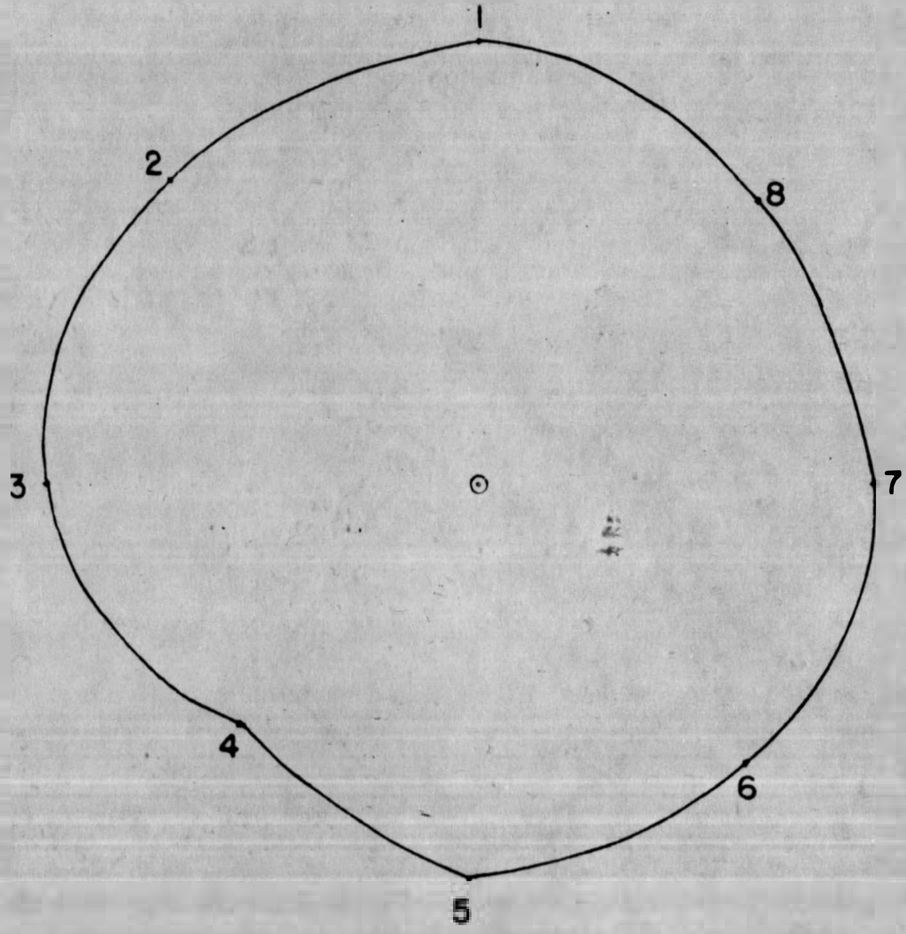
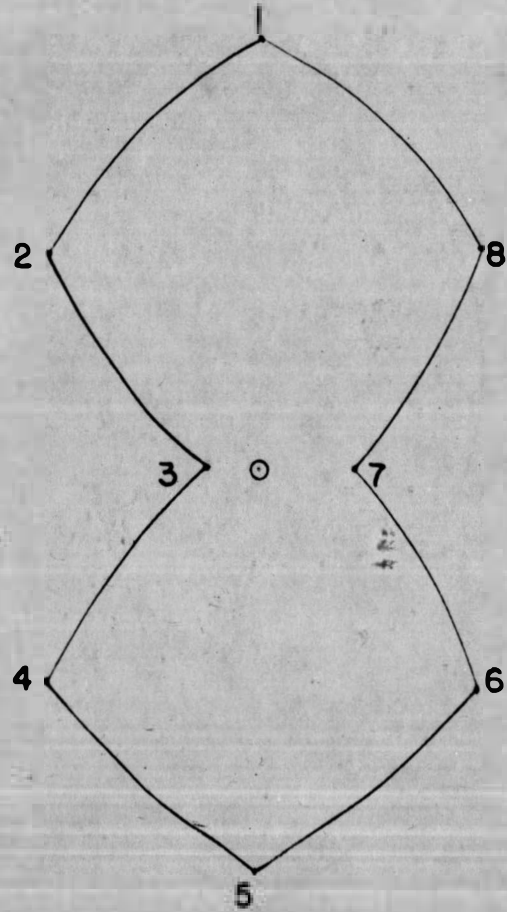
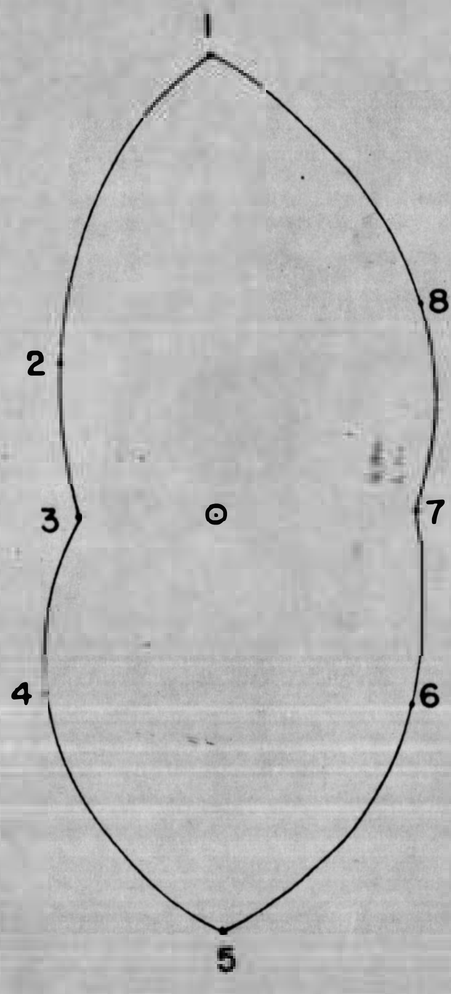


Figure 27 Radiant heat pattern for the infra-red heat lamp brooder (All lamps burning for week two)



SCALE 1/16"=1"

Figure 28 Radiant heat pattern for the infra-red heat lamp brooder (Two lamps burning for week two)



SCALE 1/16" = 1"

Figure 29 Radiant heat pattern for the infra-red heat lamp brooder (Two lamps burning for Week three)

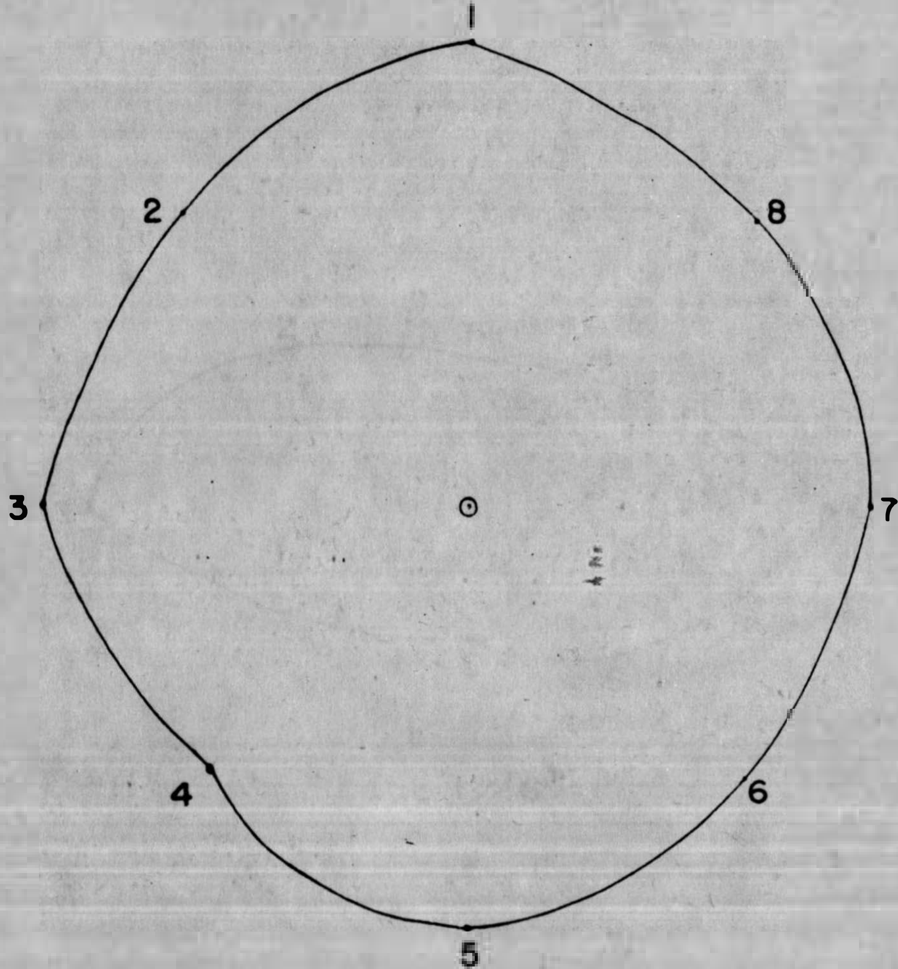
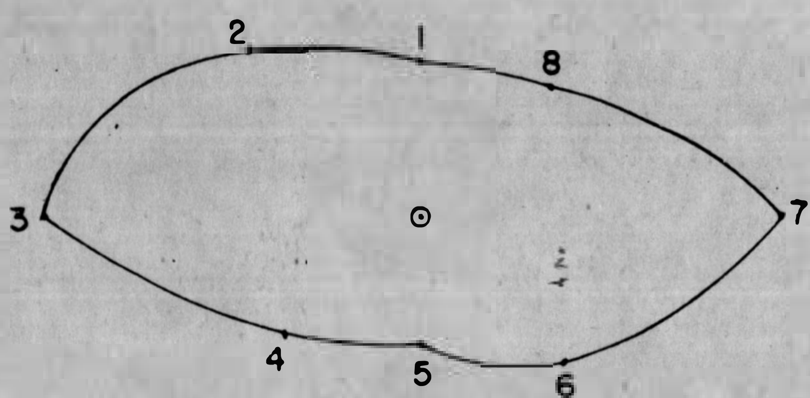


Figure 30 Radiant heat pattern for the infra-red heat lamp brooder (All lamps burning for week three)



SCALE 1/16" = 1"

Figure 31 Radiant heat pattern for the infra-red heat lamp brooder (Two lamps burning for week four)

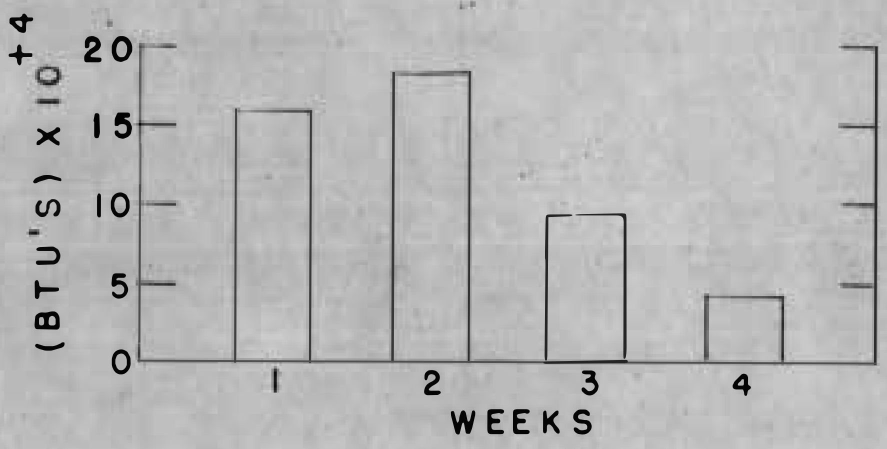


Figure 32. Heat input by weeks for the portable floor plate brooder with electric heating elements

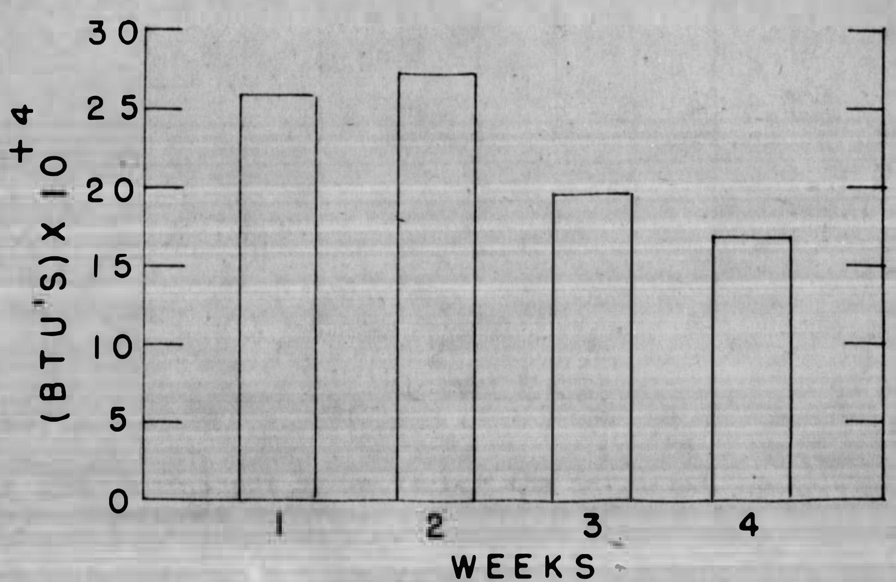


Figure 33. Heat input by weeks for the conventional electric brooder

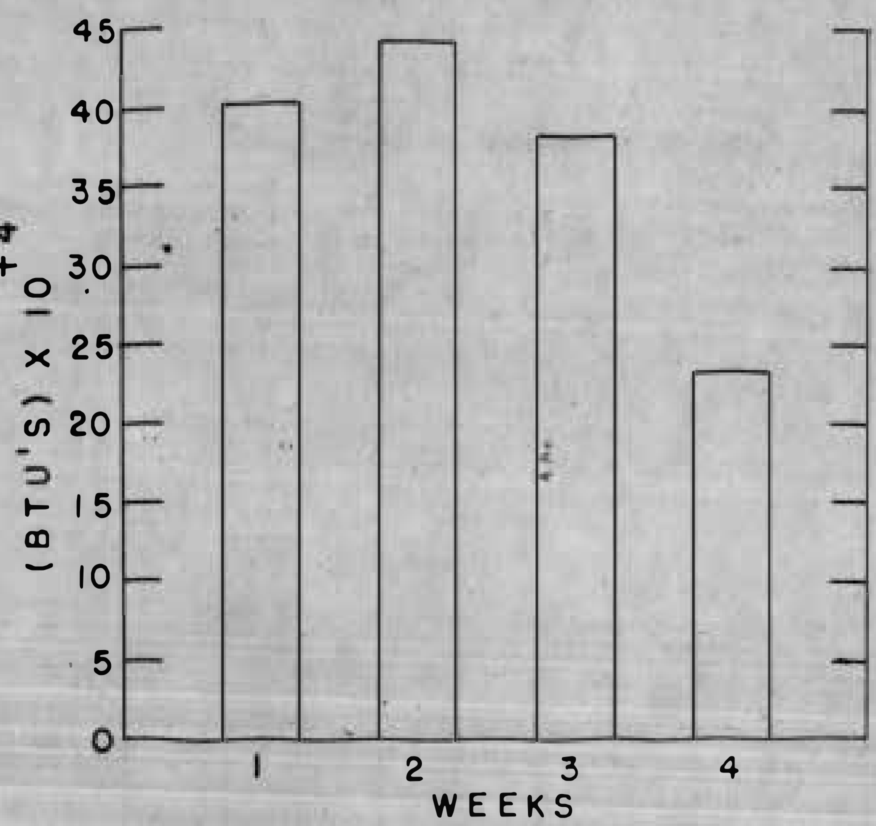
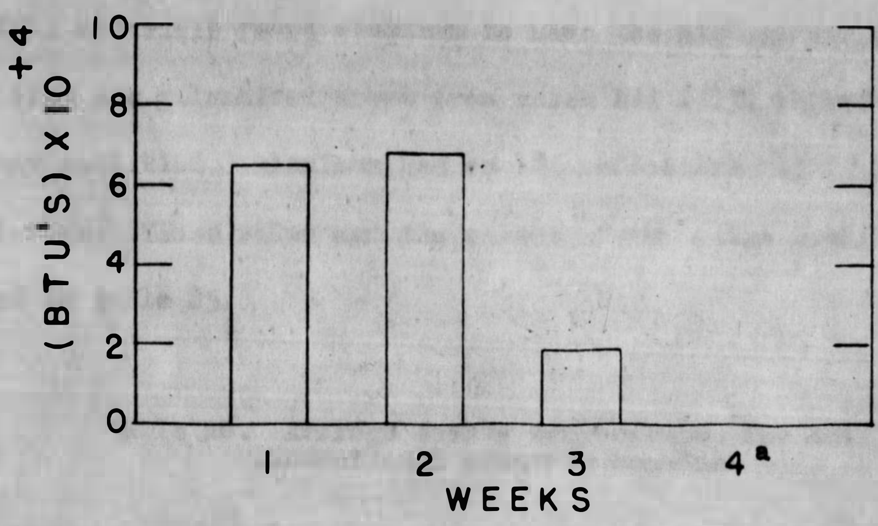


Figure 34 Heat input by weeks for the infra-red heat lamp brooder



[a]Heat transfer exceeded heat input

Figure 35. Unaccountable heat transfer (BTU) for the portable floor plate brooder with electric heating elements

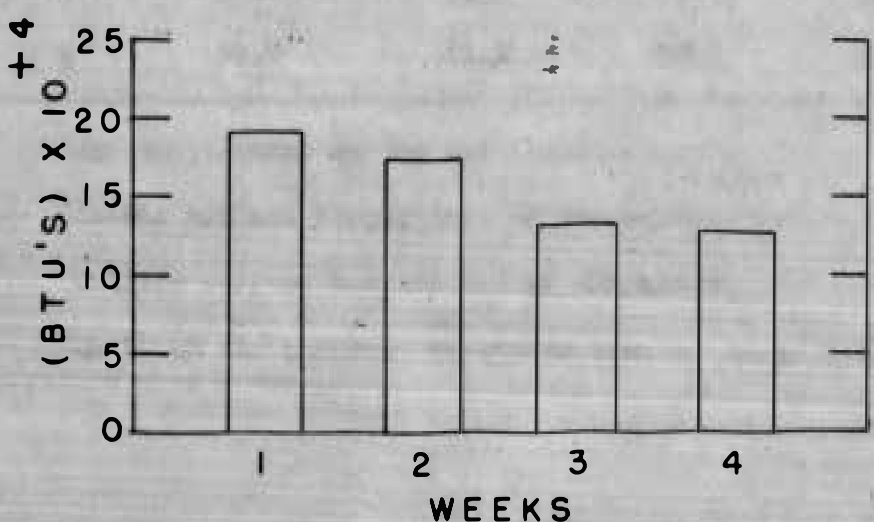


Figure 36. Unaccountable heat transfer (BTU) and heat transfer through the floor for the conventional electric brooder

various materials found aluminum to have the highest value. Second on the list was galvanized sheet iron which had a 13% reflection of the direct radiation. Aluminum had an 18% reflective value of direct radiation. These value and the values of the other materials are found in Table 25.

Table 20. Average weekly temperatures for the conventional electric brooder

Week	T_2[a]	T_3[b]	T_4[c]	T_5 & T_6[d]
1	99.2	95.4	73.0	57.4
2	101.8	97.1	71.5	57.5
3	96.8	95.3	76.7	68.2
4	90.8	91.8	78.9	73.9

[a]Air temperature at the fan inlet.

[b]Inside surface temperature of the hover.

[c]Outside surface temperature of the hover.

[d]Combined air temperature inside brooder house wall and air temperature near hover.

Table 21. Average weekly air velocity (FPM) measurements for the conventional electric brooder

Week	Points		
	1[b]	2,3,6,7[c]	4,5,8[d]
1	104.4	29.1	28.4
2	111.4	29.6	28.2
3[a]	127.7	25.6	29.4
4[a]	124.4	25.2	30.4

[a]Windows were open the third and fourth weeks.

[b]Air velocity through the ventilator opening.

[c]Air velocity by natural convection near top of hover.

[d]Air velocity under hover edge.

Table 22. Average weekly air velocity (FPM) measurement for the infra-red heat lamp brooder

Week	Points
	1, [illegible][b]
1	31.5
2	27.4
3[a]	26.6
4[a]	23.9

[a]Windows were open the third and fourth weeks.

[b]Air velocity at the base edge, a central location near the top surface, and a location midway between base center and edge.

Table 23. Comparative cost figures for broode units used in this research[a]

Brooder units	Cost Per Bird	Kilowatts Consumed
1. Infra-red heat lamp brooder	4.36 cents	429.0
2. Conventional electric brooder	2.65 cents	264.5
3. Portable floor plate brooder with electric heating elements	1.43 cents	142.0

[a]Test run for a four week period.

Table 24. Per cent power cost of the infra-red heat lamp brooder[a]

Brooder units	Per cent Cost
1. Infra-red heat lamp brooder	100.0 %
2. Conventional electric brooder	61.6 %
3. Portable floor plate brooder with electric heating elements	33.1 %

[a]Per cent power costs.

Table 25. Radiation reflection characteristic of materials in per cent of direct radiation from a 250 watt infra-red heat lamp bulb at a distance of one foot

Materials	Per cent Reflection
Direct radiation	100.0 %
Polished aluminum	18.0 %
Galvanized sheet iron	13.0 %
Masonite, aluminum painted surface	11.2 %
Celotex, smooth side	9.3 %
Cardboard, glossy white	8.7 %
Masonite, white painted surface	6.8 %
Plywood	6.8 %
Masonite, plain	6.2 %
Masonite, rough back	6.2 %
Asbestos-cement flexible wall board	6.2 %
Asphalt, black	1.2 %
Masonite, black painted surface	.6 %

ANALYSIS OF THE RESULTS

Heat input for the infra-red lamp brooder and the conventional brooder was considerably higher than the input for the portable floor plate brooder with electric heating elements. All three units had a higher input in the second week due to the cold weather. Warmer weather in the third and fourth weeks caused the input to drop considerably. When the chick is young, the brooding temperature has to be high to keep metabolism at a minimum. The chick has little covering to prevent heat from escaping from its body surface. The high surface weight ratio and an incompletely developed homeothermic mechanism in the chick give a high heat production characteristic to the young chick.[13] As the chick matures the temperature at which metabolism is at a minimum is lower.

Heat transfer by conduction through the hover was greater for the portable floor plate brooder with electric heating elements. This could be accounted for by the added insulation of the conventional electric brooder. The added insulation was formed by the loft or air space in the hover. Heat transfer by conduction dropped in the third and fourth weeks of the brooding period. This was true in all cases except in the fourth week of the infra-red heat lamp brooder. An accurate calculation was not made for the heat transfer by radiation so it was not separated from the amount of heat transferred by conduction. This should account for greater heat transfer by conduction through the base of the infra-red heat lamp in the fourth week

---

[13] Barre, H. J., Sammet, L. L. Farm Structures. New York, John Wiley & Sons. p. 193. 1950.

than in the preceding weeks. (Figure 19)

Heat transfer by radiation was the least for the portable floor plate brooder with electric heating elements. This was due to the fact that the hover was made of polished aluminum which has a low value for emissivity.

Heat transfer through the ventilator of the conventional electric brooder was higher than the portable floor plate brooder with electric heating elements. This could be accounted for by the fact that the portable brooder depended on ventilation by natural convection while the conventional electric brooder had a forced draft system. The forced draft system had a greater air velocity and also the quantity of air was greater due to the larger ventilator opening.

The transfer of heat from the infra-red bulbs was handled by direct measurement. A radiation meter was used to plot a radiant heat pattern in the chick zone. When the patterns were superimposed upon each other, the areas representing radiant intensity had the same pattern and very little difference in area. The factor that changed the patterns was the number of bulbs burning at the time the measurement was taken. The difference in the radiant intensity pattern for the fourth week was due to the warmer weather. Only the two bulbs controlled by the thermostat were used for this measurement.

Unaccountable heat transfer for the conventional electric brooder was considerably higher than for the portable floor plate brooder with electric heating elements. The conventional electric brooder had little insulation below the heating element. The only resistance to heat flow

downward was the litter, the floor, and the chick. The portable brooder had added insulation of celctex to prevent downward heat flow. These factors contributed to the difference in unaccountable heat transfer for the two brooders.

SUMMARY AND CONCLUSIONS

The portable floor plate brooder with electric heating elements performed satisfactorily on this test in late spring under South Dakota conditions. Temperatures at this time of year in South Dakota range above 25 degrees Fahrenheit. For early spring when sub-zero weather is encountered more heat will be needed than was produced by the heating source in the portable floor plate brooder.

The following conclusions are presented.

1. The portable floor plate brooder with electric heating elements is more economical than the conventional electric brooder and the infra-red heat lamp brooder. Less heat is required when the floor plate brooder with electric heating elements is used to maintain a comfortable brooding temperature for the chicks. Results show the amount of heat needed for the floor plate brooder is approximately one half the amount of heat needed for the conventional electric brooder and approximately one third as much as would be needed if the infra-red heat lamp brooder were used.

2. The operating costs of the portable floor plate brooder with electric heating elements can be further reduced by adding insulation in the hover to reduce heat transfer by conduction in that area.

3. Results show high unaccountable heat transfer for the conventional brooder. This is believed due to the high heat transfer through an uninsulated floor.

4. Results for the portable floor plate brooder with electric heating elements show low heat transfer by radiation. Polished aluminum which has a low emissivity value was used in the construction of the hover. This low emissivity value is confirmed in the radiation reflection study of various materials. In this study polished aluminum had an 18% reflection of direct radiation. Galvanized sheet iron with a 13% reflection also shows low emissivity.

5. The radiation intensity pattern for the bulbs of the infrared heat lamp brooder varied to a small degree. When the patterns were superimposed upon each other, the areas representing radiant intensity had the same pattern and very

little difference in area. The factor that changed the pattern was the number of bulbs burning at the time. Sunlight accounted for a slight pattern difference.

6. The floor plate brooder with electric heating elements was portable. Its weight could easily be lifted by one man. However, due to the size and shape of the hover it was somewhat awkward to handle alone.

The above conclusions are based on this test. They are representative of only one condition and one location. More tests should be made before recommendation of the under heat brooder for commercial use.

LITERATURE CITED

Barre, H. J., and Sammet, L. L. Farm Structures. N. Y. John Wiley & Sons. p. 193. 1950.

Bywaters, James H. The Physiological Aspects of Chick Brooding. Journal of Ag. Eng. Volume 33. p. 298. 1952.

Card, Leslie E. Poultry Production. 8th Ed. Phil. Lea & Febiger. 1952.

Eldridge, John A. College Physics. 3rd Ed. N. Y. John Wiley & Sons. 1949.

Honeywell. Catalog of Automatic Controls. p. 86. 1955-56.

Hough, J. H. Report on a Portable Under Heat Brooder using Electric Soil Heating Cable. Louisiana State University. Dept. Circ. 20. p. 9. 1955.

Hassler, F. J., and Puchett, H. B. Supersensitive Thermostat. Journal of Ag. Eng. Volume 34. p. 841. 1953.

Kemp, J. G., and Cook, F. D. Cyclic Temperature Regulator. Journal of Ag. Eng. Volume 35. p. 40. 1950.

Laurens, Henry. The Physiological Effects of Radiant Energy. The Chemical Catalog Co. N. Y. 1933.

Oliver, J. H., and Seeger, K. C. Radiant Energy Chick Brooding. Journal of Ag. Eng. Volume 32. p. 278. 1951.

Pender, H., and Del Mar, W. A. Electrical Engineers' Handbook. 3rd Ed. rewritten. N. Y. John Wiley & Sons. 1936.

Stanley, J. M., and Baker, Vernon. Control Equipment for Infra-red Poultry Brooding. Journal of Ag. Eng. Volume 34. p. 751. 1953.

Strock, C. Heating and Ventilating's Engineering Databook. 1st Ed. N. Y. The Industrial Press. p. 5-10. 1940.

Weld, L. D. A Textbook of Heat. N. Y. The MacMillan Co. 1948.

Wright, F. B. Electricity in the Home and on the Farm. N. Y. John Wiley & Sons. p. 251. 1950.

Young, F. D., and Soderholm, S. H. Different Thermostats for Agricultural Applications. Journal of Ag. Eng. Volume 33. p. 205. 1952.