HATCHERY

ROSS TECH

Investigating Hatchery Practice

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ROSS

Aviagen provides customers with detailed product Performance Specifications, Management Manuals and Nutrition Specifications as a basis for managing their flocks.

This document, produced by Aviagen's Technical Transfer Department, is one of an ongoing series of Ross Techs. The Ross Techs covering hatchery practices focus on the topic of hatchery monitoring and management. They give background and practical details on aspects of hatchery and incubation practice, and aim to improve understanding of the principles of successful hatchery management for good hatchability and chick quality.

Good practice in egg and hatchery management will maximise the hatchability of eggs produced by a flock, and will ensure good chick quality and the best possible start for good performance of the progeny. The principles described here have a broad relevance to most regions and production strategies.

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Dr Steve Tullett is a Consultant for Aviagen specialising in incubation and fertility. Steve is a graduate from the University of Bath, England, where he received his BSc and PhD degrees.

He spent ten years at the AFRC's Poultry Research Centre, now the Roslin Institute, near Edinburgh, Scotland, where he conducted studies in energy metabolism, incubation physiology and egg quality.

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After this, he joined Bernard Matthews Foods Ltd with responsibility for advice on turkey and chicken production in England and Hungary.

He joined Ross Breeders (now part of Aviagen) in Edinburgh as Worldwide Technical Services Co-ordinator. Later he rejoined Bernard Matthews Foods Ltd as their Research Manager, where he had special responsibility for technical matters in Europe and Asia. Steve then took the position of Technical Director for Anitox, a worldwide supplier of bacterial and mould control products for the animal feed industry.

In March 2006, Steve founded Cornerways Poultry Consultants Ltd. His 30 years of experience in the poultry industry and colleague network enables him to provide technical inputs into many aspects of poultry production around the world.

Steve has published over 40 scientific research papers and book chapters, reviews poultry papers and books for scientific journals and is a regular presenter at many seminars and conferences.

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Executive Summary

In this document the biological targets which need to be met in the chicken hatchery to ensure good hatchability and chick quality, and how to assess, measure and incorporate these into routine quality control programmes are described.

Several traits should be recorded and monitored on an ongoing basis within the hatchery, including fertility (a number of different ways to identify infertile eggs are described) and embryonic mortality patterns. Accurate identification of fertility is important if the appropriate corrective action is to be taken when candling clears are high. The pattern of embryonic mortality and the identification of certain abnormalities and malpositions will provide an indication of when incubation conditions are inappropriate. Targets for these traits are given for different flock ages for both detailed and simplified break-outs.

The document also covers methods for monitoring egg weight loss to transfer and chick yields at take-off, which should be around 12% and 67% of the fresh egg weight respectively. Monitoring egg surface temperatures is also important as this will show when the eggs come up to temperature too slowly (increasing early dead mortality) and if they become overheated in the later stages of incubation (increasing late mortality and culls). Monitoring egg surface temperatures will also provide useful information for changes in future incubation temperature programmes.

Regular monitoring of the biological outcomes of incubation is vital for identifying when incubation conditions are below optimal and in determining what needs to be changed in order to improve hatchability.

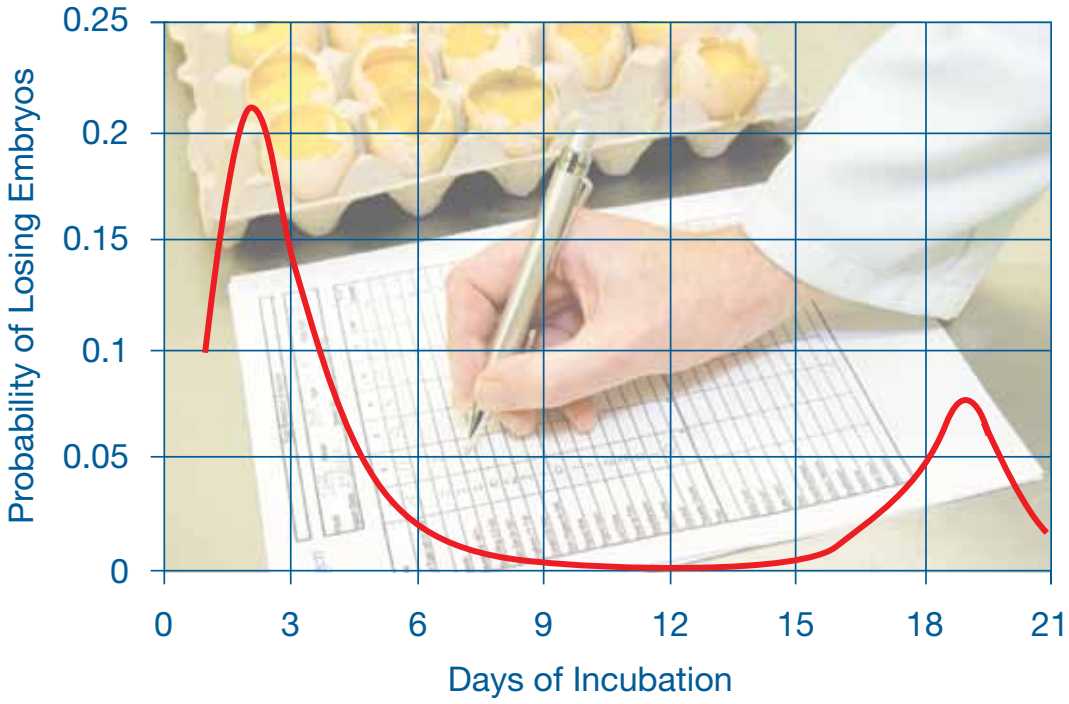
Introduction

To achieve good hatchability and chick quality, fertile eggs need careful management from the time they are laid. Environmental conditions during egg collection, egg shell disinfection, transport, pre-storage incubation, storage, pre-warming or during incubation are all important. Inappropriate treatment can result in depressed hatchability, change the pattern of embryo mortality and may also affect post-hatching performance. The investigative procedures described in this Ross Tech can be used in the routine quality control programme in the hatchery to benchmark hatchability levels and the nature of embryo losses against accepted best practice standards. Other information is provided that may be useful when troubleshooting hatchery problems.

Routine Quality Control in the Hatchery

Not all fertile eggs hatch. Even eggs from flocks which are hatching well follow a predictable embryonic mortality pattern. Mortality is usually higher in the first few days of incubation when all the organ systems are forming in the embryo. The middle period of incubation is essentially a period of rapid growth and is usually characterised by very few embryo deaths. Mortality rises again in the last few days of incubation when the embryos turn towards the air cell in order to ventilate their lungs, redirect their blood circulation, retract their yolk sacs and finally attempt to hatch. **Figure 1** shows a normal pattern of mortality in a flock which is hatching well.

Figure 1: Normal pattern of embryo losses during incubation. Based on Kuurman *et al*. (2003). Poultry Science, 82:214–222



Gathering data on fertility, hatchability and the time and nature of embryo losses relative to flock age is an important part of the routine quality control programme in any hatchery. Hatchery workers should be trained to gather the relevant data. They need to know how to recognise infertility and egg contamination, and to identify the stage of development reached by embryos that failed to hatch. They also need to recognise embryonic malformations and malpositions.

Accurate data allows hatchery performance to be compared against best practice standards and provides the baseline for investigating hatchability problems when they arise. By establishing where deviations from the normal pattern of embryonic mortalities are occurring, it is usually possible to identify where the problem lies.

For example:

- Losses in the first week of incubation tend to be due to problems arising before incubation (i.e. on farm, in transport or in storage).

- Losses in the second week of incubation are most likely to arise from contamination or faults in nutrition, although occasionally inappropriate setter conditions may be involved.

- Losses in the final week of incubation are usually associated with inappropriate incubator conditions.

Procedures for Monitoring Hatchery Performance

Procedures and skills that can be used in routine hatchery quality control, when carrying out a hatchery investigation and when troubleshooting hatchability problems include:

- Assessing fertility
  – breaking out fresh unincubated eggs
  – breaking out partially incubated eggs
  – breaking out incubator “clears”

- Examining the hatch debris
  – recognising developmental stages and malformations
  – recognising the normal hatching position and malpositions
  – recognising egg contamination

- Monitoring weight loss during incubation
  – egg weight loss to 18 days
  – chick yield

- Monitoring temperatures
  – monitoring the temperature exposure profiles of eggs
  – measuring eggshell temperatures during incubation

- Monitoring the hatch window

Assessing Fertility

Breaking Out Fresh Unincubated Eggs

After fertilisation, the egg spends about a day travelling down the oviduct. During this time the number of cells in the blastoderm increases to about 60,000. The characteristic organisation of these cells just under the yolk sac membrane makes it possible, with practice, to distinguish between an infertile blastodisc and a fertile blastoderm when breaking out fresh unincubated eggs.

The infertile blastodisc is a small dense white area about two mm across (**Figure 2**). The white area is usually of an irregular shape and is never perfectly round. It is surrounded by a clear, roughly circular area up to four mm in diameter which appears to be filled with bubbles, which are in fact globules of yolk (**Figure 3**).

Figure 2: A fresh unincubated infertile egg as it appears to the naked eye

Figure 3: Magnified blastodisc of a fresh unincubated infertile egg

The fertile blastoderm, by contrast, is larger (4-5 mm diameter) than the dense white area of the infertile blastodisc and is always uniformly round (**Figure 4**). The usual form is that of a white ring or “doughnut” with a clear centre (**Figure 5**). In some eggs there may be a small white spot in the centre of the ring. Occasionally eggs are seen which were laid with the blastoderm at an earlier stage of development, when it will appear as a solid white, perfectly round disc.

Figure 4: A fresh unincubated fertile egg as it appears to the naked eye

Figure 5: Magnified blastoderm of a fresh unincubated fertile egg showing organised ring structure

Natural variation in appearance occurs within each category and undue emphasis should not be given to small differences. It is important to practice recognising fertility in fresh eggs, initially by using eggs from flocks known to have a highly fertility status and infertile eggs from a commercial table egg laying flock. Eggs should be opened by removing the shell over the air cell and then gently peeling back the inner shell membrane in order to remove it from the surface of the albumen. If the dense bright white area characteristic of the infertile egg or the white "doughnut" characteristic of the fertile egg cannot be clearly seen then the contents of the eggs should be tipped into one hand and the yolk gently rolled over until either the blastodisc or blastoderm is definitely observed (**Figure 6**).

At least one hundred eggs per flock should be examined. The technique is useful because it can give a rapid indication of true flock infertility levels in order to guide breeder management decisions. The technique requires the destruction of hatching eggs. Testing reject eggs is an alternative, but this tends to underestimate true fertility.

Figure 6: You may have to remove the egg contents and roll the yolk in your hands in order to locate the blastodisc (infertile) or blastoderm (fertile) in fresh unincubated eggs

The internal examination of fresh unincubated eggs will also allow the identification of any abnormalities. For example, mottling of the egg yolk is a disturbance of the vitelline membrane usually caused by stress in the parent hens. Stressors include handling (e.g. for blood sampling), changes in routine and overmating. Feed containing Nicarbazin or mycotoxins can also result in high levels of mottling. Mottling of the yolk may cause elevated numbers of early dead embryos and appears to make the eggs more susceptible to bacterial contamination. **Figure 7** shows a fresh egg affected by pronounced mottling.

Figure 7: Fresh egg yolk affected by pronounced yolk mottling

Thin watery albumen (e.g. due to Infectious Bronchitis or prolonged egg storage) will also reduce hatchability.

Cotton and Kapok seed meal as a contaminant of feed can cause the egg yolk to become thick and viscous (rubbery) and will also reduce hatchability.

An example form for recording the breakout of fresh unincubated eggs is given in **Appendix 7** (**Form 1**).

Breaking Out Partially Incubated Eggs

The fertility test undertaken on partially incubated eggs requires the destruction of some hatching eggs, but is easier and requires considerably less practice than examining fertility in fresh unincubated eggs. Once again, a 100-egg sample per flock is the minimum requirement, although it is usually more practical to use one or more full setter trays. Eggs should have been incubated for 3-5 days prior to examination. Each egg should be opened very carefully from the top of the air cell so as to avoid any disruption to the egg contents, then the blastoderm or infertile disc will be on the upper surface of the yolk and very easy to see. Do not spend too much time trying to identify signs of membrane development – if it is not obvious it has not happened.

A truly infertile egg will have the characteristic small dense white area described previously for fresh unincubated eggs.

Embryos dying in the first and second day of incubation will show development of extra-embryonic membrane growth over the top of the yolk. This is characterised by a cream coloured disc much larger than the white doughnut in the fresh unincubated fertile egg. After one day of incubation, the area occupied by the extra-embryonic membranes will be about one centimetre in diameter (**Figure 8**), whilst after two days the membranes will occupy almost the entire upper surface of the yolk (**Figure 9**).

Figure 8: Embryo after one day in the setter

Figure 9: Embryo after two days in the setter

After three days of incubation, live embryos will have well developed circulatory systems (see **Figure 10**).

Figure 10: Embryo at the “Blood Ring” stage

On days three and four of incubation the inner shell membrane looks white when the shell above the air cell is removed. This is due to a drying process as water moves from the albumen into the yolk to form the sub-embryonic fluid. The sub-embryonic fluid is milky and sits on top of the yolk, giving the yolk a paler and more watery appearance than in the earlier stages of development or in the fresh egg.

From day five onwards, the characteristic feature of the embryo is the black pigmented eye (**Figure 11**). The term "Black Eye" has been used to describe the embryo from day five to day 12 of incubation, after which time there is the obvious development of feathers.

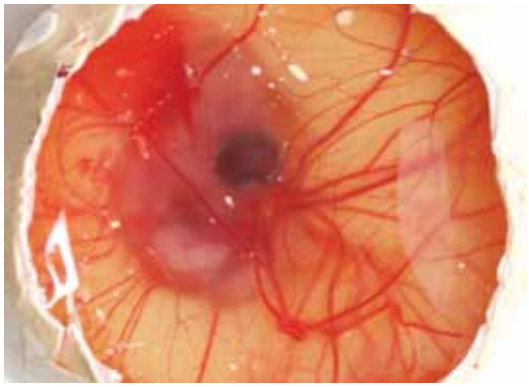


Figure 11: Embryo at the "Black Eye" stage. Note the early development of the wings and legs at this stage

An example form for recording the breakout of partially incubated eggs is given in **Appendix 7** (**Form 2**).

Normal Early Embryonic Development

The embryonic development which occurs whilst the egg is still inside the hen simplifies identification of infertility prior to incubation. An unfertilised germinal disc will show little evidence of any structure except for a condensed white spot of variable shape (**Figures 2** and **3**). A fertilised blastoderm has a pronounced ring or "doughnut" appearance (**Figures 4** and **5**). The difference is visible to the naked eye even when unmagnified.

After one day's growth, there will be a ring of cream coloured membranes measuring about one centimetre in diameter. (**Figure 8**).

After two days of incubation, the cream coloured membranes will cover most of the top surface of the yolk. (**Figure 9**).

By day three there will be a well developed circulation system (**Figure 10**).

Breaking Out Incubator "Clears"

Incubator "clears" are those eggs in which no obvious development is seen when a bright light is shone through the eggs in the process known as candling (**Figure 12**). The term is often, but incorrectly, used as being identical to infertile.

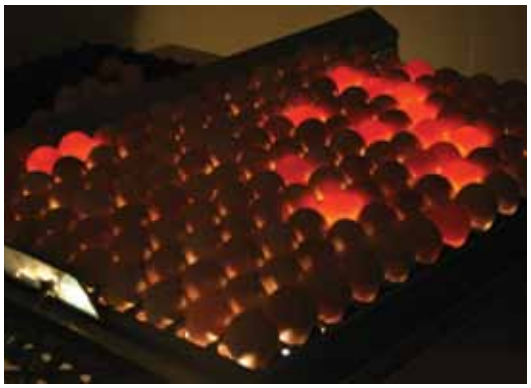
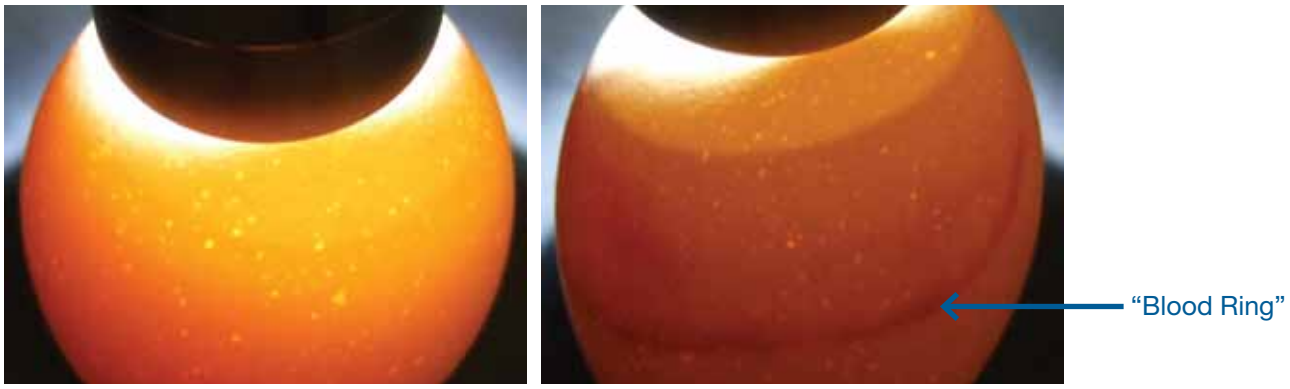


Figure 12: Candling table. The infertile eggs and those dying early in incubation show up as the brighter "clear" eggs

Depending on the quality of the candling lamp or table and the pigmentation of the shell, incubator "clears" can be candled out from as early as four or five days of incubation. For the brown-shelled eggs of broiler breeders, candling the eggs at eight to 10 days of incubation is usually straight-forward and allows for single-stage incubators to be run sealed up until the time of this candling procedure.

Figure 13: "Clear" eggs identified using a candling lamp; no development on left, "Blood Ring" mortality on right



By candling eggs at eight to 10 days of incubation, the eggs which died at the "Blood Ring" stage can also be identified easily during candling and can be counted at this stage without the need to open the eggs (**Figure 13**). However, it is usually more accurate and as quick to open all eggs to distinguish the truly infertile eggs from those in which early embryonic mortality has occurred. Accuracy of identification will be improved if the eggs are examined while they are still warm.

Figure 14: If candled at 8 to 10 days of incubation, the "Blood Ring" will be visible when the egg is opened

Opening eggs candled at eight to 10 days incubation (**Figure 14**) ensures that the cream coloured extra-embryonic membranes characteristic of the first two days of development will still be relatively intact even if the embryo died at this stage. By candling the eggs at eight to 10 days of incubation the extra-embryonic membranes can be easily recognised and differentiated from contamination and bacterial growth that cause deterioration in the membranes and egg contents if the eggs are left in the setter for a longer period.

Eggs are often candled at the time of transfer to the hatchers at around 18 days incubation. By this time, the egg contents can have deteriorated. This is due to the longer exposure to heat and/or development of contamination that often follows embryo death. This can make accurate differentiation of true infertility and very early embryo deaths extremely difficult. The differentiation is considerably easier and more accurate when breaking out the "clears" from eggs candled at up to 10 days of incubation.

Form 2 in **Appendix 7** would be suitable for recording the breakout of incubator "clears" from eggs candled early in incubation. **Forms 3** and **4** are for egg breakouts from the transfer candling.

Examining the Hatch Debris

Recognising Developmental Stages and Malformations

Before collecting the hatch debris, it is good practice to count and then weigh in bulk the Grade-A chicks from the tray in order to calculate an average chick weight and the chick yield (ratio of the average chick weight to the average fresh egg weight or egg weight at setting). The reasons for this are described more fully on *page 17.* The number of dead chicks on the tray and the number of cull chicks should also be recorded. The unhatched eggs should then be collected onto egg trays for internal examination. For hatchery troubleshooting, debris from around 1000 eggs set should be collected, taking samples in a structured way from throughout the setter. It is important to know whether or not the sample trays have had clear eggs removed, and if the spaces created were back-filled.

In the past, we have probably relied too much on the analysis of the hatch debris, but the deterioration in some eggs, along with the complicating factor of contamination (**Figure 15**), can make the accurate differentiation of infertiles and early dead embryos difficult. However, if candling is performed early in incubation (see previous sections) it is much easier to correctly place eggs into the infertile and early dead categories.

Figure 15: In the hatch debris, it can be difficult in some eggs to diagnose whether the egg was infertile or at what stage the embryo died because of contamination and decomposition

Examination of the hatch debris is really only for the accurate diagnosis of embryo deaths from the “Blood Ring” stage onwards. A detailed list of diagnostic features for each stage is given in **Tables 1** and **2** (see *pages 22-23*). Decomposition after death means that in the hatch debris there is often no blood visible in eggs that died at the “Blood Ring” stage. A clear area in the centre of the egg caused by the fluid-filled amniotic sac may be the only evidence after 21 days of incubation (**Figure 16**).

Figure 16: In the hatch debris, eggs containing embryos that died at the “Blood Ring” stage do not usually still have obvious blood present. However, the remains of the cream coloured extra-embryonic membranes and the amniotic sac which gives rise to a clear area on top of the yolk are characteristic of “Blood Ring” deaths in the hatch debris

The amniotic sac can be lifted out with forceps and the remains of the embryo may be found within it (**Figure 17**).

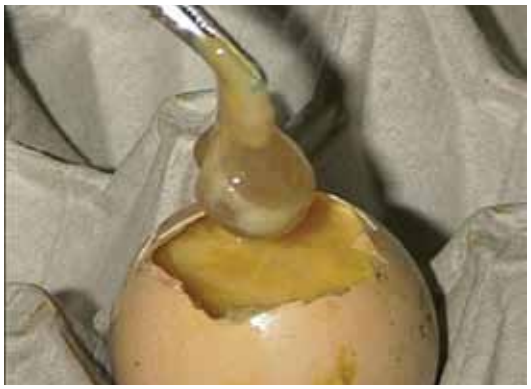


Figure 17: The amniotic sac and small, usually decomposing, embryo can normally be lifted from the yolk in any "Blood Ring" deaths present in the hatch debris

Embryos at the "Feathers" stage are easily identified in the hatch debris (**Figure 18**).

Figure 18: Embryos dying at the "Feathers" stage are easily recognised in the hatch debris. This embryo died about 16 days of incubation. The egg contents are often a dark reddish-brown colour from the decomposing blood

If in doubt, it is better not to try to disintinguish between infertile and early dead embryos in the hatch debris, but to note if the infertiles plus early deads exceed target. More accurate examination may then be made of fresh unincubated, or partially incubated eggs or incubator "clears".

When examining hatch debris any malformations of the embryo should also be recorded (e.g. exposed brain, extra limbs, exposed intestines) and the position of embryos that were close to hatching should be noted.

Example forms for recording the breakout of the hatch debris are given in **Appendix 7** (**Forms 5** and **6**). The recording forms include details of embryonic malpositions and contamination which are explained in the next sections (also refer to **Tables 1** and **2,** *pages 22-23*).

Recognising the Normal Hatching Position and Malpositions

A small number of embryos fail to hatch because they end up in so-called malpositions. Not all malpositions are lethal, but they should be recognised by the person examining the eggs and recorded in case their frequency changes as a result of inappropriate management practices.

Normal Hatching Position. The normal hatching position is where the spine of the embryo runs parallel to the long axis of the egg and the beak is positioned underneath the right wing. The tip of the beak is directed towards the air cell in the blunt pole of the egg. When the beak is under the right wing, the wing holds the shell membrane away from the face of the embryo and thus gives the beak more freedom of movement. In addition, the wing helps stretch the inner shell membrane and helps the piercing of this membrane by the beak. In this way, the embryo gains access to the air cell of the egg and begins to ventilate its lungs.

If the head of the embryo has turned to the right, it stands a good chance of hatching. However, the actual hatching percentage will be influenced by whether the head is above or below the right wing or in the large end or small end of the egg.

There are six recognised malpositions (viewed from the top of the egg):

Malposition 1 – Head between thighs. This is the normal position for the majority of 18-day old embryos and the head normally then begins to turn towards the air cell as the embryo assumes the normal hatching position on day 19. Embryos with their head between their thighs in the hatch debris probably represent either embryos dying around day 18 of incubation or, if still alive, embryos in which development has been retarded.

Malposition 2 – Head in small end of egg. Easily identified because the hocks, yolk sac and/or navel of the 18-day+ embryo are immediately visible on opening the shell over the air cell **(Figure 19).** This position is commonly seen in eggs that have been incubated upside down and is also more prevalent in eggs that have been incubated horizontally compared to eggs incubated with their large ends uppermost. The position can occur in eggs that have been incubated the right way up (especially those eggs with a rounder shape), eggs which have been exposed to high temperatures in the setters or when the angle of turning is too small. The frequency of this malposition is heavily influenced by the percentage of eggs that are set upside down. Ideally, the frequency of this malposition should be less than 10% of total malpositioned embryos.

Eggs that have been set upside down can be reinverted up to day eight of incubation without ill effect. Inverting eggs after this time risks breaking the blood vessels in the chorioallantois which is beginning to attach itself to the shell membranes from day nine onwards. Embryos that are upside down on day 20 of incubation hatch at about 80% of the normal rate.

Malposition 3 – Head turned to left. This malposition is more prevalent in eggs incubated large end up than eggs incubated horizontally. In many instances the beak will be above the left wing. When the head turns to the left it reduces the chances of hatching to about 20%.

Malposition 4 – Beak away from air cell. The incidence of this position is five times greater in eggs incubated horizontally than large end up and is thought to be nearly always lethal. However, it is a difficult malposition to recognise.

Malposition 5 – Feet over head. A common malposition in which one foot or both feet become trapped between the head and the shell (**Figure 20)** and prevent the normal back thrusts of the head required to pip the eggshell. The feet of the embryo are also involved in the final rotation of the embryo as it cuts off the top of the eggshell to emerge from the egg. Thus, if the feet over head position has not prevented pipping of the shell, it may prevent the final rotation and escape of the embryo. This is usually the second most common malposition, representing about 20% of the total malpositioned embryos.

Figure 19: "Head in small end of egg"

Figure 20: "Feet over head" is a common malposition in which the feet interfere with movement of the head and rotation of the embryo and reduce the likelihood of hatching

Malposition 6 – Beak above right wing. This is usually the most commonly recorded malposition, representing 50% or more of the total malpositioned embryos. Many embryos will have hatched from this position and it is often regarded as a natural variant of the normal hatching position. However, it has recently been suggested that an excess of embryos in this position could be an indication of embryos experiencing heat stress. Linoleic acid deficiency has also been linked to this malposition.

A combination of malpositions may occur in the same embryo.

Recording Egg Contamination

It is a topic of debate whether contamination has always killed the embryo or whether the contamination was held in check until the embryo died. Nevertheless, every egg opened should be assessed for bacterial contamination, (e.g. egg contents green, black, emitting rotten odours or egg explodes on opening). However, colour should not be the sole guide as brown colourisation can be due to the deoxygenating process.

Heavily contaminated eggs often explode on opening and in others the embryo may be hard to distinguish easily. It is not important to accurately record the time of embryo death in grossly contaminated eggs. The objective is to record the total percentage of contaminated eggs and compare the result with standards from best practice. This will enable you to assess the effectiveness of your egg handling and sanitation procedures. The eggs could be recorded as an “Early rot” if the embryo died at the “Black Eye” stage or before, “Late rot” if it had reached the “Feathers” stage or simply recorded as “Contaminated”.

Aspergillus represents a special case of contamination and can be a serious problem in some areas. Whenever eggs are opened through the air cell and mould growth is observed on the inner shell membrane this should be recorded as a potential aspergillus contamination and care should be taken not to breathe in or spread the mould spores.

Monitoring Egg and Chick Weights

Egg Weight Loss to 18 Days

The average chicken egg has about 10,000 pores running through the shell so the developing embryo can exchange oxygen and carbon dioxide with the incubator air. However, water is also lost through these pores and the total amount lost during incubation has to be controlled if the embryo is to avoid dehydration. This is most easily done by monitoring the weight loss of eggs during incubation. Any weight loss is due solely to the loss of water from the egg.

Observations across all avian species have shown that the weight loss between the start of incubation and pipping of the eggshell (i.e. approximately the time of transfer to the hatcher in the domestic fowl) is about 12% of the fresh egg weight. The only way in which hatcheries can influence the weight loss from eggs is by altering the humidity in the incubator. Chick quality and hatchability can only be optimal when the eggs lose about 12% of their fresh egg weight to pipping.

Hatcheries normally do not know the fresh egg weight, but commonly weigh the eggs just before setting. If the eggs have been stored for a short period (up to six days) under good conditions then the correct egg weight loss to pipping is 11.5% of the egg setting weight. The optimal weight loss as a percentage of the egg setting weight is determined by the weight loss in storage.

The percentage egg weight loss should be measured by weighing whole trays of eggs (**Figure 21**). Accurate electronic scales are relatively cheap and using them to monitor weight loss from trays of eggs in various locations in all the setters is an invaluable way to check that eggs are receiving the ideal humidity conditions. The use of this method helps check that the humidity programmes and humidity control systems are working in all the setters and is thus an essential management tool in the hatchery.

Figure 21: Monitoring the weight loss of eggs during incubation is an important hatchery management tool

Monitoring Chick Yield

Monitoring the weight of the chicks, and their relationship with the weight of the eggs they came from (chick yield) is another essential hatchery management tool. It is best done using the trays where egg weight loss has already been monitored. The technique involves counting and then weighing in bulk the Grade-A chicks from a hatcher tray (**Figure 22**) in order to calculate an average chick weight and then the chick yield. Chick yield is the average chick weight divided by the average fresh egg weight multiplied by 100. An ideal target for best chick quality is a chick yield of 67% of the fresh egg weight or 67.5% of the egg setting weight when the eggs have been exposed to short-term storage. If egg weight loss to pipping has been correct, but the chick yield is lower than 66% of the fresh egg weight, then incubation duration is too long. It needs to be adjusted by setting eggs later or by pulling chicks earlier. Every 1% loss in chick yield is equivalent to about three hours extra in the hatcher.

Figure 22: Monitoring chick yield (chick weight as a percentage of the egg weight) gives important information about egg weight loss, incubator humidity and hatch times

If the chicks face a long journey before placement or are being transported in hot conditions then the chick yield could be increased to 69-70% by increasing the setter humidity and/or taking the chicks out of the hatchery slightly early.

An example form for recording the egg weight losses during incubation and chick yield is given in **Appendix 7** (**Form 7**).

Monitoring Temperatures

Monitoring the Temperature Exposure Profiles of Eggs

Miniature battery-powered data loggers, such as Tinytags, will record temperatures for a pre-set period and make the investigation of egg handling conditions easy. A data logger can be placed in the nest box overnight, be collected with the eggs and then used to follow the temperature profile that the eggs are exposed to through all the ensuing processes, including incubation.

On the farm, the eggs should be cooled to below 24°C (75.2°F), within four hours of collection and then held at the optimum temperature for the expected period of storage. 24°C (75.2°F) is known to be "Physiological Zero" for broiler breeder eggs and cooling eggs below this temperature will ensure that there is no chance of embryo development during storage.

Common problems in relation to temperature during egg handling include:

- Eggs left too long in the nest, allowing them to re-warm when another hen occupies the nest.
- Infrequent collection in automatic nests where eggs are held at house temperature without cooling.
- Eggs packed on to fibre egg trays, which only allow very slow cooling. Use plastic egg trays.
- Eggs held in the poultry house after packing until the end of the working day, rather than being moved into the cooled store immediately.
- Egg store door left open, especially during hot weather.
- Temperature control in egg store inadequate with high diurnal variation due to hot weather, poor cooler capacity and/or poor insulation. This will weaken the embryos and could result in weaker chicks.
- Trolleys held outside the egg store prior to arrival and loading of egg collection vehicle.
- Egg collection vehicle not temperature-controlled.
- Farm and hatchery stores held at different temperatures.
- Prolonged pre-warming of eggs in an environment fluctuating around Physiological Zero.

Any of the above will increase the "Early Dead" and "Blood Ring" mortality. The use of temperature data loggers may allow the problem areas to be identified.

Temperature data loggers can also be useful in evaluating incubation conditions and identifying where there are hot and cold spots in the setters that need to be rectified.

Measuring Eggshell Temperatures During Incubation

Embryos are resistant to periods of cooling, but short periods of heat stress can cause malformations, malpositions or may be lethal. Rather than just allowing an incubator temperature programme to run its course, it is prudent to monitor eggshell temperatures in order to prevent overheating of the embryos. This can be done using a relatively cheap infra-red thermometer such as the Braun Thermoscan which works accurately within the temperature range found in incubators. Check egg surface temperatures at the equator of the egg, not at the air cell.

All setters have 'hot spots' and 'cold spots' and it is important to check that the embryos in the hot spots are not subjected to damaging heat stress during days 16 to 18 of incubation. An ideal eggshell temperature is 37.8°C (100°F), but towards the end of the setter phase eggshell temperatures up to 38.3ºC (101°F) are common and largely without effect. However, eggshell temperatures higher than this can be damaging and temperatures of 39.4ºC (103°F) and above are known to be detrimental to hatchability and chick quality.

Monitoring the Hatch Window

The term "hatch window" describes the period of time over which chicks are actually coming out of the eggs. The "hatch window" has also been called the "spread of hatch" and it is assessed relative to the time of taking the chicks out of the hatcher. The spread of hatch is influenced by the variability in temperature in the setters.

In Ross products the total spread of hatch (from 1% of chicks being hatched to 99% of the chicks being hatched) is about 30 hours. Ideally, no more than about 1% of the chicks should have hatched 30 hours before chick take-off. If take-off is delayed once all the chicks are hatched, then growth and uniformity of the flock on farm will suffer, so it is important to monitor the window, and adjust either the egg setting or chick take-off times accordingly.

In order to take account of the variations in temperature that occur in setters, the trays used for monitoring the hatch window should come from several different locations. For example, top, middle and bottom trays, front and back, left and right of the setter. Check the hatcher 30 hours before the chicks are due to be taken off. There should be no more than one or two hatched chicks out on each tray at this time.

At chick take-off, some chicks (about 5%) should still be damp on the neck (**Figure 23**) and the inside of recently hatched shells should still be moist.

Figure 23: 5% of chicks should still be damp at the back of the neck at take-off

Other observations may be made that will help the hatchery manager judge if the hatch has occurred too early or too late. For example, if the insides of all the shells are very dry and all the shells can be easily crushed into little pieces (**Figure 24**), if there is a lot of meconium on the shells (**Figure 25**) or if all the chicks are dry and the wing feathers of the chicks have spread a lot from the end of their sheaths then the hatch is probably occurring too early.

Figure 24: Dried out shell membrane in the egg on the right shows the chick hatched very early

Figure 25: Meconium on egg shells after delayed take-off

An even spread of hatched chicks on the hatcher trays during monitoring of the hatch window and reasonably clean egg shells at chick take-off are indicators of good conditions during incubation and the correct take-off time.

Routine Quality Control in the Hatchery and the Recording and Analysis of Results

Routine quality control can be a very time-consuming process. For this reason, the precise details of what should be recorded and analysed should be discussed by the Quality Control Team in each hatchery and they should also define how the information collected will to be used. The role of this publication is to provide ideas for discussion.

Some suggestions for the possible ways of classifying the time of death of the embryo are given in **Tables 1** and **2**.

Tables 3 and **4** give top quartile targets for hatchability losses.

Some ideas for recording forms are given in **Appendix 7**, but they should be modified to suit individual needs. **The entry of the results into an electronic database and the analysis of trends is highly recommended in order to define working targets.**

The appearances of chick embryos at different stages of development are well documented, but an embryo which dies at four days of incubation and which then remains in the incubator for a further 17 days will be subject to considerable deterioration. For this reason, the opportunity to open eggs as early as possible by candling at eight to 10 days of incubation is recommended. Thereafter, removal and examination of any dead eggs at transfer and an examination of the hatch debris is recommended.

As a minimum requirement the following are suggested for inclusion into any routine quality control system:

- At least three setter trays of eggs should be monitored weekly for each flock in lay; ideally the sample trays should be representative of the whole hatch.
- The three setter trays should be weighed empty and the weight recorded.
- The trays should then be filled with eggs and the weight of each tray plus eggs recorded.
- The trays should be weighed again at the time of transfer to the hatcher. The eggs should then be candled and the “clear” eggs broken out to enable categorisation and enumeration of infertiles and early deads, mid-term deads and contaminated eggs.
- At chick take-off the number of chicks should be counted and recorded from each of the three trays and the chick weight expressed as a percentage of the fresh egg weight or egg weight at setting.
- Examination of the hatch debris from the same trays will complete the records.
- All data should be recorded to flock age and the setter and hatcher the eggs were incubated in.
- The percentage of eggs falling into the different categories should be calculated and compared with the working targets set from historical data. Any large deviations from the working targets should be investigated. Some possible reasons for failures are given in a later section entitled “*Interpretation of Results*”. A more comprehensive guide for troubleshooting hatchery problems is H.R. Wilson’s “Hatchability Problem Analysis” published by the University of Florida and available as a free download on the internet.

Table 1: Detailed classification system for the time of embryo death suitable for a diagnostic/research type egg break-out

Developmental time in days	Classification on recording form	Observations
0	Infertile	No obvious sign of development
1	24h "Early Dead"	Cream coloured extra-embryonic membranes occupying area up to one cm diameter
2	48h "Early Dead"	Cream coloured extra-embryonic membranes occupying area up to three cm diameter
2.5-4	"Blood Ring"	Obvious "Blood Ring" and the beginning of formation of the sub-embryonic fluid
5-12	"Black Eye"	The black pigmentation of the embryo's eye is obvious. The wings and legs can be seen as well
13-17	"Feathers"	Feathers present. Although the first feathers are seen as early as 11 days, they are often not obvious over the entire body until 13 days of age
18-19	Turned	The embryo is moving from the "head between thighs" position to the hatching position and the yolk remains outside the body of the embryo
20	Internal Pip	The beak of the embryo has come through the inner cell membrane into the air cell
20	External Pip	The beak of the embryo has broken through the eggshell
0-10	Early Rot	Deep discolouration of the egg contents with emission of rotten odours
11-21	Late Rot	Obvious embryo with deep discolouration of the egg contents and emission of rotten odours

Table 2: Simplified classification system for the time of embryo death suitable for a Quality Control type egg break-out

Developmental time in days	Classification on recording form	Observations
0	Infertile	No obvious sign of development
0-7	Early Dead	Any death in the first week of incubation. The end of this period is delineated by the appearance of the egg tooth on the end of the beak
8-14	Mid Dead	Embryos with an egg tooth, but feather development is not immediately obvious over the entire body
15-19	Late Dead	Well feathered embryo almost filling the egg. The yolk may be external to the body, or may be retracted
20	External Pip	The beak of the embryo has broken through the eggshell
0-21	Contaminated	Deep discolouration of the egg contents with emission of rotten odours

Table 3: Top quartile targets for hatchability losses when performing detailed diagnostic/ research type egg breakouts (% of total number of eggs set)

Flock Age	Stage of Development of Embryo										
	Infertile	24 hours	48 hours	Blood Ring	Black Eye	Feathers	Turned/ Malposi-tioned	Pipped Air Cell	Pipped Shell	Cracked	Contam-inated
Young 25-30 weeks	6	1	2	2.5	1	1	1.5	1	1	0.5	0.5
Peak 31-45 weeks	2.5	0.5	1	2.0	0.5	0.5	1	1	0.5	0.5	0.5
Post Peak 46-50 weeks	5	0.5	1	2.5	1	0.5	1	1	0.5	0.5	0.5
Ageing 51-60 weeks	8	0.5	1	3.0	1	0.5	1.5	1	0.5	1	1

Table 4: Top quartile targets for hatchability losses when performing routine quality control type egg breakouts (% of total number of eggs set)

Flock Age	Stage of Development of Embryo						
	Infertile	Early Dead	Mid Dead	Late Dead	External pip	Cracked	Contaminated
Young 25-30 weeks	6	5.5	1	3.5	1	0.5	0.5
Peak 31-45 weeks	2.5	3.5	0.5	2.5	0.5	0.5	0.5
Post Peak 46-50 weeks	5	4	1	2.5	0.5	0.5	0.5
Ageing 51-60 weeks	8	4.5	1	3	0.5	1	1

Planning, Organising and Carrying Out a Hatchery Investigation

It may become necessary to carry out a detailed investigation if hatchability or chick quality problems arise. Hatchability of fertile eggs, chick quality and post-hatching performance are affected by the conditions experienced by eggs from oviposition until hatching. Therefore, any hatchery investigation should encompass all the events between the time the egg is laid through to the start of brooding on the farm. The performance of the chicks during the first week on the farm, especially mortality levels and seven-day body weights should also be examined. Although chick performance is influenced by farm management, the initial impact of hatchery procedures is often underestimated and should also be considered when problems arise.

Careful planning of any hatchery investigation will ensure that the material examined is representative of the system as a whole. The result of an investigation will be to suggest alternative management practices within the process. Quality control routines must then be adapted to monitor the results of any changes which are made and to prevent recurrence of the same problems.

The following equipment will be required when investigating hatchery problems:

- Scales with which to weigh entire trays of eggs to the nearest 10g (0.4 oz)
- Miniature temperature data loggers capable of measuring temperature to an accuracy of 0.2ºC (0.4ºF)
- Forceps, knife or scissors to open eggs
- A table placed in good light, away from routine hatchery work
- A plentiful supply of egg trays
- A large waterproof bin to receive waste
- Paper towels
- Recording forms (see examples in **Appendix 7**)
- Disinfectant spray
- Gloves

Choose up to four farms for investigation, approximately one week before the eggs are to be set and 28 days before the planned hatchery visit.

On each farm, place one or more miniature temperature data loggers in a nest box after the last egg collection of the day. During egg collection the following day, treat the data loggers in the same way as the eggs from that collection. Pass the data loggers through any disinfection procedure, protecting them from water or chemical damage by the use of plastic bags and tape as necessary. Place the data loggers in the egg trays with the hatching eggs before placing the trays in the egg store. Mark the trays containing the data loggers, so that they can be found at the hatchery.

At the hatchery, identify 8-10 setter trays of eggs per farm (i.e. 1,000-1,500 eggs in total). These should be of known and similar egg age and, if possible, they should be representative of the egg age currently in the system. Include the trays containing the temperature data loggers in the sample; leave the loggers in place through the hatching process. Mark the trays clearly and weigh each tray. Record the weights on **Form 1** (**Appendix 7**). Record the weight of empty trays.

Distribute the sample trays evenly throughout the setter (e.g. one top, one middle and one bottom tray at up to three different locations throughout the setter), so that incubator position effects can be identified.

Three or four days before the due hatch date, set one full tray of eggs from each farm for fertility assessment. These eggs will all be opened and therefore will not be available for hatching.

At candling, do not remove any eggs from the sample trays unless they are rotten or leaking, in which case they should be recorded on **Form 4** (**Appendix 7**).

Re-weigh the trays at transfer, noting the date.

On the day of the hatch, select all the trays required for analysis (**Figure 26**).

Figure 26: Sample hatcher trays saved for investigation

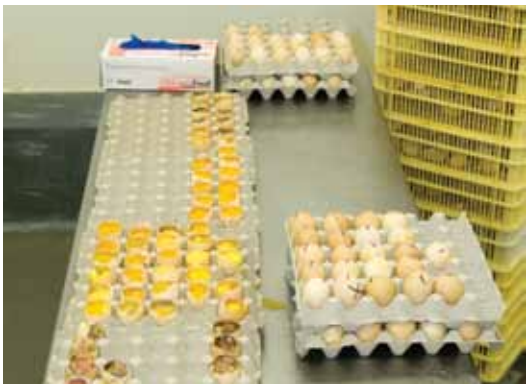
Count the Grade-A chicks and weigh in bulk to hatcher tray. Count the culls and dead chicks on each tray. Record the numbers on **Form 1 (Appendix 7)**.

Find all the unhatched eggs and transfer them to egg trays labelled with the flock code and hatcher tray number. The hatcher trays can then be released for washing.

Working through each tray within the sample, open each egg (**Figure 27**). Classify the contents according to when the embryo died or whether there is bacterial contamination. Record any developmental abnormalities. Descriptions of the different categories are given in **Tables 1** and **2**.

Figure 27: Opening unhatched eggs in the hatchery is useful in order to monitor whether the embryo losses are following the expected normal pattern

Figure 28: The results from the egg break-outs need to be accurately assessed and recorded



Sort the eggs by developmental stage on to egg trays (**Figure 28**), and then record the number of eggs in each category, by tray, on **Form 2**.

Total the number of eggs in each category for every flock and then calculate as a percentage of the total number of eggs set.

Compare the results with the targets relevant for the particular flock age (**Tables 3** and **4**). The categories having the greatest deviation from target should indicate where problems are occurring. Health, nutrition and management can all affect patterns of embryonic mortality, so these targets are intended only as a guideline to establishing precise targets for the hatchery.

Occasionally, hatchery investigations cannot be organised and planned as rigorously as outlined above. However, even if an investigation is unplanned and required at short notice and a small number of hatcher trays taken at random on the day of hatch are the only materials available make sure the investigation is organised in such a way that the results can be expressed as a percentage of the eggs set.

Several other observations may have to be interpreted whilst carrying out a hatchery investigation. For example, if the number of unhatched eggs on each tray is very variable (e.g. the worst tray having twice as many unhatched eggs as the best) this may indicate uneven holding or incubation conditions or the presence of trays containing washed/floor eggs in the sample. Washed or floor eggs will usually have a large percentage of “Black Eye” mortality and “Early Rots”.

An excessive number of contaminated eggs should trigger further enquiry into egg handling and sanitation procedures. A high incidence of contamination and rots can be due to poor nest hygiene. Implementing a programme of increased egg collections and more frequent changes of nesting material may help. It could also be due to poor or inappropriate sanitation technique. The egg handling procedures should be closely observed also to see if the eggs are subjected to wetting or condensation on the eggshell at any stage. Candling of eggs would show if the contamination is the result of rough handling leading to hairline cracks.

By monitoring egg-weight losses in the setter, it is easy to identify any incubators that are not achieving the suggested egg-weight loss to pipping. The humidity control system should be examined in such incubators (e.g. look for blocked spray nozzles). If the humidity control appears to be working satisfactorily then a change in the humidity setting to achieve the correct egg-weight loss is desirable. In a multi-stage setter, a change of 1% in weight loss (e.g. from 13% to 12%) is achieved by a change of about five percentage points in relative humidity or a change in wet bulb temperature of 1ºC or 2ºF. Increasing the relative humidity or wet bulb temperature will decrease the loss in weight from the egg, and vice versa.

In the single-stage incubation programmes where the setter ventilation may be closed for the first eight to 10 days of incubation, the egg-weight loss during this period may be as low as 2% of the fresh egg weight. This means the eggs then have to lose 10% of their fresh weight during the eight to 10 days remaining to transfer. This may be difficult to achieve without switching off the humidity system for a number of days and may not be achievable when the incoming air humidity is high.

Measuring the average chick weight from trays where egg-weight loss has been monitored is good practice. If the eggs have lost 12% of their fresh weight to transfer, but the chicks at take-off do not weigh 67% of the fresh egg weight, then your egg setting/chick take-off times need to be adjusted. As a rule of thumb, a chick yield which is one percentage point below target can be corrected by setting the eggs three hours later. But, first ensure that your egg-weight loss to pipping really is about 12% of the fresh egg weight, or 11.5% of the egg weight at set (for short-term storage).

Interpretation of Results

Many hatchability and chick quality problems can be solved by careful analysis of the data gathered using the techniques described in this publication. Some possible causes of losses at different stages of development are considered below.

Excess Infertiles
No visible embryonic growth. The dense white area characteristic of the infertile blastodisc may be seen if the eggs are candled and examined early in incubation. It may not be obvious after the full incubation period.

Possible Causes: Immature males, males not mating because they are overweight or have foot problems. Males losing condition due to insufficient feed. Mating ratio too high or too low. Females avoiding males because they are, or have been, too vigorous (i.e. overmating). Disease.

Excess Early Dead Embryos (set to two days)
There may be no obvious embryo, but the growth of the cream coloured extra-embryonic membranes should be evident (up to one centimetre diameter by one day of age, up to three centimetres in diameter by two days of incubation) if eggs are candled and broken out early in incubation. There is no blood present.

Possible Causes: Most likely to be a farm, transport or storage problem. For example, infrequent egg collection. jarring in handling or transport, eggs not allowed to settle at hatchery before setting, eggs stored too long (i.e. >7 days) or stored in unsuitable conditions (i.e. too cold, too warm or fluctuating temperature). Incorrect disinfection of eggs (e.g. washing at too high a temperature or fumigation in the first 12-96 hours of incubation) or high early incubation temperatures are other possible causes.

Excess "Blood Ring" (embryonic death from 2.5 - 4 days)
Cream coloured membrane growing over the surface of yolk and a circulatory system with obvious blood should have developed. After the embryo dies, the blood vessels are not obvious because the blood flows into the peripheral ring and becomes darker in colour. The peripheral "Blood Ring" usually survives to transfer, but the remnants of the cream coloured extra-embryonic membranes and the presence of the fluid-filled amniotic sac on top of the yolk may be the only evidence after 21 days of incubation. There is no obvious black pigmentation in the eye.

Possible Causes: Same as for early dead embryos, with the possibility also of nutritional deficiency or bacterial contamination.

Excess Black Eye (embryonic death from 5 - 12 days)
The embryo will have developed an obvious black coloured eye. Small wings and legs are also clearly visible. Embryos that die at this stage are often contaminated.

Possible Causes: Bacterial contamination caused by cracked eggshells, poor nest hygiene, inappropriate egg disinfection or sweating of eggs due to a sudden change in temperature and/or humidity during any egg handling procedures. Often associated with floor eggs, especially those that have been washed. Possibility of a nutritional cause.

Excess "Feathers" (embryonic death from 13 - 17 days)
Feathers start to appear at about 11 days of incubation, but may not be obvious over all the body until day 13. Dead-in-shell embryos in this category do not quite fill the shell. The head tends to be in the pointed end of the shell. In the hatch debris, the egg contents of embryos dying during the "Feathers" stage are often a dark reddish-brown colour due to the decomposing blood.

Possible Causes: Most embryos tend to survive this period of rapid growth. However, nutritional deficiencies will increase mortality at this stage, as will contamination and inappropriate incubation conditions.

Excess of "Turned" Embryos (embryonic deaths from 18 - 19 days)
The embryo fills the egg and the head has "turned" to the air cell in the blunt end of the shell. The yolk sac is still outside the abdomen. The chick should be examined for signs of developmental abnormalities, excessive moisture or an upside down malposition.

Possible Causes: Inappropriate temperature or humidity in the setter or hatcher. Damage at transfer. Nutritional deficiencies or egg contamination will increase mortality at this stage. Turning problems in the setter (i.e. frequency of turning or angle of turning). Egg set upside down. An excess of moisture in the egg associated with low egg weight loss due to high humidity in the setters.

Excess Pipped Air Cells
The embryo fills the shell, and the beak has penetrated the air cell in the blunt end of the shell. The yolk sac is mostly or entirely inside the abdomen. Developmental abnormalities may be visible.

Possible Causes: Same as for an excess of "turned" embryos, but also possibility of humidity being too high after transfer.

Excess Pipped Shells
Fully formed embryo has made a hole in the shell, but has not emerged. It may be alive or dead at the time of opening.

Possible Causes: Low humidity, high temperatures or inadequate ventilation in the hatcher. Inadequate turning or eggs set upside down. Nutritional deficiencies or disease can also increase mortality at this stage, as can excessive egg storage time, transfer damage or excessive fumigation during hatching.

Malformations

Head

For example, exposed brain, missing eye(s), beak and/or face abnormality (**Figure 29**).

Possible Causes: High early incubation temperatures or nutritional deficiency.

Figure 29: Malformation – Exposed brain

Legs and toes

Shortened, bent or twisted legs, malformed toes. Lameness in hatched chicks.

Possible Causes: Nutritional deficiency. Paper in bottom of hatcher baskets too smooth.

Ectopic Viscera

Intestines are outside the abdominal cavity of an otherwise fully developed chick (**Figure 30**).

Possible Cause: High setter temperatures during mid-incubation.

Figure 30: Malformation – Ectopic viscera

Extra Limbs

Extra legs and/or wings.

Possible Cause: Rough handling/jarring of eggs during collection and/or transport.

Effects of Nutrition on Infertility, Embryo Mortality and Hatchability

The effects of vitamin and mineral deficiencies on embryo mortality and malformations are well documented. General knowledge of breeder ration supplementation requirements is good and severe vitamin and mineral deficiencies are relatively unusual nowadays because vitamin and mineral premixes are generally reliable if sourced from suppliers who are ISO, HACCP and GMP accredited. However, occasional problems arise and the main findings from nutritional research and field observations are noted below.

Infertility may be associated with a deficiency of vitamin A, vitamin E or selenium, particularly in the male rations.

Early embryo deaths may be associated with a deficiency of vitamin A (failure to develop circulatory system), vitamin E (circulatory failure), biotin, niacin, pantothenic acid, copper, selenium or thiamin. Excess boron or molybdenum could increase the proportion of early deaths.

Mid-term embryo deaths have been associated with a deficiency of vitamin B12, riboflavin, phosphorus and zinc.

Mid to late deaths have been associated with a deficiency of vitamin B12, niacin, pyridoxine, pantothenic acid and riboflavin

Late embryo deaths have been associated with deficiencies of vitamin B12, vitamin D, vitamin E, vitamin K, pantothenic acid, riboflavin, folic acid, biotin, calcium, manganese, magnesium, phosphorus, zinc, iodine and thiamin. Excess selenium could increase the proportion of late deaths.

Excess iodine and vitamin D can cause high embryo losses.

Achieving the optimal level of selenium supplementation can be difficult because there are variable levels of selenium in the soil (and thus plant feeding stuffs) depending on geographic region. In some cases, the use of organic selenium has resulted in improved fertility and hatchability.

In case of prolonged vitamin B12 or niacin deficiencies, embryo mortality may change from early to late stage in incubation, and from late to early embryo deaths in case of prolonged riboflavin deficiency. Niacin can be formed from tryptophan, so a deficiency is usually the result of an antagonism with other dietary components. A deficiency of linoleic acid can affect embryos at all stages.

The supplementation requirements for egg production and hatchability differ. Egg production can be affected by deficiencies of energy, essential amino acids, vitamin A, pyridoxine (B6), B12, magnesium, manganese, sodium, iodine and zinc, whilst deficiencies of vitamin D, calcium, phosphorus or zinc may exert an effect on hatchability through effects on shell quality.

An excess of crude protein may reduce fertility and a low energy to protein ratio in breeder rations can reduce hatchability.

Contamination of breeder diets with ionophore anticoccidials (from the feed mill) or certain mycotoxins (from raw materials) can also lead to a reduction in hatchability. Some specific malformations in late embryos have been associated with deficiencies in:

- Vitamin B12 (short beak, poor muscle development in legs, perosis, early chick mortality).
- Vitamin D (stunting, soft bones, shortened upper beak).
- Vitamin E (haemorrhage in chicks after hatch).
- Vitamin K (high level of late deads, ectopic viscera and haemorrhage in the late deads).
- Biotin (shortened twisted legs, feet and wings, crooked beak (parrot beak)).
- Folic acid (bent legs, webbing between toes, parrot beak).
- Niacin (face abnormalities, missing beak).
- Pantothenic acid (subcutaneous haemorrhaging, abnormal feathering).
- Riboflavin (dwarfing, curled toes, oedema, clubbed down).
- Iodine (incomplete closure of the navel, prolonged incubation period).
- Iron (anaemia, pale coloured circulatory system).
- Manganese (short leg bones, slipped tendons, parrot beak, deaths 18-21 days, globular head, short wings, protruding abdomen, oedema).
- Zinc (spinal, limb and head abnormalities, small eyes).

Excesses of boron (e.g. from insecticides used to treat litter) have resulted in face abnormalities and excess selenium can lead to late deaths, crooked toes, shortened wings and a short or missing beak.

Loss of vitamin activity can occur if the vitamin pre-mix is stored inappropriately.

Heat treatment of feed during conditioning and pelleting can result in the degradation of some vitamins. Vitamin recovery studies should be conducted at the feed mill in order to determine the level of degradation that occurs during heat treatment. This will enable supplementation levels to be adjusted to ensure that the final feed contains the desired vitamin levels.

Developmental abnormalities tend to be immediately obvious and memorable and it is usually important not to overemphasise their relevance. It must be borne in mind that malformations of the embryo can be caused not only by nutrition but also by adverse incubation conditions (e.g. high temperature). Thus, if a trait is seen at high incidence (i.e. most or all of the late dead embryos) on two or three consecutive trays this could indicate positional effects arising from uneven incubation conditions in the setter.

Appendix 1. Some Rules of Egg Collection

- Wash hands before collecting eggs.
- Collect eggs at least three times a day - the more frequently eggs are collected the better the hatchability.
- Collect clean nest eggs first, without touching any dirty, cracked or floor eggs.
- Collect the dirty nest eggs, cracked eggs and floor eggs separately.
- Do not put floor eggs into nests to make them easier to collect later, you will only contaminate the nests.
- Remove any dirt and faecal material from the nest and dispose of it onto the floor litter.
- Top up the nest material regularly or, if using nest pads, remove clean and disinfect the pads regularly.
- Clearly identify the naturally clean nest eggs for the hatchery.
- If dirty eggs and floor eggs are sent to the hatchery they should be clearly identified and segregated from the clean eggs so the hatchery can set them in a separate setter or in the bottom trays on a trolley or rack - so if they do explode they cannot contaminate clean eggs below them.
- Cool eggs to below 24°C (75.2°F) within four hours of collection and continue cooling until the optimum storage temperature for the expected egg age at set is achieved.

Appendix 2. Some Rules of Egg Selection

The best eggs for the hatchery are those that are naturally clean, a good oval egg shape and collected from clean nests. When the breeder farm and hatchery are short of eggs then anything which is roughly egg-shaped may be considered worthy of setting.

However, be aware that:

- Small and large eggs do not hatch as well as medium-sized eggs.
- Round eggs tend to hatch less well than oval shaped eggs.
- Dirty eggs and floor eggs will hatch less well than naturally clean nest eggs and may spread contamination in the hatchery.

Pictured below are some eggs that may cause problems and should be considered for rejection:

Dirty

Dirty

Dirty (Yolk)

Dirty (Yolk)

Dirty (Blood)

Dirty (Blood)

Cracked

Toe Hole

Wrinkled

Wrinkled

Ridged

White, thin shell

Appendix 3. Some Rules of Egg Disinfection

- Disinfect egg shells as soon as possible after collection.

- Dry methods are preferable (e.g. fumigation, UV light or ozone).

- Fumigation using formaldehyde gas is the preferred and proven method, but may not be allowed in some regions.

- If wetting eggs by spraying or fogging make sure:
  - The products are designed for use with hatching eggs (i.e. they will not react with the cuticle or be left as a deposit on the eggshell that may interfere with gas or water exchange across the eggshell).
  - The solution is warmer than the eggs (otherwise the contraction of the egg contents may pull the solution and microbes across the shell and cause the eggs to rot and explode).
  - The concentration of disinfectant is appropriate (follow manufacturer's recommendations).

- If washing or dipping eggs follow the advice above and keep checking the disinfectant concentration is being maintained. Replenish the solution frequently. Only soiled eggs should be washed.

- Wet eggs should be allowed to dry before they are placed in the egg store.

- Avoid scraping or sanding of the eggshell surface – you can compact the cuticle into the pores and reduce embryo metabolism and growth.

- Avoid using cloths to clean eggs because they quickly become contaminated and will only serve to spread the contamination to other eggs.

- Monitor eggs when moving them from a cold egg store into a warmer environment to make sure condensation does not form on the shell surface. If eggs are sweating do not fumigate them and do not put them into a cold egg store until they are dry.

Appendix 4. Some Rules of Fumigation

- Observe local legislation concerning operator safety.
- Use 43ml formalin (37.5%) and 21g (0.7 oz) potassium permanganate OR heat 10g (0.4 oz) paraformaldehyde prills per m^3 of fumigation room.
- Ensure temperature is ≥24°C (75.2°F) and humidity is ≥60% RH.
- Ensure room is well sealed during fumigation and allow at least 20 minutes for the gas to circulate after it has been generated.
- Make sure eggs are well separated on plastic trays and that the fumigant gas can easily penetrate between them.
- Run a circulating fan during fumigation to help circulate the fumigant gas between the eggs.

If any of these conditions are not met then the efficiency of the fumigation will be reduced.

Appendix 5. Some Rules of Egg Storage

- Never put wet eggs (from spraying, washing or dipping) into the egg store. Allow them to dry thoroughly first.
- Eggs benefit from a period of rest after transportation.
- Do not set eggs on arrival at the hatchery, allow them to settle in the egg store for 24 hours.
- Egg store should be well insulated and the door should be kept closed as much as possible.
- Direct the air from inlets and air coolers away from the eggs.
- Take care that the humidification system does not wet the eggs.
- Ceiling fans help provide a gentle air movement through the eggs and will reduce spatial variation in temperature in large egg stores.
- Use the appropriate temperature, humidity and pre-warming depending on the period the eggs are predicted to remain in store before setting:

Storage Period (Days)	Temperature of Store °C (°F)	Humidity (%RH)	Pre-warming at 23°C (73°F) (Hours)
1-3	20-23 (68-73)	75	n/a
4-7	15-18 (59-64)	75	8
> 7	12-15 (54-59)	80	12
> 13	12 (54)	80	18

- Eggs which have been stored at 12°C (54°F) are liable to sweat (moisture on eggshell from condensation) if not given a short time at an intermediate temperature before pre-warming. See Dew Point or Condensation Table (**Appendix 6**).
- Stored eggs take longer to hatch (about one hour per day of storage) and hatchability will be reduced.

Appendix 6. Dew Point or Condensation Table

When eggs are moved from a cold environment into warmer, more humid conditions, they may sweat. The following table gives the shell temperature that will result in condensation when moving eggs into a wide variety of temperatures and humidities.

Eggs may sweat when they are transported from a cold egg store on the farm to a warm hatchery or from a cold egg store in the hatchery for pre-warming or incubation.

If eggs are sweating do not fumigate them and do not put them into a cold egg store until they are dry.

Temperature °C (°F)	Relative Humidity (%RH)					
	40	50	60	70	80	90
15 (59)					11	13
20 (68)			12	14	16	18
Pre-warming 23 (74)		12	15	17	19	21
25 (77)	10	13	16	19	21	23
30 (86)	14	18	21	24	26	28
35 (95)	18	21	25	28	31	33
Incubator	21	25	28	31	34	36
40 (104)	23	27	30	33	36	38

To avoid condensation the egg shell temperature needs to be higher than given in the table.

Appendix 7. Some Suggestions for Hatchery Recording Forms

Form 1. Breakout of Unincubated Eggs

Company _____

Date _____

Farm								
No. of Eggs Sampled								
Fertile								
Infertile								
- Mottled Yolk								
- Watery Albumen								
- Sticky Yolk								

Form 2. Breakout of Partially Incubated Eggs

Company _____

Date _____

Farm								
No. of Eggs Sampled								
No. of Days Incubated								
Live Embryos								
Dead Embryos - 24 h “Early Dead”								
Dead Embryos - 48 h “Early Dead”								
Dead Embryos - “Blood Ring” (3 days)								
Dead Embryos - “Black Eye” (5-12 days)								
Infertile								

*See **Tables 1** and **2** (pages 22-23) for classification systems for time of embryo death.*

Form 3. Transfer Candling Analysis

Company _____ Date Set _____

Farm _____ Date Candled _____

Age _____ Date Broken Out _____

Setter Tray Size _____ Setter No. _____

Tray No.	1	2	3	4	5	6	7	8	9	10	Total	% of eggs set
No. of eggs removed												
Infertile												
24 h Early Dead												
48 h Early Dead												
“Blood Ring” (2.5-4 days)												
“Black Eye” (5-12 days)												
“Feathers” (13-17 days)												
Live Embryos												
Early Rot												
Late Rot												
Poor Shell Quality												
Cracked Shell												
Notes:												

*See **Tables 1** and **2** (pages 22 - 23) for classification systems for time of embryo death.*

Form 4. Transfer Candling Analysis – Simplified Version

Company _____ Date Set _____

Farm _____ Date Candled _____

Age _____ Date Broken Out _____

Setter Tray Size _____ Setter No. _____

Tray No.	1	2	3	4	5	6	7	8	9	10	Total	% of eggs set
No. of eggs removed												
Infertile												
"Early Dead" (0-7 days)												
"Mid Dead" (8-14days)												
Contaminated												
Poor Shell Quality												
Cracked Shell												
Notes:												

*See **Tables 1** and **2** (pages 22-23) for classification systems for time of embryo death.*

Form 5. Hatch Debris Analysis

Company _____ Date Set _____

Farm _____ Date Candled _____

Age _____ Date Broken Out _____

Hatch Tray Size _____ Setter No. _____

Hatcher No. _____

Tray No.	1	2	3	4	5	6	7	8	9	10	Total	% of eggs set
No. of eggs removed												
Infertile												
24 h “Early Dead”												
48 h “Early Dead”												
“Blood Ring” (2.5-4 days)												
“Black Eye” (5-12 days)												
“Feathers “ (13-17 days)												
Turned (18-19 days)												
Internal Pip												
External Pip												
Dead and Cull Chicks												
Early Rot												
Late Rot												
Poor Shell Quality												
Cracked Shell												
Malpositions - Head in small end of egg												
- Head to left												
- Feet over head												
- Beak above right wing												
Malformations - Exposed brain/Eye defect												
- Extra limbs												
- Ectopic Viscera												
Embryo - Wet												
- Dehydrated												

Notes:

Form 6. Hatch Debris Analysis - Simplified Version

Company _____ Date Set _____

Farm _____ Date Candled _____

Age _____ Date Broken Out _____

Hatch Tray Size _____ Setter No. _____

Hatcher No. _____

Tray No.	1	2	3	4	5	6	7	8	9	10	Total	% of eggs set
No. of eggs removed												
Infertile												
“Early Dead“ (0-7 days)												
“Mid Dead” (8-14 days)												
“Late Dead” (15-21 days)												
External Pip												
Dead and Cull Chicks												
Contaminated												
Poor Shell Quality												
Cracked Shell												
Malpositions - Head in small end of egg												
- Head to left												
- Feet over head												
- Beak above right wing												
Malformations - Exposed brain/Eye defect												
- Extra limbs												
- Ectopic Viscera												
Embryo - Wet												
- Dehydrated												
Notes:												

Form 7. Egg Weights and Chick Weights

Company _____ Date Set _____

Farm _____ Date Hatched _____

Age _____ Date Broken Out _____

Setter No. _____ Hatcher No. _____

Tray No.	1	2	3	4	5	6	7	8	9	10
No. of Eggs										
Weight of Empty Tray										
Weight of Full Tray										
Transfer Weight										
No. of Chicks Hatched										
Total Chick Weight										
Culls and Deads										
Unhatched Eggs										
Egg Weight Loss (%)										
Mean Egg Weight (g)										
Mean Chick Weight (g)										
Chick Yield (%)										

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Every attempt has been made to ensure the accuracy and relevance of the information presented. However, Aviagen accepts no liability for the consequences of using the information for the management of chickens.

For further information on the management of Ross stock, please contact your local Technical Service Manager or the Technical Department.

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