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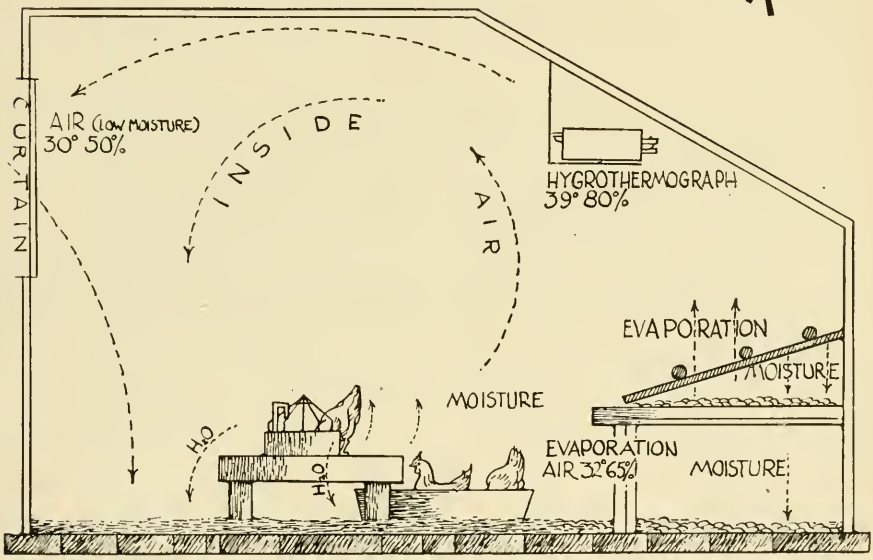

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THE PROBLEM OF MOISTURE IN POULTRY HOUSE LITTER*

A Three Year Study

T. B. Charles, A. E. Tepper,[1] W. T. Ackerman,[2] B. W. French,[3] R. C. Durgin[4] and R. B. Halpin[5]

INTRODUCTION

The problem of moisture in poultry house litter is one of general concern. Attempts to eliminate the problem in a practical way, have been and are being tried by many poultrymen. Most of these methods involve the associated problems connected with the application of heat, use of insulation, and variable controls of ventilation.

Previous work at this Station involving litter mositure has been confined to brooding conditions. (See Cir. 46, June 1934 and Bul. 303, March 1938)

The phases of this subject which appear not to have been established are: (1) a specific and technical standard of "Proper Litter Condition", (2) how much moisture (measured) exists in both "desirable" and "undesirable" litter conditions, and (3) what other factors in addition to heat, insulation and ventilation may exert control over litter moisture conditions.

Twelve different litters or combinations of litters commonly used under practical conditions were employed in the experimental study. (See Plot House Data)

Any study of cause and effects of litter moisture in poultry houses is influenced by the normal climatic conditions during the experimental period. Dr. D. H. Chapman of the Geology Department has furnished the following statements on the general weather in the Durham area:

"The mean annual temperature for Durham is 46°. During 1940, the highest temperature recorded was 95° on July 26; the lowest, -17°, on December 4. January usually is the coldest month, with the normal temperature of 23°. February is practically as cold. July, with a normal temperature of 69°, averages fully 2° warmer than August. In Durham during 1940, the last spring freezing temperature occurred May 14, and the first fall frost was recorded September 27. The year 1940 was almost exactly normal as regards temperature.

The normal annual precipitation at Durham is 38.01 inches, but

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[2] Resigned June 30, 1941.
[3] Resigned June 30, 1941.
[4] Resigned December 31, 1940.
[5] Leave of Absence from September, 1941.

1940, with 43.80 inches of rain, had nearly 6 inches more than usual. The greatest precipitation during any month of 1940 occurred in November, when 6.92 inches fell, while less than .25 inches of rain fell during the entire month of October. Rainfall is generally distributed fairly evenly throughout the year; September averages 3.52 inches and is the wettest month, while February, with 2.83 inches, is the driest month. During 1940, 54 inches of snow fell in Durham. Rain fell on 120 days of 1940 and 155 days were clear.

Winds are prevailing from the northwest in Durham during the winter while southwest winds are more common in summer. Sea breezes are often felt in Durham during the latter part of spring and summer afternoons and often bring a sudden drop in temperature."

OBJECTIVE

The general objectives of this experimental study were to determine methods for the elimination of excessive moisture in poultry house litter to reduce the spread of disease, labor of cleaning, and costs of operation and to improve sanitation, appearance, general management operation and the physical condition of poultry house litters.

REVIEW OF LITERATURE

Dann (1) reported that the rate of evaporation of water from the litter depends on the available heat, the rate of air movement over the litter, the frequency of turnover of the litter, and its depth. Dann maintained that when the temperature of the litter is higher than the temperature of the air above it, the entrained air in the litter will hold more moisture and so the evaporation from the litter will be hindered. As deep litter has more spaces with entrained air than shallow litter, Dann felt that deep litter would not dry as readily as shallow litter. Therefore, he recommended that the floors of houses not be heated and that a litter not to exceed four inches in depth be used.

This statement is directly contrary to conclusions from the Western Washington Experiment Station by Miller, Smith, and Svinth (2) that warming the floor of the houses will maintain dry litter. These authors also conclude that cooling of poultry house floors by direct exposure to outside air is usually conducive to wet litter. They state, however, that it is not desirable to heat poultry house proper in order to dry the litter.

Miller, Gordon, and Cushing (3) at Washington found that it was possible to maintain dry litter when the rate of egg production and the climate were favorable for the production of wet litter by keeping the floor 7.50° warmer than the air just above the floor. They stated that they were unable to keep the floor dry by either slow or rapid ventilation.

Card and Moore (4) at Michigan also reported that warming the floor keeps the litter dry. They placed an electric heating element in the floor of the house.

At Western Washington, Shoup and Smith (5) reported that in control houses it was necessary to change the litter every 4 to 14 days during the rainy season in order to have reasonably dry litter in the houses, the exact time between changes depending on the moisture content of the litter. When they used artificial heat in the houses they found that a one degree increase in temperature decreased the moisture content of the air by 4%. In the houses that were warmed they state that the litter was at all times in good condition when changed only once a month.

Carver (6) also at Washington, reported that under the climatic conditions at Puyallup, it was impossible to provide dry litter by the use of controlled ventilation in an insulated or uninsulated curtain house. He states that the difference in temperature between the floor and the air above the floor causes condensation of moisture. Carver (7) also states that in a straw loft house with which he was working, the litter would often reach a moisture content of 30%, reaching this figure within a week after it was placed in the house, yet the moisture in the straw in the straw loft averaged about 12% and the straw did not seem to absorb moisture from the litter.

While the forgoing writers indicate that heating the house is a desirable practice, Lee and others (8) state that the use of heat in an uninsulated house with which they were working in central New York State, resulted in a lower annual egg production, slightly lower feed consumption, occasionally a lower litter requirement and a serious and consistent lowering of the net flock income.

On the other hand, Smith (9) working at Nebraska found that the maximum egg production was obtained when the temperature of the house was not permitted to vary widely. He states that the exact temperature range to be maintained is not of much importance, but it is important to pick a fairly narrow range and maintain it.

Kennard and Chamberlain (10) in a discussion of winter housing for layers said that the air in an insulated house is warmer and damper than the outside air. This warm inside air is pushed out of the house through open doors and windows or through cracks and crevices in the wintertime by the colder, heavier, dryer outside air. As the warmer air leaves the house it carries out a large amount of moisture with it.

They state that the condition is somewhat different in an uninsulated house in the winter as the outside and inside temperatures are practically the same, therefore, there is not this movment of air and so the uninsulated house is damper than the insulated one.

Heywang (11) studying the water consumption of hens found that two pens of Rhode Island Red hens consumed 19.8 and 19.9 gallons of water, respectively, per hen per year. He made allowances for evaporation from the water pens. Increases in air temperature, live weight, and rate of production tended to increase water consumption and decreases in any of these factors tended to decrease water consumption. In some cases, he reported that the effect of increases in

air temperature on water consumption was masked by the resulting decrease in egg production.

Mitchell and Kelly (12) in studying the ventilation of poultry houses found that at a temperature of 82° a four-pound White Plymouth Rock hen consumes in twenty-four hours, 82 grams of dry matter, and gives off 238 Cal. as heat, 47 liters of carbon dioxide and vaporises 164 grams of water. At a temperature of 50° the bird gives off only 57 grams of water vapor per day.

Their data showed that 4.2 cubic feet of air per bird per hour are necessary to maintain a desirable limit of carbon dioxide. They ascertained the amount of air necessary to remove moisture on the basis of an assumed temperature within the house of 50° F. and a relative humidity of 75% with a temperature of 15° F. and a relative humidity of 80 % of the admitted air. The inside air, they state, will thus hold 3.057 grains of moisture per cubic foot and the admitted air would bring in 0.789 grains. Hence, there would be, in a pen of 200 birds, 7,315 grains of water per hour to remove. On this basis 16 cubic feet of air per hour per bird would be required to remove the excess moisture.

They also stated that there is some doubt as to the amount of water that can be removed from the litter by ventilation. Much depends on the floor temperature, the vapor pressure balance of the air entrapped in the litter and that just above, and depth and kind of litter.

Summary of this preceding literature shows that there is a great deal of contradiction relative to wet litter in the poultry house and the part it plays in the economic situation of the flock-owner.

THE EXPERIMENTAL PLOT HOUSE

The experimental work was initiated in November 1938 with the construction of a litter "plot house" used to house representative samples of materials suitable for use as poultry litter. This house was built for study of the effects of outside air conditions upon the samples of litter used. Twelve "plots" were built inside the house, each 5½' long, 2' wide and 4" deep. Each plot was filled 3½" deep with a different sample of litter.

The house was built upon posts with an uninsulated floor 2 feet off the ground and exposed to currents of air passing underneath. A water-tight roof was constructed to protect the samples from rain and snow. The sides of the house were of two layers of muslin, designed to keep rain and snow out but to allow a free circulation of air.

THE POULTRY PENS

For the observation of actual litter conditions under practical usage, ten poultry pens of the University Poultry farm were selected. Eight of these pens, No. 11-18, inclusive, were located in a long combination-roof laying house with pens 18' x 22' in size with a similar size service room. The other two pens, Nos. 1 and 2, each being 30' x 30' in size, made up a 30' x 60' combination roof laying house.

Pen 11 located at the southwesterly end of the long house was

insulated with 7/16" insulating board on all sides and ceiling, with shavings packed as a fill between studding on the three exposed outside walls. This pen was equipped with a commercial ventilating system with four intake flues and a central ceiling outtake flue, manually operated.

Pen 12, adjacent to Pen 11, was insulated on all sides and ceiling with a similar commercial 7/16" insulating board without shaving fill. The ceiling was so constructed as to allow a forward motion of air to pass out over the front plate as in the usual rafter ventilation process.

Pen 13, adjacent to Pen 12, was uninsulated but provided with a straw loft during the years 1938-40. This loft was removed for the 1940-41 season.

Pen 14, next to Pen 13, was used during 1938-40 as an uninsulated pen with front sliding-curtain ventilation. For the 1940-41 season this pen was equipped with a ventilating system identical to that in Pen 11.

Pens 15, 16, 17 and 18 were all similar in construction, non-insulated, with ventilation provided by front sliding curtains, manually operated.

The curtains in all of these pens were of glass-substitute material.

Pens 1 and 2 constituted a separate 30' x 60' two pen laying house with 1" fiber insulating board, provided with sliding glass windows and furnished with dropping pits attached to the side walls of each pen. Pen 1 was equipped with a commercial ventilating system of the convection type having a thermostatically controlled outlet valve at ceiling level and a main outlet opening about 18" above the floor level. Pen 2 was equipped with a commercial ventilating system provided with an outlet at ceiling level and a four speed exhaust fan installed in the outlet flue. Pen 1 was located above a heated incubator cellar while Pen 2 was above a closed-in cellar containing a small heated room opproximating ⅛ of the floor space of the above pen.

PEN EQUIPMENT USED

All feeders were of a conventional type supported on legs about 18" off the floor. The nests were all metal, thirty nests being provided in pens 11 to 18 inclusive, and forty units in pens 1 and 2. Grit and shell hoppers were in each pen.

The pens in the long house were provided with dropping platforms with wire covered roosts. Pens 1 and 2 were equipped with dropping pits.

All pens of birds were supplied with artificial lights during the fall and winter period through a central time switch, thus providing a normal 13½ hour light period daily.

The waterers were open refrigerator pans mounted on stands. During the winters of 1939-41, these waterers were placed over inverted metal electric hover tops to collect and measure water spillage. Electric water heaters were used in Pens 11 to 18 inclusive, but not in heated Pens 1 and 2.

RECORDING INSTRUMENTS USED

Instruments for recording humidity and temperature were placed in the plot house and Pen 16, on December 3, 1938 and maintained in these positions throughout the course of the experiment. Each consisted of a liquid type recording thermometer and a horse hair recording hygrometer, installed on shelves hung from the ceiling, the plot house recorder being about 4½' off the floor and the poultry pen instrument about 5' from the floor. A continuous automatic record of humidity (in terms of percent moisture) and of temperature (in degrees Fahrenheit) was kept by these instruments.

Two wet-dry bulb recording instruments with weekly charts were operated for part of the time in Pens 1 and 2.

LITTER SAMPLING

To determine the moisture content of litters both in plot house and poultry pens, samples of these litters were taken weekly and a record of their moisture content was maintained throughout the test period. The sampling in plots was done by taking 3 or 4 scoops of the litter material from each plot. In the poultry pens, sampling meant that six scoops of litter were taken from the floor, one from each corner of the house, one from the rear center of the pen under the dropping board and the other within one foot of the waterer. These scoops were mixed thoroughly in a bushel basket and a sample was transferred to a quart jar, loosely poured in until a weight placed in the neck of the jar showed it full.

DETERMINATION OF MOISTURE CONTENT OF SAMPLES

Samples were tightly sealed with a jar rubber and screw cap to prevent loss of moisture between the time of sampling and the drying test.

The drier was a large metal cabinet heated by a coil of steam pipes. Ventilation was provided by a ¼ h.p. exhaust fan connected in the ventilating shaft. The fan and shaft also aided in carrying off odors from the samples during drying. The fan moved air from the drier at a rate of 860cu. ft. per minute, providing three air changes per minute.

The temperature of the cabinet interior was maintained between 180° and 190° F. During the weighing procedure, when doors were being opened and closed frequently, the temperature would drop to 130° or 140° F.

Each litter sample was removed from the jar and placed in an open pie pan, weighed and then placed on a wire screen shelf in the drier. Weights of the samples were taken at 72, 138 and 172 hours following their entrance into the cabinet. The final 172-hour weighing was a check on the 132-hour weight, but as full evaporation of moisture was accomplished at the 132-hour period, calculations are on this basis.

The grams of moisture evaporated was found by subtracting the

weight of the sample and pie pan after the final stage of drying from the original weight of the sample and pan. The wet weight of the sample was obtained by subtracting the weight of the pan from the initial weight of the sample and pan. The per cent of moisture was determined as a ratio of the grams loss of moisture to the gram weight of the wet sample. Thus, if one sample has a moisture percentage of 50 it means that a 300 gram sample would contain 150 grams of water and 150 grams of dry litter material.

Although the moisture content of the wet sample is 50%, referring to the dry sample it would be 100%. The calculations given herein are all made on the basis of weight of water to wet weight of sample. A sample containing 50% moisture, then, really consists of equal weights of litter and of water.

EFFECT OF SAMPLE DRYING UPON PLOT HOUSE AND POULTRY PEN LITTERS

Each week a sample of litter was taken from each pen of the plot house, brought into the laboratory and kept in the drier for about two weeks. At the end of this time the dry sample was returned to the plot house. Thus a sample leaving the plot house with 10 to 18 per cent moisture was returned at 0+ per cent moisture. Each plot contained approximately 5,000 cubic inches of litter and the sample removed had a volume of approximately 50 cubic inches. Thus, it would require 100 samplings to have dried out all of the litter in one plot, providing each removal consisted of litter not previously used. In actual practice some litter particles were dried more frequently than others. The average sample consists only of one per cent of the total volume.

It is evident that humidity conditions in the air influence the litter samples to cause a gain or loss from week to week. It seems logical to assume that the dry litter returned to the plot soon assumed the degree of humidity of the rest of the plot, which is in apparent equilibrium with the air moisture. In any case, the effect of drying the litter samples would be small.

The poultry pen litter is not affected by the return of dry samples because (1) the sample is so small in comparison to the amount of litter, and (2) because of the much greater humidity condition of the poultry pen. Assuming the average litter depth to be at least 1¾ inches, the pen litter would have a volume of 100,000 cubic inches. The sample is but 0.05 per cent of this total as compared to the 1.0 per cent for the plot samples.

GENERAL MANAGEMENT FACTORS

The birds used in this experimental study are listed by pens on the general summary tables. Pens 15, 16, and 17, contained each year representative New Hampshire pullets from regular pedigreed matings and so far as possible all pens were identical as to bird complement. The birds of other breeds used were carefully selected for

egg production characteristics and represent a satisfactory sample of the strains of birds on the University Poultry farm. Their general performance records are listed in the summary table, No. 4.

Feeding procedure followed the recommendations of the New England College Feed Board, consisting of mash and grain, plus pellets and condensed buttermilk as supplementary feeds. The laying mash used consisted of yellow corn meal—632 lbs; wheat bran—300 lbs; standard middlings—300 lbs; ground whole oats—300 lbs; alfalfa leaf meal—50 lbs; soy bean oil meal—100 lbs; dried skim milk —50 lbs; meat scraps, 50% protein—150 lbs; fish meal, 50% protein —50 lbs; limestone with manganese—50 lbs; salt—10 lbs; fortified cod liver oil—8 lbs. The grain formula consisted of whole yellow corn—1000 lbs., wheat—500 lbs., and whole oats—500 lbs.

The hard grain was hand fed in the litter three times daily, the mash, grit, and oyster shell were hopper fed.

General management of all pens was similar with the exception of litter treatment. This is outlined as follows:

LITTER TREATMENT

A Original litter plus additions when necessary with no removals.
- I Conditions of management
  - a Pen cleaned thoroughly at start of test and new litter added to the depth of two inches.
  - b Additions of fresh litter made when deemed desirable for the improvement of litter conditions.
    1. Each addition not to exceed 30% of the original litter in the pen.
  - c No removal of litter from the pen throughout the test period, except for samples which are returned.
  - d No raking over of the litter.
  - e Droppings boards to be cleaned regularly at about two month intervals (wire below rails prevents access of birds to droppings)

B Regular routine of litter management as normally practiced.
- I Conditions of management
  - a As seen fit by the foreman of the poultry plant.
  - b All litter additions to be of same kind as the original.
  - c As followed on most commercial poultry farms.

C Optimum conditions of litter.
- I Conditions of management
  - a Pen cleaned thoroughly at start of test and new litter added to a depth of two inches.
  - b All additions of fresh litter to be of a similar kind.
  - c Entire pen to be raked over frequently to aerate and redistribute litter over pen floor.
  - d Optimum of litter condition to be maintained.
  - e Additions or removal of litter to be made as frequently as necessary to maintain an apparent "dry" condition.

LITTER USED

An attempt was made to use a series of various kinds of litters throughout the experimental period so as to include as far as possible all commonly used types. Those for the plot house were maintained throughout the test period as originally set up, as given below:

List of Litter Samples as Used in Plot House 1939-41

Plot Number	Litter
21	Sawdust
22	Stazdry
23	Peat Moss and Shavings
24	Hay
25	Shavings
26	Servall
27	Peat Moss
28	Peat Moss and Straw
29	Oat Hulls
30	Straw
31	Sand and Gravel
32	Sand, Gravel, and Straw

The variations in type of litters used according to pens are listed in the pen summaries in Tables 4, 5, and 6.

DISCUSSION

In Tables 1 and 2 the monthly averages of the moisture content of poultry pen and plot house litters is given as found during the three year experimental period. It will be noted that during January, February and March the pen litters had the greatest moisture content. Likewise, the late fall and winter months were of greatest influence in raising the moisture content of the Plot House litter samples. This shows that the fall and winter months, the normal period of high atmospheric moisture, are the most critical in control of moisture in poultry litters.

The peat moss litter absorbed and retained the highest moisture content of any of the litters used. Sand and gravel both in the poultry pens and plot house absorbed and retained the least moisture throughout the experiment.

A question may be here raised, therefore, as to whether it is more desirable to select for poultry litter one having a relatively high absorptive capacity for water which retains absorbed moisture or one having a low absorptive capacity and a low moisture retention value.

Several tests were made of the moisture holding capacity of the different plot house litters. These results can only be considered approximate, but give an indication of the relative absorptive values. These results are presented in Table 3. As shown, the figure is a ratio of the weight of water absorbed to the dry weight of the sample. Thus for peat moss the figure 4.5 indicates that 100 grams of peat moss would hold 450 grams of water, or 4.5 times its own weight.

TABLE 1. MOISTURE CONTENT OF PLOT HOUSE AND POULTRY PEN LITTERS, BY MONTHLY AVERAGES, 1938 - 39

Pen No. Sample Number	Material	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
		%	%	%	%	%	%	%
1	Shavings	28.6	32.9	27.6	24.3	20.7	—	22.0
2	Shavings	34.9	38.1	38.1	36.5	25.4	20.5	17.5
11	P. M. and Shavings	45.6	37.1	44.0	41.9	36.9	24.9	—
12	P. M. and Shavings	36.4	42.4	45.9	42.6	35.7	22.7	18.1
13	P. M. and Shavings	42.5	47.6	50.8	56.3	41.8	33.6	21.6
14	P. M. and Shavings	43.9	48.4	51.8	54.3	40.9	28.5	19.4
15	Peat Moss	51.5	56.8	63.2	64.9	50.7	38.4	22.4
16	Peat Moss	48.9	53.4	60.3	60.3	53.2	29.5	19.5
17	Peat Moss	46.6	52.2	59.5	54.3	57.6	39.6	25.1
18	P. M. and Shavings	41.6	43.1	48.7	45.9	40.8	28.0	18.4
Plot Number								
21	Sawdust	16.9	14.1	13.9	12.9	11.6	8.9	9.2
22	Sugar Cane (Coarse)	11.2	10.7	11.1	9.9	9.4	8.1	7.8
23	P. M. and Shavings	15.2	15.0	15.0	13.7	12.6	10.4	10.6
24	Chopped Hay	13.0	12.2	12.5	11.3	10.5	9.3	8.2
25	Shavings	13.0	12.8	12.8	12.0	10.4	8.8	8.2
26	Sugar Cane (fine)	11.2	10.7	11.3	10.2	9.0	8.0	7.9
27	Peat Moss	18.1	17.5	17.2	16.0	14.4	12.5	11.9
28	P. M. and Straw	16.6	16.2	16.1	13.7	13.9	11.8	10.9
29	Oat Hulls	11.2	11.2	11.2	10.8	9.8	8.4	8.2
30	Straw	13.2	13.0	13.5	11.6	11.0	9.2	9.1
31	Sand and Gravel	0.4	0.3	0.4	0.3	0.2	0.2	0.2
32	Sand, gravel & Straw	1.8	1.1	1.3	1.1	0.9	0.6	0.7

EFFECT OF LITTER MOISTURE ON PRODUCTION AND HEALTH OF BIRDS

Tables 4, 5, and 6 presents a management and production summary for the experimental pens used during the test. During the first test period three different breeds of birds were used, but in the two succeeding periods only New Hampshires were carried in the experimental pens.

There appears to be no relationship between the rate of egg production and the average moisture content of the litter (See Figure 6). Litter treatment "A" was designed to produce a relatively poor litter condition. It did just that and the moisture content of the pens so managed was the highest of all. Those birds in the pens exceedingly wet and otherwise of apparently "poor sanitation" laid just as well as those in the drier pens.

Litter treatment "C", designed to maintain the most optimum condition of litter in the pen, was only slightly effective. The tables

TABLE 2. MOISTURE CONTENT OF PLOT HOUSE AND POULTRY PEN LITTERS, BY MONTHLY AVERAGES, 1939 - 1940

Pen No. / Sample No.	Material	July	August	September	October	November	December	January	February	March	April	May	June
1	Peat Moss	15.6	15.6	18.4	22.2	19.5	26.1	30.4	....	....	....	....	....
2	Shavings	16.6	17.2	18.8	20.7	22.9	33.0	29.2	....	....	....	....	....
11	Chopped Hay	19.4	19.8	17.7	22.1	23.2	33.0	43.4	43.0	39.1	28.9	24.4	19.3
12	Sawdust	17.7	24.5	17.8	18.7	22.3	25.9	34.6	40.7	44.7	36.5	28.2	21.0
13	Sand and Gravel	....	1.6	1.9	3.4	4.7	5.8	9.0	12.0	12.7	9.8	7.0	7.0
14	Peat Moss - Chopped Hay	18.1	21.8	22.7	21.1	23.9	29.5	41.5	46.2	41.7	29.5	30.4	21.3
15	Peat Moss	19.9	21.1	16.8	22.0	27.3	33.9	45.8	44.7	54.6	53.0	57.0	21.6
16	Peat Moss	18.7	21.9	19.3	21.6	26.2	34.3	44.3	49.3	53.2	44.0	36.0	24.1
17	Peat Moss	20.6	21.1	20.1	21.9	24.0	37.6	44.7	48.5	51.8	40.0	31.1	21.9
18	Peat Moss - Sugar Cane (fine)	16.6	21.1	17.6	25.0	23.7	24.8	28.9	37.3	36.1	30.7	32.0	19.8
Plot No.													
21	Sawdust	8.1	8.9	9.7	9.6	10.0	11.1	10.1	10.1	11.0	7.8	9.8	9.4
22	Sugar cane (coarse)	7.1	7.9	7.9	8.1	8.6	9.8	8.4	8.2	9.6	7.9	8.7	8.3
23	Peat Moss and Shavings	7.3	10.1	10.9	10.3	11.3	12.1	13.8	10.1	12.2	10.6	10.5	10.6
24	Chopped Hay	7.6	9.0	8.4	10.1	9.3	11.7	12.6	10.0	11.1	8.8	9.6	9.7
25	Shavings	7.6	9.1	8.6	9.4	9.6	10.3	9.7	8.2	10.6	8.8	9.0	8.9
26	Sugar cane (fine)	6.3	7.6	8.8	8.9	8.8	9.8	9.2	8.3	10.2	8.8	10.1	8.8
27	Peat Moss	10.9	11.9	12.2	13.0	13.4	14.3	14.5	13.3	14.8	12.8	13.1	12.0
28	Peat Moss and Straw	9.7	10.9	12.4	12.6	12.9	14.1	13.5	12.5	12.8	12.2	11.5	12.9
29	Oat Hulls	7.3	9.7	9.7	10.4	10.1	11.0	10.5	9.4	10.6	9.8	9.5	9.8
30	Straw	8.2	10.5	9.5	10.7	10.1	11.4	11.4	8.9	12.9	9.8	8.4	8.8
31	Sand and Gravel	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.2	0.2	0.3	0.2
32	Sand, Gravel and Straw	0.7	0.8	0.7	1.3	0.8	0.9	0.9	0.6	0.6	0.8	0.8	0.4

TABLE 3. MOISTURE HOLDING ABILITY OF LITTERS USED

Litter	Absorptive Ability
1. Peat Moss	4.5
2. Sugar Cane (Coarse)	4.4
3. Straw	4.4
4. Sugar Cane (fine)	4.2
5. Peat Moss and Straw	4.2
6. Peat Moss and Shavings	3.7
7. Sawdust	3.3
8. Hay	3.2
9. Shavings	2.5
10. Oat Hulls	1.4
11. Sand and Gravel	0.14

show that the type of litter used was the factor of most influence. The type of insulation or ventilation did not seem to influence greatly the egg production of the birds or the moisture content of the litters.

To show the influence of wet litter condition on mortality of laying birds, Table 7 gives a summary of the mortality by pens during the three test periods.

The total mortality was relatively low and as far as could be determined was not closely related to the moisture content of the pen litters. If one were to group the reported figures on the basis of (1), less than 40% moisture in litter and (2), more than 40% moisture in litter and take an average value of the per cent mortality for such grouping, it would indicate that those pens under (1) experienced a mortality of 6.02% whereas those of (2) had an average mortality of 8.04%.

WATER CONSUMPTION AND SPILLAGE

During the period January 9 to May 20, 1940, detailed records were maintained in several pens on the amount of water consumed and spilled from the waterers. Figure 8 shows the method of catching the spillage by the use of inverted metal electric brooder hoods which directed the spillage into a lower, centrally located refrigerator pan. No attempt was made to estimate and allow for loss of water from evaporation or the absorption of small amounts by the dust particles adhering to the cone-shaped hood under the waterer.

Table 8 presents a summary of the results procured and shows that an estimated average of 22.6 gallons of water are consumed per bird per year. This figure compares favorably with that of 19.9 gallons as reported by Heywang (11). He allowed for 1.24 gallons of water lost as a result of normal evaporation. The per cent of water spilled according to our measurements amounted to 2.15 per cent or .486 gallons per bird per year. The effect of this spillage of water on

TABLE 4. SUMMARY OF THE LITTER MOISTURE EXPERIMENT, 36-WEEK PERIOD, 1938-39

No. of Pen	No. of Wks. Test Period	Type of Litter	Ave. Pounds Feed per Bird		Ave. No. Birds	Total Eggs	Eggs Per Bird	Litter Added (Lbs.)	Litter Removed (Lbs.)	Increase in Wt. (%)	Litter Treatment	Ave. Percent Moisture For Test	Breed of Birds Used
			Total	Per Week									
11	28	Shavings & Peat (mixed)	56.83	2.39	89.23	8,948	91.96	....	....	....	B	41.1	B.P.R.
12	30	Shavings & Peat (mixed)	51.67	1.72	94.58	9,950	102.81	....	....	....	B	40.1	S.C.W.L.
13	30	Shavings & Peat (mixed)	57.85	1.93	88.68	9,146	103.00	....	....	....	B	47.8	B.P.R.
14	30	Shavings & Peat (mixed)	51.00	1.70	101.29	10,003	98.48	....	....	....	B	47.9	S.C.W.L.
15	30	Peat Moss	54.28	1.80	119.88	13,320	111.13	431	2969.25	589	A	57.4	N. H.
16	30	Peat Moss	55.37	1.84	119.96	13,082	109.06	686.5	3165.00	361	B	55.2	N. H.
17	30	Peat Moss	55.98	1.86	119.93	13,222	110.19	512.5	2745.00	436	C	54.1	N. H.
18	30	Shavings & Peat (mixed)	62.01	2.06	96.62	12,032	123.59	....	....	....	B	44.0	N. H.

TABLE 5. SUMMARY OF LITTER MOISTURE EXPERIMENT, 36-WEEK PERIOD, 1939-40

No. of Pen	Type of Litter	Ave. pounds Feed per Bird		Ave. No. Birds	Total Eggs	Eggs Per Bird	Litter Added (Lbs.)	Litter Removed (Lbs.)	Increase in Wt. (%)	Litter Treatment	Ave. Percent Moisture For Test	Breed of Birds Used
		Total	Per Week									
11	Chopped Hay	68.46	1.90	108.54	13,808	128.33	....	....	....	B	37.5	N. H.
12	Sawdust	65.16	1.81	108.19	13,079	121.36	....	....	....	B	36.5	N. H.
13	Sand and Gravel	66.78	1.85	80.95	9,124	109.25	....	....	....	B	9.9	N. H.
14	Peat Moss for first three weeks Chopped hay after	67.64	1.88	109.25	15,031	140.14	....	....	....	B	37.7	N. H.
15	Peat Moss	64.85	1.80	121.22	17,026	140.81	633	2690	325	A	46.4	N. H.
16	Peat Moss	64.93	1.80	121.02	17,287	142.86	760	3420	350	B	45.0	N. H.
17	Peat Moss	65.21	1.81	121.36	16,844	141.07	840	3710	342	C	44.5	N. H.
18	Peat Moss first six weeks—Sugar cane after	62.17	1.73	66.02	7,231	110.95	....	....	....	B	31.6	N. H.

TABLE 6. SUMMARY OF LITTER MOISTURE EXPERIMENT, 36-WEEK PERIOD, 1940-41

No. of Pen	Type of Litter	Ave. pounds Feed per Bird		Ave. No. Birds	Total Eggs	Eggs Per Bird	Litter Added (Lbs.)	Litter Removed (Lbs.)	Increase in Wt. (%)	Litter Treatment	Ave. Percent Moisture For Test Mar. and Apr. only	Breed of Birds Used
		Total	Per Week									
11	Chopped Hay	65.64	1.82	124.93	18,652	148.85	....	....	....	B	41.9	N. H.
12	Chopped Hay	69.49	1.93	85.98	13,328	157.48	....	....	....	B	34.9	N. H.
13	Chopped Hay	69.28	1.92	85.99	12,668	150.50	....	....	....	B	33.1	N. H.
14	Chopped Hay	63.42	1.81	119.60	16,832	126.29	....	....	....	B	46.1	N. H.
15	Sawdust	67.13	1.86	121.30	17,488	141.18	1,402	2,580	84	A	53.3	N. H.
16	Sand and Gravel	67.21	1.86	120.10	16,849	144.08	11,424	14,090	23	B	17.6	N. H.
17	Peat Moss	67.15	1.86	118.07	18,163	150.57	355	1,965	453	C	43.8	N. H.

TABLE 7. FLOCK MORTALITY FOR EXPERIMENTAL PENS DURING THE THREE TEST PERIODS

Pen. No.	No. Birds Housed At Start	No. Birds Added	Total No. Birds Housed	Total No. Birds Died	Mortality Based on Total Birds Housed	Ave. Moisture Of Litter
1938-39						
11	118	1	119	5	4.2	38.4
12	114	26	140	7	5.7	34.8
13	118	60	178	14	7.8	42.0
14	116	....	116	14	12.1	41.0
15	120	10	130	9	6.9	49.7
16	120	13	133	12	9.0	46.4
17	120	10	130	5	3.8	47.8
18	112	....	112	9	7.5	37.9
1939-40						
11	120	....	120	7	5.8	32.1
12	120	....	120	10	8.3	31.4
13	120	55	175	9	5.1	8.0
14	124	....	124	6	4.8	32.9
15	125	9	134	14	10.4	42.2
16	125	8	133	16	12.0	38.6
17	125	5	130	9	6.9	37.4
18	94	1	95	4	4.2	29.8
1940-41						
11	149	38	187	14	7.4	42.3
12	139	21	160	9	5.6	36.3
13	130	....	130	4	3.1	34.2
14	139	23	162	11	6.7	46.7
15	104	50	154	15	9.7	53.8
16	125	12	137	7	5.1	17.9
17	125	10	135	9	6.6	44.5

the condition of litter adjacent to the waterer is noticed in Figure 9. In those pens under litter treatment "A" an excessive dampness about the waterer soon was evident and subsequent litter additions merely served to absorb the spillage, especially in peat moss pens, and to maintain a wet, soggy mass about the waterer. Water spillage has a definite influence on the condition of the litter and some method to reduce this spillage or to prevent its retention in the litter should be adopted. The use of a water catching device and the use of a litter which has a low water retention value is recommended.

TABLE 8. WATER CONSUMPTION AND SPILLAGE FROM FOUNTAINS IN STATED EXPERIMENTAL PENS, JANUARY 9 - MAY 20, 1940

	Pen 11	Pen 14	Pen 15	Pen 16	Pen 17	Pen 18	Total or Average
Total Quarts Water Added	3516.0	3711.5	4248.0	4210.0	4169.5	2272.5	22,127.5
Total Quarts Water Spilled	68.0	61.5	89.9	108.0	98.0	51.5	476.9
Net Quarts Water Consumed	3448.0	3650.0	4158.1	4102.0	4071.5	2221.0	21,650.6
Average Quarts Water Consumed Per bird 19 wks.	31.77	33.82	33.23	32.52	32.65	35.82	33.08
Average Quarts Water Consumed per bird per wk.	1.67	1.78	1.74	1.71	1.71	1.88	1.74
Est. Gallons of Water Consumed per bird per year	21.7	23.1	22.6	22.2	22.2	24.4	22.6
Percent Water Spilled	....	....	....	....	....	....	2.15

TEMPERATURE, HUMIDITY AND MOISTURE CONTENT STUDIES

Since the data in this experiment consist of a rather large collection of figures, they are presented as a series of curves. In all curves the abscissa is used to show time and the ordinate to show per cent humidity, temperature, or other factors.

The information on the moisture content of the various litters is included in certain of these curves. To picture the changes in humidity of the air in the plot house, which approximates outside air conditions, and the changes in the poultry house, a daily and weekly average humidity was obtained.

The daily average humidity was obtained by taking six values of humidity from the humidity record chart at 4 a.m., 8 a.m., 12 noon, 4 p.m., 8 p.m., and 12 midnight. The average of these six figures is taken as the average humidity for the day. The seven daily averages were likewise combined to secure the approximate weekly humidity value.

Daily and weekly averages of temperature were also computed in the same manner as for humidity. The barometric pressure data was obtained from the official weather records recorded at the Durham station twice daily, at 8 a.m. and 5 p.m. These reports were averaged to give a daily figure for use on the curves.

In Figure 1 is illustrated (1) average moisture content of plot house litter samples, (2) average moisture content of poultry pen litter samples, (3) poultry pen air humidity, and (4) effect of new litter additions on litter moisture content. A review of this chart in-

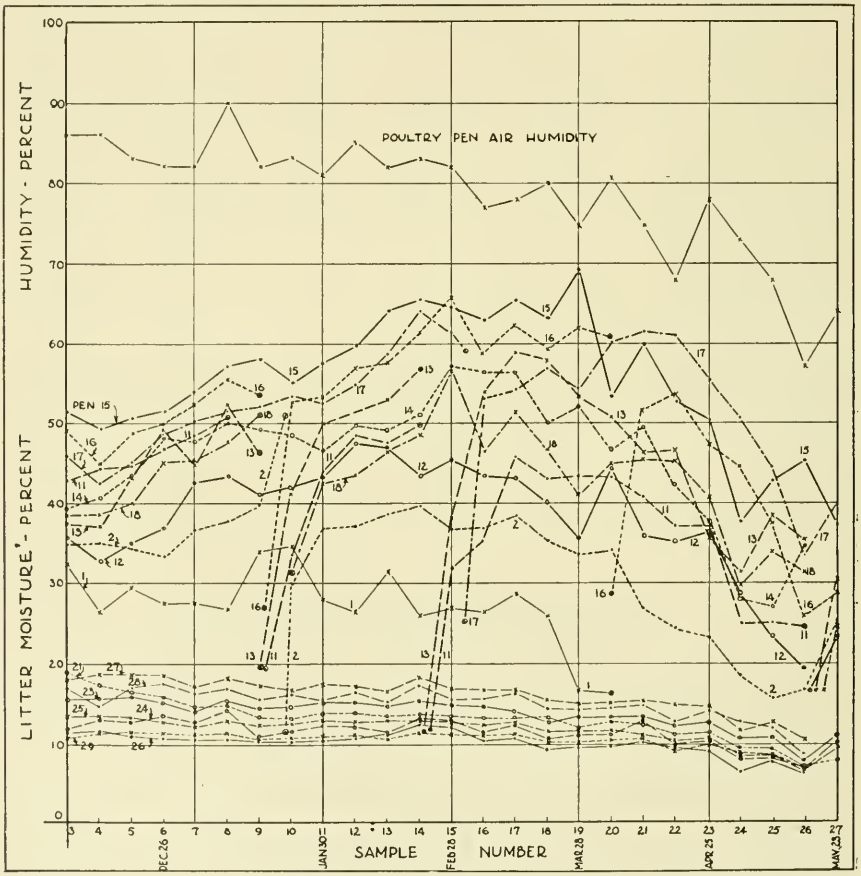

FIG. 1. EFFECT OF NEW LITTER ADDITIONS TO POULTRY PENS ON LITTER MOISTURE CONTENT. NOS. 11-18, POULTRY PENS. NOS. 21-29, PLOT HOUSE.

dicates that the litter moisture in the plot house samples started out at a fairly low level (10 to 18 per cent) and gradually declined in all litters throughout the experimental period to an average of about 10 per cent on May 23.

In contrast to the above, the poultry pen litters started with a moisture content averaging about 40 per cent, gradually increased to a high of 68 per cent (Pen 15) and then followed a general downward trend to a low of 23 per cent on May 23. The litter moisture in Pen 1, however, does not follow this trend. It is, no doubt, due to the fact that the pen is insulated, heated, control ventilated and has floor heat from the incubator cellar below. There is no general upward or downward trend, although there are variations from week to week. The moisture content holds very near an average of 28 per cent.

The poultry pen air humidity holds fairly steady for the months of December, January and February, averaging over 80 per cent. Following this period there is a gradual decline in per cent humidity to about 64 at the end of the period.

When new litter additions were made to pens 2, 11, 13, 16, 17, and 18 a surprisingly rapid rate of moisture increase occurred. Shavings required two weeks to achieve a stable and normal rate of gain. During this two weeks they gained from 23 - 32 per cent of moisture, averaging 26 per cent. Peat moss required but one week to gain 26 per cent. After this initial period of moisture gain, the new litter settled down to a more uniform rate of increase, corresponding to that held previously by similar types of litter.

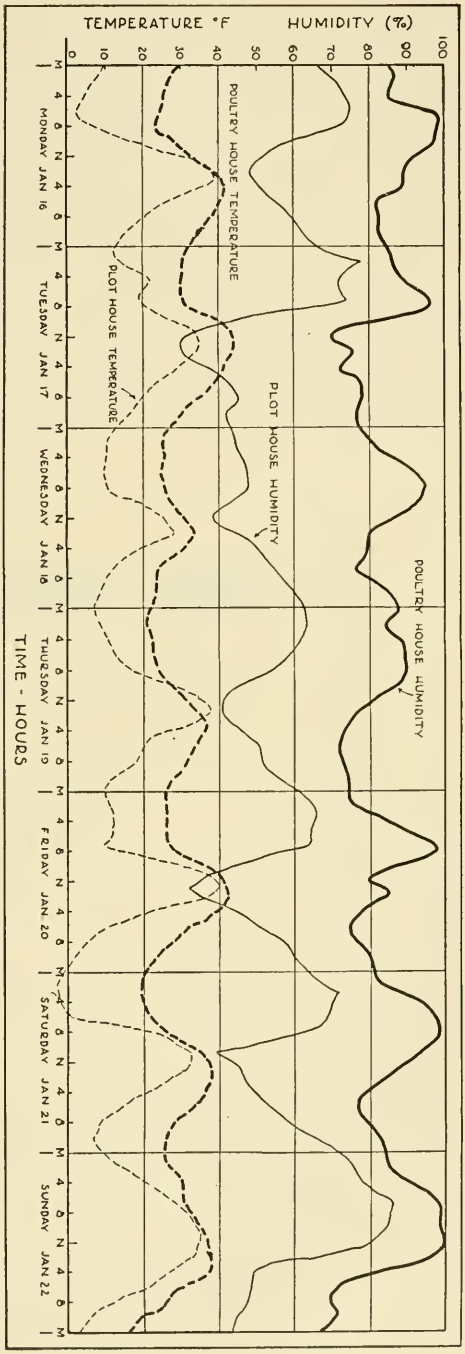

FIG. 2. SAMPLE—DAILY VARIATIONS IN TEMPERATURE AND HUMIDITY, JAN. 16-22, 1939.

Figure 2 shows the variation of poultry house and plot house humidity and temperature for the period January 16 - 22, 1939. This illustrates to good effect the daily variations of these factors as well as their related effect on the first new litter additions as noted on Figure 1. Obviously, with a poultry house humidity of more than 80 per cent, new additions of fresh, dry, absorptive litter will pick up large amounts of moisture rapidly and then settle down to a uniform rate of increase similar to the old litter.

Daily averages of humidity and temperature of the poultry house and plot house, together with barometric pressures, wind direction and precipitation are presented in Figure 3. It is noted that both plot house and poultry house humidities follow closely the outside atmospheric conditions. On cloudy or rainy days they increase, whereas on clear days the house humidity decreases.

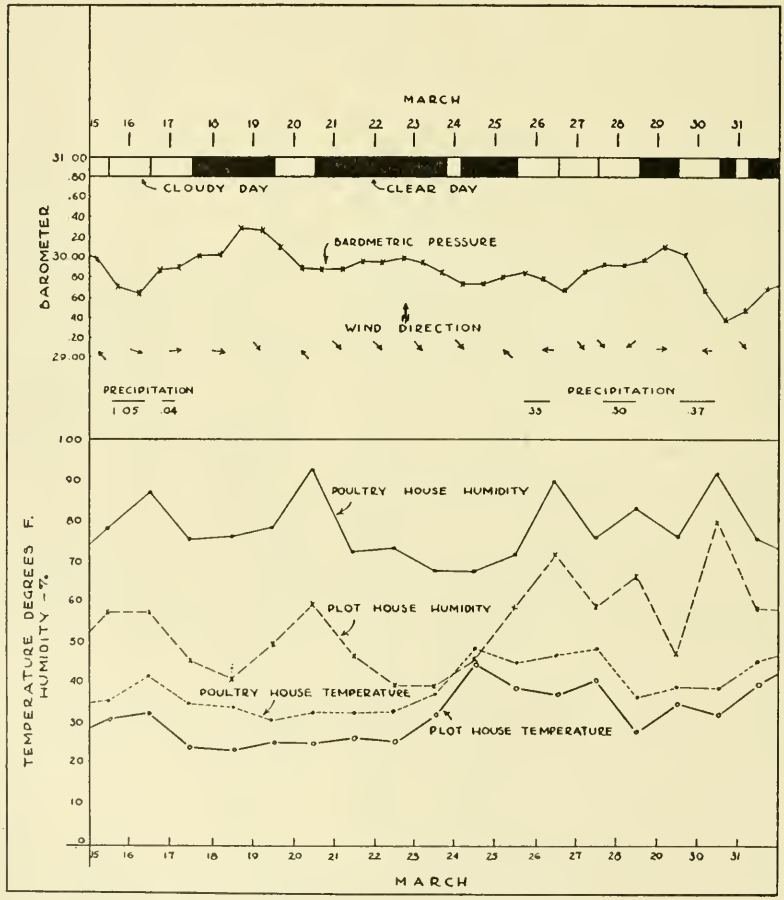

FIG. 3. BAROMETRIC PRESSURE, WEATHER CONDITION, TEMPERATURE AND HUMIDITY OF PLOT HOUSE AND POULTRY PENS, MARCH 15-31, 1939.

Figure 4 shows the actual and calculated (saturated) moisture carrying capacity of the air in plot house and poultry pen 16 for a period of seventeen months. General conversion factors were used in calculating moisture carrying capacity of air at the various temperatures. It will be noted that the actual moisture carried by the air was considerably less than its theoretical moisture carrying capacity. This was especially true, as noted by the cross-hatched section of the chart, from May to October. During the colder months the air moisture carrying capacity is reduced to a point only slightly above the actual capacity. Consequently, a sudden drop in temperature of only a few degrees will cause the dew point to be reached and moisture to be deposited in the pen.

It is thus apparent that the addition of some heat to raise the pen temperature would greatly increase the moisture carrying capacity of the air and thus make it possible to remove the excess moisture from the litter (See Fig. 1, pen 1).

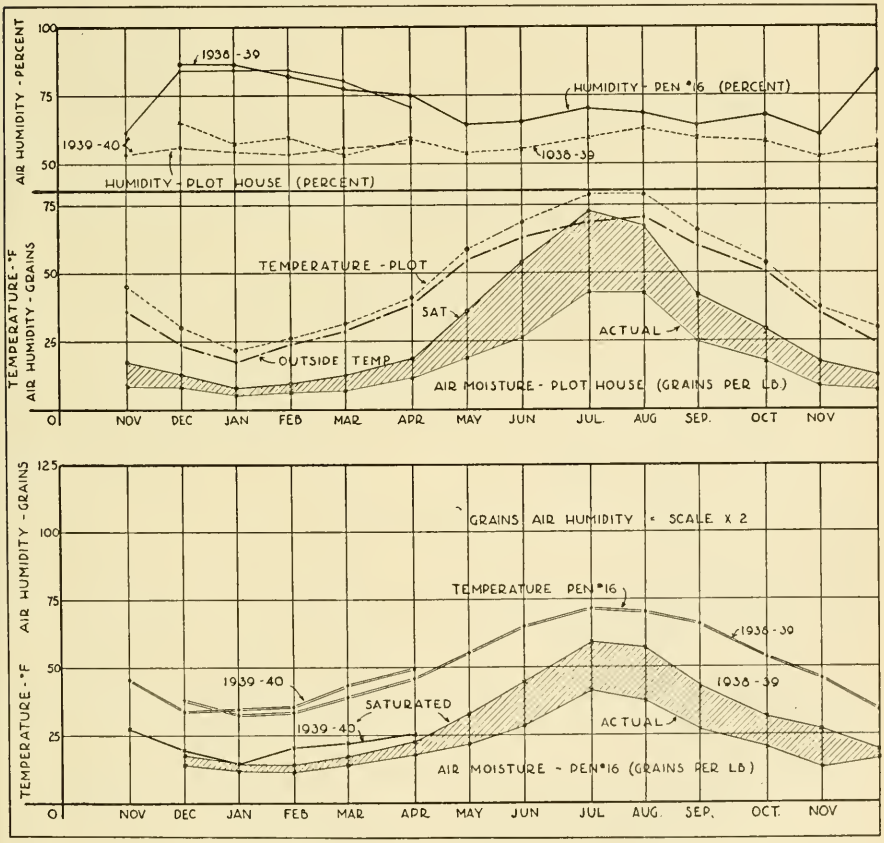

FIG. 4. ACTUAL AND CALCULATED (SATURATED) MOISTURE CARRYING CAPACITY OF AIR IN PLOT HOUSE AND POULTRY PEN 16.

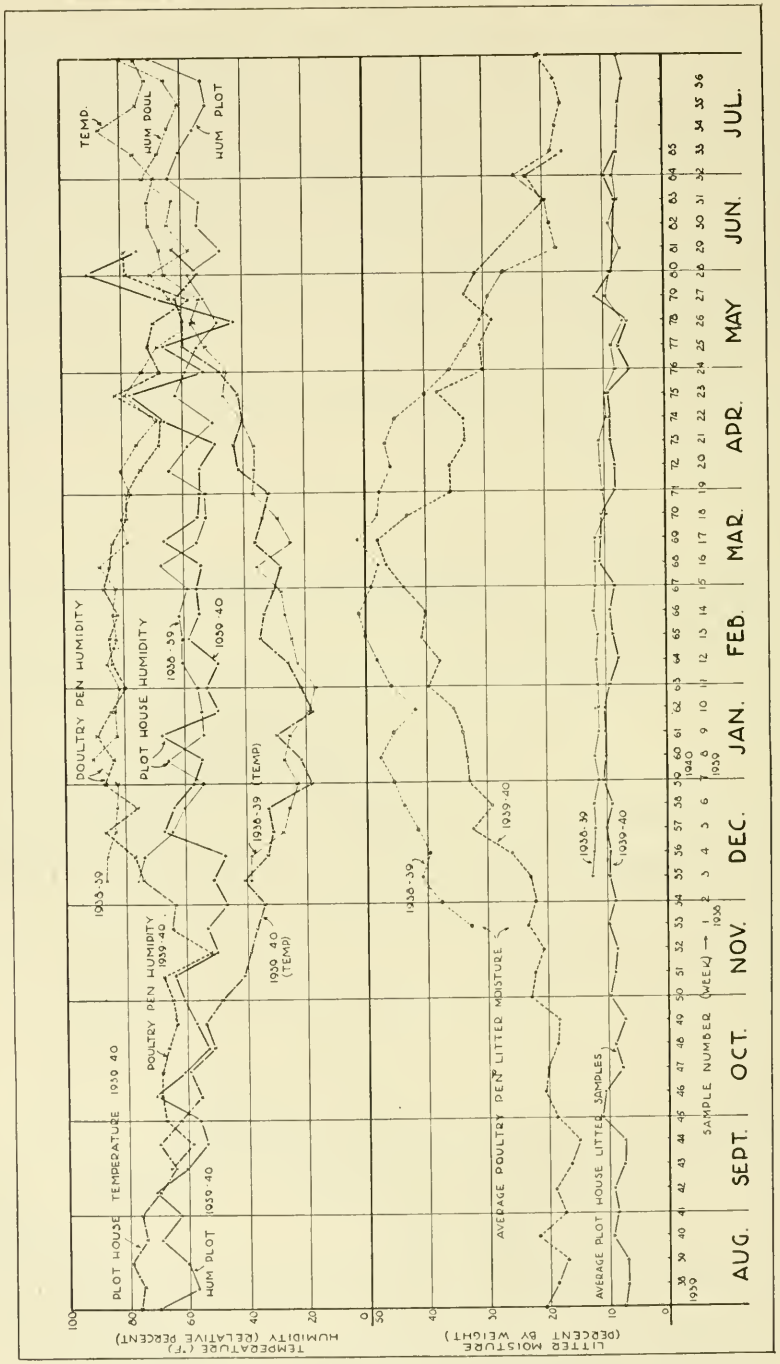

FIG. 5. LITTER MOISTURE, TEMPERATURE, AND HUMIDITY OPSERVATIONS OF PLOT HOUSE AND POULTRY PEN 16, 1938-40.

As previously mentioned, Chart 1 presents the individaul averages of plot and poultry house litter moisture content. To supplement this data Figure 5 has been drawn to show the relation between the average moisture content of all plot house litters and poultry pen litters and to present the temperature and humidity records of the two locations. The plot house litter moisture curve presents evidence that the litters included in this study, subjected only to atmospheric conditions and without the presence of birds, maintain a uniformly low moisture value throughout the year. On the contrary, the litter in the poultry pens carried approximately twice as much moisture through the summer months as did the plot house litter samples. With the approach of less favorable fall and winter weather conditions the moisture content of all litters increased at a fairly uniform rate, reaching a peak of about 50 per cent by weight in February and early March. Following this period and with the improvement of

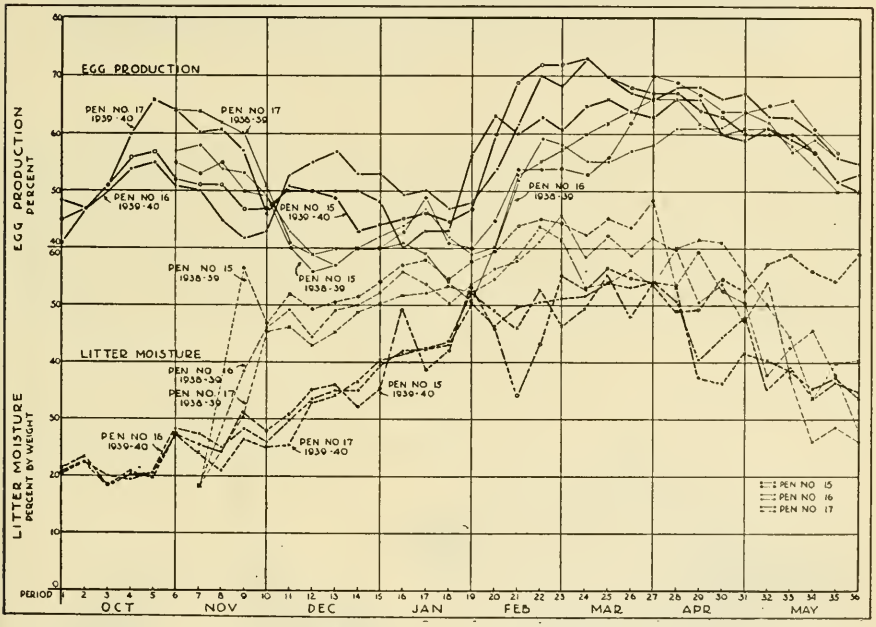

FIG. 6. RELATION OF LITTER MOISTURE CONTENT TO PERCENTAGE EGG PRODUCTION, 1938-40.

weather conditions in the Spring there was a gradual decrease of litter moisture until the latter part of June, when it again averaged about 20 per cent.

The plot house temperature curve shown on this chart can be considered as an approximate reading of outside temperature conditions. While the plot house humidity curve shows a relatively steady value, that of the poultry pen follows the general trend of the pen litter moisture curve. It would appear from this that with a relatively

FIG. 7. LONG TYPE COMBINATION ROOF LAYING HOUSE INCLUDING PENS 11-18, INCLUSIVE.

steady oustide air humidity value, its effect in raising the humidity value inside the poultry pen is of less significance than is the presence of birds within the pen. Related to this, of course, is the reduced moisture carrying capacity of the cold air moving in, around, or out of the poultry pen. Aside from the normal respiratory and excretory moisture from the birds there must also be considered (1) water spillage by birds or attendants and (2) moisture accumulations from rain or snow storms through openings in the pens.

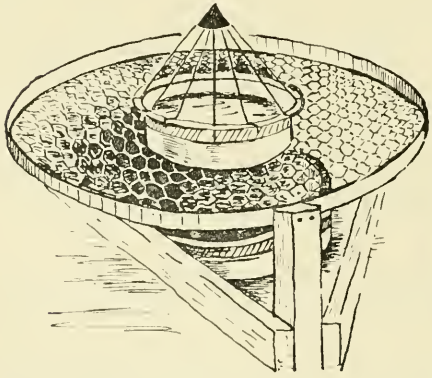

FIG. 8. ILLUSTRATES THE METHOD OF CATCHING WATER SPILLED BY THE BIRDS DURING THE DRINKING PROCESS.

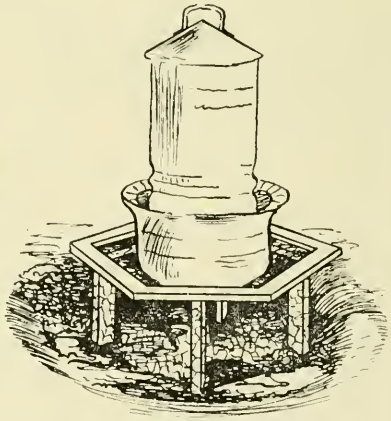

FIG. 9. THE EFFECT OF WATER SPILLAGE ABOUT WATERERS WITH PEAT MOSS LITTER UNDER TREATMENT "A" IN PEN 15, MAY 1939.

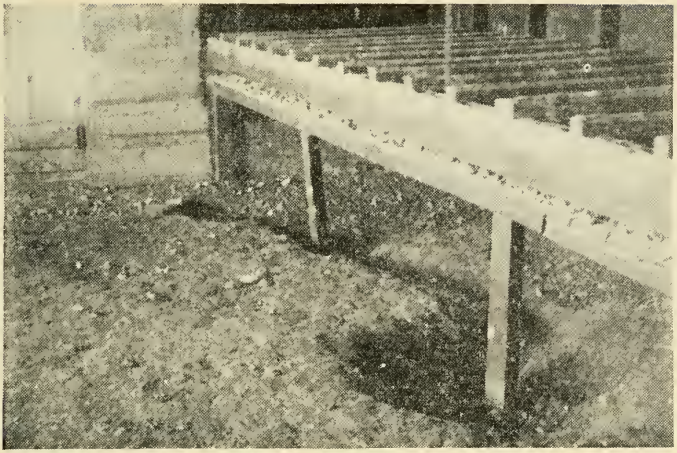

FIG. 10. VIEW NEAR EDGE OF DROPPING BOARD IN PEN 15 UNDER LITTER TREATMENT "A", MAY 1939, SHOWING PACKED LITTER CONDITION.

The relation of the litter moisture content to the percentage of egg production in pens 15, 16, and 17 is presented in Figure 6. It appears evident that there are two seasonal peaks in egg production and one in litter moisture. The first peak in egg production occurs in October and November, during which time the litter moisture values are at a relatively low level. The second egg-production peak occurs between February to April, inclusive, and is associated with the period of highest litter moisture content. Since these peaks of egg production occur at both high and low litter moisture values, it is apparent that there is no relation between percentage of egg production and percentage of litter moisture. Egg production is primarily dependent upon time of hatch, and upon breeding and management and is independent of the seasonal litter moisture curve.

SUMMARY

Data have been collected and observations have been made on litter moisture conditions for a period of approximately three years. These observations and data have included poultry pen humidity, temperature and litter moisture content, similar records for litter maintained in a separate "plot" house affected solely by atmospheric conditions, water absorptive capacity and retention values of various litters, rate of moisture increase in litter replacements to poultry pens, egg production, mortality, water consumption and spillage by birds, effect of under floor heat on litter moisture and sources of litter moisture.

The chief sources of litter moisture are (1) poultry droppings, (2) respiration, (3) water spillage by birds and attendants, (4) atmos-

pheric moisture and (5) snow or rain storms beating into pen. It does not seem probable that moisture is deposited from the outside air directly, although this air, no doubt, controls certain conditions resulting in high litter moisture. Winter outside air is usually lower in temperature and humidity than the poultry house air and therefore could not add moisture to the poultry pen from its own mass. Cold air entering a poultry pen can, in mixing with warmer, more humid air, chill it below its dew-point and cause the precipitation of some of its moisture.

The outside air does aid removal of moisture from the poultry pen. During the night when the front curtains are partially or entirely closed the humidity increases in the pen to nearly 100 per cent. Also lower temperatures at night serve to increase the moisture content of the air. Just as soon as the curtains are lowered in the morning the pen humidity drops sharply. These factors indicate that during the day conditions are optimum for the removal of litter moisture from the pen. The drier outside air enters, mixes with the more humid air of the pen, decreases its actual moisture content and moves it out of the pen through the ventilating devices. The higher temperature of the poultry house favors evaporation from the litter and the humidity of incoming air being lower, allows this air when warmed to absorb more moisture.

While the plot house litter moisture curve remains steady and shows no particular trend, the poultry pen litter moisture shows a definite seasonal character. The litter in the poultry pens carried about twice as much (20%) moisture through the summer months as did that of the plot house. With the approach of less favorable winter weather conditions the moisture content of the pen litter increases, reaching a maximum of about 50 per cent by weight in February and early March. Following this period and with the improvement of weather conditions of the Spring there was a gradual decrease of litter moisture until the latter part of June, when it again averaged about 20 per cent. Under-floor heat is conducive to dry pen litter conditions.

Peat moss was found to possess the highest absorptive capacity for moisture of any of the litters studied, and also the greatest retention of this absorbed water. Sand and gravel showed the least water absorptive capacity.

It was well established, as noted in Figure 1, that additions of fresh, relatively dry litter to poultry pens during the winter months do not result in continued dry litter conditions. The newly added litter picks up moisture rapidly and in a few weeks reaches the moisture level of the old litter.

There appears to be no relation between percentage of egg production and percentage of litter moisture. The mortality of housed layers is not directly related to litter moisture condition.

Records indicate a water consumption of approximately 22.6 gallons per bird per year. Since water spillage by the birds was noted as a cause of wet litter a cone-shaped device (Figure 8) was constructed

and utilized in the measurement of this spillage. Approximately 2.15 per cent or nearly one-half gallon of water per bird is spilled per year within the pen.

CONCLUSIONS

1. Warming the floor of the poultry pen helps to maintain dry litter.

2. Controlled ventilation alone does not maintain dry litter in an insulated or uninsulated house with sliding front curtains.

3. Uninsulated houses are damper than insulated houses with the same type of litter used.

4. New Hampshires may be expected to consume approximately 22½ gallons of water per bird per year.

5. No specific standard of proper litter conditions can yet be set up.

6. The moisture content of "desirable" poultry pen litters should not exceed 40 per cent.

7. Litter treatment method "C" will assist materially in maintaining good outward appearance of pen litter but is not very helpful in reducing average litter moisture content. (See Table 4.)

8. The type of litter used appears to have a greater influence on litter moisture values than either insulation, ventilation or area of floor space per bird.

9. Under our experimental conditions, there were no measureable differences in the health, condition or production of birds on "wet" or "dry" litter. It is conceivable, however, that in the presence of certain diseases or epidemics wet litter may seriously interfere with their control.

10. Prevention of spillage of water by the birds about the waterer is desirable.

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