Commercial hatcheries face three key challenges in the future: genetic progress, uniformity and post hatch performance.

Genetic progress demands greater control over the management of hatchery conditions, to maximise the potential of modern poultry breeds, while high chick uniformity will continue to be an essential precursor to outstanding post hatch performance.

In this series of articles, originally published by Pas Reform in 2004, we share our insights into meeting these challenges for future growth and profitability with you.
Standards for successful commercial incubation were defined during the first half of the 20th century. In 1969, Harry Lundy reviewed the data available at that time on artificial incubation, to publish *The fertility and hatchability of Hen’s eggs* (Carter, TC and Freeman BM, eds, Edinburgh (1969) 143-176). To this day, Lundy’s review is widely regarded as the definitive reference for the design of incubators, as well as incubation setpoints for temperature, humidity and ventilation.

As one of the world’s leading hatchery technology companies, Pas Reform has, through the research, training and consultation activities of its academy worldwide, recognised the need to update this important reference work, in order to meet the needs of the embryos of today’s modern poultry breeds. For that reason we looked at the impact of advances in modern poultry genetics in relation to the application of Lundy’s standards in single stage incubation, with the emphasis on air and embryo temperature.

**Incubation and chick quality**

The poultry industry has undergone major changes since Lundy wrote his review in the late sixties. Genetic selection and highly developed management practices have greatly improved the efficiency of meat and egg production. In modern broilers for example, the growing chick spends half the time on the farm than it did a little over 26 years ago, with the rearing period having decreased since then from 84 days to just 42 today.

In the seventies, chicks spent 20% of their total lifespan, from egg to slaughterhouse, in the incubator. The modern broiler chick now spends 33% of its life in an incubator climate. It is therefore obvious that the impact of incubation conditions on the growing embryo and chick are fundamental to the growth performance and feed conversion ratios of modern broilers – and as such, should not be neglected as an important factor in determining commercial breed performance.

**Embryonic management change**

It is not just the proportion of lifetime spent in the incubator that has changed. With genetic progress, the diversification of egg types has also increased dramatically over the past 30 years. Within this diversification, specific egg producing and meat producing industry needs have emerged, induced by extreme selection pressure. While high egg production is the defining genetic factor for the former, the latter demands fast growth complemented by low feed conversion rates. And further, within the broiler (meat-type) breeds alone, selection for breast meat yield and percentage of abdominal fat, for example, have shaped the management needs of the broiler breeder industry specifically.

In the farm environment, the most obvious difference between layer hens and broilers is the difference in their respective growth rates. Layer hen chicks reach a weight of 500g at 42 days, while broiler chicks grow to over four times that weight, around 2300g, in the same period.

These differences are equally evident in the embryonic phase. Pal (2002) showed that genetic selection for growth not only influenced growth at the farm, but also the growth and body composition of the embryo in the second week of incubation.
Clum (1995) went further, to show that different growth patterns are associated with changes in the pattern of embryonic reallocation between tissue types. For example, higher growth rates are associated with decreases in bone, feather and brain mass. And in quail, selection for high postnatal growth rate is accompanied by a more rapid early development of the digestive organs. Metabolic disorders like ascites also find their origin in the embryonic phase.

**Broilers and layers**

In separate experiments, we have found that at 40 hours, broiler embryos and layer embryos were both in stage 10 of the Hamburger and Hamilton standards, while at 48 hours of incubation, broiler embryos were in stage 13 and layer embryos had only developed to stage 12. These results indicated that the higher growth rate of broiler embryos is in evidence before the blood ring stage at 80 hours of incubation.

What becomes critically important as a factor for successful incubation, is that fundamentally, different growth rates result in different levels of heat production between layer and broiler breeds. This makes it impossible to combine the incubation of eggs from a layer strain and a broiler strain under the same conditions in one incubator.

**Growth and metabolic heat**

The rate of embryonic as well as post-natal growth (growth at the farm) is determined by the rate of bio-synthesis of tissue, which depends on the availability of nutrients and oxygen. A strong physiological relationship exists between the rate of bio-synthesis and metabolic heat production. In trials conducted in collaboration with the Humboldt University in Berlin, Pas Reform has shown that at day 18, metabolic heat production, based on oxygen consumption, is about 26% higher for Ross 308, for example, when compared to a white leghorn breed (Table 1).

<table>
<thead>
<tr>
<th>Day of incubation</th>
<th>Metabolic heat production W per 1000 eggs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ross 308*</td>
</tr>
<tr>
<td>17</td>
<td>151.2</td>
</tr>
<tr>
<td>18</td>
<td>156.6</td>
</tr>
<tr>
<td>19</td>
<td>164.4</td>
</tr>
<tr>
<td>20</td>
<td>252.0</td>
</tr>
</tbody>
</table>


It is also clear that within broiler breeds, as selection for increasingly high breast meat yields and low percentages of abdominal fat continues, this further diversification will lead to still greater variability in the development and growth of broiler embryos and, consequently to breed specific incubation programmes.

**Table 2 - Setpoints for temperature recommended for single stage incubation of a brown layer and a broiler breed**

<table>
<thead>
<tr>
<th>Day of incubation</th>
<th>Embryonic age (hr)</th>
<th>Average egg shell temperature</th>
<th>Setpoint of temperatures in incubator</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>ºC   ºF</td>
<td>ºC   ºF</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>37.8 100.0</td>
<td>38.0 100.4</td>
</tr>
<tr>
<td>4</td>
<td>72</td>
<td>37.8 100.0</td>
<td>37.9 100.2</td>
</tr>
<tr>
<td>7</td>
<td>144</td>
<td>37.8 100.0</td>
<td>37.8 100.0</td>
</tr>
<tr>
<td>10</td>
<td>216</td>
<td>37.8 100.0</td>
<td>37.8 100.0</td>
</tr>
<tr>
<td>13</td>
<td>288</td>
<td>37.8 100.0</td>
<td>37.6 99.7</td>
</tr>
<tr>
<td>16</td>
<td>360</td>
<td>38.3 100.9</td>
<td>37.4 99.4</td>
</tr>
<tr>
<td>19</td>
<td>432</td>
<td>38.8 101.8</td>
<td>36.9 98.5</td>
</tr>
</tbody>
</table>
Metabolic heat production in the modern broiler breeds Ross 308 and Ross 508, is about 20% higher than the metabolic heat produced by the North Holland Blue, a traditional meat producing breed that was common in commercial poultry production when Lundy produced his review in the sixties (Table 1). The higher metabolic heat production of modern broilers as compared to a slower growing breed, is the result of higher growth potential. It is interesting that, at all time points measured, the Ross 508 embryo produced slightly – though not significantly – less metabolic heat. This was a surprise, given that there is a common belief today that breast meat producing breeds like the Ross 508 produce more metabolic heat during incubation. However Pas Reform results seem to indicate that high heat production by a broiler embryo is determined more by high growth rate than breast meat yield.

**Incubating modern breeds**

For incubator manufacturers today, the challenge is to design incubators that can support optimum embryonic development for each egg at each stage of development. The heating capacity of the incubator must be sufficient to initiate embryonic development in every egg placed in the incubator. Genetic selection has not only had an impact on production traits, but has also resulted in larger eggs with a decreased percentage of yolk volume. The greater volume of eggs produced by modern breeds means that a greater volume of eggs must be warmed – and therefore the heating capacity of the modern incubator must be increased in comparison to the older incubators.

It is a well known fact that metabolic heat production increases as the embryo grows. The cooling capacity of the incubator must therefore be sufficient to remove the heat produced by the older embryos, as the higher metabolic heat production of modern broiler embryos increases the risk of overheating. To avoid this, incubation setpoints are adjusted such that the embryo temperature is always maintained at the correct level.

In order to ensure optimum conditions for the growing broiler embryo in a commercial single stage incubator, setpoints for temperature are lower, compared to the temperature setpoints needed for the optimum development of layer embryos (Table 2). Further, the increased diversification of broiler breeds increasingly requires the development of breed specific incubation programs, whereby the eggshell temperature can be used as a leading parameter for the temperature setpoint.

**Conclusions**

- It is clear that genetic selection for high post-natal growth has fundamentally changed the pattern of embryonic development and rates of biosynthesis (=growth), resulting in higher metabolic heat production that must be carefully managed in the incubator environment to optimise hatchability and uniformity. In addition: for the optimum support of embryonic development, the incubator must have sufficient heating and cooling capacity.
- Optimum eggshell temperature for highest chick quality can vary between breeds, because of inherent variations in the embryo and egg characteristics of different breeds bred for either meat or egg producing purposes.
- Since the hatchery is the first and formative stage of broiler's life, breeder companies that support the hatchery with optimum eggshell temperature advice for each stage of development will deliver stronger, more breed-representative results.
- In this respect, to achieve the most efficient and productive poultry production both for the broiler and egg laying sectors, the incubator industry and breeder companies are well advised in their use of co-operative research, to share knowledge and explore the needs of the growing embryo.

**Note:**

1 Hamburger and Hamilton standards relate to a series of normal stages in the development of the chick embryo. The Hamburger and Hamilton standards are used by embryologists to describe the embryonic stages of different breeds.

2 Because the temperature of the embryo cannot be measured without damage to the egg, the temperature of the eggshell is used as a reference for embryo temperature.
Good hatchability is no accident. Nature has created a heat-dependent process that draws on maternal body temperature and the production of metabolic heat, to produce healthy chicks in three distinct and critical phases of incubation. Nature has the answers – and our aim in the hatchery must be to replicate these most natural of conditions, to produce healthy chicks that meet the ever-growing demands of commercial poultry markets around the world.

It is widely recognised that genetic improvements in poultry have resulted in an enormous diversification of breeds – all of which require specific incubation conditions. It is clear that embryo metabolism is changing as a result of selection for production traits – and that further changes will continue to emerge, as genetic advancement continues.

However, it is only recently that the majority of incubator manufacturers have recognised the value of improving and adjusting incubation technologies, to better meet the needs of the growing embryo. The hatchery forms an essential component of the poultry production chain, in that together with egg-related (genetic) factors, it is this process that determines the quality and vitality of the day old chick – a factor that ultimately determines the quality and technical performance of the final poultry product.

The development of a vital day old chick is a complex process that can roughly be divided into three phases: a phase of cell differentiation, a phase of growth and a hatching phase – each requiring specific incubator conditions.

**Temperature and embryonic differentiation**

Embryonic differentiation is characterised by the formation of different tissues that will develop into the chicken’s final organs in the growth phase (Figure 1). This first phase of cell differentiation starts in the hen, when the single-cell oocyte divides many times so that, in the un-incubated egg the embryo consists of about 30,000 cells. These 30,000 cells are organised as a plate of cells, known as the early gastrula, which floats on the top of the yolk.

After laying, the temperature of the egg decreases and the development of the embryo ceases or stops completely if the temperature falls below the physiological zero (25-27°C). Embryonic differentiation continues only when the temperature of the egg rises.

**Definition of incubation temperature**

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Embryo temperature</td>
<td>the body temperature of the growing embryo</td>
</tr>
<tr>
<td>Eggshell temperature</td>
<td>the temperature of the surface of the egg</td>
</tr>
<tr>
<td>Air temperature</td>
<td>the temperature of the air close to the eggs</td>
</tr>
<tr>
<td>Incubator temperature</td>
<td>the set point of the incubator</td>
</tr>
</tbody>
</table>

The differentiation phase is characterised by a ‘folding’ of the early gastrula, to form a three dimensional structure in which premature organ structures of the head and heart can be recognised within 36 hours. Movement of cells mediates this folding process, whereby the cells in the early gastrula ‘travel’ from one side to the other – and this process is highly temperature dependent.

In the differentiation phase, it is not only the embryonic structures that develop, but also the extra-embryonic tissues — such as the amnion and chorio-allantois, both essential structures in the transport of oxygen and nutrients from the yolk to the embryo.

In this stage of development, the embryo floats to the top of the egg, where it is nearest to the eggshell, and normal,
Within the growth phase, we recognize two different periods: growth decreases because maturation starts at about day 17 (Figure 1). In the part of the chick embryo's growth phase, which increases the growth rate and thus shortens the incubation period. Conversely, lower incubation temperatures result in longer incubation periods because they produce slower maturation. Higher incubation temperatures applied during this phase increase the growth rate and thus shorten the incubation period. Conversely, lower incubation temperatures result in longer incubation periods because they produce slower maturation.

Embryonic growth and temperature

During differentiation, the premature organs are formed and relatively minor changes in the size of the embryo are seen. However, the rate of growth is greatly increased during the last half of incubation. Embryonic growth is characterized by an increase in mass while the development of the organs continues (Figure 1). As we have seen in the first phase of embryonic development, temperature can also have a profound effect on the growth of an embryo—best speeding up or slowing down growth, and at worst, affecting the growth and left/right symmetry of skeletal parts and the lungs, as shown when broiler embryos were exposed to heat (39.6°C; 103.3°F) and cold (36.9°C; 98.4°F) for periods as short as six hours each day. Even within the normal temperature range of 37-38°C, differences in temperature induce different rates of development and growth.

Within the growth phase, we recognize two different periods during which the developing embryo responds differently to variations in temperature. The first part of the growth phase, which for a chick embryo starts at about day seven, sees an increase in the size of organs and the embryo as a whole. This phase is characterized by a rapid increase in embryo mass (Figure 1), which, within the 37-38°C range, is highly dependent on incubation temperature. Higher incubation temperatures applied during this phase increase the growth rate and thus shorten the incubation period. Conversely, lower incubation temperatures result in longer incubation periods because they produce slower growth rates.

In the second part of the chick embryo's growth phase, which starts at about day 17 (Figure 1), growth decreases because the maturation of tissues and organs takes place. For this reason, this phase is sometimes called the maturation phase.

Maturation of the organs is characterized by the accumulation of dry matter and, thus, the loss of tissue water. In addition, during maturation, the organs become responsive to specific signals such as heat or cold stress. In this phase, the absolute growth of the embryo is decreased and growth rate is inversely related to temperature.

Managing incubator temperature for optimum development

As described above, the development of a vital chick is a process of cell differentiation and growth controlled by the incubation temperature provided by the brooding hen during natural incubation. To mimic these conditions during artificial incubation, precise control of the incubator temperature is absolutely critical. In a commercial incubator, many other eggs surround each egg in the same stage of development—all of which must be warmed to start embryonic differentiation and to promote continuing development. During the first week of incubation, Pas Reform accepts an average eggshell temperature difference between trays of 0.1°C (0.2°F)—and it is our aim to maintain homogenous temperature distribution, as the spread of hatching is determined by any temperature variation in this warming period.

As the embryo grows, its metabolic rate increases and this is accompanied by increased heat production. Consequently, the pattern of the eggshell temperature shows an increase towards the end of incubation (Figure 1). For example, the temperature of the embryo in a single turkey egg rises to 38.4°C (101.1°F) on day 23, while the eggshell temperature parallels the embryo temperature, at a slightly lower level of 38.3°C (100.9°F). The temperature of the air surrounding this single egg fluctuates between 37.5-37.8°C (99.5-100.4°F), so that in this case, the heat produced by this single egg is removed efficiently.

In an incubator, however, every fertilized egg produces metabolic heat at the same level and will ultimately cause the temperature of the air surrounding the eggs in a tray to rise to unacceptably high levels if no cooling is applied. In a modern incubator, cooled air flows over the eggs to avoid this overheating effect, and for optimum hatchability and chick quality, an average eggshell temperature difference within one section of 0.25°C (0.5°F) during the last week in the setter is acceptable.
Single stage versus multi stage incubation

Based on excellent scientific research, Harry Lundy (1969 in The fertility and hatchability of hens’s eggs – Carter, TC and Freeman BM, eds, Edinburgh 143-176) summarised the incubation conditions needed for optimum chick development. When he wrote his review in 1969, it was common to set eggs of several embryonic ages in one incubator: the so-called multi-stage incubation.

In multi-stage incubators, the temperature, humidity and ventilation are set at a fixed point. The advantage of multi-stage incubation is its simplicity both with respect to the control system of the incubator as well as the management of incubation. The main disadvantage however, is that the multi-stage incubation environment cannot, by its nature, create optimum conditions for every egg set.

For example, in a multistage incubator, the average eggshell temperature may vary from 37.5°C (99.5°F) for the youngest embryos, to 39.5°C (103.1°F) for the later embryonic stages –, so it is difficult to find a temperature set point such that eggshell temperature is correct for each embryonic stage. Consequently, in multi-stage incubation, it is impossible to optimise both hatchability and chick quality, especially when dealing with variable egg quality.

It is clear therefore, that single-stage incubation maximises hatchability and chick quality – because incubation temperature, humidity and ventilation can be adjusted for each embryonic age and batch of eggs.

In a single stage incubator the incubator set points are adjusted such that the average eggshell temperature follows the natural pattern and thus maximises the quality of the ultimate product.

For example, in Cobb eggs, it has been shown that chicks hatched from eggs incubated at 37.2°C (99°F) until day 16 and then at 38.3 (100.9°F) from day 16 to hatch produced the highest body weight at 44 days, compared to eggs hatched at lower and higher incubation temperatures. For optimum development the eggshell temperature should follow a natural pattern of 37.6-37.9°C (99.7-100.2°F) during the first two-thirds of incubation and 38.1-38.8°C (100.6-101.8°F) during the last days in the setter, as shown in Figure 1.

Minor variations in this pattern are permissible due to differences in egg types.

Eggshell temperature as the leading parameter

Single stage incubation requires incubators to be equipped with heating, cooling, ventilation, humidifier and turning mechanisms that are controlled accurately and independently. The uniformity and power of heat transfer from the incubator’s temperature to the mass of eggs is a key aspect of incubator performance, because to achieve a uniform hatch, the eggs must be warmed rapidly and homogeneously. Homogenous temperature is best facilitated in an incubator divided into separate units, each with its own climate control. Results, not to mention the hatchery manager’s job, will be greatly enhanced with the tools to design and monitor customised incubation programmes that accommodate the specific requirements of the developing embryo in different egg types.

In addition the temperature control system must be accurate so that unacceptably large deviations or fluctuation in temperature around the set point, or ‘overshoots’ are avoided. Again, the hatchery manager must have the facility to adjust the incubator temperature to keep eggshell temperatures at the desired level. In the design of the incubation program, the average eggshell temperature of a representative sample of eggs should be the leading parameter.

Conclusions

- It is now understood that genetic improvements in poultry have resulted in an enormous diversification of breeds, all of which have very specific incubation conditions. The embryo metabolism is changing through selection for production traits.
- For optimum cell differentiation and growth the embryo is dependent on specific eggshell temperatures. It is therefore essential that the hatchery manager have the ability and facilities to control the set points of temperature, humidity and ventilation independently and as accurately as possible.
- In tests, Pas Reform recognised the importance of temperature for optimum embryonic development and defined eggshell temperature as the leading parameter for the design of incubation programs.
- For optimum hatchability and chick quality we have found – and therefore advise – that the eggshell temperature follows a natural pattern within a range of 37.6-37.9°C (99.7-100.2°F) during the first two-thirds of incubation and 38.1-38.8°C (100.6-101.8°F) during the last days in the setter. Minor variations in this pattern may occur because of differences in egg types. In this way the hatchery manager can predict the time and uniformity of the hatch.
- Single stage incubation facilitates optimum incubation programming, per batch and egg type, according to the natural temperature pattern. A single stage incubator should be divided into small, separate units, each with its own climate control.
Maximising chick uniformity, performance and vitality

Healthy, vital day-old chicks are the basis of success for any hatchery operation. The success of each hatch can be actively manipulated while the embryo is still in the egg. Opportunities to control the hatchery’s output can have significant impact on the resulting broiler.

The poultry industry has undergone major changes since the late 1960’s, with genetic selection and highly developed management practices greatly improving the efficiency of meat and egg production. These changes have resulted in the development of highly specific selection programmes, which are reflected in today’s industry by the growth of distinct specialisations for the production of either broiler or layer chicks. It is becoming increasingly obvious that meat and egg producing birds differ in physiology to such an extent that their respective embryos need very specific and differing incubation conditions. This factor is well illustrated in studies undertaken by Pas Reform in conjunction with the Humboldt University in Berlin in 2003, which found that based on embryonic oxygen consumption, Ross 308 embryos produce around 26% more metabolic heat than embryos from a traditional meat producing breed.

As a consequence of increased metabolic heat production in these new breeds, it is of vital importance that the temperature set points and cooling capacities in a commercial incubator, often containing 100,000 broiler eggs, are set appropriately. This avoids a build-up of unacceptable temperature levels, which can indeed be detrimental to the health of the developing embryo.

Incubator climate
The role of the incubator climate on the development of the chick and, thus, the vitality and performance of the chick post-hatch, is highly significant. Embryonic development is a continuous process with typical accents on cell differentiation, followed by the growth and maturation of the organs and physiological control systems in the later phases of development.

Here we focus on the last ‘maturation’ phase of chick development and its impact on chick vitality and uniformity in hatchlings.

During the maturation phase, the organs become responsive to specific signals such as heat or cold stress; the absolute growth of the embryo is decreased – and growth rate is inversely related to temperature.

A fully developed thermoregulatory system is essential for the maintenance of a constant body temperature, even under heat or cold stress inducing conditions. During the escape from the egg, the metabolism of chicks switches from lipid digestion to carbohydrate and protein metabolism – a transition that to be successful relies entirely on the capability of the fully matured digestive tract.

Once hatched, it is important to understand the status of the new chick, and for that reason, this paper also describes methods to evaluate the vitality of individual chicks, as well as introducing definitions of uniformity for batches of hatchlings.
**Matured thermoregulation**

A vital day old chick is an active chick that has the physiological potential to grow at the best rates with the lowest feed conversion rates. Vitality is the result of optimum differentiation, growth and the maturation of all organs and physiological controlling circuits. The process of maturation starts shortly before hatching, the so-called peri-natal period, and continues during the first week post-hatch. It has been shown that during this short time window, the emerging chick is equipped to cope, within certain limits, with the acute change in environmental conditions. In recent years, significant research has been undertaken on the development of the thermoregulatory system of the chick embryo and hatching. This research has shown that with the development of the thermoregulatory system, the hatching develops the capability to maintain its body temperature under changing environmental temperatures. Changes in incubation temperature at the end of embryonic development induce epigenetic adaptation, which results in a post-hatch long-lasting cold or heat adaptation.

In addition, hatchlings can be physiologically manipulated to better tolerate heat stress, by short-term exposure to mild heat stress (36-37.5 ºC) until day 3 post hatch. Subsequently, these treated chicks are thermally conditioned and show the highest growth rates with low feed intake and higher feed efficiency at 42 days of age than chicks that have not been conditioned in this way.

The maturation of the thermoregulatory system during the first week also includes the development of the regulation and response of heart rate baseline to changing environmental temperatures. By adapting the incubation environment throughout the last phases of incubation, we can manage the embryo’s ability to regulate body temperature while it is still in the egg.

**Matured digestive system**

Alongside the development of competence to regulate body temperature, full maturation of the digestive tract is equally essential for broiler performance. Before internal pipping at the nineteenth day of incubation, the embryo begins to draw the yolk sac into its body – and by the end of the twentieth day in the egg, the entire yolk sac has been absorbed. The lipid-rich residual yolk content serves as an important energy source for the day old chick and will continue to be a major source of energy during its first days of life.

The residual yolk sac is known to be essential for the maturation of the digestive tract and maturation of energy metabolism. The growth of the embryo depends primarily on the utilisation of yolk lipids – and thus lipid metabolism continues after hatching, to be gradually replaced by the capacity to use carbohydrates and proteins.

The Japanese researcher Murakami (1992) and colleagues showed that the removal of the yolk sac delayed growth by two days for at least seven days when compared with control chicks, mainly because of slower development of the digestive tract. Also, the development of the gastro-intestinal tract lags behind under fasting conditions, which may support the belief that food intake in the first days after hatching actively stimulates yolk utilisation. Today, we have the ability to manage embryos inside the egg, to the extent that yolk-sac absorption can be controlled to various levels up to the moment of hatch.

From these fundamental physiological studies, it is clear that the differentiation, growth and maturation of the broiler chick is a continuous process, starting as the temperature of the egg rises to 37-38ºC (98.6-100.4ºF) and continuing during the first week of hatching. The main body functions mature during this ‘sensible’ phase, such that the adult chick can adapt to environmental changes.

In practice, this means that the broiler industry can manage and predict efficiencies in growth and feed conversion by carefully managing conditions in the incubator, with the ability to actively manipulate outcomes by controlling conditions while the embryo is still in the egg, for optimum post-hatch performance.

**Chick vitality**

Along with the maturation of the thermoregulatory system and the digestive tract, the growth and maturation of the individual embryo has been shown to be highly dependent on incubator conditions. For optimum hatchability and chick vitality, eggshell temperature for each egg in the incubator should follow a natural pattern within a range of 37.6-37.9 ºC (99.7-100.2ºF) during the first two-thirds of incubation, and 38.1-38.8ºC (100.6-101.8ºF) during the last days in the setter.

Within this natural pattern, minor changes in eggshell temperature induce different growth rates, which can be used to manage chick development in the egg – in order to adapt the incubation to embryonic needs of different broiler breeds. In the hatchers, temperatures higher than 39.5ºC (103ºF) must be avoided because they induce increased late mortality and slower post-hatch broiler growth compared to lower 38.3ºC (101ºF) hatcher temperatures. In addition, constant exposure to high temperatures will adversely affect normal maturation and hatch, producing many stunted chicks with poorly closed navels and red hocks.

Daily hatchery practice shows us that poor incubation conditions result in poorly closed navels and abnormally developed beaks and legs. In collaboration with Wageningen University and Research centre, Pas Reform’s studies have shown that broiler chicks with red hocks develop significantly more leg problems at 30 to 40 days of age.
It is clear that the vitality of an individual day old chick can be described using different aspects of the chicks' morphology. These morphological criteria have been used to develop the so-called Pasgar score and, separately, researchers from the Catholic University of Leuven in Belgium have developed a more detailed score for chick vitality. In both scoring systems, chicks lose points from a total of 10 (Pasgar score) or 100 (Leuven score) for abnormalities seen in navels, beaks, legs and yolk sac volume. The Pasgar score has proven its worth in current hatchery practice – and because it is easy to teach to hatchery personnel, is currently in widespread use to improve incubation programmes around the world. The Leuven score includes greater differentiation for degrees of deviation from normal for each of the criteria used. Using this scoring system, researchers from Leuven University have shown that, within one batch, chicks with scores of 100 produced significantly higher relative growth than that of chicks with quality scores less than 100.

Maximising uniformity

We have seen how various physiological systems can be manipulated to influence chick vitality. In reality, today's commercial hatcheries must deal with hundreds of thousands of broiler embryos – each developing, growing and maturing in one incubator. While the Pasgar and Leuven scoring systems are used to describe the vitality of individual chicks and batches of chicks when representative samples are scored, uniformity in each batch of day old chicks is of equal and fundamental importance to commercial success.

The greatest challenge for the modern hatchery is to achieve uniform flocks of high vitality chicks. It is generally understood that a batch of poor quality chicks, combined with poor farm management, will result in unacceptable variations in bird size or low uniformity in the flock. Poor flock uniformity puts immense pressure on farm management, who to maximise the performance of their operations, must deliver high quality birds while simultaneously keeping feed conversion rates as low as possible. Good uniformity makes it possible to manage the flock to a lowest mortality and feed conversion. Training and consulting activities in Pas Reforms' Academy have taught us that hatchery managers need an objective measure for uniformity, to predict performance at the farm. Despite the fact that maternal age and incubation conditions, like temperature and humidity, influence both the weight and the length of the chick – we subscribe to the use of weight and chick length as a viable measure of uniformity. Analysis of our research data, based on these criteria, has lead us to conclude that both chick weight and chick length are applicable, because uniformity is based on the variation and not on the absolute values. In broiler production, uniformity is expressed as the percentage of birds whose weight falls within 10% of the flock's average weight (Figure a, b and c) – and current industry standards dictate that to achieve good uniformity, 80-85% of birds must fall within 10% of the average flock weight.
We have found that for certain batches of chicks, 100% uniformity based on chick weight is possible, when uniformity is defined as the percentage of chick weights that fall within 10% of the average chick weight in a batch of hatchlings. Our preliminary research has shown that uniformity based on chick weight may also be used to predict mortality in the first week.

Total chick length may also serve as a useful parameter for a uniformity test – although we have found that in measuring the total chick length from the tip of beak to the toe, differences of 0.5-1.0 cm can arise when different people measure the length of the same chick. In any case, Pas Reform’s research is leading to the conclusion that to apply uniformity scores based on chick length, a 3% range from the average is advised, to achieve viable, measurable differences.

**Conclusions**

- **Managing the embryo in the egg**: The process of maturation starts shortly before hatching and continues during the first week post-hatch. In this short time window, the chick is equipped to cope with the acute change in environmental conditions. The maturation of the thermoregulatory system and the digestive tract was described, whereby the thermoregulatory system matures through changes in incubation temperature at the end of the embryonic phase – and maturation of the digestive tract is facilitated by the absorption of the residual yolk sac.

- **Hatch spread**: If temperature distribution does not meet the embryo requirement for each egg placed in the incubator, the embryos will grow at different rates resulting in a large spread of hatch and, consequently, a spread in chick weights: chicks that hatch early lose weight due to dehydration. Incubators should therefore be designed to simulate a hatching period close to the natural variation in the incubation duration of chicks.

- **Vitality** of day old chicks can be optimised by scoring morphological criteria. The Pasgar score has proven its worth in current hatchery practice worldwide.
Smart thinking puts the future of hatchery technology at our fingertips

Today’s hatchery demands a super-clean, super-efficient, technologically-driven environment, to recreate the optimum scenario for sound embryonic development and high volumes of healthy, day-old chicks. Yet with the rapid pace of change and the ever-increasing economic demands that are being placed upon them, even these modern hatcheries face three serious challenges to their continued growth and profitability in the future.

- Genetic progress – brings with it increasing pressure to deliver optimum environmental management, not only to meet the needs of today’s modern breeds, but also to keep abreast of genetic advancement for the next twenty years and beyond.
- Uniformity – the golden egg of poultry production. Achieving ever-higher levels of day old chick uniformity in terms of physical appearance is already a significant prerequisite to hatchery performance.
- Post hatch performance – a natural result of high uniformity, the achievement of outstanding post hatch technical results relies on the ability to deliver optimum results on feed conversion, liveability, yield and egg production.

To define the hatchery of the future is a multi-faceted task. Pas Reform has invested in the co-operation of embryologists, poultry integration experts, hatchery management specialists, electro-mechanical engineers and industrial designers, to focus solely on these three, key challenges.

The impact of genetic progress

Genetic selection and highly evolved management practices have dramatically improved poultry meat and egg production. In modern broilers, for example, the growing chick spends half the time on the farm than it did a little over 25 years ago. The rearing period has decreased since the late eighties, from 84 days to just 42 today. Similarly, whereas in the past chicks spent just 20 per cent of their total lifespan, from egg to slaughterhouse, in incubation, today’s modern broiler breeds now spend 33 per cent of their lives in the incubator.

While less time in rearing has reduced the overall cost of inputs for the growing broiler, it is also clear that quality and performance in the incubation of the embryo has a fundamental and dramatic impact on the growth performance and feed conversion ratios of modern birds. For that reason, incubation plays a vital role in determining commercial breed performance.

And it is not just the proportion of lifetime spent in the incubator that has changed. Research has proven that each modern breed generates its own unique metabolic heat signature in the egg. This is hugely significant to achieving healthy embryonic development – and a factor that fully advocates the adoption of single-stage incubation, to cater for the different needs of emerging modern breeds in the future.
Genetic selection for high post natal growth has fundamentally changed the pattern of embryonic development and rates of biosynthesis (growth), resulting in ever-higher levels of metabolic heat production, that must be carefully managed in the incubator to achieve optimum hatchability and uniformity. For example, metabolic heat production in Ross 308 birds has been shown to have increased by 26 per cent over recent decades, when compared to the traditional breed ‘North Holland Blue’. This is a feature that will become more pre-eminent in the future, and one that can only be fully optimised by a system that provides breed and age specific incubation environments. Such accurate and sensitive management of embryonic temperature is only achievable in a modular single stage incubation environment that provides homogeneous temperature distribution.

Achieving high uniformity
High uniformity in day old chicks is one of the greatest challenges facing commercial hatcheries. Yet synchronising the hatch as closely as genetically possible is feasible with the knowledge we have at our disposal today. Uniformity is a feature of synchronisation: starting the incubation process in a batch simultaneously, with a rapid and uniform increase in eggshell temperature towards set point, will achieve a uniform start to embryonic development.

Failure to optimise homogeneous temperature distribution to the specific requirements of each egg will cause the embryos to grow at different rates, resulting in large variations in the development or maturation of day old chicks at the point of hatching and a large spread of hatch. Failure to manage eggshell temperature homogeneously and accurately for each egg is proven to have highly detrimental effects on uniformity – and further, to significantly undermine subsequent post hatch performance.

Hatchery managers are beginning to understand that it is possible to actively manage the embryo while in ovo. Modular single-stage incubation fully maximises hatchability and chick quality – because temperature, humidity and ventilation can be finely adjusted to the needs of each breed, embryonic age and batch. In this way, flock uniformity is steered by the shortest possible spread of hatch.

<table>
<thead>
<tr>
<th></th>
<th>Multi Stage incubation</th>
<th>Pas Reform Single Stage incubation</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bodyweight 5 wks (g)</td>
<td>1702</td>
<td>1742</td>
<td>+/- 40 g</td>
</tr>
<tr>
<td>Feed conversion (1700 g)</td>
<td>1.71</td>
<td>1.64</td>
<td>+/- 0.07</td>
</tr>
<tr>
<td>Mortality (%)</td>
<td>5.75</td>
<td>5.14</td>
<td>+/- 0.61</td>
</tr>
</tbody>
</table>

Post hatch performance
It is now widely accepted that homogenous conditions result in the shortest spread of hatch to give high levels of uniformity and the fullest expression of genetic potential.

Good uniformity of day old chicks is so highly prized, because it dramatically improves technical results at farm level, including the lowest feed conversion and mortality rates, the fastest growth rates and excellent processing yield and egg production (see Table 1).

Defining the future of hatchery technology
Pas Reform has a long-standing track-record for innovation in the development of hatchery technologies. Over the past three years, the company has dedicated substantial resources to working closely with a range of specialists, in a major R&D project to design an incubation system that successfully and reliably meets the three key challenges facing hatcheries in the future.

The result of these investigations is the design and development of Smart, the next generation incubation system that not only meets these challenges in today’s terms, but forecasts the emergence of new parameters and trends to future-proof the Smart system.

Smart enables the hatchery to fully realise the benefits of genetic advancement, with the capacity to cater for the incubation requirements of specific and individual breeds for at least the next twenty years. High chick uniformity is reliable and consistent, due to modular design and unique control systems – and as a natural result of genetic optimisation, every key performance indicator, from uniformity to processing yields is significantly improved.
Thinking ahead with the Smart™ incubation system
Pas Reform has been at the forefront of single-stage incubation technology for the past thirty-five years. Building on the tried and trusted success of its existing systems, Pas Reform’s new Smart incubation system takes established principles a stage further, to fully maximise the benefits of homogenous temperature control as the single most important criteria for success in rearing modern breeds and their future offspring. At its core, Smart embraces the ability to actively manage the developing embryo while it is still in the egg. Modular design and total control over every operating parameter mean that a diverse range of incubation environments can be created and managed at any one time, to meet the breed-specific needs of the growing embryo.

The full Smart incubation system comprises SmartSet™ (Setter) and SmartHatch™ (Hatcher), combined with the Smart Drive™ incubator control system, to allow for the careful management of individual conditions per egg type, and SmartCenter™, a powerful hatchery management information system.

SmartSet™
As we have seen, homogenous temperature distribution is the single most important parameter for successfully incubating today’s modern breeds, each of which has a unique temperature ‘signature’ for embryonic development.

Even minor temperature fluctuations can have a major impact on uniformity and post hatch performance. With SmartSet™, the average difference in eggshell temperature is less than 0.5ºF. Its modular design meets this specific requirement by enabling set points to be defined separately for each section of 19,200 hen eggs – and this allows for both single-stage (All in/All out) and multi-stage incubation.

With capacities up to 115,200 hen eggs, SmartSet™ is the largest closed-door, single-stage incubator available on the market today. Once the trolleys are in, total system control is possible from outside the setter, eliminating any need to move trolleys during the setting period and fully preserving the integrity of heat management and distribution.

SmartHatch™
To deliver a fully-automated hatching system that delivers accurately regulated temperature, humidity and ventilation – Pas Reform has developed SmartHatch™, an exemplary hatcher that delivers high day old chick uniformity with no need for human intervention.

SmartDrive™
SmartDrive™ delivers total control over every function and setting within each, individual incubator, from humidity and CO₂ levels and the position of air inlet valves, to the individual operating parameters – temperature, heating, cooling, ventilation and turning – required per batch/egg type. Ergonomic design and the use of clear, full colour TFT displays and icons, allow SmartDrive™ to be configured quickly and simply to programme incubation conditions to meet breed-specific requirements.

SmartCenter™
Pas Reform’s new Smart incubation system employs an intelligent, responsive, 24-hour ‘brain’: SmartCenter™, a powerful, simple-to-use total management information system that communicates with every SmartDrive™ unit to continuously monitor each incubator and finetune settings to ensure that optimum conditions are maintained at all times.

Conclusions
From conception, the new Smart™ incubation system has been designed to overcome all three key challenges in hatchery operations:

- Smart™ enables the hatchery to fully realise the benefits of genetic advancement, with the capacity to cater for the incubation requirements of specific and individual breeds, now and over the next twenty years
- Smart™ reliably and consistently delivers high chick uniformity, due to its modular design and its unique control systems and programming parameters
- Smart™ dramatically improves post hatch performance in terms of liveability, feed conversion, growth rate, processing yield and egg production.
SmartSet™
SmartHatch™
SmartDrive™
SmartCenter™
Pas Reform is an international company, which has specialised in the development of innovative hatchery technologies for the poultry sector since 1919.

The company has earned its position as one of the world’s leading hatchery equipment manufacturers, through decades of research into the biological and physiological aspects of embryo development, combined with a complete understanding of all aspects of the poultry production chain - and a dedicated focus on the future.