ARTIFICIAL EGG INCUBATION

A GUIDE TO HATCHING BACKYARD POULTRY

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ROBERTS FARM

Mallards, Brown Chinese Geese, Dominique Hens, Bronze Turkeys, & India Peafowl

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INCUBATION CHECKLIST

This checklist highlights several important factors to consider during the incubation process but does not serve as a substitute for reading and understanding all factors outlined in this guide.

- ☐ **DO** prepare your breeding stock prior collecting incubation eggs including selecting the best, unrelated parents, worming your birds, feeding high quality feed, and cleaning nests, & renewing nesting material.
- ☐ **DO** carefully plan your incubation and hatch schedule. Whenever possible, avoid setting eggs at different times or of different species unless you have a second incubator dedicated to hatching only.
- ☐ **DO NOT** wash or refrigerate eggs for incubation. For best results, use eggs that are less than 7 days old. However, eggs up to 18 days old can be successfully hatched if stored correctly.
- ☐ **DO** consider the accuracy of any digital thermometer you decide to purchase. Most thermometers are only accurate to $^{+/-}$1.0 to 2.0° when an accuracy of $^{+/-}$0.1 to 0.2° is needed.
- ☐ **DO NOT** trust the gauges built into your incubator. **DO** use a separate, calibrated thermometer to monitor the incubation environment. Improper temperature control is the primary reason for hatch failure.
- ☐ **DO** place your incubator in a room with a steady temperature, away from windows, drafts, or direct sunlight. Difficulties with regulating an incubator are often the result of poor incubator placement.
- ☐ **DO** calibrate and regulate your incubator at least 48 hours prior to setting eggs. For best results, use water bottles to fill empty space during the regulation and calibration process.
- ☐ **DO** become familiar with warm and cool spots within your incubator by measuring the temperature at various locations during the regulation and calibration process.
- ☐ **DO NOT** keep your eggs in the same spot for the entire incubation period. For best results, move the eggs sitting on the outer edges to the center and the eggs sitting in the center to the outer edges daily.
- ☐ **DO NOT** fiddle with the thermostat while eggs are in the incubator. Some fluctuation in temperature is normal and you're likely to cause more problems by fiddling with the temperature controls.
- ☐ **DO** remove any automatic egg turner at the beginning of day 19 to avoid injury or death of newly emerged hatchlings.
- ☐ **DO** completely fill troughs/pans full prior of water prior to lockdown – the last three days of incubation. **DO NOT** open the incubator unless absolutely necessary until the hatch is complete.
- ☐ **DO** add sufficient warm, wet sponges during lock down to raise the humidity to at least 65% or until a small amount of moisture accumulates on the viewing pane.
- ☐ **DO** remember that chicks burn a great deal of oxygen during the hatching process. **DO** remove any vent plugs during lockdown. **DO NOT** sacrifice fresh air for humidity during the final days.
- ☐ **DO** remember that hatchlings live for 48-72 hours after hatch by feeding from the absorbed egg yolk. The bumping of unhatched eggs by hatchlings encourages the unhatched to pip, zip, and emerge.
- ☐ **DO** remember that 12 or more hours may elapse from the first pip to the first emergence and that hatching is an exhausting process… hatchlings may rest for extended periods of time during the process.
- ☐ **DO NOT** assist eggs during the hatching process unless it is absolutely necessary. In most cases, a healthy hatchling will emerge on their own and assisting can easily cause more harm than good.
- ☐ **DO** carefully evaluate your hatch results using the recommendations in this guide. **DO** view each hatch as a learning process with a primary goal of improving with each subsequent batch.
- ☐ **DO NOT** forget that home flock hatching should be an enjoyable process… not every egg will hatch and not every hatchling will survive. Celebrate your successes and do not focus on your failures.

INTRODUCTION

There are many factors involved in successfully hatching poultry eggs. Failure to address any single factor can result in poor fertilization, embryo development failure, pipping or hatching failure, and weak and malformed hatchlings. The following guideline outlines important factors and provides advice for a successful hatch.

QUICK START GUIDE

If you're looking to start incubating without a comprehensive understanding of the entire process, then you're making a serious mistake. While it doesn't take a nuclear scientist to hatch eggs successfully, there are numerous things that can go wrong any one of which can result in a hatch time disaster. Avoid a bad experience; gain a good understanding of the entire process before you set the first egg. The following provides the basic steps in the incubation process:

1. Preparing the parents, housing, and nests to obtain high quality hatching eggs.
2. Collecting and storing the eggs to ensure they remain sanitary and healthy.
3. Preparing and calibrating the incubator to establish the ideal temperature before setting.
4. Setting and caring for the eggs during incubation to encourage proper embryonic development.
5. Candling eggs to monitor embryonic development, humidity, and potential problems.
6. Establishing the ideal hatching environment during the final days to assist the hatching process.
7. Evaluating hatch results to identify problems and necessary corrections.

BROODY HENS VS. ARTIFICIAL INCUBATION?

Many hobbyists and breeders prefer to incubate eggs the old fashion way – let a broody hen do all the work. This method is helpful in that we don't need to worry about temperature, humidity, turning, or power outages. Unfortunately, it also removes the hen from egg production. Many report that a broody hen improves hatch rates and viability especially with more difficult species such as peafowl and rare bantams. Some professional breeders, such as Legg's Peafowl Farm,[1] allow broody hens to incubate eggs for the first week before placing them in an artificial incubator.

Incubator vs. Broody Hen[2]	
Artificial Incubation	**Broody Hen Incubation**
Incubators are easily obtained	Broody hens availability may be limited
Initial investment high with low maintenance cost	Initial investment low with some maintenance cost
Incubators available 365 days a year	Broody hens generally limited to Spring and Summer
Batch size virtually unlimited	Clutches limited by hen size
No effect of egg production	Removes the hen from egg production
Scheduled according to incubator space availability	Scheduled according to broody hens availability
Success rate generally stable and predictable	Success rate may vary according to hen traits
Lower success among difficult breeds & species	Higher success among difficult breeds & species
Must manually monitor temperature and humidity	No manual input required
Requires electricity	Self-powered
Losses due to human error	Losses due to hen's unpredictable and accidents
Artificial brooding required	Hen cares for hatchlings
Must manage exposure to Coccidiosis	Coccidiosis exposure naturally occurring, less impact
Loss due to brooder disease and power outages	Losses due to predators and other flock members

[1] *Brad Legg, "Incubation & Hatching Peafowl Eggs," Legg's Peafowl Farm, NDA, <http://www.leggspeafowl.com/incub.htm>*
[2] *Several ideas drawn from "INCUBATOR VS. BROODY HEN," Community chickens, NDA, <http://www.communitychickens.com/incubator-vs-broody-hen/>*

Personally, the only broody hen types in my flock are Heritage Bronze turkeys and Mallard ducks. The turkeys have not proven to be successful mothers frequently breaking eggs and not leaving the nest after the hatch. Since they prefer to brood on the ground, fire ants take a significant toll on hatchlings. Conversely, my Mallard ducks have proven to be highly successful at brooding their young. Since ducks are exceptionally messy, there is far less work involved in broody ducklings naturally than with an artificial brooder. Unfortunately, brooding takes a duck out of egg production, and I do not permit natural brooding until after Spring needs are fulfilled.

How do I get a hen to go broody? Generally, a hen will go broody when she's is good and ready. Silkies and Cochins tend to go broody frequently; however, many breed, such as Leghorns have been bred over many decades no to go broody – they're expected to lay eggs not hatch chicks. Fresh Eggs Daily recommends the following:

Five Ways to Encourage a Hen to go Broody[3]

1. The first thing you can do is choose breeds that tend towards being broody, such as Australorps, Brahmas, Buffs, or Cochins and bantam breeds such as Silkies, bantam Cochins or Orpingtons.
2. A second way to encourage a hen to go broody is to leave some eggs in the nests ('dummy' eggs, such as golf balls or plastic Easter eggs work just as well as real eggs and don't risk being broken). This can encourage your hen to start sitting on them.
3. You can also encourage a hen's broody nature by providing her a dark, safe place to sit on the eggs. Hang some curtains across the front of the nesting boxes, even a piece of sheet or fabric will help convince her the nest is a secret place to raise her chicks.
4. Adding some herbs to the nesting boxes such as lavender or chamolile can help the hen relax and feel safe and secure.
5. Check the nesting boxes for insects, mites and mice. A hen generally won't sit if she senses critters in the boxes that could harm her eggs or chicks. Be sure the nesting box material is fresh and clean, and that there is a nice thick layer so the eggs won't touch the wooden floor and risk breaking.

How to I Break a Broody Hen? When I was a child, I noticed a neighbor's hen in a small wire cage and asked him why he had locked her up… His response, "She stopped laying eggs and a chicken that doesn't lay eggs isn't worth much." Within my flock, spring eggs are valuable; they produce hatchlings; and hatchlings pay the feed bill… I collect eggs two or three times a day to discourage broodiness.

Five Ways to Break a Broody Hen

1. Collect the eggs frequently; however, some hens will sit on anything that looks like an egg or even imaginary eggs.
2. Remove the hen from the nest, carry her for 10-15 minutes, and then place her outside the coop; however, since broodiness generally involves hormones, I wouldn't have high expectation.
3. Deny access to her nesting spot or place her in a small pen without any nesting spots; sometimes, just a change in the environment or making it difficult to nest may be sufficient to end the process.
4. Dunking the lower portions of her body in cool water until her feathers are saturated; some give a full bath hoping the "cooling off" will break the cycle.
5. Place her up in a wire cage for five days, a small dog crate with food and water but no nesting material. (Old timers, like my neighbor did not always include food or water.)

[3] *"Five Ways to Encourage a Hen to go Broody," Fresh Eggs Daily, April 10, 2014 <http://www.fresheggsdaily.com/2014/04/five-ways-to-encourage-hen-to-go-broody.html>*

ARTIFICIAL INCUBATORS

An effective artificial incubator maintains a constant temperature, generally 99.5° F, provides a means to regulate humidity, and permits routine egg turning. They can either be manual where the user does all the work, semi-automatic where the incubator does some of the work, or automatic where the incubator does all of the work. Which one should you buy? I recommend that you decide how many eggs you want to incubate at one time and then buy the most expensive model you can comfortably afford. In my opinion, most manufacturers produce the best possible product they can at any given price range – if they didn't, then their reputation would suffer and they couldn't stay in business long. Incubation problems generally stem from user error, not the equipment. If used properly, almost all incubators can reliably hatch eggs. My first incubator was an inexpensive styrofoam Little Giant desktop model; it has been extremely reliable and is still in use today.

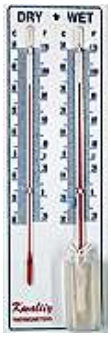
1. **Insulation**: What materials are used to separate the eggs from the room environment? The least expensive models utilize polystyrene foam (styrofoam) or simple plastic, others use plastic board, while still others use insulation sandwiched between plastic and metal. While all incubators do best in a climate controlled room, better insulated incubators have fewer temperature and humidity fluctuations than those that use a thin layer of plastic.

2. **Thermostat**: How is the temperature regulated? The simplest, and perhaps most accurate, thermostat uses a simple wafer switch to regulate temperature – as the temperature warms, the wafer expands and opens the heating element contact. Unfortunately, these models rely upon a screw or knob to set the temperature. Many manufacturers are currently using digital thermostats employing an LED panel to display and control temperature. While this type of control is certainly easier to use, quality may suffer in lower end units. Additionally, most digital controls can only be calibrated by the manufacturer and may lose accuracy over time – it is best to always use a separate, calibrated thermometer to validate the control's reading.

3. **Air Circulation**: How are all sides of the eggs warmed? The least expensive incubators are "still air" and contain no fan to circulate the warmed air. Many claim that this method is the best one in that is closely resembles a hen setting on eggs where only one side is heated. However, most prefer a "circulated" or "forced" air system where a fan circulates the warmed air throughout the incubator. In lower-end models, a fan in an optional component and must be purchased separately. A third and rare method attempts to replicate a broody hen using a plastic bladder to cover and warm the eggs; this method but is rare because of the expense and limited batch size.

4. **Humidity Controls**: How is humidity monitored and maintained? With lower costs units, the control may measure the humidity but has no means to raise or lower it -- humidity is controlled by manually adding or withdrawing water from a pan or trough. While simple, I've found that with a little experience, this method is perfectly adequate in maintaining a fairly narrow humidity range. With expensive units, the controller automatically measures and manipulates the humidity. While automatic humidity controls are certainly convenient, they frequently add considerably to the cost. As with temperature, the humidity within a incubator should be monitored using a separate, calibrated hygrometer.

5. **Wet Bulb vs. Relative Humidity**: Experienced incubation purists frequently assert that a "wet bulb reading" is the only accurate means of measuring humidity. Under normal conditions, the amount of moisture in the air varies as the temperature varies and this is most accurately measured using a wet-bulb. However, within an incubator, the temperature does not vary and a wet-bulb reading provides no real benefit and is more complicated than necessary. Relative Humidity is measured by percent, is easier to read and conceptualize, and is more than adequate to accurately measure humidity for home incubation.



6. **Egg Turning**: How are eggs turned and how frequently? Studies indicate that eggs do best when turned 45° every two hours. In the least expensive incubators egg turning is accomplished by the user opening the incubator and manually turning the eggs 180° three to five times a day. To eliminate this tedious task, most low-end incubators offer automatic egg turners that tilt the ends from side-to-side. While convenient, few of these turners are able to achieve a full tilt of 45° and I've found them to be inadequate when used with more sensitive species such as duck or peafowl. Large cabinet incubators frequently rely upon tilt shelves where eggs are placed into plastic trays and the entire shelf tilts either left or right. Another method includes rolling the egg from side to side.

7. **Desktop Models**: ($50.00-$800.00) Small desktop models holding between 3-48 chicken eggs. For beginners, I recommend purchasing a relatively inexpensive styrofoam model with circulated air and an automatic egg turner. Although these models require greater time and effort, they give the hobbyist time to *figure out the incubation process* enabling them to better understand the type, style, and price range of the incubator best suited for their needs. Some hobbyists discover they don't like incubating eggs while others realize they need greater capacity and flexibility.

8. **Cabinet Models**: ($700.00-$2,350.00) Large floor models holding between 190-600 chicken eggs. These models, intended for serious hobbyist or small professionals, range from semi-automatic to fully automatic operation with almost all models having automatic egg turning capabilities. Which one is right for you? Each brand has their loyal fans who assert that their brand has the best hatch rate and is the easiest to use. My recommendation? Choose the one within an affordable price range and the capacity to meet your needs.

9. **Homemade Models**: My first cabinet incubator was made from ½ inch foam board sandwiched between two sheets of ½ inch plywood. It had three tilt trays that held 54 chicken eggs each – I was too cheap to spend the money necessary for a commercially made model. It worked superbly and continues in use today. Its only problem was the trays had to be tilted manually. If you're an industrial individual who likes to build things, then you may want to consider building your own.

- Multiple examples of homemade incubators can be found at: http://www.backyardchickens.com/a/ homemade-chicken-egg-incubator-designs-pictures.
- The original plans for my cabinet model may also be found at: http://www.calvinroberts.us/Incubator.pdf.

Example Hobbyist Incubators								
Model	Capacity	Price	Ease	Type	Make	Air Flow	Control	Turning
Rcom Mini	3	125.00	★★★★☆	Automatic	Rcom	Circulated	Digital	Automatic
Brinsea Mini ECO	7	95.00	★★★★☆	Semi-auto	Brinsea	Circulated	Digital	Automatic
Brinsea Mini ADV	7	160.00	★★★★☆	Semi-auto	Brinsea	Circulated	Digital	Automatic
Janoel JN-12	12	120.00	★★★☆☆	Semi-auto	Janoel	Circulated	Digital	Automatic
Rcom Max 20	20	385.00	★★★★★	Automatic	Rcom	Circulated	Digital	Automatic
Brinsea Octagon 20 ECO	24	180.00	★★★☆☆	Semi-auto	Brinsea	Circulated	Digital	Optional
Rcom King Suro Eco 20	24	190.00	★★★★★	Semi-auto	Rcom	Circulated	Digital	Manual
Janoel JN-24	24	230.00	★★★★☆	Semi-auto	Janoel	Circulated	Digital	Automatic
Rcom King Suro 20	24	280.00	★★★★★	Automatic	Rcom	Circulated	Digital	Cradle
Brinsea Octagon 20 ADV	24	350.00	★★★★★	Semi-auto	Brinsea	Circulated	Digital	Cradle
HovaBator 1602	41	50.00	★★☆☆☆	Manual	GQF	Still Air	Knob	Optional
Farm Innovators 2100	41	50.00	★★☆☆☆	Manual	Farm Innovators	Still Air	Knob	Optional
Little Giant 10300	41	75.00	★★★★☆	Manual	Miller	Circulated	Digital	Optional
Farm Innovators 4200	41	90.00	★★★☆☆	Manual	Farm Innovators	Circulated	Knob	Optional
Little Giant 9300	46	45.00	★★★☆☆	Manual	Miller	Still Air	Digital	Optional
Janoel JN-48	48	140.00	★★★★☆	Semi-auto	Janoel	Circulated	Digital	Automatic
Brinsea Octagon 40 ECO	48	380.00	★★★★☆	Semi-auto	Brinsea	Circulated	Digital	Optional
Brinsea Octagon 40 ADV	48	450.00	★★★★★	Semi-auto	Brinsea	Circulated	Digital	Cradle
Rcom Max 50	48	685.00	★★★★★	Automatic	Rcom	Circulated	Digital	Automatic
Hovabator 2362E	50	80.00	★★★☆☆	Manual	GQF	Circulated	Knob	Optional
HovaBator 1588	50	140.00	★★★★☆	Semi-auto	GQF	Circulated	Digital	Optional
Janoel JN5-60	60	130.00	★★☆☆☆	Manual	Janoel	Circulated	Digital	Manual
Rcom Max 190C	168	1,100.00	★★★★★	Automatic	Rcom	Circulated	Digital	Automatic
Brinsea Ova-Easy 190	192	1,150.00	★★★★★	Semi-auto	Brinsea	Circulated	Digital	Automatic
Sportsman 1502	270	720.00	★★★★☆	Semi-auto	GQF	Circulated	Digital	Automatic
Rcom Maru 380C	336	1,500.00	★★★★★	Automatic	Rcom	Circulated	Digital	Automatic
Brinsea Ova-Easy 380	384	1,400.00	★★★★★	Semi-auto	Brinsea	Circulated	Digital	Automatic

PARENT STOCK

The quality of hatchling is directly related to the quality of the parents – only select, mature parents that are healthy, free of internal and external parasites, and conform to breed standards produce highest quality hatchlings. Unless breeding for a specific purpose, parents should be genetically unrelated. For two to three months prior to egg collection, parents should have free access to high quality and high protein feed along with crushed oyster shells to enhance quality egg production. Additionally, to aid in egg sanitation, nest boxes and housing should be cleaned just prior to the laying season.

CULLING BREEDING STOCK

All too frequently, hobbyist attempt to set all available eggs hoping to increase the number of hatchlings produced. Unfortunately, this can be a strategic mistake as eggs from young, old, weak, unhealthy, or nonconforming parents negatively impacts the fertility rate, hatch rate, and hatchling viability. In general, no more than 50 percent of my females are suitable for breeding purposes. If I have 20 laying hens, perhaps 8 or 9 will be selected for their hatching eggs. If I have three roosters, only one will be used for breeding. This becomes more difficult with rare or expensive birds; however, using lower quality birds for breeding lowers hatching success and perpetuates bad qualities among the flock. Weak or defective birds may be wonderful pets, but do not use them for breeding purpose.

> In actuality, culling inferior birds and selecting superior birds results in improvements to a flock over time. Good improvement breeding need only focus on mating together birds that share good traits to cause them to occur more frequently in the flock, as well as making sure that mated birds do not share the same faults so that faults occur less frequently. We call these two aspects of improvement breeding "emphasizing good traits" and "offsetting faults." *Don Schrider, "Breeding the Home Flock," 2011*

GENETIC POOLS

Rare breeds, such as Serama Bantams, have a smaller genetic pool than more common breeds, such as Rhode Island Reds. Additionally, birds with significant inbreeding, such as “Show Quality” birds, have less genetic diversity than common, barn-yard animals. Eggs with less genetic diversity have lower fertility rates, higher embryonic death, lower hatch rates, and weaker hatchlings than those from larger genetic pools. Do not expect purebred bantams to hatch at the same rate as hybrid laying hens. While experienced breeders utilize line-breeding to achieve a specific effect, inbreeding should be avoided in most circumstances. For best results, use parents that are unrelated and originate from different flocks.

> Line breeding (parent to child) can produce very rapid gains in the quality of your line for certain traits, but nearly always results in a degeneration of the reproductive capacity of your line and you end up outcrossing and starting over. For a few generations it can give you some outstanding birds at a higher frequency than you would get by not inbreeding, but there is no such thing as a free lunch. This is why commercial breeding companies try to avoid inbreeding and concentrate on improving the whole population. The gains are not as dramatic, but they don't fall on their faces as often. *"Inbreeding," Polish Breeders Club, 2010*

FERTILIZATION

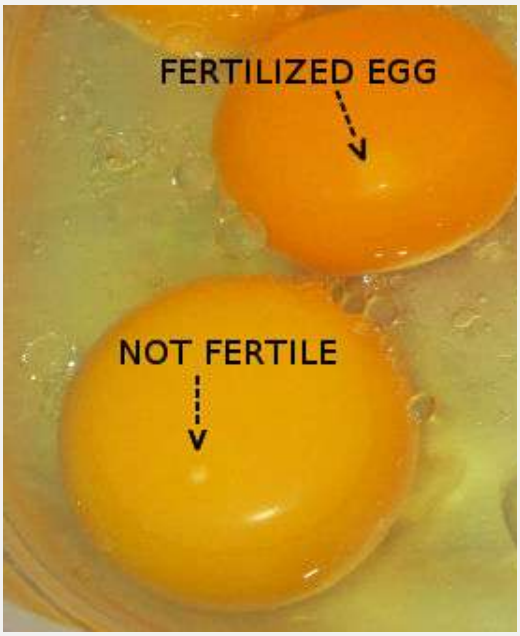
If you have a rooster, your eggs will probably be fertile. The health and age of the rooster has a significant impact on fertility: very young or very old roosters are less effective than young, mature roosters In general.

How many males do you need? For most species a ratio of 1 male for 10 females should provide satisfactory fertilization rates; for my flock, I generally use the following:

Geese	1:2
Bantams	1:3
Peafowl	1:3
Mallard ducks	1:4
Turkeys	1:5
Chickens	1:10

When placing a new rooster in with hens, the rooster may immediate mate with the hen or it may take a few days before the hens accept him. I generally wait a week before collecting eggs for incubation.

When changing roosters, how long should you wait to ensure that it is the new rooster who will parent the chicks? After 10 days, virtually all of the chicks will come from the new rooster; however, if you want to be 100% positive, it is best to wait a full month:



To check fertility, crack an egg open and locate the blastoderm (small white spot); if the spot is small and solid, the egg is not fertile; if the spot is spread out or resembles a bulls-eye, the egg is probably fertile.

- “If a rooster is removed from the flock and replaced by another, it may require 3 weeks before it can be assured that all eggs will produce chicks sired by the new rooster." *Mississippi State University*.
- “The sperm host glands can store sperm for long periods of time – 10 days to 2 weeks.” Dr. Thomas Caceci, *Virginia-Maryland Regional College of Veterinary Medicine*.
- “Sperm can be stored and remain capable of fertilizing an egg for more than two weeks, although it isn’t likely to occur after tens.” *Raising Chickens For Dummies*, by Kimberly Willis and Rob Ludlow.

How long to produce fertile eggs?

If a sexually active rooster is placed into a flock of hens, fertile eggs can be produced by the second day after introducing the rooster. If mating occurs within a short period, the next egg yolk released by the hen's body can be fertilized. The remainder of the albumen and shell requires about 26-28 hours to be formed around the fertilized yolk. Therefore, a minimum of 30-36 hours is necessary to produce a hatchable egg.

Mississippi State University

EGG SELECTION & STORAGE

Proper egg collection and storage has a significant impact on hatching success. For best results:

1. Use fresh, large pine shavings to line nesting boxes or nesting areas. Hay, straw, or other materials may contain mold or other contaminates possibly infecting the embryo during development. Replace any soiled lining as soon as it becomes contaminated.
2. Thoroughly wash your hands prior to collection and avoid touching the ground or other possibly contaminated areas. Avoid cross-contamination by utilizing separate containers and collection times for hatching eggs and non-hatching eggs.
3. Collect eggs two or three times a day, more frequently if temperatures are unusually high or low.

Wash Your Hands

Before handling eggs at any stage in the process, wash your hands. Dirt, bacteria, and natural oils can have a negative impact on the egg and hatchability.

4. Remove eggs that are unusually dirty, large, small, or misshaped as these eggs hatch poorly and consume valuable incubator space. Dirty eggs can be especially troublesome as bacteria thrive in the warm, moist incubation environment and can result in exploding eggs that spread contamination.
5. Using a pencil or non-toxic marker, label eggs with the species, pen, date laid, and any other important information. These markings aid in identifying hatchlings and assist with accurate record keeping.
6. Handle the egg as little as possible. Do NOT wash or wipe off dirt or waste from the egg. Do NOT use sand paper to sand off dirt or waste. If the egg is marred by a small amount of waste, allow it to dry and then gently scrape it off with a finger nail. Washing, wiping, or sanding dirty eggs removes the cuticle, the natural antibacterial coating, and tends to push any contamination into the pores.
7. Store eggs in new, paper egg cartons or similar containers with the small end down. Tilt the container to its side 45° and change the direction daily if the eggs are to be stored for longer than seven days. Do not store eggs in the refrigerator as the temperature is too low and decreases egg vitality dramatically.
8. For best results, store eggs for no longer than 7 days as age decreases the egg viability significantly. However, clean eggs stored within a controlled environment can remain viable for up to 21 days.

   Make no mistake… longer storage results in higher embryonic death, a decreased hatch rate, and lower hatchling vitality. It also increases the incubation time on average 45 to 50 minutes for each day of storage.

Period of Storage[4]							
Settings	**1-2 days**	**3-4 days**	**5-6 days**	**7-8 days**	**9-12 days**	**13-16 days**	**17-20 days**
Temperature	66.2°F	62.6°F	59.9°F	57.2°F	54.5°F	53.6°F	52.7°F
Relative Humidity	70.0	80.0	85.0	90.0	90.0	90.0	90.0
Turning	No	No	No	No	Yes	Yes	Yes
Small end up	No	No	No	No	No	Yes	Yes

9. Moving stored eggs from a cool, dry environment to a warm, moist environment results in condensation of moisture on the shell surface – this is bad, real bad. When moving eggs from their storage location to the hatching room, I cover the eggs with a clean towel for 2-3 hours to reduce condensation. Additionally, I allow hatching eggs to slowly warm to room temperature (75-80°) over 12-24 hours before setting them.

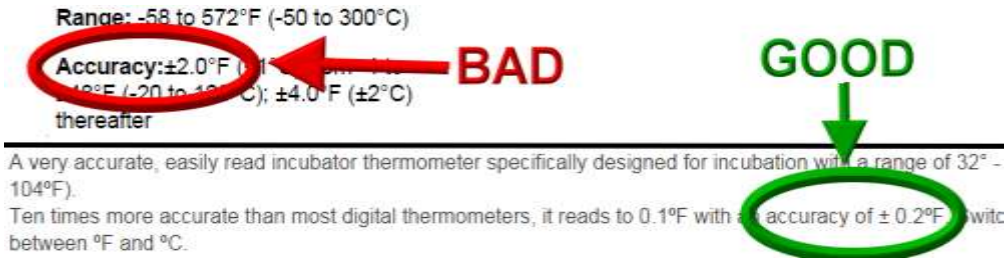
[4] *Adapted from "Incubation Guide,' Hubbard Breeders, <http://www.hubbardbreeders.com/managementguides/Incubation%20guide%20(english).pdf>*

THERMOMETERS

Chickens should hatch on day 21. If they hatch early, then your temperature is too high. If they hatch later, then your temperature is too low. While early and late chicks may survive, they are not among the healthiest or vigorous. ***It is important that you get your incubation temperature correct***.

INCUBATOR GAUGES: ***Do Not Trust*** the gauges that came with your incubator. Verify that both the temperature and humidity readings are correct with a calibrated thermometer and hygrometer. It is recommended that this verification be repeated periodically. If there is a reading difference between the incubator panel and the calibrated thermometer, trust the calibrated thermometer.

DIGITAL SENSITIVITY: ***Most digital thermometers are inadequate for incubation***. While they may read to 0.1° F, they are only sensitive to 2.0° F – while the readout may display 99.5° F the temperature will range anywhere from 98.5° F to 100.5° F. Before purchasing a digital thermometer, read the packaging. If it does not specifically list an accuracy of ±0.2° F, do not buy it…



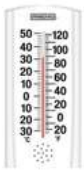
CAUTION: All digital thermometers appear to be accurate but ***most*** are grossly inadequate for incubation. A digital thermometer ***must be calibrated*** and ***must have a sensitivity*** of no less than ***±0.2° F***.

RESPONSE TIME: When the heating element comes on, the temperature will rise and continue to do so for a short time after the element switches off. Some digital thermo meters will incorrectly register this rise as a temperature spike and cause concern… "Why does my temperature seem to bounce all over the place?" Digital thermometers encase in plastic frequently continue to register this increase long after the air temperature has returned to normal. For best result, buy only digital thermometers with a probe type sensor where the probe can be slipped into a vent holes.

STEM

PRO: Slips thru vent
May be calibrated
CON: Difficult to read
Not readable to 0.1°

RED, SPIRIT GLASS



PRO: Easily calibrated
Inexpensive
CON: Difficult to read
Not readable to 0.1°

DIGITAL PROBE

PRO: Slips thru vent
Easily to read
CON: Can be Expensive
Most not accurate ±0.2°

DIGITAL

PRO: Easy to read
Inexpensive
CON: Cannot be calibrated
Most not accurate ±0.2

CALIBRATING A THERMOMETER: Thermometers must register down to 32° F or 212° F to be calibrated:

FREEZING POINT

1. Fill a glass with crushed ice cubes and cold water.
2. Stir the water and let sit for 3 minutes.
3. Stir again, then insert your thermometer into the glass, making sure not to touch the sides.
4. The temperature should read 32°F (0°C).
5. If it doesn't, loosen the glue holding the glass to the scale, move the glass up or down as needed.
6. Recheck accuracy and secure tube with a drop of glue.

BOILING POINT

1. Boil a pot of distilled water.
2. Once the water has reached a rolling boil, insert your thermometer, making sure not to touch the sides or bottom of the pot.
3. The temperature should read 212°F (100°C).
7. If it doesn't, loosen the glue holding the glass to the scale, move the glass up or down as needed.
4. Recheck accuracy and secure tube with a drop of glue.

BATCH INCUBATION

Some hobbyists may be tempted to add new eggs to their incubator every day or every few days. This practice is ill advised. Having eggs in various stages of incubation makes it impossible to create optimal incubation and brooding environments. There are significant differences in humidity and turning requirements during the final three days (humidity +70% with no turning) of than the rest of incubation (humidity 45% with turning). Additionally, during brooding, hatchlings of different ages require different temperatures and older hatchlings frequently pick on younger ones. For best results with desktop incubators, incubate only one batch of eggs at a time. When stored properly, eggs can be stored for 15-18 days without a dramatic drop in hatchability.

Whenever possible, ***AVOID*** mixing eggs in different stages of development in the same incubator – doing so complicates hatching and may lead to poor results. It is better to collect and carefully store eggs for 14-18 days and hatch all eggs at the same time.

Alternatively, if you feel compelled to set eggs every few days, buy an inexpensive, still air incubator and designate it as a dedicated hatcher. Within this dedicated hatcher, create an optimal environment for hatching (humidity +70%) and move eggs to this hatcher for their last three days.

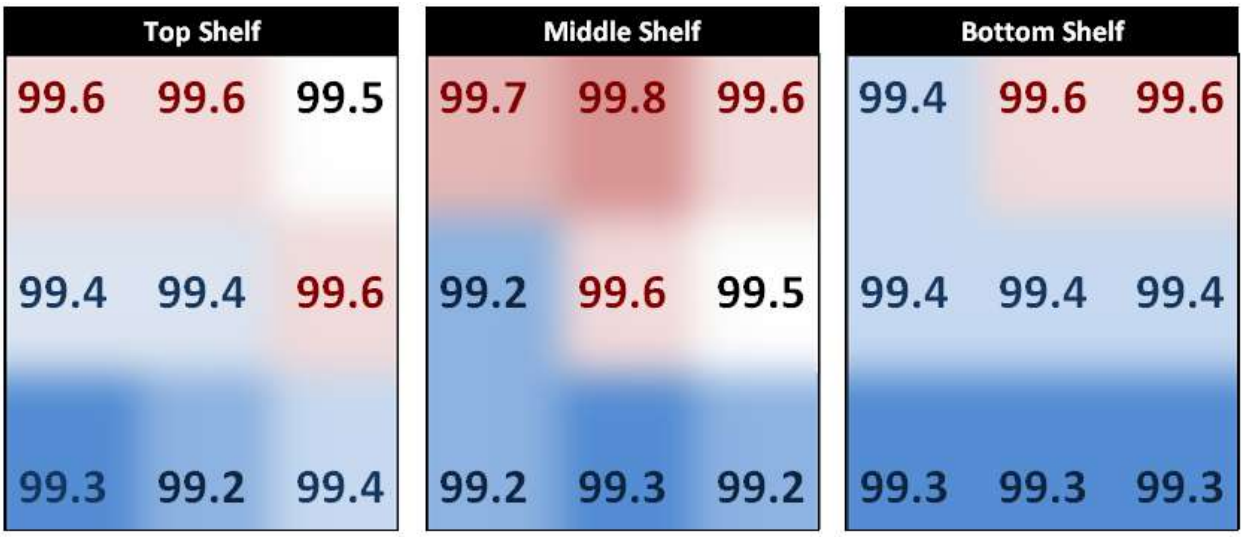
SHIPPED EGGS

Regardless of how well packed, shipped eggs may encounter a great deal of shock during shipment that may damage the air cell or disrupt internal structure. For best results, allow eggs to settle with the large end up for 24 hours prior to placing in the incubator. Additionally, do not turn shipped eggs for the first 48 hours of incubation. Even under ideal conditions, shipped eggs often have a significantly lower hatch rate than those gathered locally.

KNOW YOUR INCUBATOR

CAUTION: Fully automatic incubators may not be fully automatic. Manufacturers generally produce the best product possible within a given price range; cost restraints lead to less than perfect incubators. You, the end user, should become aware of these imperfections before setting the first egg.

Temperature variation is perhaps the most common imperfection. The following chart illustrates the imperfect temperature distribution in a new GQF 1500 incubator. The temperature for each area (zone) was measured by placing a temperature probe through an air vent, allowing the internal temperature to settle, and recording the difference from the set temperature – red indicates warm zones and blue indicates cool zone:



Without this knowledge, eggs placed in the warmer section will mature, hatch early, and possibly experience developmental issues. Those placed in the cool sections may not develop, be slow to develop, and/or experience difficulties at hatch time. With this knowledge, the end-user can make physical modifications to the incubator decreasing temperature variations; they can also address variations by placing newer eggs in the warmer sections, placing older eggs in the cooler sections, or simply routinely moving the eggs within each tray.

Small, desktop incubators can experience similar temperature imperfections with warmer areas in the center with cooler areas towards the edges. A common mistake is to set the thermometer in the location where it is the easiest to read and ignore the other areas. You should move the thermometer around until you're familiar with temperature variations.

Different incubators also react differently to changes in room humidity and egg development. For the first several batches, consider placing a second hygrometer in the hatch room and monitor the effect room humidity has on incubation humidity. Also note how the normal development of the embryos affects both temperature and humidity. Make changes accordingly and store this knowledge away for future reference.

INCUBATOR PREPARATION

The incubator should be prepared, turned on, and ***well regulated*** at least two days before setting the first egg.

AVOID getting in a hurry to set your first batch of eggs. Most beginners get into trouble by not taking the time to ensure that their incubator is operating properly, that the temperature is steady, and that the humidity is constant.

1. Do NOT trust the thermometer or hygrometer (measures relative humidity) that comes with or is built into the incubator – use at least one other independent source for measuring temperature and humidity; these serve as the "control" thermometer and hygrometer. Personally, I use a cheap, red, glass thermometer as my gold standard for measuring temperature… it has served me well over the years.
2. Carefully calibrate your control thermometer before turning on the incubator. Calibrate by placing it in stirred, ice water; it should register just slightly above 32° F.
   - For glass thermometers: You may need to slide the glass portion of the thermometer slightly up or down until the reading matches the measurement scale. Secure the glass portion using a dab of hot glue towards the middle and top of the glass tube – do not place hot glue near the bulb portion.
   - For digital thermometers: follow the manufacturer's instructions to raise or lower the reading to match 32.5° F. You may need to calibrate a glass thermometer and then use it to check the accuracy of your digital thermometer.
   - To check the calibration of your thermometer, allow the incubator to warm to 99.5 ° F according to your independent thermometer and then measure the incubator temperature using a thermometer intended for human use.

Small Incubator Loads

Incubators operate most efficiently when they at 70-80% capacity. Smaller loads negatively affect air flow and temperature stability. For best results, loosely fill empty space with a similar amount of sealed drinking water bottles. These water bottles serve as heat sinks and help maintain the temperature during brief power outages.

CAUTION: Inaccurate temperature measurement is perhaps the primary cause for hatch failure, weak or deformed chicks, and early or late hatches. To avoid these pitfalls, you **MUST** calibrate a thermometer… using two or three thermometers will not alleviate the problem.

3. Place the control thermometer in the middle of the incubation space. When the heating element is on, the air temperature will temporarily rise as the air becomes heated. To reduce this influence, I place a small, circular piece of cardboard loosely around the thermometer bulb. Digital thermometers are notorious for recording this temporary temperature rise as a temperature spike. Personally, I avoid using a digital thermometer for this reason… they are just too sensitive. If your incubator experiences frequent temperature spikes or dips, it may be your thermometer, not your incubator.

4. ***INCUBATOR PLACEMENT*** is perhaps the most overlook factor in maintaining consistent incubating temperature and humidity. For best results, place the incubator in a controlled environment free of drafts and temperature fluctuations; however, the room should have good ventilation to ensure an adequate supply of fresh air. Place the incubator in the corner of the room away from windows, drafts, and direct sunlight. Personally, I keep my incubator in a spare bedroom with the curtains closed.
5. After turning on the incubator, allow several hours for it to warm up prior to attempting to regulate the internal temperature. After initial warm-up, slowly adjust the temperature until your control thermometer reads 99.5° F. When making adjustments, take temperature readings when the heating element is off, adjust the thermostat in very small increments, and wait at least one hour before making additional adjustments. It can take 24 hours to complete this process; do not rush this process as it can lead to temperature problems throughout incubation. Once adjusted, allow 24 hours before setting the first egg and RESIST any temptation to fiddle with the thermostat once eggs are in the incubator.

CHECKING YOUR HYGROMETER: Dampen a towel (not dripping wet) then wrap the hygrometer in the towel for 30 to 45 minutes. Then unwrap it and quickly read the humidity; it should read exactly 100%. You should make a mental note of how far over or under the actual humidity is from the reading from your hygrometer.

6. Adjust the humidity using the incubator's instruction manual. For manual incubators, humidity is controlled by the amount of water surface area open to the air (the width of the water container) – increasing the surface area increases the humidity; decreasing the surface area decreases the humidity. For manual incubators, always use warm water when adding to the water container.

TEMPERATURE & HUMIDITY SETTINGS

Hatching Chart						
Species	**Incubation Period**	***Temp**	**Humidity (RH)**	**+Stop Turning**	**Hatch Humidity**	**Setting Notes**
Chicken	21 days	99.5 F	45-50%	19th day	+70%	Pointed end down
Duck, Mallard	27 days	99.5 F	55-60%	25th day	+70%	Place on side
Geese, Brown Chinese	30 days	99.5 F	60%	27th day	+70%	Place on side
Peafowl, India Blue	28 days	99.5 F	55-60%	26th day	+70%	Place on side
Pheasant, Golden	22 days	99.5 F	55-60%	19th day	+70%	Place on side
Turkey, Bronze	28 days	99.5 F	45-50%	26th day	+70%	Pointed end down

****Temperatures are for forced air/circulated air incubators. FOR STILL AIR INCUBATORS, PLEASE ADD 1.5-2° F.***

+Stop turning eggs, remove turner, and increase humidity at the very beginning of the day indicated – three days before the hatch.

The temperature of the air within the incubator does not accurately reflect the temperature experienced by the embryo. The actual embryonic temperature is the combination air temperature, embryonic metabolism, and ventilation/air flow. As the embryo develops, it increasingly produces its own heat through metabolism. If the air temperature remains constant (99.5° F) then the actual temperature inside the egg will rise as the embryo develops. Equipment permitting, the settings below provide a more ideal environment for developing embryos:

Still Air Incubator Temperature[5]

Maintain a still-air incubator at 102 degrees F. to compensate for the temperature layering within the incubator. Obtain the proper temperature reading by elevating the bulb of the thermometer to the same height as the top of the eggs when the eggs are laying horizontal. If the eggs are positioned in a vertical position, elevate the thermometer bulb to a point about ¼- to ½-inch below the top of the egg. The temperature is measured at the level where the embryos develop (at the top of the egg). Do not allow the thermometer's bulb to touch the eggs or incubator. Incorrect readings will result.

Ideal Air Temperature & Ventilation[6]

Incubation Day	Air Temperature	Embryo Temperature	Ventilation
1-4	100.0-100.5	100.0-100.0	0-10%
5-8	99.8-100.0	100.0-100.2	10-20%
9-10	99.5-99.9	100.0-100.5	30-40%
11-12	98.5-99.6	100.0-101.0	40-50%
14-16	98.0-98.8	100.0-101.0	50-60%
17-18	98.0-98.5	100.0-101.0	60-70%
19-20	98.0-98.5	-	30-50%
21	97.0-98.0	-	50-70%

***NOTE OF CAUTION**: The above recommendations are **ONLY** suitable with single stage incubation (one batch of eggs at a time) and **ONLY** with advanced digital equipment. Fiddling with a tricky thermostat while eggs are in the incubator can have disastrous results. Changing incubator settings is NOT recommended for the hobbyist.*

In Case of Power Outage[7]

If you experience a power failure, do not scrap the hatch. Most of the time the hatch can be saved. The key is to keep the eggs as warm as possible until the power returns. This can be done by placing a large cardboard box or blankets over the top of small incubators for additional insulation. To warm the eggs, place candles in jars, light them and place the jars under the box that covers the incubator. Be careful not to put any flammable material closer than a foot from the top of the candles. The heat from the candles can easily keep the eggs above 90°F until the power returns.

Embryos have survived at temperatures below 90°F for up to 18 hours. You should continue to incubate the eggs after the outage; then candle them 4 to 6 days later to check for further development or signs of life. If, after 6 days, you do not see life or development in any of the eggs, then terminate incubation. Most of the time, a power outage will delay hatching by a few days and decrease the hatchability to 40-50 percent.

[5] *Tom W. Smith, "Care and Incubation of Hatching Eggs," The Poultry Site, May 27, 2004 <http://www.thepoultrysite.com/articles/166/care-and-incubation-of-hatching-eggs>*

[6] *Adapted from "Incubation Guide," Hubbard Breeders, <http://www.hubbardbreeders.com/managementguides/Incubation%20guide%20(english).pdf>*

[7] *Phillip J. Clauer, "Incubating Eggs," Virginia Cooperative Extension, Virginia Tech, NDA, http://pubs.ext.vt.edu/2902/2902-1090/2902-1090_pdf.pdf*

SETTING EGGS: NO AUTOMATIC TURNER

DO NOT attempt to set any eggs until the incubator's temperature and humidity has been stable for at least 24 hours doing so will lead to multiple problems that are difficult to correct once eggs are in the incubator.

1. Allow the eggs to warm if they have been stored below 75-80° F.
2. Using a pencil, mark one side of each egg with an **X** and the other side with an **O**. These markings will help ensure that each egg is completely turned.

3. Lay the eggs on their side, on top of the mesh, in the middle of the incubator. It is perfectly fine for the eggs to touch but they should not be overly crowded or stacked.
4. Close the lid, walk away, and do not return for several hours. It is normal for the incubator to take some time before warming to the set temperature. It is also not uncommon for the temperature to spike a degree or two above the set temperature after setting eggs. ***Avoid fiddling with the thermostat during the first 24 hours***.

5. Before opening the incubator to turn your eggs, examine your temperature and humidity readings. While you will need to occasionally add water to keep the humidity up, you should not need to touch the thermostat. If the temperature is off, do nothing and check the temperature in another hour. If the thermometer continues to read high or low, you may carefully make a small adjustment.

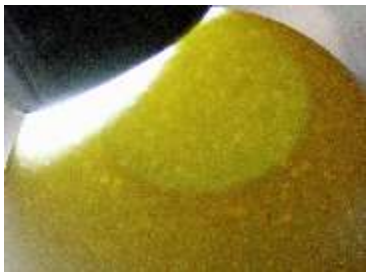
> Temperatures normally fluctuate from time to time. If your incubator has difficulty maintaining the set temperature, look at where you placed your incubator… perhaps a more stable place will help. Always be reluctant to alter your thermostat settings as fiddling with the thermostat frequently causes more problems than it solves.

6. Three times a day – morning, afternoon, and bedtime – move the eggs in the middle to the edge and roll the ones on the edge to the center. Check to ensure that each egg has been turned by checking your **X**'s or **O**'s.

SETTING EGGS: WITH AUTOMATIC TURNER

DO NOT attempt to set any eggs until the incubator's temperature and humidity has been stable for at least 24 hours doing so will lead to multiple problems that are difficult to correct once eggs are in the incubator.

1. Allow the eggs to warm if they have been stored below 75-80° F.
2. Identify the large (fat) end of the egg and draw a small circle on that end with a pencil. If you have difficulty determining which end is the large on, place a small flashlight on each end – the large end contains the air cell.



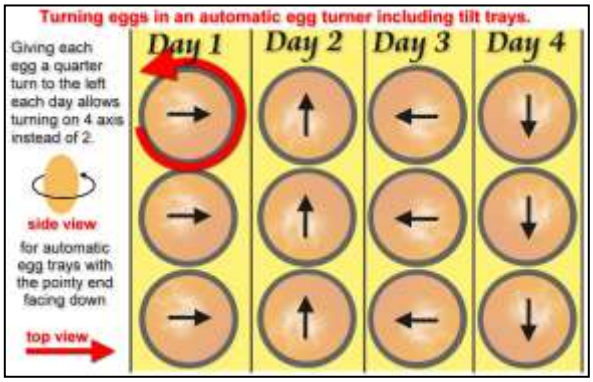
3. Place the eggs in the center section of the turner with the large end up – the pointy end down.
4. Close the lid, plug in the auto-turner, walk away, and do not return for several hours. It is normal for the incubator to take some time before warming to the set temperature. It is also not uncommon for the temperature to spike a degree or two above the set temperature after setting eggs. ***Avoid fiddling with the thermostat during the first 24 hours***.
5. Twice daily check your temperature and humidity. While you will need to occasionally add water to keep the humidity up, you should not need to touch the thermostat. If the temperature is off, do nothing and check the temperature in another hour. If the thermometer continues to read high or low, you may carefully make a small adjustment.

Temperatures normally fluctuate from time to time. If your incubator has difficulty maintaining the set temperature, look at where you placed your incubator… perhaps a more stable place will help. Always be reluctant to alter your thermostat settings as fiddling with the thermostat frequently causes more problems than it solves.

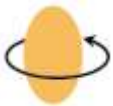
6. Automatic turners turn at a very slow pace and you may not see any motion. Occasionally, take a look at which way the eggs are tilted. You know that your egg turner is working when the eggs are tilted in different directions at various times.

SETTING EGGS: CABINET MODELS WITH TILT TRAYS

Broody hens instinctively know when to sit, when to turn, and how to regulate temperature and humidity. Artificial incubators attempt to replicate broody hens but are far less effective:



1. Set fresh eggs in the uppermost incubator shelf. Few incubators maintain a consistent temperature throughout the incubating space, newly set eggs benefit from a slightly higher temperature than eggs that are nearing hatch, and the top shelf is usually warmer than the bottom shelf. For incubators with only one shelf, the center of the shelf is usually the warmest area.
2. Be sure there is space for air circulation between eggs. A broody hen depends on conductivity (touch) to warm eggs; an incubator depends on convection (air movement). Keeping eggs evenly spaced helps avoid "hot" and "cold" spots. Additionally, rearranging egg placement within the tray can also reduce the impact of hot and cold spots.
3. Routinely turning eggs provides the embryo with needed exercise, helps develop the circulatory system, and prevents hatchlings from sticking to the shell membrane. For best results:



- **Cabinet Incubators with Tilt Trays**: Chickens, turkey, and duck eggs should be placed in egg trays with their pointed end facing down. Eggs will benefit from a daily quarter turn to the right so they experience tilting on four axes rather than only two. Additionally, shuffling eggs within the tray (moving the eggs in the center towards the edges and the outer eggs towards the center) reduces the influence of hot and cold spots.

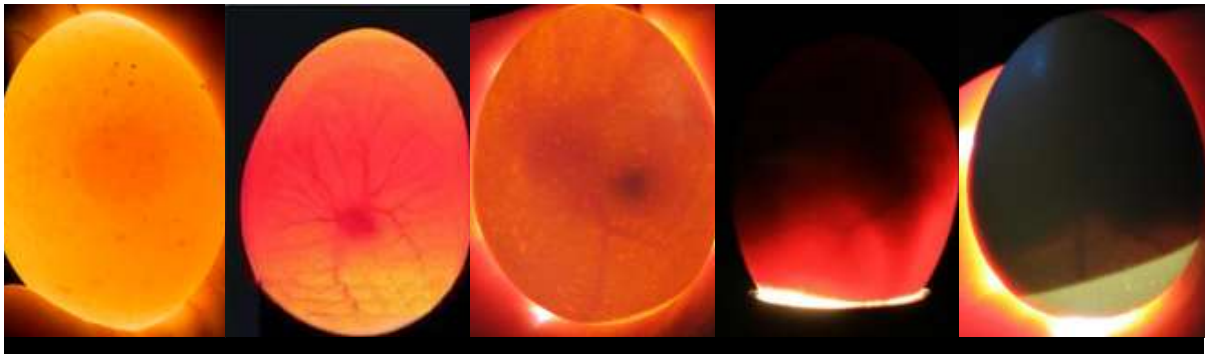
- **Peafowl, Goose, and Larger Eggs with Tilt Trays**: Peafowl, goose, and other large eggs do better when placed on their side rather than pointed end down. Manually turning these eggs 180° daily will avoid the embryo from settling towards the bottom of the shell and increase overall embryo health and improves the hatch rate. Additionally, eggs laid on their side benefit from periodically being rearranged within the tray.

4. After adding fresh eggs to the incubator, the temperature and humidity will fluctuate, both up and down, while the eggs are warming. It is not uncommon for the temperature to rise to 101°F within an incubator during the first hour; resist any temptation to adjust the temperature or humidity. These temporary fluctuations will not affect the hatch rate and will eventually settle to calibrate temperature and humidity.

CANDLING EGGS

Candling is not a necessity but can help ease anxiety about how eggs are progressing.

1. Candling is the process of applying a strong light to the outside shell allowing a glimpse of the inside. A small LED flashlight and a dark room is sufficient to candle lightly colored eggs, many utilize their smart-phone flashlight app.
2. For dark colored or thick shelled eggs, I use a candling box constructed out of a shoe box, old light fixtures from a ceiling fan light, two 23 watt CFL bulbs (100 watt equivalent), and lots of duck tape. The CFL bulbs are cooler than traditional incandescent bulbs.
3. Most people candle their eggs on day 7, 14, and 18. However, on day 4 you should be able to see a small reddish embryo with blood vessels in white eggs. For darker colored or thick eggs, you may not be able to see anything but a dark shadow on day 10.



Day 0 *Day 4* *Day 7* *Day 14* *Day 18*

4. Eggs that are clear and show no signs of development may be discarded on day 14. If in doubt, leave the egg in the incubator. If an egg develops a bacterial infection, it probably will develop an odor. You can locate the bad egg by sniffing each egg individually.
5. Potential problems such as cracks or internal bacterial infections. Eggs that demonstrate problems should be removed as early as possible to prevent possible contamination of other eggs.
6. You will also want to examine the size of the air cell. The longer the egg is in the incubator, the more water will evaporate. If the humidity is too high, the air cell will be small. If the humidity is too low, the air cell will be large.
7. For illustration of normal development visit: http://www.backyardchickens.com/t/261876/chicks-are-here-egg-candling-pics-progression-though-incubation.

How are you candling?

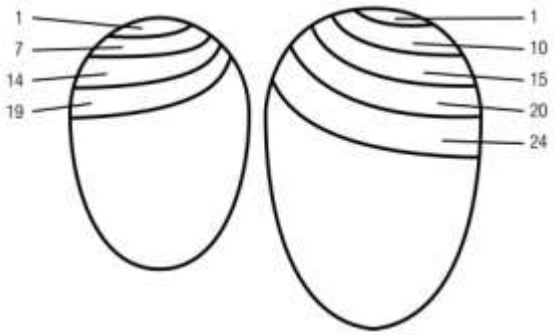
With my Ameraucana and Cream Legbar eggs, at 10 days I can candle from the pointy end and see quite a bit of space usually at the bottom, which tells me the dark mass I see from the top is a growing chick. If it is dark through and through at 10 days that is a bad sign. Also, sniff test them- seriously- at least open the incubator once a day and take a good sniff at the door. You will know LONG before a bad egg explodes if you sniff daily that there is a bad one somewhere in the bunch. Sniff them one at a time until you find the stinker!

Once you are used to what they are supposed to look like a quick candling along the top of the eggs is plenty good enough. But at first exploring them from all angles and comparing them to each other is important to teach you what they SHOULD look like at each stage.

You should be monitoring air cell size anyway- you want the egg to lose about 30% of it's volume inside to air space before the eggs hatch. But sometimes looking from the side or pointy end can give you valuable clues as to whether or not the chick is live and well. Time is a factor, too- if this is your first time, or you only have a small incubator, candling is a fun thing to do. I've got anywhere from 90-300 eggs in at a time so I don't take any longer than necessary anymore. *Rinda Sudweeks Myers: Hatchaholics Anonymous*

HUMIDITY

Opinions vary as to the best humidity setting and its impact on hatch success; it may take several batches before discovering the settings that work best within a particular situation. During incubation, eggs must lose 11-12% of their water content prior to hatch. If insufficient water loss occurs, the hatchling may have difficulty moving inside the egg, fail to locate the air cell, and possibly drown. If too much water loss occurs, the air cell will consume too much space crowding the hatchling and possibly preventing it from rotating and completely zipping the shell.



Airspace Development throughout Incubation

Factors such as hatch room humidity, altitude, shell quality, shell thickness, bird species, and dirt on eggs affect water loss. Removal of the cuticle by washing results in greater water loss than unwashed eggs. While we cannot control all variables, we should take care to closely monitor air cell size by candling each egg at least weekly. If the air cell is too small, decrease the incubator humidity; if it is too large, increase the humidity. In some cases, the hatch room humidity must be raised or lowered when the incubator is incapable of reaching the desired levels.

Incubation Tip: As the embryo matures, it will start producing its own heat through metabolism… the actual temperature of the egg will be higher than the air temperature. If the bulb or probe tip is touching an egg shell then your temperature reading will not be accurate.

Different environments and incubators require slightly different humidity settings. The humidity settings provided in the next sections can serve as starting references that should require adjustments according to your individual circumstances. When making changes, make them gradually, check for results, and then readjust as needed. Sudden, large adjustments can dramatic changes that can be difficult to correct.

Pipped Eggs That Do Not Hatch[8]

The air exchange requirement within an incubator is greatest during the last day of incubation. The chick embryo's oxygen requirement continually increases during development and especially when breathing using the respiratory system just before hatching. The vent openings are frequently restricted at this time in an attempt to boost incubator humidity. Instead of helping the chick hatch, the chick is suffocated from lack of ventilation. Never decrease ventilation openings at hatching in an attempt to increase humidity. Increase humidity by other methods. If any vent adjustments are made, they should be opened more.

Another reason for mortality during hatching is improper humidity adjustment. The deaths can be produced from too much humidity during the entire incubation period or from too little humidity during the hatching period.

The desired egg weight loss during incubation caused by water evaporation is about 12 percent. If humidity during incubation is kept too high, adequate water evaporation from the egg is prevented. The chick can drown in the water remaining in the shell at hatching. A dried coating around the chick's nostrils and beak indicates that drowning was likely. Attention to maintaining proper incubation humidity during incubation will reduce the potential for this problem at hatching time.

If the humidity is allowed to decrease after the chick pips the shell, the membranes within the shell can dry-out and stick to the chick. This prevents the chick from turning inside the shell and stops the hatching process. The chick eventually dies. If the membranes around the shell opening appear dried and shrunken, the cause is probably low humidity during hatching. This condition can occur quickly (within 1 or 2 minutes) when the incubator is opened to remove or assist other chicks that are hatching. When hatching begins and proper incubator conditions are attained, the incubator should never be opened until after all chicks are hatched and ready for placement in the brooder.

[8] *Poultry: Reproduction & Incubation. MSUCares. Mississippi State University Extension Service. August 21, 2014 <http://msucares.com/poultry/reproductions/poultry_pipped.html>*

THE HATCHING PROCESS

Hatching involves a multi-step process where the hatchling performs a task, rests, and then proceeds to the next step. Each step requires physical exertion and the hatchling may rest for an extended period of time between each. The last three days of the hatching process is frequently called "lockdown" as the eggs are no longer turned, the humidity is increased, and the lid remains closed.

1. **LOCKDOWN PROCEDURE**: Lockdown should begin at the start of third days prior to hatch and consist of the following procedures:
   - Remove the eggs from the turner, remove the turner, and remove the turning tray.
   - Set the eggs on the bottom mesh on their side with the large end slightly elevated.
   - Remove all ventilation plugs.
   - Increase the humidity to 65-70%.
   - Close the lid and keep it closed except to add water when necessary.
   - Remain patient – hatching takes time.

Ventilation[9]

Ventilation is very important during the incubation process. While the embryo is developing, oxygen enters the egg through the shell and carbon dioxide escapes in the same manner. As the chicks hatch, they require an increased supply of fresh oxygen. As embryos grow, the air vent openings are gradually opened to satisfy increased embryonic oxygen demand. Care must be taken to maintain humidity during the hatching period. Unobstructed ventilation holes, both above and below the eggs, are essential for proper air exchange.

2. **POSITIONING**: Two to three days before hatch, the hatchling will move into its hatching position. Normally, the hatchling's head will be positioned towards the large end of the egg. Occasionally, the head may be in a different position – breach. Causes of mal-positioning include incubating the egg upside down, inadequate turning, inappropriate incubation temperature, extra-large egg size, or poor flock health. Malpositioned hatchlings may hatch without assistance but often suffocate in their shell without pipping or are unable to turn and zip if they are able to successfully pip.

Some hobbyists prefer to allow eggs to stay in the turner during hatching; they simply unplug the automatic turner. Eggs remaining in the upright position place the chick in an unnatural position delaying hatching and making zipping more difficult. For best results, remove the eggs from the tray and lay them on their side.

3. **INTERNAL PIP**: The hatchling will peck a hole in the membrane separating it from the air cell, begin to breathe, and may begin to chirp. At this point, the hatchlings begin to absorb the egg yolk, a process that may take several hours or even a day to complete. Since the internal membrane is punctured, the drying process begins. If the incubator's humidity is too low, the internal fluids become sticky and may glue the hatchling to the shell. Additionally, the hatchling starts to become dependent on the available oxygen. Fresh air increasingly becomes a necessity for the hatchling's survival.

REMOVE ALL VENTILATION PLUGS three days prior to hatch. As the hatching process proceeds, the hatchling becomes more and more dependent on its outside environment rather than the yolk sac. Hatching requires a great deal of physical exertion and oxygen. Failure to remove ventilation plugs can lead to exhaustion, weakness, and possibly death.

NOTE: If the humidity was too high prior to lockdown, the air cell will be too small and the hatchling may not be able to locate and breach the air cell. In such cases, the hatchling will likely suffocate (drown) without externally pipping.

[9] *Tom W. Smith, "Care and Incubation of Hatching Eggs," The Poultry site, May 27, 2004 <http://www.thepoultrysite.com/articles/166/care-and-incubation-of-hatching-eggs>*

4. **EXTERNAL PIP**: When ready, the hatchling will peck a hole in the large end of outer shell. At this point, things begin to pick up speed: absorption of the yolk sac increases, blood vessels attached to the yolk sac begin to shrink and dry, the membrane becomes increasingly dry, and the demand for oxygen increases. In my experience, the time between the first external pip and the first hatchling to emerge is 12 hours, and that first hatchling to pip is not necessarily the first one to emerge.

> **GUARD YOUR HUMIDITY**: The membrane that protects the chick from outside bacteria or an excess loss of water during incubation can dry out in as little as 60 seconds if humidity is lost. Once dried out, this membrane prevents the chick from hatching and becomes a death shroud. Guarding your humidity – it's a matter of life and death.

NOTE: Low humidity, inadequate turning, inadequate ventilation, low temperatures prior to lockdown, or high temperature after lockdown are all common reasons why a hatchling fails to pip externally. In many cases, the hatchling simply does not have the consistency for continued life and is not the result of a flawed incubation.

5. **ZIPPING**: Once the initial hole is made, the chick will turn inside the shell and proceed to make a crack around the diameter of the shell – zipping. If the humidity is low during this process, the membrane may dry out, shrink, and the chick may become stuck – shrink wrapped. The task of zipping may take anywhere from a few minutes to a few hours. Almost all hatchlings that make it this far will hatch unless there is inadequate ventilation of the hatching temperature is too high.
6. **EMERGENCE**: Once zipping is complete, the chick may rest for a spell. Once it regains strength, it will push against the bottom of the shell using its feet eventually freeing itself from the shell.

> Assisting a chick too early can easily result in permanent harm or death. In most cases, a healthy chick will rest periodically and will emerge in time. If you decide you must assist a chick, please use caution and follow the advice in the following article:
>
> http://www.back yardchickens.com/a/step-by-step-guide-to-assisted-hatching

7. **TEMPERATURE**: In small, desktop incubators with relatively weak fans and filled capacity, physical exertion from the hatchlings may cause the temperature to rise. In such cases, the thermostat should be carefully lowered in order to prevent overheating and exhaustion. For incubators with reliable digital controls, the recommended temperature during the final hatching phase is 97-98° F.
8. **EARLY HATCHING**: If the incubation temperature has been a little high throughout incubation or the eggs are small, the chicks may begin to hatch early. If they do, there is little you can do except maintain your temperature and humidity.

9. **LATE HATCHING**: If the incubation temperature has been a little low throughout incubation or the eggs are large, the chicks may begin to hatch late. If they do, there is little you can do except maintain your temperature and humidity.
10. **UMBILICAL CORD**: Prior to hatching, the chick will absorb the remainder of the egg yolk and the blood vessels attached to the shell contends will dry out. If a chick emerges too quickly, what appears to be an umbilical cord will be attached to its bottom. This cord will fall off without any assistance.
11. **HERNIATED YOLK SAC**: On rare occasions, a chick will emerge from its shell before the egg yolk is completely absorbed – herniated yolk sac. It should absorb on its own if the area remains moist.

12. **ENDING THE HATCH**: How long should you give an egg to hatch? Many people wait 2-3 days after the due date before discarding unhatched eggs. Personally, I will end the hatch a few hours after any visual activities have stopped. With experience, you will adopt your own preference on how long to wait.
13. **REMOVING HATCHLINGS**: Hatchlings should be completely dry and actively moving about before removing from the incubator. Hatchlings absorb their egg yolk just prior to hatch and can easily survive 48-72 hours after hatch without food or water. In most cases, it is best to wait until the entire hatch is complete before removing any hatchlings… Do not be in any hurry to remove hatchlings.
14. **PATIENCE**: Even the experienced feel anxiety at hatch time; beginners may be overwhelmed with excitement and concern. Be patient. Mother Nature has designed each step in the process for a reason and each step takes time.

EVALUATING THE HATCH

Hatches consisting of 100% fertility and 100% hatching are rare. A hatch rate of 85% for all eggs set is generally consider satisfactory and is the industrial norm. Experienced hatchers understand that there is always something to be learned and will carefully evaluate each batch seeking to improve the next.

1. **FERTILITY RATE**: *Number of eggs set ÷ Number of eggs begin development = Fertility Rate*. Among my flock, rare birds, such as Sebrights, may have a fertility rate of 15-20% while the rate for more common breeds, such as Mallard ducks, may run 100%. Low fertility rates are generally the result roosters that are too old or too young, too few roosters, lack of genetic diversity among rare breeds, inbreeding, or environmental extremes.
2. **HATCH RATE**: *Number of hatched hatchlings ÷ Number of fertile eggs = Hatch Rate*. A hatch rate of 85% is generally considered satisfactory among most breeds of fowl. Some species, such as turkeys and bantams naturally produce a lower hatch rate than average. Other breeds, such as hybrid laying hens, will produce a higher hatch rate than average. The incubation factors as well as those that influence the fertility rate also play a role in the hatch rate.

Hatch Rates

What is a good hatch rate? Many people claim they get a hatch rate of 90%, 95%, even 100%, BUT that is not normal and should not be expected. There are too many variables to declare a 85% hatch rate good and a 50% rate bad. In some situations, I'd be thrilled with a 40% hatch rate (Sebrights) while I'd be disappointed in a 90% rate (hybrid layers). I need 18 mallard eggs for 12 healthy ducklings in February but only 14 in May. In January, 16 goose eggs will produce 10 vigorous goslings but only 8 in April. Species, genetics, age, maturity, health, weather, season, and experience all play a role in hatching – there is more to incubating than correct temperature and humidity. What is a good hatch rate? I'd first set a goal of 50% and then raise or lower that goal as you gain experience. What is a good hatch rate? You have a good hatch rate when you are happy with the results! Good luck!

3. **DID THE CHICKS HATCH ON TIME?** If they hatched early, then your temperature may have been a little high. If they hatched late, then your temperature may have been a little low. You may need to recalibrate your thermometer. The accuracy of digital thermometers should be checked against a trusted, calibrated glass thermometer. It is also not uncommon for small eggs to hatch early and large eggs to hatch a little later than average size eggs.
4. **DID ALL EGGS HATCH WITHIN A 12-16 HOUR PERIOD?** If more than 12-16 hours transpired between the first chick and the last chick, then you may have warm and cool spots. Randomly moving the eggs around periodically will prevent an egg from staying within a warm or cool spot for a long period of time. Additionally, eggs will begin developing if they are stored in temperatures above 70° causing older eggs to hatch a little earlier than fresh ones. When possible, store eggs at below 70 °.

5. **EGGTOPSY:** Not all chicks will hatch. There are multiple reasons why this occurs from hen nutrient deficiencies, cold temperatures during collection, bacterial contamination, genetic flaws, and flaws in incubation methods. Eggs that did not hatch should be opened and examined to determine, if possible, why the chick failed to hatch. The following link from The Chicken Chick provides an excellent look at the stages of development: http://www.the-chicken-chick.com/2012/03/chicken-embryo-development-views-from.html.

6. **OTHER CONSIDERATIONS**: Other factors to consider include:

   - **THERMOMETER PLACEMENT**: The control thermometer was not placed within the incubator at the ideal location. Placing the thermometer within the air flow directly influenced by the heating element will result in a high temperature reading and an early hatch. Placing the thermometer is an isolated area or one out of the main flow of circulation will result in a low temperature reading and a late hatch.
   - **HEATING ELEMENT**: The incubator heating element is either under powered or overly worn. If the heating element indicator comes on frequently, then the unit is having a hard time keeping the incubator warm. It may be time to replace the element with a new one or perhaps increase the element's wattage.
   - **INADEQUATE AIR CIRCULATION**: There should only be a minimum temperature difference between the top tray and the bottom tray. If there is more than a 0.5° F difference then the air circulation is inadequate. This could be caused by a low powered fan and/or blockage of the air flow. Check spacing between eggs and be sure other items are not blocking the air flow. If the fan is not moving a good deal of air, consider replacing it with a more powerful one.
   - **POWER OUTAGE**: Extended power outages play havoc with incubation. While a short outage will have little effect on large eggs placed in the middle shelf, the results could be devastating on small eggs placed either on the top tray (overheating) or the bottom tray (under heating) – hot air rises. If power outages are common, consider installing a battery operated fan within the incubator to keep the air circulating and consider an alternative means of heating the hatch room. My hatch room has access to natural gas heating and I've raised the room temperature to 98-99° F during extended power outages.
   - **UNEVEN HEATING**: It is nearly impossible to maintain the exact same temperature in all parts of the incubator. Randomly moving eggs around on the incubation tray can help accommodate minor temperature variations. Additionally, ensuring that eggs are evenly distributed and not blocking the air flow will help reduce hot and cold spots. If the hatch gap is a persistent problem, then you may want to take a temperature reading at various locations to identify any hot or cold spots. The addition of small air baffles may be necessary to direct air away from hot spots and/or direct air to cold spots.

2014 HATCHES

Batch Number	Set Date	Species	# Set	# Fert	% Fert	Due Date	# Hatch	% Hatch	# Cull	# Sold	# Res.	# Other
201432	Nov. 27 2014	Goldenreds	71	61	85.9%	Dec. 18 2014	54	88.5%	1	30	5	13
201430	Nov. 03 2014	Ameraucanas	13	13	100%	Nov. 24 2014	13	100%	0	0	13	0
201429	Oct. 26 2014	Goldenreds	67	55	82.1%	Nov. 16 2014	41	74.5%		41	0	0
201428	Oct. 13 2014	Serama	5	4	80%	Nov. 03 2014	4	100%	0	1	2	0

HATCH PROBLEM IDENTIFICATION

Problem	Possible Causes
Eggs candle clear	♦ Rooster too young or too old ♦ Too many hens for each rooster ♦ Too many roosters – interference during mating ♦ Season decline late summer and fall ♦ Eggs stored at below 40° F ♦ Extreme weather before collection ♦ Hens too old or in poor health
Eggs candle clear with blood ring present	♦ Eggs stored too long or at wrong temperature ♦ Excessively high temperature spike ♦ Temperature too high at start of incubation ♦ Hens too old or in poor health
Dead embryos before day 18	♦ Inadequate turning or turning angle ♦ Lack of ventilation or blocked pores ♦ Egg contamination – bacterial infection ♦ Hens too old or in poor health
Dead embryos after day 18 *Eggs not pipped*	♦ High average humidity before lockdown ♦ Low humidity after lockdown ♦ Malposition of embryo ♦ High temperature after lockdown ♦ Hatcher opened too frequently after lockdown
Eggs pipped but not hatched *Chick dead in shell* *Sticky chicks* *Shell sticking to chick*	♦ Low average humidity before lockdown ♦ Low average temperature ♦ Low humidity after lockdown ♦ Insufficient turning ♦ High temperature after lockdown ♦ Insufficient ventilation
Chick pips wrong end	♦ Eggs incubated small end up ♦ Inadequate turning ♦ High temperatures during lockdown ♦ Not placed on side at lockdown
Eggs hatch early	♦ High average temperature ♦ Small eggs or difference between breeds ♦ Low average humidity before lockdown
Eggs hatch late	♦ Low average temperature before lockdown ♦ Large eggs or difference between breeds ♦ High average humidity before lockdown
Hatch window longer than 12-16 hours	♦ Eggs stored above 70° F or for different lengths of time ♦ Temperature variations in incubator ♦ Mix of large and small eggs ♦ Mix of eggs from young and old hens
Crippled chicks	♦ Air cell too large – low overall humidity ♦ Temperature to high during incubation ♦ Poor nutrition of hens ♦ Genetic defects
Weak chicks	♦ Temperature too high at hatching ♦ Low average temperature before lockdown ♦ Lack of ventilation ♦ Poor nutrition of hens ♦ Contaminated eggs

21 DAYS OF INCUBATION

Chickens should hatch on day 21 of incubation.
The elapsed time between first chick and last chick should be no more than 24 hours.

While each incubator and each batch of eggs are unique, hatch time should be pretty consistent. Evaluating imperfect hatch results will help us identify flaws in our incubation method, take corrective actions, and ultimately improve our techniques. After each batch, I consider each of the following items to discover how I can make the next batch better:

GOAL 1: THE HATCH SHOULD BE COMPLETE BY THE END OF DAY 21

- **MOST EGGS HATCH LATE**: **POWER OUTAGE**: If the electricity goes off or the incubator inadvertently becomes unplugged, the temperature will drop. While most eggs can tolerate lower temperatures for several hours, the hatch will be delayed. Small eggs lose heat faster than large eggs and will usually hatch even later.
- **MOST EGGS HATCH LATE**: **LOW AVERAGE TEMPERATURE**:

> *Yep, I had my thermometer in the wrong place (taped in the window at top) first hatch - failed miserably it was a 10° degree difference!* *Nichole Hansen, Backyard Chickens*

  - **THERMOMETER PROBE TOUCHING EGG SHELL**: As the chick grows, it begins to generate its own heat through metabolism. As development progresses, the shell temperature becomes warmer (101° F) than the circulated air. If the bulb or probe is resting on the egg shell, the thermometer will read high.
  - **THERMOMETER PLACEMENT LEVEL TOO HIGH**: Warm air rises and cool air sinks. The incubator's temperature should be measured at the TOP of the eggs especially for still air incubators. While the fan in desktop forced air models circulates air, they still experience heat layering and the thermometer probe should be kept at egg top level.
  - **THERMOMETER INACCURATE**: Digital thermometers should be accurate to ±0.2° F. Unfortunately, most are only accurate to ±2.0° F meaning if the display reads 99.5° F the actual temperature can be anywhere from 98.5° F to 100.5° F. when buying a digital thermometer ensure that it is accurate to ±0.2° F.
  - **THERMOMETER UNCALIBRATED**: Most thermometers claim to be calibrated at the factory, but almost all thermometers are incorrect. Thermometers should be calibrated by placing its bulb/probe in a pan of crushed ice and water – the thermometer should read 32.0° F.
  - **THERMOMETER PROBE/BULB IN COOL SPOT**: All incubators have warm and cool spots. If the thermometer is kept in a warm spot, then the overall temperature will be cooler than needed. When regulating your incubator, measure the temperature is several different areas. Place the thermometer in an area that is neither cool not warm.
- **MOST EGGS HATCH EARLY**: **HIGH AVERAGE TEMPERATURE**:

> *Because overheated chicks hatch earlier than they should, they are often smaller, weaker and more prone to infections as well as a host of other health problems.* *Cobb Hatcheries*

  - **THERMOMETER PLACEMENT LEVEL TOO LOW**: Warm air rises and cool air sinks. The incubator's temperature should be measured at the TOP of the eggs especially for still air incubators. While the fan in desktop forced air models circulates air, they still experience heat layering and the thermometer probe should be kept at egg top level.
  - **THERMOMETER INACCURATE**: Digital thermometers should be accurate to ±0.2° F. Unfortunately, most are only accurate to ±2.0° F meaning if the display reads 99.5° F the actual

temperature can be anywhere from 98.5° F to 100.5° F. when buying a digital thermometer ensure that it is accurate to ±0.2° F.

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GOAL 2: ALL CHICKS SHOULD HATCH WITHIN A 24 HOUR PERIOD (HATCH WINDOW)

- **EGGS STORED ABOVE 70° F**: A chicken embryo begins to grow before the hen lays the egg; however, this process ceases at temperatures below 70° F permitting hens to lay full clutches before incubation begins.[10] Common practices allow eggs to be stored at room temperature for seven to ten days; unfortunately, older eggs may experience greater development than newer ones as room temperature approaches 80° F. For best results, store eggs below 70° F (55-65° F) allowing them to warm to 75-80°F prior to setting.

> *Cooling at ordinary temperatures will not kill the embryo, and it will begin to develop again when the egg is placed in the incubator. Keeping eggs at temperatures above about 80° F (27 C) prior to incubation will cause a slow growth which leads to a weakening and eventual death of the embryo.*
>
> *University of Illinois, 1988*

- **HOT & COLD SPOTS INSIDE INCUBATOR**: Few incubators maintain perfectly even temperatures in all areas – some spots will be warmer and some spots cooler – differing as much as one full degree. Fans help circulate the air reducing temperature variations; however, automatic egg turners, covering the mesh flooring, and cramming eggs into a small space decrease air flow and fan effectiveness. Many hobbyist set their eggs in the turner and then hope that the incubator will do all of the work; unfortunately, eggs resting in a cool spot for the entire incubation will hatch later than those resting in a warm spot. For best results, eggs should be shuffled periodically – eggs in the center moved to the sides and those on the sides to the center.

> *Broody hens provide optimum conditions for embryos developing in the eggs they are sitting on. The brood patch provides heat from one direction only, and the eggs at the side of the patch are cooler than those in the middle of the nest. However, because the broody hen regularly **turns and moves** the eggs in the nest, uniform egg temperature is achieved.* *Pas Reform Hatchery Technologies*

- **EGGS STORED DIFFERENT LENGTHS OF TIME**: According to Cobb Hatcheries, not only does prolonged storage decrease hatchability (about 1% for each day after the initial six) but it also prolongs incubation time, "On average, one day's storage adds one hour to incubation time."[11] To decrease the storage effect, eggs should be carefully stored using the following recommendations. Warm eggs for 4-6 hours before setting.

Hubbard Hatcheries	Days of Storage 1-2	3-4	5-6	7-8	9-12	13-16	17-20
Temperature	**66.2°F**	**62.6°F**	**59.9°F**	**57.2°F**	**54.5°F**	**53.6°F**	**52.7°F**
Humidity	70.0	80.0	85.0	90.0	90.0	90.0	90.0
Turning	No	No	No	No	Yes	Yes	Yes
Small end up	No	No	No	No	Yes	Yes	Yes

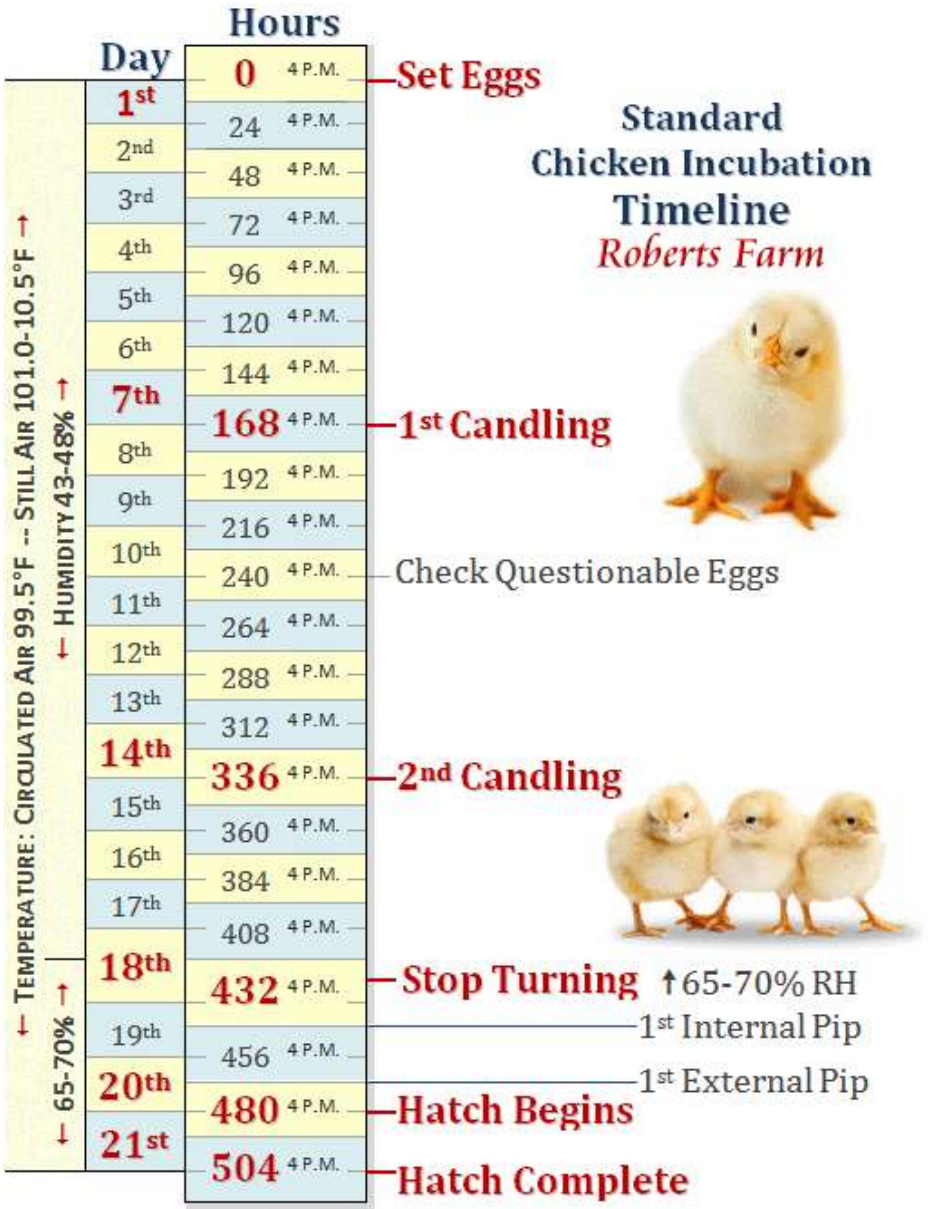
[10] *from Gaylene M. Fasenko, "Optimal egg storage conditions," University of Alberta, 2006*

[11] *"Hatching egg storage and transport," Cobb Hatcheries, NDA, <http://www.cobb-vantress.com/cobb-academy/overview/blog/detail/cobb-academy/2012/12/14/hatching-egg-storage-and-transport>*

- **EGGS FROM YOUNG & OLD HENS**: Research indicates that eggs from hens 32-45 weeks old produce the healthiest and most vigorous chicks. Unfortunately, most home flocks consist of hens from various age groups. For best results, attempt to avoid eggs from very young or very old pullets. While these may produce healthy chicks, they expand the hatch window and experience more difficulties.

> *Maternal age directly affects the rate of embryonic development. Embryos from 'pubescent' flocks (< 32 weeks) require longer incubation periods than embryo's from 'mature' flocks (>32 weeks).*
>
> *The Poultry Site, 2006.*

- **EGG SIZE VARIATIONS**: Within an environmentally stable and consistent environment, small eggs will hatch at the same time as large eggs. When the temperature within an incubator is inconsistent – bounces up and down – smaller eggs will hatch significantly earlier or later than larger eggs – small eggs heat up and cool down faster. If this occurs, consider your incubator placement and move to a location free of drafts, heating/cooling vents, and direct sunlight or a room with a more stable environment.



NOTATIONS

1. **Precision**: Probably the most common difficulty experienced with beginners is the lack of attention to details. A temperature of 98.5° is close, but it is not close enough. A Relative Humidity that fluctuates between 40% and 80% will result in a poor hatch. Turning eggs only when you feel like it hampers the embryonic development and result in weak hatchlings that have difficulty breaking out of their shell. Purchase and calibrate your control thermometer before you turn on the incubator. Place the incubator in an area with a controlled environment. Regulate the incubator temperature 48 hours before setting the first egg. Keep an eye on the humidity and add water to the water pan when needed. Turn the eggs at least three times per day. Precision makes a significant difference when hatching time arrives.
2. **The first 24-48 Hours**: The first 24-48 of incubation is critical. During this time period many people do not turn the eggs eliminating the possibility of jarring the egg and disturbing the embryonic germ. Additionally, research tends to indicate that a higher CO2 level (closed vents) and slightly higher temperature (100.5° F) during the first several days is beneficial to embryonic development. However, creating these conditions within a small, styrofoam incubator is nearly impossible and fiddling with the thermostat can do more harm than good.
3. **Fiddling with Thermostat**: Even the best incubators have variations in temperatures, usually resulting from changes in room temperature, humidity, or other external factors. Temporary spikes or drops in temperature usually have little effect on the hatch. Resist the urge to fiddle with the thermostat in order to get things perfect. Many a hatch has gone bad because of minor adjustments that resulted in a significant imbalance.
4. **Bad Smell**: If you notice a bad odor within the incubator, you must immediately locate the culprit. This can be accomplished by sniffing and/or candling the individual eggs. Upon candling, a bad egg will be completely dark, show a blob without distinct borders, or contain multiple dark areas. Failure to find and remove the culprit can result in an explosion that contaminates other eggs and causing a mess.
5. **Leaking Eggs**: Eggs that are cracked and leaking fluid will not hatch but may become glued to the wire floor or other eggs. Look for small cracks when candling; remove these eggs as soon as they are discovered.
6. **Daily Cooling**: In Nature, a hen will leave the nest to eat, drink water, and defecate. During this time, eggs will cool slightly. In some species of birds, especially waterfowl, artificially incubated eggs benefit from a daily cooling period making the shell more brittle and allowing the hatchling to emerge more easily. Personally, for waterfowl and peafowl, I replicate this process following the first week by removing the eggs from the incubator to room temperature (70-75° F) for a period of 10-15 minutes. For waterfowl, I mist the eggs with lukewarm water (100° F) prior to placing them back into the incubator.
7. **Heat Sinks**: Even the best incubators experience temporary spikes and dives in temperature that can cause havoc on hatching eggs. Fortunately, the eggs within a full incubator effectively serve as heat sinks and help moderate these temporary variations. Sealed drinking water bottles (or rocks) in less than full incubators also serve as heat sinks and help moderate fluxes in temperature. When using artificial heat sinks, be careful not to block or impede the flow of circulating air.
8. **Digital Thermometers**: In an attempt to achieve perfection, many people purchase expensive digital thermometers to accurately measure temperature. Unfortunately, many of these devices are extremely sensitive and will register temporary temperature spikes such as when the heating element turns on. This may cause the user to adjust the thermostat when no adjustment is needed. Personally, I prefer an old fashion, inexpensive, red, glass thermometer. Once calibrated, they are sufficiently accurate to bring in a good hatch without the complications of measuring temporary fluxes.
9. **Protection from Children**: Children are naturally curious and will fiddle with an incubator's thermostat or open the door to get a look at what is inside. With my grandchildren, it is sufficient to show and explain… then double check everything when they leave. I've heard many reports where children have fiddled with incubators ruining the hatch. Check even if you don't believe that your children have been near your incubator.

SIMPLE FACTS, TIPS, & TRICKS

BAD EGGS:

- Eggs with severe bacterial infections can be identified during candling by multiple small dark spots floating within the egg or by an unusually large dark area. For best results, compare a questionably bad egg with other eggs that possess a normal appearance.
- There should be very little odor coming from your incubator. If you notice an unusual smell, open the incubator and sniff each egg individually. Removing any egg that smells will reduce the chances of a bad egg leaking or exploding and contaminating other eggs within the incubator.

CLEANLINESS:

- Placing porous, cloth shelf liner placed on top of the mesh prior to hatching will allow moisture to pass through from the bottom water chambers but prevent the gunk from dropping into the lower portion of the incubation… easing the task of cleaning the incubator following a hatch.

CRACKED EGGS:

- It is generally a bad idea to incubate cracked eggs; it is also generally a good idea to discard any eggs that develop a crack during incubation. However, if an expensive or prized egg has or develops a crack, the cracked can be repaired using a small amount of un-perfumed wax. Use as little as possible and watch the egg during hatching as the seal may make hatching more difficult.

EGG ANATOMY:

SOURCE: *GeoChemBio*: http://www.geochembio.com/biology/organisms/chicken/#egg

EMBRYONIC DEVELOPMENT:

Source: **Okeedokee Early Learning Center**.
http://www.okeedokeekids.com.au/_content_data/_image_upload/embryo%20development.jpg

FERTILITY:

- The ***fertility rate*** is calculated by dividing the total number of eggs that show signs of development by the total number of eggs set. set 28 show development ÷ 30 = 0.93 or 93%.
- The recommended ***rooster to hen ratio*** is 1 rooster for every 8-10 hens. In some breeds such as rare bantams, that ratio may be lower – 1:3.
- A hen generally remains fertile for 10 days following the removal of a rooster. To guarantee that chicks are fathered by a specific rooster, hens should be separated from other roosters for three or four week.

HUMIDITY:

- Humidity is determined by surface area not water depth. To increase the humidity, increase the area water is exposed to the air either by using a wider pan or sponge.
- When adding water to an incubator, the water should be lukewarm – neither hot nor cold. Adding hot water will temporarily boost the humidity and may result in temporary uneven heating.
- During the final three days, placing warm wet kitchen sponges on top of the mesh will boost the humidity. Be sure all detergent is washed out of the sponges before using. Also be sure to carefully wash and scald sponges after each batch to prevent bacterial growth.
- To decrease humidity within an incubator, add uncooked dry rice to the incubator pan.
- If you have difficulty seeing the water in the water chambers, add a drop or two of food coloring. As the water level drops, the color will drop. It will lighten once again as you add more water.
- You can add water to the chambers underneath the mesh without opening the incubator. At lockdown, thread a small tube through a ventilation hole, through the mess, and into the chambers. Attach a children's medical syringe with the plunger removed to the tubing and then use the syringe as a funnel.

INCUBATION PERIODS:

Texas A&M AgriLife Extension[12]	Incubation Conditions			Hatcher Conditions		
	Total Days	Temperature °F	Humidity RH%	Stop Turning	Temperature °F	Humidity RH%
Canary	13–14	100.5	56–58	11	99	66–74
Chicken	21	99.5	58	18	98.5	66–75
Cockatiel	18–20	99.5	58–62	15–18	99	66–74
Cockatoo	22–30	99.5	58–62	20–27	99	66–74
Dove	14	99.5	58	12	98.5	66–75
Duck	28	99.5	58–62	25	98.5	66–75
- Mallard	26.5	99.5	58-62	23.5	98.5	66-75
- Muscovy	35	99.5	58–62	31	98.5	66–75
- Runner/Crested	29	99.5	58–62	26	98.5	66–75
Finch	14	99.5	58–62	12	99	66–74
Domestic Goose	30	99.5	62	27	98.5	66–75
- Chinese/African	31	99.5	62	28	98.5	66–75
Grouse	24–25	99.5	54–58	22	99	66–74
Guinea	28	99.5	54–58	22	99	66–74
Lovebird	22–25	99.5	58–62	20–22	99	66–74
Macaw	26–28	99.5	58–62	23–25	99	66–74
Mynah	14	100.5	56–58	12	99	66–74
Parakeet	18–26	99.5	58–62	15–23	99	66–74
Budgerigar	18	99.5	58–62	15	99	66–74
Parrot (various)	18–28	99.5	58–62	15–25	99	66–74
Parrot (African)	28	99.5	58–62	25	99	66–74
Chukar Partridge	23–24	99.5	62	20	99	66–74
Peafowl	28–29	99.5	58–62	25–26	98.5	66–75
Ptarmigan	21–23	99.5	58–62	18–20	99	66–74
Raven	20–21	99.5	58–62	17–18	99	66–74
Ringneck Pheasant	24–24	99.5	58–62	21	99	66–74
Pheasant	22–28	99.5	58–62	20–25	99	66–74
Pigeon	17–19	100.5	58	14	99	66–74
Bobwhite quail	23	99.5	54–58	21	99	66–74
Japanese quail	17–18	99.5	58–62	15	99	66–74
Swan	33–37	99.5	58–62	30–33	99	66–74
Turkey	28	99.5	54–58	25	98.5	66–75
Emu	49–50	97.5	32–40	47	97.5	69
Ostrich	42	97.5	32–40	39	97.5	69
Rhea	36–42	97.5	50	34–37	97.5	69

POWER OUTAGES:

- Power outages do occur and usually at the most inopportune time. Fortunately, an outage of 2-3 hours and a temperature drop in to the mid-80s will have little effect on embryos. Longer power outages may harm the embryos and a delayed hatch. Placing a blanket over your incubator will help reduce heat loss. Additionally, if you have access to non-electric heat source, such as natural gas, cranking up a space heater can reduce possible negative effects. Regardless of the length of the power outage, do not abandon the hatch; candling the eggs a few days later will help determine if any embryos died.

[12] *Gregory S. Archer and A. Lee Cartwright, "Incubating and Hatching Eggs," Texas A&M University, July, 2013. http://posc.tamu.edu/files/2012/08/EPS-001-Incubating-and-Hatching-Eggs.pdf*

SEPARATING CHICKS AT HATCH:

- Using plastic canvas knitting sheets, construct cages for each group of eggs you wish to keep separate. The cages should be as large and tall as possible avoiding the heating or other incubator components. Each cage must have a lid to prevent the hatchling from climbing over the side and into the next cage.

SEX DETERMINATION:

- Unlike in humans, the hen determines the sex of the chick by passing along either a W chromosome for females or a Z chromosome for males.
- Although not scientifically demonstrated, some hobbyists believe that round eggs produce females and pointy eggs produce males.
- Although not scientifically demonstrated, some hobbyists believe that lower incubation temperatures produce more females and higher incubation temperatures produce more produce males.
- Some specifically bred hybrids (breed mixes) produce chicks where males will be one color and females will be a different color; these hybrids are known as sex-links.

TEMPERATURE STABILITY:

- Full incubators will experience fewer temperature fluctuations than nearly empty ones. If you must incubate only a small number of eggs, add a heat sink – sealed water bottles or rocks. A heat sink will absorb excess heat during short spikes in temperature and release that heat during short dives.

WET BULB CONVERSION:

Dry Bulb →	98 °F	99 °F	100 °F	101 °F
↓ Wet Bulb ↓	↓ Relative Humidity (Percent) ↓			
90 °F	72%	70%	68%	65%
89 °F	70%	67%	65%	63%
88 °F	67%	65%	63%	60%
87 °F	65%	62%	60%	57%
86 °F	61%	59%	57%	54%
85 °F	58%	56%	54%	51%
84 °F	55%	53%	51%	49%
83 °F	53%	51%	48%	46%
82 °F	50%	48%	46%	44%
81 °F	48%	45%	43%	41%
80 °F	45%	43%	41%	39%

DUCKS & GEESE SPECIFICS

Much of the information pertaining to hatching chickens applies to ducks and geese, but there are some differences.

1. **Duck Turning Trays**: Duck eggs, except mallard and call ducks, are usually larger and may not fit comfortably into regular trays. In desktop models, it is probably best to remove the automatic turner, lay the duck eggs on their side, and turn manually. For cabinet models, Extra-Large trays used for turkey, ducks, and peafowl are required.
2. **Goose Turning Trays**: Goose eggs are large, sometimes very large and require a special incubation tray or set on their side during incubation. I do not recommend commercially manufactured goose egg trays as they are relatively expensive and hold only very few eggs. Personally, for desktop models, I simply lay the eggs on their side and turn them by hand. For cabinet incubators, I fabricate a goose egg tray using ½ inch hardware cloth by folding the wire in a |_|_|_|_| manner.
3. **Incubation Period**: Instead of 21 days, Mallard ducks hatch in 27.5 days, Pekins in 28, and Muscovy ducks in about 35 days. Geese require 30 days of incubation.
4. **Humidity**: While chicken eggs do well with low humidity during their first 18 days, ducks usually require a higher relative humidity – 55-60%.
5. **Cooling & Misting**: Many waterfowl egg shells are thick and hard making it difficult for the duckling/ gosling to emerge at hatch time. Although the exact mechanism is unknown, allowing the eggs to cool followed by a misting of lukewarm water causes the shell to become more brittle. Personally, following day 7 of incubation, I remove the eggs from the incubator, allow them to sit on a counter at room temperature for 15 minutes, mist one side with lukewarm water, flip each egg 180°, mist the other side, and then replace them in the incubator. If you have an infrared temperature gun, the shell surface should cool to 86° F. I do not cool or mist the eggs once I stop turning three days before hatch.

Dirty Eggs

Badly soiled eggs should be washed as soon as possible after gathering (within two or three hours after being laid, to be effective) to reduce the numbers of bacteria invade the egg's interior through the shell pores.

Washing does remove the cuticle (a protective film on the shell that reduces dehydration), making it necessary to raise the humidity level during incubation by approximately 5-10 percent. If incorrectly done. Washing can drastically lower hatchability. Nonetheless, dirty eggs that have been properly washed and sanitized result in a much cleaner environment within the incubator, reduce exploding eggs and minimizing infected navels in newly hatched goslings.

When eggs are washed, it is imperative that clean water, 10° to 25° F (6° to 14° C) warmer than the eggs is used. Washing with fouled water spreads contaminants from egg to egg, while cold water causes filth to be pulled deeper into the shell pores. A hatching egg sanitizer should be used in the wash water or else eggs should be washed under running water.

David Holderread, The Book of Geese, 1981

6. **Hatching Temperature**: If you can do so without affecting other eggs, ducklings and goslings benefit from a lower temperature during hatch – 98.0-98.5° F. Do not attempt to adjust on models where you must turn a small knob to adjust the temperature; the risk of causing excessive temperature swings outweighs any benefits from a slightly lower temperature.

> While some birds that are assisted from the shell develop into fine specimens, a large percentage of them are usually handicapped by a deformity or weakness. When it is understood that the hatch is a fitness test given by nature to cull out the weak and deformed-protecting them from facing a life for which they are unprepared-we can take a more realistic view of helping ducklings from the shell.
>
> *David Holderread, Raising a Home Duck Flock. 1978*

7. **Hatching**: Normally, the first pip will occur 36-48 hours prior to the hatch date. It can take 24-36 hours for a duckling to completely zip the shell and emerge. They will naturally rest between efforts so resist any temptation to help a tired duck from their shell. Be patient, unless there has been an unexpected incubation event, healthy ducklings will emerge from the shell under their own power.

8. **Brooding**: Ducks and geese are excessively messy birds. Do not use water containers that allow them to play in the water as the litter will become damp promoting the growth of mold. Additionally, the down of artificially brooded ducklings and goslings does not repel water; a wet ducklings and goslings chills easily resulting in death. Personally, I brood waterfowl on old, cloth towels for the first three days and then raise them on ½ inch hardware cloth thereafter. I do not allow ducklings or goslings to swim until their down has been largely replaced with feathers.

PEAFOWL SPECIFICS

Many say that peafowl are especially difficult to hatch. I have yet to find that to be true; however, there is a lot less room for error with peafowl than chickens. Most of the information provided in this guide applies directly to peafowl, but there are a few specifics that need to be considered:

1. **Incubation Period**: Peafowl require 28 days of incubation.
2. **Setting & Turning**: Peafowl do best when they are set on their side. While chickens do alright if you forget to turn them routinely, peafowl are less forgiving. Turn them on schedule and don't forget to manually flip each egg 180° at least twice daily.
3. **Incubator Placement**: Peafowl do better when the incubator is placed where the climate experiences little temperature and humidity variations. Be especially careful to avoid rooms with a low humidity; peafowl eggs seem to be sensitive to low humidity.
4. **Initial Setting**: Some breeders initially place their peafowl eggs under broody hens for the first week and then transfer them to an artificial incubator. Personally, I get them started by placing them in a well regulated styrofoam incubator with closed vents and a temperature of 100.5° F. I do not turn then the first 48 hours; thereafter, I manually turn them 3 times a day until they are transferred to the cabinet incubator at the end of day 6.
5. **Placement within the Incubator**: The temperature within a cabinet incubator can vary by 0.5-1 degrees between the top and bottom shelves. While it may be difficult to correct these variations in temperatures, they can have a significant impact on hatchability. Place newer eggs on the top shelf as

they benefit from the slightly warmer temperature. Place older eggs on the bottom as they do better with lower temperatures.

6. **Humidity**: Peafowl lose internal water at a much faster rate than chicken eggs and require higher incubation humidity; 60% is generally recommended although I have found that 56% works better in my environment.

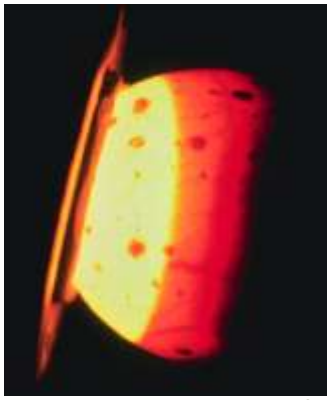
7. **Daily Cooling**: Peafowl shells are thicker than chicken eggs making it more difficult for the peachick to emerge at hatch time. Although the exact mechanism is unknown, allowing the eggs to cool causes the shell to become more brittle. Personally, following day 7 of incubation, I remove the eggs from the incubator, allow them to sit on a counter at room temperature for 10 minutes, flip each egg 180°, and then replace them in the incubator. If you have an infrared temperature gun, the shell surface should cool to 90° F. Do not cool eggs once turning has stopped three days before hatch.
8. **Brooding Peachicks**: Peachicks hatch by a hen do well when cared for by their mother. For some reason, they seem to avoid the ill effects of Coccidiosis while peachicks artificially hatched and brooded do not. Artificial brooding should involved keeping the peachick off the ground until they are 14-18 weeks old along with feeding medicated feed. Additionally, peafowl mature at a much slower rate than chickens. Chickens will be completely mature by 6 months; it takes 2 years for peafowl. Consequently, peafowl benefit from a longer stay under artificial heating and lighting.

TURKEYS SPECIFICS

Many hobbyists report that turkeys are more difficult to hatch than chickens. Many factors may contribute to this perceived difficulty such as smaller genetic pool, inadequate protein feed for parent stock, larger egg size, and incubator temperature instability. Turkeys can be hatched successfully when attention to detail if given to each factor involved in the incubation process.

1. **Incubation Period**: Turkeys require 28 days of incubation.
2. **Egg Size**: Turkey eggs are about 50% larger than chicken eggs; they take up more space in the incubation tray and take more time to warm than chicken eggs. NOTE: Eggs from mature hens may be too large to comfortably fit into Extra Large plastic setting trays. You may need to leave some spaces open or lay them on their side in a goose setting tray.
3. **Turning Eggs**: Turkey eggs are too large for automatic turners in desktop models and should be set on their side with manual turning. For tilt tray models, turkey eggs do well in extra-large plastic trays with the small end pointed down. Turkey eggs are sensitive to temperature variations and should be rearranged daily within the egg tray to ensure avoid extended exposure to hot or cold spots.

   ***Still Air Desktop Models**: It is very important that the temperature be regulated at the top of the turkey eggs; do not assume that the setting used for your last batch of chickens will be satisfactory for a new batch of turkeys.*



24 day normal old turkey egg[9]

4. **Temperature Precision**: My hatch rate for all eggs set the first year was about 75%; I was able to increase that rate to 90.4% the second year by focusing on better temperature control during the various

stages of development. Turkey eggs are larger than chickens and a turkey embryo will produce more internal, metabolic heat than a chicken. Placement within the incubator seems to have a significant impact on hatchability – newly set eggs are placed on the top shelf where the temperature is warmer, 100.0°F and the oldest eggs are placed on the bottom shelf where the temperature is cooler, 99.0°F. Additionally, lowering the temperature to 98.5° F during the active hatching phase reduces the hatching stress and end-stage mortality.

5. **Candling Eggs**: Turkey eggs are frequently thicker and darker than chicken eggs making it more difficult to clearly visualize the interior during candling. Frequently, after the first two weeks, only dark and light are visible within the egg. Movement may or may not be visible. In generally, development can be judged by the growth of the dark area rather than visualization of finer details. [13]

[13] *R. A. Ernst, et.al. "Egg Candling and Break Out Analysis for Hatchery Quality Assurance and Analysis of Poor Hatches" Animal Science Department, University of California <http://animalscience.ucdavis.edu/Avian/pfs32.htm>*

INCUBATOR DATA CHART

Day #	Date	Turning			Temperature		Humidity	Water ✓	Remarks
		1	2	3	Room	Incubator			
0									
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
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18									
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21									
22									
23									

HATCHABILITY AND MORTALITY RECORD

ID	Set Date	Candling		Hatching			Chicks		Statistics		
		Infertile	Deaths	Date	Live	Dead	Cull	OK	Fertility	Hatch	Total