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AGRICULTURAL STRUCTURES AND ENVIRONMENTAL CONTROL BTAP3105

PHYSIOLOGICAL REACTIONS OF ANIMALS



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REACTIONS OF ANIMALS TO THERMAL & OTHER ENVIRONMENTAL FACTORS

Functions of all organs and systems ultimately depend upon absorption and nutrition. The food taken in by the animal is used in constructing new tissue while some is broken down that is, oxidized by tissue cells to produce heat and energy. The heat produced by oxidation processes can be measured which will determine the metabolic rate. The metabolic rate of animals is an therefore indicator of their nutritive and productive status. It is also very much influenced by the environmental variables such as temperature humidity air velocity and radiation. The heat and moisture released through respiration are simple and this heat must be dissipated out.



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Homeostasis

Homeo – like or similar

Stasis - standing

Preventing changes or keeping things the same. It refers to the maintenance of a fixed internal environment in animals through dynamic, self – regulating processes, operating on the feedback principle. Many internal factors are maintained constant. These include body temperature, mature body weight, blood pressure, respiration, body fluid, hormones and movement.



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HOMEOTHERMY

Maintenance of appropriate internal body temperature is an excellent example of homeostasis, sometimes called homeothermy.

The regulation of internal temperature is carried out through several sets of feedback mechanisms. Mammals and birds are homeotherms and they are equipped with peripheral receptors in the skin and central receptors in the brain. There exists for each species a range of environmental temperature that is optimal in terms of minimum action by the regulating mechanisms. This range is the thermoneutral condition. When the environment cools below this range, the condition is sensed peripherally and transmitted to a specific part of the brain, (the posterior hypothalamus), which activates a set of protective actions. These include increase in appetite and rate of heat production, decrease in blood flow to the periphery, and change in posture of hair coat or feathers. With continued decrease in external temperature shivering is initiated. Shivering is involuntary muscle contractions that increase the rate of heat production.



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When external temperature rises above the optimal, another set of protection devices is activated. The surface blood vessels dilate, appetite decreases, rate of moisture evaporation increases, respiration rate increases, in humans, profuse sweating occurs. These actions are involuntary and are mainly controlled by the anterior hypothalamus in response to blood temperature changes. Increase in appetite increases metabolic rate, the other actions serve to increase rate of heat loss to the environment.



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Thermoneutrality occurs within a range of environmental temperatures in which the body's homeothering mechanism maintain, a balance between heat loss and heat production without stress. Within this range the thermal regulation is minimal – neither heat nor cold is felt. In these terms, thermoneutrality defines a “comfort” zone. The overall objective in animal housing systems design thus is to create environments in which the animals approach thermoneutrality, but with appropriate balance between the productive value of thermoneutrality and the cost of systems to maintain it.



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Animal Reactions

The reactions of animals to environmental factors can be arbitrarily divided into two classes Productive and physiological. The distinction is artificial rather than real, but has value to an engineer to whom the productive factors are more useful. The physiological reactions are body temp, pulse rate, and respiration rate.

(i) Temperature:

This is the most significant parameter Environmental temperature is the integrated total of all temperatures surrounding the animal is $4\pi sr$ (steradians). If the walls, ceiling, floor and air temperatures are identical, then the environmental temperature is simply the air temperature. But this is a rare case. The more usual case is that surfaces and air are at different temperatures and adjoining A THI of 75 is a critical value for even the low producers while the higher producers are already affected at this THI. Hence THI should be between 72-75 for normal cows.



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Light

The seasonal variations in physiology of farm animals are related to light, including both duration and climate. It appears that length of day, or rate of change of day length, have marked effects on hair coat of cattle and wool growth and breeding behaviors of sheep.

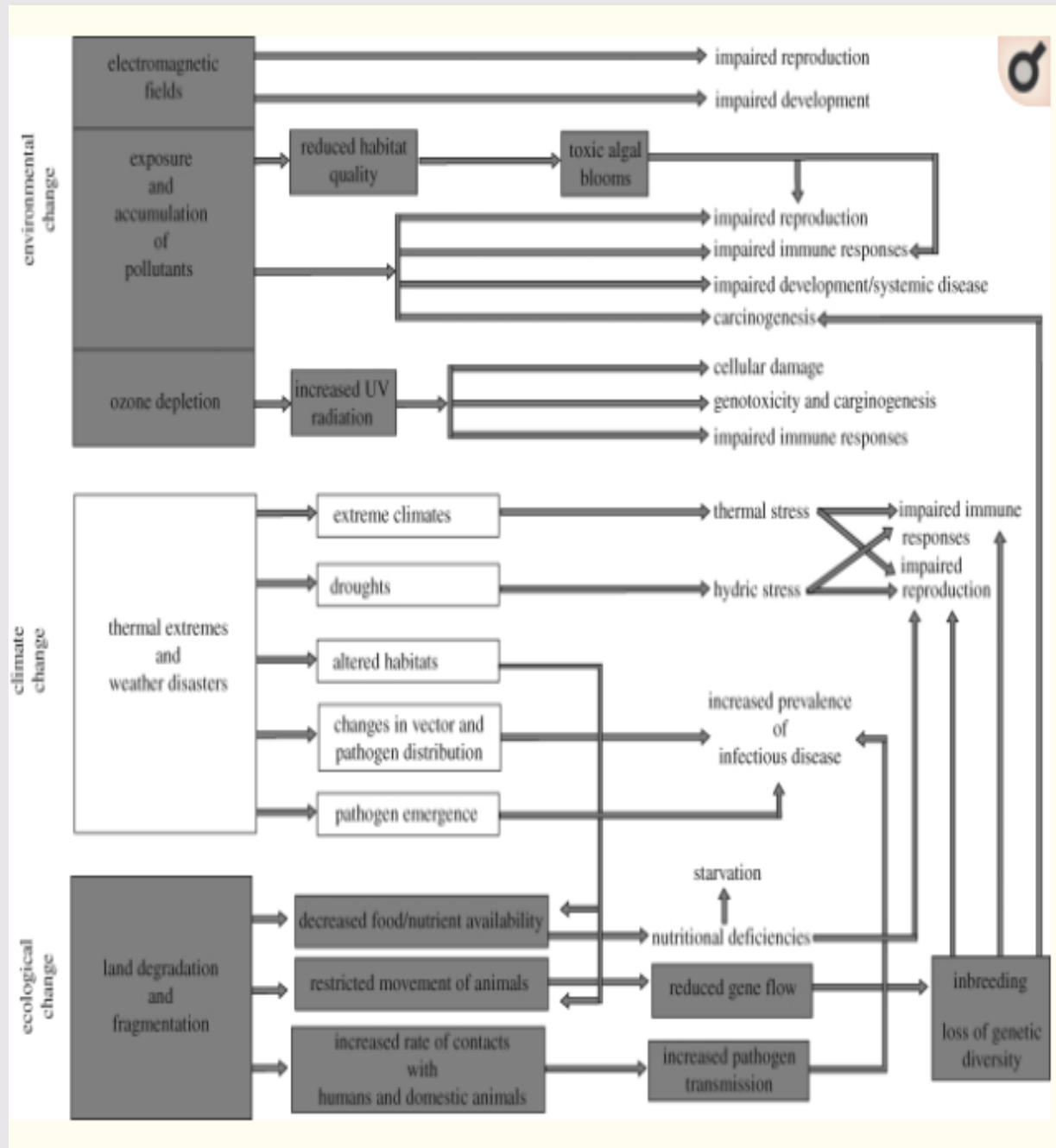
Air movement:

Animal heat loss is influenced by air velocity, which is important at both low and high temperatures. Under confinement conditions the air velocity can usually be regulated by fans. In the case of dairy cattle held at 95°F air temperature an increase in air flow rate from 0.5 to 10 mph (mily per hour) tended to reduce production losses normally experienced at such high temperatures. However, 10mph is a rather high velocity inside a building and would be particularly annoying if conditions happened to be dusty. The favorable effect of increased air flow at high temperatures is due to the increase in evaporative heat loss. The daily weight gains of beef cattle in summer are considerably less at 0.5 mph compared to 4mph. Increasing air velocity above the latter figure, however gives no further advantage.



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PHYSIOLOGICAL REACTIONS OF FARM ANIMALS

Since the major purpose of environmental control in buildings for housing livestock is for comfort of the animals, it should be fairly obvious that the physiological reactions of the animals are of extreme importance in determining design conditions. Warm-blooded animals, such as cattle, swine, sheep, and poultry, give off heat and moisture during normal living processes. The rate at which these are expelled will vary with environmental conditions. Unfortunately, complete information is not available on the reactions of all animals under all conditions. Research is under way at various stations in the United States to determine this information where such information are based on practical experience.



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Dairy Cattle: The first approach to presenting information on the heat and moisture production of dairy cows was made in 1921 by Armsby, who presented a method of computing the heat production of dairy cows. Based on Armsby's method, together with research information on steers presented by various works, Strahan suggested basic information to be used in design of insulation and ventilation for dairy barns. ¹ This information is shown in Figure 14.4. Curve A shows the effect of environmental temperature on the percentage of total heat in latent form. Latent heat is that heat contained in the vaporized moisture expelled by the animal. As the temperature increases, more moisture is given off by the animal, carrying with it more heat in latent form to regulate the body temperature of the animal. Curves B and C show the reduction in sensible-heat production with increasing temperature; Fig. 14.4. Effect of temperature on heat and moisture production of dairy cattle. (From J. L. Strahan, *A method for Designing Insulation and ventilation for Animal Shelter Buildings, Agr. Engg.*)



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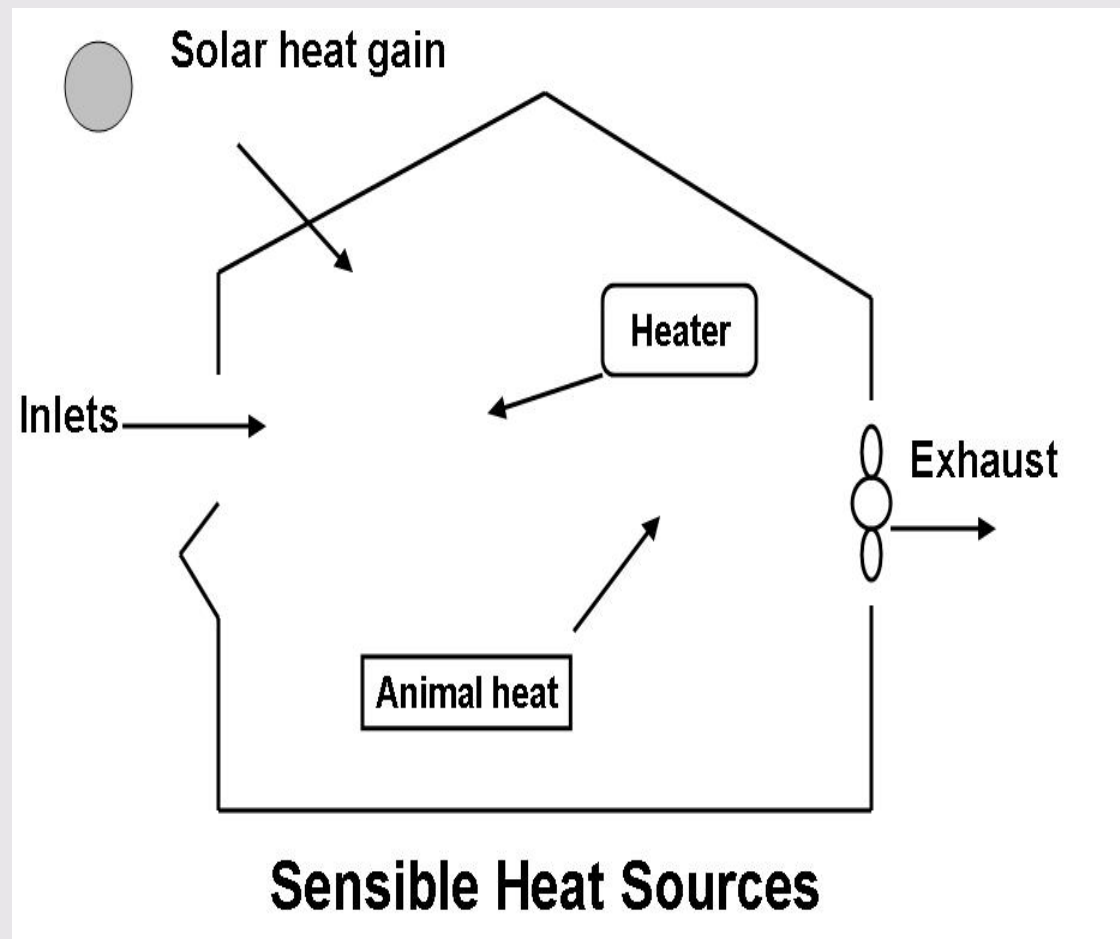
Poultry. Studies of the physiological reaction of poultry to environmental conditions are under way at Beltsville, Maryland, by the Division of Farm Buildings and Rural Housing, Bureau of Plant Industry, Soils, and Agricultural Engineering, USDA. Although these studies have not been completed, some information has been reported which can be used as tentative considerations for design procedure.¹ Results of this study to date are shown graphically in Figure 14.5. All data re converted to a single basis of 5-pound Rhode Island Red hens. Results shown on the lower chart would indicate that the optimal temperature range for egg production lies in the neighborhood of 50 to 55°F. Temperatures as low as 45° and as high as 65° do not seem seriously affect egg production.



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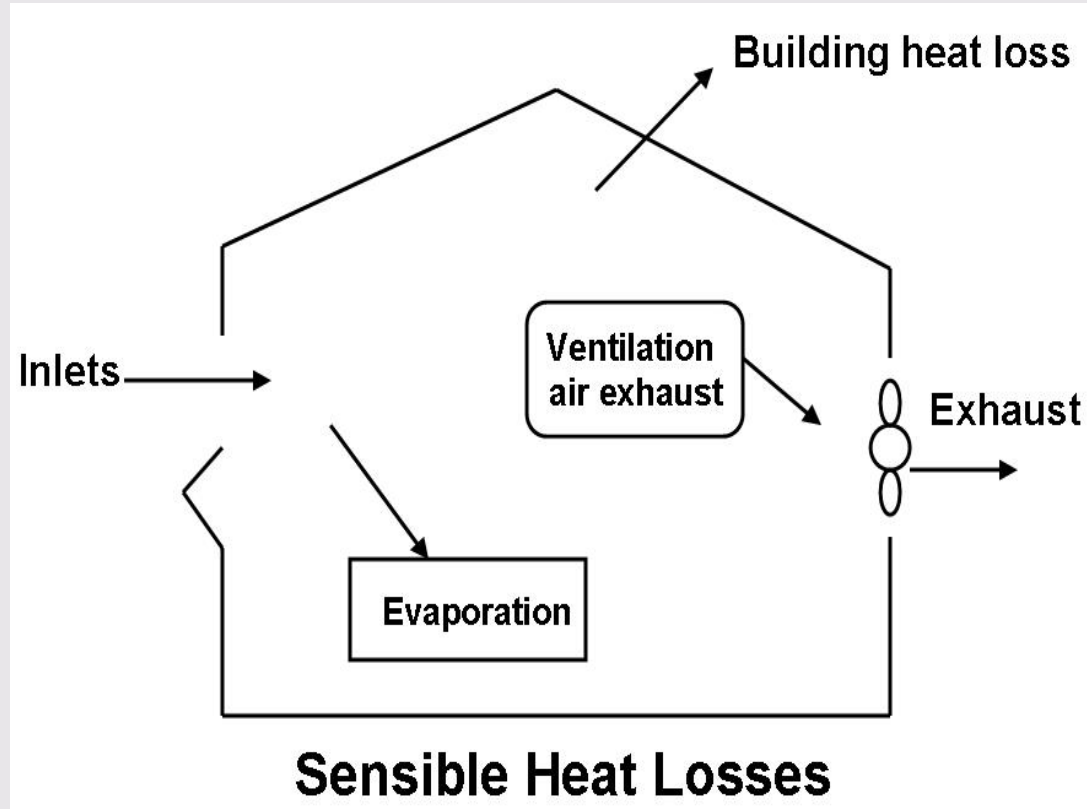
Relationships among the psychrometric characteristics play important roles in the ventilating process. To control the temperature within a building the sensible heat produced by the broilers and supplemental heaters and the heat either gained or lost through the building surfaces (i.e., ceiling, walls, windows, etc.) must be balanced with the heat removed by the ventilation air.





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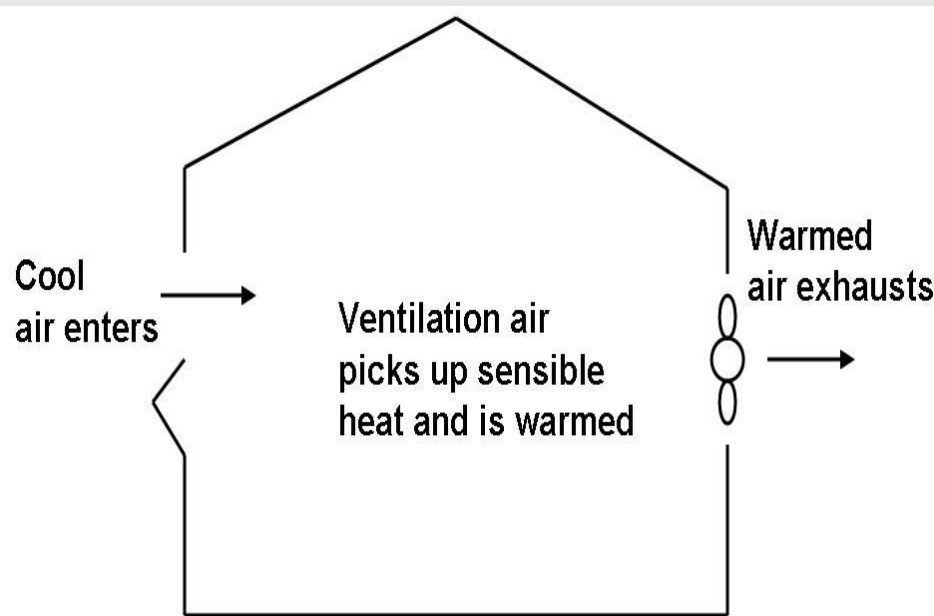




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Through ventilation, cold or relatively cool, outdoor air is brought into the poultry house. Sensible heat produced within the building is transferred to the cool air and warms the air. This warm air is exhausted from the building and replaced with more cool outdoor air and the process is repeated. This process is illustrated in Figure 7.5 below. The amount of air exchanged to control temperature depends on the indoor and outdoor temperature difference, number and age of broilers housed, and building insulation level.



Schematic of ventilation for temperature control



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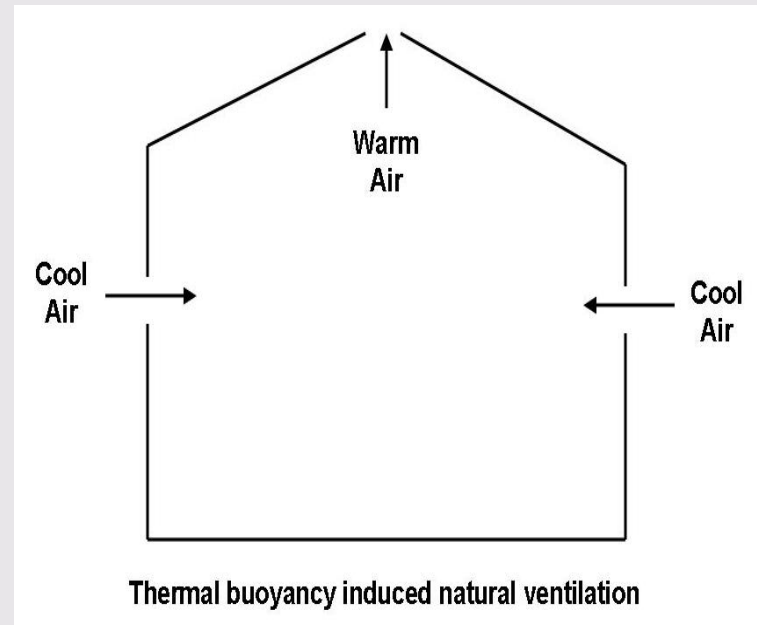
- If the sensible heat sources remain constant, reducing the amount of air exchange will raise the indoor air temperature. Increasing the air exchange will lower the indoor temperature. If the air exchange rate and sensible heat sources are kept constant the indoor temperature will shadow outdoor air temperature changes.
- As broilers grow, so does the amount of sensible heat they produce. To remove the increased amount of sensible heat and maintain a constant indoor air temperature, the air exchange rate per broiler needs to increase as the birds grow.
- Some sensible heat may be used to evaporate liquid water (i.e., spilled water, wet feces and spraying mists). In cold weather when sensible heat from the broilers and heaters is needed to maintain the desired indoor temperature, the heat used to evaporate spilled water is a loss, unavailable to heat the building. In hot weather when excess sensible heat is available sprinklers and evaporative cooling are used to help dissipate excess heat.



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VENTILATION SYSTEM

In cold weather conditions, when a naturally ventilated building's openings are nearly closed, buoyancy-induced ventilation is often the primary mechanism of air exchange. With any wind acting on the structure, wind forces will quickly override buoyancy effects. In warm weather conditions with more sidewall and ridge area open on the building, wind-induced ventilation becomes the primary mechanism for ventilation. In regions where extreme heat and cold exist throughout the year, both wind and buoyancy-induced ventilation operate to deliver required fresh air to the birds





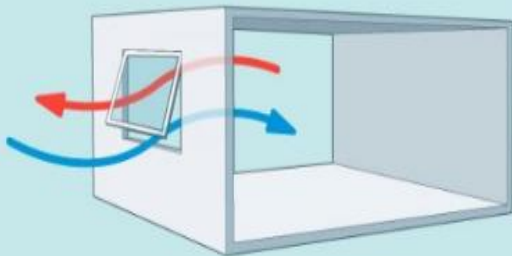
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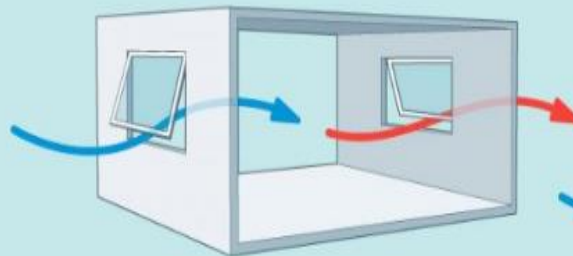
NATURAL VENTILATION SYSTEMS

Natural ventilation, as the name implies, is a system using natural forces to supply a building with fresh air. Air exchange is accomplished through designed inlets and outlets in a building. It is important to recognize that naturally and mechanically ventilated buildings operate under different principles. Mechanically ventilated buildings use fans to exchange air, which can be controlled to provide the desired air exchange rate. Thermal buoyancy and wind are both dependent on uncontrollable weather. This makes natural ventilation control different.

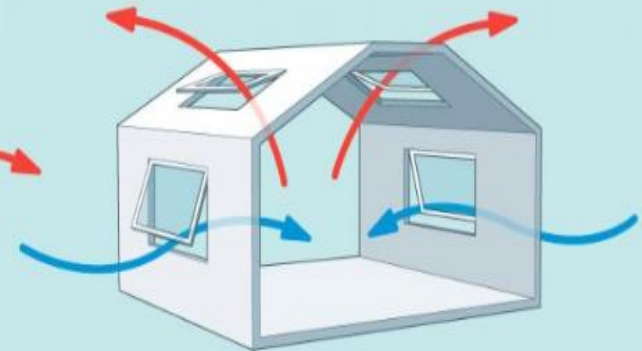
SINGLE SIDED VENTILATION



CROSS VENTILATION



STACK VENTILATION





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Advantages-

Lower cost

Lower maintenance

Lower electrical use

Disadvantages-

More challenging to control

Periodic replacement of open coverings

Rain/snow/sun entrance to building

Large building 'footprint'



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Emergency Ventilation

Carbon dioxide (CO₂) concentration in properly ventilated poultry housing can be 3,000 ppm. High CO₂ concentration (above 30,000 ppm) contributes to oxygen deficiency and asphyxiation. Similarly, heat and moisture can build up. Since broilers can die if the power or ventilation system fails, emergency ventilation should be provided. ***Poultry can survive only 20 to 30 minutes at temperatures above 97°F with still air.***

Emergency ventilating systems can range in complexity from an **electromagnetic, automatic sidewall-curtain drop** for naturally ventilated buildings, to a **stand-by electric generator** that automatically engages when electrical power fails for mechanically ventilated houses. Emergency ventilation openings with curtain drop should be sized according to broiler age and outside weather conditions. With young, floor-raised broilers, 12V battery-driven brooders may be used to provide emergency heating during cold weather and power outage.

Consider installing an **alarm system** to alert you when electrical power is off.

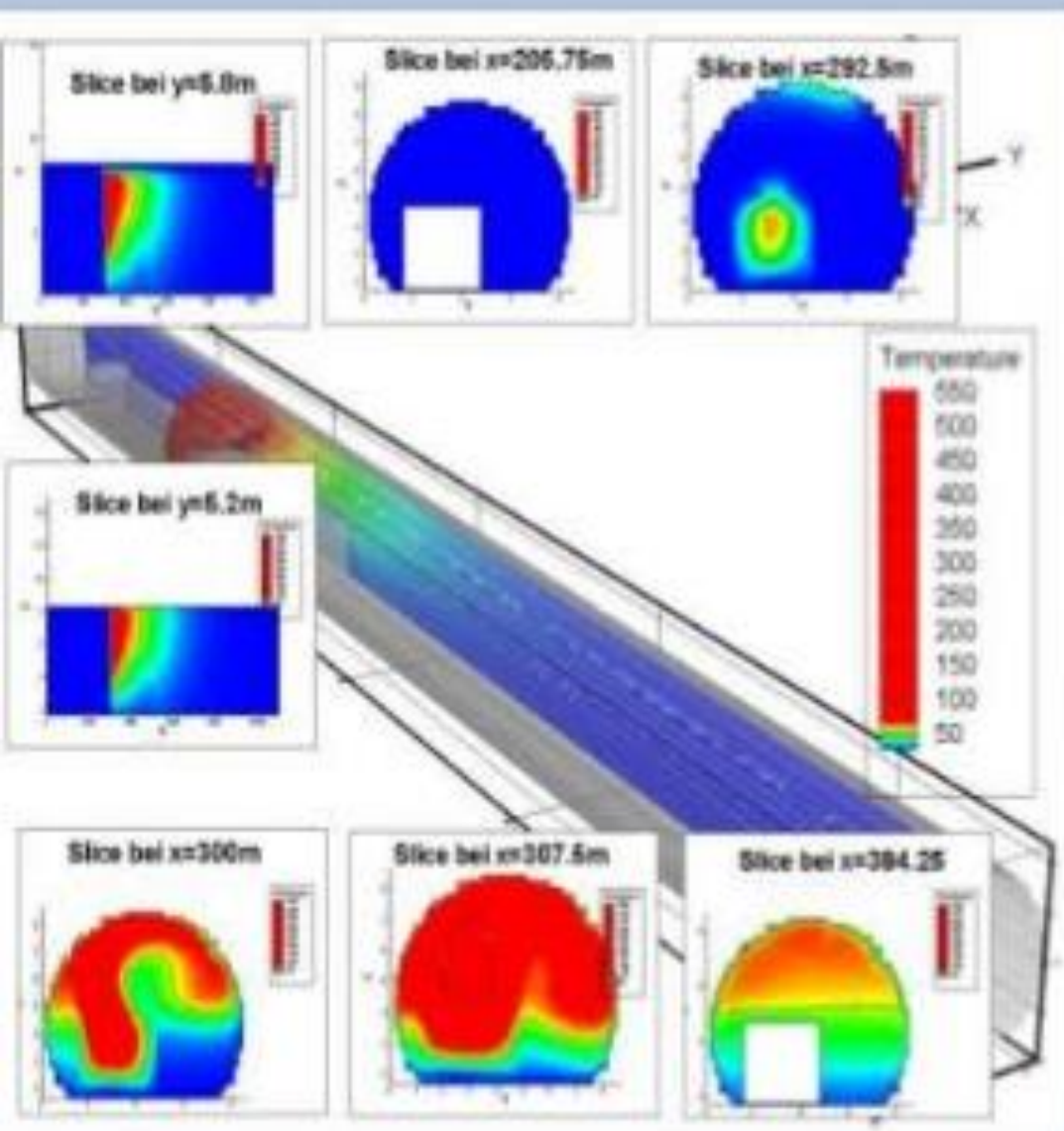
Test your emergency ventilation and alarm systems regularly according to the manufacturer's instructions.

Emergency Ventilation Design Approach:

TEMPERATURE /
SMOKE PROGRESSION
ALONG THE LENGTH
HEIGHT

Computation fluid
dynamics (camatt)

- Design Fire
- Tunnel Geometry
- Fan design & Configuration
- Thermo Dynamics
- Fluid Dynamics





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Advantages-

- Improved Air Quality
- Low Humidity Levels
- Health Benefits
- Comfortable Home

Disadvantages-

- Ventilation control for Critical velocity might be not appropriate in case of fires in congested traffic
- Short detection and ventilation response times are vital for ventilation during the self-rescue phase