Ontario Department of Agriculture.

ONTARIO AGRICULTURAL COLLEGE

BULLETIN 163

Incubation of Chickens

Hatching and Rearing Chickens

By W. R. GRAHAM, Poultry Manager and Lecturer.

Humidity in Relation to Incubation

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By R. HARCOURT, Professor of Chemistry, and
H. L. FULMER, Demonstrator in Chemistry.

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Experiments in Hatching and Rearing Chickens.

BY W. R. GRAHAM, POULTRY MANAGER AND LECTURER.

For a number of years the Poultry department has been endeavoring to locate the cause or causes for the large losses of young chickens, particularly of those hatched artificially. Numerous visits have been made to farms where chicks were being grown both naturally and artificially. The most casual observer would have noticed that, upon the average, the chickens hatched naturally were more thrifty and vigorous. I have often seen, however, some choice chicks that were hatched by the artificial means, and also a few chicks hatched by hens that were far from first-class. In a general way, nearly all large poultry farms that I have visited, where 1,000, or even say 500, chickens are hatched annually, there was a very heavy death rate, so heavy as to render the business unprofitable. The death rate among chicks hatched artificially, when there is not more than one hundred hatched, is proportionately not so heavy, so far as I can judge from correspondence and observation; yet even among these growers, numerous complaints are made, and the average mortality is very serious. The questions to my mind are as follows:

(*a*) Is artificial incubation to blame? If so, wherein does it differ from natural incubation?

(*b*) Is the heavy mortality due to inferior breeding stock?

(*c*) Are the methods of feeding and brooding the causes of the trouble?

All the questions have to be considered seriously, and it is very difficult to separate them so as to be positive that one and only one is influencing the results. Therefore the writer would ask the reader to carefully consider the methods of selecting eggs for incubation, as well as the methods of feeding and brooding the chickens, before drawing conclusions as to incubation. Many of these experiments, if not all, will have to be duplicated for a number of years.

In taking up the question of how a hen hatches eggs, we at once felt the necessity of a careful study in every detail, and to do this we asked the co-operation of the departments of Physics and Chemistry. The work done by these departments is given in this Bulletin. What may be termed the practical work, or that which may be done by any poultryman who will take the trouble, was done by the Poultry department.

The experiments were commenced in the summer of 1906 and were reported upon in the Annual Report of the College. The experiments of 1906 indicated that a hen was a better hatcher than an incubator, and that so far as we had learned, she differed from incubators in having less evaporation of the egg content, and in having a much higher amount of carbonic acid gas in the air immediately surrounding the eggs. Last year we kept no detailed record of the mortality of the chicks. The July and August chickens lived and grew fairly well. This may have been due to the fact that the machines of 1906 were washed with a solution of zenoleum, mainly for the reason that they then looked cleaner and had less of the incubator odor. We thought the good results obtained were due to the fresher air of the incubator room, but as the same room and many of the same machines were used this year, we cannot maintain the idea as being correct.

We have this season tried to make the conditions in the machines more like those found under the hen. It will be noticed in the tables that we have operated nearly all the makes of incubators, at times, different to the manufacturers' directions; hence, one should not judge a machine by these results.

Eggs Used for Hatching.

It is a well known fact that eggs vary in their power of hatching. Some eggs are infertile; some are fertilized, but the germ is so weak that it dies early in the period of incubation; others reach practically the hatching stage and then die. The power of hatching is influenced by breeding, feeding, housing, etc. Where one proposes to follow the vitality of chicks or even to consider any phase of the incubation or rearing problems, it becomes necessary to have eggs as nearly alike as possible; hence, we have used in nearly all the experiments, eggs laid by the same individual hens. We have been trap-nesting over 500 hens and have used such eggs in this work. We have also used shuffled eggs which were purchased from outside sources. By shuffled eggs is meant, simply, a common box or basket of eggs such as would be gathered from an ordinary flock.

The tables which follow give the results obtained from the individual eggs, with the exception of the mortality column, which gives the mortality of the chicks from all sources. The results obtained from the shuffled eggs are omitted for the reason that we failed to get anywhere near an equal division of the eggs as to fertility, etc. We regret that the results should be so. We tried many methods of mixing and separating the eggs with the results as above mentioned. The mortality of the chicks from both kinds of eggs was very nearly the same; therefore, there was no necessity of separating the deaths from each kind of eggs.

If the method of incubating has no effect upon vitality, and the same hen's eggs are in each machine, then the chicks should live in nearly the same proportions, provided that the brooding, feeding, and care are the same. On the other hand, should there be a considerable variation in mortality with brooding, feeding, etc., alike, we must then come to the conclusion that the method of incubating influences the chick's vitality.

The incubators used were divided into three groups in order that we might set a number of machines each week throughout the natural hatching season. Later in the season these groups were somewhat broken up.

In many instances hens were set upon eggs laid by the same individuals as those used in the machines. We tried to have a number of hens to set at the same time we set the incubators, but owing to a shortage of "cluckers" we were not always able to do so. We give a table which shows the results as obtained from each method of incubating and brooding.

Fig. 1.—The Experimental Incubator Room.

Incubators Used in These Experiments.

Chatham Incubator. Manufactured by the Chatham Incubator Co., Chatham, Ont. This machine is classed under the radiant type of machine, and can be operated with or without moisture. There are moisture pans sent out with each machine.

Peerless Incubator. Manufactured by the Lee-Hodgins Co., Pembroke, Ont. This is a hot water machine and, according to the manufacturer's directions is to be operated without moisture.

Hearson Incubator. Manufactured in England and sold by Spratt's Patent, Notre Dame Street, Montreal. This machine is also of the hot water type. It has an updraft circulation of air, which makes it, in this respect, in a class by itself. When operating, moisture should be used in this machine, according to the manufacturer's directions.

Model Incubator. Manufactured by the Model Incubator Co., of Toronto, and Buffalo. This is a hot air machine of the diffusion type. The manufacturer's directions call for the machine to be operated without moisture. It differs from the Cyphers incubator in that the bottom of the machine is slatted. There are other differences, but these are not so marked.

Cyphers Incubator. Manufactured by the Cyphers Incubator Co., Buffalo. These machines are of the hot air diffusion type,-and are supposed to be used without moisture. We have divided the machines here into the two types, known as the 1905 and 1906. The 1906 machine is much deeper than the 1905 machine, and for this reason we thought it well to divide the machines.

Prairie State Incubator. Manufactured by the Prairie State Incubator Co., Homer City, Pa., U.S.A. Of these machines we have two types, one known as the Open Bottom Prairie State, which is a radiant machine. Moisture pans are sent out with these machines, so that moisture may be used in limited quantities. This machine has a cloth bottom. The 1907 Prairie State is somewhat different in design from any other make. This machine is a combination of the radiant and the diffiusion types. It also has a large moisture pan in the bottom, and the ventilation is somewhat different from most other makes. These machines are to be operated with moisture according to the manufacturer's directions.

Cortland Incubator. Manufactured by the Cortland Incubator Co., Cortland, N.Y., U.S.A. This is a diffusion incubator with a large moisture pan in the bottom of the machine.

Climax Incubator. Manufactured by the Climax Incubator Co., Castorland, N.Y. This machine is somewhat of a combination of the radiant and diffusion type. It is practically an open bottom incubator, but has sent with it a large moisture pan to be used in the bottom of the machine if the operator so desires.

Continuous Hatcher. Manufactured by the Hacker Incubator Co., St. Louis, Mo. This machine is different in design from any of the others. Ventilation is by diffusion. The air passes through the side walls of the incubator, which are made of cloth. With this incubator there is a limited supply of moisture.

Of the makes mentioned, nearly all of the machines are of about 100 egg capacity. By this, we mean that they may vary in capacity from 100 to 140 eggs. The 1906 Cyphers, Peerless, and Continuous Hatcher are 200 egg machines. The Continuous Hatcher and the Climax incubators were received late in the season, so could not be included in earlier trials. We are not prepared to state what these machines may do in the way of hatching or in the production of normal chickens earlier in the season.

We have tried operating nearly all the incubators with and without moisture. Had we all of the incubators of one make or one type we could have given more satisfactory results as regards methods of operating incubators to decrease the mortality in the chicks. We have not had in every instance what would be called a check machine in each series. While the results appear to point strongly in favor of the use of certain materials in the way of decreasing the death rate of young chicks, yet these results would be far more satisfactory had we had check machines in each series.

The tables given will indicate what each of the machines has done for us in our incubator room. Those who have not had any serious mortality in incubator chickens may not have to pay much attention to the preventives suggested here, but my observation has led me to believe that sooner or later, practically all operators have trouble in rearing incubator chickens.

Operating the Machines.

Our aim was to operate the machines so that the chicks would begin hatching on the night of the twentieth day. Our experience with hens was that they would average to begin hatching at this time. The machines were run at a temperature of 100° to 101°, with a clinical thermometer lying on the top of the eggs. A record was kept of the temperatures, also of the temperatures as indicated by the hang-up thermometer. In some makes of incubators it was necessary the first week to run the hang-up thermometer at 105° to get 100° on the eggs. With the temperature at 101° and very little airing, except that given while the eggs were being turned, we seldom failed to get the hatch off on time. The temperature the first ten days was usually a little under 101°, and the last ten days nearly 102°. It was difficult, at times, to keep up the temperature at the beginning of the hatch, and equally as troublesome to keep it down toward hatching time.

The eggs were turned twice daily after the third day and were tested on the ninth day. No test was made after this. We ceased turning the eggs on the seventeenth day when moisture was used, and pans used in the bottom of the machines were removed on the night of the nineteenth day or the morning of the twentieth.

Brooding.

Two makes of brooders have been used in brooding the chickens: the Prairie State Universal Hover and Out-door Brooder, and the In-door and Out-door Model. Most of the brooding has been done with the Universal Hovers, as we had more of them. It may be stated here that we did not find any marked difference in the mortality of the two brooders. The hovers were attached to colony houses, and these in turn were placed about the poultry yards, in the College orchards, and in the farm cornfield. The chickens brooded by hens were placed in the same fields, and the method of feeding was the same for all.

Chicks from each incubator in a series were placed in the brooder. Each brooder had some chickens from all machines in the series, so that should the brooders vary, or the care be not the same, some chickens from each machine received an equal share, whether it was good or bad. It may be interesting to know that there was not in any series any marked

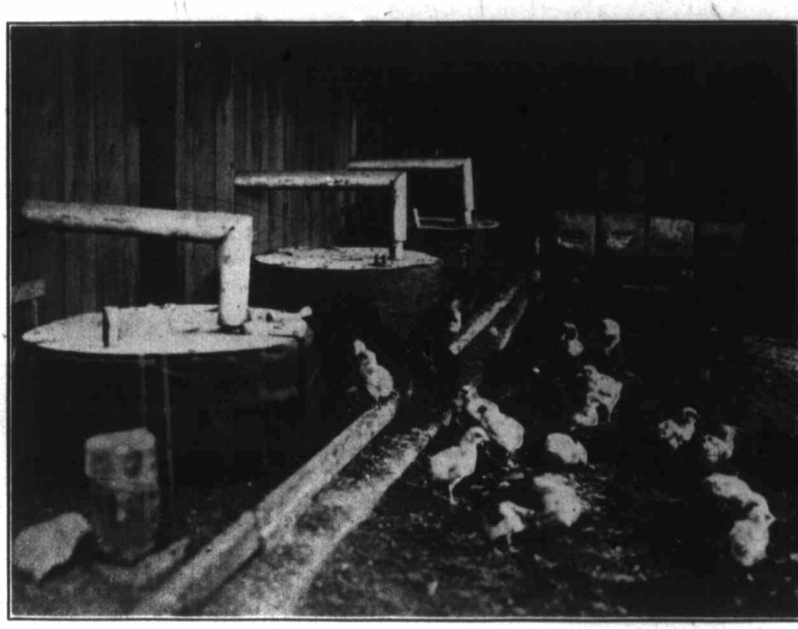

Fig. 2.—This cut shows the method of Brooding, etc.

difference between the different brooders used, but there was a marked difference in the hens used as brooders.

Feeding

We tried to adopt a plan of feeding that could easily be used by most growers. I would like to call attention to the fact that these chickens were grown out-of-doors and not under hot-house conditions, such as we get in January, February, and March; and further, the plan about to be given is not satisfactory for winter use, mainly because the chicks do not get sufficient exercise.

The chicks were usually placed in the brooders when forty-eight hours old, but a few were put in when nearly twenty-four hours old.

The plan of feeding was somewhat as follows: A clean, wide board was placed near the hover, on which was scattered a chick food, either Purina or Model. On the board was also a fountain of water. This food was kept in constant supply for about three days, and the chicks were confined close to the hover; thus we did not risk any chance of them straying away in a corner and becoming chilled. About the fourth day the chick food was scattered in cut hay so as to get the chicks to work, the

Fig. 3.—Growing Chickens in the Cornfield.

run near the hover being gradually enlarged day by day. They nearly always took to this kindly. We now ceased feeding the chick food from the board, but placed a trough of dry mash before them for an hour, two or three times a day. This mash was composed of bran, shorts, oatmeal, cornmeal and beef scrap of equal parts by measure, with the exception of the cornmeal, of which we use double the quantity of any other food. We aimed to give the chicks from the start all the green food they would eat, consisting of lettuce and sprouted grains. The former was grown especially for the late hatched chicks, and what was fed the earlier ones was largely refuse from the garden. I believe it would pay most poultrymen to grow a little lettuce for the young chicks. When the chicks reached

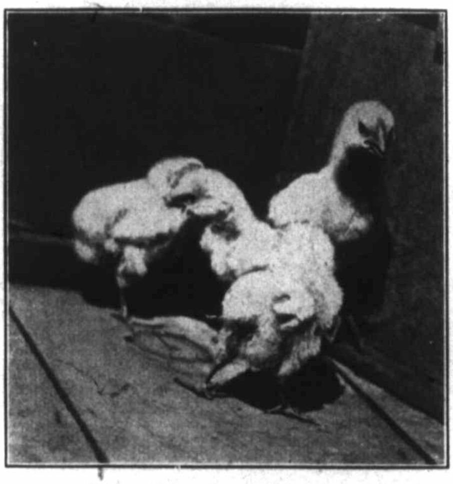

Fig. 4. – White Wyandotte chicks at about two weeks of age. A healthy chick at the back, and three white diarrhœa chicks at the front.

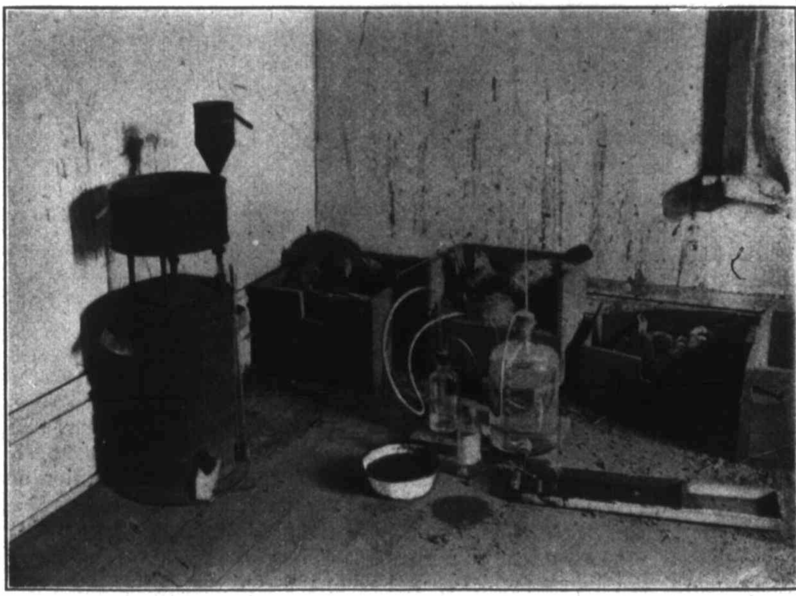

Fig. 5.—Apparatus and methods of studying Natural Incubation.

n age of three weeks; wheat was gradually substituted for the chick food. Nearly all the food from this time on was fed from hoppers, or otherwise kept constantly in front of them.

The April chickens were fed more in the litter because they could not get out of doors as well owing to bad weather.

Why Certain Materials Were Used in the Incubators.

Early in the winter we were looking for some method by which to increase the carbon dioxide in incubators. The idea was suggested to us that by the use of a species of bacteria which produces large quantities of gas we might be able to get the carbon dioxide in sufficient quantities. We obtained from the Bacteriological Laboratory a culture which would grow readily in milk. This culture was said to be one of the most gassy known. In order to produce the carbon dioxide this culture was mixed with milk and the milk renewed every four days during the period of incubation. We next considered whether sweet milk would be better than sour milk, or whether whole milk would be superior to skim-milk.

We tried operating machines with whole milk, skim-milk, and buttermilk. We have some machines that have been operated where buttermilk was used with the carbon dioxide starter and where buttermilk only has been used.

After making several *post-mortem* examinations of incubator chickens, and noting their peculiar conditions, we were of the opinion that this might be a bacterial disease. Not then having results of all the work done in the Bacteriological Laboratory, we thought it would be a wise precaution to disinfect the incubators. We had two common disinfectants on hand—mercuric chloride and zenoleum. The incubators during the second hatch were washed with a 10 per cent. solution of zenoleum. By this we mean that the inside of the machine, including the tray, the thermometer, the top, the bottom and the sides, were thoroughly scrubbed with this solution. While the machine was still wet, the eggs were placed on the trays and started. Practically the same method was used with the mercuric chloride, with the exception that we endeavored to use it much more freely on the woodwork than upon the metal parts of the machine. No other disinfectants have been tried. Possibly other carbolic or creosote compounds would give equally as good or even better results. We have not had the machines, nor the time, this year to branch out from this one line. Theoretically, several other compounds should be as good. One of our co-operative experimenters reports excellent results on the use of Jeyes' Fluid, and a friend says he got good results from creolin. These trials are the outcome of a knowledge of our unpublished results. When visiting poultry plants a few years ago, the writer, along with L. H. Baldwin, of Toronto, and F. C. Elford, of Macdonald College, were led to believe from observation that a strong odor of lamp fumes in an incubator room was likely to produce a chick low in vitality. A test or two was made at this College with dry machines operated in small rooms, and the results appeared to point to a weakness in chicks so hatched. I was never satisfied with these tests, and this year having machines from which the lamp fumes could be piped direct from the lamp of one machine to the intake of any other, we thought it wise to try and see what the results would be. We possibly lost a portion of the fumes and no doubt introduced some air from the room, but we did succeed in introducing sufficient lamp smoke to turn white eggs about the color of smoked ham, and the machine had a strong odor of lamp smoke. Needless for me to say that the results so far are a surprise.

General Symptoms of What is Commonly Called White Diarrhœa in Young Chicks.

When chicks are about twenty-four to ninety-six hours old, they resemble one another very much in appearance, with the exception that we have noticed that hen-hatched chickens and chickens hatched in moist incubators were longer in the down or looked larger and fluffier. The trouble generally begins about the fifth day. Some of the chicks will have a thin, white discharge from the vent; the chick is not active, it has a sleepy look, and the head appears to settle back towards the body. One would think the chick was cold or in great pain. Some of the chickens get in the warmest spot under the hover; others have intense thirst. The white discharge from the vent is not always present. The chicks may die in large numbers between the fifth and tenth days, or there may be a gradual dropping off each day until they are perhaps six weeks of age. The disease kills some quickly; others linger for a week or more. A few chicks appear to recover, but seldom, if ever, make good birds; they are small, unthrifty, and are good subjects for roup or any other epidemic to which chickens are subject.

To the ordinary observer a *post-mortem* examination will reveal the following conditions: The lungs will usually show white spots on them; these are generally seen on the side of the lungs next to the ribs. The white spots are generally quite hard and cheesy. These spots are not always present, but from our examinations I would judge they are in fifty per cent. of the cases. I have seen these in chicks on every poultry farm that use incubators where I have been this year. Some lungs have no white spots, but are red, sometimes fleshy. These, in our experience, are not very common unless the chickens get chilled.

The yolk is often hard and cheesy. It varies greatly; some yolks are of a gelatinous nature or almost like the white of the eggs; others are hard and cheesy and very yellow in color, and sometimes are greatly inflamed; other yolks appear like a custard that has curdled, and these have usually a very offensive odor. The cæca, or blind intestine, is frequently filled with a cheesy substance.

We have written notes on 463 *post-mortems* held between April and August, 1907. It may be interesting to know what are the general con-

conditions as found in these chicks. If we tabulate the results as to the common condition found—*i.e.*, cheesy spots in the lungs, non-absorbed yolks and hardened or cheesy accumulations in the cæca—we found 207 chicks had cheesy spots in their lungs, 138 had hardened yolks, and 113 had abnormal cæca. Again, if we take a combination of the conditions found where the lungs, yolk, and cæca are abnormal, we find 102 in this class; where the lungs and yolk are diseased there are 164.

Notes on Table III.—Hens vs. Incubators.

958 eggs were set in the machines, and 436 chicks were hatched, or 5.5 per cent. of the eggs set.

335 eggs were set under hens, and 196 chicks hatched, or 58.5 per cent. of the eggs set.

As the same hens' eggs were used in each method the hen has the advantage, and had she not been in cramped quarters for a portion of the hatches her hatches would have been larger.

It will be noticed that the mortality of the chicks hatched on May 11th was very high. I think that the mortality was not, entirely, due to incubation. With this hatch, we decided to mark and weigh each chick from each egg. To do this we used pedigree trays of our own design. Each hen's eggs on the nineteenth day of incubation were placed in a separate compartment, and the tray put in a machine. This, of course, makes all but one egg from each hen finished in a machine. With this particular machine we ran the temperature very high, and kept it there until the chicks were over 24 hours old. These chicks panted very much. They began dying about the usual time, and had the usual symptoms. My personal opinion is that if the chicks pant very much in a machine, they are likely to have a heavy death rate.

Pedigree and weight records were not kept of the April chicks, but were of all others with the exception of the hatch of May 6th. Where the mortality of the chicks hatched by machines, as given in the above table, is different from that given for the entire machine in another table, the mortality here given applies *only* to the chicks from the eggs laid by the same hens as those set under hens.

Hen-hatched chickens from eggs set July 18th suffered somewhat from leg weakness. More mortality was due to this than any other cause. The chickens were reared in a very small run, and were fed all they would eat, or food was in front of them at all times. Had these chickens been reared in an open field this difficulty might have been overcome. The mortality of the chicks from machine No. 2 was practically all from the common cause, bowel trouble, etc. The hens that were set in the incubator hatched chickens on the average low in vitality, several of them showing the usual symptoms of white diarrhœa. We have never hatched such chickens, in any year, from hens setting on earth.

From what I observed of the chicks, those hatched from hens setting on moist earth grew the best.

Notes on Table IV.—Moisture Machines vs. Dry Machines.

The results from the 1907 Prairie State machines leave no room for doubt that moisture increases the hatch and the vitality also.

In nearly every other make the results practically point in the same direction. With the 1905 Cyphers the results are not very different, but I would like to try moisture earlier in the season, and in parallel hatches, as was done with the Prairie State machines.

With Prairie State machines, it will be noticed that the moisture machine has less fully formed dead chicks in the shell, it hatches more chickens, a higher per cent. of the fertile eggs, as well as a higher per cent. of the total eggs set.

There is a difference of 10.9 per cent. of the eggs set, or 13.1 per cent. of the fertile eggs in favor of the use of moisture.

If a comparison be made between the two methods of operating as to the percentage of live chicks to the eggs set, we find that all the moist machines average 35.9, or if we eliminate those in which the tarry compound was used we have an average of 32.3, whereas all the dry machines give but 13.4, or eliminating the one in which the tarry compound was used they then average 12.1, or, in other words, 100 eggs hatched in the machine when operated without moisture gave us 12.1 chicks alive at four weeks of age, and 100 eggs hatched in the machine with moisture gave us 30.3 chicks alive at four weeks of age.

Buttermilk used in the moisture pan beneath the eggs appears to add vigor to the chicks. The buttermilk was changed every four or five days in nearly all machines. I cannot account for the heavy mortality in the 1905 Cyphers set May 30th.

With the Cortland incubator, through some accident, the lamp went out. The incubator room had several windows open and a gust of wind may have blown out the lamp. The chicks in this hatch I think were chilled. Buttermilk gives sufficient moisture in nearly all instances to keep the evaporation nearly equal to that of a hen.

Whole milk supplied the moisture but did not increase the hatch or the vitality of the chicks.

When zenoleum was used the vitality was very good.

As compared with buttermilk, one is led to believe that the acid of the buttermilk has some action on the shell or contents, hence a chick higher in vitality is produced.

Notes on Table V.—Machines Washed with a Ten Per Cent. Solution of Zenoleum.

This substance evidently has some beneficial action, the exact nature of which we do not know. The highest mortality, also the lowest, are from dry machines. I would use this substance in every machine set, in preference to anything we have used to date. It has worked satisfactorily on one large poultry farm in New York State.

Notes on Table VI.—Machines in which Lamp Fumes and Carbon Dioxide were Used.

The lamp fumes appear to do no harm from a vitality standpoint, but rather increases vigor.

Lamp fumes do not increase the hatch, but decrease it. I would like to test lamp fumes on many makes of machines at all seasons of the year before venturing to say that they are beneficial.

We had hoped to show better results from the use of carbon dioxide, and I do not consider the result so far as being at all final. We have not yet, to my mind, secured the proper method of application.

Thus far it appears to be a factor in vitality more than in decreasing the fully formed chicks dead in the shell.

The Model Incubator.

The heaviest mortality was from chicks hatched from the eggs set in March. The machine was run dry, and the evaporation was the largest of the season.

Washing the machine with a ten per cent. solution of zenoleum appears to reduce the mortality or increase the vitality. The hatches where the moisture was used are higher than where little or no moisture was used. It is also evident that a large surface of water requires to be exposed in order to check evaporation.

With the hatch of June 24th, the evaporation was not as great as early in the season, owing, I believe, to the interior of the machines being practically saturated with moisture gathered from previous hatches when moisture was used.

Buttermilk used as moisture produces fairly good chickens.

With this machine, as with others, some condition was present late in the season that was absent early in the season, which increased the vigor of the chicks.

Cyphers Incubators.

I have no suggestions or reasons to offer as to why the 1905 machine gave much better results than the 1906 design.

The 1906 hatched better when moisture was used. The method of applying the zenoleum was purely experimental, and led us to believe that zenoleum required to be applied thoroughly before the eggs were put in.

The chicks from the 1905 machine, when it was washed with zenoleum, were good, thrifty birds.

The use of buttermilk in this machine, so far, is not as satisfactory, especially from the vitality view.

The Peerless Incubator.

The introduction of moisture in this machine appears to have been beneficial, there being a higher hatch and fewer fully formed chicks dead in the shell from the eggs set May 11th than from another hatch. The hatch following the one in which moisture was freely used, the evaporation is not as great as in those ran earlier in the season. This, I believe, is due, as in the case of the Model Incubator, to the absorption of water by the interior surface of the hatching chamber and the evaporation of the same in the hatch following.

When the machine was washed with zenoleum the chicks were good healthy fellows.

Buttermilk used as moisture gave very good results.

The vitality was lowest early in the season.

I have no comments to make on any of the machines on this table except the Hearson. The others have not been used a sufficient length of time, and the results so far are very plain in the table.

The Hearson has some up-draft ventilation—not unlike a hen. This may account for its hatching better chickens on the average than any other make.

The use of buttermilk appeared to help the vitality when the machine gave evidence of hatching inferior chicks.

Moisture was used in all hatches, so we cannot say what it would do if run dry.

No record is given of the Chatham incubator. These machines were used largely in the 1906 experiments, and to a somewhat limited extent during the 1907 experiments. They usually worked well as compared to other makes.

TABLE I.—INCUBATOR SERIES No. I. (Machines Nos. 1, 2, 3 and 4 are 1907 Prairie State Incubators.)

Machine.	Date set.	No. of eggs set.	No. of eggs infertile.	No. of fully formed chicks dead in shell.	Hatched.	Percentage hatched of total eggs set.	Percentage hatched of fertile eggs.	Average evaporation of the eggs set.	% of chicks dead at four weeks of age.	Remarks.
No. 1...	March 10	†134	17	21	50	37.3	42.7	15.2	*67.4	No moisture used.
" 3...	" 10	†139	17	17	57	41.0	46.7	9.2	*16	Skim-milk used for moisture; milk was either [sweet or sour.
" 4...	" 10	†132	24	11	66	50.0	61.1	8.4	*15	Water used for moisture.
Hearson	April 3	56	3	8	29	51.7	54.7	12.8	26	Water used for moisture.
No. 1...	" 3	97	10	15	52	53.6	59.7	15.8	100	No moisture used.
" 2...	" 3	97	11	9	53	54.6	61 +	10.5	57.5	Whole milk used for moisture.
" 3...	" 3	97	11	9	58	59.7	67.4	12.0	22.79	Butter milk used for moisture.
" 4...	" 3	97	14	7	63	64.9+	75.9	10.8	67.2	Water used for moisture.
Hearson	" 26	48	6	10	27	56 25	64.3—	13.5	11	Water used in moisture pan.
No. 1...	" 26	71	10	7	45	63.3+	73.7	10.9	55	These machines were washed with mercuric chloride before being set. Water used as moisture.
" 2...	" 26	71	11	7	35	49.3—	58.3	13.9	79	No moisture used.
" 3...	" 26	71	13	5	39	54.9+	67.2+	10.6	55	Whole milk used for moisture.
" 4...	" 26	71	16	8	35	49.3—	63.6	10.1	13	Butter milk used for moisture.
Hearson	May 21	38	5	3	25	65.7+	75.7	10.9	59.3	Water used for moisture.
Mo. 1..	" 21	61	13	9	21	34.4	43.7	9.4	23.5	These machines were washed with a ten per cent. solution of zenoleum. Water used for moisture, also lamp fumes used in hatching chamber.
" 2..	" 21	61	8	9	38	62.2+	71.7	9.4	25.6	Water used for moisture.
" 3..	" 21	61	3	8	36	59 +	62 +	10	26.6	Artificial carbon dioxide and water.
" 4..	" 21	61	8	9	37	60.6	69.8	16.6	28.8	No moisture used.
Climax..	" 21	61	7	6	42	68.8	77.7+	10.4	21.4	Water used for moisture.
Chath'm	" 21	61	5	12	30	49.1+	53.5	12.2	8.0	Washed with zenoleum. Butter milk used for moisture.
Hearson	June 17	19	2	5	9	47.4	52.9	9.6	14.3	Butter milk used for moisture.
Mo. 1.	" 17	44	5	8	24	54.5+	61.5+	11.9	17.6	Lamp fumes in hatching chamber—no moisture used.
" 2..	" 17	44	6	3	26	59 +	68.4+	8.5	15	Washed with zenoleum—whole milk used for moisture.
" 3..	" 17	‡44	6	5	23	52.2+	60.5+	8.3	13 +	Washed with zenoleum, artificial carbon dioxide used, also water for moisture.
" 4..	" 17	44	2	5	24	54.5+	57.1+	9.3	25.5+	Washed with zenoleum and a 5 per cent solution of zenoleum used for moisture.
Climax .	" 17	44	4	11	24	54.5+	60	12.8	25	No moisture used.
Mac. 1..	July 18	68	22	8	19	28.0	43.5	14.7	16.1	Lamp fumes used—no moisture.
" 2.	" 18	68	23	10	22	32.3	48.9	14.5	38.5	No moisture used.
" 3..	" 18	68	23	2	26	38.2	57.8	9.7	15	Artificial carbon dioxide and water used.
" 4..	" 18	68	18	5	31	45.6	62.0	10.1	12.9	Washed with zenoleum—Water used for moisture.
Model..	" 18	68	19	3	32	47.0	65.3	8.3	18.7	Butter milk used for moisture.

*M rta ity or two weeks only. † The eggs used in these machines were laid by the same hen, but not all; in all other machines the same hen's egg is in each machine. ‡ One egg broken.

Table II.—Incubator Series No. II.

Machine.	Date set.	No. of eggs set.	No. of eggs infertile.	No. of fully formed chicks dead in shell.	Hatched.	Percentage hatched of total eggs set.	Percentage hatched of fertile eggs.	Average evaporation of the eggs set.	% of chicks dead at four weeks of age.	Remarks.
1905 Cyphers..	March 18	127	11	23	64	50 +	55.1	16.8	3 weeks only 46	No moisture used,
Open Bottom Prairie State.	" 18	114	15	21	33	28.9+	33.3	13.2	" " 40	2 pans of milk used beneath the egg tray, each pan was 12 in. × 6 in. × 2 in. deep.
Model........	" 18	105	8	13	55	52.3+	56.7	15.7	" " 75	A small pan of water used beneath the egg tray.
Chatham.....	" 18	103	10	16	52	50.5	55.7—	13.8	" " 30	All the machines set this date (April 11) were washed with a ten per cent. solution of zenoleum before setting.
1905 Cyphers..	April 11	83	6	9	47	56 6	61 +	14.7	7.4	No moisture used.
Open Bottom Prairie State.	" 11	83	10	12	27	32.5	37 —	12.6	15.3	A little water used for moisture.
Model	" 11	83	10	11	44	53.3	60 +	12.3	10	The bottom of the machine was dampened several times daily with tepid water.
1905 Cyphers..	May 6	108	18	12	57	52.7+	63.3	17.6	38	No moisture used.
Open Bottom Prairie State.	" 6	108	18	21	41	38 —	45.5+	11.3	41.6	Small pan of milk used in both the top and bottom of the machine.
Model	" 6	108	25	12	61	56.4	73.4	12.17	45	A pan of water nearly the size of the bottom of the machine was used under the egg tray.
Cortland......	" 6	108	20	15	45	41.6	58.4	13.2	58.8	Buttermilk used as moisture.
1905 Cyphers..	May 30	77	12	8	42	56	64.6	9.2	40	Buttermilk used in a pan beneath the egg tray.
Open Bottom Prairie State.	" 30	77	13	6	44	57.7	68.7	13.2	29	A pan of skim milk was used in both the top and bottom of the machine.
Model	" 30	77	13	5	50	64.8	78.1	10.7	21	The large pan was filled with buttermilk and placed under the eggs.
Cortland......	" 30	77	12	8	39	50 +	60	10.7	56	Whole milk used as moisture.
1905 Cyphers..	June 24	66	14	5	32	48.4	61.5	7.0	21.8+	Buttermilk used as moi-ture beneath the egg tray.
Open Bottom Prairie State.	" 24	66	13	8	38	57.5+	71.7—	9.5	25.3+	Whole milk used as moisture.
Model........	" 24	66	15	6	33	50	64.7+	13.3	27.5	Ran dry—no moisture used. The machine, however, was very moist from water absorbed from previous hatched.
Cortland......	" 24	66	18	5	34	51.5	70.8	9.7	23.2	Water used as moisture. This machine was washed with a ten per cent. solution of zenoleum.

Hens vs. Incubators.—Table III, Series III.

How Hatched.	Date Set.

HENS VS. INCUBATORS.—TABLE III, SERIES III.

How Hatched.	Date Set.	Number of eggs set.	Number of eggs infertile.	Number of chicks fully formed dead in the shell.	Number of chicks hatched.	Percentage hatched of the total eggs set.	Percentage hatched of the fertile eggs.	Average evaporation of the eggs.	Percentage of the chicks dead at four wks. of age.
Incubators.									
1906 Cyphers. No moisture used	Mar. 23	233	36	37	62	26.6	31.4	15.3	75
Peerless. No moisture used	"	198	31	21	71	35.9	42.5	15.8	90
1906 Cyphers. Pans of water used large enough to cover nearly one-half of the bottom of the machine	April 16	120	19	14	48	40	47.5	11.3	56.2
Peerless. No moisture used	"	120	19	11	54	45	53.4	15.8	44.4
1906 Cyphers. No moisture used, but the machine was sprinkled with a solution of zenoleum on the 3rd and 6th days of incubation	May 11	183	29	27	71	38.8	46.1	14.2	50.0
Peerless. Pans of buttermilk used in the bottom of the machine	"	183	26	6	116	63.3	73.9	9.1	*27.2
Chatham. Pans of milk used in the bottom of the machine	"	93	12	11	58	62.4	71.6	9.1	*27.2
Continuous. Some moisture used	June 11	142	16	16	73	51.4	58.0	12.2	9.6
Peerless. Washed with a ten per cent. solution of zenoleum	"	142	19	13	74	52.1	60.2	10.6	12.2
Continuous. Some moisture used	July 5	140	23	15	48	34.3	41.0	14.4	14.5
Peerless. No moisture used	"	141	34	14	48	34.1	44.9	14.0	52.1
1907 Prairie State. Moisture pan of water	April 26	12	1	....	11	91.6	100	10.9	See table No. 1.

* A mistake was made in marking these chicks, both machines having the same marks.

Hens vs. Incubators.—Table III, Series III.—*Continued.*

How Hatched.	Date Set.	Number of eggs set.	Number of eggs infertile.	Number of chicks fully formed dead in the shell.	Number of chicks hatched.	Percentage hatched of the total eggs set.	Percentage hatched of the fertile eggs.	Average evaporation of the eggs.	Percentage of the chicks dead at 4 wks. of age.
1907 Prairie State. No moisture used........	April 26	12	2	2	7	58.3	70	13.9	See table No. 1.
1907 Prairie State. Whole milk used in moisture pan..........................	April 26....	12	1	1	9	75.	81.8	10.6	"
1907 Prairie State. Butter-milk used in the moisture pan	April 26	12	1	1	10	83.3	90.9	10.1	"
Hearson Incubator. Water used in moisture pan	April 26	12	..	2	9	75	75	13.5	"
Hen set in wire nest; the nest raised about one foot from the floor of the incubator room	April 26	12	..	1	10	83.3	83.3	14.1	
Hen set on four inches of earth in a box in the incubator room..................	April 26....	12	1	....	11	91.6	100	11.9	16.66
Hen set on four inches of earth in a box in the incubator room..................	April 26	12	1	1	10	83.3	90.9	13.2	
1907 Prairie State. Water used in moisture pan	April 3.....	9	1	1	4	44.4	50	10.8	See table No. 1.
1907 Prairie State. No moisture used	April 3	9	1	1	3	33.3	37.5	15.8	
1907 Prairie State. Whole milk used in moisture pan..........................	April 3	9	2	....	6	66.6	85.7	10.5	
1907 Prairie State. Buttermilk used in moisture pan..........................	April 3	9	1	1	5	55.5	62.5	12	
Hearson Incubator. Water used in moisture pan	April 3	9	1	1	5	55.5	62.5	12.8	
Hen set in wire nest; the nest raised about one foot from the floor of the incubator room	April 3	9	1	....	6	66.6	75	14.2	
Hen set on four inches of earth in a box in									

1907 Prairie State. Whole milk used in moisture pan	April 3	9	2	....	6	66.6	85.7	10.5	
1907 Prairie State. Buttermilk used in moisture pan	April 3	9	1	1	5	55.5	62.5	12	
Hearson Incubator. Water used in moisture pan	April 3	9	1	1	5	55.5	62.5	12.8	
Hen set in wire nest; the nest raised about one foot from the floor of the incubator room	April 3	9	1	....	6	66.6	75	14.2	16.66
Hen set on four inches of earth in a box in the incubator room	April 3	9	2	1	5	55.5	71.4	10.6	
1905 Cyphers. No moisture used	May 6	108	18	12	57	52.7	63.3	17.6	38
Open Bottom Prairie State. Milk used for moisture	May 6	108	18	21	41	38	45.5	11.3	41.6
Model. Moisture pan of water used in the bottom of machine, moisture pan was practically the full size of machine bottom	May 6	108	25	12	61	56.4	73.4	12.17	45
Cortland. Moisture pan filled with buttermilk	May 6	108	20	15	45	41.6	58.4	13.2	58.8
Hens set in rows of boxes in a colony house very little earth used in the nest	May 6	108	18	5	62	57.4	68.8	12.2	9.7
Mach. No. 1. Lamp fumes dry	July 18	68	22	8	19	28.0	43.5	14.7	16.1
Mach. No. 2. Dry, no moisture	July 18	68	23	10	22	32.3	48.9	14.5	38.5
Mach. No. 3. Artificial CO_2, moisture pan	July 18	68	23	2	26	38.2	57.8	9.7	15
Mach. No. 4. Zenoleum and moisture pan	July 18	68	18	5	31	45.6	62.0	10.1	12.9
Model. Buttermilk in pan	July 18	68	19	3	32	47.0	65.3	8.3	18.7
Hens, set in trap nests, in pens Nos. 6 and 7. Some earth in each nest	July 18	68	10	2	26	38.2	44.8	11.3	20
The Continuous Hatcher. Moisture supplied by small tank on outside of machine	July 5	11	1	2	4	36.3	40	14.4	75
Peerless Incubator. No moisture used	July 5	11	1	3	2	18	20	14.0	50

HENS VS. INCUBATORS.—TABLE III, SERIES III.—*Concluded.*

How Hatched.	Date Set.	Number of eggs set.	Number of eggs infertile.	Number of chicks fully formed dead in the shell.	Number of chicks hatched.	Percentage hatched of the total eggs set.	Percentage hatched of the fertile eggs.	Average evaporation of the eggs.	Percentage of the chicks dead at 4 wks. of age.
Hen sitting on four inches of earth in box in incubator room	July 5	11	1	....	8	72.7	80	9.9	12.5
Hen sitting in box in incubator room, no earth in nest	July 5	11	1	....	8	72.7	80	12.9	12.5
Hen sitting in an open bottom incubator, under the eggs was the egg tray and two thickness of burlap that is used in such machines	July 5	11	1	....	8	72.7	80	14.78	37.5
Continuous Hatcher. Moisture supplied by small tank on outside of machine	June 11	12	2	1	4	33.3	40	12.2	25
Peerless Incubator. No moisture used, washed with 10 per cent. solution of zenoleum before eggs were put in.	June 11	12	2	1	6	50	60	10.6	16.6
Hen sitting on earth nest in incubator room	June 11	12	2	1	6	50	60	9.7	16.6
Hen sitting in box in incubator room, no earth in nest	June 11	12	*	2	4	33	36.3	8.9	25
Hen sitting in incubator	June 11	12	2	3	6	50	60	14.3	33
1906 Cyphers Incubator. No moisture used	May 11	12	..	2	5	41.6	41.6	14.2	100
Peerless Incubator. Moisture was supplied by two pans buttermilk; pans were full width of machine, by 1 foot wide and 2 inch deep	May 11	12	1	1	7	58.3	63.6	9.1	100
Chatham. Moisture pan used in bottom of machine	May 11	11	2	1	5	45.4	55.5	9.9	80
Hen on earth nest in incubator room	May 11	12	3	....	9	75.	100	9.5	
Hen in box in incubator room, no earth in nest	May 11	12	..	....	12	100	100	13.5	
Hen sitting in incubator	May 11	12	1	2	9	75	81.8	14.7	

* 1 infertile, 2 eggs broken 1st week.

TABLE NO. IV.—MOISTURE VS. DRY MACHINES.

	ggs Set.	Infertile	lly formed in Shell.	Chicks	atched	latched of	oration of	f Chicks weeks of	f Chicks weeks of l eggs set.

Chatham. Moisture pan used in bottom of machine	May 11	11	2	1	5	45.4	55.5	9.9	80
Hen on earth nest in incubator room	May 11	12	3	....	9	75.	100	9.5	
Hen in box in incubator room, no earth in nest	May 11	12	..	....	12	100	100	13.5	
Hen sitting in incubator	May 11	12	1	2	9	75	81.8	14.7	

* 1 infertile. 2 eggs broken 1st week.

TABLE No. IV.—MOISTURE VS. DRY MACHINES.

1907 Prairie State.	Date Set.	Number of Eggs Set.	Number of Infertile Eggs.	Number of fully formed Chicks dead in Shell.	Number of Chicks Hatched.	Percentage Hatched of Total Set.	Percentage Hatched of Fertile Eggs.	Average Evaporation of the Eggs.	Percentage of Chicks dead at four weeks of age.	Percentage of Chicks alive at four weeks of age to the total eggs set.
Water Used in Moisture Pan.										
Machine No. 4	Mar. 10	132	24	11	66	50	61.1	8.4	15	42.5
" " 4	Apr. 3	97	14	7	63	64.3	75.9	10.8	67.2	21.3
" " 1	Apr. 26	71	10	7	45	63.3	73.7	10.9	55	28.5
* " " 2	May 21	61	8	9	38	62.2	71.7	9.4	25.6	46.3
* " " 4	June 17	44	2	5	24	54.5	57.1	9.3	25.5	40.6
* " " 4	July 18	68	18	5	31	45.6	62.0	10.1	12.9	39.7
Totals		473	76	44	267	56.3	67.2	9.8		
No Moisture Used.										
Machine No 1	Mar. 10	134	17	21	50	37.3	42.7	15.2	67.4	12.2
" " 1	Apr. 3	97	10	15	52	53.6	59.7	15.8	100	......
" " 2	Apr. 26	71	11	7	35	49.3	58.3	13.9	79	10.4
* " " 4	May 21	61	8	9	37	60.6	69.8	16.6	28.8	43.1
" " 2	July 18	68	23	10	22	32.3	48.9	14.5	38.5	19.9
Totals		431	69	62	196	45.4	54.1	15.2		
Machines in which Buttermilk was used in the Moisture Pan.										
No. 3 Prairie State	Apr. 3	97	11	9	58	59.7	67.4	12	22.79	46.1
No. 4 Prairie State	Apr. 26	71	16	8	35	49.3	63.6	10.1	13	46.2

TABLE No. IV.—MOISTURE VS. DRY MACHINES.—*Concluded.*

1907 Prairie State.	Date Set.	Number of Eggs Set.	Number of Infertile Eggs.	Number of fully formed Chicks dead in Shell.	Number of Chicks Hatched.	Percentage Hatched of Total Set.	Percentage Hatched of Fertile Eggs.	Average Evaporation of the Eggs.	Percentage of Chicks dead at four weeks of age.	Percentage of Chicks alive at four weeks of age to the Total Eggs Set.
Machines in which Buttermilk was used in the Moisture Pan.										
Hearson	June 17	19	2	5	9	47.4	52.9	9.6	14.3	40.6
Peerless	May 11	183	26	6	116	63.3	73.9	9.1	27.2	45.6
Chatham	May 11	93	12	11	58	62.4	71.6	9.1	27.2	45.6
†Cortland	May 6	108	20	15	45	41.6	58.4	13.2	58.8	17.2
1905 Cyphers	May 30	77	12	8	42	56	64.6	9.2	40	33.6
Model	May 30	77	13	5	50	64.8	78.1	10.7	21	51.2
1905 Cyphers	June 24	66	14	5	32	48.4	61.5	7	21.8	37.8
Model	July 18	68	19	3	32	47	65.3	8.3	18.7	38.2
Machines in which whole Milk was used in the Moisture Pans.										
No. 2, 1907 Prairie State	Apr. 3	97	11	9	53	54.6	61	10.5	57.5	23.2
No. 3, 1907 Prairie State	Apr. 26	71	13	5	39	54.9	67.2	10.6	55	24.7
*No. 2, 1907 Prairie State	June 17	44	6	3	26	59	68.4	8.5	15+	50.2
Cortland	May 30	77	12	8	39	50	60	10.7	56	22

*These machines were washed with a 10% solution of zenoleum.

†Lamp went out when chicks were hatching.

TABLE No. V.—INCUBATOR WASHED WITH TEN PER CENT. SOLUTION OF ZENOLEUM.

*These machines were washed with a 10% solution of zenoleum.

†Lamp went out when chicks were hatching.

TABLE No. V.—INCUBATOR WASHED WITH TEN PER CENT. SOLUTION OF ZENOLEUM.

Name of Machine.	Date Set.	Number of Eggs Set.	Number of Infertile Eggs.	Number of fully formed Chicks dead in Shell.	Number of Chicks Hatched.	Percentage Hatched of Total Eggs Set.	Percentage Hatched of Fertile Eggs.	Average Evaporation of the Eggs.	Percentage of Chicks dead at four weeks of age.	Percentage of Chicks alive at four weeks of age to the total eggs set.	Remarks.
1905 Cyphers	Apr. 11	83	6	9	47	56.6	61	14.7	7.4	52.4	Run dry.
Open Bottom Prairie State	Apr. 11	83	10	12	27	32.5	37	12.6	15.3	27.5	Some milk and water used.
Model	Apr. 11	83	10	11	44	53.3	60	12.3	10	48	Some milk and water used.
Cortland	June 24	66	18	5	34	51.5	70.8	9.7	23.2	39.6	Moisture used.
Open Bottom Prairie State	June 24	66	13	8	38	57.5	71.7	9.5	25.3	42.9	Whole milk used for moisture.
No. 1, 1907 Prairie State	May 21	61	13	9	21	34.4	43.7	9.4	23.5	26.4	Lamp fume-water used for moisture.
No. 2, 1907 Prairie State	May 21	61	8	9	38	62.2	71.7	9.4	25.6	46.3	Water used for moisture.
No. 4, 1907 " "	May 21	61	8	9	37	60.6	69.8	16.6	28.8	43.1	Dry.
No. 2, 1907 " "	June 17	44	6	3	26	59	68.4	8.5	15	50.2	Whole milk for moisture.
No. 3, 1907 " "	June 17	44	6	5	23	52.2	60.5	8.3	13	45.4	Carbon dioxide, also water, for moisture.
No. 4, 1907 " "	June 17	44	2	5	24	54.5	57.1	9.3	25.5	40.6	5 per cent. zenoleum used in water for moisture.
No. 4, 1907 " "	July 18	68	18	5	31	45.6	62.0	10.1	12.9	39.7	Water used for moisture.
Chatham	May 21	61	5	12	30	49.1	53.5	12.2	8.0	45.9	Buttermilk for moisture.
Peerless	June 11	142	19	13	74	52.1	60.2	10.6	12.2	45.7	Dry.

TABLE VI.

How operated.	Date set.	No. of eggs set.	No. of infertile eggs.	No. of fully formed chicks dead in shell.	No. of chicks hatched.	Percentage hatched of total eggs set.	Percentage hatched of fertile eggs.	Average evaporation of the eggs.	Percentage of chicks dead at 4 weeks of age.	Percentage of chicks alive at 4 weeks of age to the total eggs set.
Machines into which the lamp fumes were forced.										
No. 1. Moisture used..	May 21	61	13	9	21	34.4	43.7	9.4	23.5	26.2
" 1. " " ..	June 17	44	5	8	24	54.5	61.5	11.9	17.6	44.9
" 1. " " ..	July 18	68	22	8	19	28.	43.5	14.7	16.1	23.9
Machines in which carbon dioxide was used.										
No. 3. Moisture used..	May 21	61	3	8	36	59. +	62. +	10.	26.6	43.3
" 3. " " ..	June 17	44	6	5	23	52.2	60.5	8.3	13 +	45.4
" 3. " " ..	July 18	68	23	2	26	38.2	57.8	9.7	15.	32.5
The Model Incubator.										
One small pan of water was used under the egg tray............	Mar. 18	105	8	13	55	52.3+	56.7	15.7	75.	13.1
*The bottom of the machine was wet with tepid water several times daily sufficient to keep cloths wet...	April 11	83	10	11	44	53.3	60.	12.3	10.	48.0
A large pan of water about 1 in. deep covered practically the entire space below the egg tray.....	May 6	108	25	12	61	56.4	73.4	12.17	45.	31.
The large pan was filled with buttermilk and used beneath the tray as in the previous hatch.........	May 30	77	13	5	50	64.8	78.1	10.7	10.7	51.2
No moisture used.....	June 24	66	15	6	33	50.	64.7	13.3	27.5	36.3
The large pan was filled with buttermilk and used beneath the egg tray............	July 18	68	19	3	32	47.	65.3	8.3	18 7	38.2
1906 Cyphers Incubator.										

the entire space below the egg tray.....	May 6	108	25	12	61	56.4	73.4	12.17	45.	31.
The large pan was filled with buttermilk and used beneath the tray as in the previous batch.........	May 30	77	13	5	50	64.8	78.1	10.7	10.7	51.2
No moisture used.....	June 24	66	15	6	33	50.	64.7	13.3	27.5	36.3
The large pan was filled with buttermilk and used beneath the egg tray............	July 18	68	19	3	32	47.	65.3	8.3	18 7	38.2
1906 Cyphers Incubator. 240 egg capacity.										
No moisture used.....	Mar. 23	233	36	37	62	26.6	31.4	15.3	75.	6.6
Bottom of machine was dampened with zenoleum on the third and sixth days of incubation..	May 11	183	29	27	71	38.8	46.1	14.2	50.	19.4
Two pans of moisture in the bottom of machine. Pans would cover about one half of the bottom.......	April 16	120	19	14	48	40.	47.5	11.3	56.2	17.5
1905 Cyphers Incubator. 120 egg capacity.										
No moisture used.....	Mar. 18	127	11	23	64	50. +	55.1	16.8	46.	27.
†No moisture used....	April 11	83	6	9	47	56.6	61.	14.7	7.4	52.4
No moisture used.....	May 6	108	18	12	57	52.7	63.3	17.6	38.	32.7
A pan of buttermilk with starter used under the egg tray.	May 30	77	12	8	42	56.	64.6	9.2	40	33.6
A pan of buttermilk was used............	June 24	66	14	5	32	48.4	61.5	7.	21.8	37.8
Peerless Incubator.										
No moisture used.....	Mar. 23	198	31	21	71	35.9	42.5	15.8	90.	3.6
No moisture used.....	April 16	120	19	11	54	45.	53.4	15.8	44.4	25.0
No moisture used.....	July 5	141	34	14	48	34.1	44.9	14 0	52.1	16.3
*No moisture used....	June 11	142	19	13	74	52.1	60.2	10.6	12.2	45.7
Pan of buttermilk covering nearly three-fourths of the surface under the eggs......	May 11	183	26	6	116	63.3	73.9	9.1+	27.2	45.6

*Washed with a ten per cent. solution of zenoleum. †Washed with zenoleum.

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TABLE VI.—*Continued.*

How operated.	Date set.	No. of eggs set.	No. of infertile eggs.	No of fully formed chicks dead in shell.	No. of chicks hatched.	Percentage hatched of total eggs set.	Percentage hatched of fertile eggs.	Average evaporation of the eggs.	Percentage of chicks dead at 4 weeks of age.	Percentage of chicks alive at 4 weeks of age to the total eggs set.
The Climax Incubator.										
Moisture used in bottom of machine	May 21	61	7	6	42	68.8	77.7	10.4	21.4	54.
No moisture used	June 17	44	4	11	24	54.5	60.	12.8	25.	40.9
The Cortland Incubator.										
‡Moisture pan filled with buttermilk	May 6	108	20	15	45	41.6	58.4	13.2	58.8	17.2
Moisture pan filled with whole milk	May 30	77	12	8	39	50.	60.	10.7	56.	22.
†Water used in moisture pan	June 24	66	18	5	34	51.5	70.8	9.7	23.2	39.6
The Continuous Hatcher										
A little moisture used	June 11	142	16	16	73	51.4	58.0	12.2	9.6	46.5
A little moisture used	July 5	140	23	15	48	34.3	41.	14.4	14.5	29.3
The Hearson Incubator.										
Moisture used	April 26	48	6	10	27	56.25	64.3	13.5	11.	50.
Moisture used	May 21	38	5	3	25	65.7	75.7	10.9	59.3	26.7
Buttermilk used as moisture	June 17	19	2	5	9	47.4	52.9	9.6	14.3	40.6
Moisture used	April 3	56	3	8	29	51.7	54.7	12.8	26.	38.3

‡ Lamp went out when hatching from unknown cause. Eggs were cold—chicks chilled. † Washed with zenoleum.

TABLE VII. A COMPARISON OF METHODS OF HATCHING.

How Treated.	No. of eggs set.	Per cent. of infertile eggs.	Per cent. of fully formed dead in shell.	Per cent. hatched of total eggs set.	Per cent. of chicks dead at 4 weeks of age.	Live chicks at 4 weeks in % of the eggs set.	No. of hatches.
HENS.							
Earth nests	23	13.1	4.3	60.9	14.3	52.2	2
Straw "	23	8.7	8.7	52.2	16.6	43.5	2
Ventilated nests	23	13.1	13.1	60.8	35.7	39.1	2
Roomy "	123	10.6	7.3	66.6	20.7	52.8	11
Crowded "	176	15.9	4.0	50.0	12.5	43.7	16
All Hens	299	13.7	5.4	56.9	16.5	47.5	27
INCUBATORS.							
Buttermilk and zenoleum	61	8.2	19.7	49.1	8.0	45.9	1
Whole milk and "	110	17.3	10.0	58.2	21.8	45.5	2
Water, carbon dioxide and zenoleum	44	13.6	11.3	52.2	13.0	45.4	1
Water and zenoleum	464	16.1	11.4	52.8	16.7	44.0	6
Buttermilk	583	18.3	10.0	52.0	28.0	37.4	8
Water and carbon dioxide	129	20.1	7.8	48.1	22.5	37.2	2
Water only	1,221	13.9	11.3	51.9	37.0	32.7	13
Lamp fumes dry	112	24.1	14.3	38.4	16.3	32.1	2
Zenoleum dry	327	13.1	13.7	47.4	32.2	32.1	3
Skim-milk	330	13.6	13.0	40.6	26.1	30.0	3
Water, milk and zenoleum	83	12.0	14.5	32.5	15.3	27.5	1
Lamp fumes, water and zenoleum	61	21.3	14.7	34.4	23.5	26.2	1
Whole milk	353	15.3	12.2	48.7	52.3	23.2	4
Dry or no treatment	1,406	16.3	12.6	40.7	60.5	16.1	12

MATTERS IN GENERAL.

The eggs purchased from outside sources, which includes large poultry farms and the ordinary farm flock, did not hatch chickens any better than our own. When our chickens died when hatched in certain incubators, the others died also. We received no eggs from any source that were free or anywhere nearly free of the bowel trouble, etc.

We have not included the eggs from outside source in our tables for hatches, because we failed to get a division of any lot that was uniform as to fertility, etc., and I believe that exact experimental work with incubators can not be done unless the same hens' eggs are used in each machine.

Some tests were made of putting the eggs under hens for one week and then removing them to an incubator to finish hatching. Eggs were also started in incubators for one and two weeks, and then finished under hens. We also took eggs from the machines on the nineteenth day of

‡ Lamp went out when hatching from unknown cause. Eggs were cold—chicks chilled. † Washed with zenoleum.

incubation, and finished hatching with hens. Where eggs were finished under hens from the nineteenth day of incubation, no improvement was seen in the chickens. This was tried several times from several machines.

Eggs incubated one week under hens and finished by incubators gave fairly good chicks, but eggs started in incubators for a week and finished by the hen show practically no improvement over the eggs hatched for the whole period in the machine.

This work appeared to indicate that the first portion of the hatch is a very critical time, and every care should be given at this period.

TABLE VIII.

Where Hatched.	Artificial Brooding.		Natural Brooding.	
	Number of chicks brooded.	Number of chicks that died.	Number of chicks brooded.	Number of chicks that died.
1905 Cyphers	29	6	36	8
Open Bottom Prairie State	24	5	5	0
Model	20	7	30	7
Cortland	17	7	34	18
Hens	17	0	46	5
Totals	107	25	151	38
Percentage dead in two weeks' brooding		21.5		25
No. 1, 1907 Prairie State	20	2	14	4
,, 2, " " "	20	3	20	3
,, 3, " " "	22	2	24	4
" 4, " " "	25	3	18	8
Climax	20	3	16	6
Hearson	3	0	11	2
Totals	110	13	103	27
Percentage dead in four weeks' brooding		11.8		26.2

Prairie State Brooders used in each test.

Humidity in Relation to Incubation.

By Wm. H. Day, Lecturer in Physics.

In the preceding portion of this Bulletin Mr. W. R. Graham has outlined many practical experiments that have been carried on by the Poultry department during the seasons of 1906 and 1907. For those who wish to follow this station further in its endeavors to discover the scientific laws that influence incubation, the following pages are written. We are conscious of the fact that our readers may include all classes of persons from the practical poultryman to the advanced scientist. To the former we would say at the outset: It is primarily in your interests that we investigate these problems and publish our results, hence we feel bound in so far as possible to make even the scientific side of our work intelligible to you; and hence we shall endeavor throughout to present scientific methods and truths in popular form and language.

Some time ago a series of circumstances, which need not be related here, led the department of Physics to enter upon a study of the evaporation of water from soil and from plants, and this broadened out into a study of evaporation in general. This in turn involved a study of the moisture of the atmosphere. Now the Latin word for "moist" is *humidus*, hence instead of "moisture of the atmosphere" we may say "humidity." Since we were interested in the subject, Mr. Graham asked us to co-operate with him in a study of the humidity in incubators; for opinion as to the desirability of moisture during incubation was sharply divided, some holding strongly that it was detrimental, that the chicks were often "drowned in the shell," others holding just as firmly the contrary view that moisture was highly beneficial. Before entering in detail into our investigations on the subject it may be well for the sake of our practical readers to give a brief review of the methods by which a knowledge of humidity is gained, believing that such a review will lead to a better understanding of the subject, "Humidity in Relation to Incubation."

Determining the Amount of Moisture in the Air.

Years ago little was known of the amount of moisture in the air. But as science advanced and the influence of the humidity of the air upon all life was realized, a fuller knowledge of the subject became desirable. It was known that certain acids and salts had a great affinity for water, and so the idea was suggested that if air were drawn through these substances it would be deprived of the water contained in it, the substances gaining in weight by the amount of water absorbed. Investigation proved that two or three drying tubes, in series, were sufficient to absorb *all* the moisture from air being drawn through. Figure No. 1 shows the apparatus evolved for the purpose.

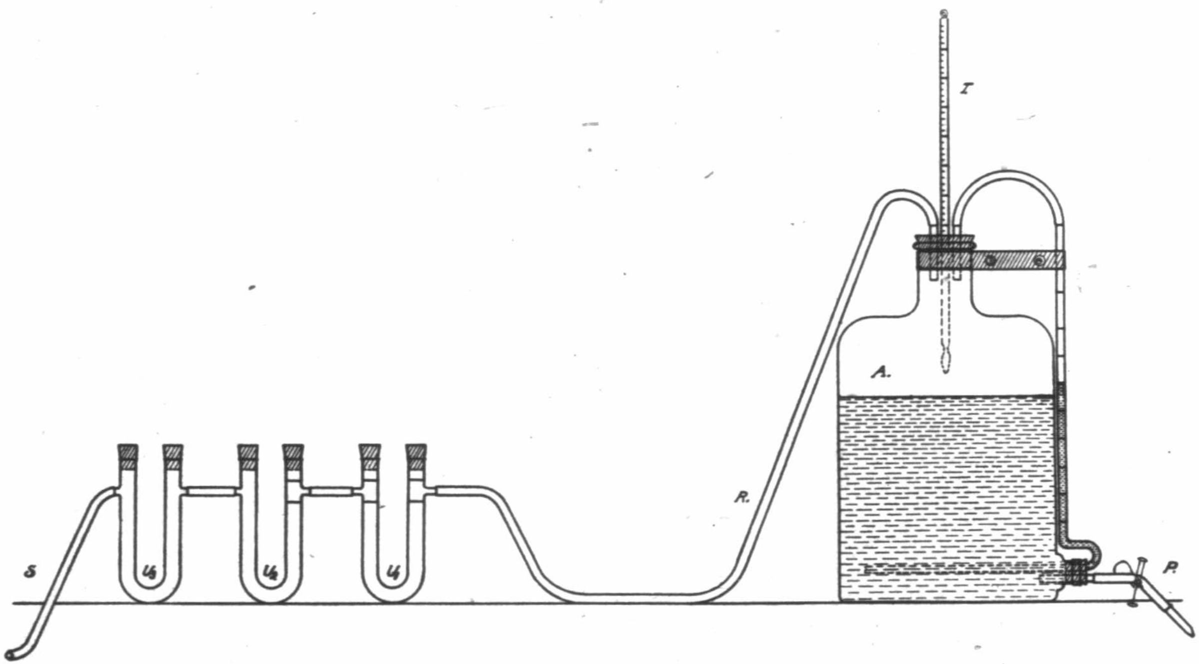

Fig. I. Apparatus used in determining the humidity of the air by the absolute method. U_1 contains fused calcium chloride; U_2 Anhydrous copper sulphate; U_3 concentrated sulphuric acid with pumice-stone. A, is a graduated water-bottle. R, a long pliable rubber tube. S, a short pliable rubber tube which may be inserted under hen or into incubator.

A is a large water-bottle, filled with water, and so graduated that a measured quantity may be drawn from it when the pinch-cock P is released. A thermometer T is inserted in the bottle. A rubber tube R joins A with a series of U tubes. U_1 contains calcium chloride freshly fused, so that all the water of crystallization is driven off; U_2 contains copper sulphate similarly treated; U_3 contains pumice stone and concentrated sulphuric acid. S is a short pliable rubber tube which may be inserted into an incubator or under a hen as desired. For convenience U_1, U_2 and U_3 are mounted on one small base so that they may be weighed. When a determination of the moisture in the air is desired, the U tubes are detached from the bottle, weighed, and then attached again. A measured quantity of water is let run from A, but as it does so the same volume of *air* must enter A, having first passed through U_3, U_2 and U_1 in succession. The U's are then detached and weighed again. The gain in weight gives the amount of water contained in the air drawn through. The weight of water in unit volume of air is sometimes called the "absolute humidity," and this method of determining the moisture content, an "absolute" method.

Investigations with apparatus such as illustrated in Fig. 1 soon showed a great variation in the moisture content of the air, even at a uniform temperature, also that for each temperature there was a limit—the air could contain a certain amount and no more. When it contained all it was capable of holding it was said to be "*saturated*," or to contain its "saturation amount" of moisture. It was also learned that the saturation amount varied with the temperature, the higher the temperature the greater the amount of moisture required to saturate the air. Saturation occurs during rain, mist, or fog; also near the ground when dew is falling. At 32° a room 10 feet long, 10 feet wide and 10 feet high is capable of holding in the air when saturated 5 ounces of water. At 70° it would hold 1 lb. 2 oz. when saturated, or nearly four times as much as at 32°. At 100° it would hold 2 lbs. 11 oz., which is more than twice as much as at 70°, and more than eight times as much as at 32°.

Relative Humidity, or "Humidity," as it is Usually Called.

The air, however, is seldom saturated, only at times of rain, mist, fog, dew, snow, or some kindred phenomenon. At all other times it has less than its "saturation amount," and if we wish to convey an idea of the amount of moisture in the air at any time, we use the saturation amount as the standard of comparison, e.g., at 70° the saturation amount for a room 10 x 10 x 10 feet is 1 lb. 2 oz., or 18 oz., but if by use of the apparatus shown in Fig. 1 we were to find that the room at 70° contained only 9 oz., we would say that the air contained only *half* as much moisture as it was capable of holding, or that its *relative humidity* was 50 per cent. Thus at any particular time we may state the humidity of a room in two ways: (1) by giving the actual amount of moisture per unit volume, e.g.,

Fig. I. Apparatus used in determining the humidity of the air by the absolute method. U_1 contains fused calcium chloride; U_2 Anhydrous copper sulphate; U_3 concentrated sulphuric acid with pumice-stone. A, is a graduated water-bottle. R, a long pliable rubber tube. S, a short pliable rubber tube which may be inserted under hen or into incubator.

9 oz. per 1,000 cu. ft.—the "absolute humidity;" (2) by comparing the "absolute" with saturation, e.g., $^{9}/_{18}$ or 50 per cent.—the "relative humidity." Of these the latter is the more useful. In the economy of nature evaporation plays a very important part. If evaporation from the ground is too rapid, the soil becomes parched and unfit for sustaining the plants growing upon it; if evaporation from the plants is too rapid, they wilt; if evaporation from our bodies is too rapid, we are conscious of feverish distress, while on the other hand if it is too slow, the air is oppressive and the perspiration, instead of evaporating, stands out in beads. These various phenomena are controlled by the *relative* humidity, not by the absolute. If the air has a low relative humidity the evaporation will be fast, but if a high relative humidity, it will be slow. Hence the "relative" humidity at any time furnishes us with much more valuable information than the "absolute." In general practice the word "humidity" is used alone to stand for "relative humidity," and will frequently be so used in the following pages.

The Wet- and Dry-Bulb Thermometers.

But the absolute method of determining the relative humidity is very laborious and very exacting—one dare not even *breathe* on the U tubes, for the moisture that would condense on them from the breath would spoil the determination entirely in many cases (a fact which we learned by bitter experience), and it could only be employed where delicate balances were available; hence if humidity determinations were to have any extended application, some simpler method had to be evolved.

Now evaporation has a cooling effect, as any one may prove by the aid of two thermometers which read the same when dry. Wet the bulb of one with water as warm as the room and hold them side by side. In a very few moments the wet one will read several degrees lower than the dry one. This is explained by the fact that heat is used up in turning water into vapor, a familiar illustration of which is to be found in the kettle heating on the stove. The water becomes warmer and warmer until at last it begins to boil. Despite the fact that heat still passes into it the temperature remains at boiling point; the heat is absorbed in turning the water into vapor. The heat thus used it called *latent* heat, because it produces no change of temperature. It takes 5.38 times as much heat to vaporize the water as to heat it from freezing to boiling. Now whenever vaporization of water takes place this same latent heat is absorbed. If there is no fire to provide it then it must come from the evaporating water, the air, and surrounding objects. At first, the evaporating water on the wet thermometer draws most of its latent heat from the thermometer itself, hence the temperature is lowered. The faster the evaporation the greater amount of latent heat required in a given time, and hence the greater the reduction in temperature. But the rapidity of evaporation is controlled by the relative humidity of the air; the lower the humidity the more rapid the evaporation, the higher the humidity the slower the evaporation. Hence the cooling produced on the wet thermometer is an inverse measure of the humidity.

As soon as these facts were correlated in this manner a secondary but simple method of determining humidity was at hand. A large number of determinations by some absolute method was made, and the results tabulated, and at the same time wet- and dry-bulb readings were taken and set down in the same tables opposite the corresponding humidities. When sufficient readings had been taken a law was established by which the humidities and wet- and dry-bulb readings for intermediate temperatures could be interpolated and the tables completed. When this had been done humidity determinations became easy: it was only necessary to take the wet- and dry-bulb readings and then refer to the tables for the humidity, which had previously been determined.

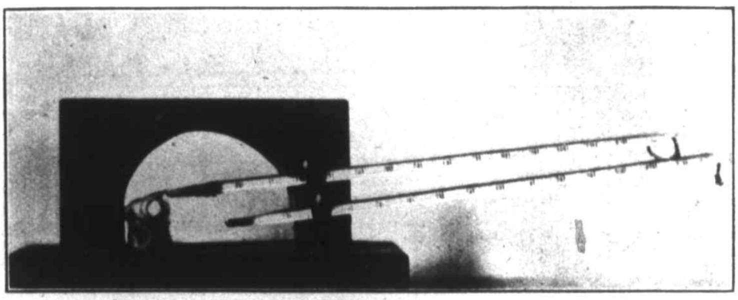

Fig. 2—Hygrometer used in incubators during 1906. In 1907 two holes were bored through the door frame of each incubator and long wet and dry bulbs inserted. This was found to be more satisfactory as it left the egg tray free, and the condition of the thermometer was always known, no trouble with filling the bottle and easier to read.

In order that the wet bulb may be continually kept moist, it is provided with a close-fitting linen sack to which is attached some candlewick which dips into a small cup or bottle of water—the water travels up the wick to the sack as the oil ascends a lampwick.

Perhaps it should be mentioned that in making humidity tables as above described the wet bulb was gently fanned to dissipate the vapor being given off by it; for if this were not done, and the air were very stagnant, that lying close around the wet bulb would become highly vapor-charged, and the humidity determined would really be representative of only that small amount of highly charged air, not of the air generally.

HUMIDITY IN INCUBATORS.

When Mr. Graham invited us to assist in his investigations, the object was to study the humidity in incubators, for we did not then think of being able to determine the humidity in the hen's nest. The method we laid down for ourselves was: (1) To determine the humidity in incubators as ordinarily run; (2) to run incubators at various humidities, note the results, and thus determine whether humidity affects the hatch, and if so to learn the most desirable amount of moisture for the production of large hatches of strong chicks. For this work it was necessary to have a wet and dry bulb so mounted that they could be set in the incubators. Fig. 2 shows the form used.

At the outset it was thought wise also to rig up each incubator with a small motor fan which could be run to fan the wet bulb in order to arrive at the proper humidity in case the incubator air should be so stagnant as to give a false reading without fanning. Fig. 3 shows the hygrometer (wet and dry bulb) together with fan and battery to run it.

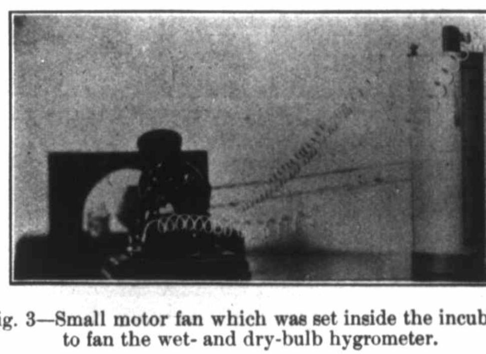

Fig. 3—Small motor fan which was set inside the incubator to fan the wet- and dry-bulb hygrometer.

Testing this apparatus in the room, we learned that at middle humidities fanning makes practically no difference in the readings, but at high or low humidities it makes a great deal. In the incubators fanning always made a great difference, giving much lower readings than without fanning, showing incidentally that the circulation of the incubators is not equal in effect to free diffusion in the room. The use of the fan in the incubator had one defect, however: it disturbed the normal conditions whenever a reading was taken, stirring up the warm and cold layers and almost invariably raising the temperature near the eggs for the moment and thus giving a humidity somewhat too low. Table No. IX. contains a record of the hatches run during the season of 1906.

TABLE IX.—HUMIDITY, EVAPORATION, CO_2, AND HATCH OF INCUBATORS.

Incubator.	When set.	How Run.	Humidity of Room.	Humidity of Incubator.		Per cent. Evaporation from Eggs.	CO_2 in 10,000 Parts.	Per Cent. Hatched.	
				With Fanning.	Without Fanning.			Of Fertile Eggs.	Of Total Set.
Chatham 5	June 25	Dry fanned, day	62.9	40.5	....	11.0	....	....	....
	July 20	"	66.2	38.5	....	12.5	8.9(3)	* 61.5	*53.3
	Aug. 20	Moisture in bottom	51.8	62.4	76.1	11.1	....	* 85.7	*80.0
								† 76.3	†61.0
Chatham 6	June 25	Dry	62.9	37.4	....	9.1	....	....	....
"	July 18	"	62.3	41.0	47.2(7)	14.6	8.1(2)	....	....
"	Aug. 12	"	68.1	40.7	51.2(8)	14.8	6.5(3)	* 78.6	*73.0
								† 65.0	†47.0
—Chatham	July 20	Dry	66.2	34.6	....	15.8	9.3(3)		
Chatham 4	July 20	"	66.2	37.3	51.0	14.6	7.8(2)	....	....
"	Aug. 20	Moisture on top	51.8	60.3	71.7	14.0	....	* 71.4	*66.7
								† 71.0	†57.0
New Prairie State	Aug. 7	Moisture in bottom	69.3	58.9 (3)	76.6	9.2	3.3(no eggs)	* 72.0	*53.0
							7.3(10)	† 68.0	†50.0
" " "	Sept.	" " "	....	....	....	9.1	7.3(9)	* 65.4	*56.6
								† 70.0	†61.0
Old Prairie State	July 17	Dry	62.3	33.9	....	15.8	6.7(2)	....	....
" "	Aug. 12	"	68.1	33.0	42.3(12)	15.3	5.6(3)	* 69.0	*60.0
								† 65.0	†45.7
Cyphers, Chas. A	July 17	Dry	62.3	35.9	44.8(6)	16.6		....	....
Model	Aug. 12	"	68.1	37.4	50.4(12)	16.7	5.4(4)	* 78.0	*68.0
								† 70.0	†48.0
Dry Machines	Averages	....	65.1	39.0	47.6	14.6	....	* 71.8	*63.6
								† 66.7	†46.9
							7.3	* 73.6	*64.1
Wet Machines	Averages	....	57.6	60.5	74.8	11.4	....	† 71.3	†57.3
Chatham 2	....	....	....	....	....	....	3.2(no eggs)		
Front Room	....	....	....	....	....	....	3.3		
Incubator Room	....	....	....	....	....	....	4.6, hens's level		
" "	....	....	....	....	....	....	2.8, machine level		

* Selected † Shuffled.

It will be observed that the humidity of the dry machines varies within narrow limits, likewise that of the wet machines, but there is a great difference between the former as a class and the latter, the relative humidity of the latter being about one-half higher than that of the former.

Relative Humidity under Hens.

We had not proceeded very far, however, when we became convinced that if our work was to have its greatest value, we must learn the conditions existing in the hen's nest. To determine the humidity in the nest, we devised the hygrometer shown in Fig. 4 (see page 39). It consists of an egg of brass strainer gauze held in shape by two perforated discs, and fitted with two tin tubes through which the wet- and dry-bulb thermometers could be inserted. To determine the humidity in the nest the "egg" was to be inserted beneath the hen, the thermometers projecting so that the readings could be taken. But I feared the vapor from the wet bulb would saturate the air under the hen. To learn if this were possible it was necessary to know the volume of air among the eggs in the nest, the amount of vapor that air was capable of holding at 100° (the temperature of the nest) and the amount of water on the sack of the wet bulb. If the latter amount was equal to or greater than the former then it would be *possible,* other conditions favoring, for the egg hygrometer to saturate the air in the nest. To gain some idea of the quantity of air in the nest a circular, flat-bottomed dish, with upright sides, was procured which just held 13 eggs in one layer. Water was poured in till the eggs were *just* covered. It took 42.5 cubic inches. This represents the air space between the eggs. Then of course something had to be allowed for the extra air space caused by the presence of the hen's legs and breast between the eggs. We thought that 17.5 cubic inches would be sufficient, making a total of 42.5 plus 17.5, or 60 cubic inches. Turning up our humidity tables we found that 1 cubic foot of air at 100° was capable of holding 19.8 grains, whence by calculation 60 cubic inches would hold .68 grains, or almost exactly two-thirds of a grain. Then weighing the thermometer before and after wetting, we found that the sack absorbed 1.27 grains, or nearly twice the saturation amount for the air in the nest. Hence if the vapor from the wet bulb were not dissipated too rapidly it should saturate the nest air. In proof of this argument the hygrometer was placed in a rubber-stoppered bottle containing incidentally just half as much air as the nest, the thermometers projecting through holes in the stopper. In three hours' time the humidity had risen from 62.9 to 95.2 per cent., pretty close to saturation, and *the sack was still thoroughly wet.*

Knowing thus the behavior of the hygrometer in a closed-up stagnant air, we next placed it under a hen. Would it saturate the air there? Here are the readings and remarks:

TABLE X. EGG HYGROMETER IN BOTTLE CONTAINING AIR.

Time in bottle.	Humidity in Bottle.	Humidity of Room.
0 minutes	62.9	62.9
5 "	85.6	
10 "	87.9	
20 "	90.2	
40 "	92.7	
3 hours	95.2	

TABLE XI. EGG HYGROMETER UNDER BUFF ORPINGTON ON STRAW NEST.

Time.	Nest Temperature.	Humidity in nest.	Humidity of Room.
0 minutes	....	....	46.0
5 "	98.75	70.6	
10 "	101.25	69.7	
15 "	101.75	69.8	
20 "	102.0	69.9	
30 "	102.0	71.5 (?)	
	Gauze becoming dry.	Gauze wetted afresh.	
40 "	102.25	70.0	
50 "	102.0	71.0	
60 "	100.5	69.6	
70 "	100.5	68.1	
80 "	100.0	64.4 (?)	
	Gauze wetted afresh.		
90 "	99.5	69.3	
100 "	100.5	74.7	
110 "	100.5	72.6	
		Average 70.1	

During two hours the sack became dry twice and almost dry again, enough water having thus evaporated to saturate the nest air six times over. Yet the humidity was practically constant from the very first reading! Very different from the behavior in the bottle. Hence we concluded it was impossible for the hygrometer to saturate the nest air. The vapor must be passing from the nest quite rapidly.

But the clearing away of one objection raised another: since so much vapor is being dissipated, it is possible the close-meshed wire gauze is hindering free diffusion, thus to a certain extent bottling up the vapor around the thermometer. If so the humidity in the "egg" does not represent that in the nest generally. Before this objection could be satisfactorily answered it was necessary to begin the humidity determinations under the hens already set. The results are shown in the following table:

TABLE XII.—HUMIDITY, EVAPORATION, CO_2, AND HATCH OF HENS.

Hens.	When Set.	Nest.	Humidity of air near hens.	Humidity in Nest.		Per cent. evaporation from eggs.	CO_2 in 10,000 parts.	Per cent. Hatched.	
				Egg Hygrometer.	Frame Hygrometer.			Of Fertile Eggs.	Of Total Set.
Buff O.	July 17	Under brooder	62.3	75.7	60.0	10.7	39.3 (3)		
Buff O.	July 17	Damp earth in room	62.3	73.4	57.7	11.1	27.4 (3)		
Buff O.	July 20	" " " "	66.2	76.0	60.3	11.4	24.5 (1)	91.7	73.3
S. L. W.	July 28	Ground, open air		76.9	61.2	11.8	20.0 (8)	84.6	73.3
W. R.	August 7	In artichokes	77.7	80.0	64.3	9.8	28.5 (10)	85.7	80.0
Buff O.	August 17	Earth, room	73.4	75.4	59.7	11.5	26.0 (3)	92.3	80.0
B. R.	August 22	In evergreens	67.0	76.2	60.5	11.5	23.4 (2)	75.0	60.0 (2 broken)
		Ground beneath box				10.2		100	73.0
Averages			68.1	76.2	60.5	11.0	27.0	88.2	73.3
S. L. W.	July 17	Chaff	62.3	73.9	58.2	11.4	22.2		
Buff O.	August 17	In colony house	67.1	75.9	60.2	12.1		85.7	80.0
Averages			64.7	74.9	59.2	11.7			
Buff O.	July 20	Board	66.2	76.9	61.2	13.3	18.9 (2)	78.6	68.8
Buff O.	August 17	Board	73.3	75.9	60.2	12.8	26.0 (3)	80.0	53 (5 broken)
Averages			69.7	76.4	60.2	13.0	22.4	79.3	60.9
L. B. 2	July 4	Ventilated	61.1	64.4	48.4	14.7			
Buff O.	July 17	"	62.3	73.3	57.6	13.1	26.6 (3)		
Buff O.	July 20	"	66.2	70.4	54.7	14.7	13.3 (1) (?)	77.0	66.7
Averages			63.2	69.4	53.6	14.2	19.9		
B. R. 3866	August 7	Rubber	69.3	77.1	61.4	10.8	21.4 (10)	100.0	80.0
B. R. 7100		Rubber, no eggs					10.4 (10)		
Averages	of all hens	on eggs	67.4	70.1	59.2	12.0	24.4	86.0	71.5

B. R. 3866	August 7..	Rubber............	69.3	77.1	61.4	10.8	21.4 (10)	100.0	80.0
B. R. 7100	....	Rubber, no eggs....	......	....	....	....	10.4 (10)	....	....
Averages	of all hens	on eggs............	67.4	70.1	59.2	12.0	24.4	86.0	71.5

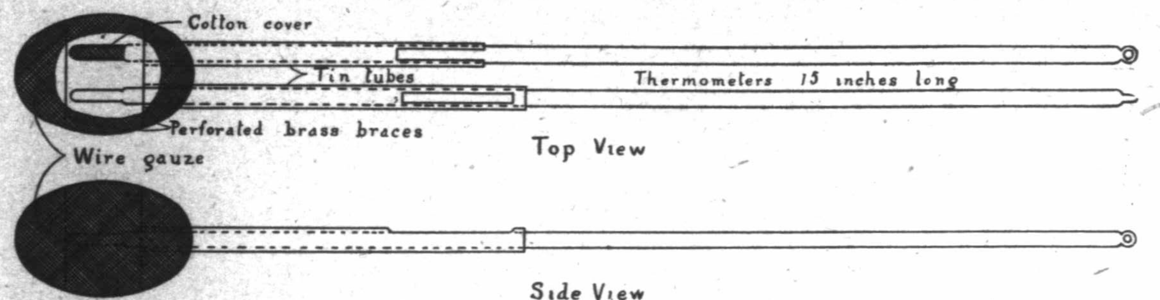

Fig. 4—Nest Hygrometer ("Egg Hygrometer").
Wet- and Dry-bulb Thermometers in Egg of Wire Gauze.

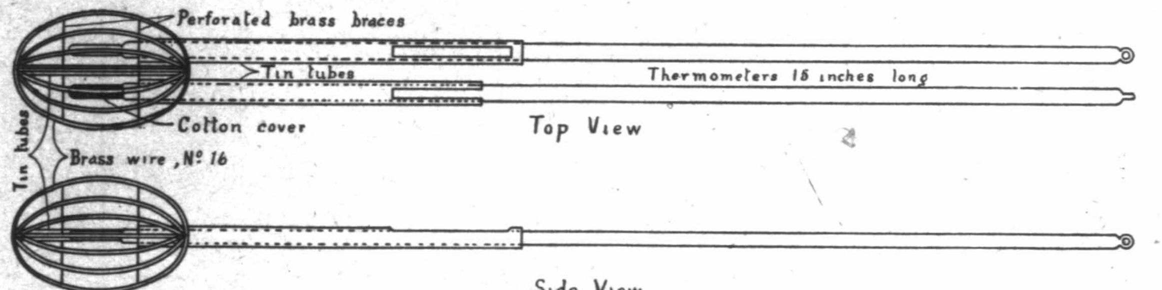

Fig. 5.—Nest Hygrometer ("Frame Hygrometer")
Wet- and Dry-bulb Thermometers in a Wire Frame Egg.

Comparing this table with No. IX., it will be observed that the humidity in the nests appeared even higher than in the wet incubators without fanning. This seemed incredible, and thus the objection previously mentioned seemed emphasized. To examine its validity a new hygrometer was devised, of which Fig. 5 is an illustration. In general design it is the same as the former, but the wire gauze is supplanted by a framework of wires converging from the centre on the ends of the egg, and being about one-half an inch apart at the widest point. This instrument we called the "frame hygrometer." The wires, we thought, could not have much effect in checking diffusion. To establish this point it was tested against an ordinary wet and dry bulb, unsheltered, and subject to free diffusion in the room. The results are given below:

TABLE XIII. COMPARISON OF FRAME HYGROMETER WITH ORDINARY HYGROMETER IN ROOM.

Temperature.	Ordinary Hygrometer.	Frame Hygrometer.	Difference.
75.5	38.9	42.2	3.3
75.5	40.7	42.6	1.9
75.5	40.7	43.0	2.3
75.5	38.9	41.2	2.3
75.5	38.9	42.6	3.7
76.0	41.2	44.8	3.6
76.0	38.9	42.6	3.7
67.0	64.2	66.6	2.4
95.0	74.6	74.6	0.0
76.0	34.0 (fanned)	34.0 (fanned)	0.0

The greatest difference is not large and with high humidity, or when fanned, the difference was nil. Having thus established that the "frame hygrometer" is at worst very nearly correct in the room, we proceeded to test the "egg hygrometer" by it. Selecting a hen in whose nest the "egg" had previously given a humidity of 74.3 (the average of ten readings) we put in the "frame." It gave a humidity of only 60.1 per cent., 14.1 per cent. lower than that given by the "egg." It seemed incredible that the difference could be so large, but repeated tests gave the same result. Then both were put under her at the same time, the "egg" on the left, the "frame" on the right, giving 65.8 and 50.6 respectively, a difference of 15.2. Another hen was selected, a White Wyandotte, under evergreens. Result: egg gave humidity of 73.9, frame 59.8, difference 14.1. Later in the day Mr. McKenney tested the same hen with the following result: egg 74.2, frame 56.7, difference 17.5. These facts are tabulated as follows:

TABLE XIV. FIRST COMPARISON OF EGG AND FRAME HYGROMETERS UNDER HENS.

Hen.	Nest.	Egg hygrometer.		Frame hygrometer.		Difference.
		Remarks.	Humidity.	Remarks.	Humidity.	
Bu. O.	Damp earth......	Average of 10 readings..........	74.3			
"	"	....	......	One reading	60.1	14.2
"	"	Egg on right......	65.8	Frame on left.....	50.6	15.2
W. W.	Under evergreens.	Egg on left	73.9	" " right ...	59.8	14.1
"	"	Reading by A. M. later in day....	74.2	Reading by A.M. later in day...	56.7	17.5

Not yet reconciled to such a great difference, we selected another hen for a more extended and exhaustive test. To begin with, the dry thermometers were placed toward the body. The wet ones outward from it. They were later interchanged, and lastly the "egg," which had been on the left side, was changed to the right, and the "frame" vice versa.

The difference ranged from 14.6 to 17.9, and averaged 15.9. The readings complete are given in Table No. XV. :

TABLE XV. SECOND COMPARISON OF EGG AND FRAME HYGROMETERS UNDER BUFF ORPINGTON HEN ON DAMP EARTH NEST.

Time.	Egg Hygrometer.			Frame Hygrometer.			Difference.
	Remarks.	Temperature.	Humidity.	Remarks.	Temperature.	Humidity.	
10.25	Left, wet outward.....	100.0	69.4	....	......	......	......
10.50	" "	99.0	67.6	Right, wet outward.	99.0	53.0	14.6
11.00	Gauze dry, wetted.....	......	......	Gauze wetted......	......	......	...
11.10	Left, wet outward.....	99.5	70.8	Right, wet outward.	99.0	55.8	15.0
11.12	Positions interchanged.	......	......	....	......	......	......
11.30	Right, wet inward.....	98.0	70.2	Left, wet inward...	100.0	53.4	16.8
11.40	" "	99.5	70.8	" " ...	99.5	54.6	16.2
	Gauze wetted.........	......	......	Gauze wetted......	......	......	......
11.50	Right, wet inward	100.0	74.1	Left, wet inward...	100.00	56.2	17.9
11.55	" "	99.0	72.3	" " ...	98.5	55.6	16.7
12.00	" "	99.5	70.8	" " ...	99.0	55.8	15.0
					Average.....		15.9

These tests established beyond doubt that our second objection was well founded, that the "egg" did bottle up the moisture and thus give readings far too high. If all the differences of both tests are averaged we find the egg readings too great by 15.7. Referring to Table XII., and subtracting 15.7 from the "egg" humidities, we obtain the next column, the humidities by the "frame."

But doubtless in the minds of some there is an objection to even the "frame" hygrometer: The wet bulb is giving vapor to the air in the nest, and although it *cannot* give enough to *saturate* the air, still it may be giving sufficient to raise the humidity considerably above what it would be if the wet bulb were not there. This objection seems plausible, but it may be stated here that during the present season (1907) the "frame" hygrometer in the nest was subjected to a rigorous test by the absolute method and it was established that the hygrometer readings are not in error to any appreciable extent. Details of this test will be given later in another connection. Then taking as correct the humidity of the nests as given by the frame hygrometer, we observe that it is very much higher than the fanned reading in the dry machines, as 59 is to 39. (See Tables IX. and XII.) Hence if we are to take the hen as our guide we must infer that dry incubators have not sufficient moisture, and that incubators cannot be expected to give best results unless they are made as moist as the hen's nest.

Now referring to Table XII., and comparing the various kinds of nests, we observe that the rubber and the earth nests had highest humidity, and that *they also hatched best.* Barring the board nests, where 5 eggs were broken, the hatch increased or decreased as the humidity did. Referring to Table No. IX., it will be seen also that on the average the "wet" machines, or machines into which moisture was introduced, gave *a considerably greater hatch than did the dry ones,* in the case of both the selected and the shuffled eggs, though the difference was the more marked on the latter. Hence from the *practical* side also for both the hens and the incubators we thought it a fair conclusion from the work of 1906 that high humidity must be productive of larger hatches. This conclusion has been thoroughly confirmed by the extended tests of 1907. Consulting Table No. VII., the reader will observe that 1,221 eggs were set in machines where moisture was introduced by use of water only, and 1,406 in dry machines. In the "wet" machines the hatch was 51.9 per cent. of the total eggs set; in the "dry" machines it was only 40.7 per cent. Then besides, more chicks hatched in "wet" machines lived than those hatched in dry ones, 63 per cent. of the former living to the age of four weeks as against 39.5 per cent. of the latter, or, counting the chicks alive at the end of four weeks in terms of total eggs set, the "wet" machines produced 32.7 per cent. as many chicks as eggs set and the dry machines 16.1 per cent., or less than half as many as the wet. Or stating it otherwise, 3 eggs in a wet machine produce 1 chick four weeks of age, while it takes 6 eggs in a dry machine to produce 1 chick the same age. This is a very remarkable substantiation in a practical way of our conclusion that since the air in the nest is very moist that in an incubator must also be very moist for best results.

But a comparison between Tables IX. and XII. will show that although the humidity of the "wet" incubators with fanning (which approximates to the correct humidity, the unfanned being too high), is slightly higher than that of the hens by the frame hygrometer (which also approximates to the corect reading) still the selected eggs in the incubators did not hatch nearly so well as those under the hens (all eggs set under hens were selected). This being the case, we must conclude that some vitalizing power (or powers) present with the hens was absent from the incubators.

Circulation in Nest.

In the work on humidity thus far reported there lies almost hidden a suggestion of a condition in a hen's nest not generally suspected, certainly not formerly suspected by us, which may ultimately be shown to be that vitalizing influence, or at least one such. The reader will recall that when the "egg" hygrometer was placed in the stoppered bottle, the sack did not become dry even in three hours' time, and the humidity rose almost to saturation. He will also recall, or by referring to Table No. XI., he may again observe, that when the same hygrometer was placed in a hen's nest it became dry in less than 40 minutes, and dry again in about 45 minutes more, and partly dry a third time in 30 minutes, enough water having thus evaporated to saturate the air at least four or five times over, notwithstanding which the humidity in the nest remained constant at only 70 per cent. These facts surprised me greatly at first, and they suggested to my mind the idea of *a fairly rapid change of air in the hen's nest.* To gain further light upon this point, the "egg" and "frame" were tested against each other in the room subject to free diffusion. The results are given in Table No. XVI.:

Table XVI. Comparison of Egg and Frame Hygrometer in Room.

Room Temperature.	Humidity of Room by Ordinary Hygrometer.	Difference between Humidities given by Egg and Frame Hygrometers.
		Per cent.
76	40.7	23.3—diffusion
68	66.3	12.7 (2)—diffusion
96	48.9	9.0—diffusion
	48.9	11.6—fanned
	48.9	11.1—fanned 10″ away
	49.2	3.7—fanned 1″ away
	52.4	7.0—fanned 18″ away
	43.7	10.7—fanned 10″ away
	48.9	12.8—fanned 6″ away

FLOOR WATERED.

Room Temperature.	Humidity of Room by Ordinary Hygrometer.	Difference between Humidities given by Egg and Frame Hygrometers.
		Per cent.
95.5	74.6	3.5—diffusion .3—fanned 6″ away 5.2—fanned 10″ away 3.1—fanned 18″ away

The first reading shows that when the humidity was low the difference was high, 23.3 as compared with 15.7 in the hens' nests. The second reading shows that with higher humidity the difference was less, being only 12.7. Many readings not recorded here were taken from time to time at average humidities of from 50 to 65, and the difference was always in the neighborhood of 15 per cent., very close to the difference in the nest. Was it possible that the air-movement in the hen's nest was equivalent to free diffusion in the room? It did not seem credible. The temperatures of course are not the same in the two cases, so that the tests are not exactly parallel, still the existence of the same difference between the hygrometers in the nest, as in the room, pointed strongly to the suspicion that the nest was subject to air movement equal in effect to the free diffusion of the room. If so, then the reading of the "frame" hygrometer was really a fanned reading, and, therefore, strictly accurate; of which more later.

But how can we reconcile the ideas of rapid air movement and high nest humidity? Surely there is not enough evaporation from the eggs to maintain such high humidity in the face of such rapid circulation. Let us examine. Referring to Table XII., under "evaporation" we learn that the average loss from all eggs under hens in 1906 was 12 per cent. of their original weight. The ventilated and board nests, however, are unnatural conditions, and the evaporation is high, hence in any argument based on evaporation these nests should be omitted. The average evaporation in the remaining kinds of nests is 11 per cent. The weight of a setting of eggs is about 26 ounces, and the evaporation would thus be 2.86 ounces. And this divided up equally amongst the first 19 days is sufficient to saturate the air under the hen at least *four* times an hour for the whole period. This known, it is not so difficult to conceive of high humidity in the face of rapid air movement. Moreover, it is possible that some moisture comes from the hen's body, aiding in the maintenance of the high humidity.

CIRCULATION IN INCUBATORS.

The idea of circulation in the nests led us to the consideration of circulation in incubators, but owing to the incompleteness of the work on the former the latter has been held in abeyance. It may be stated, however, that the differential reading between the "egg" and the "frame" hygrometers when placed in wet incubators was much less than when under the hens and quite variable in any individual incubator. In the very dryest of the dry the difference was almost the same as under the hens. That variation in circulation affects the differential reading may be seen from Table XVI. When testing the "egg" against the "frame" in the room a little Ajax motor-fan was used to produce movement of air past them. The distance of the fan from the hygrometers was varied, hence the rate of circulation was likewise varied. It will be seen that for both low and high humidities (temperature 96 in both cases) there is a rate of circulation which gives a maximum differential reading, and also that either faster or slower circulation will reduce the difference. Therefore since the differential was lower in the wet incubators than under the hens the circulation was different, either faster or slower. Likewise since the differential in the dry machines was equal to that under the hens, the circulation must have been different, for the same amount of circulation produces a much greater differential in a dry than in a moist atmosphere. Whether the circulation in the incubators is greater or less than that under hens we are not able to say from *direct measurement,* but we have, however, indirect proof that seems to indicate unmistakably that the incubator circulation is considerably the slower, proof that came to us during our study of nest humidity by the absolute method.

Humidity by the Absolute Method.

To determine humidity absolutely has given us more trouble than any other part of the work. In 1906, being busy with other problems, and having only a short time to devote to it, it baffled us entirely. Although it looks easy in description, as given on pages 29 to 32, it is difficult in application. When beginning to use it last year we made a number of determinations of the room humidity by it one after another, to test the method. The variations were so great that it was evident that something was wrong in the manipulation. The drying tubes were weighed, 500 cc. of air drawn through them, and then re-weighed. The operation was repeated over and over several times in succession, but often the tubes would gain two or three times as much in weight as the time before, while the wet- and dry-bulb readings would show constant humidity. In the spring of 1907, with more time at our disposal, it was discovered that the variations were largely due to condensation on the tubes of moisture from the breath when it happened to be directed against the cold glass. From that time on a mask was worn by the operator so that the breath could not possibly strike the tubes. As a further precaution rubber gloves were worn, so that no perspiration from the hands could condense on the tube. With these precautions we were able to determine the humidity of the room correctly by this method. Seventeen comparisons extending from May to August gave the following results:

Wet and dry bulb, average relative humidity, 49.5 per cent.
Absolute method, average relative humidity, 49.3 per cent.

Actual Humidity in Incubators.

Having thus established our manipulation of the absolute method, we could with confidence use it in determining the relative humidity in incubators and in nests. A series of machines and several hens were set in August for this special study. For the machines three facts were recorded at each determination: (1) the humidity of the room and the corresponding vapor pressure; (2) the *apparent* humidity in the incubator by the wet and dry bulb without fanning and the corresponding vapor pressure, two or three readings for one determination; (3) the *actual* humidity in the incubator by the *absolute* method and the corresponding vapor pressure, two or three readings for one determination.

Perhaps some explanation should be made of the term "vapor pressure." Every gas or vapor has an expansive power, a fact which may be shown as follows: Tie tightly a thin rubber over the mouth of a glass beaker, place it in the receiver of an air-pump, and exhaust the air from the receiver. The rubber will be seen to bulge outward as the air from around it is pumped away. Hence the air within the beaker has an expansive power. This causes it to exert a *pressure* outward on the rubber. The outside air had the same power in equal measure and as long as it was present to exert its pressure on the top, the rubber being equally pressed in both directions, was neither bulged outward nor depressed inward. But as soon as the outside air was partly removed and its pressure reduced, the expansive power of the air within manifested itself. Now, air possesses this property when not confined in a vessel, but expansion is prevented by the weight of the air above. That water vapor has an expansive power and exerts a pressure may be shown in a similar way. The more vapor in the air at any given temperature the greater the pressure it (the vapor) exerts. When vapor issues from the tea-kettle its pressure is higher than that in the air around and hence that vapor expands and keeps on expanding till the vapor pressure throughout the room is uniform. This equalization would occur even if the *air* were perfectly motionless. It is much hastened by air currents. There are various ways of determining the pressure of the vapor in the air at any time, but they are all too involved to be given here. Suffice it to say that when the temperature of the air and the weight of vapor in a cubic foot are known, then by applying certain physical laws, and performing a long mathematical calculation, we are able to determine the corresponding vapor pressure. In this calculation correction is made for the contraction of the air when entering the cold bottle A (Fig. 1). When this vapor pressure is known we are able to state the natural tendency of the moisture. If the vapor pressure outside the machine is greater than inside, then the room moisture would by its greater pressure pass through the cracks into the incubator. If on the other hand the pressure within is greater, then the moisture within will pass outward.

Five machines were examined in this test. The result is given in Table No. XVII.:

TABLE XVII: ACTUAL *vs.* APPARENT HUMIDITY IN INCUBATORS.

Incubutors.	How run.	Humidity of room by wet- and dry-bulb method.	Vapour pressure in room deduced from wet- and dry-bulb readings.	Apparent humidity of incubator by wet- and dry-bulb method.	Apparent vapour pressure in incubator deduced from wet- and dry-bulb readings.	Actual humidity of incubator by absolute method.	Actual vapour pressure in incubator deduced from absolute readings.
		%	Inches.	%	Inches of mercury.	%	Inches of mercury.
No. I. Prairie State.......	Fumes. Moisture by water in sand tray.	60.6	.458	55.4	1.116	46.6	.953
No. II. Prairie State.......	Dry.	61.3	.444	34.4	.689	21.3	.433
No. III. Prairie State.......	CO_2 and moisture by water in sand tray.	59.7	.423	47.8	.967	45.8	.928
No. IV. Prairie State.......	Zenoleum and moisture by water in sand tray.	59.7	.414	53.0	1.091	46.1	.936
No. VII. Model	Buttermilk. Tray nearly full size of machine bottom.	61.0	.412	61.5	1.276	54.4	1.135

In this table the wet- and dry-bulb results are the averages of from three to five readings, the "absolute" results of from seven to ten readings. Perhaps the dry machine should be noticed first. The actual humidity was only 21.3 per cent., an average of ten readings taken on five different days. Of these ten only one was greater than 22 per cent., and only two less than 19 per cent. In fact one of the outstanding features of this test was the uniform humidity of this dry machine; come back to it when I would, its humidity was always the same within very narrow limits of variability. Another noteworthy fact with regard to this machine is that the vapor pressure in it was practically the same as in the room, .433 inches for the former and .444 inches for the latter. The room pressure was the average of five readings taken on the same five days as the incubator readings. Since these pressures were nearly equal, there would be little transference of vapor either way. But all determinations were made during the day. At night with a drop in temperature the room vapor pressure would fall, under which conditions vapor would pass from the incubator to the room. The apparent humidity by the wet and dry bulb method was much higher than the actual as 34.4 to 21.3, *i.e.*, the apparent is astray 13.1 on 21.3, an error of 61.5 per cent. This great discrepancy is due to the lack of circulation, the moisture given off by the wet-bulb not being dissipated fast enough to indicate the true humidity. This result proves absolutely the 1906 conclusion from theoretic considerations that the real humidity of an incubator is not learned by the use of the wet- and dry-bulb hygrometer without fanning. Again, as fanning disturbs the normal conditions within the machine, the fanned reading, while correct for the artificial conditions, does not represent the exact humidity under normal conditions. Hence the only way to gain reliable information as to the actual humidity in an incubator is by this or some other "absolute" method.

Machines I., III., and IV., being all of the same make, with the moisture provided in the same way, would be expected to have approximately the same humidity. From the column "actual humidity" this would appear to be the case, while from "apparent humidity" I. and IV. are nearly alike, but III. considerably lower. The explanation of this apparent discrepancy is found in the individual readings of which 47.8 and 45.8 are the averages. During the first ten days of incubation the humidity in III. was low, apparent 43.4, real 35.5; difference 7.9. During the remainder of the hatch it was high, apparent 56.6, real 50.8; difference 5.8. It so happened that for this machine two-thirds of the readings for the "apparent" were taken while the humidity was low, but that three-fourths of those for the "real" were taken while the humidity was high. Hence the average of the "apparent humidities" is too low and of the "real humidities" too high to represent the true averages for the whole hatching period. The cause of the low humidity in this apparently moist machine during the first ten days was not discovered. The difference between the apparent and true humidities was 7.9 during the dry period and 5.8 during the moist period. In I. it was 8.8; in IV., 6.9; in VII., where the moisture was provided in the form of buttermilk, the difference was 7.5. Thus in the moist machines, too, we see that the humidity as given by the wet- and dry-bulb hygrometer is astray, an error of 7.5 (average difference) on 47.5 (average real humidity) or 15.8 per cent., and we again remark that for reliable information on the humidity in incubators an absolute method is essential.

The actual vapor pressure in these "moist" machines was in all cases more than double that in the room at the same time, and in No. VII. it was nearly three times that in the room. Hence in all these cases there would be a strong tendency for the vapor to pass outwards through the cracks.

Actual Humidity in Nests.

The same methods were applied to determining the actual humidity in hens' nests. The results are given in Table No. XVIII.:

TABLE XVIII: ACTUAL *vs.* APPARENT HUMIDITY IN NESTS.

Hen.	Kind of nest.	Humidity of room by wet and dry-bulb method.	Vapour pressure in room deduced from wet and dry-bulb readings.	Apparent humidity in nest by the frame hygrometer.	Apparent vapour pressure in nests deduced from hygrometer readings.	Actual humidity in nest by absolute method.	Actual vapour pressure deduced from the absolute readings.
I. Silver Laced Wyandotte........	Earth	62.9	.427	75.2	1.314	82.1	1.659
II. Silver Pencilled Wyandotte	Earth	62.7	.431	68.4	1.252	59.4	1.203
	Averages for earth nests..			71.8	1.283	70.8	1.431
III. Barred Rock	Straw	65.0	.437	....	....	52.8	1.074

It was found that several samples could not be taken in succession, for the second and third were invariably lower than the first. Great variations in humidity were found in all nests. For hen No. I. the range was 70.6 per cent. to 99.3 per cent.; for No. II., 48 to 83; for No. III., 40.5 to 60.4. Readings were taken in the top of the nest, the bottom, and between the leg and breast, but no uniformity was reached. Of seven readings for hen No. I. the highest was obtained at the bottom, the next three in order were top readings, the remaining three, bottom readings. For hen No. II. the highest was a top reading, the next three were bottom readings, and the remaining one a top reading. For No. III. the highest was between the leg and breast, the second and third bottom readings, the fourth a top reading; the fifth between the leg and breast, and last a bottom reading. Probably much of the variation with these hens might be accounted for if we knew how closely or remotely the reading followed some shifting of the hens. The humidity in nests I. and II. was also determined by the "frame" hygrometer, two readings in each case. In No. 1 the absolute method gave a higher reading than the hygrometer; in II. the hygrometer gave the higher reading. Of course the two methods could not be used simultaneously in the same nest, hence in fairness we could compare only the averages. Averaging the two, the hygrometer gave 71.8, the absolute 70.8. Hence we must conclude that for earth nests at least the nest hygrometer is correct within the limits of experimental error. This is the test previously referred to in discussing the frame hygrometer. Looking now at the vapor pressure in the nests, we see that it is from 2½ to 4 times as great as in the room during the same time.

Actual Humidity and Circulation.

Taking the actual humidities in nests and in incubators determined during this test as fairly representative of those during the season in the same kinds of nests and the same incubators run in the same way, let us place the results in juxtaposition for comparison.

Table XIX: Evaporation as related to Actual Humidity in Nests and in Incubators.

Incubator.	How treated.	Actual humidity as determined in August.	Evaporation.	Number of hatches of which evaporation is average.
Hens	Earth nest	70.8	9.7	3 hatches, May, June, July.
Hens	Straw nest	52.8	11.9	20 hatches, May, June, July.
Hens	Ventilat'd nest	35.0	14.5	2 hatches, June and July.
Model	Buttermilk	54.4	9.5	2 hatches. Large tray of buttermilk almost covering bottom of incubator.
No. I. 1907 Prairie State. No. III. " " No. IV. " "	Sand tray and water	46.2	9.6	10 hatches, moisture by sand tray and water.
No. II. " "	Dry	21.3	14.5	7 hatches in 1907 Prairie State, dry.

Note that the humidity in earth nests was 25 per cent. greater than that in the Model, and 50 per cent. greater than in the moist Prairie States. And yet the evaporation in the earth nests was slightly the greater, in spite of the very high humidity! These facts, it seems to me, can have only one explanation, viz., a faster circulation in the nests than in the incubators. The whole table bears out this argument. This is the proof already referred to in discussing circulation. Putting into practice this season the conclusions we reached last year, Mr. Graham has been able to almost treble the performance of the dry machine with which we began in 1906. (See Table VII., page 27.) Zenoleum and water, chicks alive in 4 weeks = 44 per cent. of eggs set; dry machines, chicks = only 16.1 per cent. of eggs set. Still we have not yet overtaken the hen, who is able to give us 52 chicks 4 weeks old for every 100 eggs set. Perhaps proper circulation is the vitalizing power that must be combined with those already established to place artificial incubation abreast or possibly in advance of the natural process.

Carbon Dioxide in Relation to Incubation.

By C. C. Thom, Demostrator in Physics.

Carbon dioxide is a colorless gas with an acid (sour) taste, and a more or less pungent odor. It is formed largely by the oxidation of carbonaceous organic matter, and is given off in considerable quantities by the lungs of the living animal during respiration. It is not a poisonous gas, although in an atmosphere containing large quantities of carbon dioxide death might result from suffocation or from want of oxygen. While carbon dioxide is not of itself injurious, yet it is a product of combustion and respiration usually accompanied with other injurious products, and the amount of it present in the atmosphere is taken as a standard by which we can judge of the quality or purity of the air. It is everywhere found in small quantities, from 3 to 4 parts in 10,000 in the atmosphere of the country.

Taking the atmosphere of the country as a standard of purity necessary to the proper maintenance of animal life, it was thought that possibly the air in the egg chamber of the incubator, during incubation, became so highly impregnated with carbon dioxide as to impair the healthy and normal development of the embryo chick. To test this theory it was decided to analyze the air in the egg chambers of a number of incubators for carbon dioxide. For this purpose a special apparatus was fitted up consisting (see Fig. 6) of a large aspirator, bottle A, so fitted and graduated that a definite volume of water could be drawn from it by opening the pinch-cock P, necessitating the same volume of air being drawn into the bottle to replace the water taken out. The air drawn in was taken from the egg chamber of the incubator by inserting the end of the rubber tube T through a small hole in the door of the incubator. The air drawn from the egg chamber was not allowed to pass directly into the large aspirator bottle, but was first made to pass through a known volume of a standard solution of potassium hydrate contained in the small bottle K, and in so doing all the carbon dioxide in the air was absorbed by the potassium hydrate uniting with it to form a potassium carbonate. In testing the solution in the small bottle K for potassium carbonate the following method was used:

To an aliquot portion of the solution was added a few drops of phenolphthalein indicator, and the excessive alkali neutralized with one-hundredth normal sulphuric acid, care being taken to keep the tip of the burette immersed in the solution to prevent the escape of any carbon dioxide. To the clear solution was then added a few drops of methyl orange indicator, and the solution again titrated with one one-hundredth normal sulphuric acid, until all the carbonate present had been broken up, as indicated by the change in color of the solution. From the amount of one one-hundredth normal acid used in the last titration, the volume of carbon dioxide in the volume of air taken from the incubator was determined. In figuring the results of these analyses no correction was made for the change in temperature of the air drawn from the incubator, as it was found that the error from this source was inappreciable. Precaution was taken, however, to make a daily analysis of the stock solution of potassium hydrate for carbonate and the error arising from this source deducted from our results.

Numerous analyses were made of the air in the egg chamber and also of the air in the incubator room. At the same time many analyses

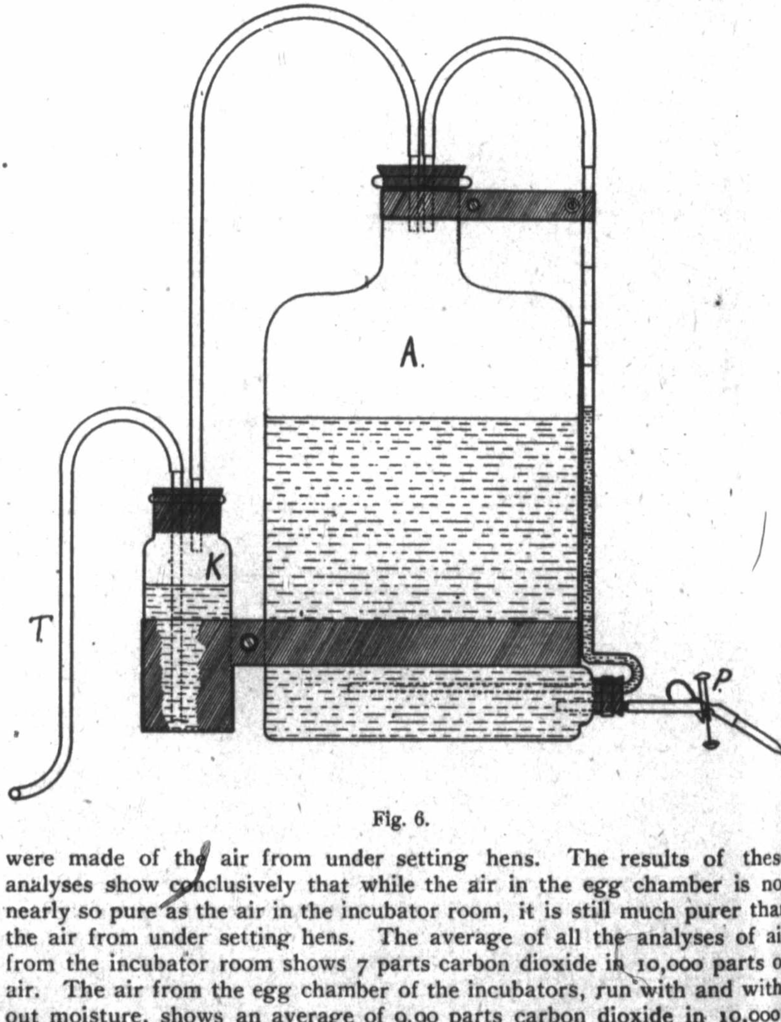

Fig. 6.

were made of the air from under setting hens. The results of these analyses show conclusively that while the air in the egg chamber is not nearly so pure as the air in the incubator room, it is still much purer than the air from under setting hens. The average of all the analyses of air from the incubator room shows 7 parts carbon dioxide in 10,000 parts of air. The air from the egg chamber of the incubators, run with and without moisture, shows an average of 9.90 parts carbon dioxide in 10,000; while the air from under setting hens shows on an average 31.93 parts of carbon dioxide, more than three times the amount found in the incubators, and over four times the amount found in the incubator room.

The knowledge of this fact led to the belief that possibly a high carbon dioxide content of the air in the incubator chamber during incubation was necessary to a successful hatch. The results of analyses so far showed that increased moisture in the incubator gave a decided increase in carbon dioxide, from 9.15 parts in the dry machines to 10.46 parts in the machines run with moisture, or an increase of 1.31 parts. By referring to Table VII. (page 27) it will be noted that the vitality of the chicks from the hatches was increased from 16.1 per cent. in the dry machines to 32.7 per cent. in the wet machines.

Four hatches were then conducted, during which a pan of whole milk was kept in each machine. The results of these tests showed that while the carbon dioxide content of the machines was increased from 10.46 parts when the machines were supplied with pure water to 12.12 when the machines were supplied with whole milk, yet the mortality of the chicks hatched was considerably greater than when pure water alone was used. Buttermilk, however, gave much better results than whole milk, the carbon dioxide content was slightly decreased from 12.12 to 12.03 parts in 10,000, while the percentage of chicks alive at four weeks in per cent. of eggs set, was increased from 23.2 per cent. for whole milk and 32.7 per cent. for water to 37.4 per cent. for buttermilk. The increase in carbon dioxide in the machines run with buttermilk and whole milk was due to the emission of this gas during the fermentation of the milk which was inoculated with *Bacillus ærogenes lactis* before being put in the machine.

To determine to what extent, if any, these successful hatches with buttermilk were due to the comparatively high carbon dioxide content, machine 3 was fitted up with a gas pipe leading from a drum of artificial carbon dioxide through the fresh air intake to the interior of the machine, where the pipe was so arranged that the gas entering by it would be distributed uniformly throughout the egg chamber. Approximately 2,500 cc. of carbon dioxide was put into this machine twice daily—just after the eggs were turned in the morning and again just after they were turned in the evening. In all, three hatches were made in which artificial carbon dioxide was supplied. Moisture also was supplied during these hatches. The analysis of the air from this machine gave an average of 43.32 parts carbon dioxide in 10,000 of air. The live chicks at four weeks, from these hatches, in per cent. of eggs set, was 37.2, an increase of 4.5 per cent. over moisture only, and about equal to that of buttermilk. The increase in vitality of the chicks from the combination of carbon dioxide and moisture over moisture only, amounting as it does to 4.5 per cent. of the eggs set, seems directly due to the higher carbon dioxide content. At the same time buttermilk used as moisture and a comparatively low carbon dioxide content gave practically the same result. Again, when the moisture machines were disinfected with zenoleum, the average carbon dioxide content in the egg chamber was decreased from 10.46 parts for water only to 8.29 parts for water and zenoleum, and from 9.15 parts in the dry machine to 5.86 parts in the dry machine disinfected with zenoleum. In every instance disinfecting with zenoleum resulted in a decrease of carbon dioxide, yet the use of zenoleum never failed to give a better hatch, and higher vitality. While a high carbon dioxide content seems decidedly beneficial in the case of machines supplied with moisture only, yet it is just possible that the function it performs in artificial incubation may be fulfilled by something else, as the results from the use of buttermilk and zenoleum seem to indicate.

Although the work on carbon dioxide is not conclusive, the results so far furnish much valuable data, and establish many useful relationships. Just what function, if any, carbon dioxide performs in incubation, and to what extent it is essential, is a point on which we have not at present sufficient experimental data to warrant conclusions.

TABLE XX. CARBON DIOXIDE UNDER SITTING HENS.

Hens	Volumes in 10,000 volumes of air								Average
Hen 2,235	26.7	20.0	28.9	24.5	26.7	20.00	24.5	24.5	24.48
" 532	35.6	33.4	35.6	35.6	33.4	37.8	33.4	.....	34.97
" 566	31.1	37.8	31.1	26.7	31.1	31.1	31.1	26.7	30.84
Hen on earth nest	35.6	35.6	.....	.....	.....	.....	.....	.....	35.6
" " flat "	44.5	37.9	33.3	37.8	37.8	33.3	35.6	.....	37.17
" in Incubator	22.2	24.5	22.2	22.2	26.7	26.7	.....	.....	24.08
Hen 5,257	28.9	31.1	35.5	.....	.....	.....	.....	.....	31.83
" 274	33.4	37.8	37.8	.....	.....	.....	.....	.....	36.33
" 642	28.9	33.3	40.0	33.4	.....	.....	.....	.....	33.9
" 81	37.8	*40.0	.....	.....	.....	.....	.....	.....	38.9
Hen under brooder	33.4	48.9	40.0	42.2	44.5	.....	.....	.....	41.8
Hen 31	35.5	31.1	.....	.....	.....	.....	.....	.....	33.3
" 605	24.5	22.2	31.1	.....	.....	.....	.....	.....	25.93
" 578	28.9	26.7	.....	.....	.....	.....	.....	.....	27.8
White Rock	31.1	.....	.....	.....	.....	.....	.....	.....	31.1
Hen A 1	35.5	31.1	35.1	31.1	26.7	.....	.....	.....	31.9
" A 2	35.1	35.6	33.5	40.0	.....	.....	.....	.....	36.05
" A 3	26.6	28.9	33.3	28.9	.....	.....	.....	.....	29.43
" A 4	31.1	31.3	33.4	35.5	.....	.....	.....	.....	32.83
" A 5	26.6	37.8	26.6	31.1	.....	.....	.....	.....	30.53
" A 6	28.9	33.4	37.8	35.6	28.9	.....	.....	.....	32.92
" A 7	28.9	26.6	26.6	28.9	42.2	.....	.....	.....	30.64
" A 8	26.7	28.9	33.3	35.6	31.1	.....	.....	.....	31.12
" A 9	33.3	35.5	35.5	31.1	33.3	.....	.....	.....	33.74
" A10	28.9	28.9	33.3	31.1	35.6	.....	.....	.....	31.56
" A11	24.4	28.9	28.9	28.9	31.1	.....	.....	.....	28.44
" A12	26.68	24.46	24.46	24.46	.....	.....	.....	.....	25.02

* 20th day.

TABLE XXI. CARBON DIOXIDE IN INCUBATORS.

Machine showing condition	Date set	Volumes in 10,000 volumes of air.						Average
Machine 1								
Water	April 26	10.00	10.00	10.00	9.45	......	......	9.86
Dry	April 3	3.34	7.78	7.78	7.78	......	......	6.67
Moisture, Fumes	May 21	50.04	56.34	61.16	......	......	......	55.85
Dry, Fumes	June 17 and July 18	53.37	55.60	62.72	61.16	......	......	58.21
Machine 2								
Whole Milk	April 3	11.12 9.45	12.23 13.34	10.00	11.12	11.12	13.34	11.46
Dry	April 26	11.12	10.00	11.12	10.00	8.89	......	10.23
Water, Zenoleum	May 21	8.89	9.45	10.00	8.89	10.00	......	9.45
Whole Milk, Zenoleum	June 17	11.12	13.34	8.89	......	......	......	11.11
Dry	July 18	8.89 9.45	7.78	9.45	10.00	7.78	7.78	8.73
Machine 3								
Buttermilk	April 3	13.34 11.12	15.56 10.00	15.56	11.12	16.68	13.34	13.34
Whole Milk	April 26	12.23	13.34	13.34	12.23	......	......	12.79
Water and CO_2	May 21	26.68	22.24	41.13	50.04	......	......	35.02
Water, CO_2, Zenoleum	June 17	41.13	61.16	55.60	62.72	......	......	55.16
Water, CO_2	July 18	55.60	41.13	48.92	60.04	......	......	51.42
Machine 4								
Water	April 3	6.72	7.78	7.78	6.72	6.72	7.78	7.25
Buttermilk	April 26	11.12	12.23	10.67	10.00	......	......	11.01
Dry, Zenoleum	May 21	5.56	4.45	6.72	6.72	......	......	5.86
Water, Zenoleum	June 17	7.78	5.56	6.72	......	......	......	6.69
Water, Zenoleum	July 18	6.72	6.72	6.72	8.89	......	......	7.26
Hearson								
Moisture	April 3	11.12	12.23	17.79	11.12	13.34	13.34	13.16
	April 26	13.34	13.34	13.34	13.34	13.34	17.79	14.08
	May 21	12.23	11.12	13.34	11.12	......	......	11.95
Buttermilk	June 17	17.79	13.34	17.79	16.68	13.34	......	15.79
Open Bottom Prairie State								
Water, Milk, Zenoleum	April 11	6.67	8.89	......	......	......	......	7.78
Dry—Eggs in galvanized tray	May 6	12.23	10.00	12.23	12.23	6.67	......	10.67
Model								
Moisture, (sprinkled) Zenoleum	April 11	8.89	......	......	......	......	......	8.89
Moisture	May 6	7.78	6.67	8.89	......	......	......	7.78
Buttermilk	July 18	10.00	11.12	10.00	12.23	8.89	7.78	10.00
Peerless								
Dry	March 23 and April 16	8.89	8.89	10.67	8.89	......	......	9.33
Buttermilk	May 11	10.00	11.12	8.89	......	......	......	10.00
Moisture, Zenoleum	June 11	10.00	8.89	7.78	10.00	......	......	9.16

CARBON DIOXIDE IN INCUBATORS—*Concluded.*

Machine showing condition.	Date set.	Volumes in 10,000 volumes of air.						Aver-age.
1906 Cyphers								
Moisture.............	April 16....	10.00	7.78	......	......	......	......	8.89
Slightly moist Zenoleum	May 11.....	10.67	8.89	5.56	7.78	......	......	8.22
1905 Cyphers								
Dry Zenoleum.........	April 11.....	5.56	5.56	......	......	......	......	5.56
Dry..................	May 6......	8.89	10.00	8.89	......	......	......	9.26
Cortland								
Buttermilk...........	May 6......	5.56	8.89	8.89	12.23	......	......	8.89
Continuous								
Moisture............	June 11.....	10.00	12.23	11.12	9.45	......	......	10.70
Incubator Room.....	April 16 to	8.89	7.78	7.78	4.45	11.12	7.78	
	July 25....	3.34	......	7.78	5.54	5.54	......	7.00

TABLE XXII. CARBON DIOXIDE—VOLUMES IN 10,000 VOLUMES OF AIR—AVERAGE RESULTS.

Hens.

Earth nest	35.6
Flat nest	37.14
Ventilated nest (hen in incubator)	24.08
All hens	31.93

Machines.

Dry, lamp fumes	58.21
Moisture, lamp fumes	55.85
Moisture, carbon dioxide and zenoleum	55.16
Moisture and carbon dioxide	43.22
Whole milk	12.12
Buttermilk	12.03
Whole milk and zenoleum	11.11
Moisture only	10.46
Dry	9.15
Moisture and zenoleum	8.29
Water, milk and zenoleum	7.78
Dry, zenoleum	5.86
Incubator room	7.00

Chemical Work in Connection With Incubation Problems.

By R. Harcourt, Professor of Chemistry, and H. L. Fulmer, Demonstrator in Chemistry.

The chemical work herein reported was undertaken with the object of gaining some definite information regarding the distribution of the mineral constituents in the different parts of the egg, and to determine the effect of different methods of incubation on the amount of these constituents absorbed by the chick. Previous investigations carried on in the department of Physics of this institution demonstrated the fact that there was a large quantity of carbon dioxide gas around the eggs during incubation by the hen. It is well known that carbon dioxide in the presence of moisture will dissolve calcium carbonate and that the shell of the egg is composed largely of this substance; consequently, the question naturally arises, has the presence of this gas anything to do with the greater vitality of the chicks incubated by the hen? This hypothesis was further strengthened by the observed fact that, although the percentage of eggs hatched was small, the chicks obtained from incubators in which lamp fumes were present were generally strong and vigorous. It was hardly thought that the humidity of the air under the hen or in the incubator was sufficient to allow the carbon dioxide to dissolve any appreciable amount of the lime, yet it was thought that the point was worth investigating.

The plan of our investigation was to determine the amount of lime (CaO) and phosphoric acid (P_2O_5) in a number of eggs from several hens, and then to ascertain the amount of these constituents in the chicks got by different methods of incubation from the eggs of the same hens. As it would, obviously, be impossible to analyze an egg and to get a chick from the same egg, we had to analyze a number of eggs from each of several hens and thus obtain figures that would be approximately correct for comparison in the after work.

Method of Analysis.

An outline of the methods employed in separating the different parts of the egg and of making the analysis is as follows:

Proportion of Shell, White, and Yolk. This part of the work required no special skill, since the different parts were separated in a strictly mechanical way. The egg was first freed of all adhering foreign matter as completely as possible, and then weighed. The parts were next separated and placed in tarred dishes and weighed, their total weight being checked with the original weight obtained.

As our object in studying the composition of the original egg was to obtain figures with which to compare the composition of the chick after incubation, the membrane lining the shell was included with the latter, since this membrane is not absorbed by the chick, but left behind. The white was drained from the shell as completely as possible, while the chalaza, which is that part of the white that joins it to the yolk, was clipped off with a pair of sharp scissors as near as could be without injuring the yolk.

A very convenient way of separating the white from the yolk was by making an opening in the shell, just large enough for the white to stream through, and yet small enough to withhold the yolk. After the white was all out, the opening was enlarged enough to allow the escape of the yolk. Rapid separation could be made in this way.

Calcium and Phosphorus in the different parts of the Egg. Methods of making solution: Since phosphorus is volatile* and cannot be determined by incineration and examination of the ash, all the solutions were made in the wet way, using strong nitric acid as the oxidizing agent.

Shell, this being largely of calcareous nature, readily goes into solution on treatment with strong hydrochloric acid. The broken shell was placed in a beaker, covered with a watch glass to prevent loss during the vigorous effervescence due to the escape of carbon dioxide, and the acid gradually added, till most of the carbonate was attacked, after which solution was completed by gentle heating. At this stage nothing is left undissolved, except the lining membrane, which is easily oxidized and decomposed by boiling the solution for half an hour with 1 or 2 cubic centimeters of strong nitric acid. When solution was effected, the whole was made up to a volume of 250 cc. and aliquot parts of this taken for the several estimations.

White and Yolk. Since the greater part at least of the calcium and phosphorus is present in the white and yolk of the egg in an organized condition, it is necessary that a complete disorganization be accomplished in order that these elements be liberated and brought into a condition from which they can be isolated by the precipitating reagent, which is used in their estimation. Carius† has found that the phosphorus of organic material can be completely removed by oxidizing the substance with strong nitric acid; while in our work here, by comparing with the ashing method, it was found that the method which removed phosphorus removed the calcium also. Consequently, we used nitric acid for oxidizing the phosphorus, and the solution thus obtained was also utilized for the determination of calcium.

As the phosphorus of both the white and yolk is probably present in combination with proteids, bodies which are comparatively easily oxidizable, we carried out the digestion with nitric acid in the ordinary Kjeldahl

*V. Barmbauer found that Vitellin, which, when treated with nitric acid gives 3 per cent. of phosphoric acid, yields barely 0.3 per cent. of ash. (Fresenius, Vol. II., p. 120, COHN.)

†Fresenius, Vol. II., p. 116, COHN.

digestion flasks used in nitrogen estimations. A small quantity of hydrochloric acid‡ was also used to hasten the liberation of oxygen from the nitric acid. As the nitric acid became exhausted more was added from time to time. After about one hour's digestion solution was usually effected and nothing but the elaidin formed from the fats was left. This latter was easily filtered off and then the solutions were made up to a volume of 250 cc. with water.

Determinations.

Calcium: Aliquot parts of the solution were used, and the calcium precipitated with ammonium oxalate and determined in the usual way.

Phosphoric acid (P_2O_5): Aliquot parts were used from which the hydrochloric acid was expelled by repeated evaporation with nitric acid. The phosphoric acid was then determined volumetrically, as outlined in Methods of Analysis under Optional Volumetric Method, p. 13.

Calcium in the Chick: The contents of the egg (the chick) after incubation were not examined for phosphorus and the method of extracting the calcium was changed for one which was not quite so exacting on time and material. The shell and membrane were completely removed and discarded.

Method of Making Solution: The chick was placed in a porcelain dish and incinerated more or less completely. Complete carbonization is as far as the process need be carried, for at that stage all mineral constituents are freed from their organic combinations. After combustion the contents of the dish were pulverized and extracted with successive portions of strong hydrochloric acid until exhaustion was complete. The different extracts were then combined and made up to a volume of 250 cc. with water.

Determination: Aliquot portions of the solution were pipetted off, treated with a small quantity of ferric chloride to remove phosphoric acid, neutralized with ammonia and the ferric phosphate and ferric hydrate filtered off and washed. Calcium was precipitated from the combined filtrate and washings with ammonium oxalate and estimated in the usual way.

The results obtained are as follows:

‡**Methods of A.O.A.C., A under total phosphoric acid in fertilizers, p. 12.**

TABLE XXIII. LIME AND PHOSPHORIC ACID IN DIFFERENT EGGS FROM THE SAME HEN.

Egg No.	Total weight of egg.	Percentage weight of			Per cent. of phosphoric acid (P_2O_5) in			Per cent. of lime (CaO) in		
		Shell.	White.	Yolk.	Shell.	White.	Yolk.	Shell.	White.	Yolk.
17	66.02	13.5	54.4	32.1	.2576	.0185	.8000	39.89	.0269	.....
	63.74	14.2	55.9	29.9	.....	.....	.8306	.....	.....	.1992
	62.16	13.9	55.3	30.8	.3090	.0058	.....	38.23	.0073	....
	62.90	13.1	57.5	29.4	.....	.0083	.4144	.....	.0159	.2276
	64.33	12.9	56.8	30.3	.....	.0069	.6168	.....	.0165	.1684
Average	63.83	13.5	56.0	30.5	.2833	.0099	.6155	39.06	.0167	.1984
360	52.65	14.1	53.2	32.7	.2547	.0165	.7881	36.44	.0312	.1946
	51.26	12.6	52.3	35.1	.3703	.0076	.6810	40.16	.0113	.2054
	49.48	12.9	53.0	34.1	.3375	.0194	.3900	43.17	.0223	.1896
	47.61	12.6	53.0	34.1	.2912	.0060	.5745	40.63	.0109	.1753
Average	50.85	13.1	52.8	34.1	.3134	.0124	.6084	40.09	.0189	.1912
40	54.80	12.4	53.3	34.3	.1909	.0104	.6899	41.98	.0138	.2072
	54.75	12.8	52.6	34.6	.1991	.0102	.7074	41.66	.0135	.1894
	50.94	13.0	50.7	36.3	.2639	.0098	.4475	41.67	.0235	.1697
	57.41	11.9	52.6	35.5	.2256	.0100	.5966	42.24	.0083	.1774
	52.60	13.6	53.9	32.5	.2686	.0268	.4884	41.07	.0223	.....
	55.43	12.6	52.4	35.0	.2155	.0087	.8156	42.18	.0191	.1718
Average	54.32	12.7	52.6	34.7	.2273	.0127	.6242	41.80	.0168	.1831
356	45.14	12.1	52.8	35.1	.3174	.0107	.8120	38.06	.0127	.1781
	43.39	12.0	51.0	37.0	.3352	.0138	.6151	39.99	.0148	.1473
Average	44.27	12.1	51.9	36.1	.3263	.0123	.7136	39.03	.0138	.1627
249	53.63	11.6	59.8	28.6	.2162	.0175	.9062	37.53	.0253	.....
	53.51	12.2	59.7	28.1	.2676	.0121	.8359	40.90	.0403	.2240
	51.07	12.3	60.4	27.3	.2531	.0129	.8055	37.79	.0414	.1984
	43.03	9.6	65.3	25.1	.2289	.0109	.7149	34.69	.0288	.1165
	47.25	13.3	60.7	26.0	.3492	.0142	.5850	40.09	.0381	.1535
Average	49.70	15.8	61.0	27.0	.2630	.0135	.7495	38.20	.0348	.1981
805	50.54	14.8	52.1	33.1	.3146	.0194	.9137	36.37	.0290	.....
	50.60	13.7	55.7	30.6	.3170	.0200	.7888	38.96	.0178	.2161
	49.65	12.3	55.6	32.1	.3600	.....	.7610	38.51	.....	.1799
	47.80	13.1	55.4	31.5	.3520	.0095	.6160	39.53	.0076	.2034
	47.93	12.9	55.1	32.0	.3698	.0096	.5256	41.38	.0248	.1706
	52.60	13.1	56.3	30.6	.3116	.0103	.6609	39.84	.0196	.1783
Average	49.89	13.3	55.0	31.6	.3375	.0138	.7110	39.10	.0198	.1897
696	51.32	11.8	55.6	32.6	.3459	.0257	.9475	39.37	.0237	.....
	55.29	11.5	53.3	35.2	.3832	.0136	.7130	45.48	.0085	.1945
	52.76	12.6	52.8	34.6	.4274	.0127	.4155	41.82	.0209	.2188
	56.29	11.6	54.8	33.6	.3067	.0082	.4936	41.94	.0179	.2188
	50.78	12.6	53.5	33.9	.3203	.....	.8569	41.33	.....	.1927
Average	53.29	12.0	54.0	34.0	.3567	.0151	.6853	41.99	.0175	.2162
517	56.75	11.6	60.3	28.1	.3404	.0187	.8622	38.15	.0261	.....
	68.09	10.5	59.7	29.8	.3295	.0187	.7454	38.66	.0279	.1420
	64.94	12.5	59.0	28.5	.2573	.0092	.....	39.44	.0164	.....
	68.83	11.3	63.8	24.9	.2445	.0103	.4435	37.08	.0229	.1521
	67.78	12.6	64.2	23.2	.2229	.0127	.5569	37.19	.0353	.1471
Average	65.28	11.9	61.4	26.9	.2609	.0139	.5216	38.10	.0257	.1471

The eggs were, with the exception of Nos. 17 and 517, rather under the average weight, and they were not uniform in weight. The greatest variation appears to be in the quantity of shell, although this may be partly due to the fact that, while the white of the egg was drained away as completely as possible, the shell was not washed to remove the last traces of the albumen. This may also account for the slightly high proportion of shell.

Regarding the distribution of the phosphoric acid and lime, it is evident that the yolk contains the largest proportion of the phosphoric acid, and the shell the most lime, while, as would naturally be expected, the white of the egg contains but little of these constituents.

To bring out more clearly the average weight of the eggs and the distribution of the lime and phosphoric acid in the several parts, the average results obtained from the analyses of the different eggs from the same hen are given in the following table:

TABLE XXIV. AVERAGE PERCENTAGE AMOUNT OF LIME AND PHOSPHORIC ACID IN EGGS FROM DIFFERENT HENS.

Egg No.	Total weight of egg.	Percentage weight of			Per cent. of phosphoric acid in			Per cent. of lime in		
		Shell.	White.	Yolk.	Shell.	White.	Yolk.	Shell.	White.	Yolk.
17	63.83	13.5	56.0	30.5	.2833	.0099	.6155	39.06	.0167	.1984
360	50.85	13.1	52.8	34.1	.3134	.0124	.6084	40.09	.0189	.1912
40	54.32	12 7	52.6	34.7	.2273	.0127	.6242	41.80	.0168	.1526
356	44.27	12.1	51.9	36.1	.3263	.0123	.7136	39.03	.0138	.1627
249	49.70	15.8	61.0	27.0	.2630	.0135	.7495	38.20	.0348	.1981
805	49.89	13.3	55.0	31.6	.3375	.0138	.7110	39.10	.0198	.1897
696	53.29	12.0	54.0	34.0	.3567	.0151	.6853	41.99	0175	.2162
517	65.28	11.9	61.2	26.9	.2609	.0139	.5216	38.10	.0257	.1471

The above average results show extremes of from 44.27 to 65.28 grams in the average weight of eggs for different hens, a difference of over 21 grams, and a variation of nearly 10 per cent. in the amount of the white of the egg.

The following table shows the absolute average weights of the different parts of the eggs and of the phosphoric acid and lime in the shell and in the contents, that is, in the yolk and white combined:

TABLE XXV. AVERAGE WEIGHT OF EGGS AND THE PHOSPHORIC ACID AND LIME IN SHELL AND CONTENTS (grams).

Egg No.	No. of analysis.	Average weight of egg.	Average weight of			Average P_2O_5 in		Average CaO in	
			Shell.	White.	Yolk.	Shell.	Contents.	Shell.	Contents.
17	5	63.83	8.64	35.75	19.44	.0248	.1353	3.431	.0436
360	4	50.85	6.58	26.57	17.09	.0205	.1052	2.622	.0378
40	6	54.32	6.91	28.75	18.65	.0157	.1205	2.891	.0337
356	2	44.27	5.34	22.98	15.94	.0174	.1114	2.032	.0285
249	4	49.70	6.35	30.89	14.13	.0222	.1164	2.483	.0312
805	6	49.89	6.65	27.44	15.59	.0223	.1149	2.594	.0349
696	5	53.29	6.40	28.79	18.09	.0229	.1270	2.691	.0431
517	5	65.28	7.65	40.74	17.49	.0196	.1187	2.908	.0364

The above data show that the lime in the contents of the egg varies from a little less than .03 grams to over .04 grams, a very small amount to supply all the lime necessary for the formation of bone in the young chick.

To ascertain the absolute weight of lime in the chick at different stages of the period of incubation, we took eggs from the incubators eleven days and twenty days from the commencement of incubation and determined the amount of lime in the partially developed and fully developed chick. It was soon found that after eleven days of incubation there was practically the same amount of lime in the partially developed chick as there was in the contents of the original egg, but that at the end of the incubation period there was a very decided increase. The eggs used in this part of the work in the June hatch were from the same hens as the eggs analyzed earlier in the season. It was impossible to secure eggs from the same hens for the study of the July hatch, but there is such a wide difference between the average lime content of the fresh egg and that of the young chick at the end of incubation period that it does not seriously affect the results. Unfortunately we were unable to take up the work of determining the lime content of the chicks until so late in the season that we could not study more than one hatch with each incubator. Conseqeuntly, the results obtained are not so reliable and conclusive as if a number of hatches with each method of incubation could have been examined. However, some very interesting facts have been ascertained, and the work will be continued another year. The following table gives the results obtained so far:—

TABLE No. XXVI. WEIGHT OF LIME IN CHICK AT DIFFERENT PERIODS OF INCUBATION.

No. of Egg.	Name of Incubator.	Treatment.	Period of Incubation.	Total Lime (CaO) in contents.	Remarks.
		June Hatch.			
360	Cyphers	Dry	11 days	.0340	
17	"	"	11 "	.0372	
696	"	"	11 "	.0385	
360	"	"	20 "	.1804	
527	"	"	20 "	.1707	
696	"	"	20 "	.1877	
527	Peerless	Dry, hot water machine	11 "	.0390	
527	"	" "	11 "	.0385	
527	"	" "	20 "	.1830	
527	"	" "	20 "	.1267	Apparently weak.
696	"	" "	20 "	.1697	
696	"	" "	20 "	.1830	
40	"	" "	20 "	.1367	
40	"	" "	20 "	.1462	
517	Continuous Hatcher	A small amount of moisture	20 "	.1580	
805	"	" "	20 "	.1462	
805	"	" "	20 "	.1650	
360	"	" "	20 "	.1482	
360	"	" "	20 "	.1822	
517	Hen		20 "	.2017	
517	"		20 "	.1940	
360	"		20 "	.2042	Yolk absorbed, chick half out of shell.
360	"		20 "	.2030	Yolk absorbed, chick picking.
360	"		20 "	.2017	Yolk absorbed.
360	"		20 "	.2000	
40	"		20 "	.1137	Apparently weak, yolk not absorbed, brownish yellow in color, thin and watery.
40	"		20 "	.1197	
40	"		20 "	.1584	
440	"		20 "	.1710	
		July Hatch.			
195	Model	Buttermilk in moisture pan	20 "	.2182	Nearly out of shell, yolk absorbed.
93	"	" "	20 "	.1820	
590	"	" "	20 "	.1860	
502	"	" "	20 "	.2157	Not a strong looking chick hatched.
476	"	" "	20 "	.1227	
164	"	" "	20 "	.2217	
57	Prairie State	Lamp fumes, dry	20 "	.1927	
502	"	" "	20 "	.2202	
590	"	" "	20 "	.1972	
311	"	" "	20 "	.1935	Yolk absorbed.
93	"	" "	20 "	.1985	
84	"	" "	20 "	.2312	
93	"	Dry	20 "	.2150	
311	"	"	20 "	.2157	

TABLE No. XXVII. WEIGHT OF LIME IN CHICK AT DIFFERENT PERIODS OF INCUBATION—*Continued*.

No. of Egg.	Name of Incubator.	Treatment.	Period of Incubation.	Total Lime (CaO) in contents.	Remarks.
57	Prairie State	Dry	20 days	.1950	
476	"	"	20 "	.1817	
693	"	"	20 "	.1717	
157	"	"	20 "	.1792	
476	"	Artifical CO_2, H_2O used as moisture	20 "	.2150	
502	"	" "	20 "	.2262	
311	"	" "	20 "	.2162	
662	"	" "	20 "	.1647	
157	"	" "	20 "	.1982	
84	"	" "	20 "	.1727	
195	"	Disinfected with Zenoleum, H_2O used as moisture	20 "	.2175	
520	"	" "	20 "	.2070	
476	"	" "	20 "	.1955	
590	"	" "	20 "	.2062	
311	"	" "	20 "	.2142	
93	"	" "	20 "	.2052	
662	Hen	....	20 "	.2330	
662	"	....	20 "	.2327	
157	"	....	20 "	.1560	
93	"	....	20 "	.1592	
476	"	....	20 "	.2065	
590	"	....	20 "	.1832	
311	"	....	20 "	.2010	
164	"	....	20 "	.2175	
84	"	....	20 "	.1787	
613	"	....	20 "	.2152	
613	"	....	20 "	.2280	

As each chick was taken from the shell notes were made on its apparent strength. It will be observed that in every case where the chick was marked as "weak" there was a very low absorption of lime, and where it was noted as being unusually strong, there was a large absorption. In this case only decided differences in appearance were noted, but in view of the above result more careful notes will be made in future work. In this connection it may be noted that the lime content of the chicks of the June hatch is lower than that of the July hatch, and Mr. Graham of the Poultry department reports that the chicks of the former month were inferior in vitality.

It is very probable that there is a vital force in the egg which imparts vitality to the chick. For instance, egg No. 360 in nearly every case produced a chick with a high lime content, and egg No. 40 in every case gave a chick with a low lime content, and three of them were noted as being unusually weak.

It is also quite probable that the method of incubation has something to do with the lime content of the chick and possibly with the vitality of the chick. The five chicks from the Continuous Hatcher were, with one exception, low in lime, and it was found that these chicks did not thrive well; while all the chicks from the Prairie State machine, in which there were lamp fumes, were high in lime and were strong and thrifty.

From what has been noted in the two preceding paragraphs, it is quite evident that, in order to get results which shall give a strictly fair and comparable basis on which to compare the merits of different methods of incubation, a series of eggs must be selected such that it is possible to have them appear in each incubator. It is also indicated, when the June and July hatch are compared, that it is quite necessary to select this series of eggs in as nearly the same season of the year as possible, or, in other words, that fresh eggs should be selected for setting.

The following table has been prepared to show the average lime content of the chicks from the different methods of incubation, the amount of carbon dioxide present, the percentage hatch, and the vitality of the chicks as indicated by the percentage number alive at the end of four weeks. In making up the average weight of lime in the chick all amounts below .1600 grams have been discarded; because all chicks containing less than that amount of lime were abnormally weak.

TABLE No. XXVIII. AVERAGE WEIGHT OF LIME IN CHICKS WITH DIFFERENT METHODS OF INCUBATION.

Method of Incubation.	Lime (CaO) content of chick, grams.	Carbon dioxide (CO_2) in 10,000 parts, grams.	Per cent of hatch to fertile eggs.	Per cent chicks alive at end of four weeks cal. to fertile eggs.
June Hatch.				
Cyphers, dry	.1796	8.22	46.1	23.05
Peerless, dry, hot water machine	.1786	9.16	60.2	52.85
Continuous Hatcher. A little moisture	.1736	10.70	58.0	53.0
Hen	*.1966	....	....	....
July Hatch.				
Model, buttermilk	.2047	10.0	65.3	53.09
Prairie State, lamp fumes, dry	.2056	58.21	43.5	36.5
Prairie State, dry	.1930	8.73	49.8	30.07
Prairie State, artificial CO_2 and H_2O used as moisture	.1988	51.42	57.08	49.1
Prairie State, zenoleum and moisture	.2076	7.26	62.0	54.0
Hen	* .2106	....	....	....
Average of hens set during whole season	....	31.93	66.0	55.1

*All eggs used for analyses.

On looking over the above table it will be seen that the average lime content of chicks got by different methods of incubation was lower in June than in July, but in both months the chicks from the hen show the largest amount. There is apparently no connection between the amount of lime absorbed by the chick and the amount of carbon dioxide surrounding the egg during incubation. It has been found that large amounts of carbon dioxide are given off from the egg itself during incubation, and it is very probable that the gas from this source would have a greater dissolving effect upon the carbonate of the shell than that in the surrounding atmosphere. This would be true, because it is acting in the presence of liquid moisture.

While we do not wish to draw any definite conclusion on the comparatively small amount of work which has as yet been done, still we think it worthy of note that there appears to be some relation between the lime content of the chick and its vitality, as indicated by the per cent. of chicks alive at the end of four weeks. Where lamp fumes were used there is an apparent exception to this, as the percentage vitality is low. This may be explained, however, by the fact that wherever this method of incubation has been used the percentage hatch is low; but, at the same time, these chicks are always strong and vigorous. It may also be noted that the Continuous Hatcher gave chicks low in lime, and of a high vitality, yet, while a large percentage of these chicks lived through the four weeks' period, they did not prove to be thrifty, thus further bearing out our previous tentative statement, that there is a marked relationship between lime content and vitality.

We are not prepared, with the insufficient data which we have at hand, to give the above hypothesis with reference to the relationship between lime content and vitality as a definite conclusion, nor to state what conditions in incubation will cause the maximum absorption of lime; but we feel that the point is worthy of further study.

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