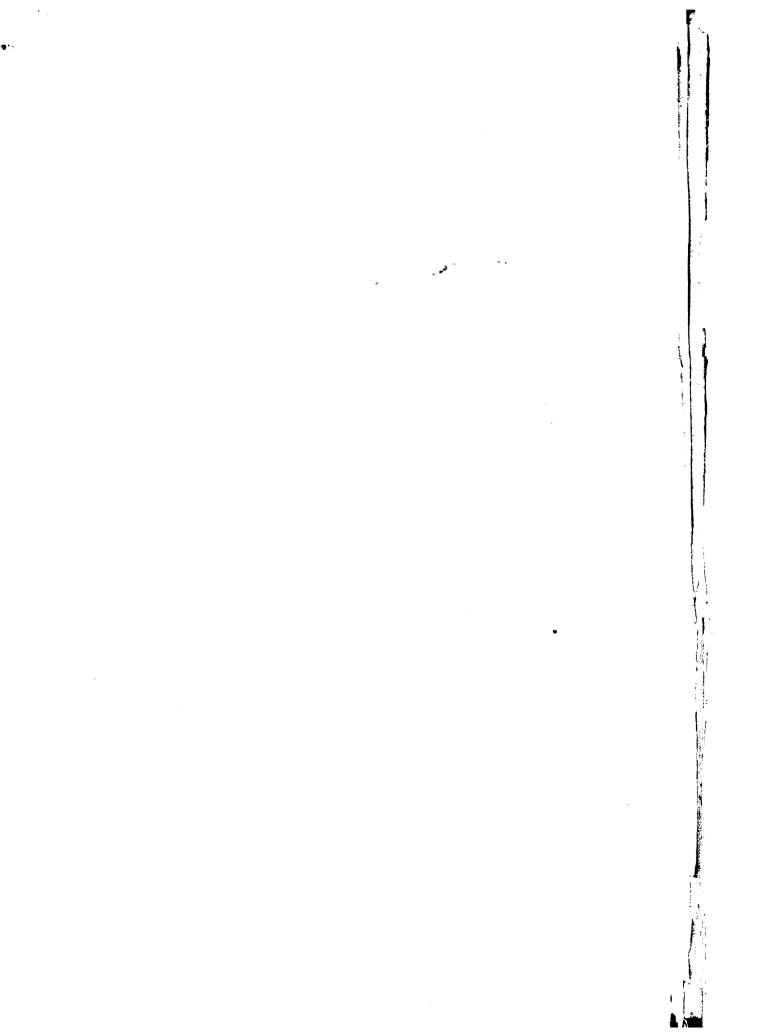
THE DESIGN AND TESTING OF AN ELECTRIC UNDERFLOOR CHICKEN BROODER

Thesis for the Degree of M. S. MICHIGAN STATE UNIVERSITY
Frank Donald Borsenik
1958



THE DESIGN AND TESTING OF AN ELECTRIC UNDERFLOOR CHICKEN BROODER

BY

FRANK DONALD BORSENIK

AN ABSTRACT

Submitted to the College of Agriculture of Michigan
State University of Agriculture and Applied
Science in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE

Department of Agricultural Engineering
1958

Approved

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ABSTRACT

Brooding chickens with electrical energy is very popular. There are many reasons for this popularity: the electric brooders are readily portable; electricity has no by-products of combustion such as smoke, carbon dioxide, carbon monoxide and water; electric brooders reduce fire hazards; and the conversion of electricity to heat is 100 per cent efficient which provides for economical operation.

Hover type brooders are normally designed for conduction and convection heat transfer and infrared lamp brooders are designed for radiation heat transfer. The energy requirements for brooding chickens were reported by Mitchell and Kelley (1933). Their publications were based primarily on conduction and convection heat transfer. Seeger and Oliver (1951) combined their research data with the data reported by Mitchell and Kelley and reported radiant heat transfer requirements for chickens.

Many types of radiant brooders have been designed. Radiant brooding with infrared brooder lamps is an accepted method for northern and southern United States conditions. However, concrete slab with electric resistance wires, electric panel and electric hover brooding are not advantageous for conditions that exist in the northern United States.

The purpose of this experiment was to design and test an underfloor electric chicken brooder for conditions that exist in the northern United States.

The designed underfloor electric brooder transferred over 90 per cent of the heat by convection and conduction. Less than 10 per cent of the heat was transferred by radiation. Many commercial radiant type brooders of similar design transfer heat in the same proportions. They are not true radiant heat brooders.

Three groups of chickens were raised on the designed underfloor brooder, sometimes called a heat slab. The brooder floor was the heat source, providing a direct contact between chicken and the heat. Also, three groups of chickens were raised under infrared brooder lamps for comparison. The infrared lamp brooder provided the standard of measurement.

A commercial radiant floor brooder was used in a late spring brooding test. This brooder was actually a conduction and convection brooder. This brooder was used in one test only. The results were not valid but are recorded with other vital results.

The designed heat slab brooder indicated: lower electric energy consumption, reduced chicken mortality, constant termperature control, and capacity for holding heat and releasing this heat during power interruptions. There was no consistent difference in chicken growth rates between the designed heat slab brooder and infrared lamp brooders.

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Thanks are also extended to the Detroit Edison Company, Detroit, Michigan, for supplying the materials of construction for the heat slab brooder, and to Radiant Products, Inc., Monroe, North Carolina for the brooder used in the second brooding test.

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INTRODUCTION

The three methods of heat transfer are: conduction, convection and radiation. The broading of chickens utilizes one or a combination of these methods. The earliest methods of broading chickens involved conduction and convection heat transfer. Less than thirty years ago electrical radiation was introduced as a method of broading chickens.

Conduction and convection broading are almost inseparable.

Conduction broading requires the chicken to be in contact with

the heat source. In the convection process the air surrounding

the chicken is heated which in turn maintains the proper chicken

body temperature. Designing a broader by the conduction and convection principle involves the use of proper broading temperatures.

These broading methods utilize various types of heat traps.

electricity on farms. The electric brooders are advantageous because; the brooders are readily portable; electricity has no by-products of combustion such as smoke, carbon dioxide, carbon monoxide and water; electric brooders reduce fire hazards; and the conversion of electricity to heat is 100 per cent efficient. The brooding cost was reduced over wood, fuel oil and gas brooding methods even though electric energy cost was high and the brooders were poorly designed.

In the early 1950's infrared brooder lamps were widely introduced as a method of brooding. The lamps had numerous uses and installation was simple. The brooding cost per chicken was higher than for other brooding methods but this was overshadowed by the convenience.

The research results of Mitchell and Kelley (1933) were put to effective use by Baker, Bywaters, Seeger, Oliver and others who were trying to reduce infrared lamp brooding costs. The proper application of their data reduced the brooding cost per chicken. The infrared lamp brooders had another disadvantage, the complete loss of heat in case of a power interruption. Electric power interruptions are more likely to occur during the winter brooding season; this still remains the principle disadvantage of infrared lamp brooders.

Electric brooding is popular because of its simplicity, it is merely necessary to energize the circuit and set a control. The ideal type of brooder should utilize electricity at low brooding costs and maintain heat for periods of time in case of power interruptions. The southern electric power companies attempted to design a brooder that retained the advantages of infrared brooder lamps and minimize the disadvantages. This brooder was used successfully in Arkansas and Louisiana.

Comparison tests conducted in the State of Washington revealed that brooding costs were not different for various electrical brooding methods. Inconsistent brooding cost was reported in

other states. An underfloor electric brooder had not been designed for Michigan or other northern states. Michigan electric power suppliers felt that a brooder could be designed to reduce electric brooding costs.

OBJECTIVES

The purpose of this investigation was to design and test a portable underfloor electric brooder and compare this brooder with infrared lamp brooders now used in Michigan. The testing of the brooder was critical in the areas of chicken mortality, feed conversion rates and electric energy consumption.

REVIEW OF LITERATURE

Mitchell and Kelley (1933) published one of the earliest papers on the brooding of chickens based on actual research. Their results, based on minimum average brooding temperatures, chicken body area subject to radiation, heat requirements below a critical temperature of 62°F, and minimum average weight of chickens, were an attempt to combine fundamental factors for the brooding of chickens. Their work was available to commercial brooder managers and manufacturers of brooders but it was not until the introduction of infrared brooder lamps that the true value of the work of Mitchell and Kelley was appreciated.

Infrared brooder lamps provided an easy and simple installation for brooding. One of the first problems, with the use of infrared brooder lamps, was the kind of radiant heat pattern they established. General Electric Company published the radiation pattern of their lamps, Fig. 1. With these radiation patterns one could determine the radiant heat requirements of chickens by referring to the Mitchell and Kelley radiant heat brooding requirements. Baker and Bywaters (1951) tried to measure the radiant heat distribution of infrared brooder lamps. Their results were limited to the infrared spectrum response of their instrument. Their results were similar to Fig. 1, with lower peaks of lamp radiation output.

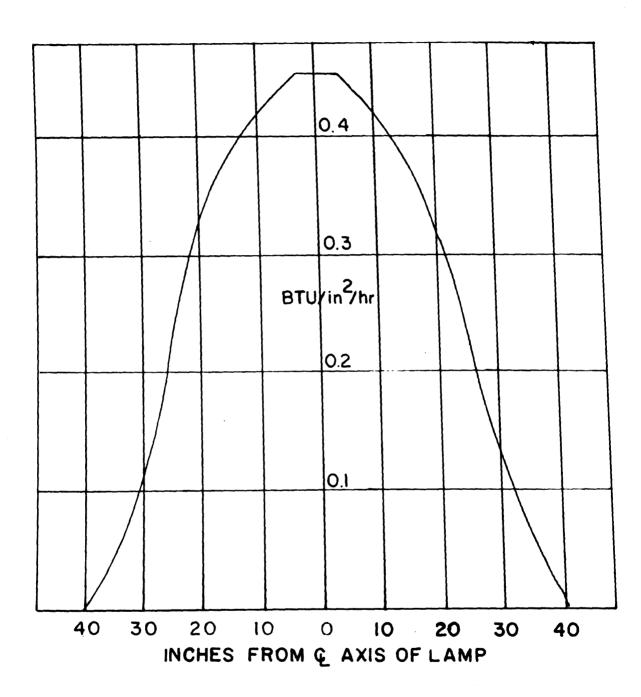


FIG.I. RADIANT ENERGY DISTRIBUTION OF A R-40 INDUSTRIAL INFRARED 250 WATT LAMP, 24" HEIGHT, E= 12 Ov., I= 2.18 amp.

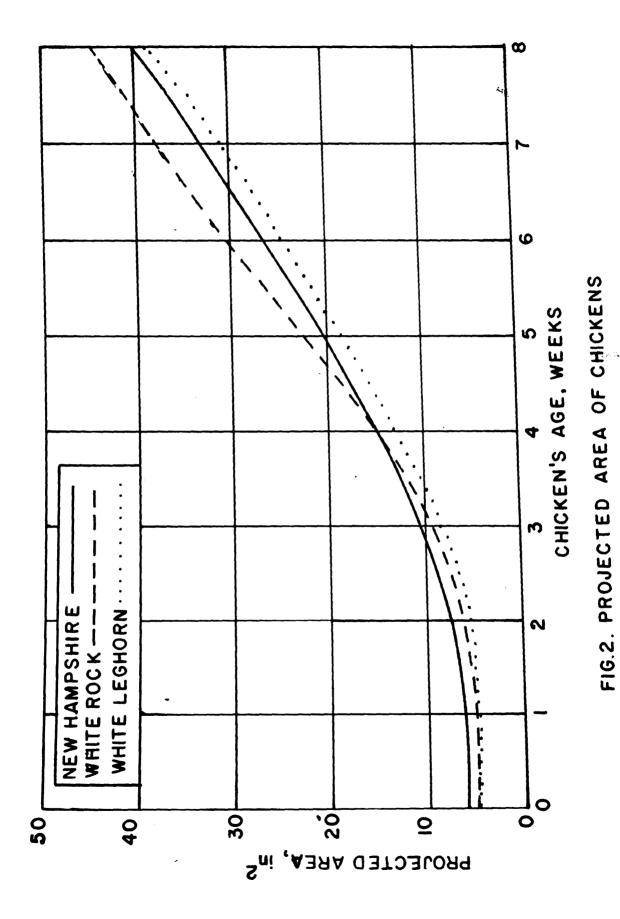
Baker and Bywaters also observed "comfort zones" of chickens at various ages. As the chickens progressed in age the majority of the chickens would not remain under the lamp but would move out away from the center of the lamp forming concentric curves of larger radii. This "comfort zone" provided a correlation between radiation distribution patterns of lamps and the work of Mitchell and Kelley.

The next problem encountered was the surface area of a chicken subject to radiation from infrared brooder lamps, known as the projected area of a chicken. Radiant energy requirements of chickens and radiation patterns of lamps are based on projected area. Mitchell (1930) graphed the projected area of three breeds of chickens at various ages, Fig. 2. The chicken capacity per lamp could now be determined. This was a very definite step towards reducing brooding operational costs as well as using basic research in brooding practices.

Seeger and Oliver (1951) further simplified brooder design procedure by publishing a set of data, Fig. 3, in which the radiant energy requirements are given for different brooder house temperatures. From this data and the projected area of chickens a radiant brooder could be designed for most conditions. The projected area of chickens and the radiant energy requirements of chickens were probably the most notable research contributions towards radiant chicken brooding.

Many of the problems involved with radiant heat brooding are eliminated or minimized with convection and conduction brooding.







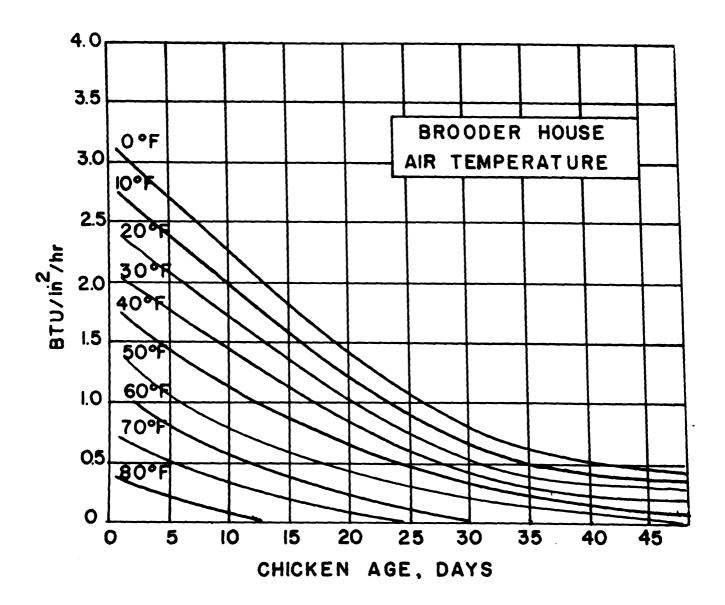


FIG.3. RADIANT ENERGY REQUIREMENTS, BTU/in /hr, FOR BROODING CHICKENS

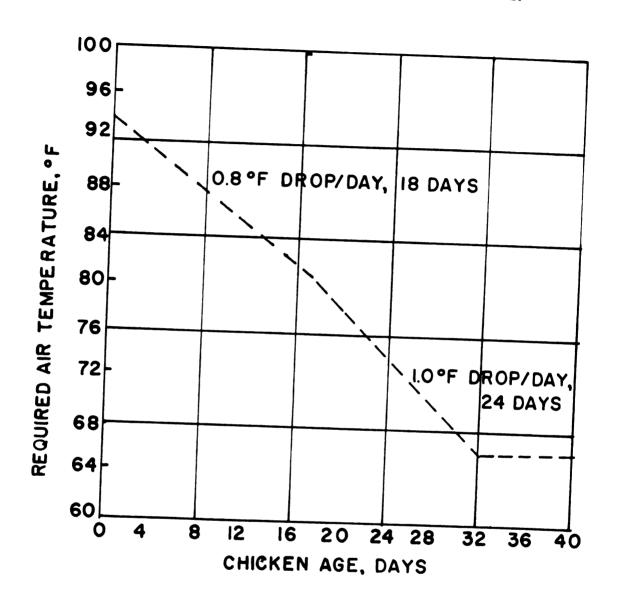


FIG. 4. BROODING TEMPERATURE FOR CHICKENS

The two major design problems of convection and conduction broading are the area of the broader and the temperature demands of the broader.

Mitchell and Kelley (1933) published a formulae which could be used to determine the required air temperatures for chicken brooding. The formulae is graphed, Fig. 4, with the required brooding temperature and the chickens age as variables.

The material presented so far is basic, one could design a radiant type of brooder on energy demands per surface area and a hover brooder could be designed from temperature requirements.

The advantages and disadvantages of infrared brooder lamps and hover brooders are of special importance to the users of the brooders.

The advantages of infrared lamp brooders are summed up as: (Maddex, Kleis and Card, 1951)

- 1. Less labor
- 2. Low initial cost
- 3. Safe and controllable brooding method
- 4. Chicks may be seen at all times
- 5. May be adapted to all size broods
- 6. Adaptable to most types of houses
- 7. Water will not freeze in the "comfort zone" of the lamps
- 8. Easy to install and operate
- 9. Low maintenance
- 10. Brooding units are easily stored

The disadvantages of infrared lamp brooders are few but important: (Virginia Polytechnic Institute, 1951)

- 1. Operating cost is usually higher than hover type brooding.
- 2. Heat is cut off with electric power interruptions.

The electric hover brooder advantages are similar to the infrared lamp brooder advantages: (Ginn, 1956)

- 1. Reduced fire hazards
- 2. Automatic temperature control is possible
- 3. Electric brooders have no by-products of combustion such as smoke, carbon dioxide, carbon monoxide and water.
- 4. Readily portable
- 5. Low maintenance
- 6. Labor saving

The disadvantages of electric hover brooding are also reported by Ginn (1956):

- 1. Initial brooder cost is higher than infrared lamp brooder installation
- 2. It is difficult to observe chickens under the hover

It would be desirable to design a brooder combining the advantages of infrared lamp brooders and electric hover brooders. Mauney (1956) experimented with such a brooder. Its acceptance was favorable in Arkansas, Mauney (1956), and in Louisiana, Barr and Hough (1956).

The brooder was a simple hover type. The floor of the brooder was the heat source; it was constructed of wood, masonite sheets, sand and electric resistance wire. The heat trap or hover frame was covered with thin plastic and a heat reflective top. This type of brooder was called a portable underfloor heat electric brooder. Arkansas and Louisiana reported that investment cost and electrical consumption per bird were less for the portable underfloor heat electric brooders than for concrete slab brooders.

Tests conducted by the Washington Farm Electrification

Council (1954) on different types of electric brooders were not

conclusive, see Table I. The Washington Farm Electrification

Council's research was conducted on commercial brooders only and

not on electric underfloor brooders designed for northern states

conditions.

Recent research has revealed important information concerning electric brooders. U.S.D.A. has reported that the heat cost of brooding with infrared lamp brooders can be reduced by using plastic hovers with the brooders, (Farm Power, January, 1957 and Successful Farming, April, 1957). The plastic hover may cause excessive temperatures. U.S.D.A. also reported, Juli (1951), that chickens can be chilled for one and one half hours at 37°F without impairing their growth rate.

The research of Mitchell, Kelley, Baker, Bywaters, Oliver and Seeger can be readily used for chicken brooder design. The charts and graphs on Projected Area of Chickens, Radiant Energy

Requirements, Radiant Energy Distribution of Infrared Lamps and
Required Air Temperatures for Brooding can be used for either hover
or radiant brooders.

TABLE 1. COMPARISON OF HEAT COSTS AND FEED EFFICIENCY
FOR VARIOUS METHODS OF BROCDING

BROODING METHOD	MORTALITY	FEED EFFICIENCY	HEAT COST PER CHICKEN
	%	lb feed/lb gain	#
Electric underfloo	or 6	2.34	3.7
Electric panel	4	2.52	4.0
Heat lamp	6	2.79	4.4
Hover	9	2.61	2.6
Electric underfloo	or 4	2.57	6.3
Heat lamp	4	2.38	2.0

EXPERIMENTAL PROCEDURE

The approach selected for this problem involved the use of experiments in which some chickens were raised under infrared brooder lamps and some chickens were raised on the designed heat slab brooder. Feed conversion, chicken mortality, temperature control and electric energy consumption were the basic criteria.

Designing and Testing the Heat Slab Brooder

A brooder was designed similar to Mauney's Arkansas heat slab brooder, Figs. 5 and 6. Electric circuits of 200, 300 and 400 watts were installed. This would give, if needed, a 900 watt output which would satisfy the radiant energy demand of 267 five day old chickens in a room at 10°F.

The electric heat slab was tested for heat output by the following methods:

- 1. Mercury thermometers
- 2. Eppley radiation meter
- 3. Iron-constantan thermocouples with a recording potentiometer

Three types of hovers were tested for heat retention utilizing the heat slab. The types of hovers were: clear plastic with
a highly reflective top on a wood frame; wood hover with burlap
side curtains; and a clear plastic on a wood frame. These tests
were to provide a suitable heat slab hover combination and a

able heat slab hover combination and a

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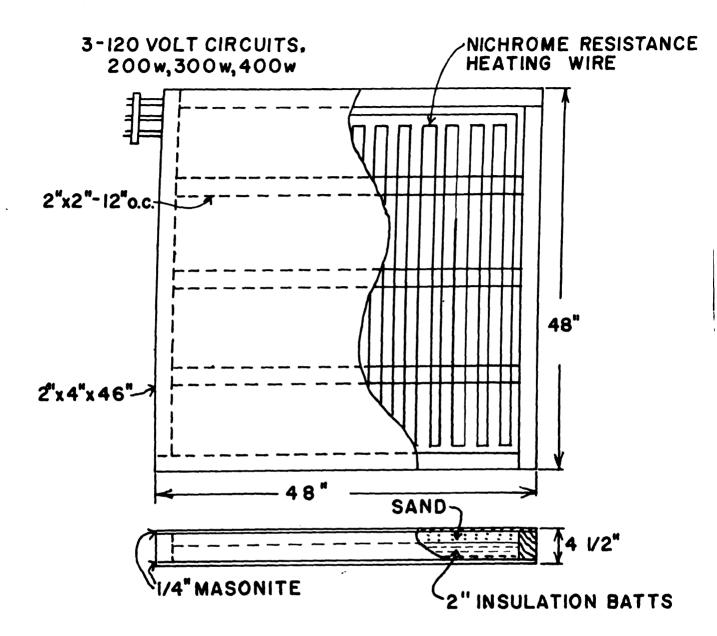


FIG.5. HEAT SLAB CONSTRUCTION FOR
A 250 CHICKEN PORTABLE BROODER

SCALE: |"= |'0"

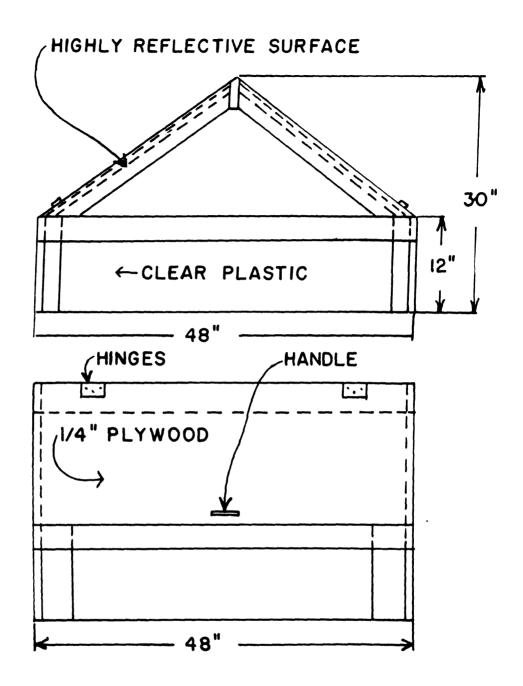


FIG.6. HOVER FOR PORTABLE HEAT SLAB CHICKEN BROODER

SCALE: I" = I'd'

method for measuring radiation or temperature under the hover.
First Trial Brooding Test

The first brooding test was conducted to find if the heat slab brooder would maintain desirable brooding conditions. One hundred and sixty eight chickens were placed on the heat slab brooder and a similar number under an infrared lamp brooder in separate brooding houses. April, 1957, Figs. 7 and 8.

The criteria of this test were, hourly temperature measurements, electric energy consumption, chicken mortality and total feed conversion ratios.

Second Trial Brooding Test

The second test was conducted with three types of hover brooders; infrared brooder lamps under a wood hover, Fig. 9; the heat slab brooder, Fig. 10; and a North Carolina commercial heat slab brooder, Fig. 11 and 12.

The criteria were: temperature control; electric energy consumption; feed conversion ratios; and chicken mortality.

Two hundred and fifty chickens were placed under each brooder.

Third Trial Brooding Test

A third test was conducted to find if a statistical significant difference existed between the weights of male and female chickens. The male chickens were kept separate from the female chickens throughout the test. Two brooders were used, infrared lamp brooder and the heat slab brooder. Sixty chickens of each sex were placed under each brooder. The criteria were feed conversion rates and chicken mortality.

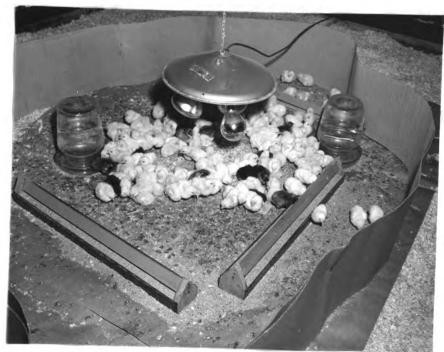


Fig. 7. Infrared lamp brooder, first and third trial brooding test.



Fig. 8. Designed heat slab brooder, first, second and third trial brooding test.



Fig. 9. Infrared brooder lamps with a wood hover, second trial brooding test.



Fig. 10. Designed heat slab brooder showing the clear plastic sides of the hover.

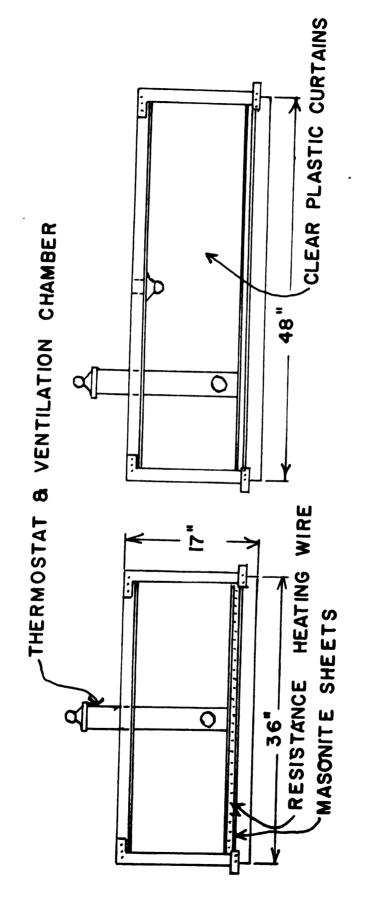


FIG. II. RADIANT PRODUCTS, INC. BROODER, 250 CHICKEN CAPACITY, 385 WATTS, 120 VOLTS

SCALE: I"= 1'0"



Fig. 12. Radiant Products heat slab brooder, used in the second trial brooding test.

RESULTS

Results of Energy Measurements of the Underfloor Type Brooder

A 16 square foot brooder was designed according to the principles established by Oliver and Seeger, Fig. 3. Assuming a low room temperature of 10°F and referring to Mitchell's results, Fig. 2, the projected area of chickens, it was calculated that a 900 watt infrared output would supply heat for 267 chickens, assuming 100 per cent efficiency.

Calculations:

900 watts/hr. X 3.413 Btu/watt = 3081.7 Btu/hr.

A five day old chicken has a projected area of five square inches, Fig. 2.

A five day old chicken in a 10°F room requires 2.3 Btu/in²/hr, Fig. 3.

5 in²/chicken X 2.3 Btu/in²/hr = 11.5 Btu/hr/chicken

Btu/hr = 3081.7 = 267 chickens, capacity of a 900 watt heating circuit

The next step is to calculate the required surface area of the brooder. The surface area should provide 2.3 Btu per square inch per hour.

 $\frac{\text{Btu/hr}}{\text{Btu/hr/in}^2} = \frac{3081.7}{2.3} = 1340 \text{ in}^2, \text{ required surface area}$ of the brooder to provide $2.3 \text{ Btu/in}^2/\text{hr}.$

The heating circuit in the heat slab brooder required an area of light square inches, this provided a heat output of:

Btu/hr = $\frac{3081.7}{11\mu\mu}$ = 2.14 Btu/in²/hr, which is slightly less than the desired amount.

The heating circuit was centered on the center of the heat slab.

The designed heat slab brooder, Figs. 5 and 6, was heated with a nickel chronium resistance wire. The cold resistance of the wire was 0.433 ohms per foot. Circuits of 200, 300 and 400 watts were installed in the underfloor brooder. The heating cable was covered with one half inch of sand to retain heat. Table 2 shows the actual wattages of the circuits as tested by a wattmeter.

TABLE 2. DESIGN WATTAGE AND ACTUAL WATTAGE OF VARIOUS

CIRCUITS FOR THE UNDERFLOOR CHICKEN BROODER:

SAND TEMPERATURE 193°F

DESIGN WATTACE	ACTUAL WATTAGE
200	195
300	225
400	415
500	415
600	585
700	615
900	780

Mercury thermometers were used to find the heat pattern above the heat slab when no hover was used, Table 3 shows the temperature pattern.

TABLE 3. THE MEASUREMENT OF HEAT ABOVE THE HEAT SLAB

BROODER WITH MERCURY THERMOMETERS

WATTAGE OF	HEAT	TEMP	ERATURI	E AT T	ie fol i	LOWING	DISTANCES	ROOM
CIRCUIT	SLAB	A	ABOVE THE HEAT SLAB SURFACE				${}^{\mathbf{o}}_{\mathbf{F}}$	
	SURFACE	lm	2 w	3"	4	5 n	6#	
	$\mathbf{o_F}$							
-	-							
200	63.0	50.0	49.5	50.0	49.0	49.0	49.0	46.5
300	66.0	53.5	52.0	53.0	51.0	51.0	51.0	46.5
400	77.0	53.5	52.5	53.0	51.5	50.5	50.5	46.5
600	87.0	54.0	51.0	52.5	50.0	50.0	49.0	40.0
900	82.0	45.5	43.5	42.0	41.5	40.5	38.5	27.0

An Eppley radiation meter was used to determine the total infrared radiation output of the heat slab. The heat slab was marked off into six inch squares and with the meter connected to a potentiometer, readings were taken for the different wattage circuits. With the 500 watt circuit in operation the Btu output was 56.59 Btu per hour. Assuming 100 per cent efficiency for radiant heating the following calculation was made:

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0.415 kw * X 3413 Btu/kw/hr = 1416.40 Btu/hr.

* The 500 watt circuit has an actual wattage of 415 watts, see Table 2.

The heat slab was found to be 4 per cent efficient for radiant heating.

The Eppley radiation meter was also used to measure the heat output of General Electric infrared brooder lamps; they were found to be 35.9 per cent efficient. A plastic type filter on the radiation meter filtered out part of the infrared spectrum. The readings were invalid as they existed because the filter could not be removed without partially destroying the meter.

Three heat traps were used to test the effectiveness of the heat slab as a heat source for a hover type brooder. The traps were: clear plastic; clear plastic with an aluminum sheet on the top; and a wooden hover. Iron-constantan thermocouples connected to a Brown recording potentiometer were used to record hourly temperatures under the various hovers. Table 4 shows the results.

The electric circuits were de-energized and the temperatures were taken under the hover with respect to time. Figure 13 shows the temperature versus time graph of the clear plastic hover with aluminum top which was selected as a desirable and efficient type hover. The selection of the clear plastic hover with aluminum top was based on chicken visibility, heat retention capacity, desirable under-the-hover temperatures and the light weight construction of the hover.

TABLE 4. AVERAGE HOURLY TEMPERATURES UNDER THREE HOVERS

PLACED OVER THE HEAT SLAB BROCDER. THE 900 WATT

CIRCUIT WAS IN OPERATION AND THE BROCDER THERMO
STAT WAS SET AT 90°F.

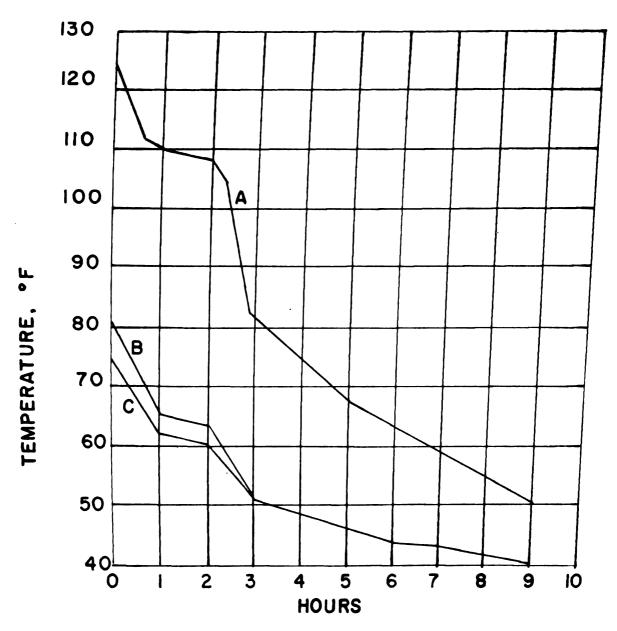
HOVER	AVERAGE ROOM	AVERAGE HEAT	6" ABOVE HEAT	HOURS
	TEMPERATURE	SLAB SURFACE	SLAB SURFACE	OPERA#
	$oldsymbol{\circ}_{f F}$	TEMPERATURE	AVERAGE TEM#	TION
		o _F	PERATURE, F	-
Clear Plastic	3 5	115	83	46
Clear Plastic with Aluminum				·
Sheet Top	32	122	82	20
Wo od	32	122	95	24

A bimetallic thermostat incased in plastic was used with the brooder. It was wired in series with the 400 watt circuit. The range of the thermostat was 60°F varying from 40 to 100°F. The accuracy of the thermostat was ±3°F. It was set directly on the heat slab surface. A finger control dial provided easy operation and control.

Results of the First Trial Brooding Test

A three week trial broading test was conducted April 3 through April 23, 1957 to observe chicken behavior under the hover of the electric heat slab broader and compare it with the behavior of a corresponding number of chickens under an infrared lamp broader.

One hundred and sixty eight chickens were used for each broader.



50

A- SURFACE TEMPERATURE OF HEAT SLAB B-6 IN. ABOVE SURFACE OF HEAT SLAB C- I IN. ABOVE SURFACE OF HEAT SLAB

FIG. 13. TEMPERATURE GRADIENT ABOVE THE HEAT SLAB, 900 WATT CIRCUIT OFF AT "O" HOUR, ROOM 20°F

The primary result in this test was that the heat slab brooder was found to be suitable for the brooding of chickens. The data collected was of minor importance.

Iron-constantan thermocouples were used with a Brown recording potentiometer for measuring hourly temperatures. The positions of the iron-constantan thermocouples were varied to find the most critical temperature locations under the brooders. Table 5 shows the chicken mortality, feed conversion rates and electric consumption.

TABLE 5. CHICKEN MORTALITY, FRED CONVERSION RATES AND

ELECTRIC ENERGY CONSUMPTION RESULTS OF THE FIRST

TRIAL BROODING TEST

<u> </u>	HEAT SLAB BROCDER 1	NFRARED LAMP BROODER
Chicken Mortality	1.19%	5.9 8%
Feed Conversion Rates	2.08 lb feed lb gain	2.17 lb feed lb gain
Electric Energy Consumption	1.365 kwh/chicke	n 2.070 kwh/chicken

Results of the Second Trial Brooding Test

A six week brooding test was conducted April 23 through May 27, 1957. The three types of brooders used in the second test are shown in Figs. 9, 10 and 12, infrared brooder lamps under a wood hover, the heat slab brooder and a commercial brooder, respectively. Two hundred and fifty chickens of various breeds were placed under each brooder in separate 10 ft. X 12 ft. brooder houses. Table 6 shows the location of the iron-constantan thermocouples which were used to obtain hourly temperature measurements.

TABLE 6. IRON-CONSTANTAN THE MOCOUPLE LOCATIONS AND THE
MEAN TEMPERATURES AT THESE LOCATIONS FOR THE
SECOND TRIAL BROODING TEST

LOCATION	MEAN TEMPERA- TURE, F
Brooder House with the Infrared Brooder	
Lamps Under a Wood Hover	
a. Approximate center of the brooder house	69.39
b. On the brooder house floor under the litter	64.79
c. Under the hover and six in. above the litter	98 .51
d. Under the hover and 12 in. above the litter	104.57
Brooder House with the Commercial Brooder	
a. Approximate center of the brooder house	66.45
b. On the brooder house floor under the litter	63.86
c. On the brooder house floor under the heat slab	94.23
d. Under the hover and six in. above the heat slab	84.76
e. Under the hover and 12 in. above the heat slab	86.24
f. On the top of the heat slab hover	79.62
Brooder House with the Designed Heat Slab Brooder	
a. Approximate center of the brooder house	64.84
b. On the brooder house floor under the litter	59•37
c. On the brooder house floor under the heat slab	72.18
d. Under the hover and six in. above the heat slab	90.79
e. Under the hover and 24 in. above the heat slab	94•33
Between the Brooder Houses, Measuring the Outside Air Temperature	55.46

Kilowatt hour meters were used to measure the total amount of electric energy used for brooding, including that required by the attached might lamp. Chicken mortality was recorded daily. The exact amount of feed consumed was recorded. Table 6 shows the mean temperatures at the various locations for the entire six week brooding period.

The 12 hour mean temperatures, six a.m. to six p.m. and six p.m. to six a.m. intervals, for the various brooders are shown in Figs. 14, 15 and 16. Two other sets of temperature measurements for a 42 hour period, hourly temperature recordings six p.m. April 23 to one p.m. April 25, 1957, are shown in Figs. 17, 18 and 19 and from four a.m. May 9 to ten p.m. May 10, 1957 in Figs. 20, 21 and 22.

Table 7 is an analysis of the total amount of electric energy used for the six week brooding period. Table 8 is an account of chicken mortality, and Table 9 is an account of the feed conversion rates.

TABLE 7. KILOWATT HOURS USED FOR BROODING FOR THREE BROODERS,

THE SECOND BROODING TEST

BROODER	TOTAL KWH	KWH/CHICKEN	KWH/HR
Infrared Brooder			
Lamps Under a Wood Hover	456	1.815	0.456
Commercial Heat Slab	157	0.636	0.157
Designed Heat Slab	237	1.110	0.237

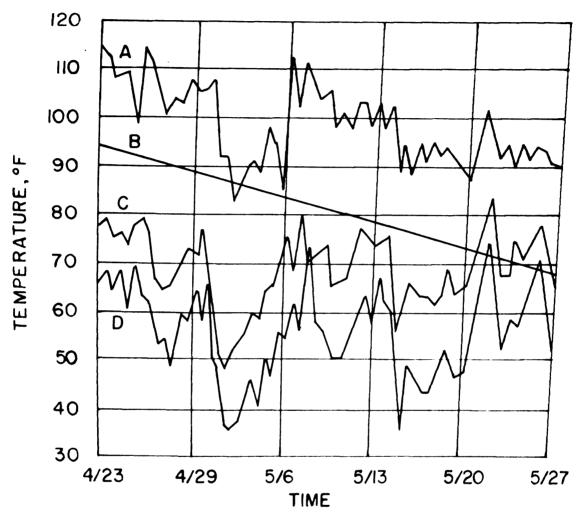
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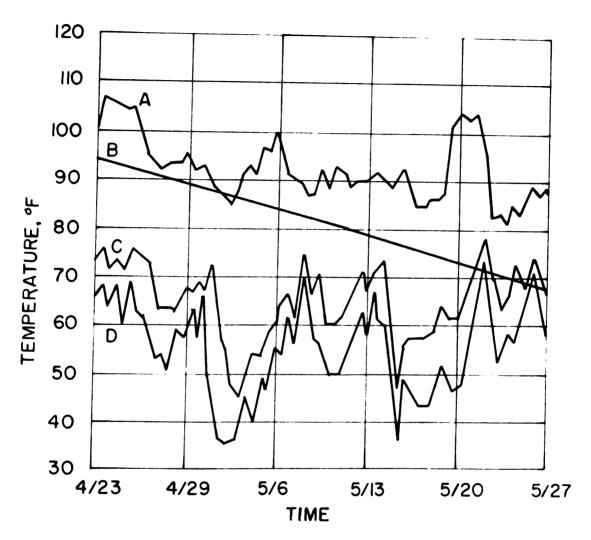
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A.6IN. ABOVE LITTER UNDER HOVER B. REQUIRED BROODING TEMPERATURE C.ROOM D.OUTSIDE

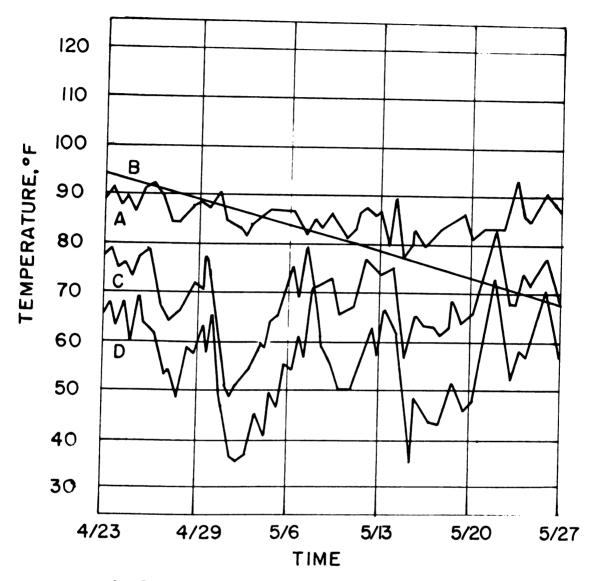
FIG.14. TEMPERATURE VARIATIONS, INFRARED

LAMP HOVER BROODER, MEAN TEMPERATURES
FOR 12 HOUR PERIODS, 4/23/57 — 5/27/57



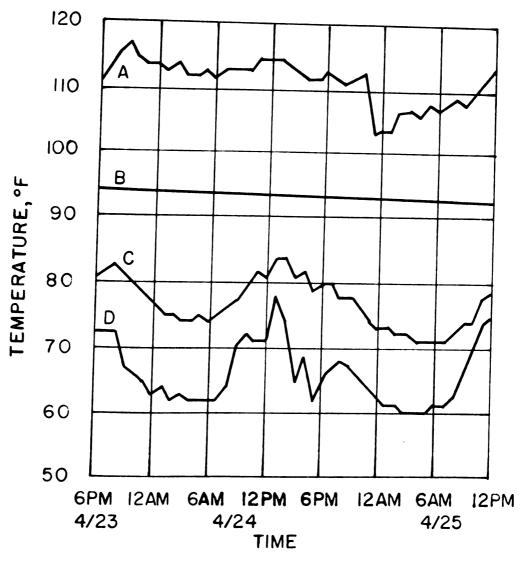
- A.6 IN. ABOVE HEAT SLAB, UNDER HOVER
- B. REQUIRED BROODING TEMPERATURE
- C. ROOM
- D. OUTSIDE

FIG. 15. TEMPERATURE VARIATIONS, HEAT SLAB BROODER, MEAN TEMPERATURES FOR 12 HOUR PERIODS, 4/23/57—5/27/57



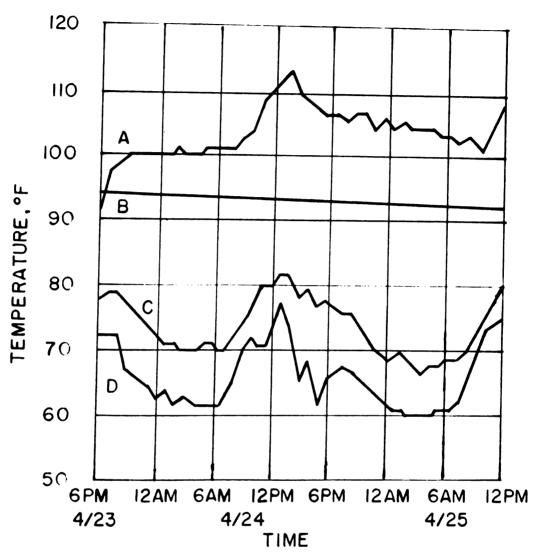
- A. 12 IN. ABOVE HEAT SLAB, UNDER HOVER
- B. REQUIRED BROODING TEMPERATURE
- C. ROOM
- D. OUTSIDE

FIG. 16. TEMPERATURE VARIATIONS, COMMERCIAL HEAT SLAB BROODER, MEAN TEMPERATURES FOR 12 HOUR PERIODS, 4/23/57—5/27/57



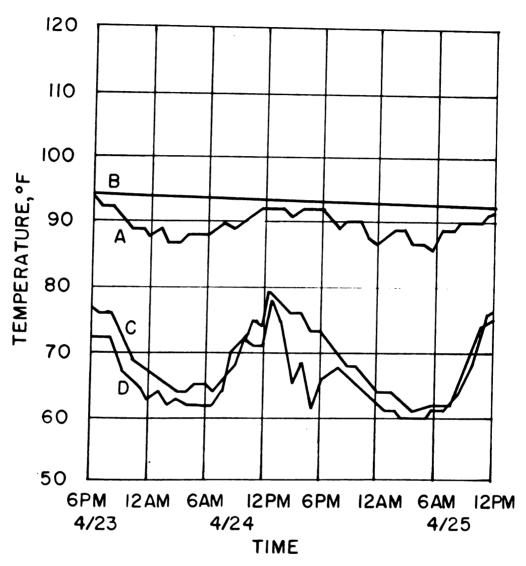
- A.6IN. ABOVE LITTER, UNDER HOVER
- B. REQUIRED BROODING TEMPERATURE
- C. ROOM
- D. OUTSIDE

FIG.17. TEMPERATURE VARIATIONS, INFRARED LAMP HOVER BROODER, 6PM (4/23/57) — 12 PM (4/25/57)



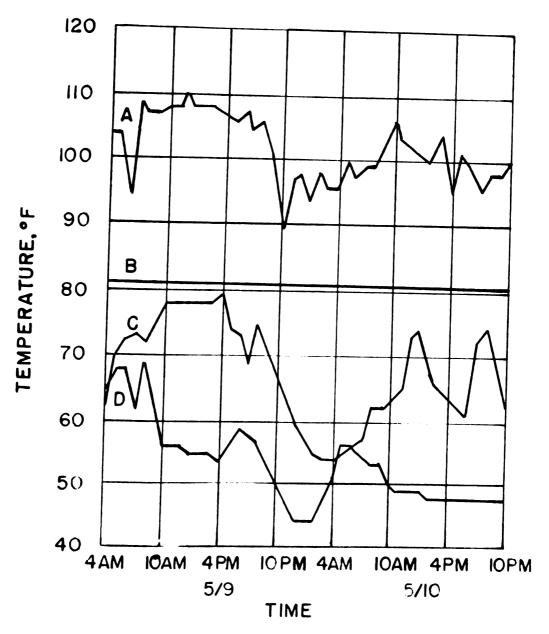
- A.6IN. ABOVE HEAT SLAB, UNDER HOVER
- B. REQUIRED BROODING TEMPERATURE
- C. ROOM
- D. OUTSIDE

FIG.18. TEMPERATURE VARIATIONS, HEAT SLAB BROODER,6PM(4/23/57) - 12PM(4/25/57)



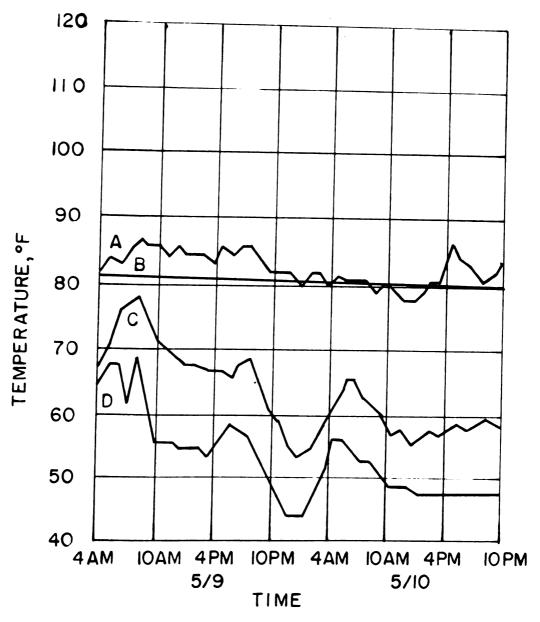
- A. 12 IN. ABOVE HEAT SLAB, UNDER HOVER
- B. REQUIRED BROODING TEMPERATURE
- C. ROOM
- D. OUTSIDE

FIG. 19. TEMPERATURE VARIATIONS, COMMERCIAL HEAT SLAB BROODER, 6PM(4/23/57) — 12 PM(4/25/57)



A.6IN. ABOVE LITTER, UNDER HOVER B. REQUIRED BROODING TEMPERATURE C. ROOM D. OUTSIDE

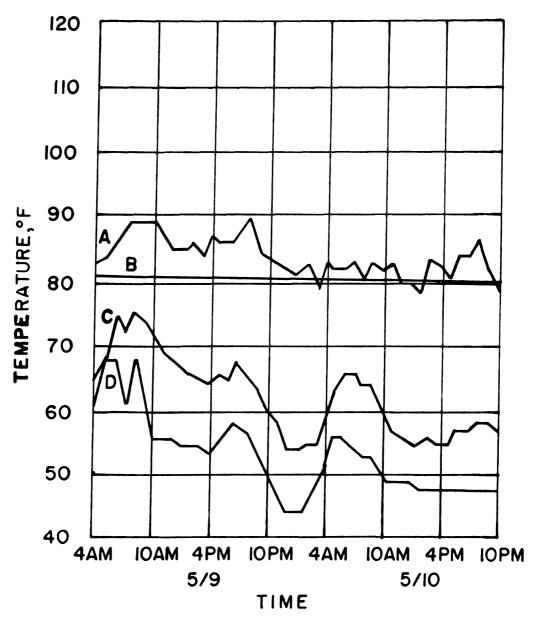
FIG.20. TEMPERATURE VARIATIONS, INFRARED LAMP HOVER BROODER, 4AM (5/9/57) — IO PM (5/10/57)



A.6 IN. ABOVE HEAT SLAB, UNDER HOVER

- B. REQUIRED BROODER TEMPERATURE
- C. ROOM
- D. OUTSIDE

FIG.21. TEMPERATURE VARIATIONS, HEAT SLAB BROODER, 4AM(5/9/57) — 10 PM(5/10/57)



- A. 12 IN. ABOVE HEAT SLAB, UNDER HOVER
- B. REQUIRED BROODING TEMPERATURE
- C. ROOM
- D. OUTSIDE

FIG.22. TEMPERATURE VARIATIONS, COMMERCIAL HEAT SLAB BROODER, 4AM(5/9/57) — IOPM(5/10/57)

TABLE 8. CHICKEN MORTALITY WITH THREE BROODERS, THE SECOND BROODING TEST

BROODER	CHICKENS STARTED	DEAD	% MORTALITY
Infrared Brooder Lamps			
Under a Wood Hover	254	3	1.182
Commercial Heat Slab	251	4	1.594
Designed Heat Slab	248	2	0.807

TABLE 9. FEED CONVERSION RATES WITH THREE BROODERS,

THE SECOND BROODING TEST

BROODER	LB FEED	LB GAIN	LB FEED/LB GAIN
Infrared Brooder Lamps			
Under a Wood Hover	735	222.1	3.309
Commercial Heat Slab	700	233.5	2.998
Designed Heat Slab	765	222.6	3.437

Individual weights of all the chickens were recorded. Tests were applied to this data to find if a statistical difference occurred between the infrared lamp brooder, the commercial heat slab brooder and the designed heat slab brooder, see Table 10.

TABLE 10. MALE AND FIMALE CHICKEN MEAN WEIGHTS AND THE STANDARD

DEVIATION OF THESE MEAN WEIGHTS FOR THE CHICKENS RAISED

UNDER THREE BROODERS, THE SECOND BROODING TEST

BROODER	MALE	MALES		
	MEAN WEIGHT	STANDARD DEVIATION LB	MEAN WEIGHT LB	STANDARD DEVIATION LB
Infrared Brooder Lamps Under a Wood Hover	0.9071	± 0.208	0.8490	± 0.191
Commercial Heat Slab	1.0264	±0.153	0.8803	‡ 0.144
Heat Slab Brooder	0.9589	±0.129	0.8633	±0.130

A statistical significant difference occurred between male

chickens raised on or under the following brooders: (See note, p. 43)

Commercial heat slab and designed heat slab

Commercial heat slab and infrared lamp brooder

Designed heat slab and infrared lamp brooder

Results of the Third Trial Brooding Test

A five week brooding test was conducted December 6, 1957 through January 10, 1958. Two types of brooders were used, the conventional infrared lamp brooder and the designed heat slab with the hover previously used in the first and second brooding tests. One hundred and twenty chickens, 60 males and 60 females, were placed under each brooder.

Temperatures and electric energy were not measured because of the few chickens being used. The brooders were designed for a larger number of chickens and the results with fewer chickens would be misleading. The temperatures were checked periodically but not recorded. On many nights the outside temperature dropped to O°F or below.

Vantress Cornish males were crossed with Arbor Acres White Rock females for the third test. Wing bands were used to identify male and female chickens. The female chickens were kept separate from the male chickens under each brooder to check feed conversion rates. Chicken mortality was recorded. Table 11 shows chicken mortality for male and female chickens under the infrared lamp brooder and the heat slab brooder.

TABLE 11. CHICKEN MORTALITY WITH INFRARED LAMP BROODER AND THE
DESIGNED HEAT SLAB. FOR THE THIRD BROODING TEST

BROODER	CHICKENS STARTED	DEAD	% MORTALITY
Infrared Lamp Brooder			
Males	60	0	0.00
Females	60	2	3.43
Designed Heat Slab			
Males Females	60 60	1	1.67 1.67

The information on feed conversion rates could not be obtained because the males and females on the heat slab became mixed. The chickens jumped over the three foot partition which separated the two sexes during the fifth week; this was not known until a couple of days before the weighing. Table 12 shows the feed conversion rates for males and females under the infrared lamp brooder and the total feed conversion ratio for the heat slab brooder.

TABLE 12. FEED CONVERSION RATES WITH INFRARED LAMP BROODER AND

THE DESIGNED HEAT SLAB BROODER, FOR THE THIRD BROODING

TEST

BROODING METHOD	LB FEED	LB GAIN	LB FEED/LB GAIN
Infrared Lamp Brooder			
Males	162	81.9	1.977
Females	152	71.9	2.118
Combined Sexes	314	153.8	2.043
Heat Slab Brooder			
Combined Sexes	285	147.4	1.932

Individual weights of all the chickens were recorded. With this data statistical tests were applied to find if a statistical differences occurred between the infrared lamp brooder and the heat slab brooder.

Table 13 shows the mean weights and the standard deviations of these mean weights for the male and female chickens. The test showed no statistical significant difference between males and females.

t Test was used to find the statistical significant difference, the results are based on 92 per cent confidence limits.

TABLE 13. MEAN WEIGHTS AND STANDARD DEVIATIONS OF THESE MEAN

WEIGHTS FOR MALE AND FEMALE CHICKENS UNDER INFRARED

LAMP BROODER AND THE DESIGNED HEAT SLAB, THIRD BROODING

TEST

BROODING METHOD	MAI ES	3	FEMALDS		
	MEAN WEIGHT	DEVIATION	MEAN WEIGHT	DEVIATION	
Infrared Lamp					
B roo der	1.365 lb.	±0.156 1b.	1.215 lb.	±0.141 16.	
Heat Slab Brooder	1.352 lb.	±0.173 1b.	1.185 lb.	±0.167 lb.	

DISCUSSION OF RESULTS

A definite procedure should be established for designing radiant type brooders for chickens. Data has been collected over the past 25 years on radiant chicken brooding, but a definite procedure for designing a radiant brooder for chickens is not available. Utilizing the information in the "Review of Literature," a suggested procedure was established.

DESIGN PROCEDURE FOR A RADIANT CHICKEN BROODER

- A. 1. Establish the number of chickens per brooder, if the output of the brooder is known, i.e. as with infrared brooder lamps, and it is desired to know the brooding capacity see part B.
 - 2. Find the projected area of the chicken; if the age of the chicken is known use the chicken's age; if it is not known, design for a four or five day old chicken, Fig. 2.
 - 3. Knowing the average coldest room temperature and the age of the chicken find the amount of heat required for proper growth, Fig. 3.
 - 4. Multiply the heat required, Btu/in²/hr, by the projected area of the chicken, in² of chicken; the product is the heat required per chicken per hour.

- 5. Step four gives the heat required per chicken, find the heat required for all the chickens. For design wattage, one watt hour is equal to 3.413 Btu.
- B. 1. Find the Btu output per hour of the brooder, one watt hour is equal to 3.413 Btu per hour.
 - 2. Follow steps two, three and four as in part A.
 - 3. The brooding capacity of the brooder must satisfy two conditions:
 - a. The heat requirements for each chicken;

 Btu (output)/in²/hr = Btu (required by chicken)/in²/hr.
 - b. The sum of the projected chicken areas should be at least 25 per cent less than the radiated floor surface area of the broader.

The heat slab type brooder was designed following the above procedure. It was first conceived that the heat slab brooder might be used by itself without the aid of a hover type heat trap. With this hypothesis, radiation patterns were determined with the heat slab.

Mercury thermometers were first used to establish a heat pattern above the heat slab. The temperatures six inches above the heat slab were two to eleven degrees F above room temperature. The heat slab surface temperature was not high enough to fulfill the brooding requirements set forth by Seeger and Oliver, Fig. 3.

An Eppley radiation meter was used to find the total infrared radiation output from the heat slab and from infrared brooder lamps.

The radiation output of the lamps could be compared with the published data of Fig. 1. This would have been an ideal criteria for comparisons. The meter had a filter that filtered out a great portion of the infrared spectrum. The filter could not be removed, so the readings were invalid.

It was established that the heat slab brooder was not a true radiant heat source, but a heat source for conduction and convection heat transfer. A chicken could lie down on the heat slab and receive energy by conduction; when the chicken would walk on the heat slab energy was transmitted to the chicken by convection and very little by radiation. The Stefan - Boltzmann Law for black body radiation provides the basis for the last statement.

The radiant heat output, Btu per hour, of the heat slab: $q = A \epsilon \rho (T_1 - T_2)$, Stefan - Boltzmann Law $A = 16 \text{ ft}^2$, area of heat source, the heat slab brooder $\epsilon = 0.90$, assumed emissivity for masonite $\rho = 0.173 \text{ I } 10^{-8} \text{ Btu/hr ft}^2 \circ_{R}^{4} (\text{Rankine degree})$, a constant $T_1 = (80 \text{ 4}60)^{\circ} R$, slab surface temperature without a hover $T_2 = (30 \text{ 4}60)^{\circ} R$, room temperature $q = 16 \text{ I } 0.90 \text{ I } 0.90 \text{ I } 0.173 \text{ I } 10^{-8} \text{ I } ((540)^{4} - (490)^{4})$ q = 155 Btu/hr, radiant heat output of the heat slab

Seven hundred and eighty watts of electrical energy were being used per hour which is equivalent to 2662 Btu per hour. The remaining heat:

2662 Btu/hr - 155 Btu/hr = 2507 Btu/hr
was being transferred by convection to the air and by conduction
through the insulation of the heat slab.

With this type of heat source a heat trap will have to be used.

The problem was to design a heat trap that would retain the advantages of infrared brooder lamps and minimize the loss of heat due to power interruptions.

One of the advantages of the infrared brooder lamps was that the chickens could be seen at all times. With this important consideration foremost, a clear plastic sheet hover was designed. The plastic used reflected the long infrared waves and transmitted the short infrared wave lengths. It would be desirable to have a plastic that reflected both long and short infrared wave lengths. The plastics investigated would do one or the other and not both.

The plastic hover maintained desirable brooding temperatures.

When an aluminum top was installed on the plastic hover electrical energy consumption was reduced. Fig. 6 shows the final hover. A wood hover maintained desirable brooding temperatures, but this advantage was disregarded in favor of the clear plastic hover with an aluminum top because of the visibility through the clear plastic.

The heat balance of the plastic sheet hower with an aluminum top is as follows, assuming the available heat above the heat slab is transmitted by convection; radiant heat is present but in very small amounts.

Heat output, Btu per hour, of the heat slab brooder:

 $q = hA(t_1 - t_2)$, heat transfer for convection heating

h = surface conductance and it is dependent on temperature
and the position of the surface

A = surface area of the heat source

t₁ = surface temperature of the heat source

to = air temperature surrounding the heat source

The following calculations are necessary to solve for the heat required to maintain an air temperature of 82°F under the hover:

The surface conductance for a flat surface over one square foot and heating upward:

$$h = 0.38(\Delta t)^{\frac{1}{4}}$$

At = 122-82, heat slab surface temperature minus the air temperature under the hover

$$\Delta t = 40^{\circ} F$$
 $h = 0.38(40)^{\frac{1}{4}}$
 $h = 0.98 \text{ Btu/ft}^2 \text{ hr }^{\circ} F$

and,

$$q = hA(t_1 - t_2)$$

$$q = 0.98x 16 x (122-82)$$

A = 16 ft² surface area of heat slab

t₁ = 122°F heat slab surface temperature

t₂ = 82°F air temperature under hover

q = 624 Btu/hr. heat loss from the heat slab to the air under the hover

The heat loss from inside the hover to the air in the brooder house is assumed to be lost by convection. The hover top and sides are approximately the same temperature as the air under the hover, the plastic conducts heat very rapidly and the aluminum by itself conducts heat rapidly. The aluminum receives its insulation value from the air film layers on each side of the sheet; however there are forty feet of crackage on the top of the hover from which heat escapes, therefore the film layers of air can be neglected and the aluminum is assumed to be the same temperature as the air under the hover.

The hover is assumed to be a rectangle having dimensions of 2.5 x 4.0 square feet on each side and 4.0 x 4.0 square feet on the top and bottom. The surface conductance for a vertical surface more than one square foot and more than one inch wide is:

 $h = 0.12(\Delta t)^{\frac{1}{4}}$

∆t = 82-30, air temperature under the hover minus the room
air temperature

 $h = 0.12(52)^{\frac{1}{4}}$

 $h = 0.325 \text{ Btu/ft}^2 \text{ hr }^0\text{F}$

and.

 $q = hA(t_1 - t_2)$

A = 2.5 X 4.0 X 4.0 = 40 ft² vertical hover surface area $t_1 - t_2 = 82-30$, air temperature under the hover minus the room air temperature

 $q = 0.325 \times 40 \times (82-30)$

q = 675 Btu/hr. heat loss through the vertical sides of the hover

The surface conductance for a flat surface more than one square foot and heating upward:

$$h = 0.38(\Delta t)^{\frac{1}{4}}$$

 $\Delta t = 82-30$, air temperature under the hover minus the room air temperature

$$h = 0.38 \times (52)^{\frac{1}{4}}$$

h = 1.025 Btu/ft² hr °F

and,

 $q = hA(t_1 - t_2)$

A = 16 ft², the surface area of the top of the hover $t_1 - t_2 = 82-30$, air temperature under the hover minus the room air temperature

 $q = 1.025 \times 16 \times (82-30)$

q = 852 Btu/hr. heat loss through the top of the hover.

The total heat transfer through the heat slab top surface is equal to the heat required to warm the air under the hover plus the heat loss of the vertical sides and the top of the hover.

q = 624 + 675 + 852

q = 2151 Btu/hr. heat loss through the top of the heat slab

The average electric consumption was 0.75 kwh for the above conditions, therefore:

0.750 kwh \times 3413 Btu/kwh hr = 2560 Btu/hr output of the heat slab and,

2560 - 2151 = 409 Btu/hr heat loss by conduction through the bottom and sides of the heat slab.

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The convection theory of heat transfer accounts for most of the heat; it also accounts for a reasonable loss through the bottom insulation and through the wood frame sides of the heat slab.

Figure 13 shows how the temperature decreases under the empty hover when the circuits are de-energized. With chickens under the hover the temperature under the hover would remain higher for a longer period. The heat slab hover brooder definitely minimizes the power interruption disadvantage of infrared brooder lamps. Two hours after the power interruption the temperature was 65°F six inches above the heat slab surface, under the hover, with a room temperature of 20°F. This would not be harmful to chickens. U.S.D.A. reported that chickens can be chilled at 37°F for one and one half hours without impairing their growth rate. A two hour power interruption would be fatal to the majority of chickens under an infrared lamp brooder in a room of 20°F.

The results of the first trial brooding test were to be used as indications of the brooding effectiveness of the two brooders used. The indications were: reduced mortality; increased feed conversion rates; and lower electric energy consumption with the advantage in favor of the heat slab brooder.

The chickens behaved very well on the heat slab. One interesting observation during this test and the next two was that a cold chicken would lie down on the heated surface and fan out its wings to increase the body surface area so it could absorb more heat by conduction.

The results of the second trial brooding test were treated more critically than the first brooding test. A detailed study was made

from the recorded hourly temperatures under the hovers of the brooders. The heat slab brooder was used without any corrections or additions. The thermostat settings for the heat slab brooder were made according to the graph on temperature requirements versus chickens age, Fig. 4.

A wood hover was used for the infrared brooder lamps to try to reduce the electric energy consumption. A commercial heat slab brooder was used for brooding and it was compared with the infrared lamp brooder and the designed heat slab brooder.

An analysis of Fig. 14 through 22, the hourly temperature recordings under the hovers, provided a criteria for measuring the relative effectiveness of the hover type brooders.

- 1. The infrared brooder lamps with the wood hover:
 - a. Temperatures under the hover were consistently higher than required for proper chicken brooding.
 - b. The temperature fluctuations under the hover were similar to the outside temperature fluctuations. This is not desirable. The hover should maintain a constant temperature. The additional heat from the lamps radiation would compensate for the difference in cold weather and would add to the chickens' discomfort on warm days. The hover eliminated "comfort zones" that are normally established with infrared brooder lamps.

2. The heat slab brooder:

a. The temperatures under the hover followed the required broading temperatures established on Fig. 4. Variations

did occur when the outside temperatures dropped to low values. The reason for this may be that the chickens remained under the hover for longer periods and this raised the temperatures under the hover.

b. The hourly temperature variations indicated that the brooder could maintain constant temperatures under the hover for a wide range of outside temperature variations.

3. . Commercial heat slab brooder:

- a. The temperatures were erratic under the hover, following a temperature curve similar to the infrared brooder lamps.

 The thermostatic control was not calibrated and as a result was difficult to set for proper temperature control.
- b. The hourly temperatures under the hover indicated that the brooder held a constant under the hover temperature.
 Temperatures varied more with the heat slab brooder than with the infrared lamp brooder.

The commercial heat slab brooder consumed the least amount of electric energy, 0.636 kwh per chicken, as compared to 1.815 kwh per chicken for the infrared lamp brooder. The infrared lamp brooder had the highest energy brooding cost. A thermostat could have been installed under the hover with the infrared brooder lamps but it would have had to work almost constantly. The high energy output of the lamps would have activated the control and the lamps would have been de-energized and the rapid cooling of the hover would again activate the control.

The chicken mortality was less than two per cent for all brooding methods. The highest mortality was 1.594 per cent with the commercial heat slab brooder. One possible reason for this was in the construction of the hover; the hover was 12 inches high and ventilation was a problem. The heat slab surface was 12 square feet and the larger chickens could easily suffocate small chickens under the hover by crowding.

The feed conversion rates were poor, varying from 3.437 to 2.998 pounds feed per pound gain. The highest feed conversion rates were with the heat slab brooder and the lowest feed conversion rates were with the commercial heat slab brooder. The reason for the high feed conversion rates was probably due to a mixed breed of chickens, some of which were not too efficient in converting feed to meat.

One interesting result is reported in Table 10, the mean weights and the standard deviations of these mean weights for male and female chickens. The commercial heat slab brooder had the highest mean weights and the designed heat slab brooder had the lowest standard deviations which indicated a greater consistency in the weight of the chickens. The infrared lamp brooder had the highest standard deviations and lowest mean weights indicating wide variations in the weight distributions.

Statistical significant differences in weights occurred between males in all the brooders but not between females. This would indicate that there may be a preference in the type of brooder for the brooding of male chickens for meat. These results led to the third brooding trial to test this difference.

The third brooding trial utilized a Vantress Cornish X Acress White Rock breed of chickens. The mortality was low, with the indication that mortality is higher for females.

Accurate feed conversion rates were obtained for the chickens under the infrared lamp brooder. The males were slightly more efficient than females. The partition for the heat slab brooder was not chicken proof; male and female chickens mixed during the week before weighing. The combined feed conversion rates for both sexes were obtained. The combined feed conversion rate was higher for the infrared lamp brooder, 2.043 to 1.932 pounds feed per pound gain.

The mean weights of the male and female chickens raised under the infrared lamp brooder were higher and the standard deviation of the mean weights was less than for the chickens raised in the heat slab brooder. This was a complete reversal of the second brooding test. There was no statistical difference between the male and female chickens. The heat slab brooder used less electric energy for brooding and chicken mortality was lower with heat slab brooding.

SUMMARY

Radiant type chicken brooding is very popular among chicken growers. In many cases the term radiant heat transfer is misleading. Radiation heat transfer requires no conducting or convection medium. Infrared brooder lamps are truly radiant type heaters. Many of the radiant type brooders are not truly radiant. A very small portion of the total heat is emitted in the form of infrared radiation. The majority of the heat transfer is by conduction or convection. The heat slab brooder constructed in this experiment was designed as a radiant heater; it turned out to be a heat source for conduction and convection heat transfer.

A heat slab brooder was designed for Michigan conditions. The brooder worked satisfactorily during three brooding seasons: mid-winter; early-spring; and late-spring. The initial cost of the heat slab brooder was higher than for a corresponding infrared lamp brooder. The life of the brooder was undetermined. It was assumed that it will last as long as the materials of which it is made will last. The maintenance of the brooder hover would be a few cents per year; the plastic sides on the hover would have to be replaced.

The heat slab brooder and a plastic hover with the aluminum top offers many comparable advantages of the infrared brooder lamps: the chickens can be seen at all times; and it is easily installed and operated.

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The heat slab minimizes two of the disadvantages of infrared lamp brooders; a complete loss of heat due to a power interruption; and high electric brooding costs. The heat slab brooder will retain a temperature of 65°F for at least two hours and temperatures above 37°F for a longer period of time after electric circuits are de-energized. The heat slab brooder should be energized 24 to 36 hours before chickens are placed in it.

There was no difference in feathering or growth rates of the chickens under the various types of brooders. Chicken behavior was similar under the infrared lamp brooder and the heat slab brooder. Chicken mortality was less with the heat slab brooder than with the infrared lamp brooder. Under the infrared lamp brooder the stronger chickens would retain positions in the various "comfort zones" averting the weaker chickens from these zones. Chickens on the heat slab brooder can receive the benefits of proper temperature and there is enough room for all the chickens.

When infrared brooder lamps were used in conjunction with a hover, desirable brooding temperatures were very difficult to maintain. Temperature fluctuations under the infrared lamp brooder were similar to outside temperature fluctuations. The heat slab brooder temperatures usually increased with outside temperature drops. This was probably due to the chickens remaining under the hover for greater periods of time and thus providing an additional heat source, the chicken's body.

The commercial heat slab brooder was used during the late-spring brooding period. The results of one late-spring test are: reduced electric energy consumption and increased chicken mortality.

In view of the discussed considerations, a heat slab brooder of most practical capacity limits, can be designed for Michigan conditions. A heat slab brooder designed for radiation heating will supply ample heat for convection heating if the heat slab is insulated and a hover trap is used. The required brooding temperatures, Fig. 4, should be followed for minimum energy requirements.

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