Humidity in incubation

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by Maciej Kolanczyk, hatchery advisor, Pas Reform Hatchery Technologies

When two environments of differing humidity levels are separated by a porous layer, humidity will migrate to the drier environment. This is exactly what happens during incubation. The watery content of the eggs has greater humidity, which dries gradually. A fresh egg will never absorb water from the air.

The speed of drying depends on physical factors such as temperature, air movement and relative humidity in the surrounding environment. In incubation, temperature and air movement are almost fixed, which does not allow us to moderate the speed of evaporation. The variable factor is the eggshell, due to varying thickness and porosity. Practically the only parameter that can be used to moderate egg weight loss is relative air humidity (RH) in the setter.

During incubation, eggs lose water. The empty space is filled with air, which reduces average egg weight and can easily be monitored and measured. Optimum egg weight loss at transfer differs depending on flock age, which affects shell quality and egg size. In eggs from older flocks, we expect 13% weight loss and for younger flocks, 11%.

In both cases, the air cell should occupy about one third of the egg at transfer, with the lower tip reaching the middle of the egg. If the air cell is too small, air deposit is limited and the embryo will suffocate before hatching. If the air cell is too large, the egg contents and the embryo will be dehydrated. Both cases produce increased late embryo mortality.

It is not only the final size of the air cell that matters, but also the time it takes to form. In the first 10 days of incubation, the embryo is small and floats in the amniotic fluid. Weight loss during this phase is mainly the effect of water evaporating from albumen and internal liquids.

After this stage, changes occur quickly: the growing embryo gradually fills the egg, excepting the air cell. Low RH set points at days 14-18 of incubation increase evaporation from the allantois – and once the allantois is emptied of fluid, moisture will be drawn from the embryo, causing its dehydration.

In designing an incubation program, we need to consider both optimum final weight loss and the way it is obtained. A program can either be based on a constant RH set point, when the eggs should lose about 0.67% weight daily over the entire incubation program, or alternatively, by using variable RH set points.

Optimum constant RH set point can differ depending on eggshell quality and usually varies between 50-55%. When using a variable step-down RH profile, slow initial weight loss in the first 10 days of incubation must be compensated by faster weight loss in the final days. However using this principle does have certain limits and applying an RH set point lower than 45-48% increases the risk of dehydrated embryos.

The main reason for using a step-down RH program is to create a more uniform environment in the setter, where humidifiers do not need to work even when opening ventilation.

Advice:

- Test at least six setter trays to check relative weight loss for each new batch of eggs. Varied shell quality may require modifying the incubation program.
- Analyse the height of pipping in hatch leftovers. High pipping indicates insufficient weight loss.
- Select a profile for RH that allows optimum weight loss with the lowest possible humidification.
- Do not allow embryos to dehydrate in the last days of incubation. Ensure that set point is not lower than 45% from day 16.
- Calculate average RH for step-down programs, ensuring that overall the average RH is at least 50%.

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People: the hatchery's greatest asset

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by Gerd de Lange, Senior Poultry Specialist, Pas Reform Academy

The importance of a dedicated, motivated team in a hatchery should never be underestimated. Even in a highly automated environment, the hatchery cannot exist without them.

Creating such a team is part of the hatchery manager's role: as important as understanding the entire incubation process, from egg to day-old-chick and all the factors that can, either positively or negatively, influence hatch results.

An experienced hatchery manager can analyse causes of poor performance, take corrective actions and evaluate their impact. He or she has the authority to change Standard Operation Procedures (SOPs) and is a good organiser and planner.

The hatchery manager is supported by team leaders, each with responsibility for specific rooms, for example the egg handling room, or SOPs, such as vaccination, within the hatchery. Often, these individuals are also responsible for collecting relevant data, such as egg weight loss, break-out results and hygiene scores.

The personnel responsible for relatively monotonous tasks, like egg setting, candling and transfer, chick handling, cleaning and disinfection, for example, are often referred to as unskilled, although this undermines the importance of their jobs.

A good technical team, for preventive maintenance and equipment repairs, is critical to optimising incubation conditions and ensuring operational continuity throughout the operation: never more so than when the hatchery is highly automated.

It is the hatchery manager's task to find, train (educate) and, last but not least, motivate employees assigned to specific tasks. Well trained personnel will follow SOPs accurately and have the skill to recognise potential mistakes and risks. For example:

- Well trained personnel in the egg handling room recognise and understand the risk of setting eggs small ends up.
- A motivated setter operator sees the urgency of fixing a turning problem if it occurs during first week incubation.
- When trained to the same standards, all chick handling personnel will recognise the same indications of unsaleable chicks. In this way, failure to cull chicks that actually should have been culled is prevented, so reducing the potential for customer complaints.

Whether for new employees or as a routine for existing hatchery personnel, training motivates people to do a great job. Rotating people so that they can experience the hatchery's different departments helps to prevent boredom and a loss of interest that can result in 'sloppy' work. It also enables individuals to find an area of particular interest – and therefore better performance – in the hatchery. In such an environment, people become more flexible as capable 'multi taskers', which is a great benefit when covering absence due to sickness or holidays.

Good hatchery managers too should welcome ongoing professional development, to grow into their job and build experience, while staying up-to-date by reading relevant articles and attending seminars.

Hatchery management training is a great opportunity, even for experienced hatchery managers, to share ideas and experiences with specialists and managers from other hatcheries.

Advice

- Invest in training to create a good hatchery team: they are a vital asset to the hatchery.
- Avoid losing the experience of a hatchery manager who leaves to take another job, by encouraging inclusion and knowledge-sharing in day-to-day hatchery practice. Your next hatchery manager may already be a member of the existing team!
- Make adequate training for new employees mandatory – and do not forget to provide regular, ongoing training for existing employees.
- Ensure that employees not only follow SOPs, but that they understand what they do – and why they do it.
- Motivate personnel by providing good working conditions and acknowledging good practice and performance: 'name and fame' is far more effective than 'blame and shame'.
- Listen to your team; they often have brilliant ideas.

SOPs, CCPs and KPIs in hatchery management

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by Dr Marleen Boerjan, Director R&D, Pas Reform Academy

In large scale hatchery operations today, a single hatchery manager is rarely responsible for managing every aspect of chick production or for the maintenance of incubators. He or she no longer relies solely on their own experience and intuitive observations to achieve good quality chicks. In some cases, an incubationist has taken over more routine tasks, including fine-tuning incubation programs and performing egg analyses to solve incubation problems.

The hatchery manager is now responsible for overall hatchery organisation, coordinating different teams to work on specific tasks, such as setting eggs or pulling chicks – and writing Standard Operating Procedures for the different tasks assigned to each team.

He or she must evaluate the output and quality of individual teams – and of the combined results that they achieve together.

Finally, whether at hatchery level or for a larger poultry integration, it is the manager's role to report on all outputs to the company's management team.

Many modern hatcheries are now organised on an industrial scale, requiring tools such as Standard Operating Procedures (SOPs) and Critical Control Points (CCP) in hazard analysis, combined with management tools like Key Performance Indicators (KPIs), to manage such complex production businesses effectively.

SOPs should at least be available for the most critical steps in the production of good quality chicks, including:

- Quality control for eggs received.
- Egg disinfection.
- Egg setting and incubation programs.
- Egg transfer.
- Loading the hatchers and hatch programs.
- Chick pulling and quality control.
- Vaccination.
- Chick transport.

Critical Control Points (CCPs) are traditionally related to hazard analysis in food safety programs.

However today, we increasingly see CCPs related not only to the production of food free of harmful contaminations (bacteria, fungi, etc), but also to other quality relevant factors.

In the hatchery, CCPs include temperature and relative humidity (RH) in egg storage, for example, to prevent too high a loss of hatchability.

The percentage of eggs set with a perfect shape and shell, or chicks with perfect navels or legs might also define CCPs.

Often these critical control points represent a reference range of 'normal' value measurements (temperature or RH, for example). Measurements outside the CCP's 'normal' range should alert the team responsible that action is required.

A KPI relates to the company's performance, combining different aspects of management to achieve a common goal.

A KPI is more likely to be a business target, for example, to achieve 'low numbers of second class chicks', which requires all teams, including technical staff, involved in production to work together and be jointly responsible for achieving the KPI.

The KPI therefore gives the manager a means of evaluating all teams against a common goal.

We can conclude, therefore, that the hatchery manager can effectively manage and evaluate his teams based on SOPs and defined CCPs created to achieve specific KPIs.

Evaluation depends firstly on the quality of the data collected, either by instruments or individual teams.

Secondly, collected data should be structured in a relational database, such that mean values and the relationships between those values can be analysed within a reference range defined as accepted or normal.

Advice

- Describe SOPs for the separate steps needed to produce high percentage volumes of good quality chicks.
- Define CCPs for hazard analysis and quality control.
- Define KPIs at both hatchery and company levels.
- Define protocols, including reference ranges for the measurement of data collected for each CCP and KPI.
- Include proper data collection procedures for each SOP, based on defined CCPs and KPIs.

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Incubation in hot, humid climates

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Successful incubation in hot, humid climates poses a number of challenges for the hatchery, one of which is achieving sufficient weight loss at transfer to deliver high hatchability and optimal chick quality. Take for example a moderately hot and humid climate of 30°C with 75%RH. With these properties, air at sea level contains approximately 20g H_2O/kg air.

If we assume a setter climate of 37.5°C and, with the aim of achieving optimal weight loss from fresh egg weight at transfer of 12%, we choose a set point of 50% RH, the air in the setter will contain approximately 21g H_2O/kg.

If the setter's air valves are closed, evaporating water from the eggs will increase both the absolute (gH_2O/kg air) and relative (RH%) humidity of air in the setter. This limits evaporation from the eggs, making it impossible to achieve 12% weight loss.

By ventilating the incubator with fresh air, evaporating water from the eggs can leave the incubator via the outlet, while maintaining an optimal incubation climate.

However, if we stay with the above example, each kilogram of air entering the incubator can extract only 21g – 20g = 1 gram of water.

This means that a lot of ventilation, starting early in incubation, is needed to allow the hatching eggs to lose sufficient weight.

Adopting a non-linear weight loss profile that starts incubation with high RH% (by sealing the setter for several days), then compensating for low weight loss by applying a low RH% (ie. less than 45%) during the second half of incubation, is not feasible in hot, humid conditions.

Such low levels of RH% can simply not be achieved, even when air valves are 100% open. This is because when RH% set point inside the setter is, for example, 45%RH, the inlet air (30°C/75%RH=20g H_2O/kg) already contains more water (37.5°C/45%RH = approximately 18g H_2O/kg).
In this scenario, a linear weight loss profile based on a constant RH% of approximately 50% is much easier to achieve.

It is possible, at least partially, to overcome these challenges and minimise the need for high ventilation rates early in incubation, by optimising the temperature and relative humidity of inlet air using an Air Handling Unit.

Outside air of 30°C/75%RH can be climatised to, for example, 25°C/60%RH, which significantly reduces the water content of the air from 20g H_2O/kg to approximately 12g H_2O/kg.

Again using the above example, each kilogram of air entering the incubator now has the capacity to extract 21 – 12 = 9 gram of water.

There is a downside to treating hot, humid outside air in this way. It requires energy, both for the cooling needed for dehumidification and also to subsequently re-heat the air to a recommended inlet temperature of 25°C (±2 °C).

This energy cost will increase the cost price of the day-old-chick – but it does give the hatchery manager an additional tool with which to better control hatchability and chick quality in a challenging, hot and humid climate.

Advice

- Aim for a linear rather than a non-linear weight loss profile in hot, humid climates, to prevent insufficient weight loss that will inevitably arise from failing to achieve the low %RH set points required during the last days of incubation using a NLWL-profile.
- Pre-condition hot, humid outside air to the inlet specifications recommended by your incubator supplier, to reduce its moisture content.
- Perform a cost-benefit analysis within these specifications, to establish the most advantageous combination of temperature, relative humidity and energy usage to achieve the highest hatchability and optimum chick quality.

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Guidelines to correct incubation programs

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Any incubation program, even when successful, is never final. Sooner or later, it will have to be adapted according to changes resulting from climate, breed, egg quality, technical upgrades of setters and hatchers and numerous other factors.

The need to adapt will be signalled by results in terms of hatchability and chick quality. The routine monitoring of eggshell temperature, yield and egg weight loss, for example, can provide an early warning that changes are needed.

Each hatchery operates in its specific, unique situation – and its incubation programs must also be specific, to correspond with local conditions. Adopting an incubation program that is successful for another hatchery, even one that operates in similar conditions to your own, is usually not the best option.

Before adjusting a program, it is therefore useful to answer a range of questions:

- Do the incubators respond accurately to programmed set points? If not, they may simply need some maintenance or a re-calibration of sensors.
- If the problem is incidental or evident in only some of the machines, the solution is likely to be found by reviewing the maintenance of those affected.
- Can the source of the problem be established? For example, if the problem is retarded embryo development or early mortality, it may be related to the setter, or if there is increased mortality in fully developed embryos, it is likely to be the hatcher.
- Is the problem affecting all the eggs, or only certain batches? The current status of the breeder flocks may require investigation.

In short, it is important to establish why a program needs to be changed – and where the problem has arisen.

An incubation program is a complex construction: the expression of a strategy that leads to the optimum development of embryos, where every element of the program is combined and mutually influences the other.

Generally, incubation programs (strategies) aim for an apparently simple task:

- Maintain the eggs at a stable temperature of 100.0°F in incubation, gradually increasing to not higher than 101.0°F in the last days,
- Allow egg weight loss of 11-13%,
- Guarantee the correct concentration of oxygen in the air.
- Turn the eggs regularly.

The aim is to achieve all this with minimal heating, cooling and humidification for energy efficiency, and what appear to be small changes: changing temperature set point by 0.5°F or RH by 2-3%, can make a big difference to results. Opening ventilation a small increment further will refresh the air, but it will also decrease humidity, increase the cooling effect and force the machine to restore set points.

The questions ‘what change has been made?, ‘when?’ and ‘for how long? can transform a simple task into a complex issue. An existing program that was, until recently, delivering ‘acceptable’ results should form the skeleton of a new program, making one change at a time to assess its impact and evolve rather than revolutionize incubation programming.

Advice

- Ensure that setters and hatchers are really working to set points accurately before making changes.
- Follow a strict and regular maintenance routine.
- Avoid unrealistic set points that are beyond the capabilities of your technology.
- Make changes to incubation parameters one at a time, to monitor its effect.
- Test and repeat each new program 2-3 times on selected machines before applying generally.
- Keep accurate records to monitor and evaluate results.
- Observe the effects of changes carefully: consider naming new programs to reflect those changes.

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Managing carbon dioxide in the setter

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Fresh, dry air contains approximately 78% nitrogen (N_2), 21% oxygen (O_2) and 0.04% carbon dioxide (CO_2). Yet while oxygen is a prerequisite for life – and essential for successful incubation – we rarely monitor oxygen levels inside setters and hatchers, or measure O_2 as a parameter for adjusting the supply of fresh air by ventilation.

On the contrary, CO_2, the by-product of embryo metabolism, is commonly monitored and measured to provide profiles for adjusting ventilation during incubation.

Just after laying, the albumen of an egg contains a considerable amount of CO_2, mostly present as bicarbonate. Since egg shell is porous and the concentration of CO_2 in the environment is much lower, CO_2 diffuses out of the egg. This results in an increase in the pH of the albumen as well as its liquefaction, both of which are needed to prepare the egg for incubation.

As this process of passive CO_2 diffusion from the egg continues during storage and in the first days of incubation, the concentration of CO_2 inside the fully sealed setter will gradually increase. The fresher the egg, the faster the increase and the higher the accumulated level of CO_2. Since the embryo's metabolism and therefore its demand for O_2 during the first 10 days of incubation is very low, the gradual increase of CO_2 to >1% does not hamper the embryo's metabolic development.

A study by Bruggeman et al. (2006) showed that, due to several buffering mechanisms, broiler embryos can tolerate a gradual increase to 1.5% CO_2 at day four of incubation, maintained until day 10. A study of white layers by Hongbin Han et al. (2011), however, showed negative results when applying 2% vs. 0.03-0.05% during the first four days, which suggests a greater sensitivity to CO_2.

The fact that no fresh air enters the setter during the first 10 days of incubation may be beneficial for temperature uniformity, depending on the type of incubator. However, it is not only the concentration of CO_2 (in a non-ventilated setter) that increases. This also applies to relative humidity, resulting in a reduced rate of egg weight loss during the first 10 days, which has to be compensated for during the last part of the setter period by imposing an extremely low relative humidity set point.

The risk of such unnaturally low relative humidity during the final days in the setter is that water will evaporate from embryonic tissues, which by that time are found directly under the shell surface.

After day 10-12, embryo metabolism increases exponentially and the need for O_2, and thus the production of CO_2, increases. It is commonly accepted that in this period, the ventilation rate of the setter should gradually increase. Over-ventilating, which may result in over-active humidifiers in an attempt to keep relative humidity at set point, is unnecessary. The ventilation rate in this period can be fine-tuned safely to a maximum CO_2 level of 0.4%.

Advice

- Ensure that air in the clean air plenum of the setter (and hatcher) contains a maximum 0.09% CO_2.
- Check and replace the filters in the air handling unit regularly.
- Avoid or minimise the recirculation of 'used' air.
- Ensure CO_2-sensors in the setter (and hatcher) are calibrated correctly for the hatchery's altitude. If calibrated for sea level, use a correction factor or a different set point.
- Remember that sealing the setter during the first days of incubation not only increases CO_2-level, but also RH%.
- Start to ventilate the setter gradually, preferably no later than on the third day of incubation. Fine-tune ventilation >day 10-12 on a fixed maximum CO_2-concentration.

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Interpretation of 'physiological zero' 71

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Hatchery managers often use the term 'physiological zero' to refer to optimum temperatures for egg handling and storage conditions in the breeder farm (including transport) and in the hatchery respectively.

On the farm, the eggs cool down after laying and are either transported on the same day or stored for a few days before transportation to the hatchery. In the hatchery, eggs are stored for different durations prior to setting. In both situations, the embryos need to be preserved in optimum conditions, to minimise or ideally avoid any adverse effects on hatchability and chick quality.

Embryonic development slows down and is eventually arrested when temperature drops below physiological zero, or the point at which temperature is low enough to maintain embryonic cell activity at a greatly reduced but reversible level. The embryo still has the potential to continue its development if temperature increases again. For this reason, the term 'arrested development' is preferred to using 'stop development'.

Consequently, we accept that physiological zero is not restricted to one specific temperature (set point), but to a range of temperatures (12-20°C) depending on the context of egg handling and storage length. This also explains why different set points for physiological zero are defined in literature.

The definition of physiological zero was first introduced by Edwards in 1902 as the temperature below which there is no embryonic development: 21°C. Proudfoot (1969) reviewed the terms of reference for physiological zero to include storage temperatures from 11.5 to 21°C (Carter and Freeman, 1969). More recently, Fasenko (2007) introduced the term 'embryonic diapause' as an alternative for the traditional physiological zero: an updated definition to acknowledge that some cellular metabolic processes continue, but gross morphological (shape and structural) changes are arrested.

Embryonic diapause has been described for many vertebrate species, including turtles, marsupials and even mammals such as roe deer. Embryonic diapause, or embryonic dormancy, describes a stage at which metabolic activity and cell division is down-regulated or arrested – and can be regarded as a strategy for coping with temporarily unfavourable environmental conditions.

In chickens, embryonic development is arrested after laying and cooling the eggs down to room temperature of between 22-25°C. During cooling under optimal conditions (temperature/no draught), the embryo develops from gastrula stage IX-X (described by Eyal-Giladi, 1976) to stage XII-XIII (Gilbert, 2006).

The definition of physiological zero is restricted specifically to stages XII-XIII of development. If the embryo has developed beyond this stage and primitive streak development has started, reduced temperatures will slow down development and finally cause the death or early mortality of the embryo. This may explain higher rates of early mortality when eggs are kept too long in the nests (Fasenko, 1991, 1999) and cooling is too slow.

Advice

- Accept that physiological zero can apply across a range of temperatures, from 12-20°C, depending on context (on the farm, during transport or in the hatchery).

- Keep in mind that if eggs are stored at 18-21°C, embryonic development has slowed down but not stopped completely.

- Reduce storage temperatures if eggs are stored for more than seven days.

- Apply pre-storage temperature treatment of the embryos if hatching eggs can only be stored at 18-20°C.

- Define a key management protocol for monitoring and evaluating temperature and relative humidity in the breeder farm, during transport and in the hatchery.

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Designing a hatchery's electrical system

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Uninterrupted electrical energy is critical to optimising incubation and other hatchery processes.

Protecting supply

Should power from the grid be interrupted or fail, a back-up generator with Automatic Voltage Regulator and auto switch-over will protect normal hatchery operations.

Generators typically load up to 80% of their capacity for continuous operation. However if there is a risk of frequent power failures, a second standby generator is recommended. Keep generators close to the main power supply and fuel storage area.

Stability of supply is also important. Voltage should not exceed ±10% variation and frequency not more than ±2% of nominal value.

Individual Uninterrupted Power Supply (UPS) is recommended, particularly for incubator controllers, ethernet switches, automation controls, computers, alarms and other key electrical functions, as this protects all the hatchery's electronics in the event of a system-wide failure.

Finally in terms of protecting your supply, make sure your system is grounded. This not only protects users, but also ensures that electronics operate reliably.

Calculating system load

Total connected electric load is expressed as 'Installed Value'. The hatchery may consume up to its total connected load, or Installed Value, either completely or in part during operation, but this load cannot be exceeded. Cables and fuses should be selected based on Installed Value.

Because electrical consumption varies, average consumption will be lower than the Installed Value. Incubators may, for example, use heating or cooling, but not both, depending on the age of the embryos. And not all motors in the hatchery, for example on hatchery automation, will run 24/7.

Total Electrical Load is calculated by adding all duty equipment (excluding standby-equipment) plus a contingency for spare or unforeseen load requirements. Depending on the accuracy of the electrical system's design, this could in practice mean an additional 10-20% spare capacity.

Safety and compliance

Follow local electricity board regulations when choosing power distribution panels, design and cable type/sizes. Note that Variable Frequency Drives require shielded cables to avoid interference with signalling cables. Using separate power and signal cable trays will also help to avoid interference.

Electronic equipment is sensitive. Take care to protect against lightning strikes and surges and if possible, provide surge arresters in distribution panels, to protect equipment from voltage spikes. Try to balance the load to all phases, for example by connecting respective incubators 123, 312, 231 etc.

The presence of water in hatcheries, eg. for washing, circulation and from condensation, requires electrical installations to be water resistant (IP66). Using 'clean' cable design above false ceilings can help, by creating fewer places for dirt to collect and by keeping electrical cabling away from sources of water.

It is important that electrical installations comply with local regulations and are carried out by suitably qualified, certified personnel. Incorrect installation increases the risk of injury to staff and can create a significant fire hazard.

Advice

- Ensure that a certified electrical supplier checks and approves your system during installation and carries out regular testing.
- Incorporate 'clean' design where possible, eg. running cables above false ceilings.
- Check the power supply backup system regularly: make sure it will work if needed.
- Provide automatically fused control boxes for each item of equipment in the power distribution panel to prevent interruption in case of tripping.
- Select hatchery equipment with energy-saving features wherever possible, including intelligent frequency drives for incubators and effective climate control systems, to significantly reduce energy consumption and lower the total cost of constructing the hatchery's electrical systems.
- Ensure that your system has sufficient capacity for future expansion.

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