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Factors Affecting Hatchability

by Joseph M. Mauldin

Numerous factors have pronounced influence on the hatchability of chicken eggs. Many of these are important long before the eggs are placed in the incubator. For example, breeder flock health, nutrition, breed, age of breeders, and breeder flock management can result in tremendous variation in hatchability. Equally important is the micro-environment surrounding the eggs prior to incubation. Egg collection, storage, and handling must be optimum to maintain embryonic viability before and during incubation. After setting in the incubator, temperature, turning, humidity, ventilation in the incubators and incubator rooms, sanitation, and general hatchery management are all critical factors to ensure embryonic survival and hatchability.

39-A. FERTILITY

Normally, fertility is the most important factor in determining hatchability performance. A study conducted in Georgia measured flock and hatchery performance in 15 broiler hatcheries over a six-year period (1984 to 1989). The life-of-flock average for infertility was 7.25%, which followed the typical pattern of infertility being the largest single cause of eggs failing to hatch.

1. *Determining Fertility*

There are three common methods to determine fertility. The first opportunity to sample fertility is with freshly laid eggs. The second opportunity

D. D. Bell et al. (eds.), *Commercial Chicken Meat and Egg Production*

involves candling eggs that have been incubated for 7 to 12 days and breaking out clear eggs to differentiate between infertility and early embryo mortality. The third method is the breakout of unhatched eggs on hatch day. This last method is a very powerful quality control procedure because it provides data on nearly all the possible causes of poor hatchability and serves as an excellent incubation troubleshooting tool.

a. Fresh Egg Breakout

The breakout of fresh eggs has the advantage of being the quickest way to estimate fertility in the breeder flock. It is useful when a flock begins to lay or when a flock has been treated for a disease or fertility problem. Fertility can be determined on the day the eggs are laid rather than having to wait until after incubation. For example, if there is a storage time of one week and fertility is determined by the hatch day breakout method, then the information regarding flock fertility is four weeks behind actual flock performance. While fresh egg breakout can provide the current status of fertility in a flock, it has several disadvantages.

The most serious disadvantage of fresh egg breakout is that it provides information only on fertility and does not measure other valuable information on additional important causes of reproductive failure such as embryonic mortality and contamination. A second disadvantage is the loss of valuable hatching eggs and potential chicks with this procedure. However, a relatively small sample size is normally used for fresh egg breakouts. Because valuable hatching eggs must be used, the sample size rarely exceeds 100, resulting in the third disadvantage, errors of prediction. A fourth disadvantage of a fresh egg breakout is that it is more difficult to distinguish between fertility and infertility in fresh eggs than when eggs have been incubated for several days. However, distinguishing fertiles from infertiles is certainly not impossible with a little practice. To correctly distinguish the differences in fertile and infertile eggs, the germinal disc must be examined.

There are three criteria that should be used to determine fertility of a germinal disc: shape, size, and color intensity.

- *Shape.* Upon close observation, a *blastoderm* (indicating fertility) is usually round (i.e., almost perfectly uniform and symmetrical). Hatchery personnel often refer to this shape as a "doughnut." The doughnut appearance is seen as a white symmetrical ring with a clear area in the center of the ring. The *blastodisc* (indicating infertility) is rarely perfectly round, and has jagged edges. There are usually more vacuoles (bubbles) present in the periphery of the blastodisc than in the blastoderm.

- *Size.* The blastoderm is almost always larger in appearance (one-quarter to one-third larger) than the blastodisc.
- *Color intensity.* The blastoderm almost always appears to be a less intense color of white than the blastodisc. The blastodisc appears as more of a small, intense white spot on the surface of the yolk. Sometimes the blastodisc is granulated. Instead of one white spot, there may be several clumped white spots.

For learning the technique of distinguishing between fertile and infertile germinal discs, it is helpful to make side-by-side comparisons of eggs known to be fertile and eggs known to be infertile. It may help to place the yolks in clear petri dishes and gently compress the lid down onto the germinal discs. This makes the discs stand out, allowing for comparisons of shape, size, and color. The beginner should use a magnifying glass to make these determinations.

While conducting a fresh egg breakout, it is important to have a sample size of at least 100 eggs per flock. Because of the disadvantages involved in the fresh egg breakout, use of this procedure is not recommended unless a quick fertility check is desired. Candling and/or hatch day breakouts should be done more routinely (every one or two weeks).

b. Candling and Breakout Analysis

Candling and breaking the clear eggs is considered the most accurate method to determine fertility. It is also useful for determining other sources of breeder flock or hatch failures, such as percentages of eggs set upside down, cracked, and embryos that have died early. Many hatchery managers incorporate the candling-breakout procedure into their quality control program to monitor the week-to-week status of breeders throughout the life of the flocks. Candling can be done as early as five days of incubation, but errors in candling often occur at this time. Because of the rapid growth rate of the embryos during the second week of incubation, very few, if any, candling errors are made on the ninth or tenth day of incubation.

There are two options for candling procedure. The fastest method involves the use of a table or mass candler. An entire tray of hatching eggs may be placed on the mass candler and examined at a time. Clear eggs consisting of infertiles and early embryo mortality emit more light than eggs with viable embryos and are removed for breakout. With mass candling, eggs can be easily compared for different defect gradations. Candling with a spot candler is a little slower, but it is more accurate for several reasons. By examining each egg individually, less candling errors occur.

The most common error with mass candling is to not recognize all the clears in a tray. For spot candling, the most common error is to incorrectly identify an egg with a viable embryo as a clear. Determining eggs which have been set upside down or cracked is much easier to distinguish with spot candling than with mass candling.

It is important to record the number of eggs set upside down, farm cracks and cull eggs (size, shape, shell quality, dirties, etc.). All hatcheries have defined quality standards for hatching egg procedures. Carelessness in sending eggs to the hatchery with the small end up will cost the company a lot of money in lost hatchability and chick quality. This becomes even more important in hatcheries using in ovo vaccination. Practically, all the embryos contained in upside down eggs will be killed by the in ovo vaccination process, as the needle impales the embryo. It is important to evaluate producers with a candling breakout analysis so that they can be encouraged to be more careful. The knowledge that a hatchery is enumerating upside down eggs will, in many cases, be enough to promote more careful egg collection.

For candling and breakout procedures to be accurate, a sufficient sample size of eggs must be used. A minimum of four trays per breeder flock (>500 eggs) is needed to ensure that estimates for fertility, eggs set upside down, farm cracks, and cull eggs are meaningful. Take trays from different areas in the incubator, as this will provide a more random sample of flock performance.

It is often suggested that candling estimates of fertility are a measure of *true fertility.* This is not correct. Candling samples of eggs only provides an estimate of true fertility. The only way to obtain the information of true fertility would be to candle every tray in a single setting of a breeder flock. To do this would not be time-efficient. Table 39-1 furnishes an example form that can be used while candling. An example of a candling breakout analysis is included in the form and reveals that fertility was excellent at 97.69% and early embryonic mortality was low at 2.47%. However, egg collection and selection on the breeder farm appeared to be a little sloppy, as percentages of cracks, upside down, and cull eggs were all greater than 0.50%.

c. Hatch Day Breakout

The hatchery may be throwing away valuable information in the waste that could help solve hatchery and breeder flock problems, and improve hatchability and profitability. Unhatched eggs can provide information that breeder and hatchery managers need. Without breaking eggs to gain this information, reasons for moderate-to-low hatchability are only guesses.

The hatch day breakout analysis involves sampling unhatched eggs from breeder flocks, and classifying them into the various causes of repro-

Table 39-1. 7- to 12-Day Candling and Breakout Analysis Form

Date: 10/14/96	Company: Big Bird		Hatchery Location: Athens			
Flock # 24	Test: No test		Breeder Flock Hatch Date: 12/27/95			
Breed:	Male X	Female Y	Age (wks): 38			
tray #	eggs/tray	infertile	early dead	farm cracks	upside down	cull eggs
1	162	3	5	1	2	1
5	162	5	5			2
10	162	4	3	2	2	1
15	162	3	3	1		1
TOTALS:	648	15	16	4	4	5
PERCENTS:		2.31	2.47	0.62	0.62	0.77

Fertility = 100% infertile = 97.69%

OTHER OBSERVATIONS: _____

Source: Mauldin, 1997

ductive failure. The procedures for this valuable management tool are described below.

The hatch day breakout analysis should be performed at least once every two weeks on samples of eggs from all breeder flocks, regardless of hatchability performance or flock age. Even good hatching flocks should be monitored to get a true picture of hatchery and reproductive efficiency. Breakout analysis on all breeder flocks is critical for pinpointing problems in setters and hatchers; comparing primary breeder performance; evaluating flock or farm management; and compiling flock histories for production, fertility, hatchability and reproductive failure. Breakouts are also beneficial for identifying problems during production, egg handling, and storage. For example, high numbers of early deads may indicate prolonged storage or storage at elevated temperatures, or inadequate egg collection procedures. In most hatcheries, breakout should be performed on two consecutive hatch days to ensure that all breeder flocks are sampled.

2. *Breakout Procedure*

- Immediately after chicks are pulled, collect a minimum of four trays of eggs per breeder flock from different locations of a single setter.

Table 39-2. Data Collection—Hatch Day Breakout

General Information	Reproductive Failures
Flock number	Infertile
Flock age	Embryo mortality
Male breed	Embryo malpositions
Female breed	Embryo abnormalities
Sample size, sample index	Pipped, unhatched
Setter number, sample index	Cull eggs
Hatcher number	Farm and transfer cracks
Management type (test)	Contaminated eggs
Hatchability	Cull chicks
	Upside down

- Remove all unhatched eggs, including pips, from the hatching tray. Place them in filler flats with the large end up and record the flock number.
- It is best to perform the breakout soon after the hatch is pulled rather than a day or two later. This gives a more accurate estimate of live versus dead in shell.
- Record the number of cull and dead chicks left in the tray.
- Break out the eggs and classify them into the appropriate categories of reproductive failure listed in Tables 39-2 and 39-3.

The best procedure is to break and peel the shell away at the large end of the egg since embryonic development will most often be located there. An alternative method of cracking the eggs over a pan is not as accurate because the embryo or germinal disc often rotates beneath the yolk and is difficult to locate. Cracking eggs also increases the likelihood of rupturing the yolk (vitelline) membrane (this membrane is weak after 21 days of incubation). When the yolk membrane ruptures, it is difficult to determine whether the egg contained an early dead embryo or was simply infertile.

a. Determining Embryo Mortality

There will be cases when the embryo or the blastodisc does not appear on the top of the yolk. When this occurs, rotate the egg and pour off some albumen so that the germinal disc (fertile or infertile) will appear at the top. If the germinal disc is still not found, the yolk may then be poured into an empty pan and examined.

The classifications of embryonic death may be as detailed as the hatchery manager wishes. However, it must be kept in mind when starting a breakout program that the quality control person is normally not an embryologist. In most cases, sufficient information can be obtained by classifying

Table 39-3. Hatch Day Breakout Analysis Form

Date: 10/14/00		Company: Big Bird			Flock #: 42				Test: no test		
% Egg Production: 73.8		Hatchery Location: Athens			Male Breed: X		Female Y		Age (wks): 38		
Breeder Flock Hatch Date:		# Set: 28,600			Actual Hatch %: 80.98				Setter #: 16		
		dead embryos			pipped	cull	cracks			cull	small
# eggs/tray	infert	1–7	8–14	15–21	unhatched	chicks	farm	trans	cont	eggs	end up
168	20	8		4	1		1			2	1
168	13	9		2	5	2		1	1	1	1
168	11	5	1	5		1	1	1		2	
168	16	6	1	3	1	2			2	1	1
Totals: 672	50	28	2	14	7	5	2	2	5	5	2
Percentages:	7.44	4.17	0.30	2.08	1.04	0.74	0.30	0.30	0.74	0.74	0.30

OTHER OBSERVATIONS: _____

% FERTILITY: 92.56

SAMPLE INDEX: 0.87 (<3.0 is good)

SPREAD: 11.58

MALFORMATIONS: None

% ESTIMATED HATCH: 81.85

% HATCH OF FERTILES: 87.49

SHELL QUALITY: OK

dead embryos by the week death occurred (i.e., first, second, or third). This is easily done after a little practice.

The clarity of the development is not as good in eggs broken after 21 days of incubation as when eggs are broken while the embryos are still alive. However, with practice, one can conduct an accurate breakout analysis by judging the embryos according to size and looking for some of the obvious changes in the developmental sequence (see *Development of the Embryo*, Chapter 35; Table 35-1). A good training technique for someone with little or no experience in breakout analyses would be to examine live embryos at different stages of development and compare them to the dead embryos obtained from unhatched 21-day incubated eggs, or embryos pictured in a number of poster publications published by the author.

b. Identifying Fertility in 21-Day Incubated Eggs

Fertility of a clear, or nearly clear, 21-day incubated egg can be identified by looking for signs of development, and by examining yolk color and albumen consistency. The two statements that follow relate to the identification of very early embryonic deaths, positive development, and infertile eggs after 21 days of incubation.

> "Generally speaking, an infertile yolk will be a brighter yellow than a fertile yolk." "The albumen of infertile eggs is thicker than the albumen of fertile eggs. The yolk of an infertile is held near the center of the egg while the yolk in a fertile egg will sink to near the pointed end of the egg."

Although these statements are correct, there are instances when they are not true. To accurately classify the egg, the presence or absence of early embryonic development must be established. The earlier description in this chapter of germinal discs of fertile and infertile eggs will also apply to the fertile and infertile discs on hatch day.

Most eggs can be classified as soon as the tops of the shells are peeled back. Others require closer examination. Always be careful not to let blood spots, meat spots, or yolk mottling result in classifying an infertile egg as fertile.

Another pitfall is that most embryos that die during the second week of incubation look dark and are often mistaken for contaminated eggs. The dark appearance results from the degeneration and rupture of the blood vessels in the large vascular system of the extra-embryonic membranes. Most contaminated eggs smell bad, which will help to classify them. In other words, second week embryonic mortality may look contaminated; however, they should only be classified as contaminated when they emit an odor.

c. Keep Accurate Records

It is necessary to collect general and reproductive failure data to provide a basis for drawing accurate analysis and inferences. Building a data base of information enables the evaluation of reproductive efficiency by flock and breed, and is an excellent diagnostic tool when problems arise in the hatchery or on the breeder farm. Also, the influences of flock management, field tests, and incubation equipment can be measured by studying their effects on fertility, hatchability, and reproductive failures.

The Hatch Day Breakout Analysis Form is a basic tool for the evaluation of reproductive performance (Table 39-3). All reproductive failures are enumerated, totaled, and the percentages calculated. From these data, reproductive efficiency measures such as fertility, percentage hatchability of fertiles, spread between fertility and hatchability, estimated hatchability, and the sample index can be generated (Table 39-4). The calculations in Table 39-4 were taken from the example data provided in Table 39-3.

By examining the results of the above example, an analysis of the problem areas of Flock #42 can be evaluated. The sample flock which was 38 weeks old should have hatched considerably higher than 80.98%. First, the fertility of 92.56% should be about 4% higher for this flock age. Also, the percentage hatch of fertiles was too low at 87.49%. This was caused by the elevated percentages for early deads (4.17%), contamination (0.74%), and cull eggs (0.74%). Therefore, the low hatchability of Flock #42 stems from problems in breeder flock and hatchery. The low sample index of 0.87 (<3.0) reveals that the sample was reliable in providing an estimate of true performance.

The sample index listed in Table 39-4 is a valuable measure in determining how representative the sample can be used in evaluating the true reproductive performance of the entire setting of eggs. A large sample index (greater than 3.0) would indicate that the sample was not a good represen-

Table 39-4. Examples for Calculating Reproductive Efficiency Values[1]

Formula:	% Fertility = 100 − (# infertiles ÷ sample size) × 100
Example:	100 − (50 ÷ 672) × 100 = 92.56%
Formula:	% Hatchability = (# hatched ÷ # set) × 100
Example:	(23,160 ÷ 28,600) × 100 = 80.98%
Formula:	% Hatch of Fertiles = (Hatchability ÷ Fertility) × 100
Example:	(80.98 ÷ 92.56) × 100 = 87.49%
Formula:	Spread = Fertility − Hatchability
Example:	92.56 − 80.98 = 11.58
Formula:	% Estimated Hatchability = 100 − % Reproductive Failures
Example:	100 − (7.44 + 4.17 + 0.30 + 2.08 + 1.04 + 0.74 + 0.30 + 0.30 + 0.74 + 0.74 + 0.30) = 81.85%
Formula:	Sample Index = % Estimated Hatchability − % Hatchability
Example:	81.85 − 80.98 = 0.87

[1] From data in Table 39-3

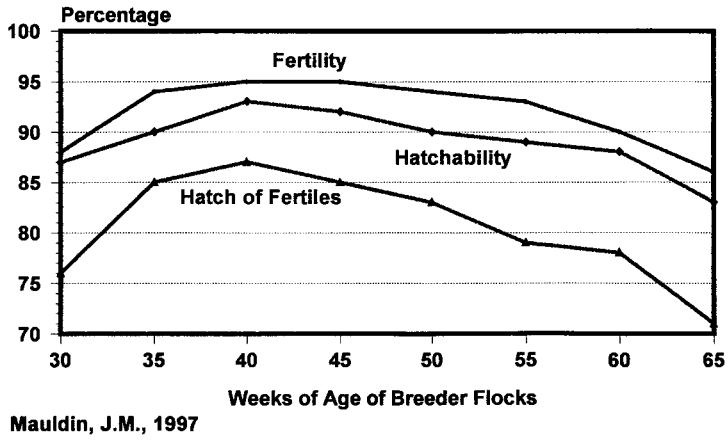


Figure 39-1. Influence of Flock Age on Reproductive Performance

tation of actual performance. Small sample sizes will result in greater variation in the sample index. Calculating these measures is necessary for interpreting results and taking corrective action. It would be a mistake to make corrective management changes in a flock or in the hatchery based on breakout analysis results when the sample index is high.

Figures 39-1 and 39-2 depict how building a data base on the life of the flock can be useful when evaluating reproductive efficiency. Notice how the age of a flock causes considerable variation in fertility, hatchability and embryonic mortality. Plotting these data provides for flock evaluations over time, and enables a manager to determine the genetic potential of breeding stock by using the best hatching flocks as examples.

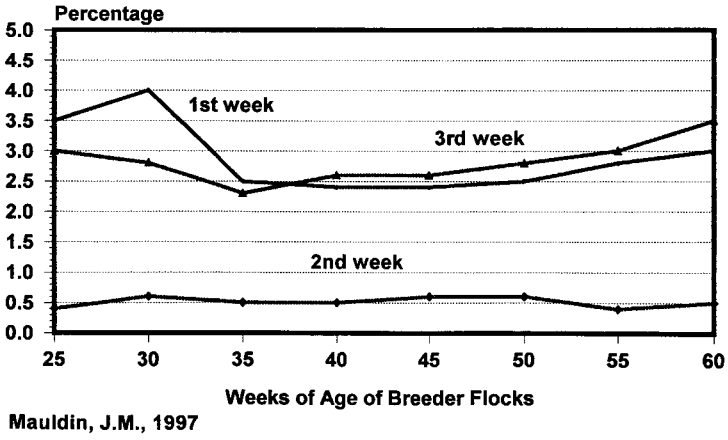


Figure 39-2. Influence of Flock Age on Embryo Mortality

39-B. SEX OF CHICKS

There is no method for determining the sex of the blastoderm from the time the egg is laid until the chick hatches. The ratio of males to females is nearly equal at the time ova are fertilized (primary sex ratio), but unequal mortality of the sexes during embryonic development usually causes more males than females to hatch (secondary sex ratio). The secondary sex ratio may vary among breeds or from the presence of sex-linked lethal genes which most frequently affect the heterogametic sex (females).

39-C. METABOLISM OF THE CHICK EMBRYO

The main influence on metabolic rate is incubation temperature. Higher temperatures accelerate growth and lower temperatures slow metabolic rate and embryonic growth. Increases in metabolic rate result in additional requirements for oxygen intake and carbon dioxide removal. When these chemical reactions are in balance the temperature is correct. In the modern setter the ideal incubation temperature ranges from 98.5°F to 100.25°F (37°C to 37.9°C). Even when the temperature setting is correct, airflow patterns and incubator condition and maintenance may result in hot and cold spots in the mass of eggs in the machines resulting in uneven hatches, poor hatchability, and reduced chick quality.

1. *Importance of Egg Moisture Weight Loss*

Avian eggs differ from reptile eggs as they never gain water from the environment. The partial pressure of water vapor inside the avian egg is always higher than the environment. This pressure differential between the inside of the egg and its environment directs the flow of moisture outward. There is a high resistance by the shell and cuticle to moisture loss, therefore incubation environmental conditions must be within an acceptable range to ensure proper moisture loss. When eggs are losing too much or too little moisture they can be brought back in line by changing humidity settings. However, over-drying early in incubation is harmful to the developing embryos. Eggs from young flocks are more susceptible to desiccation than eggs from older flocks. The optimal range of incubation moisture loss from chicken eggs is in the order of 0.60% to 0.65% of total egg weight per day. The acceptable range is from 0.55% to 0.70% per day.

Under a correct incubation environment, hatching eggs lose moisture at a fairly constant rate. During the second half of the incubation period the eggs lose moisture at a slightly higher rate than during the first half, because during the second half the embryos are producing metabolic heat which slightly raises the water vapor partial pressure. Also, shell conduc-

tance is increased slightly during the second half of incubation due to calcium absorption by the developing embryo from the shell which results in shell thinning.

2. Seasonal Variation

In climates where there is distinct seasonal variation, there are many variables that can affect incubation. For example, in the southeastern United States, summer days are very hot and nights are warm and humid. The high humidity becomes a serious problem for incubation because ambient relative humidity is near 100% for many hours every day. During the hottest part of the afternoon, the humidity falls to less than 50% but climbs rapidly about sundown. This makes it very difficult to achieve the correct incubation moisture weight loss from the eggs. The high humidity situation is aggravated as most hatcheries are cooled by evaporative cooling which adds moisture to the air. To correct for the high ambient humidity in evaporatively cooled air, many hatcheries are required to drastically lower the incubator wet bulb set points. Typically, incubator manufacturers recommend 86°F (30°C) wet bulb setting and do not recommend seasonal changes. However, hatcheries located in high humidity regions lower their wet bulb set points by two or three degrees Fahrenheit to promote greater hatching egg moisture loss and improved chick quality. In extreme instances, hatcheries have lowered the wet bulb setting to 80°F (27°C) and have seen further improvements. Because of the high ambient humidity, the actual incubation humidity will not average nearly as low as would be indicated by the new humidity set points.

During the winter, the ambient humidity is generally very low (rarely above 50% RH). Hatcheries in these areas that do not change wet bulb settings to higher temperatures can experience serious problems with too much egg moisture weight loss causing reduced hatchability, chick dehydration, and short hatch time. The low wet bulb settings have a more dramatic impact on incubation during the winter than in the summer because of low ambient humidity. These hatcheries should use different wet bulb settings that are dependent on season to achieve the correct egg moisture weight loss.

The best way to determine proper hatching egg moisture weight loss is to weigh samples of hatching eggs prior to and during incubation. When eggs lose moisture weight at a rate outside the acceptable range of 0.55% to 0.70% per day, adjustments to incubation humidity are warranted. The most common problem is that hatching eggs lose too little moisture during summer months. Signs of this may be observed by seeing how the eggs pip, and the conditions of the hatched chicks' hocks immediately after hatching. Unhatched pips located high in the shell indicate insufficient incubation moisture weight loss. Also, when moisture loss is not adequate

the chicks struggle harder than normal when emerging from the shell and may exhibit red hocks.

3. *Procedure for Determining Egg Moisture Weight Loss*

The most accurate way to determine the setters' humidity performance is to weigh a sample of eggs prior to setting, and follow those eggs through incubation with subsequent weighings. The procedure is simple and will give an accurate determination of moisture loss.

Gathering Data

Weigh individual trays to get tray weight, then add the eggs and re-weigh. Mark each tray so it can be found easily for subsequent weighings. Subtract tray weights to get actual egg weights. A scale that is accurate to at least 0.10 pounds (45 grams) is recommended. When each tray is weighed, examine the eggs closely for cracks or culls, and when found, replace them with good quality eggs.

Calculating Loss

An example is given in Table 39-5 showing how to determine egg weight loss. The example calculations represent one moisture loss measurement. If eggs are weighed twice during incubation, the second weighing should be taken between 14 days of incubation and at the time of transfer. If day-to-day fluctuations in weight loss is a concern, take several measurements, and use the appropriate days of incubation in the formula. It is important to calculate the average daily loss to see if it falls within the acceptable range of 0.55 to 0.70% per day. In the sample calculations (Table 39-5), the average daily moisture loss was 0.73% for one of the 10 trays measured. This figure is higher than the upper limit (0.70% per day) of the acceptable range indicating low relative humidity in the setter.

Moisture Weight Loss Varies

Most instances of moisture loss that fall outside the acceptable range are due to too little moisture being lost during incubation. Chick quality is also adversely affected when this happens. When eggs have an average daily loss less than 0.55%, it is necessary to lower the humidity settings in the setter to compensate.

Table 39-6 presents results describing the influence of incubation relative humidity (RH) on hatchability and chick quality. The normal humidity

Table 39-5. Example of Egg Moisture Weight Loss Determination

tray weight = 6.65 lb
egg and tray weight = 25.80 lb (day 0)
egg and tray weight = 23.70 lb (day 15)

Formula: egg weight = egg and tray weight − tray weight

Example: day 0 egg weight = 25.8 − 6.65
= 19.15 lb

day 15 egg weight = 23.70 − 6.65
= 17.05 lb

Formula: $$\% \text{ weight loss (day 15)} = \frac{(\text{day 0 egg weight} - \text{day 15 egg weight})}{\text{day 0 egg weight}} \times 100$$

Example: $$\% \text{ weight loss (day 15)} = \frac{(19.15 - 17.05)}{19.15} \times 100$$
$$= 10.97\%$$

Formula: $$\text{average daily loss} = \frac{\% \text{ weight loss (15 day)}}{15 \text{ days}}$$

Example: $$\text{average daily loss} = \frac{10.97}{15}$$
$$= 0.73\%$$

range used by commercial hatcheries is about 55%. When eggs were incubated at lower humidities (40% RH), the percentage hatchability of viable embryos at transfer was lower (90.91%) than eggs incubated at 55% RH (93.98%). Also, the incidences of chicks hatched with red hocks, eggs unhatched and not pipped, and eggs unhatched and pipped were greater when compared to eggs incubated at 55% RH. Further, eggs incubated at 70% RH fared much worse as only 56.48% of viable embryos at transfer hatched. Also, the incidence of chicks with red hocks and unhatched egg categories were the highest for the three humidity categories. Many of the chicks hatched from 70% incubation RH group were sticky with albumen, some had adhesions with the shell membranes, and others had poor yolk closures (unhealed navels).

Table 39-6. Breakout Analysis of Eggs Incubated at Varying Relative Humidities[1]

Relative Humidity %	No. Eggs	No. Hatched with Red Hocks	No. Not Pipped	No. Pipped, Unhatched	% Hatchability of Viable Embryos at Transfer	% Moisture Weight Loss
40	880	35	53	23	90.91	15
55	880	25	31	19	93.98	12
70	880	54	214	133	56.48	9

[1] From R. J. Buhr, 1998, unpublished data

Factors which may influence the degree of moisture weight loss during incubation include setter humidity control, setter room humidity, season of year, ambient relative humidity, age of breeder flock, egg size, shell quality and shell porosity. However, the relative humidity in the setters has the most pronounced influence on the moisture loss. Periodic weighing of eggs during incubation is an excellent quality control procedure to enhance the output of quality chicks.

39-D. TEMPERATURE DURING INCUBATION

1. *Physiological Zero*

Physiological zero is that temperature below which embryonic growth is arrested, and above which it is reinitiated. There is some confusion with regards to the exact physiological zero temperature for chicken eggs as there are complicating factors. For example, physiological zero will be different when eggs are warming up than when they are cooling down. The most frequent suggestion is that the physiological zero for chicken eggs is about 75°F (24°C).

2. *Optimum Temperature for Incubation*

Temperature is the most critical environmental concern during incubation because the developing embryo can only withstand small fluctuations during the period. During the first 18 days of incubation (setter phase) the range for incubation temperature is 98.5 to 100.25°F (37.2° to 38.2°C). During the last three days (hatcher phase) the temperature is lowered to between 98°F and 99°F (37° and 37.5°C). The recommended set temperatures for both setters and hatchers vary depending on the incubator manufacturer. Some commercial incubators are water cooled and others are air cooled. Additionally, fan types and alignments vary among the different incubator manufacturers. While "hot" and "cold" spots can occur in machines, the effects of the non-uniform temperature distribution can be lessened by routine incubator maintenance. The condition of the door seals, baffle doors, fan alignment and speed, etc. all have a significant impact on the airflow and temperature distribution within an incubator.

When incubation temperatures deviate from the optimum, hatchability will decline and the incidence of malformed chicks will increase. Too high an incubation temperature results in excessive late embryonic mortality. Low setter temperatures result in slow embryo growth, late and uneven hatching, and high percentages of pipped, unhatched eggs when chicks are pulled. Routine temperature checks are necessary to determine that incubation temperature is correct. Most hatcheries have an employee read

and record the incubation temperature and humidity every hour. Periodically, an accurate thermometer should be used to check the accuracy of the setter and hatcher thermometers.

Another complicating factor when recommending incubation temperature is that the optimum temperature is not the same for all eggs. The following factors may influence the proper temperature:

- egg size
- shell quality
- genetics (breed or strain)
- age of egg at setting time
- incubation humidity

In most cases, the incubator set points for temperature and humidity are established for eggs of an "average" egg age and size. Most incubation is done with multi-stage machines which incubate eggs from different flocks with varying ages, and even different breed/strains. To alleviate this condition, the industry is starting to experiment with single-stage machines. Single-stage incubation has a seeming advantage over multi-stage because the incubation conditions of temperature, humidity, and airflow can be tailored for a single setting of eggs. To date, however, single-stage machines have not exhibited quite as good performance in terms of hatchability as multi-stage machines. This is most probably due to the fact that more uniform temperatures can be maintained in the multi-stage machines because the developing embryos are at different ages. The older embryos produce heat and the younger ones require heat. Trays can be spaced so that the younger embryos benefit from the heat produced by the older embryos. In single-stage incubation, the incubator provides heat during the first 10 days, and cooling is required for the second half of incubation.

When power fails, incubators have a serious problem. All multi-stage machines and single-stage machines containing eggs that have been incubated 10 or more days will overheat. However, this is rarely a problem because nearly all commercial hatcheries have back-up generators to provide electricity during power outages.

3. *Embryo Temperature*

The importance of maintaining the correct temperature of the embryos has recently been shown to be as important as the incubator set temperatures. Ron Meijerhof, at Hybro has demonstrated that embryos may frequently become overheated during incubation, even when the incubator set points are operating correctly within the narrow temperature set point range. Problems with machine maintenance, incubator cooling, airflow patterns, or other conditions may cause embryos to overheat. Mauldin and

Buhr (1995) showed how a minor problem in incubator maintenance affected temperatures in different parts of the incubator creating areas that were outside the proper temperature range. The result of overheating is lower hatchability and reduced chick quality. Meijerhof suggested that this is a common problem that occurs frequently during incubation.

Embryo temperature should be measured frequently. Taking embryo temperatures can be easily done with the use of inexpensive digital infrared thermometers sold at most drug stores. These thermometers are ideal for measuring embryo temperatures; however, they are designed for measuring human body temperature in the ear canal. They read temperatures accurately between 50° and 104°F (10° and 40°C). Hold the temperature sensor against the side of an egg to get a temperature reading after only one second. Optimum embryo temperatures range between 99° and 101.5°F (37.2° and 38.6°C). During the first 10 days of incubation the embryo temperatures should be near the low end of the optimum temperature range and during the remainder of the days in the setter and hatcher the embryos should be near the high end of the optimum range. The low purchase price of this device is trivial to the amount of money that can be saved by using it to improve hatchability and chick quality.

39-E. INCUBATION HUMIDITY

Incubation humidity determines the rate of moisture loss from eggs during incubation. When the egg contents dry out too rapidly some embryos will fail to hatch and the ones that do will be smaller than normal and may not perform well when placed on the farm. When moisture is not lost from the eggs fast enough, hatchability and chick quality problems result. Generally, most incubator manufacturers recommend an incubation relative humidity ranging between 55 and 60%. After eggs are transferred to the hatcher the relative humidity requirements increase to about 65%. As pipping and hatching increase on the last day of incubation the relative humidity will increase to about 75%, as chicks are exhaling moisture and the wet hatch debris is exposed to the hatcher environment.

1. *Measuring Relative Humidity*

To accurately calculate relative humidity, compare the temperatures recorded by wet-bulb and dry-bulb thermometers. The dry bulb records the temperature of the ambient air. The wet-bulb thermometer is an ordinary thermometer in which the bulb has been covered with a water-moistened wick which measures the temperature of air at saturation or 100% RH. When air is forced over the wick-covered bulb, cooling is produced by evaporation, thus lowering the temperature.

Table 39-7. Percentage Relative Humidity as Determined by Wet-Bulb and Dry-Bulb Thermometer Readings

Wet-bulb Temperature		Dry-bulb Temperature			
		98.0°F (36.7°C)	98.5°F (37.0°C)	99.0°F (37.2°C)	99.5°F (37.5°C)
(°F)	(°C)	Relative Humidity (%)			
80	26.7	46	45	44	43
82	27.8	51	50	49	48
84	28.9	56	55	54	53
86	30.0	62	61	59	58
88	31.1	67	66	65	64
90	32.2	73	72	71	70
92	33.3	79	78	77	76

Source: North and Bell, 1990

The amount of moisture air will hold is determined by its temperature, i.e., moisture holding capacity of air approximately doubles with each 20°F (11°C) increase in ambient air temperature (Table 39-7). Some hygrometers directly read the percentage of relative humidity. There are also digital instruments that accurately record the relative humidity regardless of the incubator temperature.

2. *Egg Size and Its Effect on Egg Weight Loss*

Hatching eggs weighing 24 oz/doz (56.7 g/ea) and with good shell quality should lose approximately 12% of their weight during the first 19 days of incubation. While there are many factors that may influence moisture loss during incubation, egg size is possibly the greatest contributor. Table 39-8 shows the egg weight loss when eggs of different sizes are incubated at the same humidity.

Table 39-8. Daily Weight Loss of Hatching Eggs of Various Sizes (relative humidity of 50–60%)

Avg. Beginning Egg Weight		Egg Weight Loss, 1–19 Day of Incubation (%)	Avg. Daily Egg Weight Loss (%)
(oz/doz)	(g/ea)		
23	54.3	12.25	0.645
24	56.7	12.00	0.632
25	59.1	11.80	0.621
26	61.4	11.60	0.611
27	63.8	11.45	0.603
28	66.2	11.30	0.595

Source: North and Bell, 1990

Table 39-9. Relative Humidity and Egg Size as They Affect Incubation Weight Loss

Relative Humidity in Setter (%)	Original Weight of Eggs				
	22 oz/doz 52.0 g/ea	24 oz/doz 56.7 g/ea	26 oz/doz 61.4 g/ea	28 oz/doz 66.2 g/ea	30 oz/doz 70.9 g/ea
	Loss of Egg Weight, 1 through 19 days of Incubation (%)				
70–79	10.6	10.3	10.0	9.8	9.6
60–69	11.5	11.1	10.7	10.4	10.2
50–59	12.5	12.0	11.6	11.3	11.1
40–49	13.7	13.1	12.6	12.2	11.9
30–39	15.0	14.3	13.8	13.4	13.1

Source: North and Bell, 1990

3. *Shell Area and Egg Weight Loss*

The ratio of shell area to egg weight regulates, in part, the amount of moisture loss occurring during incubation. The surface area of the shell is indirectly correlated with the weight of the egg. Larger eggs have less shell area per unit of weight than smaller eggs. Evaporation depends mainly on the surface area of the shell and the resulting number of shell pores through which moisture can be lost. Therefore, smaller eggs lose a larger percentage of their weight during incubation than larger eggs (Table 39-9).

Smaller eggs produce smaller chicks not only because the eggs are smaller but chicks hatched from these eggs are also even smaller because the percentage of moisture loss is greater. With larger eggs, the reverse is true.

Most eggs from a given flock vary as much as 5 oz/doz (2 g/ea) in weight, and therefore, do not lose the same percentage of moisture during incubation.

Table 39-10 shows proper relative humidity settings for an incubator to accomplish a 12% moisture weight loss with eggs of different weights. One should calculate the average weight of the eggs before using the table. *Remember:* As egg size of the breeding flock increases during production, incubation relative humidity should be lowered to ensure adequate evaporation from the egg.

4. *Shell Quality Affects Humidity Requirement*

Shell quality has a demonstrable influence on the rate of incubation moisture loss and may require adjustments to setter wet bulb temperatures to regulate the loss. Moisture moves more freely through shells of poor quality. Thin, chalky, porous shells will allow for increased evaporation

Table 39-10. Egg Size as it Relates to Relative Humidity

Original Weight of Eggs		Relative Humidity in Setter for Eggs to Lose 12% Weight in 19 Days	Wet Bulb Temperature in Setter to Lose 12% Weight in 19 Days— Dry Bulb Temperature 99.5°F (37.5°C)	
(oz/doz)	(g/ea)	(%)	(°F)	(°C)
22	52.0	58–62	86.8	30.4
23	54.3	56–60	86.0	30.0
24	56.7	53–57	84.9	29.4
25	59.1	51–55	84.1	28.9
26	61.4	49–53	83.4	28.6
27	63.8	47–51	82.6	28.1
28	66.1	45–49	81.7	27.6

Source: North and Bell, 1990

of the egg contents, producing chicks smaller than normal, as adequate moisture has not been allowed to escape from the shell during incubation. Chicks from eggs with thick, dense shells tend to be larger than normal. Table 39-11 illustrates the relationship between shell quality and moisture loss.

39-F. AIR REQUIREMENTS DURING INCUBATION

The main components of air are oxygen (O_2), nitrogen (N_2), carbon dioxide (CO_2), and water vapor (H_2O). The free movement of these molecules through the pores of the shell and the shell membranes is important as the developing embryo must receive a constant supply of oxygen and must eliminate carbon dioxide and moisture.

Table 39-11. Influence of Shell Quality on Egg Weight Loss during Incubation (57% relative humidity)

Egg Weight		Shell	Weight Loss 1–19 Days of Incubation
(oz/doz)	(g/ea)	Thickness	(%)
24	56.7	Thin	14.0
24	56.7	Average	12.0
24	56.7	Thick	10.5

Source: North and Bell, 1990

1. *Oxygen in the Air*

The oxygen content of the air at sea level is about 21%. It is impossible to increase the percentage appreciably in incubators unless pure oxygen is introduced.

Generally, the oxygen content of the air in the setter remains at about 21%, but there may be some variation in the hatcher where large amounts of carbon dioxide are produced by the newly hatched chicks. Hatchability will drop about 5% for each 1% that the oxygen content of the air drops below 21%. The main danger in these cases, is that high levels of carbon dioxide become toxic.

2. *Air Supply Generally Adequate*

As the embryo ages, its oxygen requirement increases and more carbon dioxide is given off. Each process is speeded up approximately 100 times between the first and 21st day of incubation, as shown in Table 39-12. Therefore, on the 18th day of incubation, 1,000 eggs require 143 ft^3 (4.1 m^3) of fresh air per day (oxygen in the air at 21%). Furthermore, an incubator holding 40,000 eggs would need 5,720 ft^3 (162 m^3) of fresh air, or approximately 238 ft^3 (6.8 m^3) per hour. Therefore, air in the incubator needs to be changed about eight times a day or once every 3 hours. This rate of air exchange is the minimum required. Air exchange rates in most machines are usually more than adequate. In some cases, care must be taken to ensure that overventilation and a corresponding excessive loss in moisture does not become a problem.

3. *Carbon Dioxide Tolerance*

Carbon dioxide (CO_2) is a natural by-product of metabolic processes during embryonic development which begins during gastrulation. In fact, CO_2 is being released through the shell at the time the egg is laid.

Table 39-12. Gaseous Exchange during Incubation per 1,000 Eggs

Day of Incubation	Absorption of Oxygen (ft^3)	Expulsion of Carbon Dioxide (ft^3)
1	0.50	0.29
5	1.17	0.58
10	3.79	1.92
15	22.70	11.50
18	30.00	15.40
21	45.40	23.00

Source: Romanoff, A. L., 1930

Carbon dioxide levels increase in the air within the setter and hatcher when there is insufficient air exchange. Younger embryos have a lower tolerance level to CO_2 than older ones. The tolerance level seems to be linear from the first day of incubation through the 21st day. During the first 4 days in the setter, the tolerance level of CO_2 is about 0.3%.

Carbon dioxide levels above 0.5% in the setter reduce hatchability, with significant reductions at 1.0%, and are completely lethal at 5.0%. Hatching chicks give off more CO_2 than embryos in eggs, and the tolerance level in the hatcher is about 0.75%. Recording devices are available for measuring the CO_2 content of the air, and some incubators have them as standard equipment. The best place to measure the CO_2 is in the exhaust duct coming out of the setter or hatcher. Measurements taken inside the machines are not as accurate because opening the doors will change the environment in the machine.

4. *Speed of Airflow*

The most important aspect of airflow in an incubator is to ensure the proper mixing of temperature and humidity throughout the incubator cabinet, while bringing in fresh air for oxygen and exhausting used air to reduce carbon dioxide, excess moisture, and temperature. Different incubator manufacturers have different means of circulating air: paddles, blades, and fans. In most cases, it is the pattern of airflow that is most important. Air, like water, follows the path of least resistance. An incompletely closed baffle door, a poor door seal, or a fan out of alignment will negatively affect airflow patterns. In a poorly maintained machine, insufficient air is circulated through the mass of eggs resulting in hot and cold spots, which in turn creates slow hatches, reduced hatchability, and lower chick quality. Incubator maintenance is critical to achieve optimum airflow.

5. *Effects of Room Ventilation on Incubator Performance*

Ventilation of setter and hatcher rooms has a strong influence on the efficient operation of the machines and on subsequent hatchability and chick quality. An incubator will successfully incubate eggs even when it is placed outdoors. However, in this situation, it will neither operate efficiently nor economically, and the performance in hatchability and chick quality will be lower. For optimum performance, incubators need to be enclosed in a room where there is plenty of fresh air that has been preconditioned with temperature and humidity, with a slightly positive air pressure differential between the incubator (setter or hatcher) room and adjacent rooms. Typically, hatcher and setter rooms have thermostats, humidistats, and pressure controls that are designed to create a good

working environment for the machines. The acceptable ranges for setter and hatcher room temperature and humidity are between 75° and 80°F (24° and 25.5°C) and 50 and 65%, respectively. When these environmental parameters are outside the acceptable range, the incubators will compensate, but at an economic and efficiency cost. For example, when a setter room is too cool, the incubator will use additional heat to achieve the correct incubation temperature. However, heating the air with setter electric heating coils will be more than three times the cost of heating the room air with a gas furnace before it enters the incubator. Further, when incubators have to work harder to create the correct incubation temperature, the temperature environment inside the mass of eggs is often not optimally uniform. This results in hot and cold spots within the machine speeding the rate of development of some embryos, while delaying the development of others. Similar non-optimum results occur when the humidity is outside the acceptable range. For example, when a setter room environment is too dry, the incubator will provide the additional humidity at the expense of economics and performance. Every time the incubation humidity comes on, the mist creates evaporative cooling and the electric heating elements will respond (economic cost). Additionally, the evaporative cooling caused by the humidity mist will signal the fresh air dampers to close more, which results in less oxygen and more carbon dioxide (performance cost).

The placement of room thermostats and humidistats is critical to provide the correct ambient conditions in the rooms. These environmental control devices work much better when they are placed in the airflow of the room and not in a "dead" spot. A common, but incorrect location for thermostats and humidistats has been the setter or hatcher room end wall. When they are flush mounted on the end wall, it is unlikely that they will correctly "read" the room conditions and their responses will be incorrect. An excellent example of incorrect thermostat or humidistat placement and the corresponding effect are provided in Figures 39-3 and 39-4. In these examples,

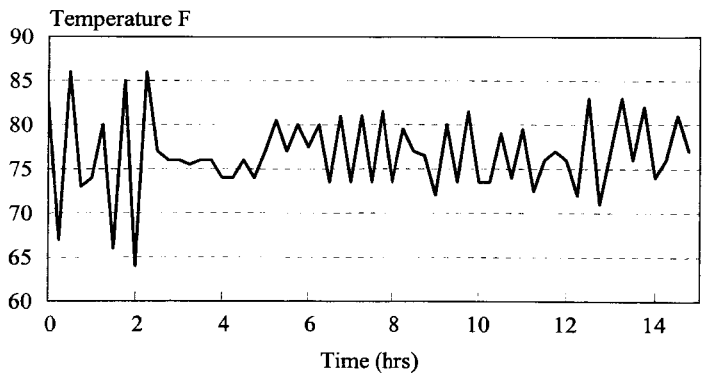


Figure 39-3. Hatcher Room Temperature Before Correct Thermostat Placement

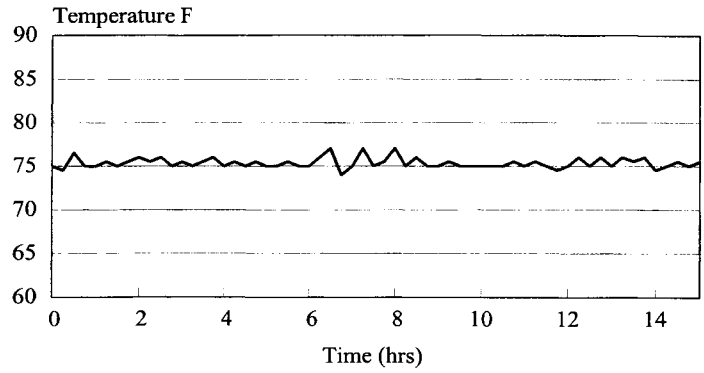


Figure 39-4. Hatcher Room Temperature After Correct Thermostat Placement

moving the thermostat further into the room significantly improved room conditions, and subsequently the performance of the machines.

6. *Incubation at High Altitudes*

It has been well documented that increases in altitude can reduce hatchability. This observation warrants some discussion, as many hatcheries around the world are located at high altitudes.

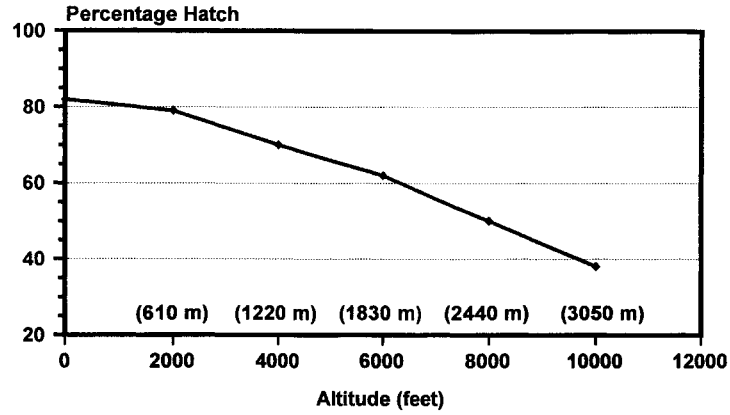
Air varies in its density according to elevation; the higher the altitude, the less dense it becomes. Because air weighs less at higher altitudes it exerts less barometric pressure. Also, when air expands, as at high altitudes, a cubic volume contains less oxygen. Data describing the relationships among altitude, oxygen content, and barometric pressure are shown in Table 39-13.

Hatchability of chicken eggs is reduced as the altitude at which they are incubated increases. However, for altitudes under 2,500 ft (760 m), the reduction is so slight as to be seldom noticed. When the altitude is over

Table 39-13. Relationship Among Altitude, Oxygen Content of Air, and Barometric Pressure

Altitude Above Sea Level		Barometric Pressure	Reduced Weight of Air (or Oxygen)
(ft)	(m)	(inches Hg)	(%)
0	0	29.92	0
2,000	609	27.82	5.1
4,000	1,217	25.84	11.2
6,000	1,829	23.98	16.4
8,000	2,438	22.22	21.4
10,000	3,048	20.58	26.2
12,000	3,658	19.03	30.7

Source: North & Bell, 1990



North, M.O. and D.D. Bell, 1990

Figure 39-5. Relationship Between Altitude and Hatchability

3,500 ft (1,067 m) the loss in hatchability becomes a chronic problem. Figure 39-5 shows the reduction in hatchability at increased altitudes based on a hatchability of 80% at sea level.

By increasing the air pressure to sea level values during incubation, it is possible to restore normal hatchability. This is one of the methods used for incubation at high altitudes. The design and construction of the hatchery determines whether or not pressurization can be economical.

The more typical and practical method of restoring normal hatchability at high altitudes is to flush oxygen directly into the incubators when eggs are incubated. Increasing the oxygen in incubators to concentrations of 23 to 23.5% will result in increased hatchability at high altitudes.

Oxygen is introduced into both the setter and hatcher compartments by way of a tube from oxygen cylinders that have a pressure regulator valve and flowmeter. A gas-analysis apparatus is required to determine the percentage of oxygen in the mixed air within the incubator cabinets. Readings and adjustments must be made several times a day to compensate for increasing embryo utilization.

7. *Other Factors to Consider with High-Altitude Incubation*

Following are important factors to be considered with high-altitude incubation and breeder flock management:

- Increases in incubation time as the altitude increases, may be due to a decrease in the carbon dioxide content of the ambient air rather than reductions in the oxygen content. The increased CO_2 as seen at sea level incuba-

tion stimulates the chicks to pip and emerge from the shell.

- Eggs produced by breeder hens kept at high altitudes produce normal hatches if they are incubated at low altitudes. Eggs produced by breeder hens at high altitude and incubated at high altitude have an increased incubation time associated with a lower metabolic rate.
- Altitude has no effect on fertility.
- Chicks produced from eggs laid by breeder hens at high altitudes and incubated at high altitudes have greater mortality during growout than normal.

39-G. POSITION AND TURNING OF THE EGG DURING INCUBATION

Frequent turning and egg orientation are important during the first 14 days of incubation. Artificially incubating eggs should be held with their large ends up. It is natural for the head of the chick to develop in the large end of the egg near the air cell, and for the developing embryo to orient itself so that the head is uppermost. This rotation occurs during the second week of incubation. When eggs are incubated with the small end up, about 60% of the embryos will develop with the head near the small end. Thus, when the chick is ready to hatch, its beak cannot break into the air cell to initiate pulmonary respiration. Eggs positioned horizontally will incubate and hatch normally as long as they are turned frequently.

Nearly half of the eggs set with the small end up will fail to hatch, and chick quality of those which hatch will be reduced. Most eggs set with the small end up are due to either carelessness or because of difficulty in distinguishing between the large and small end. Older hens lay a larger percentage of eggs that are more nearly round, thus making it difficult to determine the large and small ends.

In nature, the hen turns the eggs many times a day. For nearly all commercial incubators, the eggs are set large end up and rotated back and forth along their long axes for turning. Eggs should not be turned continuously in a circle; this practice will rupture the yolk sac resulting in embryonic mortality. Most eggs are turned to a position of 45° from vertical, then reversed in the opposite direction to 45° from vertical. One incubator turns them to a position of 90° from vertical, then reverses them to the opposite position. Rotation less than 45° is not adequate to achieve high hatchability as shown in Table 39-14.

Interval of turning. During the first 14 days, eggs must be turned regularly and often. Table 39-15 shows the percentage of hatchability of eggs turned from two to ten times a day. Although other experiments have shown that turning eggs as often as every 15 minutes is not detri-

Table 39-14. Effect of Angle of Turning Eggs during Incubation

Angle Turned to Each Side of Vertical	Hatch of Fertile Eggs (%)
20°	69.3
30°	78.9
40°	84.6

Source: North and Bell, 1990

mental to hatchability, nothing is to be gained by turning them more than six times a day when eggs are rotated back and forth along their long axes. Most commercial incubators provide for turning eggs automatically every 1 to 3 hours.

Period of turning. Table 39-16 shows the effect of turning hatching eggs at various times during incubation on hatchability. The results indicate that turning the first week is the most important, and the second week, next. Turning the last week seems to be of questionable value. In some models of multi-stage incubators, eggs of various ages are intermingled so that all eggs must be turned together.

Important. The turning process should be completed quickly, allowing the eggs to remain stationary until the next turning. Hatchability is lowered when eggs are kept in a constant back-and-forth motion.

Transferring Eggs to the Hatcher

Hatcheries transfer the eggs from setter to hatcher between 17 and 19 days of incubation. This is done either manually or mechanically. Although mechanical transfer will not save labor, it is beneficial in reducing the percentage of cracks. Pneumatic transfer machines are the best for gentle transfer and for reducing cracks. It is best to transfer eggs in front of the hatcher and not in front of the setter. Eggs transferred in front of the setter always have more cracks, as eggs are not as well protected in the

Table 39-15. Effect of Turning Eggs on Hatchability

Times Turned Daily	Hatch of Fertile Eggs (%)
2	78.1
4	85.3
6	92.0
8	92.2
10	92.1

Source: North & Bell, 1990

Table 39-16. Effect of Turning Hatching Eggs at Various Times during Incubation

Period Turned during Incubation (Day)	Hatch of Fertile Eggs (%)
no turning	28
1–7	78
1–14	95
1–18	92

Source: North & Bell, 1990

hatcher trays as in the setter flats with individual cells to hold and protect each egg. Rolling a buggy of hatcher trays down a long hallway to the hatcher is not a good practice because it increases the potential for cracks.

Length of incubation period varies. Several factors influence the length of the incubation period—breed, gender, age of eggs, size of eggs, shell quality, etc. Eggs with shorter incubation periods should be set later than those needing longer periods of incubation. When setting times are correct, all eggs should hatch within 18 hours.

Females hatch before males. There is evidence that when fresh eggs are incubated, females hatch as much as 3 hours before males. However, the spread decreases the longer the eggs are held prior to incubation and completely disappears when eggs are held for 14 days or more.

39-H. OTHER FACTORS AFFECTING HATCHABILITY

There are a number of other factors which affect hatchability. Although many of these factors may be of minor significance when occurring individually, they can be cumulative with several minor problems resulting in significantly reduced hatchability.

1. *Egg Laying Pattern and Hatchability*

The first eggs from a breeder flock do not hatch well and do not demonstrate good livability after hatch. Usually they are held in the hen for a period longer than normal, and the preincubation is detrimental to hatchability. Generally, hatching eggs produced during the first 2 weeks of egg production are not set, not only because of poor hatchability and chick growth but also because they are small and produce small chicks.

Eggs produced near the end of the laying cycle do not hatch as well as those laid earlier. There is a pattern of increased hatchability from the first eggs set until about the 12th or 13th week of egg production, after which hatchability gradually decreases as the hen continues to age.

Eggs from hens with a high rate of lay hatch better than those from birds laying at a medium or low rate. There is evidence that eggs laid in longer clutches not only have a higher rate of hatchability, but those laid near the end of the clutch hatch better than those laid at the beginning. The first eggs in each clutch are normally the worst hatching eggs.

2. *Weather Affects Hatchability*

Extremes in environmental temperatures are detrimental to hatchability. Prolonged periods of hot or cold weather are likely to cause a drop in hatchability because of their adverse effects on the hens. Short periods of hot or cold weather (1 or 2 days) are generally not a problem. Hot weather during the summer months is particularly damaging. In a study of large commercial hatcheries in the United States, the hatchability of eggs during the months of July, August, and September was about 5% lower than during the remainder of the year.

3. *Factors Affecting the Length of the Incubation Period*

The average incubation period for chicken eggs is 21 days, but can be highly variable. In fact, the variations may become so great at times as to affect the normal routine of hatchery labor and to lower chick quality. The following are some of the causes of this variation:

- Disease and other stressors in the breeder flock can lengthen the period of incubation.
- Flock age lengthens incubation time.
- The longer an egg is held in the body of the hen prior to oviposition, the greater the early embryonic growth, thus reducing the incubation time in the incubator. Embryos that are just past the gastrula stage when the egg is laid hatch best.
- Eggs produced in the warmer season have a shorter incubation period than those laid in the cooler season, which is due to preincubation development.
- The smaller the breed, the shorter the incubation period.
- The longer an egg is held at a temperature above 75°F (23.9°C) prior to setting, the shorter the incubation period.
- Increases in egg storage time will increase the incubation period. For each day of storage after five days, the incubation period will be increased by about one hour.
- Small eggs hatch sooner than large eggs.

Table 39-17. Classification of Malpositions

Classification	Description of Malposition
I	Head between thighs
II	Head in small end of egg
III	Head under left wing
IV	Head not directed toward air cell
V	Feet over head
VI	Beak above right wing instead of under

- Eggs warmed prior to setting will require a shorter incubation period.
- Lower setter relative humidities will reduce incubation time.

4. *Position of the Embryo in the Egg*

Normally, the chick embryo develops with the head in the large end of the egg (near the air cell) and with its head under its right wing. But there are many embryos that do not develop in this position. These are called malpositions, and have been classified and described. The more common malpositions are presented in Table 39-17.

Many of the malpositioned embryos will hatch as viable chicks while others will not. Of all embryos examined at 18 days of age, between 1 and 4% will be malpositioned. An examination of the dead-in-shell during the hatch day breakout analysis will be necessary to determine the percentage and type of malposition involved.

5. *Abnormal Embryos*

Embryos that develop abnormally, but still hatch, should be culled during chick grading. A partial list of these variations is included in Table 39-18.

Table 39-18. Chick Abnormalities

small head	crooked neck	clubbed down
popeyed	twisted spine	short down
one eye	thickened hocks	dwarf
no eyes	extra leg	spraddle legged
parrot beak	unabsorbed yolk	star gazer
crossed beak	curled toes	brain outside head
short beak	wingless	extra appendages

39-I. EMBRYONIC MORTALITY PATTERNS

There are four periods during the development of the embryo when mortality may be excessive and thereby offer some indication of the cause of poor hatches.

1. *Period I (Preovipositat Mortality)*

When eggs are held in the hen too long, embryonic development advances too far past the gastrula stage, and the embryonic mortality during egg holding after the egg is laid increases markedly. There is also an increase in embryonic mortality during egg holding if the period of gastrulation has not been completed when the egg is laid.

The movement of the egg through the oviduct is influenced by several factors that may lengthen the time of oviposition. Larger eggs take longer than smaller eggs, and eggs with thick shells take longer than those with thin shells to pass through the oviduct. Hens whose eggs do not become overly large through the laying period produce eggs that hatch better.

Poorer producing hens lay eggs which remain in the oviduct a longer period of time, sometimes as long as 27 hours, with embryo growth having advanced too far when the egg is laid. This is one major reason why better egg producers usually have higher hatchability.

Conversely, in prematurely laid eggs, the preoviposital incubation period is shortened. These eggs are generally characterized by thin shells, or in the case of brown-shelled eggs, by a lighter shell color. Certain respiratory diseases in the breeder flock can cause premature oviposition.

2. *Period II (Early-Dead Embryos)*

Period II represents embryos that die during the first week of incubation. Some do not reinitiate development once the eggs are placed in the setter. This may be the result of poor egg-holding conditions between the time the eggs are laid and the time they are placed in the incubator, which lowers embryo vitality. If the vascular system is advanced far enough when the young embryo dies, the blood will migrate and pool at the outer edges of the blood vessels and coagulate there, leaving a blood ring. The normal percentage of Period II embryonic mortality is about 2.75% during the life of the breeder flock.

3. *Period III (8- to 18-day Mortality)*

Embryonic mortality during Period III should remain very low, less than 0.75%. Nutritional deficiencies in the breeder diet have their greatest effect

on the embryo in Period III, although too little vitamin A may cause excessive embryonic mortality since vitamin A aids in the development of the circulatory system.

Mortality is increased during Period III when there are nutritional limitations in the breeder diet and also more embryonic abnormalities appear. Clubbed down, curled toes, dwarfing, micromelia (shortening of the long bones), parrot beak, crooked keel and beak, malpositions, blood clots, and edema may be evident. Breeder age has little influence on Period III mortality.

4. *Period IV (Nineteenth, Twentieth, Twenty-first Days of Mortality)*

These last 3 days of incubation represent another critical stage. Many changes occur in the developing chick during Period IV (see Table 35-1). A large amount of the embryonic mortality during Period IV is caused by factors of long duration. Of those chicks that fail to hatch, many will be found in an abnormal position; the most common cause of embryonic malpositions occurs when eggs are not set with the air cell up.

Survey of Embryonic Mortality

A survey was conducted to evaluate embryonic mortality patterns and reproductive failures in 15 commercial broiler hatcheries (Table 39-19). The mortality periods in the study were early (1 to 7 days), middle (8 to 14 days), and late (15 to 21 days). Variations from these values will help to determine where problems may occur, which were derived from averages for the life of the flock. Breeder flock age is normally the largest influence on most of these figures. In the first four weeks of the egg production cycle

Table 39-19. Industry Averages vs Best Company Averages for Reproductive Failure on Hatch Day

Reproductive Failure	Average %	Best Company %
Infertile*	7.25	6.27
Embryo mortality: (1–7 days)	2.46	2.27
(8–14 days)	0.44	0.32
(15–21 days)	2.75	2.12
Pips	1.12	1.05
Farm cracks	0.63	0.48
Transfer cracks	0.34	0.26
Contaminated	0.39	0.39

* Includes preovipositional mortality
Source: Mauldin, 1997

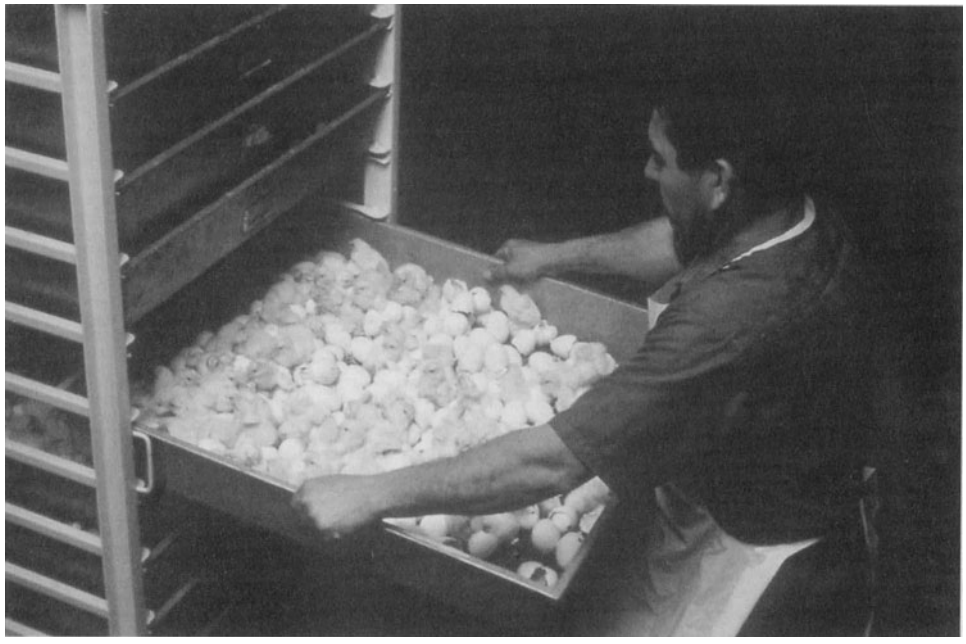


Figure 39-6. Recently Hatched Chicks

and after 50 weeks of age, reproductive failures are normally higher than the average for the life of the flock.

39-J. NUTRITIONAL EFFECTS ON HATCHABILITY

Nutritional deficiencies or toxic materials in the breeder diet can affect both egg production and hatchability, with the impact increasing gradually as the involvement becomes more acute. Sudden drops either in egg production or hatchability are more likely the result of disease in the flock or incubator failure (hatchability only).

Nutritional deficiencies cause embryonic mortality at earlier stages. For example, mortality that normally occurs during 18 to 21 days will be found at 15 to 19 days or even earlier if there are deficiencies in nutrients. A recent discussion of some nutritional deficiencies is provided in Table 39-20.

39-K. DISEASE AND HATCHABILITY

Most diseases affecting the breeder flock will also adversely affect the developing embryo, hatchability, and chick quality. Disease-producing organisms will also establish themselves in the hatchery and incubators infecting future hatches. It is almost impossible to differentiate the source

Table 39-20. Nutritional Deficiencies and Toxicities; Almost Always a Breeder Flock Problem (unless stated otherwise, the symptoms listed are the result of a deficiency)

Vitamin A	Circulatory system development abnormal; skeletal abnormalities, especially in the skull and spinal column; degenerative changes in the brain, spinal cord, and nerves; embryonic mortality is early (during days 2 to 3). Chicks hatching may have watery discharge from eyes or have eyelids stuck together. A great excess of vitamin A also will cause skeletal abnormalities.
Vitamin D_3	Deficiencies cause late embryonic mortality (>17 days); stunting; poor skeletal growth; rickets.
Vitamin E	Circulatory system problems, exudative diathesis, hemorrhages, stunting, encephalomalacia, eye abnormalities (e.g., cloudy lens or hemorrhages), edema of neck and feet; embryonic mortality peaks during days 2 to 5. Muscular weakness after hatching.
Vitamin K	Hemorrhages in embryo and membranes, especially at or near time of hatching.
Thiamin	Polyneuritis; early mortality peak and late peak ≥19 days; many dead chicks in hatching trays.
Riboflavin	Stunting, short legs, disorganization of the circulatory system, edema, clubbed down, curled toes, micromelia, anemia, brown or dark green liver; mortality peaks during days 3 to 5, 10 to 15, and 21 to 22. Mortality peaks change from late to early as breeder depletion of riboflavin proceeds.
Niacin	Hypoplasia (decreased growth and development) of skeletal muscles, edema, short upper beak, nervous and vascular system abnormalities. Mortality peaks during days 8 to 14.
Vitamin B_6 (pyridoxine)	Inhibition of early embryonic growth; mortality peaks during days 8 to 14.
Pantothenic acid	Subcutaneous hemorrhages, edema, hydrocephalus, poor feathering, twisted legs, fatty livers, opacities of the eye, pale, dilated hearts; embryonic mortality peaks during days 2 to 4 and 11 to 15.
Biotin	Chondrodystrophy and micromelia (deformed skeleton, shortened long bones, parrot beak), syndactylism (webbing between toes); hemorrhages in the embryo and chorioallantois; peak embryonic mortality during days 3 to 4 and ≥17. The early mortality peak is greatest with severe deficiency, while the late peak is greatest with mild deficiency.
Folic acid	Bent tibia, syndactylism (toe webbing), flattened head, small eyes, exposed viscera, parrot beak, other beak defects, stunting; peak embryonic mortality days >17.
Vitamin B_{12}	Edema (especially around eyes), hemorrhages, curled toes, short beak, poor leg muscle development, dwarfing, fatty liver, enlarged thyroid, dilated, irregularly shaped heart, head-between-thighs malposition; peak embryonic mortality during days 8 to 14 (small peak) and 16 to 18.
Manganese	Chondrodystrophy, deformed skeleton, shortened long bones, parrot beak, micromelia, edema, abnormal down feathers; peak embryonic mortality days >18. Chicks uncoordinated.

Zinc	Skeletal defects, especially in posterior vertebral column (most common defect is rumplessness), small eyes, exposed viscera, beak and head abnormalities, edema. Chicks are weak; will not stand, eat, or drink. Embryonic mortality can be very high.
Calcium	Effects more indirect through poor shell quality, increased egg weight loss, and increased contamination. Stunted growth, decreased bone development, and increased mortality tend to occur in later stages. A great excess of calcium also will cause embryonic abnormalities.
Magnesium	Nervous tremor, gasping, and convulsions at hatching.
Phosphorus	Abnormal bone formation, stunting; mortality peaks during days 14 to 16.
Copper	Blood and circulatory system defects. Mortality peaks during days ≤3.
Iodine	Affects thyroid activity. Deficiency or excess causes increased incubation time, decreased growth, and increased mortality. Thyroid may be enlarged.
Selenium	Exudative diathesis; selenium will spare vitamin E. Very high levels of selenium are toxic: edema of head and neck, twisted legs, necrosis in brain and spinal cord, short upper beak, missing eyes, protruding eyes, an increase in malpositions.
Molybdenum	>17 ppm in the egg results in 100% mortality by day 12.
Lithium	Excess causes high embryonic mortality associated with inhibited development, eye defects, enlarged aorta, abnormal neural tube.
Boron	Excess boron in egg (44 ppm) causes embryonic mortality in early development and at day 13. Abnormalities similar to those of riboflavin deficiency. Face, beak, and appendicular skeleton abnormalities.
Protein, amino acids	Deficiency, excess, or imbalance of some amino acids can cause embryonic abnormalities and mortality. Abnormalities include small or abnormal upper and/or lower beak, disorganized protrusions in the brain, exposed viscera, twisted and shortened limbs, twisted spine, short body, degeneration of the eye.
Fat, fatty acids	Linoleic acid deficiency: slow development, 75% of embryos in the head-over-right-wing malposition; mortality peaks during days 1 to 4, 8 to 14, and >21. Lipid transfer from the yolk to the embryo is reduced in the first few eggs produced by young pullets; this appears to result in increased embryonic mortality.
Miscellaneous substances:	
Tetracyclines	Inhibition of skeletal mineralization, erosion of long-bone cartilage, skeleton malformation.
Sulfanilamides	Retarded growth, shortened long bones, extreme micromelia, parrot beak, rumplessness.
Penicillin	Edema and hemorrhage in wings, legs, and head.
Aflatoxin B_1	Stunting (beginning at day 12), small liver, high mortality.
Ammonia (in incubators)	No closure of neural tube, mortality.

Source: Wilson, 1996

Table 39-21. Diseases Affecting Hatchability and Chick Quality

pullorum disease	infectious bronchitis
Arizona disease	Newcastle disease
fowl typhoid	avian encephalomyelitis
paratyphoid	*Mycoplasma gallisepticum* infection
aspergillosis	*Mycoplasma synoviae* infection
omphalitis	aflatoxicosis (toxin poisoning)
Escherichia coli infection	laryngotracheitis

of infection by simply observing dead embryos or newly hatched chicks. Only a laboratory examination by a properly trained diagnostician can determine the organism(s) involved. The important diseases involving incubation and chick quality are listed in Table 39-21.

39-L. TROUBLESHOOTING HATCHABILITY PROBLEMS

As outlined in this chapter there are numerous interacting factors that can further influence hatchability. Analyzing problems that lower hatchability is a complicated process. For example, a problem occurring in the management of breeder pullets and cockerels can be manifested in reduced hatch a year later. Listed in Table 39-22 are a series of signs from hatchability problems, each with a list of the most common causes.

Table 39-22. Troubleshooting Guide for Hatchability Problems

1. Sign: Eggs candle clear; broken out eggs show small white-dot germinal disc; no blood. Infertile.

   Causes:
   a. Immature males. Males may need to be photostimulated 2 weeks earlier than females.
   b. Males with abnormal sperm; females with abnormal egg (germinal disc). This occurs most often in very young or very old breeders.
   c. Too few males, resulting in infrequent mating; too many males, resulting in fighting or interference. Ratios of 1:12 to 1:15 for light breeds and 1:10 to 1:12 for heavy breeds are suggested.
   d. Extreme weather conditions.
   e. Old breeders. Spiking with young males may help if the problem is with the male.
   f. Breeder flock disease. This is often indicated by rough, misshaped, or thin-shelled eggs.
   g. Excess body weight, especially in broiler breeder males (>10.6 lb, 4,800 g).
   h. Nutritional deficiencies or excesses; severe feed restriction.
   i. Feet and leg problems, especially in males of heavy breeds.
   j. Certain drugs, pesticides, chemicals, toxins, or mycotoxins.
   k. Parasites, such as mites.
   l. Inadequate floor space.
   m. Decreased mating frequency, or no mating, is commonly seen in many of the conditions listed above; this may often be the direct cause of infertility.
   n. Inadequate lighting (intensity or day length).
   o. Improper artificial insemination procedures (if artificial insemination is used).

Table 39-22. *(continued)*

2. Sign: Eggs candle clear; broken out eggs show enlarged germinal disc; no blood. Fertile. Some are termed "blastoderm without embryo."

   Causes:
   a. Eggs stored too long. They should be stored <7 days.
   b. Eggs held under poor conditions, temperature too high or too low. Fluctuating temperatures. Temperature should be 60° to 65°F (15.6° to 18.3°C).
   c. Fumigation improper too severe or done between 12 and 96 h of incubation. Incorrectly spraying or foaming eggs with disinfectant.
   d. Eggs damaged during handling and transport by jarring, temperature shock (temperature increased or decreased too rapidly), etc.
   e. Eggshell sealed—respiration inhibited.
   f. High temperature in early incubation.
   g. Very young or very old breeders.
   h. Heredity, inbreeding, chromosome abnormalities, or parthenogenesis.
   i. Breeder flock diseases.
   j. Failure of a basic organ system to develop normally.
   k. Egg wash temperature too high.
   l. Egg-borne infections (e.g., *Salmonella*).
   m. Drugs, toxins, pesticides, etc.
   n. Infrequent or incomplete egg collection.

3. Sign: Eggs candle clear; broken out eggs show blood ring or small embryo that died before 3 days of incubation; no dark eye visible.

   Causes:
   a. Eggs stored too long or under improper temperature.
   b. Fumigation improper—too severe or done between 12 and 96 h of incubation.
   c. High temperature in early incubation.
   d. Low temperature in early incubation.
   e. Eggs damaged during transport by jarring, etc.
   f. Breeder flock diseases.
   g. Old breeders.
   h. Embryological development accidents.
   i. Inbreeding, chromosome abnormalities.
   j. Severe nutritional deficiencies, e.g., biotin, vitamin A, copper, vitamin E, boron, or pantothenic acid.
   k. Frequently associated with a high incidence of infertility.
   l. Drugs, toxins, or pesticides.
   m. Contamination.
   n. Embryos less developed at oviposition, i.e., pre-endoderm or very early endoderm formation.

4. Sign: Dead embryos; 3 to 6 days of incubation; yolk sac circulatory system present, embryo on left side, no egg tooth.

   Causes:
   a. See Causes 3.a–n.
   b. Lack of ventilation, or sealed shells, carbon dioxide >1%.
   c. Improper turning—<1/h or >6/h; improper turning angle.
   d. Vitamin deficiencies—vitamin E, riboflavin, biotin, pantothenic acid, or linoleic acid.

5. Sign: Dead embryos; 7 to 17 days of incubation; each embryo has egg tooth, toenails, feather follicles (8 days), feathers (11 days).

   Causes:
   a. Improper incubator temperature, humidity, turning, ventilation. Low humidity increases abnormalities of aortic arches (13 days).
   b. Contamination.
   c. Nutritional deficiencies—riboflavin, vitamin B_{12}, biotin, niacin, pyridoxine, pantothenic acid, phosphorus, boron, or linoleic acid.
   d. Lethal genes (>30 have been described).

6. Sign: Dead embryos—>18 days of incubation.

   Causes:
   a. Improper incubator temperature, humidity, turning, ventilation.
   b. Improper hatcher temperature, humidity, ventilation.
   c. Contamination, especially from molds *Aspergillus*, etc.).
   d. Fumigation too severe or too prolonged.
   e. Eggs chilled in transfer, or transferred too late.
   f. Broken shell—pre-set, during incubation, or at transfer.
   g. Nutritional deficiencies—vitamin D, vitamin A, folic acid, or pantothenic acid, riboflavin, vitamin E, selenium, vitamin K, biotin, thiamin, vitamin B_{12}, calcium, phosphorus, manganese, or linoleic acid.
   h. Embryonic malposition; embryo fails to move into proper hatching position (see #21).
   i. Embryological development accident. Failure to change to lung respiration and all intraembryonic circulation, and/or to retract the intestinal loops and yolk sac. These and other changes are critical at this time.
   j. Heredity—lethal genes, chromosome abnormalities.
   k. Twinning.
   l. Hatcher opened too much during pipping and hatching.
   m. Poor shell quality.
   n. Breeder diseases.

Table 39-22. *(continued)*

TROUBLESHOOTING: SPECIFIC PROBLEMS

7. Sign: Not pipped. Full-term embryo, large yolk sac; yolk sac may not be fully enclosed by abdominal wall, may have residual albumen.

   Causes:
   a. Inadequate turning, resulting in decreased embryonic membrane development and nutrient absorption.
   b. Humidity too high during incubation or after transfer.
   c. Incubator temperature too low.
   d. Hatcher temperature too high.
   e. Eggs chilled (e.g., at transfer).
   f. Nutritional deficiencies.
   g. Heredity.
   h. Embryological development accident.
   i. Breeder diseases.
   j. Inadequate ventilation.
   k. Prolonged egg storage.

8. Sign: Pipped. Full-term embryo, dead in shell.

   Causes:
   a. Low humidity or temperature for a prolonged period.
   b. Low humidity during hatching.
   c. High temperature during hatching.
   d. Nutritional deficiencies.
   e. Breeder diseases.
   f. Poor ventilation.
   g. Inadequate turning during first 12 days.
   h. Injury during transfer.
   i. Prolonged egg storage.

9. Sign: Shell partially pipped, embryo alive or dead.

   Causes:
   a. See Causes 8.a–i.
   b. Excessive fumigation during hatching.
   c. Eggs set small end up.

10. Sign: Chicks hatch early; tendency to be thin and noisy.

    Causes:
    a. Small eggs.
    b. Differences among breeds.
    c. Incubator temperature too high.
    d. Incubator humidity too low.

11. Sign: Chicks hatch late.

    Causes:
    a. Large eggs.
    b. Old breeders.
    c. Eggs stored too long (increase in incubation time/day of storage, 0.5% to 1.2% decrease in number hatched/day of storage).
    d. Incubator temperature too low.
    e. Weak embryos.
    f. Inbreeding.
    g. Incubator humidity too high.

12. Sign: Slow, protracted (drawn-out) hatch.

    Causes:
    a. Mix in the incubator of eggs stored for long and short periods (1.2% loss of hatch/day of storage when all eggs set at the same time; only 0.5% loss/day when eggs stored for long periods are set earlier to allow a longer incubation period).
    b. Mix of eggs from young and old breeders.
    c. Mix of large and small eggs.
    d. Improper egg handling.
    e. Hot or cold spots in incubator or hatcher.
    f. Incubator or hatcher temperature too high or too low.
    g. Room ventilation system improper; high positive pressure or low negative pressure. Such pressures may alter incubator or hatcher ventilation.

Table 39-22. (*continued*)

13. Sign: Trays not uniform in hatch or chick quality.

    Causes:
    a. Mix of large and small eggs.
    b. Mix of eggs from young and old breeders.
    c. Mix of eggs from different strains or breeds.
    d. Some eggs stored much longer.
    e. Lack of uniform ventilation in setter or hatcher.
    f. Disease or other stress in one or more breeder flocks.
    g. Variation in egg storage procedures among flocks.

14. Sign: Sticky chicks; chicks smeared with albumen.

    Causes:
    a. Low incubation temperature.
    b. High incubation humidity.
    c. Improper turning. This results in reduced embryonic membrane growth and reduced nutrient absorption.
    d. Old eggs.
    e. Very large eggs.

15. Sign: Chicks stuck in shell, dry; chicks with shell fragments stuck to down feathers.

    Causes:
    a. Humidity too low during egg storage, incubation, and/or hatching.
    b. Improper egg turning.
    c. Cracked eggs or poor shell quality.

16. Sign: Premature hatching; bloody navels.

    Cause:
    a. Incubator and/or hatcher temperature too high.

17. Sign: Small chicks.

    Causes:
    a. Small eggs.
    b. Low humidity during egg storage and/or incubation.
    c. High incubation temperature.
    d. High altitude. Hatcheries at high altitudes (>4,920 ft or 1,500 m) may need to adjust for low humidity, carbon dioxide, and oxygen. Atmospheric pressure <600 mm Hg (at 6,004 ft or 1,830 m) reduces growth and metabolic rate, increases loss of water from the egg.
    e. Thin, porous shells.

18. Sign: Unhealed navel; dry, rough down feathers.

    Causes:
    a. High incubator temperature or wide fluctuations in temperature.
    b. Low temperature in hatcher.
    c. Humidity too high in hatcher or not lowered when hatching complete.
    d. Inadequate breeder nutrition.

19. Sign: Unhealed navel; wet, odorous, mushy, large, soft-bodied, and lethargic chick.

    Causes:
    a. Omphalitis (navel infection). Contamination from dirty trays, unsanitary machines or hatchery, dirty eggs, inadequate egg sanitation, or fumigation.
    b. Low incubator temperature.
    c. High incubator or hatcher humidity.
    d. Inadequate ventilation.

20. Sign: Weak chicks.

    Causes:
    a. High hatcher temperature.
    b. Poor hatcher ventilation.
    c. Excessive fumigation.
    d. Contamination.

Table 39-22. (*continued*)

21. Sign: Chicks malpositioned. Normal position after 19 days of incubation: embryo's long axis same as long axis of egg; head in large end of egg; head to the right and under right wing; beak toward air cell; feet toward head.

    Causes:
    a. Eggs set small end up or in horizontal position.
    b. Inadequate or improper turning.
    c. High or low incubator temperature.
    d. High humidity.
    e. Old breeders.
    f. Round-shaped eggs or very large eggs.
    g. Nutritional deficiencies, especially vitamin A and vitamin B_{12}.
    h. Eggs handled or stored improperly.
    i. Retarded development.
    Embryos <18 days old may be in a position different from that for hatching but one normal for their age (for example, the head-between-thighs position). The feet-over-head position is hard to distinguish and may be normal. The beak-over-wing position is probably a normal variant. Some malpositions are lethal; others are not.

22. Sign: Malformations.

    Causes:
    a. Improper egg storage.
    b. Jarring of eggs or transporting large end down.
    c. Heredity.
    d. Nutritional deficiencies, e.g., biotin, riboflavin, zinc, or manganese.
    e. Inadequate turning.
    f. Improper egg orientation, e.g., small end up.
    g. High or low incubator temperature.
    h. Breeder diseases.
    i. Inadequate ventilation or shells with low porosity or permeability.

23. Sign: Crooked toes, spraddled legs.

    Causes:
    a. High or low incubator temperature.
    b. Inadequate nutrition.
    c. Smooth bottom hatching trays.

24. Sign: Short down, wiry down.

    Causes:
    a. Nutritional deficiencies, especially riboflavin.
    b. Mycotoxins and other toxic or inhibitory substances, resulting in nutritional deficiencies.
    c. High incubation temperature during days 1 to 14.

25. Sign: Eyes closed, down stuck to eyes.

    Causes:
    a. Temperature too high in hatcher.
    b. Humidity too low in hatcher.
    c. Down collectors inadequate.
    d. Chicks remain in hatcher too long after hatching.
    e. Excessive air movement in hatcher.

26. Sign: Exploders.

    Causes:
    a. Dirty eggs from nest. Dirty nests.
    b. Floor eggs.
    c. Eggs improperly washed; eggs wiped or cleaned with contaminated cloth or buffer.
    d. Dust from breeder house, cooler, transport, etc.
    e. Water condensation on eggs (sweating).
    f. Water sprayed, fogged, or splashed on eggs; eggs dipped in contaminated solutions.
    g. Contamination from earlier exploders, leakers, or broken eggs.
    h. Contamination from handling eggs with dirty hands or equipment.
    i. Contaminated setter flats, air filters, water (humidity) system.

Table 39-22. *(continued)*

27. Sign: Dwarf embryos: runts in growing chicks.

    Causes:
    a. Egg contamination.
    b. Hatchery contamination, especially during hatching.
    c. Breeder diseases.
    d. Heredity.
    e. Nutritional deficiencies.
    f. Thyroid abnormalities.

28. Sign: Crossed beak, twisted beak.

    Cause:
    a. Heredity.

29. Sign: Missing eye(s), other eye abnormalities.

    Causes:
    a. High incubator temperature during days 1 to 6.
    b. Low oxygen during days 1 to 6.

30. Sign: Exposed brain.

    Causes:
    a. High incubator temperature during days 1 to 3.
    b. Low oxygen during days 1 to 3.

31. Sign: Red hocks in hatched chicks or unhatched pips.

    Causes:
    a. Prolonged pushing on shell during pipping and hatching.
    b. Vitamin deficiencies.
    c. Thick shells, as in pullet flocks.
    d. High incubator humidity and/or low incubator temperature.

32. Sign: Small air cell, broad pip area, membrane incompletely cut, red hocks, edematous chick, unabsorbed albumen, yolk incompletely retracted, egg weight loss <10%.

    Causes:
    a. High incubator humidity.
    b. Very thick shells, as in pullet flocks.
    c. Low incubator temperature.

33. Sign: Micromelia (shortened long bones, parrot beak, bent bones); chondrodystrophy (similar to micromelia).

    Causes:
    a. Heredity, lethal genes.
    b. Nutritional deficiencies (biotin or manganese).

34. Sign: Short beak, missing beak, face abnormalities.

    Causes:
    a. Incubator temperature too high during days 1 to 5.
    b. Heredity, lethal genes.
    c. Developmental accidents.
    d. Nutritional deficiencies (niacin).

35. Sign: Ectopic (exposed) viscera.

    Causes:
    a. Incubator temperature too high.
    b. Heredity, lethal genes.

36. Sign: Hemorrhage.

    Causes:
    a. Red skin—incubator or hatcher temperature too high.
    b. Bleeding in chorioallantois—rough handling at transfer.
    c. Nutritional deficiencies (vitamin K or vitamin E).
    d. Embryos that died at days 11 to 15 and appear small and dark red—usually caused by molds or other contamination.

Source: Wilson, 1996