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CHAPTER 35

Development of the Embryo

by Joseph M. Mauldin

The current state of artificial incubation practices in the poultry industry should be prefaced with a brief description of the development of the chicken embryo. Nutrients needed for the development of avian embryos are obtained from the food material stored in the egg rather than from nutrients derived from the blood supply of the mother, as in the case of mammals. Furthermore, most of the embryonic growth occurs outside the hen's body, and development is more rapid and unlike that with most • mammalian species.

35-A. FERTILIZATION

Fertilization in commercial chickens is usually the result of natural mat¬ing. However, in some cases, artificial insemination is commonly prac¬ticed. The turkey industry especially depends on artificial insemination since natural mating is virtually impossible as a result of intense genetic selection for conformation and body weight.

1. Natural Mating and Fertilization

The completed mating in chickens is the culmination of a sequence of behaviors. The rooster will initiate mating by exhibiting courtship behavior: dropping one wing and dancing in a circle (the lowered wing will be on the inside of the circle dance). The hen will crouch to indicate receptiveness. The rooster will then mount the hen and grab her comb, neck feathers, or the skin on the back of her head or neck to help hold onto the hen's back. The next behavior is the tread (the rooster walks quickly in place on the hen's back) and finally the completed mating is the culmination of the behavioral sequence. The completed mating occurs when the rooster dips his tail to the side of the hen's tail and spreads his tail feathers so that their cloacae come in contact. At this point the rooster's ejaculate is released directly into the hen's vagina via her cloaca: the typical breeder house with thousands of birds, the entire sequence of behaviors does not always occur, and the courtship dance is frequently left out of the sequence. Chickens are polygamous, but certain males and females selectively mate regularly. Some females in the flock will show avoidance to specific males, and therefore are rarely mated by those males.

The rooster usually ejaculates between 100 million and '5 billion sperm at a time with greater concentrations produced at the beginning than at the end of the clay, when some depletion occurs after many matings. First, ejaculates average about 1 ml, but after several ejaculations, the average' ejaculate will be reduced to 0.5 ml or less (these data were obtained from semen collection by stimulating and massaging the male).'The numbers of sperm per ejaculate and the volumes of semen should be lower in natural matings as compared to semen collection by stimulation and massage. The frequency of mating follows a diurnal pattern with mating frequency reaching peaks early and 'late in the day.

A rooster may mate from 10 to 30 or more times per day, depending on the availability of hens and competition from other roosters. However, the number of sperm per ejaculate

seldom is less than 100 million which is the minimum requirement for high fertility.. With natural mating, better fertility will result when mating occurs after the hen has laid a hard shell egg. However, if the hens are mated frequently (daily), there is unlikely to be a noticeable difference in fertility regardless of when the matings occur.

The Copulatory Organ

The rooster has a small phallus that becomes engorged with lymph to form a copulatory organ. The copulatory organ is rudimentary and at the time of mating there is practically no penetration. The hen everts her vagina during copulation which helps to transfer the semen into the oviduct. Ducks, geese, and some other birds have more well-defined copulatory organs.

Movement of Sperm Cells

The sperm propel themselves into the uterovaginal spermatozoa storage tubules. Motility is an important quality for semen, as sperm that are not motile will not reach the storage tubules. After storage in the uterovaginal tubules, some of the sperm are released at regular intervals to fertilize the sequentially ovulated ova. After release, the sperm are carried to the ovum by contractions of the hen's oviduct. At this time, sperm motility is no longer critical. If there is no egg in the oviduct, the movement of sperm from the uterus to the infundibulum occurs in less than 30 minutes. Within 5 to 10 minutes after an ovulation, a few sperm move to the germinal disc (location of the pronucleus) on the surface of the ovum (egg yolk). More than 50 sperm may penetrate the outer layer of the ovum, but only one unites with the female pronucleus to form the zygote. Even though only one sperm is needed to fertilize the ovum, research has shown that in flocks of breeders when sperm penetration average is less than 30, poor fertility will be associated with those flocks. Flocks with good fertility average well above 50 sperm penetrations per ovum. On the first day, after a single mating, a fertile shelled egg may be produced, however, only 10 to 20% of these eggs will initiate cell division. Normally, maximum fertility from a flock of hens will not occur until at least the second day post-mating.

Fertility After Removal of Males from Flock

Fertile eggs continue to be produced after males are removed from the flock because of sperm storage and survival within the hen's oviduct (sperm storage tubules). Fertile eggs can be produced for up to 4 weeks after removal of males, but the concentration of sperm is reduced resulting in lower fertility and hatchability. In the last 10 years, advancements have been made in the cryopreservation of semen such that, in certain strains, 70% fertility has been achieved from inseminations with semen that has been frozen. With continued advancements in this area, storage of semen for later use, as with mammals, could become practical in the near future.

Viability of Newly Produced Sperm

Fresh sperm have a fertilization advantage. Because of their greater via-bility and the fact that the sperm from the most recent insemination are stored on top of older sperm in the storage ducts, they have a greater chance of reaching the ova. If roosters are removed from the flock and replaced with new males on the same day, after three days practically all offspring will be sired by the new males.

2. Parthenogenesis

Parthenogenesis is a process whereby cell division may occur in an unfertilized ovum. The term parthenogen is generally used to denote relatively complete development of such an individual. Parthenogenesis is rare in higher vertebrates but occurs more frequently in chickens than turkeys. Most development found in parthenogenesis will terminate before oviposition or in the first few hours of incubation. In an extremely small percentage of cases, parthenogens will complete development and give rise to homozygous males.

3. Artificial Insemination (Al)

Semen is collected from roosters to inseminate hens. After stimulating trained males by stroking the back, the abdomen below the pelvic bones is massaged to protrude the papillae and the semen is slowly squeezed (milked) out and collected in a vial or aspirated into a syringe avoiding contamination. Semen is diluted with specially prepared diluents and transferred to a storage container. Hens are inseminated with a semen dos¬age ranging from 0.025 to 0.050 ml, which normally contain 100 to 120 million spermatozoa, and are placed about 0.75 to 1.0 inches (2.0 to 2.5 cm) into the everted.vagina of the hen. Raw semen is most effective and the inseminations must be repeated every five to seven days to maintain optimum fertility. Fertility can be higher from artificial insemination than from natural mating once the technique has been mastered.

Fewer Males Needed

For natural mating, one rooster is usually required to mate 10 to 12 hens. With artificial insemination one rooster can produce enough sperm to inseminate 60 to 100 females on a weekly basis.

Semen Storage

Survivability of avian semen in vitro is very poor due to the temperature differential of the hen's body and ambient temperature, thus warranting immediate usage of raw semen or semen mixed with diluents. New diluents show hope of extending the viability during storage beyond 24 hours. Males should be ejaculated about three times weekly, although fertility will, not be impaired by ejaculating the males as frequently as once per day. However, semen volume will be lower when semen is collected more frequently. Insemination must quickly

follow semen collection for best viability. The best results are obtained when inseminations are done within 30 minutes of collection. Freezing semen and thawing will reduce the number of viable sperm by about one-half and fertility will be reduced to 20%. Thawed semen must be deposited directly into the magnum to achieve this level of fertility. Thawed semen may also have chromosomal abnormalities which can result in early embryo mortality.

Increased Cost Is the Deterrent

Artificial insemination of chickens is costly due to increased labor and equipment requirements. It requires one man-hour to collect the semen from 90 to 120 males, while about 150 to 200 hens can be inseminated per man-hour. Additionally, there is the increased cost of keeping hens and roosters in cages. The procedure is more cost-efficient in meat-type than in egg-type chickens because of the lower fertility resulting from natural flutings of meat-type birds. The procedure of AI is also a very useful tool in commercial poultry breeding as it can help to increase the selection in¬tensity by the use of a reduced number of sires than with natural matings.

35-B. PREOVIPOSITAL EMBRYONIC DEVELOPMENT

On average, the total incubation process requires 22 days; one day in the hen and 21 days in the incubator. Fusion of the male and female gametes occurs in the oviduct forming the zygote. About five hours later the zygote enters the isthmus portion of the oviduct, first cleavage (incomplete cellular division) takes place producing two, incompletely separated, daughter cells..

Nuclei of the two daughter cells divide and the incomplete cleavage furrows result in four partially separated cells. At the 16 cell stage the first central cells (completely surrounded by cell walls) are evident. Cell division is henceforth more rapid in these true cells than in the incomplete peripheral cells. Cell division occurs now on two planes thus developing a structure several layers thick and gradually increasing in diameter. The process of delamination (cells dropping and eventually coalescing into a lower layer) results eventually in two distinct cell layers, the upper (prewmptive ectoderm) and the lower (endoderm). Cells of the lower layer have a higher yolk content. The third cell layer, the mesoderm, will later come to occupy the space between these two. Organization of the primitive streak foreshadows the future orientation of the embryo, i.e., anterior/posterior, right /left.

From these three layers all the organs and parts of the body are formed. By the time the egg is laid the developing embryo will be composed of 20,000 cells.

35-C. POSTOVIPOSITAL EGG-HOLDING PERIOD

The freshly laid, fertile egg will contain an embryo with three layers, endoderm, ectoderm, and mesoderm, that has developed to the *gastrulation* stage. At this stage, development can cease for several days without reducing hatchability, provided temperature

and humidity are optimal During the holding period, eggs should be maintained at a temperature between 55° and 67°F (13° and 19°C) to arrest further development. Relative humidity should be maintained between 75 and 80%. When hold eggs for five days or less, maintain the temperature near the upper limit the suggested temperature range and for longer periods, lower the hold' temperature. If eggs have to be stored for two weeks or longer, as is oft the case with primary breeders, lower the temperature to 55°F (13°C) seal the eggs in plastic bags flushed with nitrogen to prevent dehydration and excessive loss of albumen quality.

Be careful not to put hatching eggs into cases too early. Let eggs coo to the storage room temperature at least overnight before casing. When eggs are packed densely in cases and cases stacked several cases high, they can maintain their warmth for several days allowing embryo development to continue. Such pre-incubation development during storage is harmful because the rate of division is uneven and unsynchronized, and further development makes the embryo susceptible to cold, shock. A large percent-age of these eggs will not reinitiate development after being placed in the incubator.

35-D. DEVELOPMENT OF THE EXTRAEMBRYONIC MEMBRANES

At the time of oviposition the blastoderm is in a state of late cleavag with differentiation of the *epiblast* and *hypoblast* resulting in the presence of the *area pellucida, subgerminal cavity,* and *area opaca*. Because the embryo has no anatomical connection with the hen's body, nature has endowe it with certain membranes necessary to utilize nutrients contained, with the egg.

1. Yolk Sac

Enveloping the yolk, this membrane secretes enzymes that change the yolk contents into a soluble form so that the nutrients can be absorb and carried to the developing embryo. The yolk sac and its remaining con tents are then drawn into the body cavity just prior to hatching to .sere .4, as a temporary source of food for the newly hatched chick.

2. Amnion

The amniotic sac prevents the young embryo from being injured why the egg is rolled or turned, and is filled with a transparent fluid in whit the embryo floats.

3. Allantois

This membrane serves as a circulatory system, and when fully devel-oped completely surrounds the inside of the eggshell. The allantois is initi-ated on the third day of incubation and is fully developed by the 12th day. It has the following functions:

- *Respiratory*. The allantois oxygenates the blood of the embryo and removes carbon dioxide.

- *Excretory.* It holds the excretions of the embryonic kid-ney and deposits them into the allantoic cavity.
- *Digestive.* It aids in the transportation of albumen and in absorption of calcium from the eggshell.

4: Chorion

This membrane fuses the inner shell, membrane with the allantois, and helps the latter in completing its metabolic functions.

35-E. DAILY CHANGES DURING EMBRYONIC GROWTH

During incubation, moisture is lost from the eggs through the shell pores and incorporated into the tissue of the developing embryos. The acceptable amount of moisture weight loss ranges between 0.55 and 0.70% per day of incubation until pipping. This drying reduces the volume of the egg contents and increases the size of the air cell. After 19 days of incubation the air cell should occupy almost one-third of the egg surface and should be deeper on one side than the other.

Stages of embryonic development can vary appreciably among embryos from hatching eggs produced by similar breeders. Variability in embryonic development is influenced by:

1. the rate of development of the whole embryo
2. the relative rates of development of different organs and organ systems and
3. the size (weight) of the embryo, as embryos at the same stage of development may vary in size. Table 35-1 describes the normal development of the chicken embryo.

35-F. EMBRYONIC COMMUNICATION

It has been known for some time that eggs from some species of birds tend to hatch at the same time under natural incubation even though the,

Table 35-1. Daily development of the chicken Embryo

Day	Signs of Daily Embryonic Development
1	At the end of the first day, the blastoderm has formed the embryonic shield resulting in establishment of orientation (head to tail) of the embryo. The primitive streak has extended and regressed resulting in the development of neural folds within the head area while the flank mesoderm has initiated segmentation into somites. A head fold has formed as cranial flexure toward the yolk occurs, and within the area opaca blood islands have formed resulting in the area vasculosa.
2	The neural folds have differentiated into five brain vesicles, cardiovascular circulation

has commenced, and formation of the foregut and eye (optic) vesicles have occurred. As cranial, cervical, and caudal flexures progress, the cranial amniotic fold covers from the head to the heart while the caudal amniotic fold covers the tail. The head has initiated turning onto the left side, and paired somites number more than 19.

3 Leg buds are wider than wing buds and both are elevated from the body, and the tail bud has formed. Cranial and cervical flexures have extended as the head now covers the heart. The embryo has completed rotating onto its left side, the amnion covers the entire .embryo surrounding the yolk stalk, the allantoic bud has formed, and somites extend beyond the leg buds.

4 Head and tail flexures have progressed so that the embryo is "C" shaped. The allantoic sac has vascularized, wing and leg buds are as long as they are wide, the maxillary process is longer than the mandibular, and the eyes contain dark pigmentation. Amniotic contractions are observed, a distinct digital plate has differentiated in the leg but not the wing, and the chorion and allantois membranes (CAM) have initiated fusion.

5 Elbows and knees are apparent, demarcation of the digits of the wing has occurred, the allantois (CAM) covers 1/3 of the embryo, and a complete four chamber heart is present.

6 The maxilla and mandible of the beak are prominent, three digits of the wing and four digits of the foot are apparent as the distal margin is now created, rhythmic amniotic contractions occur, and the legs extend beyond the tail.

7 The egg tooth is distinct at the end of the maxilla, seven rows of feather tracts are apparent along the lumbosacral region, six scleral papillae have formed within each eye, and the embryo will respond to touch.

8 The maxilla and mandible are equal in length, webbing between digits has greatly diminished, the nictitating membrane is present in the corner of the eye near the beak, there are 14 scleral papillae, and the circumference of the eye lid is circular. There are three rows of distinct tail feathers, the neck has distinctly elongated and gender can be determined by gonadal appearance.

9 The nictitating membrane of the eye extends toward the scleral papillae, the CAM is fixed in relation to the eggshell, complete loss of webbing between digits has occurred, and the circumference of the eye lids is ellipsoidal.

10 There is distinct presence of claws, comb, and wattles; the eye lid covers the nictitating membrane and scleral papillae; the circumference of eye lids appear as a narrow ellipses; and flight feather follicles are conspicuous along the margin of the wings.

11 The circumference of the eye lids are flattened ovals; feathers are now distinct as tail feathers are prominent; the embryo moves independent of the amnion; claws have flattened laterally, curved ventrally, and the tips are opaque; the CAM has fused with the eggshell membrane.

12 The margin of the eye lids form a narrow elliptical slit, the amniotic connection has

opened and the embryo begins to swallow albumen. White uric acid precipitates are present within the allantoic sac as the pH decreases, and primordial scales are present on the legs.

13 The eye lids have closed, the scales on the legs overlap, and the embryo is lightly covered with down.

14 The embryo is oriented along the long axis of the eggshell, beak clapping movements are observed, and the embryo is well covered with down.

15 Hereafter the embryo increases rapidly in size which can be measured by weight and increases in length of the beak and toes.

16 The yolk sac is positioned ventrally in front of the embryo.

17 The beak is directly between the thighs, yolk sac contractions are observed, and the albumen has been completely utilized.

18 The beak is oriented under the right wing and the yolk sac has started to be in corporated into the abdominal cavity.

19 The beak has pierced into the air cell (internal pipping) and the embryo initiatespulmonary respiration. The yolk sac is half incorporated into the abdominal cavity, and allantoic fluid has been completely reabsorbed.

20 The beak has pierced the eggshell (external pipping), the yolk sac has been completely incorporated, and the CAM has lost vascularization and dried up.

21 The chick has hatched and will be dry and fluffed within 12 hours.

Prepared by R. J. Buhr, USDA-ARS, Athens, Georgia

eggs have been laid over a period of several days, and even though the earlier eggs were incubated longer than those laid last. In some cases, this is the result of embryos communicating with each other by emitting a clicking noise, or physical contact with eggs. The speed of the clicking is responsible for accelerating or retarding embryonic growth.

Acknowledgment

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Chapter 36
Hatchery Planning, Design, and Construction

by Joseph M. Mauldin

A hatchery is not a typical industrial building; it is highly specialized with unique requirements for construction and operation. In reviewing the literature for this chapter, a very recent document was discovered that covers practically all the main concerns for building a modern hatchery. The document, Designing the Ultimate Hatchery, was prepared

as a joint effort by *Chick Master Incubator Company*[1] and *Hatchery Planning Company*[2], companies that are involved in the planning, design, and day-to-day operation of poultry hatcheries. It provides an excellent description of the most important concerns beginning with the planning phase and continues through design, construction, and operation of the modern hatchery. An edited version of this document is presented here.

36-A. WHAT TO CONSIDER WHEN DESIGNING A HATCHERY

Determine the Budget

A new hatchery represents a substantial capital investment. Costs vary considerably, depending upon capacity, construction materials and methods, equipment selection, engineering, geographical location, and automation. The old adage, "you get what you pay for" often rings true, but so will the law of diminishing returns. Sometimes additional expense does not result in increased productivity.

Keep one goal in mind: the construction of an efficient building, at a reasonable cost, that consistently produces a maximum number of live chicks per eggs set. When making monetary decisions, make sure that the initial expense is weighed against the potential effect on future productivity and longevity. Identify available resources and budget constraints before beginning the planning and construction phases.

Set a Production Capacity

One of the first decisions concerns the production capacity of the hatchery, and future requirements. Production capacity will, to a great extent, determine the size and cost of the hatchery. Design and construct the hatchery with a final production capacity as a goal. If the objective is for the hatchery to produce one million birds per week, a specific number of incubators and hatchers are required. These machines, in turn, require a specific amount of space. Likewise, the size of egg storage, processing areas, and mechanical room will all be relative to production capacity; as will the cost, of ventilation, plumbing, electrical, and mechanical systems. Therefore, the importance of determining production capacity early in the - planning phase is essential.

Confer with an Experienced Design Consultant

[1] Chick Master® Incubator Company, P. O. Box 704, Medina, Ohio 44258 USA.

[2] Hatchery Planning Company®, 2437 Clay Road, Austell, Georgia 30106 USA.

Once the production capacity has been determined, and before construction begins, hatchery plans must be developed to meet the specific needs of the owner. A custom design greatly enhances the overall success of the operation. Every hatchery is a specialized facility that requires an experienced design consultant. The design consultant should fully understand the requirements of incubation equipment, including ventilation, floor construction, slopes and drains, and minimum space requirements. In addition, the design firm should be well-versed in the production process, which includes workflow, room sizing, waste disposal, and automation (miscellaneous) equipment layout.

Designing the Ventilation System

Except for the incubators and hatchers themselves, the overall ventilation system is probably the single most important component in the hatchery. Hatchery ventilation design demands a specialist because hatchery ventilation is quite different from commercial and industrial building ventilation.

Proper conditioning of the fresh air supply almost always presenfs a formidable challenge. Furthermore, inadequate ventilation will severely affect the performance of incubators and hatchers. Improperly designed heating, ventilation, and air conditioning systems (HVAC) will produce a poor quality chick, lower hatch rate, and a major loss in profits over the life of the hatchery. Therefore, use only qualified hatchery design specialists to design ventilation systems.

Selecting the Best Hatchery Site

Before breaking ground for the new hatchery, choose an appropriate location. Site selection affects the profitability of the entire operation, as well as the overall performance of the hatchery. The greater the distance from breeder farms and grow-out houses, the higher the transportation costs. However, in order to provide biosecurity, the hatchery should be situated far enough away from the production units to minimize the spread of disease. The availability and cost of labor, utilities (including water, electricity, gas, or fuel oil), and waste disposal are also concerns. Generally, a hatchery should be located on high ground and should have good drainage.

Elevation is vitally important to hatchability:

Up to 3,000 ft (610 m) above sea level = optimum elevation

More than 3,000 ft (610 m) above sea level = some loss in hatchability

The greater the distance between the hatchery and other agricultural buildings, the more suitable the site. Hatcheries must be located at least 1,500 ft (460 m) from other poultry buildings. The site should be isolated from grain storage, feed mills, or other dust-producing activities. Consider prevailing wind direction and make certain that the hatchery is located upwind of these facilities. Soil composition can also affect the cost of construction. Finally,

check carefully for zoning ordinances, building codes, and restrictions that may apply to the property.

Choose Hatchery Equipment Wisely

The equipment selected is critical to hatchery performance. Choosing incubators, hatchers, ventilation equipment, environmental controls, computerized systems for data acquisition, processing and automation equipment, generators, boilers, etc. all affect the success of the operation. These decisions also have a major impact on the total cost of the project. Whenever possible, choose custom products designed and manufactured specifically for hatchery applications instead of "off the shelf" products.

Automation in the modern hatchery is becoming more prevalent. Decide early in the planning phase to what extent the hatchery will be automated. Automation will affect the layout and size of the hatchery. While the initial investment in automation will be substantial, the benefits can be realized through reduced labor costs and efficiency.

The hatchery environment is a harsh one, and it is important to remember this when choosing equipment. Equipment will be subjected to frequent washing with water and detergents, and may be exposed to corrosive disinfecting chemicals. Anodized aluminum, stainless steel, and non-reactive plastics are most suitable for the hatchery. In heavy traffic areas, equipment should be suitable to withstand the impact of a fully loaded egg .buggy. Choose equipment that is proven reliable, easy to service, safe to operate, energy efficient, and capable of continuous duty. Also consider the availability of replacement parts, service representatives, and technical assistance.

Developing a Preliminary Floor Plan

Hatchery design and ventilation specialists can assist in the development of a preliminary floor plan. This floor plan will be needed to further define budget and overall design criteria. A preliminary floor plan must be designed around the requirements of a specific incubator manufacturer, and must take into account the production capacity of the hatchery, future expansion plans, and equipment selections. Generally, the rooms should be arranged in order from clean to dirty, taking into account the flow of eggs and chicks from one area to the next (see Figure 36-1).

Two Basic Floor Plans for Hatcheries

Incorporate either a rectangular or "T"-shaped design. The rectangular building (see Figure 36-2), often used for small hatcheries, has good work-flow and excellent space utilization, with minimum square footage. The rooms are oriented in a clean to dirty progression. But this design is less suited for expansion and lacks some bio-security features found in the "T" shape.

The most common building style today is the "T"-shaped design (see Figures 36-3 and 36-4). In these layouts, incubator and hatcher halls are located in each wing and are separated from storage and processing rooms by a corridor. The egg room, clean tray room, wash room, and chick processing room are in the center area of the building. This design gives the option of starting small by building only one wing, with a center area large enough to accommodate a future wing. It also has good workflow and easily lends itself to a good sanitation program.

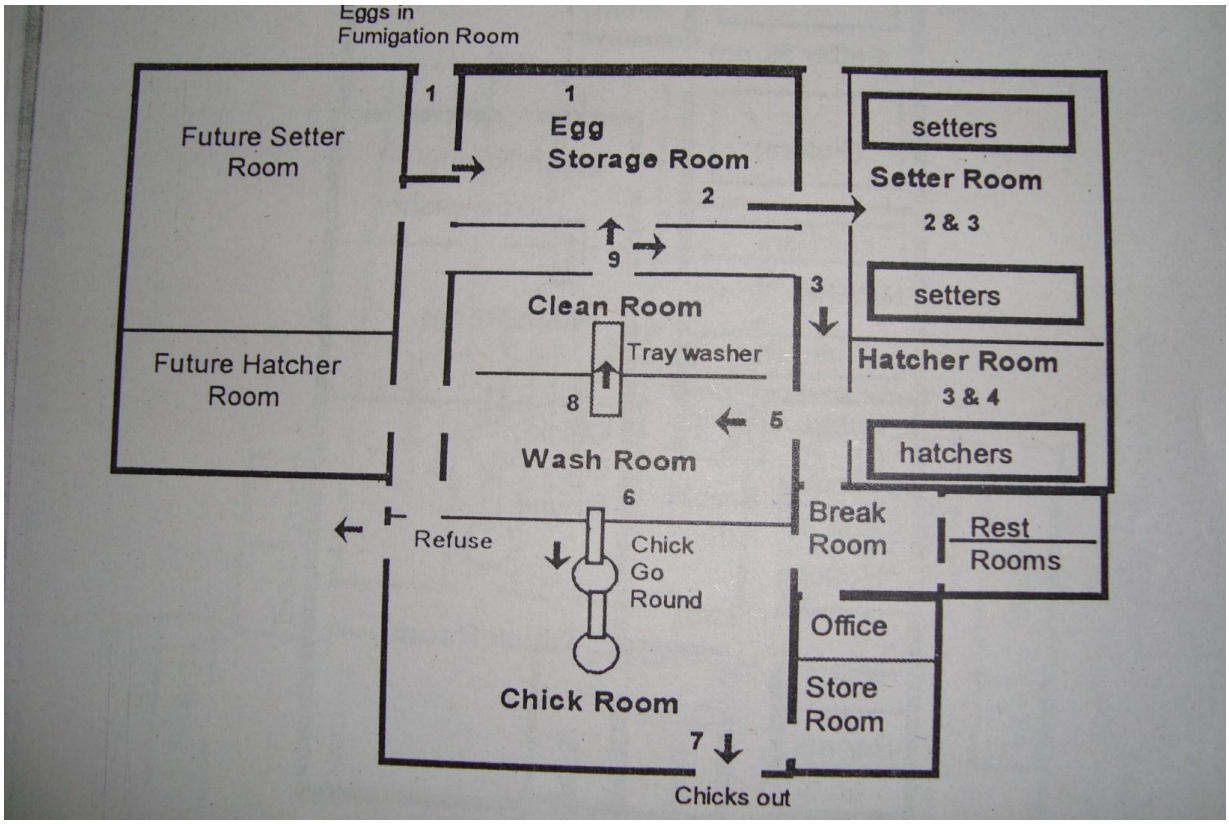


Figure 36-1. Typical Hatchery Flow

1. Eggs received for storage, fumigation, sorting and traying.
2. Buggies with tempered eggs are rolled into setter room to be transferred into setters.
3. On the 18th or 19th day of incubation, eggs are removed from the setters for transfer into the hatchers.
4. Eggs are transferred from plastic setter flats to hatcher trays and placed in the hatchers.
5. On the 21" day of incubation, chicks are transferred to the wash room (dirty room) for sorting.
6. Chicks are transferred onto chick-go-round for processing.
7. Chicks loaded onto delivery truck.
8. Hatcher trays, egg flats and chick boxes are sent through washer into clean room.
9. Clean items moved to their respective places, along with washed and cleaned buggies.

Regardless of which style is selected, one should give thought to the hatchery's .orientation on the site. Where will the roads for truck and bus traffic be located? What will be the length of utility lines and where will they enter the building?

Consider future expansion while determining the initial size and orientation of the setter and hatcher rooms. Leave adequate space from property lines so future expansion is possible. Design everything within the hatchery for easy cleaning, without the possibility of damage from water or chemicals.

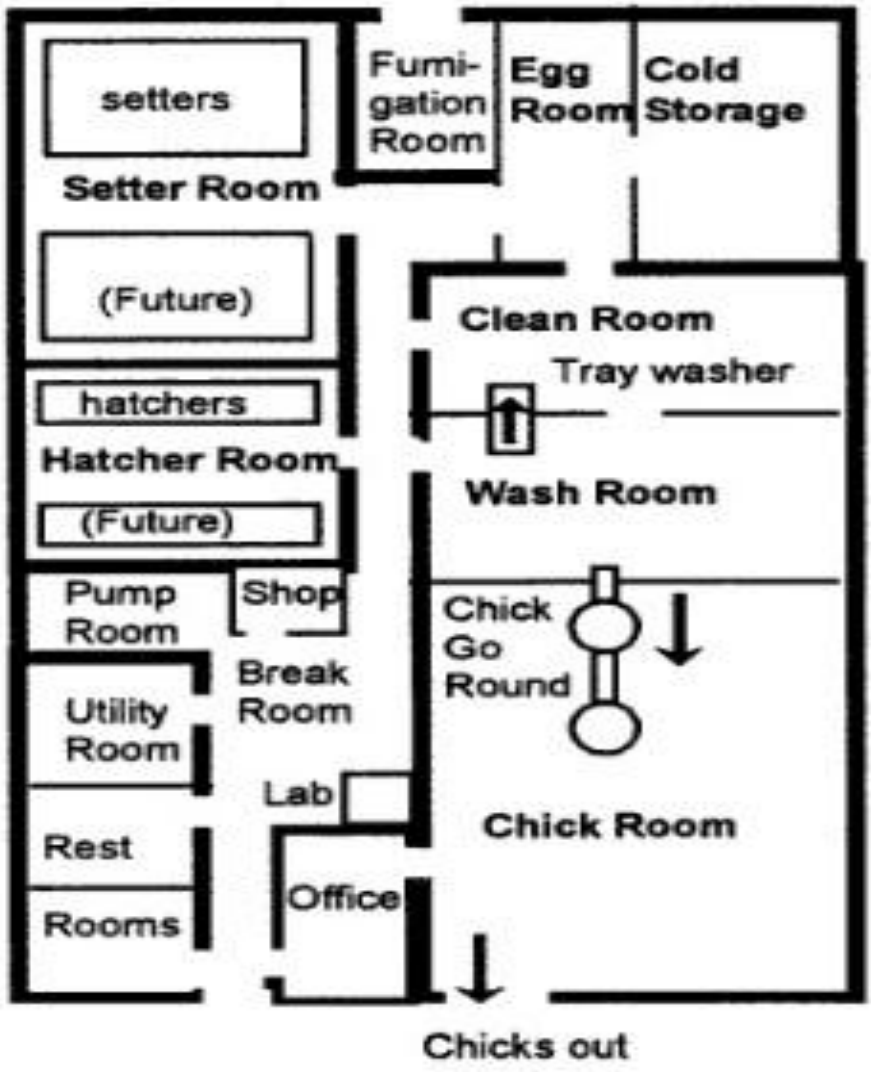


Figure 36-2. A Preliminary Floor Plan Takes into Account Production Capacity, Future Expansion Plans, and Equipment Selection.

Selecting Building Materials

Construction costs will depend upon the type of building materials selected. Common materials include prefabricated metal structural components, concrete block (CMU), precast concrete, and insulated lamina metal panels. In some cases, a combination of these materials may be used. Each has its advantages and disadvantages.

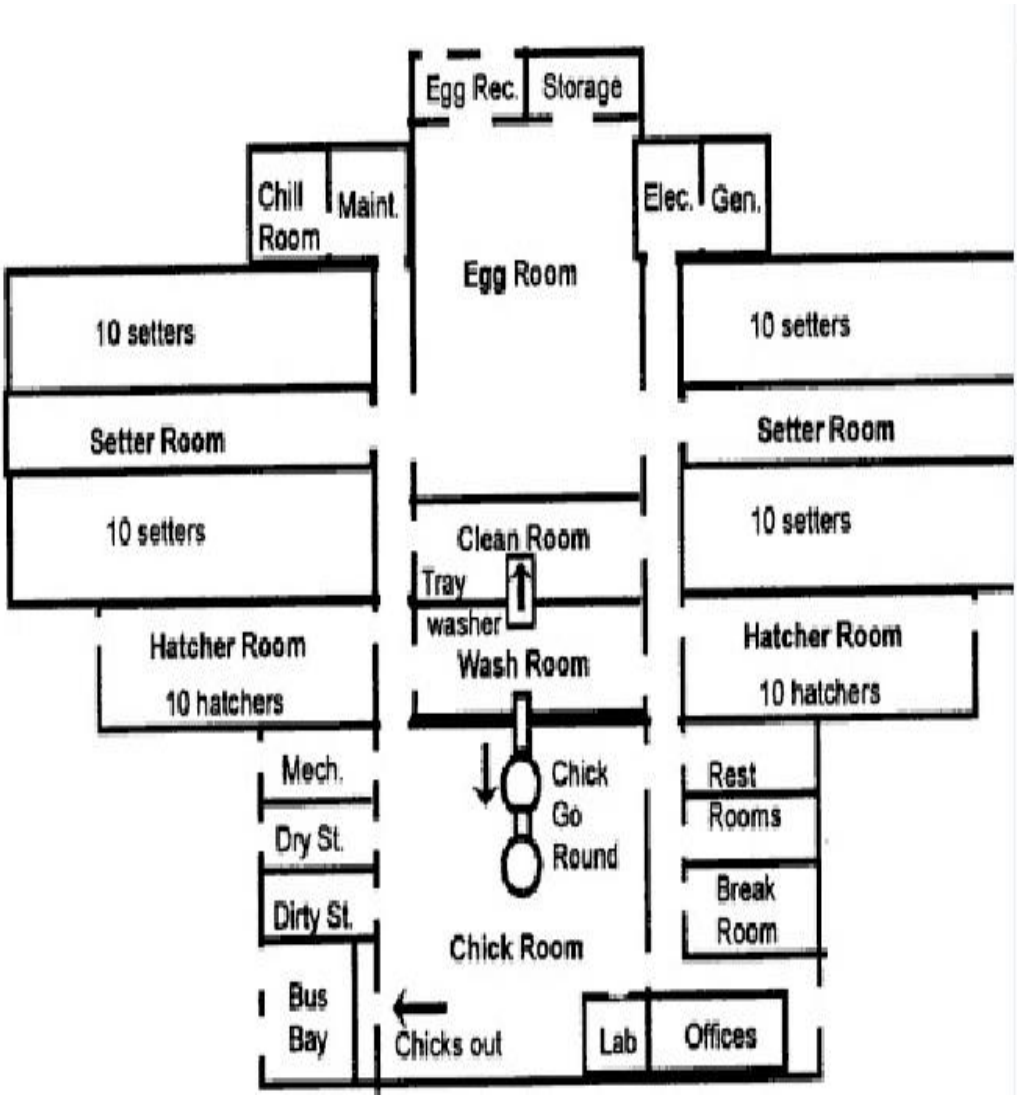
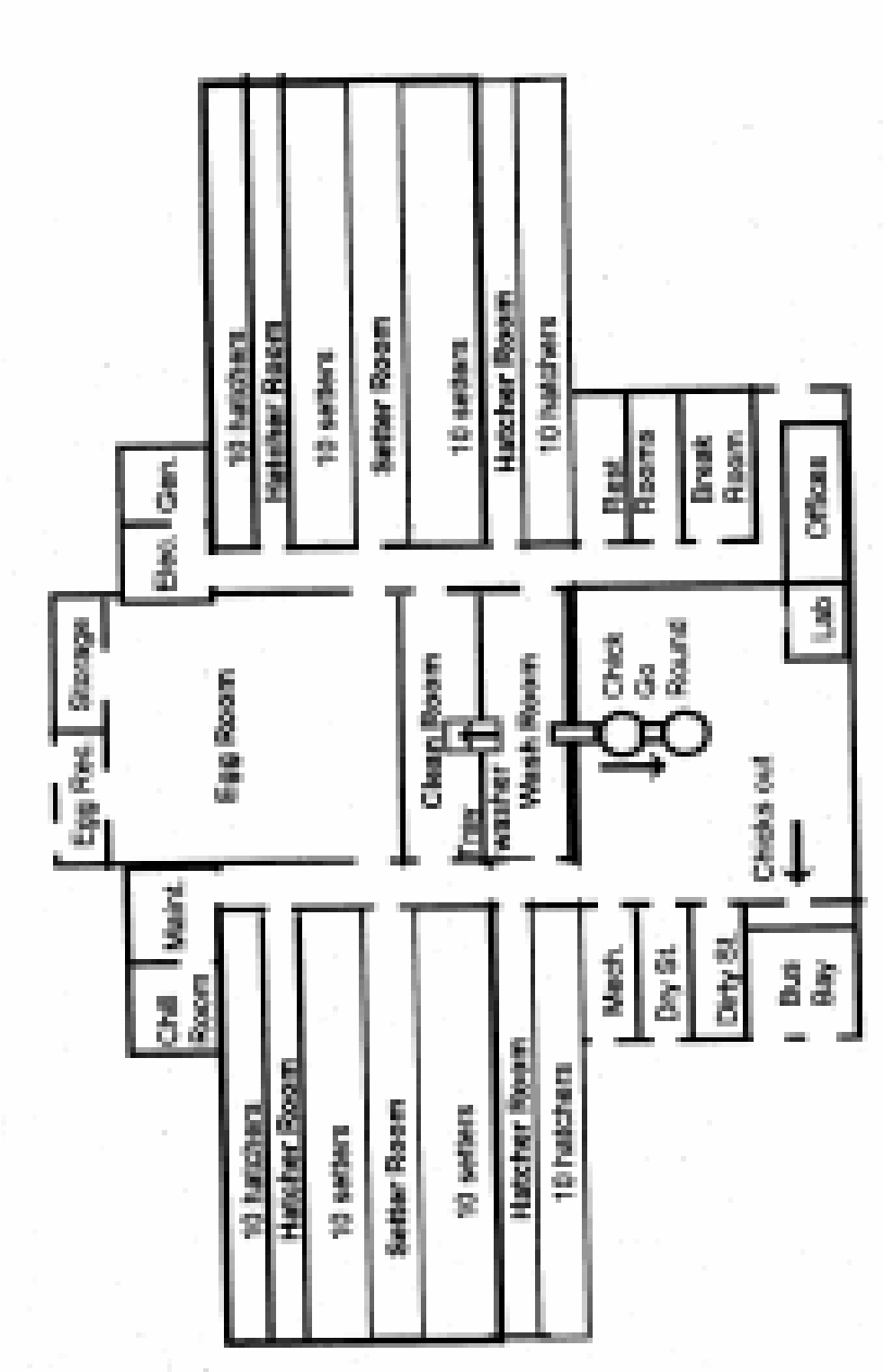


Figure 136-3. T-shaped hatchery floor plan with 40 standard incubators and 20 hatchers, 46,555 square feet (4,324 square meters). Capacity of hatchery: 1,267,200 eggs set per week (65.9 million per year).

Prefabricated metal buildings are relatively inexpensive and easy to erect. Construction time is minimal resulting in reduced labor costs. However, the roof structure is typically weak and not well suited for the insulation and maintenance of the ventilation system. The

roofing material easily damaged and may leak. The roof slope requires more expensive roof curbs and a catwalk system may be required for service access. Prefabricated metal buildings tend to rust, leak air, and have condensation problems. Concrete block (CMU) buildings take longer to construct than prefabricated metal structures; however, they can be relatively cost effective and will result in a more durable structure. The roof system in these structures can be either steel bar joists or precast concrete; when bar joists are chosen, a suspended ceiling system is recommended. A more expensive precast roof will not require a suspended ceiling and therefore, will require less labor to maintain. When CMU walls are used they will require periodic surface sealing with a durable paint.



Though relatively expensive, precast concrete can be erected rapidly and therefore can replace CMU for the sidewall construction. Furthermore, precast concrete structures are extremely durable, and can be well insulated and easily sanitized. A variety of attractive finishes and treatments are also available for precast concrete. While precast concrete does

not require significant maintenance, labor costs associated with the installation of plumbing and electrical systems tend to be higher than with other types of buildings.

Insulated metal panel buildings are energy efficient, tightly sealed, sanitary, and require minimal maintenance. However, construction is relatively slow and labor intensive, and a ceiling system is recommended.

Meeting Floor and Drain Requirements

The hatchery floor should be built to withstand the toughest conditions; provide for proper drainage; and have a smooth, durable surface finish. Concrete floors with imbedded steel to prevent cracking are the best choice, and the concrete should be a minimum of 4 inch (10.2 cm) thick.

The floors under the incubators and hatchers must be both level (within 1/4 inch (6 mm) in 10 ft (3.05 m)) and flat (within 1/8 inch (3 mm) in 2 ft (0.6 m)). Irregularities in the floor adversely affect the installation and operation of equipment. If possible, avoid floor joints under hatchery equipment. Protect all floor areas subjected to buggy traffic with a quality floor-hardening material. Never use glazed tile on hatchery floors, as tiles break under the load of egg buggies and are slippery when wet. Locate an adequate number of floor drains for all processing areas, from egg receiving through chick delivery. Drains should be conveniently located near the setters and hatchers. A floor slope of 1/8 inch (3 mm) per linear foot is recommended for all floor drains. Trenches are commonly used in high use areas, such as hatcher, wash, and take-off rooms, to speed up drainage. Drain covers and openings should be large enough to allow for drainage of water and smaller eggshell particles, but small enough to allow egg buggy wheels to roll smoothly over them. Drains in hatcher, wash, and take-off areas should also include a catch basin for trapping particulate matter, and as a rule, 6 inch (15 cm) lines are adequate for all floor drains.

Choosing Hatchery Doors

Hatchery doors in all areas having buggy traffic should be double-door, double-action, and self-closing with view windows. These doors should be equipped with complete air seals and impact bumpers. Recommended door openings are 7 ft (2.1 m) high and 6 ft (1.8 m) wide. Non-traffic doors are usually single or double doors, hollow core, single action metal with automatic closures. Typical options in these doors include view windows, push plates, and traffic bumpers. Dimensions for single leaf doors are 7 ft (2.1 m) high and 3 ft (0.91 m) wide. Double leaf doors are 7 ft (2.1 m) high and 6 ft (1.8 m) wide.

The egg-receiving and chick-bus bay areas require insulated rolling overhead doors. Larger doors of this type are usually motorized with remote start / stop buttons.

Where to Install Ceilings

When possible in hatcheries, ceilings should be limited to office and break areas. Drop ceilings using 2 by 4 ft (0.6 by 1.2 m) panels are suitable in these areas. As mentioned earlier, ceilings may also be required in the incubator, hatcher and other process areas. When the structure has ex-posed bar joists or similar components, a suspended 4 • by 8 ft (1.2 by 2.4 m) insulated metal panel system with heavy-duty aluminum tee grids is recommended. Precast roof systems do not require ceiling installation.

Designing Interior Walls

The interior walls of the hatchery should:

- have a smooth, durable surface suitable for frequent washing
- be strong enough to withstand considerable abuse
- provide for an air-tight seal between rooms, and the rooms and outside

Concrete block, finished with pore filler and epoxy paint, is a good option, but will require periodic painting. A much more durable, although more expensive option, is a wall system consisting of concrete block covered with glazed tile. This system is essentially maintenance-free and is much easier to clean than a painted surface. Many hatcheries also use insulated metal or plastic panel systems that provide for good sanitation, can be well sealed, and require relatively little maintenance.

Evaluating Water Supply

Securing an ample supply of water for the hatchery is crucial. Water is required for setters, hatchers, room humidification, and sanitation. Although a common water supply can be used for all these applications, it normally best to use dedicated lines for each application. When using dedicated lines individual temperature, flow rate, and pressure can be provided for each application.

There are four important factors when considering a water supply:

1. Temperature

Incubator cooling water. Base the optimum temperature range for ma-chine cooling water on the maximum room temperature expected. If room temperatures can be maintained between 80° and 85°F (26° and 29°C), then cooling water temperature at the machines should be between 65° and 75°F (18° and 24°C). However, if the room temperature is between 85° and 90°F (30° and 32°C), then cooling water temperature at the machines should be between 55° and 65°F (13° and 18°C).

Some hatcheries use well or city water for cooling and as long as the water temperature can be maintained within the recommended range, it is acceptable. However, in larger hatcheries where sewer and water services can be expensive, the installation of a chiller where water can be recycled may be justified. When utilizing a chilled water system, the same water is recirculated, thus eliminating a fee for sewer and water. A chilled water system also has the ability to adjust water

temperature to best satisfy the requirements of the machines. It is important to insulate all water lines to prevent sweating and dripping.

Machine and room humidity water. The optimum temperature range for humidification water is above 50°F (10°C). Humidity water lines should also be insulated to prevent sweating and dripping.

Hatchery sanitation water. Provide both hot and cold water lines for hatchery cleanup. Hot water temperature should be between 120° and 140°F (49° and 60°C). These lines should also be insulated.

2. Pressure

Machine cooling water. Pressure should be 40 to 50 PSI (2.8-3.5 kg per square cm)' at the automatic valves of each setter and hatcher.

Machine humidity water. Pressure should be 60 to 80 PSI (4.2-5.6 kg per square cm) at the automatic valves of each setter and hatcher.

Room humidification water. 30 to 40 PSI (2.1-2.8 kg per square cm) is adequate for most room humidification systems. The pressure could vary depending on the type of humidifiers used, therefore, verify the required pressure with the humidifier manufacturer.

3. Quality

Water quality can profoundly affect the operation, service life, and required maintenance of hatchery equipment. Using clean water reduces spray nozzle and water line maintenance, and extends the useful life of boilers, chillers, ventilation, and high pressure washing systems. If the water supply has a high mineral content, using a water de-ionizer, filtration or treatment system may be advantageous. A neutral pH is preferred since highly acid or alkaline water supplies can damage equipment.

4. Volume

It is better to oversize than undersize all incoming water supply line$,, Therefore, size lines based on the simultaneous operation and combined demand of all applicable equipment. Also, keep in mind the maximum demand for future expansion.

Auxiliary Systems

To support the hatchery, it is necessary to install certain auxiliary systems. Some common equipment required include standby generator, boiler, chiller, disinfectant foggers, high pressure washers, air compressors, waste vacuum or auger systems, chick transfer windows, chick vaccinating and sexing tables, machine alarm and hatchery computerization systems, tray and buggy washers, waste water filtration system, chick processing equipment, and egg transfer equipment.

Standby generator. It is a must to install a standby generator to provide electricity in case of a power outage. It is recommended that the file tank be capable of storing sufficient fuel for several days of running. The initial cost of a generator can easily be recovered with the 1oss that would occur with one power outage. Generators can be equipped with either a manual or an automatic transfer switch and are sized based on KVA (kilovolt amps) demand.

Hot water boiler. A boiler is needed to provide hot water for a variety of uses including room sanitation, tray and buggy sanitation, shower and sinks: Boilers are typically natural or propane gas-fired, are usually located in the mechanical room, and are sized based on the BTU demand required by the equipment they serve.

Water chiller. Chilled water is required to cool incubators and hatcher that are equipped with water cooling systems. Depending upon the type of ventilation system, chilled water may also be used to circulate through cooling coils in HVAC units. The size of chillers must based on the requirements of the equipment they serve. When locate in a less temperate region, chillers must be filled with a solution of water and glycol to prevent freezing.

The single most important criterion to consider when determining whether a water chiller is needed is the outdoor summer extreme wet-bulb' (WB) temperature. Should WB temperature exceed 78°F (25°C) in the area, consider a chiller system, unless there is 60°F (16°C) or below water available year round. Listed below are the allowable extremes for internal hatchery conditions. If any one of these conditions is exceeded, consider a water chiller for the hatchery.

- Maximum temperature of cooling water supply is 68°F (20°C) or above.
- Maximum room wet-bulb temperature is 78°F (25.6°C) or above.
- Maximum room dry-bulb temperature is 90°F (32.2°C) or above.

The capacity of the chiller should be between 1.2 to 2.0 tons per setter and hatcher. However, to ensure proper sizing, it is necessary to review the particulars of each application. Note: Chilled water is not used as a water source for setter and hatcher humidification or for other uses. The chilled water system has a closed loop for recirculating from the setter and hatcher to the water chiller.

Disinfectant system. Because biosecurity has become a major concern in modern hatcheries, the use of disinfectant systems is becoming more prevalent. A central fogging system will pump a disinfectant solution throughout the building, discharging it through nozzle's. The spray can be used to sanitize both rooms and machines by using controls designed and programmed to release disinfectant at specific times in the various zones in the hatchery.

Wash-down system. Use high-pressure wash-down systems to clean rooms, machines, and equipment within the hatchery. A central system pumps hot water under high pressure (800 to 1,000 psi), throughout the hatchery. Remote utility drops allow for

connection of a hose and wand assembly for washing the various areas in the hatchery.

Air compressor. An air compressor is required for many applications in the hatchery. Compressed air may be needed for room and incubator humidifiers, egg transfer machines, truck service, egg turning, and some tools. The size of the compressor is based on demand and is generally located in a mechanical room. Remote utility drops are located throughout the building to provide for convenient use of com-pressed air.

Waste removal system. Waste vacuums and augers are used to remove eggshells, dead chicks, and other debris from the work area where they are conveyed to a holding tank. The offal is then transported by truck to a rendering plant or disposal site. Suck systems aid in sanitation and reduce labor costs associated with waste disposal.

Transfer window exhaust. A chick transfer window exhaust system re-moves down and other airborne particles from the chick pulling and processing area. The system consists of an exhaust hood connected to a duct with a fan that removes the dirty air to a collection point outside the building.

Alarm System. An alarm system that gives an audible and a visual alert when conditions within an incubator or hatcher are unfavorable is required in all hatcheries. Strong consideration must be given to in-stalling a central alarm system that will monitor conditions in all hatchery rooms as well as each individual machine.

Other items. A number of other items of equipment, such as automatic egg transfers, chick separators, conveyors, vaccinators, stackers and destackers, various washers, etc., are commercially available and should be considered when designing a hatchery. A more complete discussion of these and other items can be found in Equipment for Hatcheries, Chapter 37.

Hatchery Plant Accessories

There are a number of accessories that can provide an extra measure of safety, efficiency, and convenience to the hatchery. Common accessories include roof access stairways, machine access ladders, bumper guards, rooftop utilities, eye wash stations, public address systems, maintenance, and storage items such as spare parts, dock levelers, and truck wash stations.

For service reasons, a 45-degree stairway is highly recommended to provide access to the roof. If a roof scuttle (roof opening with stairs) is provided, these stairways can be located inside the building. If exterior stairways are used they will require safety fencing to prevent unauthorized access.

Because maintenance is often required for incubators and hatchers, attaching permanent access ladders or stairs to each bank of incubators and hatchers is a convenient accessory. Bumper guards are also effective in protecting walls and machines from damage in areas where egg buggy traffic is expected. Wall guards are typically attached to the wall

approximately 3 ft (0.9 m) above the floor. Stainless steel guards attached to the floor directly in front of each machine will help protect the incubators.

Maintenance personnel welcome the convenience and efficiency provided by rooftop utilities. Compressed air drops, electrical outlets, and frost-proof water hose bibs should be located on the roof to make the maintenance and sanitation of rooftop equipment easier.

As protection against eye damage resulting from chemical spills or splashes is very important, eyewash stations should be provided for work. These stations should be strategically located for easy access. A public address system for larger hatcheries is beneficial. It can be used to summon personnel in remote locations and to provide a means of communicating information and emergency instructions.

Maintenance and storage items such as tools, spare parts, work benches, selves, hand trucks, ladders, etc. are commonly located in the shop area d are required to make service work more efficient. Dock levelers located at the egg receiving dock and chick bus dock ensure the safe and convenient transfer of products in and out of the hatchery.

Some hatcheries incorporate a truck wash station to sanitize the exterior of the chick bus, before it re-enters the truck bay. A method of cleaning interior of the truck or bus should also be provided.

36-B. HOW TO MEET YOUR ROOM REQUIREMENTS

Determine the Hatchery Layout

Chicken hatcheries are divided into three basic types: broiler, layer, and breeder. Each has unique requirements that help to determine room sizing and hatchery layout. These include the type of automation and incubation equipment used and how chicks will be processed. Other factors will depend on the hatchery building itself. Although all three types of hatcheries will be addressed, the main focus of this discussion will be broiler operations.

Arrange the rooms to provide efficient workflow through the hatchery in the following order: egg room, setter room, hatcher room, chick room, and bus bay. Auxiliary rooms such as tray wash, clean room, disposal area, box making, and storage and utility should be strategically located to support the main work effort. Locate offices, lunchroom, and reception or lobby areas so they do not interrupt the workflow. The proper layout also helps to maintain a high level of bio-security.

The single most important factor in establishing the size of the facility is the planned production capacity. This is important because the size of the egg holding room, chick room, box storage room, and clean room are predicated on chick production. Smaller hatcheries usually hatch two days a week, while larger broiler hatcheries may hatch four or six days per week to even out the daily workload. Once the daily input of eggs and output of chicks have been established, the actual room sizes and layout of the hatchery can be developed.

The following information can be used to establish actual room sizes and layout:

Egg room. Design the egg room to be large enough to provide space for storing, traying and grading eggs. A ceiling height of 12 ft (3.65 m) is ideal. The layout of this room depends on how many eggs are received daily and how they are received. Whether the eggs are received in buggies or in egg cases will affect the room size. Store buggies and egg cases 6 inches (1.5 cm) away from the wall, with 6 inches (1.5 cm) of space between the buggies or rows of cases. It imperative to rotate the stock in the egg room. "First in, first out a necessary rule to maintain hatchability.

Most hatcheries use buggies that are located at the farm to eliminate handling in the egg room. With this method, eggs are gathered plastic flats and loaded at the farm into the buggies. When they arrive by truck at the hatchery, they are ready for setting.

The maximum number of eggs to be stored at any one time must be determined before the egg holding room can be designed. Therefore, when calculating egg room size, provide 4 square feet of floor space for each 1,000 eggs to be stored (0.372 sq m). The egg room should be large enough to store the setting requirements for one week. The minimum egg room size should not be less than 600 sq ft (55.7 sq m).

Fumigation room. Additional space must be provided to fumigate e.g. cases or holding buggies. Construct the fumigation room large enough so that it can accommodate one-half of the cases and buggies used in a single day.

Prewarming room. Locate the prewarming room next to the egg room and make sure that it is large enough to hold one day's setting of egg buggies. A general rule is to provide 15 sq ft (1.4 sq m) each egg buggy. It is important to provide airspace around all buggies, and good air circulation around all eggs to maintain an even temperature.

Setter room. The setter room should be sufficiently large enough to permit easy access around the setters. Usually 24 to 30 inches (60 to 70 cm) between the ends and backs of the setters and the walls is considered adequate space for this purpose. The front of the setter should have a space at least 10' to 12 ft (3.0 to 3.6 m) wide from the front to facing wall or a facing row of setters. The aisle width will allow for the temporary storage of loaded egg buggies without interfering with normal work, such as machine monitoring and maintenance, egg candling and inspection. A good ceiling height for the setter room is 14 ft (4.27 m). This provides ample room for working and cleaning top of the setters.

Hatcher room. Hatchers must have a front aisle of at least 10 ft (3.05m) wide. When two rows of hatchers face each other there should be minimum aisle space of 10 to 12 ft (3.05 to 3.65 m) to permit work in both rows at the same time. If in ovo vaccination is used, provide an aisle width of at least 12 ft (3.65 m). Place hatchers 24 to 30 inch (60 to 70 cm) from end and back walls for cleaning purposes. This allows ample space for a plenum exhaust system, if wanted.

Only hatchers with the same hatching schedule (same hatch day) should be located in the same room. As a result, two or more hatcher rooms may be necessary so that microorganisms released during hatch will not affect unhatched eggs. Separate

hatcher rooms allow takeoff and cleanup in one room without disrupting machines on a different hatching schedule. A 14 ft (4.27 m) hatcher room ceiling height provides ample room for cleaning the tops of the hatchers.

Chick room. The size of the chick room is based on the maximum number of chicks processed daily. Determine this by dividing the total weekly hatch by the number of hatch days per week. The extent of processing planned for the chick room will also affect its required size. Provide adequate space to accommodate all chicks to be stored in the chick room at any given time. It is also desirable to separate the chick storage or holding area from the chick service area. Additional space must be included in the design if sexing, beak trimming, and / or vaccination(s) are planned. Automated chick processing equipment can also affect floor space requirements.

Whenever full chick boxes are held in the chick room, always place them on dollies and stack them at least 12 inches (30 cm) apart to allow for proper ventilation. When holding chicks in boxes stacked ten high, allow 10 sq ft (9.3 sq m) per 1,000 chicks held. After the storage and processing requirements have been determined, establish the room size. The requirements generally range from a minimum of 12 sq ft (1.12 sq m) per 1,000 chicks, up to 20 sq ft (1.86 sq m) per 1,000 chicks stored in the chick room. Using a hypothetical hatchery with a capacity of 1,663,200 eggs set per week, on a 4 day per week hatching schedule, the chick room would have to handle approximately 341,000 chicks per hatch. On this schedule, the chick room should be sized at approximately 4,400 sq ft (409 sq m).

Wash room or chick take-off room. Base the room size for this area on the maximum number of hatcher buggies that will be stored in it at any one time. Allow space for the tray washer, buggy washer, vacuum waste system, and any automation equipment. If the wash room has a chick take-off window, a vacuum or auger system for waste removal should be located in front of the window. A separate refuse area, usually outside the building, will be necessary for storage and removal of the waste.

Farm egg buggies will also be washed in this room. The buggy washer should be designed to handle farm buggies filled with flats. Allow 6 sq ft (0.56 sq m) per 1,000 chicks hatched, or 12 sq ft (1.12 sq m) times the total number of hatcher buggies per hatch day, plus adequate space for cleaning, take-off, and automation equipment.

Clean tray room. A clean tray room should be adjacent to the tray wash room and should hold all the clean trays and buggies (for one day's hatch) until hatcher rooms have been cleaned and sanitized. This room should be sized for 15 sq ft (1.4 sq m) for each buggy stored on hatch day. To reduce workload, locate the tray washer so that trays can be conveyed directly into the clean room.

36-C. DESIGNING THE HATCHERY VENTILATION SYSTEM

Basic Principles

Proper hatchery ventilation is important to obtain the best possible has high quality chicks. This fact must be strongly emphasized to all level management. Do not rely on natural ventilation such as open wind inadequate roof ventilators, or improperly installed heaters. It is important that each room have its own system for heating, cooling, and ventilation and controls must be designed to maintain the various areas at de temperature and humidity throughout the year.

Incubator and hatcher room ventilation systems must also provide recommended amounts of fresh air and exhaust-used machine air to vent a buildup of carbon dioxide in the room. Adjusting the supply (air) and exhaust air quantities in the various rooms is a method use enhance a hatchery sanitation program. By creating different pressure different rooms, an airflow pattern can be created that parallels the movement of eggs through the hatchery, thus preventing backflow and poss contamination. This continuous flow of fresh air supply and exhaust is commonly referred to as *air changes*.

Because the air in a hatchery is replenished frequently with outside having variable temperatures and relative humidities, it is a challenge to provide consistent environmental conditions within each room in hatchery. Hatchery ventilation requirements are unique, and therefore systems should be designed and installed by specialists who fully: understand their specific requirements.

Air Conditioning Units vs Evaporative Cooling

To ensure a consistent and high quality hatch, the ventilation system must precondition the air (temperature and humidity) supplied to setter and hatcher rooms. This is especially true in the less temperate zones where large swings in temperature and humidity can occur causing a loss in hatchability.

As incubators (setters and hatchers) are designed to operate under r conditions where temperature (78° to 80°F; 26° to 27°C) and relative humidity (from 45 to 55% in the setter room and from 60 to 70% in the hat room) vary little, it is imperative that the incoming air into these rooms be properly conditioned. There are two types of ventilation systems are commonly used to control room environments: the air conditioning combination unit and the evaporative cooling/ heating unit. In the combination unit, functions of heating and air conditioning are combined in one packaged unit. In the evaporative cooling/heating unit, the cooling and heating functions are performed by two different units, evaporative coolers and makeup air heaters. Based on ambient conditions, there are advantages and disadvantages to each type of system.

Air conditioning (refrigeration) units cost more to operate than evaporative coolers during the summer months because of the additional energy required to operate the compressors. However, refrigeration units, unlike evaporative cooling, remove moisture from the ambient air as condensation off the-cooling coils. This is an important factor to consider in areas that have consistently high humidity and / or temperature for extended periods of time.

Evaporative coolers are effective in cooling large areas that do not require precise temperature and humidity control. Because larger quantities of air are required to achieve a cooling effect with evaporative cooling than with refrigeration, it requires more units to cool the same area. Cooling costs, however, are generally lower with evaporative cooler units than with refrigeration units. Evaporative coolers, unlike refrigeration units, cannot dehumidify the incoming fresh air supply and actually add moisture to the incoming air.

With evaporative cooling and heating units, there is a higher installation cost because of the number of individual pieces of equipment that must be installed. Evaporative cooling systems are labor-intensive to maintain properly, but replacement parts are relatively inexpensive and are easy to find.

In cooler climates and seasons, a heating unit(s) is required to supply tempered air when the evaporative cooler's are off. A roof-mounted heating / make-up air unit is ideal to provide the continuous amount of filtered fresh air required during these times. Caution must be taken to properly balance incoming and exhaust air supplied by the heating and cooling systems so as not to disturb the various pressure differences among the rooms in the hatchery.

When heating is required, or in dry seasons or climates, a humidification system is necessary with either type of ventilation system. A self-contained automatically controlled humidification unit in most instances works well to maintain proper room humidity.

Incubator and Hatcher Exhaust Systems

The used air from the setters and hatchers must be exhausted to the outside, but not near the fresh air intakes of the ventilation equipment. Use a mechanical exhaust system to remove the air from the building. There are two general types of machine exhaust systems: exhaust duct or exhaust plenums.

Exhaust ducts. The main exhaust duct (a relatively large length of duo work) is normally suspended a few feet over the incubator or hatcher exhaust thimbles. Smaller branch ducts or drops connect to the man duct and extend down to within a few inches above the top of the machine exhaust thimbles. They do not directly connect to the exhaust-thimble on the machine. Drops to the machine exhaust thimbles mu be fitted with an adjustable damper that allows for balancing the exhaust air quantity at the thimbles. In incubator rooms, the main duct is typically routed up through the roof to a roof mounted exhaust fan In hatcher rooms, the main duct should exit through an outside IA al, of the building via a sidewall mounted exhaust fan. In some case,, there may also be one or more dampers in the main duct to balance airflow in the system.

During operation, a constant speed exhaust fan draws air through the main duct and up each branch duct or drop. The balance dampers in each drop must be adjusted so the same CFM (cubic feet per min, ute) of air is exhausted at each drop. Remember that these drops do not directly connect with the machines. As air exits the incubator

or hatcher exhaust thimble, it is captured by the drops. Because there are no. direct connections, this system will ensure that additional air, is not drawn through the machines.

Exhaust plenums. In a plenum system, ductwork is not used to capture exhaust air from the setters and hatchers. Rather an enclosure (plenum) is erected around the exhaust end of the machines to capture the discharged air. Doors are installed at both ends of the plenum for easy access for cleaning. When exhaust plenums are used, the machines will have rear exhaust thimbles. The typical hatchery using the plenum system will have a series (bank) of side-by-side hatchers or setters, with all exhausting into the common enclosure (exhaust plenum) behind the machines. An exception to this arrangement are rear door setters which exhaust through the roof of the machines, in which case, the plenum enclosure is built from the top of the setters upward to the roof of the building.

The latest design in plenum systems requires that they be' totally sealed and use a variable speed exhaust fan(s) which is activated by a sensor that measures the pressure difference between the room and the plenum. When a slight negative pressure is maintained into the plenum, all the machine air dumped into it will be exhausted to the out side of the hatchery. With this system, only the air exhausted into the plenum by the machines and not air in the room is removed from the hatchery.

Room Ventilation Recommendations

This section contains specific recommendations for temperature, relative humidity, and outside air in the principal hatchery rooms. The ventilation system for each room in the hatchery is dependent upon outside conditions.

Egg room. The egg room is unique in its requirements for temperature and humidity, as they are based on the storage time of the eggs. The -longer-you store eggs, the colder the room temperature should be. As the dry-bulb temperature is reduced to adjust for longer storage times, the relative humidity must be increased. Table 36-1 provides proper temperature and relative humidity levels based on the storage time of the eggs. When eggs are stored at the cooler temperatures, they are in a state of dormancy. During this time essentially no embryonic development is taking place, therefore the oxygen requirement of the egg is very low. The fresh air requirement of the room is based on this demand, and therefore is minimal. The minimum fresh air requirement is 0.075 cfm per 1,000 eggs (0.13 m3 / hr), based on the maximum number of eggs to be stored in the room at one time. In some cases, additional fresh air may be required to maintain a positive pressure in the room, relative to adjacent areas.

Prewarming room. The recommended temperature for this area is 76° to 80°F (24.4° to 26.7°C) with a relative humidity level below 45%. Under these conditions, the eggs will not sweat as their internal temperature increases.

The method of prewarming is very important. Allow for free air space around each egg buggy and good air circulation around all eggs in order to maintain even temperatures and help evaporate condensation. The use of horizontal ceiling fans should be considered in the prewarming room as they provide a gentle but uniform air circulation.

Setter and hatcher rooms. Setter and hatcher room conditions should be maintained as suggested in Table 36-2 to ensure for optimum operation of the incubators.

Table 36-1. Recommended Temperatures and Relative Humidities for Storing hatching Eggs

Time of storage	Dry Bulb Temperature °F (°C)	Wet Bulb Temperature °F (°C)	Relative Humidity (%)
3 days or less	65-70 (18-21)	60-65 (15-18)	75
3 to 7 days	59-62 (15-17)	55-60 (13-15)	75-80
Over 7 days	55-57 (11-12)	52-54 (9-11)	80

Table 36-2. Recommended Setter and Hatcher Room Temperatures and Relative Humidities

Room	Temperature °F (°C)	Relative Humidity (%)
Setter	78-80 (26-27)	45-55
Hatcher	78-80 (26-27)	60-70

The style of incubation equipment will dictate supply and exha air requirements, and therefore the amount of supply air and exha air will depend on the type of machines used. Also, air quantities typically higher when a plenum exhaust system is used.

Chick room. Optimal chick room conditions for holding chicks are follows:

- Temperature: 75° to 85°F (25.6° to 29.4°C)
- Relative humidity: 50 to 60%

It is important to maintain proper temperature and relative humidity in the room for the duration of processing and storage of chicks. Providing good circulation of air throughout the boxes of stored chicks is critical, especially during periods of high temperature and humidity. To help prevent high temperatures within chick box store the stacks approximately 1 ft (0.3 m) apart. The fresh air required merit for the chick room is based on the maximum number of chi held at any one time and the number of people processing chicks the room. Following are recommended minimum fresh air requi ments for the chick room:

- 12 cfm (0.34 cmm) per 1,000 chicks
- 20 cfm (0.57 cmm) per person

Wash room. The wash room in most hatcheries is also used as a ch take-off area. While holding chicks in this area the following ro conditions should be maintained:

- Temperature: 78° to 85°F (25.6° to 29.4°C)
- Relative humidity: 50 to 60%

The fresh air required in the wash room is based on the number chicks held in the room at any one time, and the number of persons working in this area. The minimum recommendations for fresh al the wash room are:

- 12 cfm (0.34 cmm) per 1,000 chicks
- 20 cfm (0.57 cmm) per person

Due to the heavy contamination (bacterially laden down, etc.) of air within the wash room, special precautions must be taken with room pressures to assure proper ventilation and to prevent cross-contamination with other areas in the hatchery. Exhaust hoods are required for the chick take-off area, and the tray washer and buggy washer (see manufacturer's recommendations). The exhaust air is necessary to remove the steam vapor and contaminated air from the room. If automated equipment is utilized in this area, such as chick separators, a special exhaust system should be provided as recommended by the equipment manufacturer.

Clean room. The clean room, which is used for drying trays and buggies dter'they have been washed, requires large quantities of fresh air to aid with drying. Adequate fresh air helps to maintain a positive pressure in this room and prevent the growth of mold and bacteria in the room and on the washed equipment. With the clean room maintained at a positive pressure with respect to the wash room, steam vapors and contaminated air will flow away from clean trays and buggies and toward the wash room exhaust systems. Inadequate or poorly balanced ventilation systems in the processing areas can rob air from incubator or hatcher rooms or cause contamination of clean rooms.

Acknowledgment

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Chapter 37
Equipment for Hatcheries
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The primary reasons for installing new hatchery equipment is to improve hatchability and chick quality, increase capacity, and reduce labor and energy costs. Some types of equipment will be common to all hatcheries while other equipment may be required only in certain types of hatcheries. There are few, if any standards. While considering which equipment is necessary and which is optional, the following points should be considered:

- Size of the hatchery
- Number of hatches per week
- Disease control programs and sanitation needs
- Primary breeders, broilers, commercial layers, turkeys, or others
- Brand and model of incubators
- Use of in ovo vaccination
- Chick processing requirements
- Labor availability and costs
- Local utilities availability and costs

37-A. WATER EQUIPMENT

Wells, Water Softeners, and Filters

Analyze the water source for minerals and dissolved impurities. Excessive minerals, such as calcium, iron, and limestone, will cause deposits on the humidity controls; spray nozzles, jets, and valve seats. There are filter systems and conditioners available to remedy these problems. A water softener may also be necessary (see Consumption and Quality of 'Watt Chapter 22).

When well water is used, an elevated water tank will be necessary supply the hatchery with adequate amounts of water during periods peak demand at reasonable operating pressures. When using municipal water, it is still a good practice to have a reserve tank to ensure adequate supplies and pressures.

Water Heaters

Large quantities of hot water are necessary for hatchery operations. Hot water will be necessary for operating most hatcher tray washers and general cleanup. If steam generated humidification is used, it will also r quire hot water to operate. A large capacity boiler is generally used provide hot water. Investigate the costs of various locally available fuels prior to purchasing water heating equipment.

Steam Humidification

Steam has been used for decades for providing humidity for many of industrial and home environments. Until recently, it has been considered too expensive for hatchery use, and

therefore has not been used. Currently, steam as a hatchery humidity source is more affordable and is being utilized in some larger hatcheries.

There are many ways hatcheries are currently humidifying their setter, hatcher, egg, and chick rooms. The type of equipment selected depends on the size of the room, air movement capabilities, and ceiling height. A problem most humidification systems have is that unevaporated water falls out of the air and onto the floors and equipment, making accurate humidity control very difficult. This can be a significant problem in summer when nighttime ambient relative humidity is frequently over 90 and daytime humidity is also high due to the use of evaporative cool systems. The reason floors become wet with some humidifiers is that droplet sizes are relatively large, ranging from 2 to over 100 microns. Steam is ready-made water vapor with minuscule droplets and can be used to reduce excessive wetting. Steam is also hot and will add a small amount of temperature to the room, which can be an advantage in winter. During the summer, the added heat is generally not a problem because there is so much humidity in the room from evaporative coolers that only small amounts of steam humidity are required. Table 37-1 provides the sizes of many common items including droplet sizes for conditional and steam humidifiers. It should be noted that the smallest droplet size attained with conventional humidifiers is about 2 microns, whereas steam (ready-made water vapor) has a droplet size of 0.0006 microns. An added advantage of steam is that it is sterile. This reduces the potential of introducing contamination through the humidification system.

Table 37-1. Typical Particle Sizes of Common Substances

Material	Particle Size (Microns)
Particles visible to human eye	10+
Human hair (diameter)	100
Dust	1 to 100
Pollen	20 to 50
Fog (visible vapor)	2 to 40
Mist (water spray)	40 to 500
Industrial fumes	0.1 to 1
Bacteria	0.3 to 10
Gas molecules (steam)	0.0006

Compressed Air

Some incubators require compressed air to actuate the turning mechanisms for the racks of eggs. Clean, dry compressed air may also be necessary for other functions in the incubators, including air-assisted humidification through spray nozzles. Regardless of possible other needs, a large central compressed air system is needed for blowing down dust and other dry cleaning in the hatchery. The system should be, centrally located and for convenience piped into every room of the hatchery. Consult the incubator manufacturer for data concerning the required cfm (mps) and operating pressures.

37-B. EMERGENCY STANDBY ELECTRIC PLANTS

When there is a failure in the local electrical supply, the incubators must s. have a secondary source of electricity. Therefore, a standby electrical generator located on site, generally within, or next to the hatchery building is imperative.

Type of Plant

The standby electrical plant should be adequately sized to support 100% of the essential services of the hatchery, such as the incubators, water, fresh air supply, lighting, and part or all of the electrical load of the equipment used in chick processing.

Generators are available that operate on gas, diesel, natural, and propane gas. Caution must be taken to assure that the exhaust system is properly installed to adequately remove all fumes from the building.

Automatic or Manual Starting

An automatic plant will start and transfer the operation of all essential equipment in the event of a power failure. When outside power fails, the motor used to start the generator engine will energize automatically. Transfer switches will then sequentially restart electrical equipment and lights in the hatchery. If a manual generating unit is used, transfer fr the outside power sources to the standby unit must be done manually. the starting amps of many pieces of equipment can be two to three ti the running amps, it is advisable to restart several machines at a time reduce load requirements. Hatchers should be restarted first since embryos /chicks at this stage of incubation are extremely vulnerable overheating when power fails. An audible power failure alarm syst with loud alarm bells or horns should be installed to notify the hatch personnel of a power failure.

Calculating the Electrical Load

When making the calculations for sizing the standby power plant, necessary to take into consideration the startup loads of all motors in building, including those in the incubators. Keep in mind that some bators have auxiliary heaters that will activate during temperature dr

and place additional demand on the electrical supply. A safety facto 10% should be added to the normal operating requirements' when si the standby generator.

A small hatchery with a dependable power supply may take the of operating without a standby plant, or with only LnirlIn-la I genera-capabilities for operating the hatchers, ventilators, water pumps (if ne sary) and lighting.

A power failure of 2 or 3 hours will not cause serious damage to emb in the setters, but can be disastrous to the eggs and chicks in the, hat A power failure of 6 to 8 hours will result in a severe loss in hatcha in both hatchers and setters.

37-C., EGG HANDLING EQUIPMENT

In the past, most hatching eggs were gathered on fiber flats and cardboard cases on the farm. Today, essentially all hatching eggs pro are delivered to the hatchery in plastic incubator flats in what are commonly referred to as farm carts. This is especially true for all broiler integrators who have their own breeder facilities.. The only exceptions are when a company may find it necessary to transfer excess hatching egg production from one location to another. In these cases, the eggs are normally shipped in cardboard cases.

Figure 37-1. Transferring Eggs in. Incubator

Smaller broiler and broiler-breeder producers, and smaller layer pullet, turkey, and specialty bird producers generally find it more convenient to transport hatching eggs in cardboard cases. In these instances, it will generally save time and labor, and reduce the risk of cracks if pneumatic transfer equipment is used to move the eggs from the fiber or plastic filler flats to incubator flats. There are several types of transfer heads and machines available on the market for this purpose. The most common type is the 5 X 6 or 30 egg head. There are also heads available in 12, 24, 36 egg patterns for use with in-line incubator flats. Staggered heads are also available to move every other row of eggs half a position. These are sized for all common commercial incubator flats, including 42 and 54 egg versions. A vacuum pump or regenerative blower will be necessary to create the suction for the lifters.

Hatching Egg Graders

Commonplace in the past, but currently no longer recommended is a grader for sizing hatching eggs. It is more important to set all eggs from a single breeder flock together to ensure that the progeny have a similar immune response, than attempt to set eggs by size.

It is also recommended that eggs from each breeder flock be set together to allow the hatchery manager to identify and correct problems associate with fertility, embryonic mortality, poor hatchability, diseases, etc. Had, day breakout analysis, as discussed in Factors Affecting Hatchability, Chapter 39, is of little value if the eggs in the tray are from several differei 16: flocks. Further, keeping life-of-flock records on hatchability performanc.., is nearly, impossible when eggs are set according to weight rather than by flock. Another

serious problem with grading eggs for size is that procedure requires another egg handling which will result in loss fro cracks.

Hatching Egg Washers/Sanitizers

A discussion of mechanical hatching egg washers and sabitizers is pre, sented in Maintaining Hatching Egg Quality, Chapter 38. Hatching egg sani tation is much more effective when the eggs are sanitized as soon as possi, ble after lay and before bacteria on the shell surface have had time to penetrate. Therefore, these machines are more appropriately located on the breeder farms.

37-D. INCUBATION EQUIPMENT (SETTERS AND HATCHERS)

Modern Commercial Setters and Hatchers

Incubation equipment, specifically setters, are generally divided into several different types or categories depending on how they operate and whether they are used for single- or multistage incubation.

Figure 37-2. Incubator Room in Hatchery

Multistage machines. Most are used for large broiler operations which require a fixed number of birds on a weekly basis. They are generally "set" with either 3 or 6 different ages of eggs, 6 or 3 days apart. Once fully loaded with eggs, these machines are rarely shut down or turned off. These machines use available animal heat from older embryos to assist with heating younger embryos.

Single-stage machines. These machines are typically used for primary breeders, table egg breeders, turkeys, and other operations which re-quire varying the number of birds hatched from day-to-day and week, to-week. Single-stage incubation has an advantage as the environment in the unit can be tailored to accommodate specific requirements for different breeds, ages of flock, egg size, and storage time, as well as different requirements at various stages of embryonic growth. They also provide an advantage in sanitation, as the machines can be emptied and thoroughly cleaned before each batch of eggs is set, a factor that makes them valuable for quarantine types of incubation. However, additional heating and cooling capacity is required which makes single-stage incubation substantially more expensive to operate than multistage machines. The various styles of machines found around the world include:

- Walk-In or Corridor. They are used for multistage incubation, and have fixed racks or removable trolleys. A central front door leads into a corridor with overhead fans running the length of the machine.
- Tunnel. These are also multistage machines with moveable racks for eggs with fans located at the entrance end of the machine. In the past they would have had entrance doors on the side of one end and exit doors on the other

side (side loaders). Today, they generally have a pair of entrance doors and exit doors on opposite ends (old loaders). Vertical Fan. These machines have moveable racks for eggs with one or more large {7 feet or 2.13 m diameter) bi-directional high volume fan(s) in the center. The fans circulate air to the left and right simultaneously. They can be .operated as single- or multistage.

- Drum. These machines have a high volume fan in the rear or in the ceiling and were popular smaller units sold in the 1940's, '50's, and '60's and are virtually obsolete now. They could operate as single- or multistage.

A brief discussion of each of these incubator types follows with the advantages and disadvantages.

Walk-In Incubators

The most common models include the ChickMaster® 102 (USA)1, an the CASP® 125 (Brazil).2 In the past, these units were also sold by Buckey (USA' and UK4), La Nationale® and Bekoto® (France),5 and Stabil® (Ge many).6 The fixed rack versions are set manually by taking ,the farm ra into the corridor of the machine and transferring plastic flats from far racks to incubator racks. Although additional labor is necessary to sct egs: labor costs are frequently offset by increased hatchability because th are forgiving for minor malfunctions or mistakes. The fixed racks of egg are normally 15 rows high and 18 rows from front to back, holding 6 differ ent ages of eggs 3 days apart. Eggs are transferred to hatchers after 1 days.

This method of setting allows the exchange of heat from older embryo-that produce heat to younger embryos that require heat. When the ma chines are operating normally; the only time that heat is called for is ju after introducing a new setting of cool eggs and in some cases, when hu midity is added.

Improvements in the last decade include state-of-the-art controls wits remote, computer control capabilities, standard high speed fans, wider se lections of plastic egg flats, plastic hatcher trays, removable circulating fan assemblies, and all-aluminum and fiberglass reinforced plastic (FRP) cat, net construction. The basic operation of these machines has changed ver little in the last 40 years. There are some newer versions available wi roll-in racks; however, hatchability will be a little lower due to the effect of having a single age of embryos in one part of the machine.

ChickMaster, P.O. Box 704, Medina, Ohio 44258 USA. CASP, S.A. Industria e Comercio, Rua Sebastiao Goncalves Cruz, 477, Sep. 13904-904, Ampdf SP Brazil.

Buckeye USA, no longer in business. Buckeye Company, Mill Lane, Petherton, Lopen, South Petherton, Summerset TA1305JS Engla s La Nationale, Z.1. De Vaugereau, 45250 Briare, France. 6-Stabil, no longer in business.

Tunnel Type Incubators

These incubators have been manufactured by Jamesway® (Canada)?

Butler® (USAV and Harrison® (Australia), 9 since the early 1960's, and continue as a very popular style of machine. Tunnel machines have roll-in incubator racks equipped with pneumatic egg-turning devices. The machines are characterized by pairs of large roll-in racks which are introduced with new eggs in one end of the machine and are then moved forward twice each week during the 18-day cycle. The machines hold a complement of 12 racks, each with 45 trays.

The racks of 18-day-old eggs are rolled out the exit end of the machine and then transferred into the hatcher trays. This method provides substantial labor saving when compared to fixed-rack machines. Tunnel machines are extremely efficient and use excess heat from older eggs to assist heating younger eggs as the air flows from back to front (older to younger embryos).

Tunnel machines require more management, as they must be closely watched for problems such as malfunctioning rack-turners and fans. Defiderides discovered must be fixed at once or the hatch will be dramatically affected.

Vertical Fan Incubators

These European-designed incubators represent the newest types of ma-chines. They have very large floor to ceiling belt-driven fans in the center of the machine blowing to the left and right side simultaneously. The fans generally have four large metal blades on each side, for a total of eight blades, spaced 45 degrees apart. The incubator racks turn by independent electric or pneumatic actuators, or by coupling the racks together and slid-ing them into a mechanical turning sleeve located at the rear wall.

This type of machine is available as single or multistage units. When operated as multistage, the racks are rearranged when a setting of eggs is removed or added, with the oldest, heat producing, eggs toward the center of the machine and the newer eggs against the outside walls. They are available worldwide, and are manufactured by Petersime® (Belgium),1° Pas Reform s (Netherlands)," Buckeyes (UK),4 Best / National Ser-vices R (France / Italy)," GASPS® (Brazil)? and Cumberland® (USA)13 and

Jamesway Incubator Company, 30 High Ridge Court, Cambridge, Ontario, Canada N1R 7L3. 8Butler, no 1pnger in business.

g Harrison International Pty. Ltd., P. 0. Box 84,

9 Malta Street, Villawood, N.S.W. Australia.

Petersime N.V., Lentrumstreet 125, B-9870 Sulte, Belgium.

11Pas Reform, P.O. Box 2, Zeddam, 7038ZG, Holland.

12 Best/Natiopal Services, RCS Montargis B 407670033, ATE 293D -TVA France 64407033. '3 Cumberland Hatthery Systems, 501 South Line, DuQuion, Illinois 62832 USA.

Nature Forme (USA). " Most are now using PLC (Programmable Logic Controller) controls and can interface with other units and download data and are compatible with standard IBM type computer terminals.

37-E. HATCHERY AUTOMATION EQUIPMENT

A detailed analysis of available labor and its cost should be made before various types of hatchery automation equipment are considered. Method. of Marek's vaccination and equipment that increases hatchability and im¬proves overall hatchery sanitation should also be considered.

Forethought and planning must be used when detailing job savings with automation. It is easy to accidentally end up with several "half jobs" in different parts of the hatchery that may require a full time (paid) worke to perform. Also, machines that perform 95% of the physical labor portiori of a job duty, but still require a worker to watch and be available for clear¬ing jams and frequent maintenance, will not offer true payback for capital expenses.

Cleanup and standard maintenance time must also be carefully consid-ered. There is no financial savings earned by replacing 20 hours of un¬skilled labor with 4 hours of the maintenance crew's time. There is only a true payback if the total annual labor and maintenance costs, inch Kling amortizing the equipment costs and paying for all cleanup and upkeep, are lower than the cost to operate the hatchery without the automation.

Hatcher Tray Washers

Tray washers are generally very large machines that are approximately 5 feet (1.5 m) wide and up to 45 feet (14 m) long. Most require a separate hot water boiler system. These machines should have repetitive filter systems with descending and / or rotating filter screens capable of removing even the smallest eggshell particles. With the plastic hatcher trays currently used in most incubation systems it is necessary to utilize washers with extremely high pressure (>1,000 psi) to ensure that hatcher trays are completely cleaned.

Use tray washers that receive trays widthwise or sideways instead of two parallel lanes. If a conveying system is added to automatically load the trays into the washer, a "thinking" (alternating) conveyor will be necessary to first load a tray to one side and then the other side. •

Washers should have nozzles that can be easily removed and cleaned. Typically, most washers use a drag chain to convey the trays. This type of conveyor can break hatcher trays, sometimes at an alarming rate. Fortunately, there are some new machines available specifically designed for plastic trays typically found in hatcheries around the world. They use a rubber roller system, similar in principle to a wringer-type clothes washer. These

washers pinch the trays between the rollers and push them into the washer, forcing the previous tray further along. In addition to thorough cleaning, high pressure washers use less water than lower pressure units, thus reducing boiler capacity needs. The high pressure pumps themselves also assist with heating the water, further reducing boiler capacity. All washers should be equipped with dryers to help reduce the opportunity for microbial growth and the subsequent adherence of foreign material.

Waste Removal Systems

There are three types of systems used for removing offal and waste by-products from the hatchery:

Mechanical conveyors. Auger (screw) or drag-type conveyors are very effective and will stand up to the abrasive and caustic environment 'of hatchery waste. However, they are not designed to handle excessively liquid materials. These conveyors are only practical for short distances and for inclines of no more than 45 degrees.

Vacuum systems. Using a Roots type blower system, mounted out¬side the hatchery to supply low pressure, high volume air (500+ cfm at 10 psi) on the suction side is an effective means of transporting hatchery waste. The vacuum system conveys the waste into an outside pressure-rated storage container or silo by means of a 4-inch (10 cm) (preferably) stainless steel pipe. Vacuum systems require filters that must be cleaned regularly; when the filters become clogged, the sys¬tem will shut down. Tightly welded pipe seams are necessary to re¬duce outside air leakage. An oscillating slide gate is also necessary at the entrance of the pipe to allow the negative pressure to build in the pipes to reduce the possibility of clogs.

Positive pressure systems. These systems use a Roots F.15 type blower, as does the vacuum system, except they utilize the positive air pressure side of the system. A 4-inch (10 cm) PVC line designed for 10 psi air pressure is run from the blower to beneath the waste hopper in the chick pulling area or separator, where it is connected to an adapter mounted beneath a 10-inch (25 cm) rotary-type airlock. Four-inch (10 cm) stainless steel pipe is then directed up and out into an open or closed waste container (dump truck, silo, etc.). This type of sys-tem can transport waste as much as 25 feet (7.62 m) vertically and 330 feet (100 m) horizontally.

b Dresser-Rand Company, Steam Turbine, Motor and Generator Division, Wellsville, New York ' 14896. USA.

Positive pressure systems are not prone to clogs and can be easo field assembled with sanitary pipe couplings replacing welds. The are no filters to clean and the waste holding receptacle does not ha to be a raised pressure rated vessel. The primary drawback is th care must be taken not to drbp any metal (tools, water hose ends, etc into the valve as the blades of the airlock can be bent or otherwi damaged. The

airlock valve may still operate but the unit will "bur air out making a mess if there is excessive liquid (yolk / albumen) the system.

Transfer Machines

After the tray washer and waste removal system, this is possibly tt next piece of hatchery automation that should be considered. In additin to increasing hatchability, the machine makes the transfer job easier the transfer crew. Generally speaking, with heavy broiler breeds and corresponding egg size and shell quality, a pneumatic transfer mach which lifts the eggs out of the incubator flats and places them into hatcher tray, will provide a payback in 3 to 6 months.

The increase in hatchability is twofold. First, most exploders or bange (infected or contaminated eggs) will tend to remain in the setter flat, the suction of the individual egg-lifting cup is calibrated to leave eg offering increased resistance in the flats. These cull eggs can then be is lated and disposed of without contaminating adjacent eggs. In additio the machines will reduce the incidence of repetitive motion disorde among workers such as carpal tunnel syndrome.

Second, the manner in which the eggs are gently picked up and th placed into the hatcher tray will substantially reduce the number of tra fer cracks. With a "flip-over" transfer system, it is also possible for e bryos to become disoriented. When using the pneumatic machine, the fa that eggs remain on the same vertical axis in which they have been po tioned for the last 18 days in the incubator will eliminate the possibili of embryo disorientation.

Choose transfer machines that are easy to clean, maintain, and have Si ple controls. Avoid complicated printed circuit boards and off-brand el tric motors or other components that may be difficult to locate when placements are needed.

The smaller, more portable transfer machines are easier to move arou the hatchery and are generally simple to operate and maintain. The chine must be able to fit through doors in the hatchery as the trans should always be done in front of the hatchers. When the eggs are play into the hatcher tray, they should not be moved or handled again.

Once eggs are removed from the plastic incubator flats where each e sits isolated and protected in individual cells, they are vulnerable to cracks checks from movement. Transfer machines, which have pneumatic controls as. well as pneumatic components, offer dependability, and are easy to service. Transfer machines with flip-over tables will not offer the same increase in hatchability as those machines that gently pick the eggs up and place them back down, right side up.

In Ovo Vaccination Equipment

Since 1993, undoubtedly the most popular piece of accessory equipment for a hatchery has been the in ovo (in-shell vaccination of the embyro) vaccination machine. The in ovo vaccination for Marek's disease was used for about 85% of the broilers produced in the

United States during 1999. The machine injects each individual egg at 18 days, at the time of transfer .froni incubator flats to hatcher trays. A pneumatic lift transfer machine, a separate unit, is incorporated into the last stage of in ovo vaccination. In ovo vaccination has been shown to be a very effective means of controlling Marek's disease and heightens the broilers' immune response. While there are other applications planned for the future, at the present time there are few additional benefits with operational costs substantially higher than with chick vaccination.

The costs of equipment rental, necessary extra. doses of vaccine, special sanitation chemicals, and other miscellaneous items necessary for the proper upkeep and maintenance can be high, and many times there are very few economic savings or pay backs. Favorable payback can possibly be accomplished if a hatchery has difficulty training and keeping .trained vaccinators, and increases in workmen's compensation claims for carpal tunnel or repetitive motion disorders occur.

In 1999, Embrex'316 was the only supplier of in ovo vaccination equip-ment in the United States. However, there are several competing machines now on the market in other countries.

Candlers

It may be wise to consider candling equipment to coordinate with the transfer machines or in ovo vaccination equipment. Fertility, especially in broiler breeds, can be lower than a decade ago. Hence, there is a substantial number of clear, infertile eggs to contend with at transfer time. Also, when using in ovo equipment, payment is on a "per egg" basis, and it costs the same to inoculate an infertile as a fertile egg. A candler can be operated in a partially lighted room which will require two operators: one to mark the clear eggs and the second further down the line to remove the marked egg. The use of the second worker prevents the first worker from being blinded by the light emitted from the vacant spots after clear eggs are removed. It may also be desirable in some instances to have the second worker replace the clear infertiles with fertile hatching eggs.

Most hatcheries are not designed to have a 100% hatch because of insufficient oxygen available in the machines. However, there are modifications on the market to enable such hatchers to accommodate a full complement of fertile eggs.

It can be a benefit to remove the clear eggs with or without in ovo vaccination as it will provide more room in the tray, create more uniform temperatures and reduce the overall risk of contamination. There are new ma-chines coming to the market that will automatically candle and remove infertile and other clear eggs. The per hour capacity of these machines is not currently fast enough to provide a reasonable payback. However, as designs improve and speeds approach 75,000 eggs per hour, there will be a market for them.

Chick Box Washers

Commercial washers, dedicated to washing and sanitizing chick boxes, are becoming more commonplace. Placed in or near the receiving area of the hatchery, where boxes can be washed before re-entering the chick room, enhances biosecurity in the hatchery. There are also machines available that wash boxes and return them to the operator, allowing the worker who unloads the chick delivery vehicle to wash the boxes before returning them to the chick room.

Buggy/Rack Washers

A washer is needed for "roll-in" incubator racks to thoroughly clean these units. Once washed, a room must be available to allow the racks to dry thoroughly before taking them back to the egg room for reloading. The same washer can be used to wash the farm racks before they are re¬turned to the farms.

Chick and Eggshell Separators

While these machines can represent the most expensive piece of automa-tion in the hatchery, they can have a rapid financial payback. There are two basic types of machines available. The first uses a design that has been around for 25 years or more with a wide traveling roller conveyor bed of oscillating stainless steel round tubes measuring approximately 1. inch (2.5 cm) in diameter. The contents of the trays (chicks, shells, eggs) are tipped onto the conveyor or onto a belt conveyor which then transports the chicks, eggs, shells, etc. to the separating roller conveyor. As the birds spread out across these oscillating rollers, they fall through the opening between the rollers to a belt or rod conveyor, which removes them from the machine. This process separates the chicks from the unhatched whole eggs and larger eggshells, as they are transported to the waste removal system.

The overall length of the traveling roller conveyor systems can be as much as 30 to 40 feet (9 to 12 m), and requires substantial horsepower. In addition, the stainless rollers can become fouled with broken egg matter, especially from older flocks producing thin shells. A hot water cleaning system followed by a dryer is 'necessary to clean the rollers as they return to the tipping end of the machine. These cleaning machines are generally very large and can be expensive to maintain, clean, and operate. They also require a relatively large amount of electrical power.

The second type of separating machine employs a stationary grid of similarly sized (1-inch or 2.5-cm) stainless steel round tubes which oscillate. The tray contents are tipped onto a vibrating grid perpendicular to the tubes; the birds fall through to a rod conveyor which removes them from the machine while whole eggs and large shell pieces are conveyed along the oscillating tubes and fall off the ends. This type of machine has fewer moving parts, bearings, and other high maintenance components. These separators are considerably smaller and simpler and are easier to clean with lower maintenance.

Both types of machines efficiently separate the chicks from the shells at similar operating speeds, with the .waste product going into a collection hopper where it is removed from the

building by means of an offal or waste removal system. Various types of blower and vacuum systems are used to remove the remaining pieces of shell from the conveyors as the chicks are moved toward the processing room. As a precaution, avoid ma-chines with complicated cloth or paper filtration systems, or units that use vacuum systems requiring more than 2112 horsepower.

Some separators are available with manual tipping, where the operator dumps the contents of the tray onto a belt conveyor or onto the separator conveyor system itself. These machines separate the contents of the trays, but generally cannot be upgraded or improved to an automatic tipping system.

A "semi-automatic" version where the operator places the tray onto a conveyor system or into a tipping cage is also available. The machine then tips the tray after which the operator manually loads it into the washer, Or a machine may convey it to the tray washer automatically. When choosing a manually tipping unit, attempt to find a machine that can be easily tipgradcl "co a semi- or fully automatic unit at a later date without substantial rerriod'eling.

Remember that chick and eggshell separators are high maintenance items and thus will malfunction. Make sure that replacement parts are readily available (off-the-shelf, if possible) and are designed in such a wa that they can be easily replaced. Machines utilizing interchangeable driv and motors are preferred so the required number of spare parts can be reduced.

For extremely large hatcheries (two million chicks per week and abov dual automated lines should be considered, so that in the event of a brew down, one of the two lines will still function and allow birds to be pro cessed and delivered to the farms in a reasonable amount of time. It is tremendous chore to pull 400,000 to 500,000 chicks by hand when a separ for is not operating for lack of a spare part.

Hatcher Tray Destackers

When connected to a fully automatic separator, a hatcher tray destack will allow the operator to load it with a full cart of hatchet trays, whe they can be fed automatically into the chick separator. It is wise whe using destackers to have an operator nearby to clear jams or hang-ups order to keep the line operating at full speed. While the actual worklo can be reduced, the labor required to operate the separator, with or with out a destacker, will be about the same. When clean-up time and mainte nance are included, a destacker may actually increase the operating cost

When calculating payback it is necessary to include maintenance ma hours, cost of replacement parts, clean-up time, plus the cost of the work who is still needed to operate the equipment.

Vaccinating/Sexing/Grading Systems

Hatcheries using needle-vaccination after hatch versus in ovo vacci tion require some type of belt conveyor or carousel system. Such syste may also be needed if feather- or color-sexing and chick grading are quired. The most popular systems are either carousels or in-line belts.

- *Carousels*. These round conveying systems are very pop- ular because they hold a large number of birds, are eas-. ily available for the chick processors to work (sexing, vaccinating, grading), and because they are round the birds cannot fall off the ends. They allow the cull chicks and shell pieces to accumulate where they can be eas¬ily removed. They do, however, require a substantial amount of space in a large room.

  Carousels are available with cone units for the chicks to be dropped into a funnel-shaped cone in the center. With the cone, chicks are allowed to gently slide down to a belt conveyor that moves them to the next work area. Carousels are also available with chutes for drop-ping the chicks straight down to circular conveyers that move around the perimeter of the units and then move birds to another belt for conveying to the next area.
- *In-Line Belts*. As an alternative to carousels, a variable speed belt drive controlled by a foot switch can be used. The birds move down the length of the conveyor and are processed (vaccinated, sexed, graded, etc.) and dropped into a chute or tube to a waiting chick box. At a preset quantity (100 / box), an audible alarm or light is acti¬vated and the box is moved to a full box conveyor. These systems allow the manager to observe the productivity of the operator. Also, spray dye markers can be added to the individual chutes to show which operator processed the birds. Also, these conveyors do not require as much space as carousels.
- *Automatic Hand Vaccinators*. Automatic hand vaccinators are available from several manufacturers and are used around the world. The operator picks up each chick from the carousel trough or the conveyor belt and its head is placed against a locating block on the vaccinator which correctly aligns the machine's needle to the back of the birds neck. Sometimes a dye is placed in the vaccine to show when the needle has missed its mark. Pneu-matically operated vaccinators are recommended as they can be thoroughly cleaned without harming the machine's components. A well-trained worker can vac-cinate from 2,000 to 3,000 birds per hour. Unfortunately, this job is recognized as the number one cause of repettive motion disorder or carpal tunnel syndrome among hatchery workers in North America and thus was the motivating factor for the introduction of in ovo vaccination.
- Robotic Automatic Vaccinators. These machines are more complicated (and more expensive) as they automatYtally beak trim using a laser needle and spray vaccinate each bird with exacting accuracy. The chick's beak is placed in a hole, at which time the machine automatically takes over. These robotic machines can process approximately 4,300 chicks per hour.

- *Beak Trimmers*. Although at one time a standard hatch¬ery practice, beak trimming is no longer performed on day-old broiler chicks. However, male breeder chicks are beak-trimmed and de-toed in the hatchery. Beak trimming is generally done with a machine which cauterizes the end of the beak with a red-hot blade.

Chick Belt Conveyors

Care should always be taken when considering belt conveyors (or other systems) for moving baby chicks in the hatchery. Many times when part of a turn-key automation package, their design and reliability are over¬looked or possibly taken for granted which can cause problems later.

Chick Counting and Boxing Systems

Unheard of 15 years ago, these machines are currently very popular in hatcheries around the world, especially with the use of in ovo vaccntirig :` equipment. The chicks move through a series of ascending speed belt cdri veyors. Then as chicks tend to spread out as they go from the slower to the faster belts, the chicks are counted with an electronic eye and gently dropped into a chick box.

While there can be substantial variations in accuracy, an acceptable (and achievable) accuracy is + or — 3 chicks per stack of 10 chick boxes with 100 chicks per box.

Determine the spare parts needed and availability before choosing a counter. When a counter breaks down, it will be difficult to get the birds counted manually and shipped out in a timely manner.

Chick Box Destackers, Turntables, and Restackers

To automatically feed and position empty boxes under the chick counter, a chick box destacker can be used. These accept nested stacks of empty chick boxes, generally 25 to 30 per stack and feed one box at a time to the counter. A strong individual is required to load the stacks of empty boxes onto the destacker holding area. When the destacker jams or breaks down, the counter, separator, and tray washer will also shut down until the chick counter has a supply of empty boxes.

If a restacker is to be used at the end of the chick counter system, a turntable will be required for chick boxes used in North and South America, as these boxes nest in one direction and stack when every other box is rotated 180 degrees. Rotation must occur prior to chick counting in order to avoid crushed chicks at the restacker,

Along with a totally automated chick processing system, consideration may be given to a chick box restacker which stacks the boxes prior to loading chicks for transport to the brooder house. There are several drawbacks to restackers:

No chick culling. When the chick processing room is totally automated, there is little opportunity to remove dead or obviously poor quality chicks. This can cause problems including contamination and grower discontent.

Economic payback. At typical wages paid in North America, it is difficult to realize a payback for destackers or paper padders.

Increased maintenance costs. When calculating payback on any item of equipment, it is necessary to compare the differences in salaries of the chick room workers the equipment replaces with the higher salaries of the maintenance men, welders, and electronic technicians that will be necessary to keep the machinery operating properly. The cost of cleanup, depreciation, and spare parts must also be included.

Paper Padder

Paper padders cut and place a sheet of paper into each chick box to prevent chick leg injuries on the slick box surface. In order to supply chick boxes with paper in place and ready for filling at the chick counter, a paper padder is required. Care must be used when calculating payback of the padder. Things such as wasted paper, clean-up time, preventive mainte¬nance time, and replacement parts, and upkeep must be considered. Also, if this piece of equipment breaks down, the entire line, including the count¬ers, separator, and tray washer will also stop until the boxes can be manually padded or the machine is repaired.

Chick Box Conveyors

Most of the chick counting systems on the market use a gravity flow system of conveyois to separate and count baby chick boxes. Hence, the boxes must be conveyed back up to a proper ergonomic work height be¬fore a worker picks them up.

Spray Vaccinating Systems

Several commercial spray vaccinators are available which direct the vac-cine spray as a fine mist across full boxes of chicks. A choice can be made between a manually triggered hood, which will spray a box of chicks when the worker places the box under the hood, or an automatic unit that sprays the box as it passes underneath or through a hood. These are commonly used for Newcastle/bronchitis vaccinations. Sometimes the spray hoods will be made available by the vaccine manufacturer a t on charge. Determine what is available in your area.

Plastic Chick Boxes

Most hatcheries use a stacking / nesting single compartment box th holds 100 chicks. Two different types are found in North and South America. The European industry tends to use non-nesting smaller boxo that hold 80 birds. Hatcheries, which sell chicks, sometimes use four co partment or single compartment, disposable, cardboard boxes. Some other breeder companies also use four compartment boxes to prevent th birds from crowding. This

is especially true of male breeders. Remember that four compartment boxes are difficult to evenly fill with automatic chick counters.

Chick Box Dollies

Open framed dollies or carts should be used for stacked boxes. Thi allows for additional ventilation through the box. It is no longer reco mended to store boxes on fixed racks.

High-Pressure Pumps

High-pressure, cleaning systems are necessary to thoroughly clean man areas in the hatchery. A central high-pressure pump with outlets statione throughout the hatchery will considerably reduce overall clean-up tim Portable units are also available.

Central and Portable Disinfectant Fogging Systems

Central fogging systems with a central pumping station provide an e cellent and effective means of dispensing disinfectants in the setters, hatc ers, and various hatchery rooms. They are operated with automatic tim that program the fogging of certain rooms or machines at various pre-times. For the sake of safety, rooms where workers may be present sho be fogged during the evening hours when there are no employees prese

Computer Software Programs

Various software programs specifically designed for hatchery management and for controlling the heating, ventilation and air conditioning systems, and the incubators are now available. When reviewing programs, the operator must determine whether it is to be used for accounting purposes or for technical management. Programs with both features are not currently available. Look for programs that will save manpower and time when summarizing data that are pertinent to the operation of the hatchery. It is advisable to choose a program that can track a chick's history from pullet flock, breeder flock, egg collection date, arrival at the hatchery; set and transfer dates, to placement time and location.

It is also an advantage when the software can accept data down-loaded from Programmable Logic Controller (PLC) controls on chick counters and separators and integrate it with the information such as how many chicks came from each flock and from which hatcher. There are programs avail-able that can operate and maintain the heating, ventilating, and air conditioning (HVAC) systems as well.

Monitoring Instruments

Monitoring instruments are valuable tools for measuring various parameters in the hatchery (temperature, humidity, specific gravity, air-flow, speed, etc.). With the technology incorporated in today's hatchery, it is wise to have the following instruments on hand:

- Digital thermometer with instant reading capabilities
- Digital hygrometer with instant reading capabilities (relative humidity)

- Digital anemometer with averaging capabilities (air velocity)
- Digital (3 digit) multimeter (for reading volts, amps, ohms)
- Master-certified mercury thermometer [95 to 101°F (35 to 39°C) with 0.1° increments]
- Carbon dioxide sampler
- Hand-held egg candler (fertility check)
- Digital infrared thermometer (sold for measuring chil-dren's body temperature in the ear) or taking embryo temperatures (see Factors Affecting Hatchability, Chapter 39-D).
- Hydrometer (specific gravity)

38
Maintaining Hatching
Egg Quality
by Joseph M. Mauldin

The quality of the hatching egg cannot be improved after lay. From the time of lay until it is set in the incubator the best strategy is one that will retard any loss in hatching egg quality. There are a number of biological, physical, and environmental factors which can influence the quality of hatching eggs.

38-A. MAINTAINING EGG QUALITY IN THE BREEDER HOUSE 1. Nesting Material

Use ,enough clean, dry, and mold-free nesting material to avoid cracked and dirty eggs. Nesting material provides a cushion for the eggs and when it is insufficient, many eggs can be broken by the hens. With wet litter conditions, the nesting material will soil rapidly, and will contaminate the hatching eggs. Wet litter will also reduce air quality and increase respira¬tory disease. A good practice is to replace or add nesting material as needed during egg collection and to remove wet litter from 'the floor.

Nesting material should be absorbent, durable, and coarse so that it will not be easily blown or scratched out of the nest. Other qualities to look for in nesting material include low in dust, high in porosity, cushioning qualities, and to be inexpensive. Common nesting materials include:

wood shavings
dried sugar cane pulp peat moss
rice hulls
extruded volcanic ash chopped corn cobs straw or hay
excelsior -pads

peanut hulls artificial grass pads
carpet remnants shredded paper
sawdust
2. Training Birds to Use Nests

Early training of hens to lay in the nests, whether conventional or m chanical, is essential to prevent contamination and to reduce the incideric of cracked eggs. Open the nests one week prior to the expected first eg, and make sure that there is sufficient padding or nesting material in t

nests. Caretakers should walk the slat and litter areas frequently durirk the first few weeks of production, remove floor eggs, and encourage he to move toward and recognize the nests. Wood shavings or other nesting materials may be used in mechanical nests with artificial nest pad:. to encourage hens to use the nests., These materials should be remove when egg production reaches 25 to 35%. Other training tips include:

a. Locate the lowest perch no more than 27 inches (69 cm) above the litter.

b. Place the nests in the house before the time pullets are housed at the breeder farm.

c. Put the nesting material in the nests at the time they are first placed in the house. Check the nesting material ev¬ery two or three days and remove fecal material. Hens may refuse nests that are soiled, dusty, or dirty.

d. Make certain the nesting material is adequate to provide sufficient cushioning to entice the hens.

e. Provide a well-ventilated breeder house environment so that the nesting material and floor litter remain dry. Also, clean up water spills and repair leaking drinkers at once. Dryness and quality of the litter floor influence the con¬dition of the nest litter.

f. Provide one nest for every four hens with conventional nests and one nest for every five to seven hens with me¬chanical nests.

g. Pick up the floor eggs six to eight times per day when the birds first start to lay. The sight of a floor egg is a visual cue to the hen when she is searching for a nesting site.

h. Nest boxes should be checked for stray electrical voltage, especially if they are mechanical nests. The local power company should assist with this testing.

38-A. MAINTAINING EGG QUALITY IN THE BREEDER HOUSE 709

3. Hatching Egg Collection

The frequency of hatching egg collection is very important to main- taining quality. This is especially true in extreme weather (hot or cold) conditions. Most published reports suggest that hatching eggs should be coliected a minimum of four times per day with conventional nests. How-ever, in practice, most producers collect their eggs only three times per day. The typical flock lays most of its eggs in the morning. In practice, some eggs would have been laid only a few minutes before collection while others may have been in the nests three or four hours. This time difference is important as older eggs may have been subjected to preincu¬bation by subsequent hens which causes variation in incubation time and subsequently hatch time and possibly chick quality. With mechanical nest-ing, it is typical for the producer to run the egg belts almost continuously when most of the eggs are being laid during the morning hours, then run the belts again in mid-afternoon, and finally, at 5:00 p.m. to collect the remaining few eggs.

Hatching eggs are susceptible to contamination and every effort must be made to reduce this potential. Therefore, it is imperative that people wash and sanitize their hands before collecting eggs from the nests or egg belts. The flats that eggs are placed on must also be sanitized and free of organic material.

4. Hatching Egg Containers

Plastic flats are the best hatching egg container for at least two reasons. First, the eggs must be cooled to proper storage temperatures, in the range of 55° to 67°F (13° to 19°C), as soon as possible after collection. In plastic flats the eggs are exposed to the circulating air in the storage room and will cool faster than eggs in fiber flats. Second, because eggs have more exposed surface area with plastic flats, they can be sanitized more easily than with other types of flats. Plastic flats are ideal for fumigation, mechan¬ical hatching .egg washing, and spray sanitizing. In most cases, the flats on which eggs are collected will be used in the incubator. This eliminates labor costs associated with transferring eggs to incubator flats, as well as reduces the opportunity for cracks and breakage.

Paper and fiber flats are readily available in the poultry industry but have weaknesses as hatching egg containers. These flats cannot be sani-. tized and therefore are a potential source of contamination or recontamina¬tion. They can hold dust, dirt, shavings, fecal material, and feathers which are all potential sources of hatching egg contamination.' If fiber flats must be used they must not be reused, but rather discarded after their first use, which normally makes them cost-prohibitive.

710 MAINTAINING HATCHING EGG QUALITY

Wire baskets have been and are still being used for collecting hatching eggs. However, their use is not recommended as cracks occur when eggs are piled on top of each other in a rigid wire container. Also, eggs must be transferred into egg flats for transport to the hatchery, creating another handling resulting in additional cracks. Each time eggs are handled, at least a' 1% increase in cracks is expected. •

38-B. HATCHING EGG SELECTION

In general, hatching eggs with poor shell condition do not hatch as well as those with good quality shells. Eggs with moderate to severe shell de¬fects should be culled upon collection rather than sending them to the hatchery. Those with minor defects should not be culled in the selection process. It is up to the person doing the selection to make judgment calls as to the degree of shell imperfection and whether it should be culled.

Eggs closest to the ovoid shape hatch best. Excessively long, thin, or completely round eggs do not hatch well. Other defects including wrin¬kles, hair-line cracks, toe-punches, pointed ends, dark tops, calcium depos¬its, etc. exhibit reduced hatchability. Table 38-1 shows the results of incu¬bating various classifications of cull-hatching eggs.

Most cull eggs are also more easily penetrated by microorganisms than normal hatching eggs, and if they explode or break during incubation they can contaminate hundreds of other eggs in the incubator environment.

There are many types of defective eggs that should be culled during hatching egg collection at the breeder farm. Their causes are numerous-and must be. understood in order to reduce the number of cull eggs reach¬ing the hatchery.

Table 38-1. Hatchability of Abnormal Broiler - Breeder Eggs

Description of Abnormality	Reduction from Normal 0/0
Misshape (slight deviations due to ridges)	8.9
Slightly round	10.7
Small (<50 g; <21 oz/doz)	11.5
White (no pigment)	24.6
Obviously round	26.1
Pimpled (rough shell)	55.1
Wrinlded (obvious)	61.2
Dark top (rough area)	66.3

38-B. HATCHING EGG SELECTION 711

1. Mechanical Factors

Inevitably, some hatching eggs will become dirty, stained, cracked, or punctured in the breeder house. It is essential to follow the good nest man-agement practices given earlier.

2. Biological Factors

The physiological condition of the hen can affect the quality of the eggs she lays. Stress and certain diseases affecting the oviduct and ovaries, i.e., bronchitis and IBD, may cause thin or wrinkled eggshells and erratic ovu-lation. Early maturing pullets lay more defective eggs than when sexual maturity is delayed. An added advantage of delaying sexual maturity is an increase in egg size at the onset of lay. Feed the hens a diet adequate in protein, calcium, phosphorous, vitamin D, and other nutrients. When shells_ appear thin, calcium may be added in the form of crushed oyster shell or large particles of limestone. The source of calcium is important because of its solubility. If a source of calcium is low in solubility, thin shells may result even though dietary calcium in the ration is sufficient.

The iii.Wence of defective eggs is also influenced by heredity. Certain types of defective eggs, such as those produced by erratic ovulation, have a strong genetic basis. Nevertheless, in most cases good management will minimize the incidence of defective eggs.

When an egg is delayed in the shell gland, two types of defective eggs will be formed: the first egg will be extra-calcified and the second egg will be slab-sided. The slab-sided egg has a circular, smooth area surrounded by wrinkled shell. The smooth circular area is the imprint of the first egg which has been delayed in oviposition. Unfortunately, the extra-calcified eggs are difficult to distinguish from normal eggs, and they do not hatch well because of the increased shell thickness which reduces the necessary gaseous exchange capacity between the developing embryo and its outside environment. Discard all slab-sided and extra-calcified

eggs from hatchery deliveries. To reduce the incidence of this problem, make sure that the hens do not become overweight or unduly stressed.

Erratic Ovulation

Erratic ovulation is the major biological factor causing defective eggs. Erratic ovulation occurs when more than one ovum or yolk is released from the ovary into the reproductive tract in less than 25 hours.

Occasionally, hens are stimulated to lay eggs before the 20 hours re- quired for shell deposition in the shell gland. When this happens, membra-nous or soft shell eggs are laid. Double- and triple-yolked eggs are also found when two or three ovarian follicles rupture simultaneously, send' two or more yolks into the oviduct.

3. Other Types of Defective,Eggs (see Shell Egg Quality and Preservation, Chapter 60)

Body checks. Body checked eggs occur when the shell is cracked whit in the shell gland. In this case, additional shell will be laid down o top of the cracked shell, repairing the egg to some degree before it laid. The majority of body checked eggs occur when hens are di turbed during the early to middle stages of shell formation when th shell is still quite thin. This usually happens in the late afternoon o early evening. Avoid management practices that disturb hens burin this period. Strains of birds that are excitable tend to have a highe incidence of body checks than more docile strains. More body checks may also occur when hens have to jump too high or fly to reach the

nest or slats.

Wrinkled shells. Wrinkled shells are usually the result of a damage shell gland. A small percentage of wrinkled shells will appear in the flock after an incidence of respiratory infection. Although infectious bronchitis is a respiiatory infection, it sometimes localizes in the shelt gland. Irreversible damage occurs to the shell gland, and the affected hens will continue to lay eggs with wrinkled shells and odd-shaped eggs throughout the duration of their productive life.

Pimples or calcium deposits. Pimpled eggs or calcium deposits are an,' other form of extra-calcification, and are the result of "calcium seed¬ing" during shell formation. Severe examples should not be used for hatching.

Over and undersized eggs. Cull all body checked, wrinkled, pimpled, and over or undersized eggs. They are likely to become cracked dur¬ing handling, and are susceptible to dehydration and contamination. Eggs that are over- or undersized may not qualify as defective eggs, however, they should not be sent to the hatchery. Odd cases of defec¬tive eggs are sometimes found, such as an, egg without a yolk or a normal egg within another shell or membrane. Generally, these will be either over- or undersized, and should be selected out. A hatching egg selection poster has been published that presents color photo-, graphs of examples of cull eggs that should be eliminated from hatch¬ing egg shipments (Mauldin, 1989).

4. Shell'Color and Thickness

better than those with lighter shells. However, it is inadvisable to routinely remove lighter eggs as they hatch almost as well as dark eggs and they are not a liability to sanitation.

Eggshell thickness is also an important factor when considering hatch-ing egg quality. Few eggs with a shell thickness below 0.27 mm will hatch. For best results, the shell thickness should be between 0.33 and 0.35 mm. Unfortunately, thickness cannot be measured without breaking the shell. For this reason shell thickness cannot be a factor in the hatching egg selec¬tion process. ,However, when problems occur with shell quality it may be advisable to break a sample of eggs to measure shell thickness.

5. Evaluation of Shell Quality (see Shell Egg Quality and Preservation, Chapter 60)

It has been well documented that poor shell quality adversely affects hatchability. Age of flock, stress, disease, and marginal nutritional defi-ciencies have strong negative influences on shell quality. Shell quality is typically high in eggs from young flocks, and rapidly declines during the later stages of production. Stressors can include poor management, crowd¬ing, temperature outside of the comfort zone, vaccine reactions, improper beak trimming, etc. Any disease affecting the reproductive tract will also lower shell quality. Restoration of shell quality in a breeder flock may de¬pend on improved management or treatment of disease rather than forti¬fication. of rations.

Shell quality may be assessed in several ways. Poorer shell quality is apparent when increased percentages of eggs are found with cracks, rough or misshapen shells, shells with ridges or• sandpaper ends, and body checks. Shell quality can be assessed by measuring shell thickness, break¬ing strength, deformation, porosity, shell shape, smoothness, and'specific gravity.

Testing specific gravity (SG) is not a difficult quality control procedure to implement, and is frequently the test of choice for measuring, shell qual¬ity. The best compromise between accuracy and time efficiency to obtain reliable estimates of shell quality is to prepare three saline solutions with specific gravities of 1.075, 1.080, and 1.085. The saline solutions may be accurately prepared with the use of a hydrometer. Table 38-2 determines approximate salt and water quantities necessary. The temperature of the solutions and eggs must be maintained at 65°F (18.5°C) to ensure the accu¬racy of the testa This procedure is most accurate when freshly laid eggs are used. On average, eggs will lose about 0.001 SG per day of storage, but this jOughly variable.

Dip eggs into the 3 saline solutions beginning with the lowest specific gravity; count and remove the number of eggs that float in each solution.

Table 38-2. Amount of Salt Needed to
Produce Specific Gravity Solutions

Pounds_of Salt per	Grams of

Specific Gravity 1'2	4 Gallons of Water'	Salt per Liter of Water3
1.075	2.6	65
1.080	4.0	100
1.085	4.1	102

' Perform SG at 65°F (18°C)

2 A hydrometer must be used 'Distilled water is recommended

For example, if you have 100 eggs and 20 float in the 1.075 solutions, 40 in 1.080 and 40 in 1.085, the average specific gravity is calculated as 1.081.

When an egg does not float in the 1.085 SG solution, classify it as 1.090. Flock averages below 1.080 generally indicate poor shell (polity. Iff case, consult a nutritionist and / or add oyster shell. The age of the hens is the largest determining factor for shell quality with younger hens having better shell quality than older hens.

6. Cracked Eggs (see Egg Handling and Egg Breakage, Chapter 56)

In a study of commercial hatcheries, it was found that up to, 2% (in some cases more) of all eggs set were cracked prior to hatching. On average, 1.1% were cracked at the time of set and 0.9% were cracked at transfer. Cracked eggs result in a significant economic loss, and therefore, care must be taken when eggs are handled to reduce shell damage. Mechanical trans¬fer machines have been shown to reduce the number of transfer cracks, especially those machines that lift the _eggs from the setter flats and,place them with the large end up into the hatcher trays.

7. Interior Quality

The interior quality of hatching eggs is another determining factor of hatchability. The average interior egg quality of a flock maybe determined by breaking out a sample of freshly laid eggs and measuring the Haugh units. Best hatches are obtained when the average Haugh units exceed 80. The Haugh units decrease during storage because of a loss in albumen viscosity and carbon dioxide and a corresponding increase in pH.

The incidence of tremulous (floating) air cells will lower hatchability.

38-C. REDUCING CONTAMINATION OF HATCHING EGGS 715

dome.eggs are laid with tremulous air cells while others develop 'them when jarred or roughly handled.

38-C. REDUCING CONTAMINATION OF HATCHING EGGS

Poor hatching egg sanitation can be a major cause of lower hatchability and poor chick quality. Every effort should be made to ensure that hatch-ing eggs are kept free from risks of contamination from the time the eggs are laid until the chicks are delivered to the growers.

There is no such thing as a sterile eggshell. Even eggs removed from the oviduct will have some bacteria. More bacteria are picked up on the shell when the egg passes through the

cloaca where urine and intestinal contents also pass. The bacterial load found on an eggshell at the time of lay ranges from 300. to 500 organisms. After oviposition, every surface the egg_comes in contact with can further inoculate the shell surface. In con-ventional nests, it is very important to maintain clean nest litter to prevent further contamination. Periodically remove fecal material from the litter and add fresh litter. The condition of the floor litter will also influence the amount of filth hens bring into the nest on their feet. Eggs laid on the floor can have thousands of bacteria, even if the shell appears clean. Table 38-3 shows the relationship between shell surface contamination and subse¬quent two-week chick mortality. Slightly soiled eggs resulted in more than twice the chick mortality while dirty eggs experienced more than four times the chick mortality compared to nest-clean eggs. After an egg is laid it begins to cool. During the cooling process the egg contents begin to shrink producing negative pressure. This is one of the more opportune times for bacteria on the shell surface to penetrate the eggshell. Therefore, it is imperative that the eggs be moved to cool storage as soon as possible after lay.

The Natural Defenses Against Bacterial Penetration

The egg has many natural defense mechanisms to reduce bacterial pene¬tration. The shell itself provides some protection. Although the normal

Table 38-3. Eggshell Contamination and 2-Week Chick Mortality

Egg i Condition	Total Bacteria	Coliforms	2-wk Mortality (%)
Nest clean	600	123	0.9
Slightly soiled	20,000	904	2.3
Dirty. \	80,000	1307	4.1

Table 38-4. Shell Quality and Bacterial.Penetration of Eggs

Specific Gravity of Eggs	Shell Quality	Bacterial Penetration of Shell After 30 min	After 60 min	After 24 hr
1.070	Poor	34	41	
1.080	Average		18	25
1.090	Good	11	16	

Source: Sauter and Petersen, 1979

eggshell will have about 8,000 to 10,000 pore openings, most of the .por are too small in diameter for bacteria to penetrate. However, there pores large enough to accommodate penetrating bacteria. Shell quality a thickness are two very important factors which affect

penetration. search has shown that shell quality and thickness have more influence th storage time in the rate of bacterial penetration of the.eggshell (Table 38

The cuticle on the surface of the eggshell is the best natural .barrier penetration. However, there is variation in cuticle thickness even on ti same egg and the ability of organisms to penetrate varies according cuticle thickness. The inner and outer shell membranes provide additio barriers. Many times bacteria will penetrate the pores of the shell and trapped between the outer and inner shell membrane and cannot mo further. This is no consolation because these bacteria can infect the embr as it pips through these membranes and the shell during hatching. P1 after hatching, healthy chicks are exposed to these infected membranes the hatching trays. The albumen provides a somewhat effective cont over contamination. The albumen has a high pH in which most bacte cannot survive. The chalazae contain an enzyme, lysozyme, which has.a tibacterial properties. The yolk membrane (vitelline) will not prevent b terial contamination.

Methods of Sanitizing Hatching Eggs

Management that encourages the production of clean nest eggs is pro bly the best form of hatching egg sanitation. Many companies and prod ers choose to go the extra step by providing other means of sanitati. Whichever method is chosen, the critical factor is time. Bacteria have be reported to penetrate the shell in less than 30 minutes after lay.

Sanding, buffing, and wiping hatching eggs are, not good methods sanitation. Sanding and buffing will remove at least part of the cuti resulting in eggs that are more susceptible to penetration. The sand process itself may actually grind the bacteria further into the shell.

general rules for sanding, buffing, or wiping are (1) never exceed one wipe to remove material on the shell, and (2) if possible, don't do it at all.

Fumigation with formaldehyde gas is an effective method for sanitizing hatching eggs. The procedure requires generating a 3 x dose (4.06 oz. for¬malin and 2.12 oz. potassium permanganate, 120 ml and 60 g, respectively) of formaldehyde in an airtight cabinet or room and expose the eggs for 30 minutes. Formaldehyde provides excellent bacterial kill on contact and it is very easy to fumigate a large number of eggs at a time. One of the disadvantages of formaldehyde fumigation is that in many cases it cannot be administered as soon after lay as some other methods of hatching egg sanitation. Another disadvantage is that its use is now restricted in the United States by the Occupational Safety and Health Administration (OSHA) as a possible carcinogen. Other countries, as well, are beginning to restrict the use of formaldehyde. Hatching eggs may also be fumigated with ozone provided by ozone generators. Although ozonation has been shown to be somewhat effective, it is not as effective as other methods of egg sanitation, unless used in conjunction with the perioxy perfusion pro¬cess which is discussed later..

Hand spraying hatching eggs with a disinfectant is sometimes a moder¬ately effective measure. Solutions containing quaternary ammonia, forma¬lin, hydrogen peroxide, mixtures

of quaternary ammonia, and formalin or phenols have been used for egg sanitation. Some of the drawbacks of hand

o spraying include low pressure and thus, incomplete shell surface cover

, age, very little cleaning, and no temperature control of the disinfectant.

All disinfectants work better when the solution temperature is high

)1 (>110°F or >40°C). Additionally, those eggs with adhering organic matter

is are not properly sanitized with hand spraying.

.A few decades ago, immersing hatching eggs in a vat with heated disin-fectant was used for sanitation. Although the procedure was shown to be very effective it did not work well on a mass basis. Many producers who tried this did not change the solutions frequently enough and caused more contamination than they prevented. The recommended time of immersion was five minutes and there were many instances when the eggs were left in the tank too long resulting in elevated yolk temperatures causing prein¬I a- cubation and lower hatchability. Leaving them in the disinfectant solution

too short a time resulted in inadequate sanitation. Lack of proper tempera-)n, tore control of the dip solution was another major drawback. After re-...peated immersions, the temperature of the solution would fall to ineffec¬tive levels. In short, immersion dipping proved to be a very ineffective method, and was even harmful in some cases resulting in a bias against cl hatching egg sanitation in the United States. However, immersion dipping,

if accurately monitored, is very effective. There are parts of the industry

where it is still in use as an effective sanitation procedure. It appears to

be more effective when sanitizing the more expensive eggs such as those

from turkey and primary breeders. The reason for its success in these situa

tions is probably due to the extra care in the implementation that the mo expensive eggs require.

Mechanical Spray Sanitation of Hatching Eggs

The turkey industry has been using mechanized spray sanitation hatching eggs for many years. Mechanical egg washers are able to avoi the pitfalls (improper solution temperature, poorly timed exposure, an old disinfectant solutions) commonly experienced with immersion di ping and hand spray applications. Earlier models of mechanical egg was ers only sanitized one egg at a time and used brushes to aid in the cleanin process. The broiler hatching egg industry has been reluctant to try in chanical egg washing because:

1. a bias against wetting the egg even with a disinfectant due to earlier problems with immersion dipping

2. washing one egg at a time is not time-efficient in broiler breeder flocks where many more eggs are produced each day than in the typical turkey and primary breeder house

3. the value per egg of broiler hatching eggs is much less than with turkey and primary eggs

4. the fear of removing the egg's cuticle protection with the brushes

The turkey industry favors hatching egg washing which offers some degree of cuticle removal with the washing brushes. This has also pro¬vided for more moisture loss and improved hatchability during incuba tion. The broiler hatching egg industry has not shown a benefit due t cuticle removal.

Currently, there are several models of mechanical egg washing ma-chines that can wash one plastic flat of eggs at a time and without the us of brushes. These machines have conveyors which are wide enough for plastic flats to pass through the wash and spray cycles. The spray is pro vided by nozzles placed above and below the egg flats. The temperatur of the wash solutions are precisely maintained during washing (the m chine will automatically stop when the temperature rises above or fal below the desired temperature range). The typical hatching egg washin machim will have at least two liquid tanks, the first containing a was solution with a sanitizer such as chlorine or hydrogen peroxide, and t second will contain a disinfectant such as quaternary ammonium, pheno or hydrogen peroxide. In the first tank the wash solution (temperatur 111°F; 44°C) is recycled after filtering and the metering in of an addition

sanitizer. In the second tank (temperature 118°F; 48°C), there is no recycl-ing, only a fine mist spray of the disinfectant solution.

These 'machines provide convenient washing for hatching eggs as flats of eggs can be sanitized immediately after collection and loaded directly into hatching egg buggies before being moved to the egg storage room on the farm. They work well with both conventional and mechanical nesting systems. Nest clean hatching eggs are passed once through the machine. Very few eggs will be more than three hours old at the time of sanitation, a considerable advantage. Each day, after the last collection of eggs has been run, most of the floor eggs can be salvaged by passing them through once at a slower speed and then a second time at high speed. Floor and dirty eggs showing no adhering debris after washing can be sent to the hatchery as hatching eggs. In a 12,000 hen broiler /breeder flock field study in Georgia, salvaging most of the floor eggs through mechanical egg wash¬ing resulted in an additional case of hatching eggs being sent to the hatch¬ery each week. Floor and dirty eggs are normally sold as commercial eggs with a value of about $5.70 per case while a case of hatching eggs is worth about $37.00 per case. During 40 weeks of production, salvaging an extra case of hatching eggs per week resulted in more than $1,000 in additional net income for the contract grower. The main benefit of mechanical egg washing, however, is not to salvage floor and dirty eggs but to improve sanitation of all eggs and flats entering the hatchery.

In a recent field study using a mechanical egg washer, both nest clean and dirty eggs exhibited reductions in shell surface contamination by more than 99% while hatchability when Compared with unwashed nest clean and dirty'eggs remained unchanged (Table 38-5).

Examination of sanitized and non-sanitized eggs when using electron microscopy revealed that very little cuticle loss occurred due to the washing procedure and that yolk temperatures were not elevated.

The main drawback to mechanical egg washing on the farm is expense. For optimum results, a mechanical egg washer would have to be placed bit every,liteeder house. The mechanical egg washer could be used in the

Table 38-5. The Influence of Mechanical Egg Washing on Microorganism Recovery and Hatchability

Treatment	Total Plate Count	Hatchability % Reduction	Hatchability 0/0 of Fertiles
Clean	447	89.82a	
Clean sanitized	2	99.6	91.30a
Dirty	3,631	84.64b	
Dirty sanitized	27	99.3	84.68b

a•b Means with different superscripts are significantly different (P 0.05)

Source: Cox, et al., 1994

hatchery to reduce the expense of purchasing one for each breeder house, but the effectiveness is reduced dramatically because the hatching eggs are a few days old when they arrive at the hatchery and in most instance microbial penetration has already taken place. Some hatching egg bugg washers can be utilized for sanitizing whole buggies of eggs at a time the hatchery. Again, the problem with this is that sanitation doe not ocC early enough.

One incubator manufacturer has developed a process for sanitizin hatching eggs called perioxy perfusion. This process is performed at they hatchery and involves placing several trays of hatching eggs into a charri ber under a vacuum. After the vacuum (negative pressure), the chambe is pressurized With ozone (positive pressure). While under pressure, ozo is taken into the shell killing microorganisms that may be present in shell pores and immediately under the shell

38-D. TRANSPORTING HATCHING EGGS

Hatching eggs should be picked up from the breeder farm a minim of twice each week and transported in environmentally controlled e trucks. For egg pickup and transportation, the main considerations are prevent cracks and to maintain proper temperature and humidity. Whe eggs are transported in cases, proper stacking must also be practiced. Mos eggs are currently delivered to the hatchery on farm carts or egg rac where cracks can easily occur. Smooth concrete walkways should be pr vided for cart transfers at the farm and the hatchery. The egg truck shoul be equipped with locks to hold buggies firmly in place to prevent jostl.

and cracks during transportation. In most cases, the worst jarring eg receive is on the driveway leading out of the breeder farm. For this reaso it is important to properly maintain breeder farm roads.

Hatching egg trucks must be equipped to control both temperature a humidity. Temperature should be kept at 65°F (18°C) and the relative h midity in a range from 60 to 70%.

Eggs shipped in cases by air freight will generally have an increase cracks created from additional handling. Another problem associated Wi any freight is the time required for shipments to reach their destinati and temperature and humidity fluctuations that may occur during sin ment. All of these conditions reduce hatchability.

38-E. HANDLING EGGS PRIOR TO INCUBATION

Hatching eggs are generally 1 to 3 days old by the time they reach hatchery where they are stored prior to incubation. Holding conditi

38-E. HANDLING EGGS PRIOR TO INCUBATION 721

Days
5.00
4.50
4.00 -
3.00
2.00
, 1.50

1.00 1.00

0.00

Sealed Vented Wire Hatchery
Cases Cases Baskets Buggies

Source: North and Bell, 1990

Figure 38-1. Time Required to Reduce Internal Egg Temperature to 65°F from 100°F

along with any handling procedures can have a great bearing on their potential to hatch and produce quality chicks.

1. Hatchery Egg Holding Room Temperature

Temperature in the hatchery egg room should be kept at about 65°F (18°C) to prevent preincubation embryonic development. When eggs must-be stored for a week or longer, it is advisable to reduce egg storage room temperature to 55°F (13°C). The types of hatching egg containers being used (egg carts vs cases) will influence the amount of time required to reduce egg temperatures to the storage room temperature. Figure 38-1 shows the amount of

time required to reduce internal egg temperature from 100°F to 65°F (38°C to 18°C) with different packing methods. Over four days were required for the proper reduction in temperature to occur when eggs were sealed in cases, while less than one day was needed where 'eggg'Were stored on hatchery buggies. This long period required for tem¬perature reduction can be avoided when the eggs are not packed into cases until they have been in the breeder farm egg room at least overnight. Therefore, for transporting eggs in cases, the best practice is to hold eggs in the cooler at least 12 hours prior to placing them in cases.

2. Hatchery. Egg Holding Room Humidity

Moisture from inside the egg is lost through shell pores via evaporation. The rate of moisture loss is controlled in part by the relative humidity of

the air surrounding the egg. When relative humidity is low, loss is greater than when the relative humidity is high. Relative humidity in hatchery egg storage rooms should be maintained between 75 and 80%. Figure M, 2 shows the, optimum environmental conditions for storing hatchin eggs.

Hatchability will be optimum when hatching eggs are held from one t five days. After five days of storage, hatchability begins to fall. The rat of decline in hatchability increases for each day eggs are held after fiv days. Long holding periods not only reduce hatchability but also increas the incubation time. For each day of egg holding longer than five days th incubation time will increase about one hour. Figure 38-3 shows the effect of egg holding time on hatchability and hatching time. Hatchability fall rapidly after five days of storage and incubation time increases by nearl

TEMPERATURE RELATIVE HUMIDITY

(Degrees Fahrenheit)
WARNING 100

(Percent)
WARNING

SAFE
,...(554680
Tempe;r:atv,e,,Icr,the, an: limit of the
safe rogloii,mar induce plcoati.n$=,when 'eggs,-01p-ternoved.
WARNING

Sweating occurs when eggs are moved to warmer locations.

Eggs will freeze, embryos will be killed at temperatures below 32°F.

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Figure 38-2. Hatching Egg Room Temperature and Relative Humidity

38-E. HANDLING EGGS PRIOR TO INCUBATION 723

N te A P$1 N" fro

Days Storage

Stored at 65 degrees F(18 degrees C)

Source: North and Bell, 1990

Figure 38-3. Effect of Egg Storage on Hatchability and Incubation Time

10 hours after 22 days of storage. Long storage times also reduces chick weight and ultimately market weight in broilers.

Plastic bags may be used to prevent rapid moisture loss when eggs are stored for long periods. For further preservation of egg quality,, flush the plastic bags with nitrogen and seal the bag. Hatching eggs stored in this manner will hatch better than eggs stored for the same length of time but without sealed bags containing nitrogen gas.

Procedure for storing eggs in plastic bags:

1. Disinfect eggs with a good sanitizer.
2. Cool eggs thoroughly to 55°F (13°C).
3. Place eggs in plastic bags, flush with nitrogen gas, and seal.
4. Store eggs at 55°F (13°C).

3. Positioning and Turning Eggs During Long-Term Storage

When storing eggs less than 10 days, store them with the large end ui If eggs are held for 10 days or more, hatchability will be improved if stored with the small end up. It is necessary to turn them back over with the blunt end up before setting. For long periods of egg storage, some producers will turn eggs 90° daily. This procedure is questionable, as research shows little benefit from this practice.

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4. Moisture Condensing on the Shell

When eggs are moved from a cold.to a warm room, moisture will condense on the shells which is referred to as egg sweating. This is a par larly hazardous condition since moisture on the shell surface will incr the growth and penetration of microorganisms on the shell. Nest c eggs that have 500 or fewer bacteria on the shell are not considered a s contamination risk, unless they sweat. Unfortunately, it is commo moisture to form on the shells after eggs are

removed from a cool storage room, creating a serious hazard. Following are three suggest that will help reduce egg sweating:

1. If practical, decrease the humidity in the room where the eggs are being moved.

2. Move air across the eggs with circulating fans. A strong airflow will help by evaporating the moisture as it forms. Caution! Never fumigate moisture laden eggs with formalde¬hyde gas. All eggs must be dry before fumigation.

3. Allow at least four hours after removing eggs from the cool rooms before they are set.

The effects of relative humidity and temperature on moisture conde

tion on the eggshells is shown in Table 38-6. It can be that eggs s

at 65°F (18°C) are much less likely to sweat than when stored at

Table 38-6. Effect of Humidity and Temperature on Moisture Condensation on Eggshells

Egg Room Temperature					
55°F (13°C)		60°F (16°C)		65°F (18°C)	
Temperature of New Room		Eggs Will Sweat if Relative Humidity in Egg-traying Room Is Higher Than			
°F	°C	%	,.0/0		
60	16	82	—		
65	18	70	85		
70	21	58	71	83	
75	24	50	60	71	
80	27	42	51	60	
85	29	36	44	51	
90	32	30	37	43	
95	35	26	32	38	
100		38	22	28	32

(13°C). However, if eggs do sweat, they are less likely to become contami

nated if they have been sanitized by mechanical washing prior to storage.

38-F.. PREWARMING HATCHING EGGS

Prewarming eggs before setting involves holding them for 4 to 12 hours in a room that is warmer than the egg holding room but cooler than the incubator(s). In many cases, this is in the hallways between the setters. Prewarming is done to reduce the cooling effect the freshly set eggs will have on eggs in the incubator. Generally, if the incubator temperature re-covers to the set point within 11/2 hours after setting new eggs, there is no need for prewarming. There is disagreement among incubator companies as to the benefits of prewarming eggs before incubation. Some feel that prewarming invites egg sweating. Others feel that it helps by reducing the time it takes for the incubator to stabilize temperature and humidity after setting. The incubator company making the recommendation whether or not to prewarm

probably knows which method works best for its ma¬chines. In single-stage machines, there is no need for a prewarming room, as temperature can be more carefully controlled in the setter.

39
Factors Affecting. Hatchability
by Joseph M. Mauldin

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

39-A. FERTILITY

Normally, fertility is the most important factor in determining hatchabil¬ity performance. A study conducted in Georgia measured flock and hatch¬ery performance in 15 broiler hatcheries over a six-year period (1984 .to 1989). The life-of-flock average for infertility was 725%, which followed the typical pattern of infertility being the largest single cause of eggs failing to hatch.

1. Determining Fertility

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

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

a.

Fresh Egg Breakout

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

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

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

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

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

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

While conducting a fresh egg breakout, it is important to have a sample size of at least 100 eggs per flock. Because of the disadvantages involved in the fresh egg breakout, use of this procedure is not recommended unless

a quick fertility check is desired. Candling and / or hatch day breakouts

should be done more routinely (every one or two weeks).

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b. Candling and Breakout Analysis

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

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

730 FACTORS AFFECTING HATCHABILITY

The most common error with mass candling is to not recognize all clears in a tray. For spot candling, the most common error is to incorre identify an egg with a viable embryo as a clear. Determining eggs w have been set upside down or cracked is much easier to distinguish -1,□, spot candling than with mass candling.

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

For candling and breakout procedures to be accurate, a sufficient san size of eggs must be used. A minimum of four trays per breeder fl (>500 eggs) is needed to ensure that estimates

for fertility, eggs set up down, farm cracks, and cull eggs are meaningful. Take trays from differ areas in the incubator, as this will provide a more random sample of fl performance.

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

c. Hatch Day Breakout

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

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

39-A. FERTILITY 731 Table 39-1. 7- to 12-Day Candling and Breakout Analysis Form

Fertility = 100% infertile = 97.69%

OTHER OBSERVATIONS:

Source: Mauldin, 1997

ductive failure. The procedures for this valuable management tool are de-scribed below.

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

2. Breakout Procedure

• Immediately after chicks are pulled, collect a minimum of four trays of eggs per breeder flock from different lo¬cations of a single setter.

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

The clarity of the development is not as good in eggs broken afte days of incubation as when eggs are broken while the embryos are , alive. However, with practice, one can conduct an accurate breakout an sis by judging the embryos according to size and looking for some 0 obvious 'changes in the developmental sequence (see Development Embryo, Chapter 35; Table 35-1). A good training techriclue for soniA with little or no experience in breakout analyses would be to examin embryos at different stages of development and compare them to the embryos obtained from unhatched 21-day incubated eggs, or embryos tured in a number of poster publications published by the author.

b. Identifying Fertility in 21-Day Incubated Eggs

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

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

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

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

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

c. .Keep Accurate Records

It is necessary to collect general and reproductive failure data to provide a basis for drawing accurate analysis and inferences. Building a data base of information enables the

evaluation of reproductive efficiency by flock and breed, and is an excellent diagnostic tool when problems arise in the hatchery or on the breeder farm. Also, the influences of flock management, ,;field tq..,,ts,..apd incubation equipment can be measured by studying their effects on fertility, hatchability, and reproductive failures.

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

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

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

Table 39-4. Examples for Calculating Reproductive Efficiency Values'

Formula: % Fertility = 100 — (# infertiles + sample size) x 100

Example: 100 — (50 + 672) x 100 = 92.56%

Formula: % Hatchability = (# hatched + # set) x 100 Example: (23,160 + 28,600) x 100 = 80.98%

Formula: % Hatch of Fertiles = (Hatchability + Fertility) x 100

Example: (80.98 + 92.56) x 100 = 87.49%

Formula: Spread = Fertility — HatChability

Example: 92.56 — 80.98 = 11.58

Formula: % Estimated Hatchability = 100 — % Reproductive Failures ExaMple: 100 — (7.44 + 4.17 + 0.30 + 2.08 + 1.04 + 0.74 + 0.30

+ 0.30 + 0.74 + 0.74 + 0.30) = 81.85%

Formula: Sample Index = % Estimated Hatchability % Hatchability Example: 81.85 — 80.98 = 0.87

'From data in Table 39-3

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

tation of actual performance. Small sample sizes will result in greater v ation in the sample index. Calculating these measures is necessary for, terpreting results and taking corrective action. It would be a mistak make corrective management changes in a flock or in the hatchery ba' on breakout analysis results when the sample index is high.

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

Mauldin, J.M., 1997

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

39-C. METABOLISM OF THE CHICK EMBRYO 737

39-B. SEX OF CHICKa

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

39-C. METABOLISM. OF THE CHICK EMBRYO

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

1. Importance of Egg Moisture Weight Loss

Avian eggs differ from reptile eggs as they never gain water from the environment. The partial pressure of water vapor inside the avian egg is always higher than the environment. This pressure differential between the inside of the egg and its environment directs the flow of moisture out¬ward. There is a high resistance by the shell and cuticle to moisture loss, therefore incubation environmental conditions must be within an accept¬able range to ensure proper moisture loss. When eggs are losing too much or too little moisture they can be brought back in line by changing humid¬ity settings. However, over-drying early in incubation is harmful to the developing embryos. Eggs from young flocks are more susceptible to des¬iccation than eggs from older flocks. The optimal range of incubation

mois¬ture loss from chicken eggs is in the order of 0.60% to 0.65% of total egg weight per day. The acceptable range is from 0.55% to 0.70% per day.

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

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

2. Seasonal Variation

In climates where there is distinct seasonal variation, there are ma variables that can affect incubation. For example, in the southeaster United States, summer days are very hot and nights are warm and hurni The high humidity becomes a serious problem for incubation because a bient relative humidity is near 100% for many hours every day. Dur the hottest part of the afternoon, the humidity falls to less than 50% climbs rapidly about sundown. This makes it very difficult to achieve correct incubation moisture weight loss from the eggs. The high humid situation is aggravated as most hatcheries are cooled by evaporative co ing which adds moisture to the air. To correct for the high ambient hum ity in evaporatively cooled air, many hatcheries are required to drastica lower the incubator wet bulb set points. Typically, incubator manufa turers recommend 86°F (30°C) wet bulb setting and do not recomme seasonal changes. However, hatcheries located in high humidity regio lower their wet bulb set points by two or three degrees Fahrenheit top mote greater hatching egg moisture, loss and improved chick quality. extreme instances, hatcheries have lowered the wet bulb setting to 8 (27°C) and have seen further improvements. Because of the high ambi humidity, the actual incubation humidity will not average nearly as 1 as would be indicated by the new humidity set points.

During the winter, the ambient humidity is generally very low (rar above 50% RH). Hatcheries in these areas that do not change wet b settings to higher temperatures can experience serious problems with much egg moisture weight loss causing reduced hatchability, chick de dration, and short hatch time. The low wet bulb settings have a more matic impact on incubation during the winter than in the summer beca of low ambient

humidity. These hatcheries should use diffe;rent wet b settings that are dependent on season to achieve the correct egg mois weight loss.

The best way to determine proper hatching egg moisture weight lo to weigh samples of hatching eggs prior to and during incubation. eggs lose moisture weight at a rate outside the acceptable range of 0. to 0.70% per day, adjustments to incubation humidity are warranted. most common problem is that hatching eggs lose too little moisture du summer months. Signs of this may be observed by seeing how the pip, and the conditions of the hatched chicks' hocks immediately hatching. Unhatched pips located high in the shell indicate insuffi incubation moisture weight loss. Also, when moisture loss is not ad

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

Procedure for Determining Egg Moisture Weight Loss

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

Gathering Data

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

Calculating Loss

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

figure is higher than the upper limit (0.70% per day) of the acceptable range indicating low relative humidity in the setter.

Moisture Weight Loss Varies

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

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

39-D. TEMPERATURE DURING INCUBATION 741

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

39-D. TEMPERATURE DURING INCUBATION

1. Physiological Zero

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

2. Optimum Temperature for Incubation

Temperature is the most critical environmental concern during incuba¬tion because the developing embryo can only withstand small fluctuations during the period. During the first 18 days of incubation (setter phase) the range for incubation temperature is 98.5 to 100.25°F (37.2° to 38.2°C). Dur-ing the last three days (hatcher phase) the temperature is lowered to be-tween 98°F and 99°F (37° and 37.5°C). The recommended set temperatures for both setters and hatchers vary depending on the incubator manufac-, turer. Some commercial incubators are water cooled and others are air cooled. Additionally, fan types and alignments vary among the different incubator manufacturers. While "hot" and "cold" spots can occur in ma-chines7the effects of the non-uniform temperature distribution can be les-sened by routine incubator maintenance. The condition of the door seals, baffle doors, fan alignment and speed, etc. all have a significant impact on the airflow and temperature distribution within an incubator.

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

and record the incubation temperature and humidity every hour. Perin cally, an accurate thermometer should be used to check the accurac\L tie setter and hatcher thermometers.

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

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

In most cases, the incubator set points for temperature and humi 'P. are established for eggs of an "average" egg age and size. Most incuba is done with multi-stage machines which incubate eggs 'from diffe flocks with varying ages, and even different breed/ strains. To alley this condition, the industry is starting to experiment with single-stage chines. Single-stage incubation has a seeming advantage over multi-st because the incubation conditions of temperature, humidity, and air f1 can be tailored for a single setting of eggs. To date, however, single-st machines have not exhibited quite as good performance in terms of ha ability as multi-stage machines. This is most probably due to the fact t more uniform temperatures can be maintained in the multi-stage machi because the developing embryos are at different ages. The older embr produce heat and the younger ones require heat. Trays can be space. that the younger embryos benefit from the heat produced by the ol embryos. In single-stage incubation, the incubator provides heat d the first 10 days, and cooling is required for the second half of incuba

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

3. Embryo Temperature

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

Buhr (1995) showed how a minor problem in incubator maintenance af¬fected temperatures in different parts of the incubator creating areas that were outside the proper

temperature range. The result of overheating is lower hatchability and reduced chick quality. Meijerhof suggested that this is. a common problem that occurs frequently during incubation.

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

ge h-tat 39-E. INCUBATION HUMIDITY

Les

cis Incubation humidity determines the rate of moisture loss from eggs dur

so ing incubation. When the egg contents dry out too rapidly some embryos

lq will fail to hatch and the ones that do will be smaller than normal and

ng may not perform well when placed on the farm. When moisture is not lost from the eggs fast enough, hatchability and chick quality problems result.

ge Generally, most incubator manufacturers recommend an incubation rela

:-u-live humidity ranging between 55 and 60%. After eggs are transferred to the hatcher the relative humidity requirements increase to about 65%. As ro pipping and hatching increase on the last day of incubation the relative humidity will increase to about 75%, as chicks are exhaling moisture and the wet hatch debris is exposed to the hatcher environment.

1. Measuring Relative Humidity

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

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

Dry-bulb Temperature

Wet-bulb 98.0°F 98.5°F 99.0°F

Temperature		(36.7°C)	(37.0°C)	(37.2°C)
(°F)	(°C)	Relative Humidity (%)		
80	26.7			
82	27.8			
84	28.9			
86	30.0			
88	.31.1 .			
90	32.2			
92	33.3			

Source: North and Bell, 1990

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

2. Egg Size and Its Effect on Egg Weight Loss

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

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

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

Source: North and Bell, 1990

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

Original Weight of Eggs

Relative Huinidity in Setter (%)

22 oz /doz
52.0 g/ea

24 oz/doz
56.7 g/ea

26 oz/doz
61.4 g/ea

28 oz/doz 30 oz/doz
66.2 g/ea 70.9 g/ea

10.6	10.3	10.0	9.8	9.6
11.5	11.1	10.7	10.4	10.2
12.5	12.0	11.6	11.3	11.1
13.7	13.1	12.6	12.2	11.9
15.0	14.3	13.8	13.4	13.1

Source: North and Bell, 1990

3. Shell Area and Egg Weight Loss

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

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

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

Table 39-10 shows proper relative humidity settings for an incubator to accomplish a 12% moisture weight loss with eggs of different weights. One should calculate the average weight of the eggs before using the table. Remember: As egg size of the breeding flock

increases during production, incubation relative humidity should be lowered to ensure adequate evapo-ration from the egg.

Shell Quality Affects Humidity Requirement

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

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

Original Weight of Eggs (oz/doz) (g/ea)	Wet Bulb Temperature in Setter to Lose 12% Weight in 19 Days-- Relative Humidity in Setter for Eggs to Lose 12% Weight in 19 Days (%)	Dry Bulb Temperature 99.5°F (37.5°C)
22 52.0		58-62
23 54.3		56-60
24 56.7		53-57
25 59.1		51-55
26 61.4		49-53
27 63.8		47-51
28 66.1		45-49

Source: North and Bell, 1990

of the egg contents, producing chicks smaller than normal, as adequate

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

39-F. AIR REQUIREMENTS DURING INCUBATION

The main components of air are oxygen (02), nitrogen (N2), carbon diox¬ide (CO2), and water vapor (H20). The free movement of these molecules through the pores of the shell and

the shell membranes is important as the developing embryo must receive a constant supply of oxygen and must eliminate carbon dioxide and moisture.

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

Egg Weight		Shell	'Weight Loss 1-19 Days of Incubation
(oz / doz)	(g / ea)	Thickness	(0/0)
24	56.7	Thin	14.0
24	56.7	Average	12.0
24	56.7	Thick	10.5

Source: North and Bell, 1990

39-F. AIR REQUIREMENTS DURING INCUBATION 747

1, Oxygen in the Air

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

Generally, the oxygen content of the air in the setter remains at about 21`)/0, but there may be some variation in the hatcher where large amounts of carbon dioxide are produced by the newly hatched chicks. Hatchability will drop about 5% for each 1% that the oxygen content of the air drops below 21%. The main danger in these cases, is that high levels of carbon dioxide become toxic.

2. Air Supply Generally Adequate

As the embryo ages, its oxygen requirement increases and more carbon dioxide is given off. Each process is speeded up approximately 100 times between the first and 21st day of incubation, as shown in Table 39-12. Therefore, on the 18th day of incubation, 1,000 eggs require 143 ft3. (4.1 m3) of fresh air per day (oxygen in the air at 21%). Furthermore, an incuba¬tor holding 40,000 eggs would need 5,720 ft3 (162 m3) of fresh air, or ap¬proximately 238 ft3 (6.8 m3) per hour. Therefore, air in the incubator needs to be changed about eight times a day or once every 3 hours. This rate of air exchange is the minimum required. Air exchange rates in most ma¬chines are usually more than adequate. In some cases, care must be taken to ensure that overventilation and a corresponding excessive loss in mois¬ture doe's not become a problem.

3. Carbon Dioxide Tolerance

Carbon dioxide (CO2) is a natural by-product of metabolic processes during embryonic development which begins during gastrulation. In fact, CO2 is being released through the shell at the time the egg is laid.

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

Day of Incubation	Expulsion of Carbon Dioxide (ft3)	(ft3)
	0.50	0.29
	1.17	0.58
10	3.79	1.92
15	22.70	11.50
18	30.00	15.40
21	45.40	23.00

Romanoff, A. L., 1930

working environment for the machines. The acceptable ranges for setter and hatcher room temperature and humidity are between 75° and 80°F (24° and 25.5°C) and 50 and 65%, respectively. When these environmental parameters are outside the acceptable range, the incubators will compen-sate, but at an economic and efficiency cost. 17or example, when a setter room is too cool, the incubator will use additional heat to achieve the cor¬rect incubation temperature. However, heating the air with setter electric heating coils will be more than three times the cost of heating the room air witha gas furnace before it enters the incubator. Further, when incuba¬tors have to work harder to create the correct incubation temperature, the temperature environment inside the mass of eggs is often not optimally uniform. This results, in hot and cold spots within the machine speeding the rate of development of some embryos, while delaying the development of others. Similar non-optimum results occur when the humidity is outside the acceptable range. For example, when a setter room environment is too dry, the incubator will provide the additional humidity at the expense of economics and performance. Every time the incubation humidity comes on, the mist creates evaporative cooling and the electric heating elements will respond (economic cost). Additionally, the evaporative cooling caused by the humidity mist will signal the fresh air dampers to close more, which results in less oxygen and more carbon dioxide (performance cost).

The placement of room thermostats and humidistats is critical to provide the correct ambicnt.conditions in the rooms. These environmental control devices work much better when they are placed in the airflow of the room and not in a "dead" spot. A common, but incorrect location for thermostats and humidistats has been the setter or hatcher room end wall. When they are flush mounted on the end wall, it is unlikely that they will correctly "read" the room conditions and their responses will be incorrect. An excel¬lent example of

incorrect thermostat or hurnidistat placement and the cor¬responding effect are provided in Figures 39-3 and 39-4. In these examples,

Temperature F

0 2 4 6 8 10 12 14

Time (hrs)

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

Figure 39-5. Relationship Between Altitude and Hatchability

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

By increasing the air pressure to sea level values during incubation, it is possible to restore normal hatchability. This is one of the methods used for incubation at high altitudes. The design and construction of the hatch¬ery determines v;i;-6.-her or not pressurization can be economical.

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

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

7. Other Factors to Consider with High Altitude Incubation

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

- Increases in -incubation time as the altitude increases, may be due to a decrease in the carbon dioxide content of the ambient air rather than reductions in the oxygen content. The increased CO2 as seen at sea level incuba

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

- Eggs produced by breeder hens kept at high altitudes produce normal hatches if they are incubated at low alti-tudes. Eggs produced by breeder hens at high altitude and incubated at high altitude have an increased incuba-tion time associated with a lower metabolic rate.
- Altitude has no effect on fertility.

• Chicks produced from eggs laid by breeder hens at high altitudes and incubated at high altitudes have greater mortality during growout than normal.

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

Frequent turning and egg orientation are important during the first 1 days of inc-dbatidp. Artificially incubating eggs should be held with their large ends up. It is natural for the head of the chick to develop in the large end of the egg near the air cell, and for the developing embryo to orient' itself so that the head is uppermost. This rotation occurs during the second week of incubation. When eggs are incubated with the small end up, about 60% of the embryos will develop with the head near the small end. Thus, when the chick is ready to hatch, its beak cannot break into the air cell to initiate pulmonary respiration. Eggs positioned horizv-8-ally will incubate and hatch normally as long as they are turned frequendS.

Nearly half of the eggs set with the small end up will fail to hatch, an chick quality of those which hatch will be reduced. Most eggs set with' the small end up are due to either carelessness or because of difficulty distinguishing between the large and small end. Older hens lay a large percentage of eggs that are more nearly round, thus making it difficult t determine the large and small ends.

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

Interval of turning. During the first 14 days, eggs must be turned reg larly and often. Table 39-15 shows the percentage of hatchability eggs turned from two to ten times a day. Althougfuother experime have shown that turning eggs as often as every 15 minutes is not de

39-G. POSITION AND TURNING OF THE EGG DURING INCUBATION 753

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

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

Source: North and Bell, 1990

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

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

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

Transferring Eggs to the Hatcher

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

Table 39-15. Effect of Turning Eggs on Hatchability

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

Source: North & Bell, 1990

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

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

Source: North & Bell, 1990

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

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

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

39-H. OTHER FACTORS AFFECTING HATCHABILITY

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

1. Egg Laying Pattern and Hatchability

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

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

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

2. Weather Affects Hatchability

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

3. Factors Affecting the Length of the Incubation Period

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

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

Table 39-17. Classification of Malpositions

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

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

4. Position of the Embryo in the Egg

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

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

5. Abnormal Embryos

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

Table 39-18. Chick Abnormalities

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

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39-I. EMBRYONIC MORTALITY PATTERNS

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

1. Period I (Preoviposital Mortality)

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

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

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

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

2. Period II (Early-Dead Embryos)

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

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

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

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Figure 39-6, Recently Hatched Chicks

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

39-J. NUTRITIONAL EFFECTS ON HATCHABILITY

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

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

39-K. DISEASE AND HATCHABILITY

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

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

Vitamin A Circulatory system development abnormal; skeletal abnormalities, especially in the skull and spinal column;

degenerative changes in the brain, spinal cord, and nerves; embryonic mortality is early (during days 2 to 3). Chicks hatching may have watery discharge from eyes or have eyelids stuck together. A great excess of vitamin A also will cause skeletal abnormalities.

Vitamin D3 Deficiencies cause late embryonic mortality (>17'days); stunting; poor skeletal growth; rickets.

Vitamin E Circulatory system problems, exudative diathesis, hemorrhages, stunting, encephalomalacia, eye abnormalities

(e.g., cloudy lens or hemorrhages), edema of neck and feet; embryonic mortality peaks during days 2 to 5. Muscular weakness after hatching.

Vitamin K Hemorrhages in embryo and membranes, especially at or near time of hatching.

Thiamin Polyneuritis; early mortality peak and late peak .._19 days; many dead chicks in hatching trays.

Riboflavin Stunting, short legs, disorganization of the circulatory system, edema, clubbed down, curled toes, micromelia,

anemia, brown or dark green liver; mortality peaks during days 3 to 5, 10 to 15, and 21 to 22. Mortality peaks change from late to early as breeder depletion of riboflavin proceeds.

Niacin Hypoplasia (decreased growth and development) of skeletal muscles, edema, short upper beak, nervous and

vascular system abnormalities. Mortality peaks during days 8 to 14.

Vitamin B6 (pyridoxine) Inhibition of early embryonic growth; mortality peaks during days 8 to 14.

Pantothenic acid Subcutaneous hemorrhages, edema, hydrocephalus, poor feathering, twisted legs, fatty livers, opacities of the eye,

pale, dilated hearts; embryonic mortality peaks during days 2 to 4 and 11 to 15.

Biotin Chondrodystrophy and micromelia (deformed skeleton, shortened long bones, parrot beak), syndactylism

(webbing between toes); hemorrhages in the embryo and chorioallantois; peak embryonic mortality during days 3 to 4 and .-1.7. The early mortality peak is greatest with severe deficiency, while the late peak is greatest with mild deficiency.

Folic acid Bent tibia, syndactylism (toe webbing), flattened head, small eyes, exposed viscera, parrot beak, other beak defects,

stunting; peak embryonic mortality days >17.

Vitamin B12 Edema (especially around eyes), hemorrhages, curled toes, short beak, poor leg muscle development, dwarfing,

fatty liver, enlarged thyroid, dilated, irregularly shaped heart, head-between-thighs malposition; peak embryonic

mortality during days 8 to 14 {small peak) and 16 to 18.

Manganese Chondrodystrophy, deformed skeleton, shortened long bones, parrot beak, micromelia, edema, abnormal down

feathers; peak embryonic mortality days >18. Chicks .u.nc rdinated.

Zinc Calcium
Magnesium Phosphorus Copper
Iodine
Selenium
Molybdenum Lithium
Boron
Protein, amino acids Fat, fatty acids
Miscellaneous substances: Tetracyclines
Sulfanilamides

Penicillin
Aflatoxin B,
Ammonia (in incubators)

Skeletal defects, especially in poSterior vertebral column (most common defect is rumplessness), small eyes, exposed viscera, beak and head abnormalities, edema. Chicks are weak; will not stand, eat,,.or drink. Embryonic mortality can be very high.

Effects more indirect through poor shell quality, increased egg weight loss, and increased contamination. Stunted growth, decreased bone development, and increased mortality tend to occur in later stages. A great excess of calcium also will cause embryonic abnormalities.

Nervous tremor, gasping, and convulsions at hatching.

Abnormal bone formation, stunting; mortality peaks during days 14 to 16.

Blood and circulatory system defects. Mortality peaks during days

Affects thyroid activity. Deficiency or excess causes increased incubation time, decreased growth, and increased mortality. Thyroid may he enlarged.

Exudative diathesis; selenium will spare vitamin E. Very high levels of selenium are toxic: edema of head and neck, twisted legs, necrosis in brain and spinal cord, short upper beak, missing eyes, protruding eyes, an increase in malpositions.

>17 ppm in the egg results in 100% mortality by day 12.

Excess causes high embryonic mortality associated with inhibited development, eye defects, enlarged aorta, abnormal neural tube.

Excess boron in egg (44 ppm) causes embryonic mortality in early development and at day 13. Abnormalities similar to those of riboflavin deficiency. Face, beak, and appendicular skeleton abnormalities.

Deficiency, excess, or imbalance of some amino acids can cause embryonic abnormalities and mortality. Abnormalities include small or abnormal upper and/or lower beak, disorganized protrusions in the brain, exposed viscera, twisted and shortened limbs, twisted spine, short body, degeneration of the eye.

Linoleic acid deficiency: slow development, 75% of embryos in the head-over-right-wing malposition; mortality peaks during days 1 to 4, 8 to 14, and >21. Lipid transfer from the yolk to the embryo is reduced in the first few eggs produced by young pullets; this appears to result in increased embryonic mortality.

Inhibition of skeletal mineralization, erosion of long-bone cartilage, skeleton malformation Retarded growth, shortened long bones, extreme micromelia, parrot beak, rumplessness. Edema' and hemorrhage in wings, legs, and head.

Stunting (beginning at day 12), small liver, high mortality.

No closure of neural tube, mortality.

Source: Wilson, 1996

Table 39-22. Troubleshooting Guide for Hatchability Problems

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

Causes:

a. Immature males. Males may need to be photostimulated 2 weeks earlier than females.

b. Males with abnormal sperm; females with abnormal egg (germinal disc). This occurs most often in very young or very old breeders.

c. Too few males, resulting in infrequent mating; too many males, resulting in fighting or interference. Ratios of 1:12 to 1:15 for light breeds and 1:10 to 1:12 for heavy breeds are suggested.

d. Extreme weather conditions.

e. Old breeders. Spiking with young males may help if the problem is with the male

f. Breeder flock disease. This is often indicated by rough, misshaped, or thin-shelled eggs.

g. Excess body weight, especially in broiler breeder males (>10.6 lb, 4,800 g).

h. Nutritional deficiencies or excesses; severe feed restriction.

i. Feet and leg problems, especially in males of heavy breeds.

j. Certain drugs, pesticides, chemicals, toxins, or mycotoxins.

k. Parasites, such as mites.

1. Inadequate floor space.

m. Decreased mating frequency, or no mating, is commonly seen in many of the conditions listed above; this may often be the direct cause of infertility.

n. Inadequate lighting (intensity or day length).

o. Improper artificial insemination procedures (if artificial insemination is used).

Table 39-22. (continued)

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

Causes:

a. Eggs stored too long. They should be stored <7 days.

b. Eggs held under poor conditions, temperature too high or too low. Fluctuating temperatures. Temperature should be 60° to 65°F (15.6° to 18.3°C).

c. Fumigation improper too severe or done between 12 and 96 h of incubation. Incorrectly spraying or foaming eggs with disinfectant.

d. Eggs damaged during handling and transport by jarring, temperature shock (temperature increased decreased too rapidly), etc.

e. Eggshell sealed—respiration inhibited.

f. High temperature in early incubation.

g. Very young or very old breeders.

h. Heredity, inbreeding, chromosome abnormalities, or

i. Breeder flock diseases.

j. Failure of a basic organ system to develop

k. Egg wash temperature too high.

1. Egg-borne infections (e.g., Salmonella).

m. Drugs, toxins, pesticides, etc.

n. Infrequent or incomplete egg collection.

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

Causes:

a. Eggs stored too long or under improper temperature.

b. Fumigation improper—too severe or done between 12 and 96 h of incubation.

c. High temperature in early incubation.

d. Low temperature in early incubation.

e. Eggs damaged during transport by jarring, etc.

f. Breeder flock diseases.

g. Old breeders.

h. Embryological development accidents.

i. Inbreeding, chromosome abnormalities.

j. Severe nutritional deficiencies, e.g., biotin, vitamin A, copper, vitamin E, boron, Or pantothenic acid.

k. Frequently associated with a high incidence of infertility.

1. Drugs, toxins, or pesticides.

m. Contamination.

Em OS less developed at oyipa-,ition, (_ pre-endoderm. or very earl en lode

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

Causes:

a. See Causes 3.a–n.

b. Lack of ventilation, or sealed shells, carbon dioxide >1%.

c. Impropef turning—<1 /h or >6/h; improper turning angle.

d. Vitamin deficiencies—vitamin E, riboflavin, biotin, pantothenic acid, or linoleic acid.

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

Causes:

a. Improper incubator temperature, humidity, turning, ventilation. Low humidity increases abnormalities of aortic arches (13 days).

b. Contamination.

c. Nutritional deficiencies--riboflavin, vitamin B12, biotin, niacin, pyridoxine, pantothenic acid, phosphorus, boron, or linoleic acid.

d. Lethal genes (>30 have been described).

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

Causes:

a. Improper incubator temperature, humidity, turning, ventil

b. Improper hatcher temperature, humidity, ventilation.

c. Contamination, especially from molds Aspergillus, etc.).

d. Fumigation too severe or too prolonged.

e. Eggs chilled in transfer, or transferred too late.

f. Broken shell—pre-set, during incubation, or at transfer.

g. Nutritional deficiencies—vitamin D, vitamin A, folic acid, thiamin, vitamin B12, calcium, phosphorus, manganese, or

h. Embryonic malposition; embryo fails to move into proper

i. Embryological development accident. Failure to change to intestinal loops and yolk sac. These and other changes are

j. Heredity—lethal genes, chromosome abnormalities.

k. Twinning.

1. Hatcher opened too much during pipping and hatching.

m. Poor -shell quality.

n. Breeder diseases. ation.

or pantothenic acid, riboflavin, vitamin linoleic acid.

hatching position (see #21).

lung respiration and all intraembryonic critical at this time. E, selenium, vitamin K, biotin,

circulation, and to retract the

Table 39-22. --(continued)

TROUBLESHOOTING: SPECIFIC PROBLEMS

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

Causes:

a. Inadequate turning, resulting in decreased embryonic membrane development and nutrient absorption.

b. Humidity too high during incubation or after transfer.

c. Incubator temperature too low.

d. Hatcher temperature too high.
e. Eggs chilled (e.g., at transfer).
f. Nutritional deficiencies.
g. Heredity.
h. Embryological development accident.
i. Breeder diseases.
j. Inadequate ventilation.
k. Prolonged egg storage.

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

Causes:

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

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

Causes:

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

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

Causes:

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

11. Sign: Chicks hatch late.

Causes:

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

g. Incubator humidity too high.

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

Causes:

a. Mix in the incubator of eggs stored for long and short periods (1.2% loss of hatch/day of storage when all eggs set at the same time; only 0.5% loss/day when eggs stored for long periods are set earlier to allow a longer incubation period).

b. Mix of eggs from young and old breeders.

c. Mix of large and small eggs.

d. Improper egg handling.

e. Hot or cold spots in incubator or hatcher.

f. Incubator or hatcher temperature too high or too low.

g. Room ventilation system improper; high positive pressure or low negative pressure. Such pressures may alter incubator or hatcher ventilation.

Table 39-22. (continued)

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

Causes:

a. Mix of large and small eggs.

b. Mix of eggs from young and old breeders.

c. Mix of eggs from different strains or breeds.

d. Some eggs stored much longer.

e. Lack of uniform ventilation in setter or hatcher.

f. Disease or other stress in one or more breeder flocks.

g. Variation in-egg storage procedures among flocks.

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

Causes:

a. Low incubation temperature.

h. High incubation humidity.

c. Improper turning. This results in reduced embryonic membrane growth and reduced nutrient absorption.

d. Old eggs.

e. Very large eggs.

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

Causes:

a. Humidity too low during egg storage, incubation, and/or hatching.

b. Improper egg turning.

c. Cracked eggs or poor shell quality.

16. Sign: Premature hatching; bloody navels.

Cause:

a. Incubator and / or hatcher temperature too high.

17. Sign: Small chicks.

Causes:

a. Small eggs.

b. Low humidity during egg storage and/or incubation.

c. High incubation temperature.

d. High altiiiide. Hatcheries at high altitudes (>4,920 ft or 1,500 m) may need to adjust for low humidity, carbon dioxide, and oxygen. Atmospheric pressure <600 mm Hg (at 6,004 ft or 1,830 m) reduces growth and metabolic rate, increases loss of water from the egg.

e. Thin, porous shells.

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

Causes:

a. High incubator temperature or wide fluctuations in temperature.

b. Low temperature in hatcher.

c. Humidity too high in hatcher or not lowered when hatching complete.

d. Inadequate breeder nutrition.

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

Causes:

a. Omphalitis (navel infection). Contamination from dirty trays, unsanitary machines or hatchery, dirty eggs, inadequate egg sanitation, or fumigation.

b. Low incubator temperature.

c. High incubator or hatcher humidity.

d. Inadequate ventilation.

20. Sign: Weak chicks.

Causes:

a. High hatcher temperature.

b. Poor hatcher ventilation.

c. Excessive fumigation.

d. Contamination.

Table 39-22. (continued)

Causes:

a. Eggs set small end up or in horizontal position.

b. Inadequate or improper turning.

c. High or low incubator temperature.

d. High humidity.

e. Old breeders.

f. Round-shaped eggs or very large eggs.

g. Nutritional deficiencies, especially vitamin :A and vitamin B12.

h. Eggs handled or stored improperly.

i. Retarded development.

Embryos <18 days old may be in a position different from that for hatching but one normal for their age (for example, the head¬between-thighs position). The feet-over-head position is hard to distinguish and may be normal. The beak-over-wing position is probably a normal variant. Some malpositions are lethal; others are not.

22. Sign: Malformations.

Causes:

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

23. Sign: Crooked toes, spraddled legs.

Causes:

a. High or low rtcubator temperature.
b. Inadequate nutrition.
c. Smooth bottom hatching trays.

24. Sign: Short down, wiry down.

Causes:

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

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

Causes:

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

26. Sign: Exploders.

Causes:

a. Dirty eggs from nest. Dirty nests.
b. Floor eggs.
c. Eggs improperly washed; eggs wiped or cleaned with contaminated cloth or buffer.

d. Dust from breeder house, cooler, transport, etc.
e. Water condensation on eggs (sweating).
f. Water sprayed, fogged, or splashed on eggs; eggs dipped in contaminated solutions.
g. Contamination from earlier exploders, leakers, or broken eggs.
h. Contamination from handling eggs with dirty hands or equipment.
i. Contaminated setter flats, air filters, water (humidity) system.

Table 39-22. (continued)

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

Causes:

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

28. Sign: Crossed beak, twisted beak.

Cause:

a. Heredity.

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

Causes:

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

30. Sign: Exposed brain.

Causes:

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

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

Causes:

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

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

Causes:

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

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

Causes:

a. Heredity, lethal genes.

b. Nutritional deficiencies (biotin or manganese).

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

Causes:

a. Incubator temperature too high during days 1 to 5.

b. Heredity, lethal genes.

c. Developmental accidents.

d. Nutritional deficiencies (niacin).

35. Sign: Ectopic (exposed) viscera.

Causes:

a. Incubator temperature too high.

b. Heredity, lethal genes.

36. Sign: Hemorrhage.

Causes:

a. Red skin—incubator or hatcher temperature too high.

b. Bleeding in chorioallantois—rough handling at transfer.

c. Nutritional deficiencies (vitamin K or vitamin E).

d. Embryos that died at days 11 to 15 and appear small and dark red—usually caused by molds or other contamination.

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Operating the Hatchery

by Joseph M. Mauldin

The task of operating a commercial chicken hatchery requires continu¬ous monitoring of numerous environmental factors that may affect chick hatchability and quality. Any small.deviation in operating procedures, the quality of hatching eggs, and the care the chicks receive following the hatch can have a major impact on the success of the hatchery and, there-fore, the economics of the operation. Not only are the chicks affected at the time, but oftentimes mismanagement in the hatchery can affect the overall performance of the flock.

40-A. SECURING HATCHING EGGS

In the United States and to a lesser extent in other countries, the poultry industry is vertically integrated. With vertical integration, the company that owns the hatchery generally owns the breeders supplying hatching eggs. However, in many countries where vertical integration is less prevalent, ' the hatchery does not have a guaranteed source of hatching

eggs, and therefore must purchase from suppliers. In these situations, the quality of hatching eggs can vary with each supplier due to breeder flock age, management, fertility, holding and shipping times, sanitation, egg han¬dling, and many other factors.

Source of Eoqs

Hatchery owns the breeder hens. The most common situation in the United States is that the hatching eggs are produced by contract grow-ers who have an agreement with the hatchery to supply eggs. Growers

own the farms, including buildings and equipment, and the hatchery owns the breeder flocks and supplies the feed and all other inputs. In some cases, the hatchery owns the farms and breeders and hires' employees to manage the farms.

.Hatchery secures eggs from flock owners. Under this arrangement, the hatching egg producers own both the farms and breeders and bu feed and other supplies from retailers. Most of the producers in this situation have a contract with the hatchery to produce eggs in prede termined quantities.

Other hatcheries supply eggs. Occasionally, one hatchery may have an oversupply of hatching eggs and sells to another hatchery that is expe riencing a shortage. This practice happens frequently, especially with large integrators.

Hatching egg suppliers. Many companies produce only hatching egg that are then sold to hatcheries worldwide. They contract with each hatchery to supply an agreed upon quantity of eggs each week an in many situations ship eggs by air freight to their final destination. Hatching egg brokers purchase eggs to sell while others maintain breeder flocks.

Delivery to the Hatchery

Hatching eggs generally arrive at the hatchery by truck. If arriving from greater distances, they may be shipped by air. As most hatcheries hay e programs to produce Mycoplasma gallisepticum negative and Mycoplasma synoviae negative chicks, care must also be taken to prevent hatchery expo¬sure to these disease-producing organisms, as they can be vertically trans¬mitted. The best biosecurity for egg delivery includes mandatory showers sanitized clothes, and headgear, and plastic or rubber boots or sandals for the egg truck drivers and their helpers. Biosecurity is further strengthened when the truck drivers and helpers are restricted from entering the hatch¬ery. Egg trucks should also be disinfected before being loaded with eggs. Ideally, the loaded egg truck, as it enters the hatchery premises, would also pass through a truck wash station where the outside, including wheel and undercarriage, are sprayed with a disinfectant. The above suggestion are all components of an effective biosecurity program. Unfortunately, practice, only primary breeder hatcheries and a few integrator hatcherie incorporate all of these biosecurity practices in their operations. Integrat companies frequently require egg truck drivers to assist with loading an unloading at the hatchery, requiring the driver to enter the building. Cu rently, with the advent of in ovo vaccination which punches holes in eg at transfer making them more susceptible to infection,

and with regulator agencies insisting on pathogen reduction from the human perspective, IN security must be continually strengthened. A reasonable compromise•t(

40-B. HANDLING HATCHING EGGS 777

an integrator in this instance would be for the driver to change into clean coveralls, boots, and hat before entering the hatchery egg room.

Egg Delivery Records

Ii is necessary to establish a system whereby the identity of hatching eggs and their chicks can be maintained from the breeder house through the production system. This provides records for the hatching egg pro¬ducer, trucking company, hatchery manager, hatchery bookkeeping de-partment, and broiler and pullet growout. Delivery records should in-dud ;

- Source of eggs (flock, trucker, supplier)
- Dates eggs are laid and are received at the hatchery
- House, pen, or flock number(s)
- Breed combination (male and female)
- Number of cases or number of dozens of eggs received.

40-B. HANDLING HATCHING EGGS

Careful handling of hatching eggs in the hatchery is important. Always avoid unnecessary handling of eggs. For example, egg grading is a proce¬dure that results in many cracks. Due to increased cracks and other nega¬tive factors associated with grading (see Maintaining Hatching Egg Quality, Chapter 38), the hatchery should avoid grading or sizing eggs.

Traying Hatching Eggs

The most efficient method of traying is to have the eggs collected directly onto plastic setter flats at the breeder farm. This practice will eliminate extra handling of the eggs. Plastic flats are excellent for a variety of other reasons as well (see Chapter 38). In situations when eggs must be packed into boxes or cases and sent to the hatchery, they should be trayed as close to setting time as possible. This procedure, however, is labor-intensive when compared to gathering the eggs directly onto setter flats.

Make flock identification cards which contain all the necessary informa-tion regarding the eggs. If egg settings are made twice weekly, these cards are numbered 1 through 6 corresponding to the 6 settings of eggs in the machines at one time. The #1 refers to the first setting, #2 refers to the second setting, etc. With plastic setter flats, the cards are placed into a cell with an egg. For ease of identification, some hatcheries find it helpful to color code the cards. The numbers and color coding make it easier for the transfer crew to select the correct trays of eggs at transfer time.

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Figure 40-1. Traying Hatching Eggs

Pre-warming Eggs Prior to Setting

There is considerable disagreement in the poultry industry regarding the value of pre-warming eggs prior to setting. Those who favor pre-warming state that it reduces the amount of time required for the Seftez to return to the normal operating temperature, thus having a lesser effect on the developing embryos already in the machines. Those who diSagree with the practice of pre-warming generally acknowledge those advan¬tages, but claim that pre-warming invites egg sweating. They feel that sweating is more detrimental than any temporary loss in setter tempera¬ture. The author agrees with the thoughts of the latter group. When decid¬ing on whether or not to pre-warm, it is important to observe how long it takes the setter to return to its set point temperature after the new eggs are set. When it takes the incubator 90 minutes or less to return to normal temperature, pre-warming is not needed. When that time period is more than 90 minutes, pre-warming may be warranted.

When pre-warming is required, it must be done correctly. Following is a list of suggestions to use, when pre-warming:

- Ideally, a dedicated pre-warming room should be used (most hatcheries do not have this).
- The ideal temperature and relative humidity for pre

warming is about 73°F (23°C) and 45%, respectively.

There must be a very strong airflow in the pre-warming area. First, the strong airflow will help to evaporate con-densation as it forms, and second, it prevents the prob-lem of uneven warming that will cause uneven hatch¬ing. Without a strong airflow, the top and bottom trays along with the eggs around the periphery of the buggy will warm faster than those in the middle. The strong airflow reduces the effect of this phenomenon.

- Never pre-warm more than six to eight hours before set-ting.
- Pre-warming is not required with single-stage incuba¬tion. The eggs are placed into setters for pre-warming. Set temperature for pre-warming in single stage ma¬chines can be controlled at 73°F (23°C) and there is plenty of airflow.
- For multi-stage incubation, avoid pre-warming, if pos-sible.

Variability in Hatching Time

Even under optimum conditions, chicks from a single setting will not hatch at the same time. In laboratory conditions where there is very little environmental variation, there will be 24 hours between the hatching of the first chicks and the last chicks in the same setting. In the industry this time, lapse between first and last chicks is normally about 32 hours. This is generally the result of variable egg storage and incubation conditions.

There are many factors which influence variability and duration, of hatch time. Some of these are:

- Time of year: Eggs produced in the summer will have the shortest incubation time while winter-produced eggs will have the longest.
- Flock age: Generally, eggs from older hens require a longer incubation time
- Egg size: With the exception of the first eggs laid by a flock, larger eggs require more incubation time than smaller ones. For every 2.5 grams above a 50 gram aver-age egg weight, add 30 minutes to the incubation time (Hodgetts, 1992).
- Breed or strain: Hatching eggs from table-egg layer breeders require less incubation time than eggs from broiler breeders. There is also considerable variability in incubation time within breeds and strains.

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- Egg storage time: As eggs are stored for longer periods, the incubation time increases. This becomes an impor¬tant factor after five days of storage. For every day of storage beyond five days, add one hour to incubation time.
- Conditions which lengthen the time of hatch between first and last chick include transferring eggs with differ¬ent egg storage times into the same hatcher, mixing eggs from different flocks, ages or breeds into the same hatcher, hot and cold spots either in the setter or hatcher, and poor ventilation in the setter or hatcher.

40-C. PULLING THE HATCH

The process of removing chicks from the hatcher is often called puffin the hatch. The time chicks are pulled can have a significant effect on chic quality and can affect mortality after being placed on the farm. When chicks are pulled too soon, there will be a percentage of chicks with thei navels not fully closed. These chicks are vulnerable to contamination a they progress through chick processing and to the farm. The open nave provide an entry point for invading microorganisms. Chicks pulled too early also will not have sufficiently dry down and chicks with wet down are susceptible to chilling and stress.

Chicks that are pulled too late can be dehydrated. Dehydration sign cantly lowers overall chick quality and results in elevated chick mortal' after placement. Dehydrated chicks are very difficult to recognize in th hatchery as most appear normal.

There are several methods or indicators that can be cietermul

the correct time to pull chicks. The first is to check how the hatch is pro gressing the day before it is to be pulled. At 12 hours before pull time look at several trays in each hatcher.

Trays from the top, middle, and bot tom should be included in this examination. At 12 hours before pull, ap proximately 50 to 60% of the chicks should be fully out of their shells. T second method is to determine the number of chicks that are still wet the time of pull. At the optimum time of pull, 5 to 10% of the hatche chicks from various trays should be damp around the neck area. The thir method involves looking for signs of pulling too early or late by obsery the chicks and the hatch debris. These include:

Chicks are being pulled too late if:

- They are chirping loudly.
- They are gasping or panting.
- They are all completely dry.

Chicks are being pulled too early if:

- They are still wet.
- There are a lot of pipped, unhatched eggs.
- Navels are not completely closed.

Also observe the hatch debris (broken shells and unhatched eggs) left in the tray. They were pulled too late if the outside of the shells are dirty and stained. When there is. blood on the inside of the shells and the shell surfaces are relatively clean, the hatch was pulled too early.

Grading Chicks

Grading chicks is an important quality process for any hatchery. Deliv¬ering only quality chicks will maintain the hatchery's reputation while re¬ducing grower / customer complaints. In non-automated hatcheries, grad¬ing is a several step process. The first step occurs during chick dumping or harvesting (removal of the chicks from the hatcher trays). Personnel removing the chicks should cull those with obvious problems such as de¬formities, partially closed navels, crooked toes, excessively wet down, twisted legs, etc. The second step occurs during, processing (vaccination, beak trimming, sexing, toe-clipping, dubbing). Many 'hatcheries have a

quality control person evaluate several boxes of chicks from each flock tQ determine that proper quality stand ards are being met.

In a fully automated hatchery, chick grading is more difficult, mainly because the chicks are not handled as in more conventional hatcheries. First, there are no personnel dumping chicks when a chick / shell separator is in use. Further, vaccination is done in ovo and chicks are counted by machine. However, there are at least two opportunities for chicks to b graded in an automated hatchery. The first opportunity occurs when th chicks are moving down the conveyor from the separator. Automate hatcheries should have a person(s) grading and

culling chicks for quaff at this point. The second opportunity is provided after the chicks ar placed in boxes. A quality control person(s) can evaluate chicks in eac box and remove the culls

In some countries, there is a market for chicks that have been culled. this situation, the hatchery classifies chicks as either first-, second-, o third-class. First-class chicks are delivered to the farms. Second-clas chicks are sold at a reduced price to individual customers. Third-clas chicks (severe problems) have no value and are destroyed.

Chick Holding Room

After the chicks have been counted and boxed they should be Mimed* ately moved to the chick holding room. The temperature in this roo should be maintained at 75°F (24°C) with a relative humidity of about 70 These environmental conditions prevent chicks from chilling and deh, dratin.g. The ideal situation is to have the chick holding room separat from other rooms in the hatchery. However, most hatcheries cons large chick processing rooms which also serve as the holding room. So times this can be a problem in automated hatcheries, where it is not u common for all chicks to be processed by 10:00 or 11:00 a.m. The probk occurs when the processing area is cleaned and disinfected soon after cessing, but there are still several flocks of chicks in the room awai delivery. In such cases the disinfected areas of the room become reconta nated, presenting a hazard to the next day's chicks. Internationally, m hatcheries hold the chicks overnight for next day delivery. Therefore, it poor practice to hold chicks in the chick processing room.

Chick boxes are generally stacked 8 to 10 high and all boxes from e flock placed together in the holding room. When chicks are sexed, m hatcheries have different color chick boxes for males and females. though holding room conditions may be correct for both temperature humidity, it is possible for the top boxes of chicks m each stack to bec chilled and stressed. To avoid this, place an empty box on top of stack. Many hatcheries have chick box tops expressly for this purpo

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calculating Hatchability

The only chicks that should enter into calculations for hatchability are first quality chicks. For each flock, the number of first quality chicks is divided by the number of total eggs set and then expressed as percentage hatchability. Hatcheries that sell second-class chicks calculate percentage hatchability for two categories: hatchability of first quality class and hatch-ability of second quality chicks. Most hatcheries place two or more addi-tional (extra) chicks in each box to compensate for counting errors and for mortality that may occur in shipment.

40-D. CHICK DELIVERY

Safe and sanitary, delivery of day-old chicks is the last of the many hatch-ery. operations. Most deliveries are made by chick trucks or buses, al¬though other means of transportation such as rail and air are sometimes used.

Chick Trucks and Buses

Specialized trucks and buses are used for delivery and are most often either custom-built or secured from a chick transport vehicle manufac¬turer. They must have good ventilation and a means of stacking and sepa¬rating the boxes. Typical chick trucks can hold from 10,000 to 50,000 chicks. The size of chick trucks is determined by the size of the hatchery, delivery distance, and the number of days per week• the hatchery operates.

Chick trucks need to have adequate heating, cooling, and ventilation systems to prevent the chicks from becoming stressed during delivery. SNerilihoUsand chicks generate a lot of heat and when confined into the relatively small space in the chick truck, adequate ventilation is required to remove the heat. Special fans, air intakes, and exhausts must be provided.

In cold climates, the chick compartments need to be heated. Water heated by the truck engine is the usual source of heat, while electric heaters are sometimes used. During summer months, or in hot climates, a refriger¬ation unit is required to prevent heat stress. In many cases, the cooling units are powered by small gasoline engines that must be properly ex¬hausted.

The distance chicks are transported will determine the amount of truck cooling required. If the haul is only a short distance and can be completed during the cooler part of the day, adequate ventilation, rather than re¬frigeration, may be all that is needed.

fer which includes a layover of six or more hours. When possible, book direct flights.

Type of flight

- Passenger flights. Passenger carriers vary in their ability to ship chicks properly. Check the type of equipment the carrier has prior to arranging chick deliveries on pas¬senger flights.
- Freighters. Freighters also vary in their ability to properly handle chicks. Check the freighter prior to making ar-rangements for chick deliveries.

Other factors to consider are:

- 100 boxes generally represent. maximum loads.
- Are pallets used for loading?.
- Check where the chicks are to be located in the plane. Belly compartments may not be properly ventilated. Never load the chicks into a compartment containing dry ice (frozen carbon dioxide).

Instructions at the airport. Generally, more chicks die or are damaged at the airport waiting for shipment than on the plane. Therefore, extreme precautions must be taken. Comply with the following:

- The captain of the flight must be informed that chicks will be on board.

- Keep chicks in shade prior to loading.
- Keep chicks away from drafts.
- Do not allow chicks to stay outside in cold weather, or in the sun at any time.
- Do not cover chicks with a tarpaulin. Never place chick

boxes in the corner of a room. Keep chicks in a well-venti-

lated,room inside an adequately heated cargo building.

n

- Do not stack boxes over eight high to minimize over¬heating.
- Never allow boxes to become wet as they will collapse.
- Do not stack other cargo on top of chick boxes and leave airspace around stacks of boxes.
- Keep boxes level at all times.

40-E. HATCHERY SANITATION

A sanitary hatchery is necessary for good hatchability and chick quality. The hatchery sanitation program must also include hatching egg sanitation on the breeder farm as most contamination seen in the hatchery originates

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Figure 40-3. Hatchery Sanitation Is a Must

from the farm. See Chapter 38 for an in-depth discussion on breeder farm and hatching egg sanitation.

Key Elements of a Good Hatchery Sanitation. Program

Many poultry industry personnel incorrectly correlate the success of hatchery sanitation with certain disinfectants. The types of disinfectants used are certainly important, but disinfectants constitute only one of the key elements in a good sanitation program. When there is a breakdown in any of the other key elements, it matters very little which disinfectant is used, as the program will not be successful. For example, when there is a breakdown in biosecurity, the sanitation program will suffer. The nine components of a good sanitation program are:

- Safety
- Biosecurity (isolation)
- Hatchery design

- Hatchery ventilation
- Clean-up
- Disinfection
- Waste disposal
- Microbiological monitoring
- Communication

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Safety: "Safety First" is always a good slogan and it certainly applies to hatchery operation and sanitation. In most countries, hatcheries are re-quired by law to have a good safety program. A safety program in a hatch¬ery involves frr:quent meetings with employees to remind them of impor¬tant safety issues, and to become and remain safety conscious. Included in these meetings are plans of evacuation for disinfectant spills, locations of eyewash stations, and specific information regarding each chemical.

Every chemical used in the hatchery, including disinfectants, sanitizers, cleaners, etc. should have a Material Safety Data Sheet (MSDS) on file which describes the active chemicals, their dangers and toxicity to employ-ees, and suggested antidotes or treatments for accidental exposure. The hatchery manager should only designate those employees who do not show chemical sensitivities to handle the mixing and dispensing of these products. An employee is sensitive to a chemical when he / she shows a rash or other allergic reaction after exposure. Sensitive employees may exhibit allergies even when the chemical is in its final, most diluted state.

Certain chemicals should never be used when employees are present in ,the,room. where they are being dispensed. For example, fumigation with formalin and potassium permanganate emits formaldehyde gas which is very dangerous to employees. The person who mixes these two chemicals should always be the only person in the room where it is being used and he / she should always wear a good quality mask. Fumigation with formal-dehyde should always be done in the hatcher room after the normal work-ing hours in the hatchery. In 1989, the US Occupational Safety and Health Administration (OSHA) severely restricted the use of formaldehyde stat¬ing that the fumigation process in hatcheries produced too much exposure to employees. The result is that in many instances actual fumigation with formaldehyde is no longer a viable option in the United States. Some hatcher¬ies will pour a quantity of formalin into a shallow dish and allow it to eva¬porate into the hatcher air. This procedure, although helpful, does not com¬pare to the effectiveness of actual fumigation. Even with formalin evaporation, employees should not enter the rooms where this is being done.

Central fogging systems emit a timed exposure of a disinfectant into setters, hatchery, and selected rooms. Central fogging is the newest and best method of dispensing disinfectants. However, in the case of room fogging, the system should be timed to fog only after employees have fin-ished work for that day.

,Biosecurity (isolation): After safety, biosecurity should be the next most important consideration for hatchery sanitation. The goal of biosecurity is to isolatd the hatchery, and environments within the hatchery, from sources of contamination. The hatchery building should be isolated from potential contamination. Locating the hatchery near a feed mill, processing plant, or other industrial buildings which exhaust dust or pollutants does not constitute good biosecurity. The hatchery premises should be isolated

from unwanted visitors. Place a wall or fence around the hatchery with a gate and a guard. Discourage visitation and allow visitors by appointment only. Visitors serve as a potential for introducing unwanted pathogens as they may have been on a contaminated farm, may own pet birds or back-yard flocks, or have been exposed to other serious disease reservoirs.

Good biosecurity includes a truck wash station where all vehicles enter-ing the hatchery premises are sprayed with a disinfectant. This recommen-dation is implicitly observed at primary breeder hatcheries, but seldom at parent stock (integrator) hatcheries in the United States. However, in many parts of the world, truck disinfection stations are seen at parent stock hatcheries. The same applies for other biosecurity recommendations such as hatchery and breeder farm shower-in facilities with changes of clothe's, etc. The potential for moving contamination from one room to another in the hatchery should be reduced to a minimum. This can be done in the following manner:

- Follow the correct ventilation requirements for air pres-sure and movement. Keep doors closed to maintain cor-rect room pressure (see Hatchery Planning, Design, and Construction, Chapter 36).
- Place foot baths with disinfectant at all entry and exit doors in every hatchery room.
- Design the hatchery so that the work flow always moves from clean areas to less clean or dirty areas.
- Never roll clean egg buggies through dirty rooms.
- Restrict employees from moving through dirty rooms into clean ones.

Hatchery design: The design and construction of the hatchery can con-tribute significantly to the sanitation program. The design must include biosecurity considerations, such as work and egg flow patterns, and the placement of ventilation inlets and exhausts for fresh and used air. Incor-porate into the design of the hatchery the strategic placement of high pres-sure hot water outlets for cleaning purposes. Also, surfaces in the hatchery should be constructed of easy-to-clean materials that are resistant to corro-sive chemicals.

Hatchery ventilation: For the purposes of this discussion, fresh air will be thought of as a disinfectant. Fresh air replaces stale contaminated air in the hatchery and should be made as plentiful as possible. A simple way to distinguish between a well-ventilated, clean hatchery and a poorly ventilated, dirty one is by smell. Does the air smell fresh and clean or stale and

like rotten eggs? Ideally, each room should have its own ventilation system isolated from other rooms. Adjust the air pressure in each room so that the cleanest rooms have the highest positive pressure. In the winter,

or in cool climates, always mix enough fresh air with re-circulating air to satisfy fresh air requirements. Hatchery ventilation is discussed in detail in Hatchery Planning, Design, and Construction, Chapter 36.

Clean-up: The most important time for clean-up is after each hatch. After a typical day of hatching (pulling the hatch, processing, and holding chicks), the hatchery becomes filthy with a vast amount of organic mate¬rial. Remove all of the organic material as completely as possible. The pres¬ence of organic material will reduce the effectiveness of any disinfectant, Some more than others. The only truly difficult place to clean after each hatch day is inside the setters. All other areas should be thoroughly cleaned before disinfection. After the organic material is removed, clean¬ing with high pressure hot water is an excellent method to remove contam¬ination. Sanitizers and detergents aid in the cleaning process while limiting microbial populations. On non-hatch days, more attention can be given to cleaning the entire hatchery including the setters and setter rooms. Re¬member to remove all water from the floors after cleaning, especially in the setter and hatcher rooms, so that humidity can be accurately controlled..

Disinfection: In the late 1980's nearly all disinfectants used in the hatch¬ery fell into six categories: alcohols, aldehydes, halogens, peroxides, phe¬nolics, and quaternary ammonium compounds. Some contained a combi¬nation of compounds formulated from various classes of chemicals. They are still very popular hatchery disinfectants, but numerous new disinfec¬tants are currently available that do not fall into these categories.

Note: In the fourth edition of this book (Chapter 9), there was a very descriptive summary of most hatchery disinfectants including their chemi¬cal properties, effectiveness against certain types of organisms, and explicit directions for their use. Please refer to the pfevious edition for this type of information. The discussion here will focus on important considerations for disinfectant use including newer methods for dispensing them.

Fogging: The advent of central fogging systems has greatly assisted the hatchery operator in reducing contamination. Central fogging sys-tems incorporate high water pressure nozzles located throughout the -hatchery, including inside the setters and hatchers. The various environments within the hatchery receive a timed release of disinfectant mist. For example, the setters can be fogged once per hour, or even more frequently, if needed. Fogging has

provided a great boost for hatc1-::v. sanitation. Before fogging, setters were rarely disinfected as they were rarely empty of eggs and could almost never be thoroughly cleaned. However, with frequent fogging, bacterial populations in set-ters can be kept at very low levels. Rooms may also be fogged on regular intervals, but, for the sake of safety, the time of fogging should. be programmed when employees are not present.

Portable and pneumatic foggers are also commonly used in hat ery sanitation. Portable fogging units have the advantage of being expensive and can also produce relatively small droplet sizes, w is an advantage for dispersal. Their biggest disadvantage is that th require considerable labor to fill and move to different locations. 0 cause of this, the frequent use of portable foggers is not practical.

Pneumatic foggers are advantageous because they are stationary and can offer frequent timed fogging. However, droplet sizes are a little larger than droplets from portable foggers. The major disadvan,, tage of pneumatic fogging systems is that the nozzles have a propen sity for clogging. A clogged nozzle will not dispense disinfectant. For example, in a large hatchery, it has been reported that 80 man-hours per week are necessary to clean nozzles to keep the pneumatic fogging system operating properly.

Central fogging units are the best for several reasons:

1. their nozzles rarely clog,
2. very little labor is required on a weekly baSis to operate the system,
3. disinfectant spray droplet sizes are the smallest of the three fogging systems available,
4. the nozzles provide a wide angle of spray, and
5. each environment in the hatchery can be programmed for time of spray.

The one disadvantage of central fogging is that it is the most expen¬sive of the fogging systems. However, considering its effectiveness in reducing contamination, it may very well be the cheapest system. A comparison of central and portable fogging systems and untreated controls was made in a hatchery and are shown in Figure 40-4. As noted in the figure, central and portable units considerably reduced bacterial load as compared to the untreated controls.

The use of electrostatic technology in the hatchery: Two new methods of sanitation currently being made available to hatcheries involve elec-trostatics. Hatcher air ionization, or electrostatic space charging in¬volves introducing an electrostatic charge into hatcher air after eggs are transferred (Mitchell, 1998). The electrostatic charge placed in the hatcher results in all particles within the air (fluff, dust, etc.) having a strong negative charge. These ionized particles immediately leave the air and adhere to specifically designed surfaces located within the hatcher. The result is that more than 90% of the particles in the air can be removed along with the microbes adhering to them. A metal plate must also be installed in each hatcher. A specially designed metal plate and flushing system at the top of the plate

rinses the fluff off every three to four hours so that new fluff particles will have a place to adhere. Without regular rinsing, the electrostatic charging

A. Untreated
B. Fogged, 12 hour intervals 6 ounces/gallon (portable)
C. Fogged, hourly 0.5 ounce/gallon (central)

0 12 24 36 48
Time in Hours

Figure 40-4. The Effect of Central and Portable Fogging Systems
and Untreated Controls on Bacterial Counts in a Hatchery

would lose its effectiveness. Agar plate samples taken after hatcher air ionization have revealed highly significant reductions in airborne pathogens.

Another use of electrostatics in hatchery sanitation involves nega¬tively charging the disinfectant as it is being dispensed as a mist or fog. The charged disinfectant mist adheres evenly to all surfaces within the hatchery environment which results in better distribution and consequently better microbial kill. This system has been tested in hatchers and other hatchery environments and has been shown to be an effective method to reduce pathogens.,

Sanitizers and disinfectants. Sanitizers are chemicals with detergent and bleaching agents that aid in the cleaning process and are used prior to the application of disinfectants. Sanitizers are also capable of killing most of the organisms present on the surfaces being cleaned, however, their use should be followed by a disinfectant. With the use of sani¬tizers followed• by disinfectants, the microbial kill should be in the range of 99% or gfeater. In some cases the sanitizer is simply a more diluted form of disinfectant. In other cases, the sanitizer is from an entirely different group of chemicals than the disinfectant. When the lattO situation is true, the surface should be thoroughly rinsed with water after the sanitizer has been used and before the disinfectant is applied to prevent any chemical or pH incompatibilities. In most cases, incompatibility merely renders the chemicals ineffective; how¬ever, in some cases, toxicity problems may result from incompatible chemicals.

Considerations for disinfectant use. There are numerous choices when de-ciding whe're and how to use a disinfectant in a hatchery environment. Even though a certain disinfectant may be extremely effective, it may

not be used for certain applications because of one or more of the following considerations:

• pH: Disinfectants can be either alkaline or acidic, de¬pending upon their chemical structure and the structure of their chemical carriers. Therefore, it is recommended to vary the pH of the disinfectants at six-month intervals to reduce the buildup of biofilms. Biofilms a:

cally undetectable, minute layers of material produced by bacterial populations. Using disinfectants will kill or¬ganisms on the top of the film, but the undersurface can be protected by the biofilm and can contain growing mi¬crobial populations. The best way to eliminate biofilms is to vigorously scrub surfaces and to periodically change the pH of the disinfectant being used. Another consideration regarding pH is the compatibility of the pHs of the disinfectant and sanitizer or detergent. If not properly managed, the disinfectant may be neutralized.

• Compatibility: Since there are many chemicals used in the hatchery for sanitizing and disinfecting, the compatibil¬ity of these chemicals with each other must be consid¬ered. Disinfectants and sanitizers vary in their chemical structure and pH and may neutralize each other when used together in the same environment. Compatibilities of chemicals must be seriously considered before their use. Product labeling and directions for use provide in¬formation regarding compatibility.

• Temperature: Nearly all disinfectants and sanitizers work more effectively when the temperature is high. For ex¬ample, formaldehyde fumigation does not reach its peak effectiveness until the environmental temperature is at least 75°F (23°C). At 65°F (18°C) formaldehyde fumiga¬tion is only about 50% effective. This eliminates the egg room as an acceptable environment for fumigation. An¬other example is observed with the use of sanitizers in mechanical egg washing machines. In these machines, the temperature of the sanitizing solution in the first (wash) cycle is about 115°F (41°C) and the disi:;fPctani solution temperature in the second (sanitizing) cycle is 118°F (44°C). Therefore, egg sanitation is most effective at these high temperatures.

• Relative humidity: Humidity considerations are only im¬portant when gaseous fumigation is used, as in the case of formaldehyde fumigation. Fumigation is more effec¬tive at higher relative humidity, i.e., 75% or higher.

• Toxicity: Consideration of toxic properties of disinfec-tants to both humans and chickens is extremely impor-tant in hatchery sanitation. Unfortunately, this consider-ation eliminates certain very effective disinfectants for consideration in the hatchery. An example includes cre-sylic compounds. These are used primarily for poultry house disinfection but are too toxic for such confined areas as hatcherie.s. Most disinfectants can be toxic to humans, embryos, and newly hatched chicks when they are used improperly. For example, hydrogen peroxide is one of the most effective disinfectants available to the poultry industry. When used at the correct dilution (2% to 4%) it is very effective. However, solution strengths • exceeding 5% are very dangerous. Extra care must be taken in the storage and mixing of any

disinfectant in a hatchery. Read the disinfectant label and MSDS records so that the disinfectant is mixed safely and at the correct strength. Never increase the strength of a disinfectant over the manufacturers' recommendations to attempt to achieve better microbial kill. This can be harmful to de-veloping embryos, and possibly, the employees. If the disinfectant is not effective at the recommended dilu-tion, change the disinfectant, not the strength of the dis-infectant.

- Methods of disinfectant application: Previously, the method of application was to spray surfaces with disinfectant or fumigate after cleanup. Currently, there are more op¬tions for disinfectant application. Foaming disinfectants may be used to increase the duration of contact of the disinfectant with the surface. Fogging disinfectants with timers also provides an excellent means of keeping mi¬crobial populations, especially airborne microbes, at a minimum.

Waste disposal: Hatchery waste potentially contains a tremendous amount of fast-growing microbiological contamination. The waste in-cludes infertiles and non-hatched embryos, fluff, shell fragments, plus dead and cull chicks. It must be effectively removed from the hatchery while minimizing the possibility of recontaminating hatchery environ-ments. Hatchery Planning, Design, and Construction, Chapter 36, includes a discussiOn on the types of mechanical equipment available for hatchery waste disposal. Positive and negative pressure waste removal systems are popular in newer hatcheries, while auger systems are common in older ones. The location of the waste reservoir in such systems is important to prevent recontamination. Generally, storage reservoirs are placed at the

rear of the hatchery, away from hatchery entrances and employee parkin lots.

There are several ways that a hatchery can dispose of the waste after it is collected into the waste storage tank. These include:

- Sanitary landfill: The waste is hauled on a fully enclosed truck and dumped at a sanitary landfill.
- Rendering plant: Rendering plants process hatchery waste for use as feedstuffs for poultry and other ani¬mals. Due to variation in hatchability the nutrients in hatchery waste can be highly variable. When -r1;tchabil¬ity is high there is an associated decrease in the protein level and an increase in calcium content of the hatchery waste. The opposite is true for periods of low hatchabil¬ity. Hatchery waste by-product can replace up to 6% of the meat scrap or soybean oil meal in a growing ration, while the shell meal can be substituted totally for other sources of calcium in the feed. In the layer ration, up to 16% of the total feed can be composed of rendered hatchery waste.
- Lagoon: Ground hatchery waste may be pumped into a lagoon with floating aerators. The final liquid material from lagoons is generally applied to the land.

• Composting: The solid portion of the hatchery waste (54 to 56%) can be composted by using various materials depending on what kind of final product is desired. The liquid fraction (44 to 46%) is dried and rendered.

Microbiological monitoring: A good microbiological monitoring pro-gram must be implemented in every hatchery. The monitoring program provides useful information on the levels of contamination found in all environments within the hatchery. There are numerous methods available for monitoring microbiological populations including swabs, air plates, and others. There are three important rules when implementing a monitor¬ing program: (1) do it correctly, (2) do it consistently, and (3) apply the information obtained from it. Always collect the samples the same way each time and at the same time each day and week. Remember, swabs and air plates only give relative data with regard to bacterial and fungal growth. With these tests the exact amount of microbial growth in an envi ronment Cannot be completely assessed. However, the tests are Ult,ef al be¬cause results can be compared weekly, monthly, and yearly to determine progress and effectiveness of the hatchery sanitation program. If this week's results show more contamination in an environment than previ¬ously recorded, then it can be concluded that the current sanitation pro

gram was not as successful as earlier programs and steps can be taken to correct it.

Consistency in the method of sampling will ensure accurate and mean-ingful results. To be consistent in taking air samples, the amount of air flow in the test environment must be the same every time. For example, air plates will show more contamination in a clean room where there is a strong airflow than in a dirty room where the air is not moving. Always expose the air plates for the same length of time in each environment. When swabbing surfaces to measure microbial contamination, always swab the same amount of surface area each time. Microbial detection kits have recently been introduced to the poultry industry and give rapid and quite accurate measures of the extent of microbial contamination in a sam¬pled area. One of the methods measures the amount of adenosine triphos¬phate (ATP) produced by bacteria on test surfaces.

A thorough microbiological monitoring program will include 100 or more samples each sampling period. The most critical areas for sampling are:

- Egg room air.
- Air inlets of each setter and hatcher.
- Inside each setter.
- Vaccination room air and surfaces.
- Vaccine and diluent samples (Marek's and spray vac-cines); take samples after mixing.
- Chick room air.
- Chick processing equipment surfaces.

In some states, diagnostic laboratory systems provide a valuable service to the poultry industry by monitoring microbiological populations in hatcheries. These laboratories routinely sample hatcheries and provide re-ports on the levels of contamination found in each area. They have a rating system for contamination, whereby every. sample is given a score indicat¬ing its level of microbial contamination. An area is assigned a value of:

1—if the plate (swab or air) contains less than 10 bacterial colonies,

2—if the number of colonies is between 10 and 19, 3—if the number of colonies is between 20 and 29, 4—if the number of colonies is between 30 and 39, and 5-1--when number of colonies exceed 40.

Scores are averaged for each environment in the hatchery, i.e., inside set-ters, chick processing rooms, etc. The hatchery receives an overall score ranging from 1 to 5 giving an indication of overall sanitation and cleanli-ness.

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The best hatchery monitoring efforts normally include an in-house pro-gram backed up by a state program. It is important to test before and after any change in the sanitation program to determine if changes are beneficial.

Communication: For hatchery sanitation to be successful there must be good communication between the hatchery managers and their various employees, and with breeder farm personnel. For example, the breeder farm manager or serviceman should communicate to the hatchery any un¬usual problems occurring with a delivery of eggs, i.e., eggs getting wet accidentally from water hose, egg sweating problems, or poor sanitation of egg flats from the hatchery returning to the farm. The hatchery manag¬ers should be in constant communication with their employees regarding the goals and practices to be followed including procedures of the sanita¬tion program. Quality control personnel must discuss their microbiological monitoring results with hatchery managers so that the sanitation program can be continually monitored for improvement.

Changes in the Extent of Hatchery Contamination Over the Last Ten Yetirs

When the use of formaldehyde for disinfection in hatcheries was re-stricted in the United States in 1989, the poultry and allied industries be-came concerned. At that time formaldehyde was considered as the most effective disinfectant available. The poultry and allied industries re-sponded by increasing biosecurity, developing new disinfectants, devel¬oping new methods of dispensing disinfectants (such as central fogging systems), and by strengthening hatchery and breeder flock sanitation pro¬grams. Also, Hazzard Analysis Critical Control Points (HACCP) programs were implemented which directed the attention of poultry managers to critical and potential problem areas in all live bird operations and processing. The result of these efforts is that hatcheries are much cleaner now than when formaldehyde was used.

Another reason for lower levels of contamination now than a decade ago has been the development and practice of in ovo Marek's disease vac¬cination. Vaccinating eggs leaves

holes in the shell, making them more vulnerable to contamination. Realizing this, the company leasing in ovo vaccination equipment requires that participating hatcheries have an ex-cellent sanitation program. Microbiological populations are rigorously monitored and must be at a certain low level before the equipment ca be installed. Currently about 85% of the broilers produced in the Unite States are vaccinated in ovo.

A series of research projects conducted in Georgia have shown a dra¬matic reduction in Salmonella populations over a five-year period (Cox,

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D1990 ILIIII 1995

100 Percentage

80 - 76
60 -
40
23
20 91

Hatchery

Source: Cox, et al., 1997
Figure 40-5. Percentage of Samples Positive for Salmonella in Three
Georgia Broiler Hatcheries in 1990 and 1995

et al., 1990, 1997, and 1999). In 1990, three broiler and two primary broiler breeder hatcheries were sampled and tested for the presence of Salmonella spp. in fluff, eggshell fragments, chick box paper pads, and chick belts. In 1995, the same three broiler hatcheries were sampled again to determine changes in the presence of Salmonella (Figure 40-5). The results show a dramatic decrease over time in the incidence of positive samples for Salmonella in all three hatcheries. In addition, the number of Salmonella positive

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samples that exhibited greater than one thousand colonies was 95% 1990, and were reduced to only 16% in 1995.

Figure 40-6 shows the changes observed in Salmonella populations, in the two primary breeder hatcheries between 1991 and 1998. Primary breeder hatcheries exhibited fewer positive samples for Salmonella in 1991 and 1998 than did broiler hatcheries in 1990 and 1995. However, unlike results from the broiler hatcheries, there was not much difference in the percentages of positive samples from the primary hatcheries over the seven-year period.

Primary breeder hatcheries have much more rigid hatchery sanitation and biosecurity programs than do broiler hatcheries, which probably explains why the primary hatcheries had low levels of Salmonella contamination for both testing periods.