Incubation

R V. Vagg

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THE artificial incubation of eggs is not a recent innovation. For many centuries, some species of birds—our mallee-hen being a typical example—have hatched out their eggs by the heat generated in mounds of decaying vegetation. Furthermore, they have shown considerable skill in maintaining the mounds at uniform temperatures throughout the hatching period. A number of reptiles employ similar methods to hatch their eggs, although in these instances there does not seem to be the same need for carefully-controlled temperatures.

Even man is not exactly a beginner in the art of artificially incubating the eggs of the domestic fowl. Thousands of years ago he achieved some success in augmenting the efforts of the broody hens by placing eggs in baskets and maintaining them at a constant and uniform temperature by various ingenious devices.

Later, with increases in world population and the development of poultry-farming into an important primary industry, many types of specially designed incubators were invented and manufactured until today we have a wide variety of models ranging from small 50-egg cabinets to huge machines capable of hatching many thousands of eggs simultaneously.

Although these modern machines embody many ingenious ideas such as automatic temperature controls and methods of regulating humidity and ventilation, their successful operation depends upon an understanding of certain basic principles of incubation. Individual machines—even of identical makes and models—have their own peculiarities, appreciation of which only comes with experience. Even a thorough knowledge of the incubator and the principles of its operation are not sufficient in themselves to ensure maximum success.

We know today that much of the success or failure of a hatch is predetermined before the eggs are placed in the incubator—even before the eggs are laid.

FEEDING IS IMPORTANT

The feeding of the parent birds plays an important part. Incorrect feeding, while it does not appear to affect fertility to any marked degree, can seriously reduce the hatchability of the eggs and can affect the subsequent well-being of the chickens which do hatch out.

Research work carried out in many countries throughout the world has provided us with important information on foods and feeding. We are learning more concerning the importance of vitamins—substances which are present in natural foods and exercise an influence upon nutrition which appears to be out of all proportion to the amounts consumed.

Where animals or birds are feeding under natural conditions with a wide
range of foodstuffs available, they can usually obtain all the vitamins they need. Under domesticated conditions where the range of foodstuffs is limited, they are liable to suffer from vitamin deficiencies unless special care is taken to include vitamin-rich preparations in the rations.

There are a number of vitamins known to science, but some of the most important to the hatcheryman are vitamins A, B₂, D and E. Vitamin A is normally supplied in good succulent greenfeed, but because adequate supplies of suitable greenfeed are not always available when needed, the poultry-raiser would be well advised to augment the greenfeed supplies with a vitamin A supplement.

These supplements are usually prepared from fish-liver oils—a rich source of vitamin A, and an intake of 4,720 international units of this vitamin per 1 lb. of food is regarded as the necessary level for breeding hens.

Experiments have shown that where breeding hens were fed on rations deficient in vitamin A, the survival rate of chicks—hatched from their eggs and fed on a ration that was purposely deficient in vitamin A—was in direct proportion to the degree of deficiency in the hen's rations. This indicates that where the parent birds receive adequate supplies of this vitamin the chicks receive the benefit and are given a good start in life.

Vitamin B₂, riboflavin is present in yeast, young greenfeed, milk powder, liver, egg-yolk, lucerne meal, etc., and is a particularly important ingredient of poultry rations. A deficiency of this vitamin causes paralysis in chicks, with a tendency to walk on the hocks, followed ultimately by a curling of the toes. It also results in lowered egg production, increased embryonic mortality and an increase in the size and fat content of the birds' livers.

Before the advent of synthetic riboflavin supplements poultrymen were limited in their choice of foodstuffs that were rich in riboflavin. Because of the high cost of such foods and because many breeders were unaware of the importance of vitamin B₂, many poor hatches were experienced. Today, synthetic riboflavin is widely used and, with the inclusion of natural sources of riboflavin in the diet of the breeding birds, excellent hatching results have been achieved.

Vitamin D deficiency is not normally a serious problem in this State as most of our breeding birds are exposed to direct sunlight which enables their bodies to synthesize ample supplies of this vitamin. Where birds are intensively housed, the sheds should be designed to admit direct sunlight and, as an added precaution, a vitamin D supplement should be added to the ration. This is particularly necessary during long periods of overcast weather. Vitamin D deficiency causes lowered production, decreased hatchability, weak-shelled eggs and heavy chick mortality. There is evidence to indicate that "sticky hatches" can be caused by vitamin D deficiency.

Vitamin E is necessary for good hatchability. Adequate supplies in the diet of the breeders will help to maintain the reproductive organs in good condition.

It is found in grains, lucerne meal, greenfeed and wheat germ. An insufficient supply can result in high embryonic mortality and heavy losses in young chicks.

Selection of eggs for hatching is of importance. The quality of eggs determines to an extent the kind of chicken that will be hatched. Eggs of sound shell and good texture are the only eggs that should be set. Egg size has a bearing on the size of the chick hatched as there is a correlation between egg size and chick size. Average sized eggs also hatch better than small or large eggs. (In this State the egg set usually weighs two ounces.)

The practice of discarding underweight eggs is a crude method of egg size control. Removal from the flock of the birds laying undesirable size eggs is the logical method of egg size control.

VENTILATION

Many practical hatcherymen do not pay sufficient attention to this very important part of incubation and a few explanatory notes may prove of assistance.

The ventilation of a machine is controlled by inlet and outlet vents the use of which differ in individual makes of incubators and therefore it is important to follow the makers' recommendations until the operator is well aware of the required procedure of the machine concerned.
There is a connection between moisture and ventilation for instance; if the humidity is high the moisture trays can be removed or if no moisture trays are being used humidity can be lowered by opening the ventilators. Both inlet and outlet ventilators should be opened a similar amount to ensure that enough oxygen is replacing the forced out stale air.

As an egg is incubated the amount of carbon dioxide gas produced by the embryo increases by approximately 40 times and this waste gas is eliminated through the shell membrane and shell as incubation proceeds. Naturally oxygen requirements increase and the importance of replacing spent oxygen cannot be over emphasised. For normal embryonic development the surrounding atmosphere should contain from 0.4 to 0.6 per cent. carbon dioxide. If the carbon dioxide content is one per cent. then hatchability is greatly reduced and at two per cent. there is no chance of the embryo surviving. If the carbon dioxide produced by the embryo cannot escape the embryo dies from an accumulation of CO₂ in the blood-stream.

An interesting example is the extent of exchange of gases during incubation of 1,000 eggs for the whole period of 21 days. These eggs will take up 290 cu. ft. of oxygen and give off 150 cu. ft. of carbon dioxide.

During a power failure it is generally thought that chicks in the process of incubation are killed by a concentration of heat at the top of the incubator, and a lack of heat on the lower trays; this however is not so. Whilst the heat falls the production of carbon dioxide does not and the gas accumulates rapidly very often weakening the embryos or if the stoppage is for a long period killing them.

It is therefore important to keep the fans operating by some mechanical process during a power breakdown. Another important step is to open the vents sufficiently to allow the CO₂ to escape. The best form of insurance is a power plant where electricity is available to keep both the fans turning and a constant supply of heat.

An important point is that an insufficient supply of oxygen will result in dead germs and malformed chicks.

**TEMPERATURE**

The optimum hatching results are obtained when the temperature is at 100° F., oxygen concentration 21 per cent., carbon dioxide concentration less than 0.5 per cent. and air movement past the eggs 12 c.m. per minute.

Incubator operators may, after some observations, find that a maximum hatching heat of 101° F. gives best results. This is probably due to a 1° variance in the thermostatic mechanism which controls maximum and minimum heat. That is if the minimum heat was 100° F. and the maximum heat 101° F. then the approximate average heat would be 100½° F.

Whilst this ½° F. extra heat may not seriously affect hatch results the maximum results are possibly not being obtained.

If the same machine was allowed a maximum heat of 100½° F. and a minimum of 99½° F. the optimum hatching heat of 100° F. would be obtained.

Different incubators have varying degrees of temperature error; if however, in any machine the variance is more than 1° F. corrective measures should be applied to the thermostatic temperature controls.

Temperatures greater than required give rise to an increased growth of the embryo and considerably increased liberation of carbon dioxide. Dead germs and abnormal chickens are bound to result if this high temperature incubation is practised.

Temperatures lower than required have an opposite effect. Early embryo mortality will occur and chicks will be slow to hatch.

The operator should have the incubator thermometers checked regularly to avoid error through faulty instruments.

**HUMIDITY**

In the incubation of eggs humidity plays a most important part and too much care cannot be given to this particular incubation phase.

It is possible to hatch chickens without the inclusion of any moisture save that introduced by the eggs themselves. In this case eggs are placed in the incubator, ventilators all closed in the setting compartment and the machine stays this way except for turning until the eighteenth
day when they are transferred to the hatching compartment. It can be seen that whilst this may provide sufficient moisture there is one element of danger in regard to the lack of oxygen.

Seasonal differences have an effect on the humidity present in the atmosphere and therefore exert an influence on the concentration of moisture in the incubator. It well may be that these atmospheric conditions provide sufficient humidity without the inclusion of additional moisture to the incubator and in such a case additional moisture would prove harmful.

A note of caution is that this is not usually the case although it does occur and is usually brought about by an insufficient flow of air throughout the incubator which of course is detrimental to hatching.

Relative humidity refers to the ratio between the actual amount of water vapour in the atmosphere and the amount of water the atmosphere is capable of holding.

As the temperature rises the atmosphere is capable of absorbing more moisture, therefore at 50°F, 1,000 cubic ft. of air is capable of holding 0.587 lb. of water, at 100°F the same quantity of air can hold 2.857 lb. of water. If at 100°F, 1,000 cubic ft. of air is found to contain 1.800 lb. of water which is equal to 63.003 of its capacity the relative humidity is 63.003 per cent.

For the measurement of humidity a wet bulb thermometer and a dry bulb thermometer are used. The wet bulb thermometer is simply an ordinary thermometer which has a cotton wick enclosing the mercury bulb with the other end of the cotton wick immersed in water. The water travels along the wick and encases the mercury bulb. Air from the incubator fans passes over the wet bulb and a reading can be made on the column of the graduated thermometer.

It must be clearly understood that this reading is only a wet bulb reading and is not a relative humidity reading. This is obtained by calculations obtained from wet and dry bulb readings.

The following table contains readings obtained from the wet bulb thermometer and converted by this process to degrees of relative humidity.

In incubation there is a drying out process and the size of the air cell increases as incubation proceeds. This is of course necessary but too much drying out is harmful. The inclusion of water assists

<table>
<thead>
<tr>
<th>Wet Bulb Thermometer Reading</th>
<th>Percentage of relative Humidity when Dry Bulb thermometer reading is at</th>
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</thead>
<tbody>
<tr>
<td>Degrees</td>
<td>98 Deg.</td>
</tr>
<tr>
<td>94</td>
<td>86</td>
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<tr>
<td>93</td>
<td>85</td>
</tr>
<tr>
<td>Matching Range</td>
<td>92</td>
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<td>78</td>
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<td>90</td>
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<td>86</td>
<td>73</td>
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<td>85</td>
<td>72</td>
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<tr>
<td>Setting Range</td>
<td>84</td>
</tr>
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<td>83</td>
<td>70</td>
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<tr>
<td>82</td>
<td>69</td>
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<tr>
<td>81</td>
<td>68</td>
</tr>
<tr>
<td>80</td>
<td>67</td>
</tr>
</tbody>
</table>

In creating a moisture laden atmosphere and too rapid drying is prevented.

The amount of relative humidity is controlled by ventilation, as stated in the section Ventilation, and opening of the ventilators lowers the incubator humidity, as the outside air usually contains less moisture than that inside the machine.

To increase humidity close the ventilators as necessary but remember the necessity of air circulation.

It will be noticed that a setting range and hatching range has been suggested and until the operator is familiar with the workings of his incubator, hatching within these ranges will prove satisfactory.

Another type of humidity gauge is the hygrometer. This instrument works on the principle that a certain length of catgut or hair contracts or lengthens respectively when it becomes wet. As the material used becomes dry or wet the decrease or increase of length is magnified by a suitable mechanism which moves a pointer giving a reading of relative humidity direct.

This instrument besides being costly, is not reliable and needs constant recalibration.

Eggs from the lighter breeds such as White Leghorns seem to require a lower

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RELATIVE HUMIDITY TABLE

<table>
<thead>
<tr>
<th>Wet Bulb Thermometer Reading</th>
<th>Percentage of relative Humidity when Dry Bulb thermometer reading is at</th>
</tr>
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<tbody>
<tr>
<td>Degrees</td>
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<td>72</td>
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<td>Setting Range</td>
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<td>82</td>
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</tbody>
</table>
humidity than eggs from heavier breeds and it is suggested that a wet bulb reading of 80° in the setting compartment and 90° in the hatching compartment will better suit this breed. For heavier breeds a wet bulb reading of 83° in the setting compartment and 93° in the hatching compartment seems to be optimum.

**GENERAL HATCHING PROCEDURE**

In most cases the manufacturers directions are given and should be followed until the operator becomes skilled in incubator operations.

The eggs are first placed on trays small end down and it is important to observe this rule. Hatching results can be seriously affected if the eggs are set with the small end uppermost. This is because the air cell is situated at the larger end of the egg and the chickens head must form at this point if it is to hatch. Let us assume that the incubator has previously been warmed to the correct temperature required for setting and the required humidity has been reached.

When placing the eggs in the incubator it is advisable to adopt the practice of first switching the machine off. Quite a few fingers have been lost through not observing this rule, and apart from this much of the valuable humidity will be lost.

If the operator intends to hatch only once weekly then the first hatch is dispersed evenly throughout the incubator and then the second the next week until the machine is running at full capacity. It is not advisable to set the eggs in a wall one week and then in a wall the second week as cold spots can be created in the machine and consequently the eggs take a greater time to warm up than when even distribution, is practiced.

The hatch from each week must be clearly distinguishable from any other to enable identification at the time of transfer to the hatching compartment.

The eggs are then incubated for 18 days in the setting compartment and throughout this period correct temperature and humidity levels must be sustained.

It is necessary to turn the eggs night and morning at regular times.

Most hatcherymen candle the eggs at the six and 18 day periods. All clears and dead shell are removed. For further information re candling see section entitled Candling the eggs.

On the 19th day the eggs are then transferred to the hatching compartment where all the necessary humidity and temperature adjustments have been made. The eggs remain in this compartment for the remaining three days and are no longer subjected to turning.

During this hatching period close watch should be kept on the temperature. As the animal heat increases so does humidity and temperature and therefore extra ventilation is needed. This is provided by opening up the vents sufficiently to counteract the increase in humidity and temperature of the inlet and outlet vents. The inlet and the outlet vents should be opened an equal amount.

On the 21st day the heat may increase beyond the control of the vents and the thermostatic control. This is because the heat being generated has increased to a pitch beyond the control of these two mechanisms. Should this condition arise the hatched chickens must be removed to avoid overheating and eventual death of the chicks. It will probably be found that the hatch is complete.

This increase in heat may arise before the 21st day as sometimes occurs in the summer hatching period, then it may be necessary to open the machine to avoid the overheating of the chicks.

Those intending to hatch during the summer period should take precautions to keep the incubator room at a set controlled temperature.

When the hatch is complete the chicks should be taken off and placed in good clean chick boxes and stacked in racks in such a manner that they will not overheat and suffocate. Chicks in boxes should never be stacked in the sun. After sexing, the chicks are disposed of to the clients or to the hatcherymen's brooders.

**STORING EGGS FOR INCUBATION**

Hatcherymen may receive the eggs from the breeders twice weekly or once weekly. They may for some reason wish to store eggs for a longer period to cover a large order.

It is well known that the age of an egg affects its hatchability but the environment under which hatching eggs are stored is of greater importance.
### Incubation Practices

**Incubation Chart for Chicks**

*(T. S. Townsley, Hatchery Tribune, Jan., 1942)*

<table>
<thead>
<tr>
<th>Symptoms of Trouble</th>
<th>Probable Causes</th>
<th>Suggested Remedies</th>
</tr>
</thead>
</table>
| **Eggs Clear**      | 1. Improper mating.  
2. Eggs too old.  
4. Birds too closely confined. | 1. Eight to ten vigorous males per 100 hens.  
2. Eggs set within 10 days after date laid.  
| **Eggs Candling Clear** | 1. Incubator temperature too high.  
2. Badly chilled eggs.  
3. Breeding flock out of condition (frozen combs, chicken pox, etc.).  
4. Low vitamin ration. | 1. Watch incubator temperatures.  
2. Protect eggs against freezing temperatures.  
3. Do not set eggs from birds with frozen combs or with contagious diseases.  
4. Feed fish oil and alfalfa. |
| **Dead Germs**      | 1. Wrong incubation temperature.  
2. Lack of ventilation.  
2. Plenty of fresh air in incubator room and good ventilation of machines.  
3. Feed yellow corn, milk, alfalfa meal and fish oil. |
| **Chick Fully Formed** | 1. Improper turning.  
2. Heredity.  
3. Wrong temperature. | 1. Turn eggs four times daily.  
2. Select for high hatchability.  
3. Watch incubator temperature. |
| **Eggs Pipped**     | 1. Low average humidity.  
2. Low average temperature.  
3. Excessive high temperature for short period. | 1. Keep wet bulb temperature from 85 to 90 degrees.  
2. Maintain proper temperature throughout hatch.  
3. Guard against temperature surge. |
| **Sticky Chicks**   | 1. Eggs dried down too much.  
2. Low humidity at hatching time. | 1. Proper operating temperature.  
2. Increase ventilation and lower humidity. |
| **Sticky Chicks**   | 1. Low average temperature.  
2. Small air cell due to too high average humidity. | 1. Careful operation.  
2. Proper humidity. |
| **Rough Navels**    | 1. High temperature or wide temperature variations.  
2. Low humidity. | 1. Set nothing under 23 oz. eggs.  
2. Maintain proper humidity.  
3. Watch incubator temperature. |
| **Chicks Too Small**| 1. Small eggs.  
2. Low humidity.  
3. High temperature. | 1. Proper temperature.  
2. Adequate ventilation. |
| **Large Soft Bodied Chicks** | 1. Low average temperature.  
2. Poor ventilation. | 1. Careful fumigation of incubators between hatches. |
| **Mushy Chicks**    | 1. Navel infection in incubator. | 1. Proper temperature.  
2. Careful moisture control. |
| **Short Down on Chicks** | 1. High temperature.  
2. Low humidity. | 1. Proper control of temperature. |
| **Hatching Too Early** | 1. Temperature too high. | 1. Proper operation. |
| **Draggy Hatch**    | 1. Temperature too high. | 1. Watch temperatures—check thermometers. |
| **Delayed Hatch**   | 1. Average temperature too low. | 1. Careful flock culling.  
3. Watch temperatures.  
| **Crippled Chicks** | 1. Cross beak—Heredity.  
3. Crooked toes—temperature.  
| **Excessive Yellow Colour on Chicks** | 1. Too much formaldehyde—fumigation. | 1. Too much formaldehyde—fumigation. |

Compiled by T. S. Townsley.
There is conflicting information regarding the length of time it is safe to store eggs for hatching. Temperatures and the quality of egg have a bearing on the holding time.

The following is the result of an actual experiment.

**EFFECT OF AGE AND TURNING ON HATCHING EGGS**

<table>
<thead>
<tr>
<th>Age in days</th>
<th>Group 1</th>
<th></th>
<th>Group 2</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Per cent. Hatched</td>
<td>Per cent. Hatched</td>
<td>Per cent. Hatched</td>
<td>Per cent. Hatched</td>
</tr>
<tr>
<td></td>
<td>Turned all eggs</td>
<td>Not turned all eggs</td>
<td>Turned all eggs</td>
<td>Not turned all eggs</td>
</tr>
<tr>
<td>1 to 10 days</td>
<td>44.5</td>
<td>39.5</td>
<td>55.1</td>
<td>48.6</td>
</tr>
<tr>
<td>11 to 20 days</td>
<td>34.3</td>
<td>35.0</td>
<td>41.7</td>
<td>41.6</td>
</tr>
<tr>
<td>21 to 28 days</td>
<td>18.6</td>
<td>18.1</td>
<td>17.9</td>
<td>24.5</td>
</tr>
</tbody>
</table>

This supports the contention that hatching eggs should not be held longer than 10 days before setting. It has also been found that there is little need for turning up to 7 days of age, however after this period it is desirable to turn the eggs daily.

It would seem the most desirable temperature for holding eggs is between 50° F. and 65° F. Lower temperatures also have an adverse effect on hatching.

The presence of high relative humidity during the storing of eggs may also increase hatchability.

**CANDLING THE EGGS**

Candling or testing the eggs is a relatively simple operation and in most of the larger hatcheries is carried out on the last 5 days before transferring to the hatchibator.

However if the hatcheryman has decided to sell the incubator clears to a cake making concern the eggs should be candled after approximately 6 days of incubation.

Also it is not wise to allow the clears and dead germs to remain in the incubator for the full period for dead germs are prone to go rotten and burst within the incubator and contaminate it. Clears take up room which is valuable to the chicks when they commence to hatch. A special slit type candling machine is used and the trays filled with eggs are passed over the opening in the candling machine which is lit by electric globes, the eggs to be rejected show up quite clearly.

The detection of fertile eggs, after a few days of incubation, using a source of illumination from beneath the eggs. (Factors affecting incubation, British Oil & Cake Mills Ltd.)

In small establishments it is usual to use a small candling lamp. This is passed over the top of the eggs by the operator and all rejects removed as they are detected (see below).

The rejected eggs consist largely of infertiles and dead germs. Apart from these, eggs with cracked and porous shells should be removed.
New laid egg. Note small air cell.

A fertile egg showing embryonic development after seven days under incubation.

Infertile egg after seven days in incubation.

Embryonic development at fourteen days (nearly all opaque).

Egg showing a broken yolk. This will not produce a living chicken even though some embryonic development may have taken place.

Embryonic development as seen at nineteen days. Quite opaque except for the air space marked 1 to 19 days.

(After J. P. C. Smith "Incubation"—New South Wales Department of Agriculture.)
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<table>
<thead>
<tr>
<th>Nominal Capacity</th>
<th>Steel Silo</th>
<th>Steel Earth Ring</th>
<th>Steel Floor (Opt. Extra)</th>
<th>(Opt. Extra)</th>
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</thead>
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<tr>
<td>3,700</td>
<td>£349</td>
<td>£31/10/-</td>
<td>£47</td>
<td>£47</td>
</tr>
</tbody>
</table>

*The 500-Bushel silo is not equipped with a door. Price includes steel floor.

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Please mention the "Journal of Agriculture of W.A." when writing to advertisers
To leave the subject of candling here would leave the reader somewhat puzzled as to the meaning of infertile or dead germ. An infertile egg is one that after several days of incubation still shows no sign of embryonic development, and a dead germ is one that has begun to develop but has died at an early stage, (usually denoted by a thin ring of blood which passes around the internal circumference of the egg, approximately at the base of the air cell.)

SANITATION OF ROOM AND STAFF

Today large masses of chickens are hatched together and thus the spread of disease amongst these masses could be considerable if careful attention is not given to sanitation within the hatchery. The eggs entering the hatchery, the attendants, chick boxes and equipment are all possible sources of disease. Omphali­tis, CRD, etc., are diseases that once contracted result in ultimate death of the chicken or severely retard its growth and these diseases can be introduced into the hatchery if proper care is not taken.

It is therefore apparent that to safeguard his reputation and protect his chick buyers the hatcheryman cannot spare any pains in the sanitation programme of his hatchery.

Appearance of the staff will be enhanced if a clean dustcoat is worn and in the hatchery will partly assure that disease introduction through attire is limited.

Attendants should not be allowed to enter the hatchery in outdoor working clothes.

A clean hatchery, painted and free of dust not only create a good impression but could help control disease.

Sick chickens which are returned to the hatchery by customers should not be allowed to enter the incubator building itself but should be examined in a separate building. If it is deemed necessary live specimen chicks should be forwarded to the Department of Agriculture for post mortem examination.

Used chick boxes should be well fumigated and stored in a room separate from the hatchery premises.

Eggs from suppliers should also be packed in a special packing room.

Brooders within the hatchery should always be well disinfected and used only for display purposes.

The chicken sexer should always have access to a supply of disinfected water to wash his hands.

A tray of disinfectant outside the incubator room door to control the introduction of disease on shoes should also be provided.

Dust should be kept at a minimum and a light spreading of disinfected water on the incubator room floor daily is advisable.

The hatching compartment should be thoroughly scrubbed after each hatch and the necessary fumigation programme followed.

Hatchery equipment such as incubator trays, battery brooders, etc., should always be kept completely sterilised. One of the better class sterilising agents of which there are quite a few on the market should be used to sterilise the equipment per medium of a good scrubbing. The hatchery floor should also be scrubbed periodically with the sterilising agent preferred.

FUMIGATION

Because of the possibility of bacteria entering the machine via the egg, etc., it is necessary to adopt some precautionary measures to combat these germs. This is done by carrying out a fumigating process with formaldehyde gas.

At this point it is advisable to add a word of caution. Fumigation should not be carried out between the 24th and 96th hour after setting, as, during this period, the susceptibility of the embryo to adverse conditions is at its greatest and some embryonic mortality could occur.

Outside this period fumigation can be carried out at any time. There is no advantage in fumigation after hatching and is certainly not advisable after the chicks have commenced to dry out.

Incubator operators who are obliged to incubate and hatch in the same compartment should pay close attention to fumigation and avoid fumigating during the danger period.

It is desirable that the period of fumigation be as long as possible.
(1) Preparing the fumigants. The bottle contains formalin and the large container on the right holds permanganate of potash. The operator is placing the permanganate into the receptacle to be used for mixing the fumigants.

(2) A measure of formalin has been added to the permanganate and the fumes may be seen rising. This was done for demonstration purposes only. In practice, the mixing would be done in the incubator so that none of the fumes would be wasted, and a porcelain receptacle would be used in preference to the tin.

(3) Illustrating the actual fumigation of the setting compartment while the eggs are in the machine. Formalin is about to be added to the permanganate in the tin.
Procedure for Fumigation.

(1) Calculate the size of the inside of the incubator making no allowance for space occupied by eggs or trays. To do this, measure the length, breadth and height of the interior of the compartment in feet and multiply the three figures together.

(2) Measure out the proper quantities of formalin and potassium permanganate according to the size of the incubator. It may be more convenient to have these amounts put up by the chemist from whom they are purchased.

(3) Place the potassium permanganate in a wide china, earthenware or enamel basin. This should be sufficiently wide and deep to prevent splashing as some frothing occurs when the two ingredients are mixed. The bowl is then placed in a level position on the floor of the incubator, near the door.

(4) Close the vents and bring the temperature and humidity to the correct levels for fumigation (dry bulb 100°F, wet bulb 90°F).

(5) When both temperature and humidity are correct shut off the motor, open the door, add the formalin to the potassium permanganate in the basin, close the door and turn the motor on immediately.

(6) Allow the fumigation to proceed for the appropriate time (approx. 30 minutes).

(7) Remove the bowl containing the used material, leave doors and vents open and run the motor for about five minutes to get rid of the formaldehyde.

(8) Shut doors and return machine to its normal setting.

The above instructions are written primarily for large forced-draught machines and some adaptation may be required for use in smaller incubators. In still-air models considerable variation is likely to occur in the concentration of gas in different parts. For this reason the amounts of formalin and potassium permanganate should be increased slightly in order that the maximum lethal concentration will be obtained throughout.

Unlike forced-draught machines the hot-air types have a different system of ventilation and as these systems vary considerably according to the make and size of the machine, it is essential that all ventilators be closed while fumigation is being carried out. The temperature of hot-air machines should be maintained at 103°F and the wet bulb at 93°F during the fumigation period.

Internal Sizes of some Commonly Used Incubators

(1) "Lanyon" still air, 120 egg capacity: approx. 2 ft. x 2 ft. x 1 ft = 4 cubic feet.

(2) "Multiplo" 1,350 egg capacity: 3 ft. x 2½ ft. x 4 ft = 30 cubic feet.

(3) "Gamble" 4,000 capacity—

   (Setting compartment) = 3 ft. x 5 ft. x 5½ ft. = 79 cubic ft (approx.).

   (Hatching compartment) = 3 ft. x 2½ ft. x 5¼ ft. = 39 cubic ft. (approximately).

Estimation of Ingredients Required for Fumigation

Example:

Inside measurements of incubator: 3 ft. x 6 ft. x 5 ft. = 90 cubic ft.

Using 75 c.c. formalin and 50 grammes potassium permanganate per 100 cubic feet 90 c. ft = 9/10 of 100 c. ft.

Amount of formalin required = 9/10 x 75 = 67.5 c.c.

Amount of pot. permang. required = 9/10 x 50 = 45 grammes.

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Note.—To convert c.c. to fluid ounces or grammes to ounces divide by 30. This will give an approximately correct result, e.g., 75 c.c. = 75/30 = 2½ fl. oz. (approx.).

Ingredients required for incubators of various sizes, using 75 c.c. formalin and 50 grammes potassium permanganate per 100 cubic ft. (if 150 c.c. formalin and 100 grammes potassium permanganate are used, double these quantities will be required):

<table>
<thead>
<tr>
<th>Incubator space</th>
<th>Formalin required</th>
<th>Pot. permang. required</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 cubic ft.</td>
<td>3 c.c.</td>
<td>2 grammes</td>
</tr>
<tr>
<td>30</td>
<td>22.5 c.c.</td>
<td>15</td>
</tr>
<tr>
<td>40</td>
<td>30 c.c.</td>
<td>20</td>
</tr>
<tr>
<td>50</td>
<td>40 c.c.</td>
<td>40</td>
</tr>
<tr>
<td>120</td>
<td>90 c.c.</td>
<td>60</td>
</tr>
<tr>
<td>175</td>
<td>131 c.c.</td>
<td>87.5</td>
</tr>
</tbody>
</table>

Fumigation Methods.

It is recommended that incubators be fumigated with formaldehyde gas. Formaldehyde is obtained as a 40 per cent. solution in water, known as formalin. The gas can be produced from this solution by (a) simple evaporation or (b) by mixing with potassium permanganate.

(a) In the former method, pieces of cheese-cloth about one yard square are soaked in the required amount of formalin (40 c.c. or approximately 1½ fluid ounces per 100 cubic feet in incubator space). These are then hung up near the fan so that evaporation takes place in a few minutes. In actual practice this method does not seem to be quite as efficient as the following alternative method which depends on the rapid generation of formaldehyde gas when formalin is mixed with potassium permanganate.

(b) For routine fumigation use 75 c.c. (2½ fluid ounces) of formaldehyde and 50 grammes (1½ ounces) of potassium permanganate per 100 cubic feet of incubator space. The fumigation should be continued for 30 minutes.

If an outbreak of disease occurs in the chickens it would be advisable to use a much larger amount of gas for at least one fumigation. For this, 150 c.c. (5½ fluid ounces) of formalin and 100 grammes (3½ ounces) of potassium permanganate are recommended per 100 cubic feet.

It has been demonstrated that even the largest amount of gas mentioned above has no significant effect on hatchability when fumigation is prolonged for 30 minutes, provided the eggs do not already have some inherent fault such as weak germs and providing they have not been stored for a long period prior to incubation. In these latter cases the death rate of the embryos is increased somewhat.

The exact amount of each ingredient should be used. To use an insufficient amount of potassium permanganate means that the full amount of gas is not produced, while an excess of potassium permanganate is merely wasteful as it is not used.

Temperature and Humidity.

For efficient management of incubators the operator should be familiar with the use of wet bulb thermometers which are...
used in conjunction with the ordinary dry bulb thermometer to determine relative humidity.

Fumigation is best carried out at a temperature of about 100° F. A high degree of humidity is desirable within the incubator for best results. During fumigation the relative humidity should be at least 68 per cent. This degree of humidity is obtained when the dry bulb thermometer reads 100° F. and the wet bulb thermometer reads 90° F.

In most large machines, closing the vents is all that is required to increase the humidity. In others it may be necessary to add additional water either in trays or by placing wet bags on the incubator floor. These should be removed as soon as the fumigation has been completed.

In conclusion, it must again be stressed that fumigation is only one step in the control of hatchery diseases.

Emphasis must be placed on efficient pullorum testing of adult poultry as the main line of defence. Good all-round poultry husbandry will effectively reinforce these measures.

INTERESTING ODDMENTS

Incubation Periods.

Hens, 21 days; ducks, 28 days; ducks Msc., 35–37 days; turkeys, 28 days; geese, 28–30 days.

EVENTS IN EMBRYONIC DEVELOPMENT

(Romanoff, 1931)

Before egg-laying:
- Division and growth of living cells
- Segregation of cells into groups of special function (tissues)

Between laying and incubation:
- No growth; stage of inactive embryonic life

During incubation:

First day:
- 16 hours . . . First sign of resemblance to a chick embryo
- 18 hours . . . Appearance of alimentary tract
- 20 hours . . . Appearance of vertebral column
- 21 hours . . . Beginning of formation of nervous system
- 22 hours . . . Beginning of formation of head
- 24 hours . . . Beginning of formation of eye

Second day:
- 25 hours . . . Beginning of formation of heart
- 35 hours . . . Beginning of formation of ear
- 42 hours . . . Heart begins to beat

Third day:
- 60 hours . . . Beginning of formation of nose
- 62 hours . . . Beginning of formation of legs
- 64 hours . . . Beginning of formation of wings

Fourth day . . . Formation of reproductive organs and differentiation of sex

Fifth day . . . Beginning of formation of beak

Sixth day . . . Beginning of formation of feathers

Eighth day . . . Beginning of formation of beak

Tenth day . . . Beginning of hardening of beak

Fourteenth day . Appearance of scales and claws

Fourteenth day . Embryo gets position suitable for breaking the shell

Sixteenth day . . Scales, claws, and beak becoming firm and horny

Seventeenth day . Beak turns towards air cell

Nineteenth day . Yolk sac begins to enter body cavity

Twentieth day . Yolk sac completely drawn into body cavity

Embryo occupies practically all the space within the egg except the air cell

Twenty-first day . Hatching of chick
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