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Electric Brooding of Chicks
II. Heat Requirements

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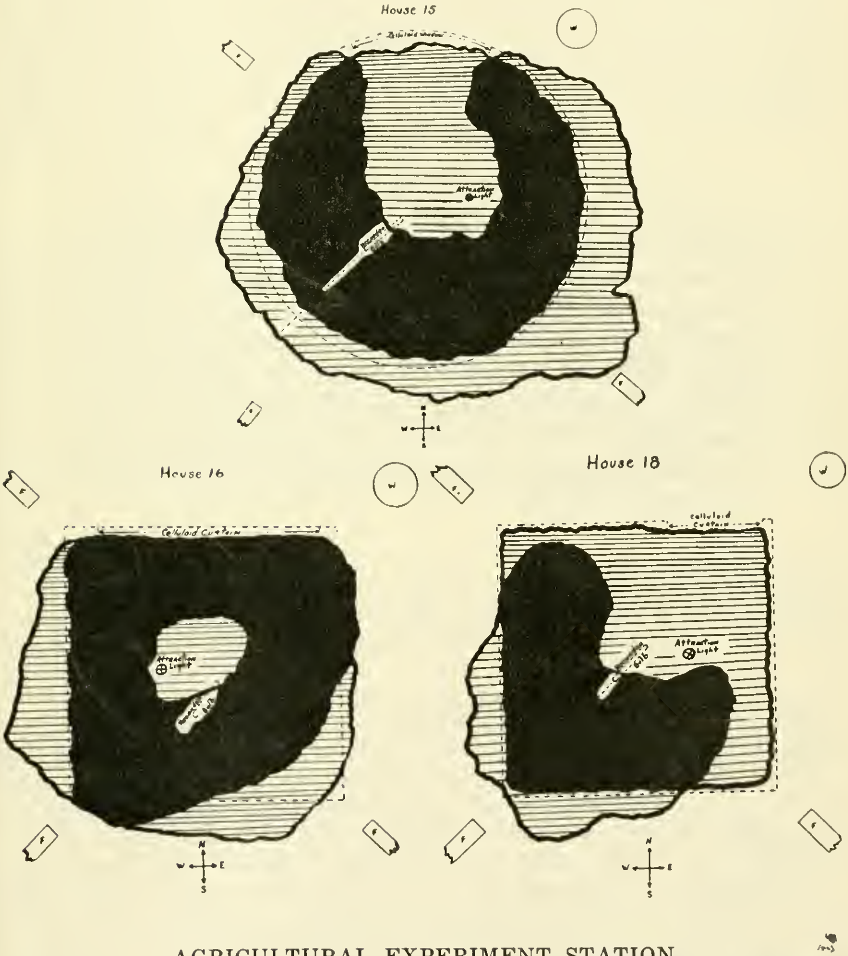

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OUR COVER

The unusual figures on the cover are not a new idea in decorative art, but rather a group of diagrams showing the concentration of chicks at night under three different brooders: areas constantly occupied (black); areas not constantly occupied (cross-hatched); and the extent of crowding out beyond the curtains (outer black line) that occurred at various times. It would appear that in Houses 15 and 18 the celluloid window had some effect on the location of chicks, but this is not substantiated by House 16. Waterers (W) and Feeders (F) are also shown.

Electric Brooding of Chicks
II. Heat Requirements

Preliminary experiments in electric brooding were reported in Station Circular 46. Certain temporary conclusions, then drawn, were briefly as follows: (1) electric brooding is practical and can be carried on under very severe climatic conditions without auxiliary heat or excessive mortality; (2) no significant differences in results were observed in insulated versus non-insulated houses; and (3) little is to be gained by house ventilation for the purpose of lowering the humidity. It was suggested that floor conditions be investigated on the premise that they might be responsible for a constant and pronounced variation in temperature throughout the 24-hour period, for degree of chick movement, and for the formation of a moist ring about the brooder.

1934-35 EXPERIMENTS

Accordingly, the insulating material on walls and ceiling of the houses used in the previous year's trials was removed. This material was then applied to the floors of the four houses so that varying degrees of floor insulation values were established. Thus, House 13 was provided with a double wood floor, paper between floors; House 14, with double wood floor plus one layer 7/16″ insulating board enclosed in a sealed tar-paper envelope laid between the floors; House 15, with similar construction except for two layers of insulation; and House 16, with three layers of insulation board. (Fig. 5.) Around the base of each house earth or boarding was placed so as to give wind protection to the floors as uniformly as possible.

Equipment

Temperature readings were obtained by installing thermocouples (1) on the under-surface of the sub-flooring and exposed to the air under the house, (2) between each layer of insulation or flooring, and (3) on the finished surface of each floor.

House 13, having no insulation between floors, and House 16, having the maximum amount, were provided with observation booths attached to the west side. A window 2′ x 4′ was placed in the wall so that chick movement could be observed without disturbance. The two remaining houses were fitted with observation windows only.

The leads from the thermocouples were carried to a connecting panel in each booth or adjacent to the observation window so that readings could readily be made with the potentiometer. Recording and check thermometers were employed as in the previous experiments.

Three standard makes of brooders were used. (See Fig. 1.) Brooder No. 1 was of circular design with a manufacturer's rating of 350 chicks. On the flat ceiling section a 440-watt, open-coil heating unit was mounted concentric with the center of the brooder. Natural

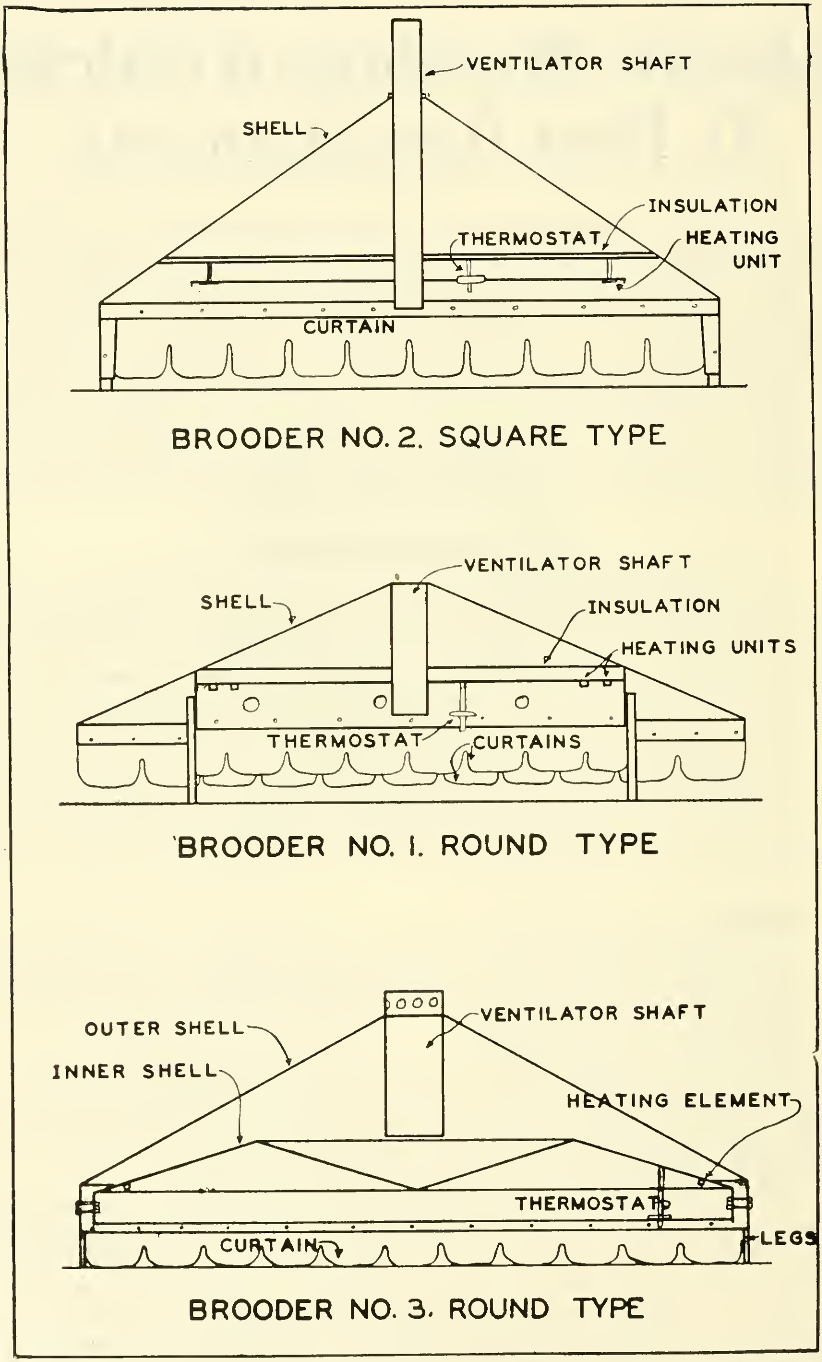


FIG. 1. Diagrams of the construction and essential parts of the three types of brooders.

up-draft ventilation through a central flue was provided. Brooder No. 2 was of square design with manufacturer's rating of 400 chicks. The heating unit of 800 watts was laid in grooves between two layers of black sheet metal. Center flue ventilation (natural up-draft) was provided. Brooder No. 3 was of circular design having a manufacturer's rating of 350 chicks. The heating unit of 550 watts was mounted at the inside periphery of the brooder at the junction of side wall and ceiling. It was enclosed in perforated porcelain tubes, mounted end to end, forming a single continuous element. Natural up-draft ventilation was provided, exhausting by way of a channel at the periphery of the brooder connected to a cylindrical tower head at the apex of the brooder.

Conditions for Use of Brooders

The brooders were set up as in 1933-34 except that the pads of insulating board on the floor were not used. The first run was made with No. 1 brooders in Houses 13 and 14, and No. 3 brooders in Houses 15 and 16. The second run was made with No. 2 brooders in Houses 13 and 14, and No. 1 brooders in Houses 15 and 16. In order to obtain some comparative cost records of operation a coal brooder was set up in House 17, which was of similar construction to House 13.

Brooder Management Schedule

Days 1- 7: Chick confining ring set 1-1½ feet from edge of brooder. The first day chicks stay mostly under the brooder voluntarily, and feed is supplied underneath. Water containers remain at outer edge of hover. On the second day chicks come out in considerable numbers and are fed and watered outside.

Days 7-18: Ring set three feet from edge of hover. Feeders and waterers spaced accordingly.

Days 18-25: Front part of ring removed but rear half retained. This is pushed back against rear wall to round off house corners.

Days 25-42: Ring entirely removed and chicks allowed use of complete floor area. Cockerels removed. (Floor area per chick approximately doubled by this separation.)

Feed Consumption and Management

A total of 2,971 New Hampshire chicks were placed under brooders in this experiment and fed the New England College Conference ration for growing chicks. The original lot was started on December 4, 1934, and the final lot started on February 7, 1935. The period of brooding was six weeks. Grain feeding was started on the fourth week in all lots. Granite grit and oyster shell was supplied in metal wall-type hoppers from the start. Total feed consumed per chick varied in Trial 1 from a low of 2.376 pounds in House 15 to 2.878 pounds in House 14. In Trial 2 variation was from 2.236 pounds in House 13 to 2.640 pounds in House 15. No consistent differences, however, were noted. The methods of handling and caring for chicks in the several houses were similar to those explained in Station Circular 46.

Growth, Weight and Condition

The growth of all groups was very satisfactory, averaging at six weeks of age .9335 pounds per chick. Some variations between groups were noted, but these were not significant. There was no significant difference between the houses used and the rate of gain in weight. Somewhat more rapid feathering was again observed in chicks under electric brooders as compared to those brooded by coal stove. The crooked-toe condition reported in Station Circular 46 was not in evidence this year.

Mortality

All birds which died during the course of the experiment, (December 4, 1934-March 20, 1935), were autopsied by the Poultry Pathology Laboratory to determine the cause of death. Of the total mortality to six weeks of age, which averaged for the entire season 14.8 per cent, pneumonia was the cause in 85 per cent of the cases. From an analysis of these records it is apparent that floor insulation was of little or no value in preventing mortality.

Labor and Fuel Costs

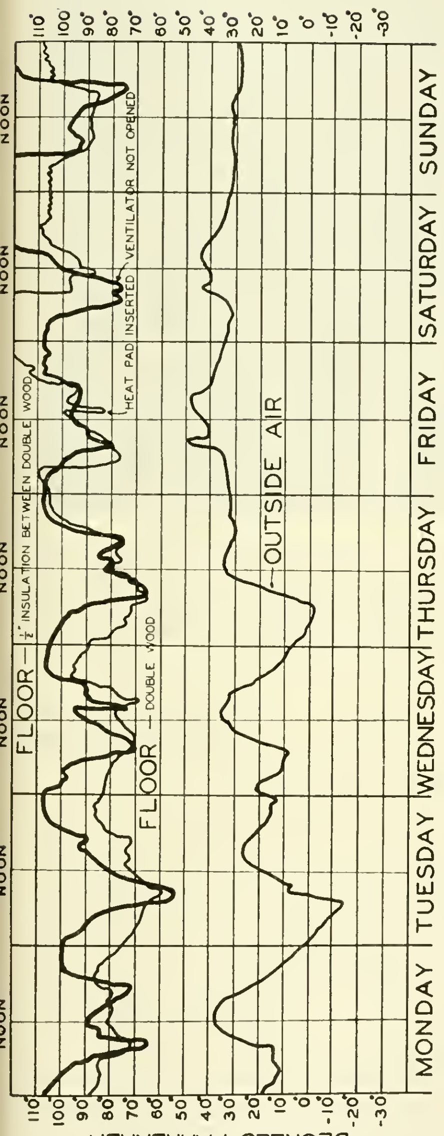
A detailed labor record-sheet was kept, showing the total time spent at each visit and the operations performed, i. e., feeding, watering, cleaning, care of stove, etc., at each of the three 10′x12′ colony brooder houses.

Table I shows a difference of four hours and four minutes actual labor time between the electrically brooded pens and the coal brooded

TABLE I. *Itemized Labor Requirements in Hours and Minutes for Electrical Brooding and Coal Brooding of Chicks.*

House No.	Run No.	Total Time	Feeding	Watering	Cleaning	Care of Stove: Coal	Care of Stove: Ash	Care of Stove: Reg. and Adjust*	Miscellaneous
13	1	11:46	1:33	3:33	3:23	....	....	3:03	0:14
(Elec.)	2	8:01	0:56	2:47	1:41	....	....	2:27	0:10
14	1	11:37½	1:31	3:16½	3:31	....	....	3:04	0:15
(Elec.)	2	9:38	1:04	2:53	2:50	....	....	2:36	0:15
17	1	15:31	1:39	3:22	1:12	3:07	2:36	3:16	0:19
(Coal)	2	13:08	1:05	2:54	1:25	2:40	2:21	2:31	0:12
Average:									
Electric		10:15½	1:16	3:07¼	2:51¼	....	....	2:47½	0:13½
Coal		14:19½	1:22	3:08	1:18½	2:53½	2:28½	2:53½	0:15½

* Regulating and Adjustment: There was very little need of this for either type of brooder after the initial setting had been determined. This column also includes the small amount of time reported for the reading of instruments.



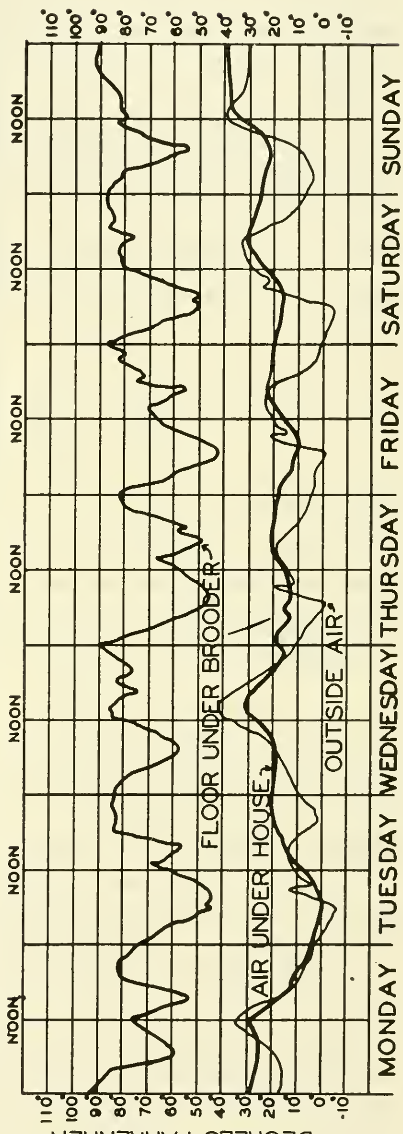


FIG. 2 (Above). Temperature curves on a double wood floor (light black curve), and a double wood floor with ½" insulation board (heavy black curve) showing the effect of the floor heating pad and improper adjustment of the ventilator at night. The week shows extremes of —15°F. to +50°F. in outside temperature. FIG. 3 (Below). Characteristics and relation of temperatures taken in three locations about the brooder house during one week when the range in outside temperature varied between —6°F. and +42°F.

pen. The latter required 39.6 per cent more time. This was in spite of the fact that cleaning the pens under electric brooding required an average total of one hour and thirty-three minutes more time. The floor of the coal house was dry at all times, but the litter in the electrically brooded pens was quite often damp necessitating frequent removal of litter.

Table II presents in brief the comparative costs of labor and fuel used under the two methods of brooding. It is to be noted that at the rates of charge for the two fuels there is a cost advantage with the electric brooding method of 52c per brood of 250 chicks.

TABLE II. *Comparative Cost Record Per Brood of 250 Chicks of Labor and Fuel for Electric and Coal Brooded Pens.*

	Total hours of labor	Cost of labor at 30c per hour	Kw. hours consumed	Cost of kw. hours consumed, 3c per kw.*	Lbs. coal consumed	Cost coal $16 per ton	Total labor and fuel cost
Ave.: Electric	10:15½	$3.08	426	$12.78	....	....	$15.86
Ave.: Coal	14:19½	4.30	......	....	1512	$12.08	16.38

* About seventy per cent of the electric consumers in this State now have available a 2-cent rate for current after the first 90 kilowatt hours are consumed.

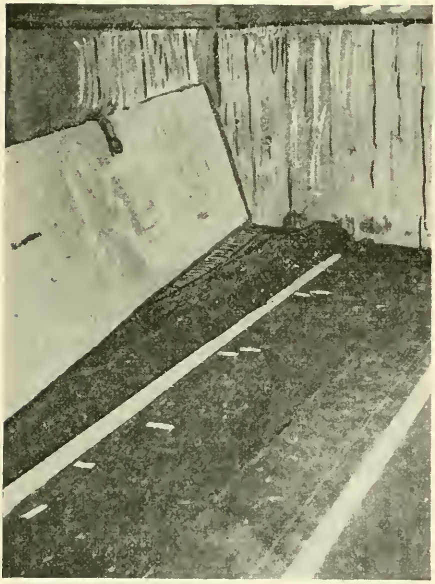
Two more bales of shavings were used in the electrically brooded pens than in the coal brooded pens. Giving this a cost value of 25c per bale (local price) and adding to the total costs, there would be but a very small cost differential between the two methods.

Insulated Floors (With Natural Ventilation Brooders)

Experiments on the insulated floor construction began in November, 1934, and temperature readings were taken with both recording thermometers and thermocouples at intervals throughout the winter.

The temperature record of one week in which there were three cold days with quite low temperatures at night and three days when the temperature was generally above freezing is shown in Figure 2.

The two upper curves show the temperature taken in Houses 13 and 14 by laying the bulb of the thermograph (measuring 1″ diam. and 12″ long) on the surface of the floor imbedded in the litter under the brooder so that it touched the floor along its length. Inasmuch as the contact with the floor was tangential and small in amount, this reading is composite of floor, litter, floor draft and some chick contact. The temperature of the wood flooring itself is shown later by the readings of the thermocouples which are in direct and complete floor material contact.



The insulated floor of one house. A piece of the insulating board stands at the left ready to be slid into place under the black waterproof envelope before it is sealed with tar. Thermocouple junctions are located under the adhesive tape squares and carried to a connecting panel.

The double wood floor showed the least tendency to vary in extremes. The average temperature up to Thursday mid-morning is higher on the insulated than the non-insulated floor, but instead of leveling out, the fluctuations seem to increase.

There is also an easily seen relation between the outside temperature of the first of the week, (shown by the lower curve), and the insulated floor. It should be emphasized that the two floor curves were taken in two separate houses simultaneously and that they follow each other closely in the nature of their fluctuations.

The main irregularities in temperature are obviously caused by sources outside the brooder, by brooder design features, by floor drafts, etc. Chick movement seems to coincide with, or be caused by, the extremes in these fluctuations.*

Heated Floor

On Friday noon, an electrically heated floor pad (60 w. capacity, operating continuously) was placed under the brooder on top of the uninsulated floor. The anticipated return of cold weather did not transpire, and the floor temperature shot up beyond all reasonable values (record off the chart on Friday night).

This pad was inserted without changing the amount of heat overhead in the brooder, showing that excessive heat can be responsible for high extremes in the temperature curves, as might be expected.

Effect of Ventilation

The same effect was brought about, however, in the house with the insulated floor on Saturday and Sunday by not opening the ventilator, showing that *without* additional heat, restriction of ventilation may also result in excessive temperatures.

The three makes of brooders show a considerable degree of variation when compared on the basis of the relation between the intake area (curtained edge of brooder) and the area of exhaust flue opening. (Table III) Similarly wide variations may be seen between the ex-

* See Page 14, "Effect on Floor Under Brooders."

haust area, square feet of brooder floor area, cubic feet of brooder compartment and exhaust area per chick. This divergence of practice in manufacture together with the fact that some brooders are used for both natural up-draft and down-draft power ventilation without other change than the addition of a ventilating fan, indicates that definite ventilating rates have not been determined up to this time. It is important to establish values for this air exchange.

Under-Brooder Heat Measurements

Temperature readings were taken in January, 1935, with thermocouples under Brooder No. 2 and Brooder No. 3, each with 250 chick loads, to determine the heat distribution, under colony house conditions.

The temperature readings were taken at 4″ intervals horizontally and 1″ intervals vertically (from ½″ to 3½″ above floor). The temperatures secured were plotted on the diagram (Fig. 4) at points corresponding to the position at which they were taken under the hover. The lines were then drawn to connect points of equal temperature. (isotherms)

Case 1 with 3-weeks old chicks showed a generally flat temperature zone but a definite tendency to lose regulation at the lower edge of the curtain. All temperature contours had a tendency to lift at the edge,

Table III. *Brooder Ventilation Factors, 1934-35.*

Factors	Brooder No. 1	Brooder No. 2	Brooder No. 3
Curtain:			
1. Length	14½′	14½′	14½′
2. Width exposed	3″	5″	3″
3. Surface exposed	523 sq. in.	870 sq. in.	523 sq. in.
4. Area exposed per sq. in. of flue opening	73.6 sq. in.	247 sq. in.	95 sq. in.
Crack clearance of curtain:			
1. Width exposed	½″	½″	½″
2. Surface exposed	87 sq. in.	87 sq. in.	87 sq. in.
3. Area exposed per sq. in. of flue opening	12.2 sq. in.	24.7 sq. in.	15.8 sq. in.
Exhaust opening:			
1. Area	7.1 sq. in.	3.52 sq. in.	5.5 sq. in.
2. Diameter	3″	2⅛″	7 holes 1″ in diam.
Square inches of exhaust opening per square foot of brooder floor area.	.415	.188	.331
Square inches of exhaust opening per cubic foot of brooder content.	.65	.277	.462
Number of chicks per square inch of exhaust.	35	71	45.5

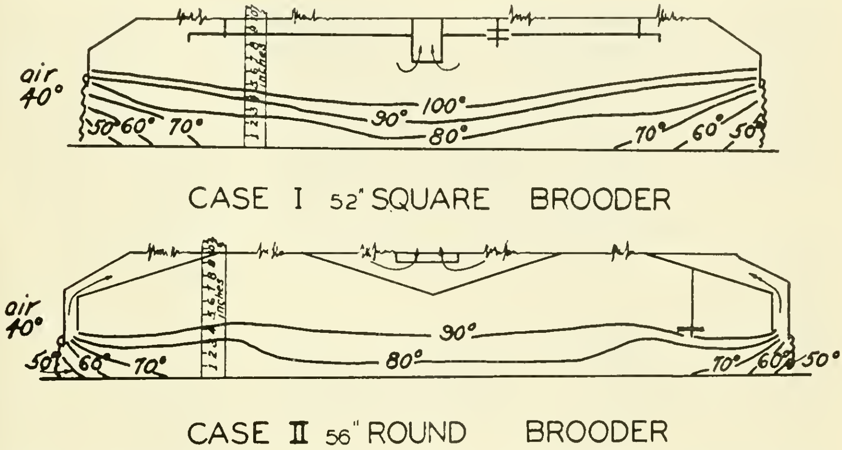


FIG. 4. Square and round type brooders, one having a center exhaust ventilation and the other edge exhaust. Thermocouple readings show the heat distribution with a full load of chicks taken under brooder house conditions.

giving rise to the possibility of recirculation effects in the upper layers and a greater degree of floor draft effects at the outer edge at floor level.

Case 2 with 5-weeks old chicks showed temperature regulation horizontally that was quite flat and regular in the center but reflected the shape of the ceiling. The temperature at the floor edge of curtain was more stable and showed 10 degrees less variation than in the first case. This indicates that floor drafts gave less trouble.

With the different types of design which are employed, there naturally follow different operating characteristics. While it is generally presumed that a uniform temperature under the hover is necessary, there is evidence that a certain variation may be desirable to suit the varying needs of different individuals. Whether this regulation should be varied horizontally, vertically, both, or not at all is not clear with present available information.

There was a vertical change in temperature within 3½" of floor of 30 degrees in the square and 20 degrees in the round brooder.

The failure to find any substantial benefit from special floor insulation points to the effect of floor drafts, brooder design and other sources of irregularities, as causes of the differences.

The above comparisons of heat regulation are, therefore, of value principally to determine the effect of different locations of out-take flues, heating elements and shapes of brooding space, on the contours of heat levels and provide information on brooder design factors.

Under-Brooder Floor Temperatures

Figure 5 shows cross sections of the floor construction in the four houses.

All indications to date point to the necessity of considering the brooder house floor as composed of two parts: (1) that part of the floor

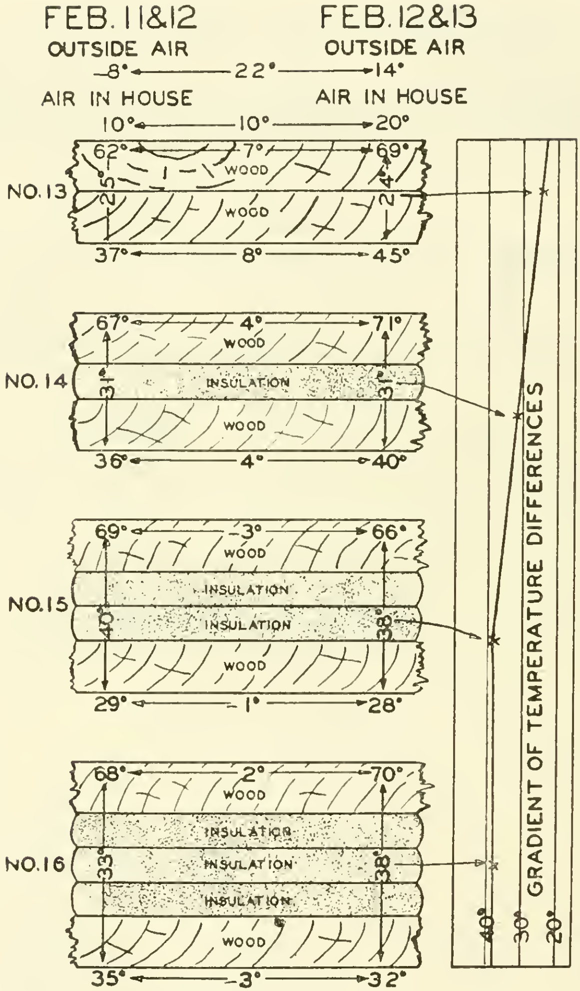


Fig. 5. The kinds of floors used in the experiment and thermocouple readings taken at the upper and lower surfaces on two representative days of average cold weather. The differentials between these are indicated by figures between arrows. The curve to the right indicates that about 1″ of insulation produces a noticeable effect on temperature regulation.

which lies directly under the brooder, and (2) that part of the floor which lies outside of the brooder area. The two parts are exposed to much different conditions, and the following data refer to only the first mentioned floor area, that directly under the brooder.

The average temperatures on top of the floor and under the floor are shown in their relative positions. The figures inserted in the arrows are the temperature differences between the points at ends of the arrows. The outside temperature on the first night averaged —8 degrees, while on the second night it averaged +14 degrees, a difference of 22 degrees. The air in the house the first night averaged +10 degrees, and the second night +20 degrees, a difference of 10 degrees.

A study of the diagram shows that the double wood floor in House 13 maintained a difference of 24-25 degrees; the double wood and ½″ insulation in House 14 maintained 31 degrees; the double wood and 1″ insulation in House 15 maintained 38-40 degrees; and the double wood with 1½″ insulation in House 16 only 33-38 degrees.

Under the conditions of this experiment the double wood floor with 1″ of insulation or its equivalent was the point of declining value, and we are led to believe that this amount will keep down heat leakage through the floor under the brooder as well as more insulation. Moreover, there is nothing to indicate that a double wood floor with a disc of 1″ insulation board or its equivalent, properly waterproofed and slightly larger than the brooder, placed on the floor under the brooder, will not be just as good as, or better than, built-in insulation, and is certainly less expensive. This would have an uninsulated area outside of the brooder to collect and transmit to the under-house section as much sun's heat as possible, with its attendant storage hold-over effect.

Floor Insulation Temperatures (1934-1935)

Temperature readings in the floors as taken by the thermocouples placed in the various floor layers are shown graphically in detail in Figure 6 for a night when the prevailing outside temperature dropped to near 15 degrees below zero.

Due to the different makes of brooders with their variations in heat production values and operating characteristics, it cannot be said that the exposure to heat on the floor surface was the same in each case.

House 13 shows a well defined relation between the outside temperature and that of the floor at all three locations. The outside temperature dropped 24 degrees in eight hours. The surface of the floor dropped 15 degrees in the same period—2 degrees greater than the under-house or internal floor drop.

This 2-degree difference, while not great, is deemed of considerable significance as it indicates a more rapid loss of heat than can be accounted for in any other readings through the floor section. This suggests the conclusion that floor drafts and brooder house air are sources of greater heat loss than through-the-floor-radiation, provided the floor is at least a double layer of wood with one layer of paper between.

Curve B in House 14 shows that the temperature just under the surface wood flooring is, on an average, about 12-14 degrees improvement in temperature over the corresponding point in the floor of No. 13. (The surface floor temperature was lost through failure of a buried thermocouple.)

In the case of House 15, neglecting the other points of measurement, Curve B (just under the surface flooring) shows the best regulation of any group with a variation of only 8 or 9 degrees, although the temperature level is about 5 degrees less than No. 14. The general characteristics of all curves for this house show improved regulation

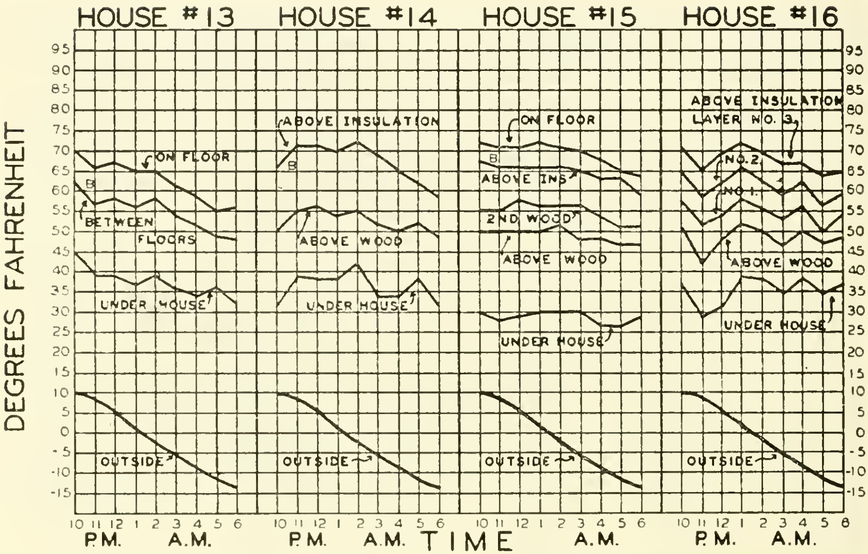


FIG. 6. A series of floor temperature readings taken with the thermocouples between night and morning in the four kinds of floors used, during a drop in outside temperature from +10°F. to −14°F.

as far as variations are concerned, but no improvement in floor surface temperatures under the brooder. Hence, this is considered to be the point of declining efficiency of insulation.

It has become evident from a study of the above curves that different sources and degrees of exposure are in effect on brooder house floors. Ground temperature, ice formed under the house, outside temperature penetrating "banking-up" material, leaks in "banking-up" material, room temperature above the floor and floor drafts are the important sources of cold which gain entrance to the floor surface under the brooder.

The amount of exposure of the upper floor surface to the temperature of the air in the house also has an effect on this brooder floor condition. For about one-third of the daylight hours, absorption of heat from the sun's rays may benefit temperature conditions on the floor. As this occurs at the time chicks are out on the litter, its value cannot be other than beneficial and it is available at an appropriate time.

For 16 hours, approximately, the effect of the air in the house will be in the opposite direction and exert a lowering influence on the floor-under-brooder temperature. A hold-over advantage after the eight hours of sunshine is believed to play a part in keeping this temperature on the upward trend until the midnight period, by which time this has been overcome by the opposite action of the house air after sundown. High wind pressures, when they occur, counteract the sun's action.

Effect on Floor Under Brooders

The upper curve in Fig. 3 (1933-34 tests) shows the temperature of the floor directly under the brooder taken simultaneously with the temperatures shown in the two lower curves of the air under the house and the outside air.

The time at which the upper curve begins to rise each morning coincides with the time at which the outside air and under-house air curves begin to rise. This, as suggested before, we believe to be due to the action of the sun's heat. The angles of the outside air and under-brooder floor temperatures are steep and reasonably parallel between mid-morning and mid-afternoon. The rise in under-brooder floor temperature continues until midnight with some abrupt interruptions.

During this period before midnight the chicks have huddled and settled down for the night. Chick movement and restlessness, described in Circular 46 and later in this report, begin as the temperature increases, due to an apparent effort by the chicks to find the most comfortable degree of heat. The downward curve of the outside air temperature from mid-afternoon to this midnight point is directly opposite to the rising temperature of the floor under brooder. Regularly at or near this midnight point the floor curve starts down steeply. This downward slide starts almost immediately after the highest point of temperature has been reached at night, and can be ascribed to the fact that the chicks break their huddle to relieve temperature and air conditions.

There is a directly traceable relation and beneficial effect of the sun and outside air temperature on the rising parts of these three curves. No correlation seems to exist between the air under-house temperature and the floor under-brooder temperature for the balance of any twenty-four hour period. This strengthens our assumption that chick movement causes the sudden downward trend of the floor temperature curve from midnight to early morning.

TABLE IV. *Brooder and Total Floor Area Relations.*
Total Chicks Per Brooder, 225

Brooder number	Type	House	House floor total sq. ft.	Sq. ft. brooder area	Sq. ft. of free floor	Sq. ft. per chick	Ratio of un-heated to heated floor surface per cent.
1	52″ sq.	13 (10x12)	120	18.7	101.3	.45	84.5-15.5
2	56″ ro.	14 (10x12)	120	17.1	102.9	.45	85.8-14.2
2	56″ ro.	15 (12x16)	192	17.1	174.9	.77	91.1- 8.9
1	52″ sq.	16 (12x16)	192	18.7	173.3	.77	90.3- 9.7

Relation of House Floor Area to Brooder Size

From the work done up to this time, especially with respect to floor insulation, it appears desirable to establish not only the space allotment under the brooder, but the amount of space which is most desirable outside of the brooder for ranging and feeding. This involves the relation between size of brooder and size of compartment or house in which it is used.

Table IV shows that only about 15% of the total floor area is exposed to a controlled heating effect (under brooder) in the case of 52″ square or 56″ round brooders in 10′x12′ houses. The balance, or 85% of the floor, is exposed on its top surface to brooder house air temperatures and floor drafts for the full 24 hours, this being tempered, as indicated in the curve of Figure 3, by sunlight, when and if available, in varying amounts for about eight hours at the most in winter weather. In the case of the same brooders in 12′x16′ houses, the unheated floor area becomes about 90% as against 10% heated.

This uncovered floor surface can and does receive, when available, sun heat on an average of one-half of its surface for not more than a maximum of eight hours per day or a net desirable exposure in area-time value of about 16%. If this 16% exposure develops the amount of improved temperature regulation that is indicated in the under-floor space, it appears that any method that would improve this action would be desirable.

The factors involved in this improvement process are considered to be as follows:

1. Balancing of size of brooder to total size of floor or vice-versa.
2. Providing maximum exposure possible of uncovered floor to sun's action.
3. Elimination of floor drafts—air cooling action.
    a. Tight banking up at base of houses.

Table V shows the space allotments as used in these experiments, according to periods or intervals of time.

Summary 1934-35

The results of the 1934-35 season, added to those of the preceding years, reduced to negligible proportions the significance of insulation or need of particular structural features in any surface of the house enclosing electric brooders. The factors affecting the heat requirements of chicks were narrowed down to the brooder itself, or conditions existing immediately adjacent to it. By the elimination of the need for any particular or special construction, relieving the practical operator from additional overhead costs, additional confirmation of the feasibility of cold room brooding was obtained.

Labor requirements in caring for a group of chicks brooded by electricity were less than for coal brooded chicks. More frequent cleanings of electric brooded pens were necessary, and cost for litter in this method was correspondingly higher. Inasmuch as some more attention and labor attends any experimental set-up, it is likely that our costs may differ from common practice. It appears that with prices of 3c per kilowatt hour for electricity and $16 per ton for bagged coal, the two methods are approximately equal in total operating cost.

On the basis of the results of the previous tests and the work herein reported, it is suggested that brooder loadings be restricted to the following: (1) 52″ square brooder—200 chicks; (2) 56″ round brooder—225 chicks; (3) 76″ square brooder—550 chicks; and (4) 80″ round brooder—500 chicks.

1935-36 EXPERIMENTS

The experiments carried on from 1933 to 1935, as already recounted, established the brooder and its immediate surroundings as the focal point of controlling heat regulation. The points of next investigation were the difficulties which had consistently been present in all previous work, namely, (1) floor drafts and (2) irregularities in floor temperature. These were considered to be closely related and possibly one and the same thing.

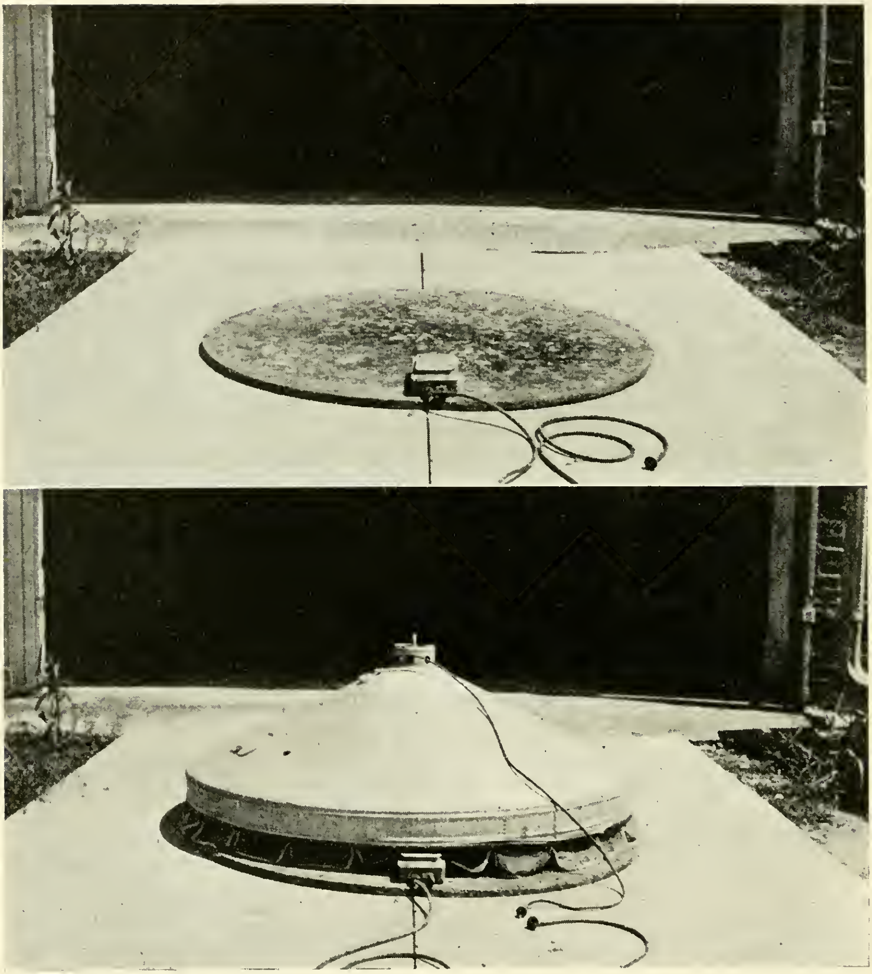
Experiments with the effects of three methods of control of these two factors were developed in 1935-36 as follows:

I. Application of additional under-heat on the floor under the brooder.

II. Placing extensions on the outside edges of the three standard brooders that were used, and adding curtains to these outer edges.

TABLE V. *Brooder House Space Allotments.*

	Space limits	Size or diam.	Area sq. ft.	Total sq. in. of floor per chick	Remarks
1st Day	Brooder	56″ Round 52″ Square	17.1 18.7	11.0	Chicks stay under the brooder voluntarily. Fed inside and watered at edge of brooder
2nd Day to 7th Day	Fence	92″ Round	46.6	30.0	Start coming out in numbers. Fed and watered outside after 2nd day.
7th Day to 18th Day	Fence	122″ Round	81.1	52.0	
18th Day to 25th Day	½ of fence	5 x 12 plus ½ fence	107.5	68.8	Front half of house used entirely. Rear half of fence used forming a half-ellipse.
25th Day to 41st Day	Entire house	10 x 12	120.0	76.8	Fence removed from house entirely.
42nd Day	Entire house	10 x 12	120.0	153.6	Cockerels removed usually reducing flock to one-half or 125.



(Above). The floor heating pad, constructed of two 7/16" insulating board, in which grooves were cut for the heating cable, the edge bound with metal, and the whole painted for moisture protection. A thermostat control is located in the box. (Below). The floor heating pad as used under the brooder.

III. Placing an artificial floor of wire-mesh under the brooder to elevate the chicks into the more stable levels of temperature and out of the section affected by floor drafts.

The construction of these attachments or accessories and their methods of use were as follows:

I. Addition of Floor Heat

No commercial floor-heating device could be found on the market; so one was constructed using soil-heating cable as the element.

A disc of ½″ insulating board practically the same size as the brooder was secured. A full 60-foot length of 400-watt, soil-heating cable was fitted into a spiral groove cut in the upper surface of the board. Another disc with exactly the same area but of ¼″ hardboard was placed on top and the two firmly bolted together. The edge was bound with brass linoleum binding. A wafer thermostat was mounted in a metal electrical outlet box, (attached to the pad), in such a manner that the wafer was practically in contact with the surface of the hardboard, forming the top of the pad. A socket for a pilot light was inserted in the end of the same box and cut into the circuit. A cord and attachment plug were used so that the pad could be inserted in a metered circuit separate from the brooder circuit.

II. Brooder Extensions

Brackets were made of strap-iron and bolted to the edge of the brooder. On these was bolted a 12″ ring cut from ½″ insulating board and a 6″ curtain was tacked to the outer edge of the extension ring. Picture-wire braces were stretched from the outer edge to the apex of the brooder to stiffen the whole assembly.

It was found during the first run that the moisture was absorbed by the insulating board to such an extent that it became soft, would not hold the curtain, and even broke up along the outer edge.

For the next two runs the extensions were constructed of ⅜″ plywood bolted to the brackets. The plywood, although it warped somewhat, stood up much better throughout the run.

III. Wire Floor

A circular frame of strap-iron slightly smaller than the brooder was constructed and well braced. To this frame legs were bolted to raise the top surface 2″ above the floor.

The frame was covered with 1″ mesh hardware cloth extending 6″ beyond the frame all around, and the extension bent down to form a ramp. A circular piece of ½″ mesh hardware cloth was then cut and fastened over the 1″ mesh.

The ½″ mesh wire was used for the first few weeks; then by simply clipping the wire ties holding it to the other, it was removed, and the 1″-mesh was left in place for the rest of the run.

Results of the Experiment

The floor temperatures obtained from the use of these methods are shown graphically in Figure 7. These may be compared with the temperature of the regular house floors the first 4½ days, as shown by Figure 2.

It will be noticed that the opposing temperature in 1936 was quite rigorous, reaching 10 degrees and 20 degrees below at night, spending much of its time at zero or slightly above, and at no time going above +20 degrees F.

A characteristic that has repeated itself consistently in all temperature curves in 2,800 daily records has been the definite correlation of the brooder floor temperatures with outside temperatures. One of

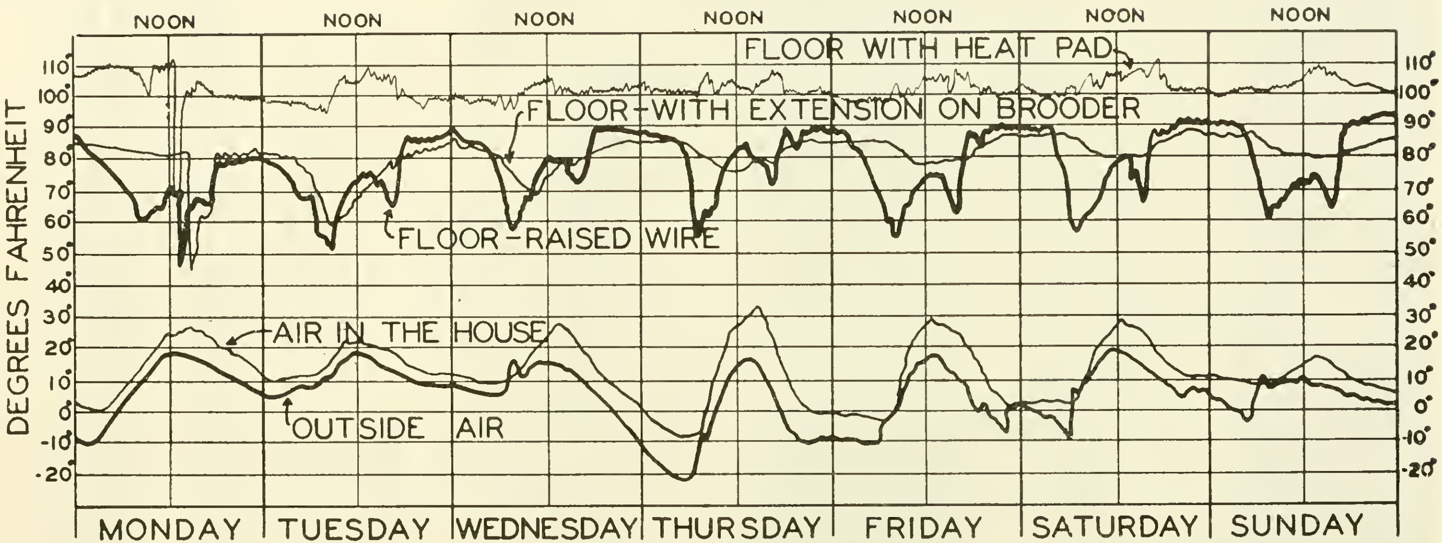
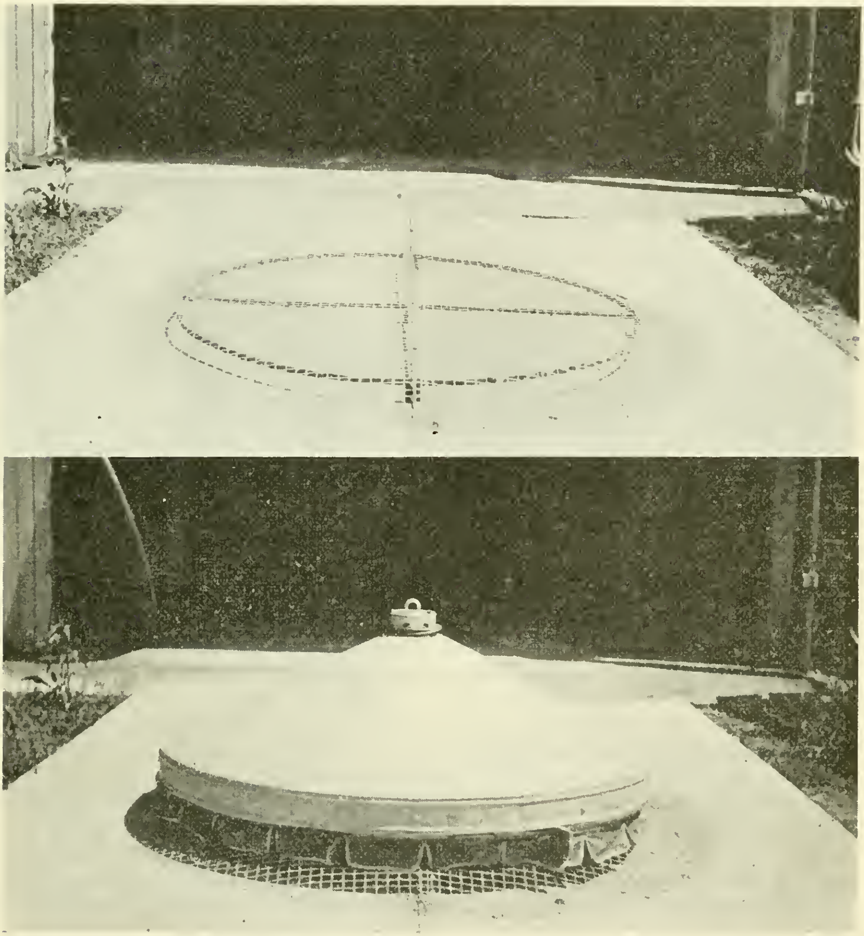


FIG. 7. Graph of the results obtained in temperature regulation under the brooder, from the use of raised wire mesh floors, extensions with additional curtain on brooder, and floor heat from a heating pad. The range in outside temperature varies from +32°F. to −22°F.



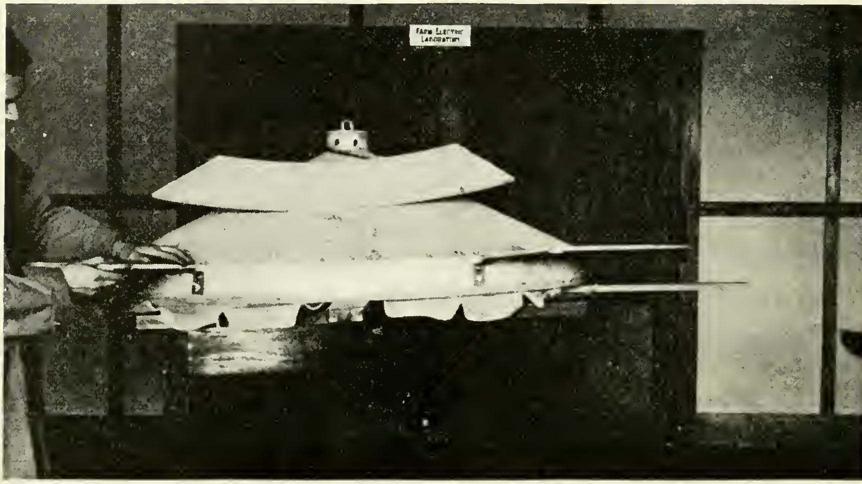
A one-inch mesh wire floor supported on a metal ring and framework, with inclined ramps is shown (above) and as placed under a brooder (below). Quarter-inch mesh was placed over the one-inch until the chicks grew to size.

the principal problems has been to determine how the outside temperature influences the floor temperatures. Supported by the investigational work already recorded, this study was an attempt to show the principal factors in the control of erratic changes of temperature in the lower stratum of air under brooders, and on the floor and litter.

Raised Wire Mesh Floors

A comparison of the curves discloses that the use of the elevated wire-mesh floor (Fig. 7) made no significant change in the character of the floor temperature curve,* other than to flatten its tops somewhat

* The thermometer bulb rested on the wire mesh.



A standard size brooder in the process of having the extensions placed on it. An additional curtain was used at the outside edge.

at the points of highest heat rise. Otherwise, the curve continues to show the same degree and cycle of variation. The range between maximum and minimum extremes is reduced from 45 to about 35 degrees, but in general this plan is rated as having no particular value over the usual floor.

Extension Rims on Brooders

The effect on floor temperature of increasing the diameter of the brooder and attaching an additional curtain without increasing the total load of chicks (225-50) is shown by the medium weight line of the upper three curves of Figure 7.

Neglecting for the moment the first part of the week of this record, it will be seen that the last three days show a brooder floor temperature held to within limits of 10 degrees variation (80-90 degrees F.). The lows and highs of this curve still retain the general cycle or trend that has characterized all readings taken to date, but a large proportion of the low and very erratic temperatures are eliminated, and a noticeable restraining of the high temperature loops is also apparent. In other words, the sought-for leveling out of the floor brooder temperature was largely accomplished by this measure.

Returning to the record of the first four days of the week, it will be noticed that following an interruption on Monday, this curve repeats the old characteristic of extreme variations, reaching as much as 28 degrees F. on Tuesday.

Wednesday it improves, and the differential between extremes reduces to 16 degrees. Thursday the low dip improves 6 degrees over the preceding day, the top of the curve flattens out still more, and the differential in extreme temperatures closes to about 10 degrees. Friday the characteristics of the curve change but little, but the level of the whole curve moves up about 2 degrees. By Saturday it has become stabilized as verified by the repetition in Sunday's record. In other words, it has taken 4½ days for the brooder to pull conditions back to normal.

The cause of this upset was the introduction of fresh cold shavings to the floor under the brooder by the cleaning operations of Monday. As a result the brooder spent a large proportion of its energy in heating and drying out this new litter.

Inasmuch as this cleaning and shifting of shavings is a regular procedure each week, while hovers are fully raised, its relative importance can be pointed to with emphasis. Methods of management to eliminate this difficulty and associated increase in current costs should be considered.

The use of fresh, dry shavings or litter, preferably taken from a moderately warm storage point, is a step in brooder management to be recommended, and the transfer of shavings from the outer floor area to under the brooder is not a good practice under cold weather brooding.

Effect of Heated Brooder Floor

The results from applying heat to the brooder floor (so-called under-heat) in the manner previously described, are shown in the top curve in Figure 7.

The general level of this curve is somewhat high, according to our standards, averaging a little over 100 degrees, although some manufacturers recommend such. This high temperature, we believe, was caused by improper location of the heat-pad thermostat, on which more reliance was placed than on the wattage of the respective elements.

Since there is a great divergence in opinion as to the optimum heat to be supplied under the brooder, the principal significance of this trial lies in the development of this method as a control measure.

It will be seen that up to Monday mid-day, the general floor temperature was well regulated and high in value. After the cleaning operation and changing of litter a steady decline took place until Tuesday at sunrise. This substantiates the deductions of the same nature just made in regard to cold, damp litter, and appears to be the time required for the heat pad to correct the new litter condition. It is apparent, however, that the time required to get the litter back into condition in this case is much less than in the previous one.

From Wednesday through the remainder of the week the temperature stayed approximately within the limits of a 10-degree range. This method, therefore, was about equally effective in range of temperature control to the extensions and additional curtain previously reported, but maintenance of a 20-degree higher level on an average accounts for the extra current consumption. (See Table 6)

The detail of the curve, however, is quite different in that it is one continuous series of small variations which are attributed to the continued influence of floor drafts. In this connection it is pointed out that no other than regular curtain equipment was employed with

Table VI. *Summary Report According to the Three Brooder Conditions (All Groups 1935-36)*

Brooder Condition	Ave. no. of chicks	Mortality to 6 weeks	Ave. wt. at 6 weeks of age	Total feed consumed per chick	Current consumption: Ave. total	Current consumption: Ave. per chick
		Per cent	Pounds	Pounds	Kw. hr.	Kw. hr.
Brooder plus under-heat	213	2.03	1.148	3.115	483*	2.276
Brooder plus raised wire floor	213	2.07	1.131	3.092	457	2.149
Brooder plus 12″ extension	212.7	3.3	1.125	3.050	361	1.703

* Of this amount 123 kw. hours were consumed by the heat-pad.

these heat pads, which leads to the conclusion that this method counteracts the effects of drafts; whereas the extension brooder gave the effect of eliminating them.

Costs by Areas and Contents

The heated area under the brooders tested is one basis of determining cost of operation by a standardized unit of measurement. Obviously if the area and cubic contents vary, the cost of heating will vary. The values obtained are given below.

Particular importance is placed on the significance of the effect on current consumed per square foot of area or cubic foot of contents by the brooders with 12″ extension rims and an additional curtain, referred to in Table VII as 1A, 2A, and 3A. Numbers 1, 2 and 3 are the same brooders without extensions. A comparison of Brooder No. 2

Table VII. *Electricity Consumed—By Areas and Contents.*

Brooder number	Size (stated)	Shape	Sq. ft. actual floor space	Kw. hrs. per sq. ft.	Cubic ft. of contents	Kw. hrs. per cu. ft.	Linear ft. of curtain
1	52″	Sq.	18.7	No record	12.7	No record	17⅓
2	56″	Rd.	17.1	23.5*	10.9	36.9*	14½
3	56″	Rd.	16.6	No record	11.9	No record	14½
1A	76″	Sq.	40.3	10.2†	34.4	11.9†	25⅓
2A	80″	Rd.	34.8	8.5†	21.2	13.9†	21.0
3A	80″	Rd.	34.3	9.5†	22.2	14.8†	21.8

* Average 6 runs, 1933-34 conditions.
† 1935-36 conditions.

with Brooder No. 2A shows that there was 2½ times more current consumed per unit of area or contents without extension rims, and extra curtain, as there was with these two features added; however, total consumption per chick was not materially different. No change was made in the number of chicks carried under the brooder.

This result appears to add emphasis to the vulnerability of brooders at the curtain edge and support previous deductions that great losses occur at this point. It also raises the question as to size of brooder with respect to the number of chicks carried.

Summary of 1935-36

The brooder extension group was operated most economically from the standpoint of kilowatt hours of electricity consumed.

By the use of extension rims and extra curtain on brooder, as previously explained, variations in brooding temperatures were considerably reduced; the temperatures for the most part were held within a 10-degree Fahrenheit range.

A comparison of three types of artificial floors as used under brooder—namely, elevated wire mesh, raised floor pad (insulation) and floor pad with heat—exhibited variable effects on brooder temperatures. The elevated wire mesh floor produced erratic and great changes of temperature under the brooder. The same characteristics with slight modifications appeared in the case of the raised floor pad. The floor pad giving under-heat showed the greatest effect in stabilizing temperature under the brooder, maintaining a 5-7 degree regulation.

The chicks under all three brooder conditions averaged to weigh slightly over one pound at six weeks of age. The type of brooder condition did not significantly affect weight, feed consumption, condition or feather growth. Percentage mortality for the experimental period varied from 2.03 in heated pad group to 3.3 in brooder extension group.

1936-37 EXPERIMENTS

With a continuation of the premise that the brooder and its immediate surroundings should be the focal point of our observations, a detailed study of chick movement was made in 1936-37. An attempt was also made to answer questions that had been raised in the field as to the effects of confining chicks in electric brooders over a period longer than six weeks.

Chick Action Under Brooder

Detailed observations were made of the hovering conditions of the chicks under the three types of electric brooders from 7 P. M. to 6 A. M., when outside temperatures were at about 32 degrees F. All brooders were fitted with a strip of celluloid in place of a portion of the regular brooder curtain. A mirror was then affixed to the side wall of the house and adjusted to such an angle that observations of chick action under the brooder could be made from the observation booth attached to the opposite side of the colony house. The attraction light under hover allowed for visibility of under-brooder conditions. To determine action outside of brooder area a quick flash of light from a common flashlight was used. Every precaution possible was exercised to prevent disturbance of chicks by the observer.

The diagrams as presented are a composite picture of the hovering conditions as determined by regular observations at fifteen-minute intervals. The area of brooder which was commonly populated by chicks is designated by the solid black section. The area indicated by parallel lines was used by the chicks at variable times and by varying numbers of chicks. Chicks were more active or "restless" within this area. Feeders and waterers as indicated were located approximately two feet from edge of hover. (See diagrams on front cover.)

A brief summary of observations made for each hover are as follows: House 15 (Brooder No. 1—1936 type)—"Chicks hovering quietly during first of night, but more "restlessness" and movement occurred following 10 P. M. No feeding or drinking occurred up to 1:50 A. M. From this time on, variable numbers of chicks were eating and drinking. All feeding up to normal daylight conditions was limited to feeder in southeast position. For the most part of night center of hover remained quite free of chicks."

House 16 (Brooder No. 3—1936 type)—"Few chicks hovered directly in center of brooder at any time during the night. Chicks were otherwise fairly evenly distributed under brooder, appeared comfortable and for the most part remained quiet. Chicks were feeding and drinking intermittently throughout the night. Only those feeders in southwest and southeast locations were used up to daylight conditions."

House 18 (Brooder No. 2—1936 type)—"Chicks were quite variable in hovering area selected. Moving, standing and picking at moisture drops on celluloid curtain was common throughout the night. When chicks covered over the recorder bulb which rested on the floor, a definite increase in floor temperature was recorded on the instrument chart. As the chicks spread out and away from the bulb, the recorded floor temperature receded. No feeding or drinking occurred from dark till 1:30 A. M., when increased action was evident. Feeders in northeast and southwest were utilized."

It may be of interest to note that the brooders in Houses 15 and 16 were fitted with ventilator fans in apex of brooder. The brooder in House 18 was provided with a natural draft central ventilating flue.

Prolonged Brooding Period

Table 8 presents summary figures for electric brooding of chicks to fourteen weeks of age. Brooders 1 and 3 were fitted with fans for providing forced ventilation. In the case of Brooder 3 the direction of air flow established by the fan was downward through the double walled conical sides to the outer periphery. At this point it was directed towards the center of the brooding compartment. A relatively high speed fan was employed. In Brooder 1 the air was directed down a central tube to strike a circular baffle plate, which diffused the forced air outwards towards the edge of the brooder. A slower speed fan was employed. Brooder 2 was similar to the original brooder, previously described in the work of 1934-35.

Males were separated from females at six weeks of age, and records were continued on females only. The average weight for New Hampshire females at fourteen weeks of age has been reckoned at 3.340 pounds.* The weights established through electric brooding by the three types of brooders used were quite comparable, varying from 3.07 to 3.38 pounds per bird. A similar comparison on total feed consumed shows a variation from 13.077 to 13.897 pounds per bird. This, as compared to the standard of 15.035 pounds, indicates somewhat better efficiency in feed utilization. Mortality was not excessive in any of the electrically brooded groups.

TABLE VIII. *Summary of Results Secured in Electric Brooding to Fourteen Weeks of Age (Average of Two Runs).*
(1936-37)

Brooder	Per cent mortality to 14 weeks	Ave. wt. in lbs. at 14 weeks (2)	Total feed consumed per chick in lbs.	Total kw. hrs. consumed	Total kw. hrs. per chick
[redacted]	3.2	3.219	13.388	588	2.35
[redacted] (3)	2.4	3.349	13.615	907	3.63
[redacted] (3)	5.6	3.092	13.228	459	1.83

(1) 250 chicks per hover. First Run: November 18 to February 24.
Second Run: March 11 to June 16.
(2) Pullets only—males removed at six weeks.
(3) Forced draft ventilation.

No difficulties in management of chicks were encountered in this prolonged brooding period. If the brooder load is held at suggested levels and not materially increased, high quality birds can be produced. No variations in normal brooder management were made necessary by the prolonged brooding period. It was found that, following the ninth week in the case of the first run and the fifth week in the second run, the brooder heat could be discontinued during the day. Hovers were disconnected at approximately 8 A. M. to 4 P. M. Heat was applied during the night period at a reduced rate. After the eighth week in the second run all heat was discontinued.

Electric Brooding and the Physiological Needs of Growing Chicks

There have been many indications during these experiments that the temperature and ventilation adjustments have *not* been entirely suited to the chicks' physiological needs or optimum comfort.

Among these indications are the following:

1. Restlessness during the night period.
2. Flashlight pictures at night showing chicks crowding out beyond curtain apparently for better air or temperature or both.

* Circular 52 of the N. H. Experiment Station on Growth and Feed Standards for New Hampshires.

3. Intestinal disturbances in chicks as a cause of mortality.
4. Lung congestion (pneumonia) as a cause of mortality.
5. Chicks have been brooded at a wide range of temperature.

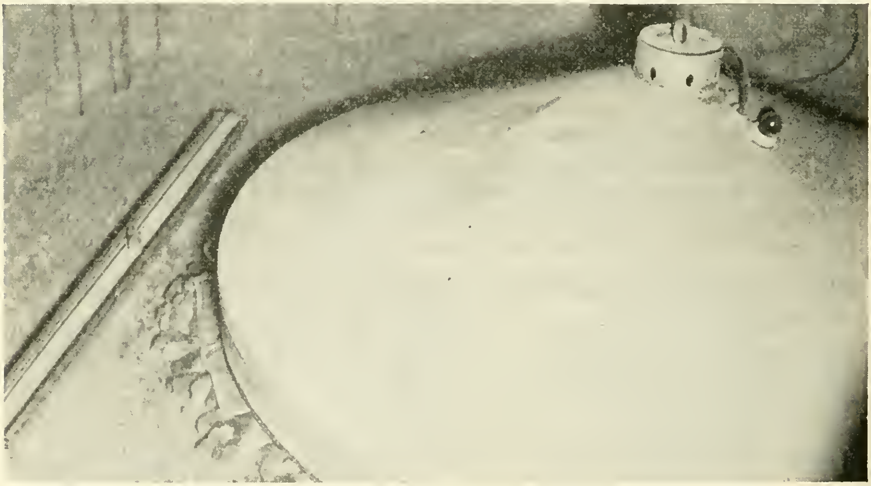
Inasmuch as the standards of temperature and brooder ventilation were established by the writers, this fact can *not* be held as a failure of the equipment. On the other hand, the evenness of maintaining a given temperature throughout the area under the canopy is a function of the brooder itself and is affected by brooder design.

Power Ventilation

One of the more recent developments in electric brooder design has been the addition of power ventilation in the form of a fixed speed motor-driven fan, running continuously. This has not changed the method to an "automatic system" but simply boosts the fixed values to higher ratios of air supplies per hour per watt of heating element. This, in turn, reduces the effective heat in the brooder compartment. From the standpoint of temperature alone this raises the question whether the same result cannot be obtained by reducing the amount of electrical heat generated and omitting the forced draft effect.

The condition of the air under the brooder as regards moisture and general quality would appear to require a definite number value of air changes per hour not now known.

Restlessness—Activity or movement of chicks during the night period has been a constant factor throughout the four years of tests. While this chick movement may be attributed to the restlessness of young individuals, there appears to be more than is normal. This is probably a result of improper temperature and air conditions. (See charts of chick movement.)



Chicks crowding beyond curtain, (taken by photo-flash lamp at night), a condition frequently observed throughout the experiments.

Curtain Crowding—The chicks frequently crowded through the curtain many times showing extended wings and open beaks. Overheating and/or a need of fresh air are the obvious causes of such action.

Intestinal and Lung Conditions—As stated previously all chicks dying during these experiments have been subject to post mortem examination by the Poultry Pathology Laboratory. The same condition has consistently prevailed during the several years' work; the great majority of deaths have shown congestion of the lungs, indicating pneumonia, and digestive disorders. At least one of these conditions was always in evidence upon autopsy. The average mortality by years has been as follows: 1933, 10.25%; 1934, 14.8%; 1935, 2.47%; 1936, 3.7% (fourteen weeks).

The presence of pneumonia would seem to indicate a lack of heat or a period of excessive heat followed by chilling. The coincidence of digestive disturbance should be noted.

Tests of the temperature regulation throughout the brooders showed a considerable variation in both a vertical and horizontal direction, most important of which were what seemed to be deficiencies in heat near the floor (vertical) and near the curtains (horizontal).

A study of these five factors (most significant of which were the digestive and lung conditions) with respect to the heat regulations, particularly in the vertical direction, led to the development of the following hypothesis as being a major cause of mortality.

The lowest temperatures and most drafts occurred near the floor of the brooder especially when the chicks' bodies blanketed off the heat from above. As a result of this condition, chilling of the digestive tract (located on the underside of the body) developed. Until stoppage occurred, no evidence of the chicks' condition would be noticed. During this period, however, a lowering of the vitality and strength of the individual was undoubtedly taking place.

At the same time the temperatures of the upper levels of air—at or just above the chicks' backs (location of the lungs)—usually were the highest, even to the point of being excessive.

If continued heat were abnormally high, weakness might develop in the digestive organs or, as an alternative result, chilling after overheating would be likely. Hence, the bird would appear to die of pneumonia whereas the probable primary cause is a digestive disorder possibly related to the temperature to which the digestive tract was exposed.

The work herein described and conducted during the past two years has had as a basis this hypothesis. Being set up as an engineering and poultry husbandry project, the objective has been to determine through the practical use of commercially manufactured electric brooders the proper operating temperatures, distribution of heat, protection from outside influences, etc., which would provide the greatest efficiency in operation and, at the same time, develop the proper environment for rearing chicks to the highest degree of physical condition.

NOTE: The work of M. Kleiber and J. E. Daugherty (published in the Journal of General Physiology, May 20, 1934, under the title "The Influence of Environmental Temperature on the Utilization of Food Energy in Baby Chicks") verifies to a remarkable degree the conclusions drawn from the experiments at this Station. A careful analysis of their report will well reward anyone who wishes to make a further study of brooding conditions.

Many of the exact requirements or specifications to accomplish the above have never been established and are not available as definite factors by which the equipment could be measured. Part of the work, therefore, has been to attempt to determine what some of these factors should be in the absence of data on the basic requirements of poultry. Much valuable fundamental material of this type awaits determination and will be essential to the satisfactory development of equipment.

General Summary of Four Years' Work

Several factors were studied and reported in Station Circular 46 of the New Hampshire Experiment Station relative to the heat requirements for electric brooding of chicks. During the subsequent years of 1935, 1936 and 1937 the following subjects have been added to the study: (1) Floor insulation. (2) Labor and fuel costs for coal versus electric brooding. (3) Application of heat under brooder. (4) Relation of house floor area to brooder size. (5) Prevention of floor drafts. (6) Extended brooding period. (7) Effects of power ventilation. (8) Chick movement. (9) Physiological needs of chicks.

1. Electric brooding is practical and can be carried on under very severe climatic conditions without auxiliary heat or excessive mortality.

2. Necessary high cost of application and lack of value from the insulation of walls and ceilings in houses used for electric brooding indicate its use to be unwarranted.

3. Although the results of our tests indicate that 1″ of insulation enclosed in a water proof bag and placed between two layers of wood is the point of diminishing returns from floor insulation, there is nothing to indicate that a double wood floor with a disc of 1″ insulation board or its equivalent, properly waterproofed and slightly larger than the brooder, placed on the floor under the brooder will not be just as good as, or slightly better than, built-in insulation, and is certainly less expensive.

4. A comparison of labor and fuel costs for coal and electric brooders indicates very little cost differential between the two methods.

5. Under cold weather brooding, when litter changes are necessary, it is recommended that the new supply be pre-heated before being placed in the pens.

6. Increasing the square area and cubic contents of a brooder by the addition of extension rims and extra curtain, without changing the chick load or heating element, was of material benefit in stabilizing temperature control under the brooder.

7. It is important to establish values for air exchange under the various types of electric brooders.

8. No difficulties in the management of chicks were encountered in a prolonged brooding period of fourteen weeks as long as the cockerels were separated from pullets at six weeks of age, thus reducing the number of chicks approximately one-half and compensating for their increased size.

9. The main irregularities in the temperature under brooders are obviously caused by brooder design features, floor drafts and chick movement.

10. It is recommended that no more than 200 baby chicks be placed under a 52″ square electric brooder and not more than 225 chicks under a 56″ round electric brooder.

11. It is our experience that loadings of baby chicks under electric brooders, higher than those mentioned above, were a direct cause of high mortality. (Refer to mortality figures, 1933 and 1934.)

Acknowledgment is here made of the valuable assistance rendered by Drs. C. L. Martin and C. A. Bottorff of the Poultry Pathology Laboratory in making the autopsies of birds, to Mr. P. A. Wilcox, Poultry Farm Foreman, who assisted materially in the actual brooding of the chicks, and to Mr. F. D. Reed, formerly of the Poultry Department, who assisted in the 1934-1935 experiments.

Sep.