hatching size to a 3 lb market size had been reduced 50 percent. Only about 9 weeks is now required. There is serious doubt that the effects of thermal environments on the growth of present day birds would be the same as with strains used 10 years ago. Limited data on the effects of thermal environments indicate that both rate of gain and efficiency of feed conversion are adversely affected at high temperatures. Fig. 4 shows the weight gains of New Hampshire broilers at 85 and 65 F.[21] Generally the larger and older the bird, the less heat tolerant it is. Very young birds will require supplemental heat under practically any weather conditions. The problems of disease and mortality during adverse weather conditions are also of much concern.

The problems of controlling disease and mortality during winter and early spring, and increasing the production of birds during summer are of much economic concern.[22]

The adverse effects of high thermal environments (above 85 F) on egg production manifest themselves in fewer eggs reduced egg weight, and thinner shells. Older hens (more than 1 yr of age) are more adversely affected than younger hens. The birds begin requiring markedly more feed below an average temperature of 45 F and become inactive and lay less eggs as temperatures drop below 32 F.[3]

Other Physiological Reactions

An increase in respiration is one of the first visible responses of farm livestock to increased air temperatures. Although some change is desirable as a heat regulation device, extremely high rates cannot be maintained without fatigue. In cattle respiratory alkalosis with a decline in the CO_2 combining power of the blood may also develop, but the temperatures at which these more drastic results occur are several degrees above those at which production starts declining.[23] Respiration rates can also be accelerated by increased percentages of CO_2 in the air. These increases occur at levels below those regarded as critical in man. A level of 0.5 percent is sufficient to increase respiration rates in calves.[24] Pulse rate is generally too erratic to be very useful as an index of thermal comfort, but, it tends to decrease with rising temperatures. In cattle at extremely high thermal discomfort (106 to 108 F rectal temperatures) the pulse rate increases.[25]

Skin temperature is generally several degrees below rectal temperature, but at an air temperature at or above the body temperature they equalize. At air temperatures above the body temperature, the skin may actually be hotter than the rectal temperature.

Thyroid secretion rates are apparently associated with changes in air temperatures. Cattle thyroid activity increases as temperature decreases.[26] Hyperthyroid chickens can withstand high temperatures better than hypothyroid chickens.[27]

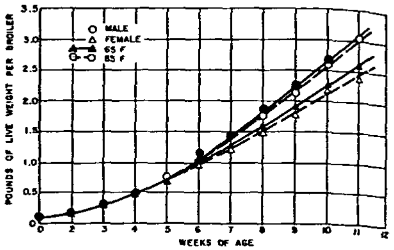
Ammonia has been observed as a serious problem in poultry shelters and high concentrations lead to reduced production and even death. First evidences of excessive concentrations is inflammation of the eyes of birds. This condition has appeared after ten days exposure to 50 ppm of ammonia. Lungs may also be damaged at concentrations above 50 ppm.[28]

The foregoing are only a few of the other physiological reactions that have been investigated in an effort to learn more about homeothermic processes, and the need for conditioning the air within livestock shelters.

METHODS OF CONTROLLING ENVIRONMENTS

Types of Systems in Common Use

In the United States attention was first given to winter protection for the livestock and the operator. This was accomplished by closing and insulating the shelters. The need to lower the humidity and to replace respired and otherwise contaminated air became a problem.



[a] *Each test started with 70 chickens, and the number was periodically reduced to 35 chickens at 10 weeks.*

Fig. 4 .... Growth of New Hampshire Broilers at 65 and 85 F[a,27]

Winter ventilation systems generally are designed to remove the moisture load within the shelter. When this is properly accomplished, CO_2 and ammonia concentrations will generally remain at satisfactory levels.

Ventilation is the most economical answer to this need. Supplemental heating of the air is generally used only in poultry brooding and swine farrowing houses. However, radiant heating devices such as electric heat lamps are frequently used for spot heating newborn farm livestock. Solar heating through the use of properly oriented double-glazed windows and movement of intake air through the space between the roof and ceiling is used to add heat in poultry houses.

Summer cooling, other than shades and hog wallows, has received little attention on most farms. Hot weather was not considered a serious problem. The current trend toward confinement housing and the maximum amount of production per pound of feed has led to the adoption of other summer cooling measures. However, mechanical refrigeration has been used to only a limited degree, mostly in hatcheries.

Ventilation

Either natural or forced draft ventilation systems without supplemental heat are the principle means of conditioning environments within livestock shelters. Natural draft ventilation with windows alone or a combination of windows or other inlets and ridge or flue ventilators have been successful, but are difficult to properly adjust with changing outdoor weather conditions. Automatic damper controls help alleviate this problem but positive movement of a given amount of air is lacking. Fans with thermostat or humidistat control have generally replaced natural draft systems for winter ventilation. The opening of windows on wall panels remains a useful device for summer ventilation but even these are frequently supplemented with large fans.

Exhaust systems, with fan drawing the air from the building and supply air coming either from leakage around doors and windows or from vent intakes, are the most popular. However, pressure systems with the fan forcing the air into the structures have been used successfully. Pressure systems need ducts or several small fans with diffusers to prevent drafts.

Exhaust fans are usually placed in the walls near the ceilings. Air ducts are avoided as they add to the initial costs,

present a winter condensation problem, and readily collect dust. In buildings where there is a deficit of heat available for warming incoming air, exhaust air may be drawn from near the floor.

In exhaust systems, short circuiting between intake and exhaust air must be avoided. Broken windows, open doors, or open hay chutes near fans are principal sources of trouble. Outdoor air should enter at a relatively low velocity to be warmed and diffused before reaching the livestock.

There are a wide variety of recommended practices in the placement of fans about the periphery of the building. The placement of the fan (or fans) along one wall and the intakes along the opposite and end walls is popular. This simple system provided circulation of air over all animals and permits fan placement in the leeward wall of the barn.

Some successful systems exhaust the air in the winter and pressurize the shelter in the summer. Wind over the backs of animals provides relief from heat.

Poultry house ventilation systems fall into two classifications: (1) those for broiler and chick brooder houses, and (2) those for laying houses. In broiler and brooder houses, growing chicks require changing environmental conditions, and heat and moisture dissipation rates are increasing. Supplemental heat usually from brooders is used up to 4 weeks of age. At the early stages of growth, moisture dissipation per bird is low. Consequently, low ventilation rates are recommended to prevent excessive dryness. Litter is allowed to build up and dust can quickly become a problem (as can wet litter if the house is too damp). Current practices for broiler houses are:

Space: 0.6 to 1.0 sq ft/bird (7 to 9 sq in./chick under brooder)
Room Temperature: 60–65 F
Temperature under brooder hover: 95 F, reducing 5 F deg per week until room temperature is reached.
Relative Humidity: 50 to 80 percent
Ventilation Rate: 0.5 to 1 cfm/lb of live weight in winter, 2 cfm/lb of live weight in summer.

Poultry laying houses have two systems of management, one with the birds on built up litter or slatted floors and the other with the birds held in cages (usually 1 or 2 birds per cage). Current practices for laying houses with birds on litter and slatted floors are:

Space: On litter, 3 to 4 sq ft per hen (may be reduced for small breeds). On litter with utility pit, 1 to 2.5 sq ft/per hen. On slats 1 to 2 sq ft per hen.
Temperature: 45 F minimum; 85 F maximum
Humidity: 50 to 80 percent
Ventilation Rate: 1–3 cfm per bird in winter and 4 to 6 cfm per bird in summer.

Current practices for laying houses with birds in cages are:

Space: 1 to 2 sq ft per hen
Temperature: 45 F minimum to 85 F maximum
Humidity: 50 to 80 percent
Ventilation Rate: 5 to 6 cfm per hen with provisions for opening windows or side walls in summer.

Current practices for egg storage are:

Hatching eggs (chickens)
Temperature: 45–55 F
Humidity: 75 percent
(Storage time not to exceed 10 days)

Market eggs
Temperature: 50–60 F
Humidity: 75–85 percent.

Current practices for transport of baby chicks are:

Temperature (within ventilated carton): 90 F (Provided by chicks when standard chick cartons are used within a van at 60 F.)
Temperature (within van): 60 F
Ventilation Rate (within van): 2 cfm per 60 chicks.

Swine housing can be grouped into two general classifications: (1) farrowing houses (for pigs from birth to 25 lb) and (2) growing houses (for pigs from 25 to 250 lb). Some larger swine producers have subdivided the housing with an additional nursery stage (1 to 2 weeks of age to weaning) and housing for breeding stock. Environmental requirements within the nursery will be similar to but less stringent than those within the farrowing house. Those for the breeding stock will approach but be less stringent than those for growing houses.

Current practices for the farrowing houses are:

Temperature: 50 to 75 F with small areas for pigs warmed to 80 F by means of brooders or heat lamps (cold drafts must be avoided).
Humidity: up to 75 percent maximum
Ventilation Rate: 10 to 50 cfm per sow (the low rate for winter and with newborn pigs—the high rate when outdoor temperatures are above 35 F, and the pigs are ready for weaning).

Current practices for growing houses are:

Temperature: 50 F (winter) to 75 F (summer)
Humidity: 75 percent maximum in winter, no established limit in summer.
Ventilation Rate: 6 to 9 cfm/pig below 35 F outdoor temperature; above 35 F, 13 to 18 cfm/pig (the low rate is for 100 pound pigs—the high rate is for 250 pound pigs).

Dairy cattle shelters are operated with stall barn systems or loose housing systems. In the stall barn system cattle are usually held in stalls about 4 ft wide, and all chore operations including milking and feeding are conducted within one structure. In loose housing systems, cattle are free to move about within a fenced lot containing a resting area with a deep bedding pack, a feeding area, and a milking area. The shelter for resting and feeding areas are generally open and require no air conditioning. The milking area, however, requires a fully enclosed area that requires ventilation. Both loose housing and stall barn systems require an additional area, called a milk room for cooling and holding the milk. Milk sanitation codes contain minimum ventilation requirements, and those for the market being supplied should be consulted.

Current practices for stall barns are:

Temperature: 35 to 55 F (winter)
Humidity: 55 to 75 percent
Ventilation Rate: 50 to 200 cfm per cow (the lower rate for poorly insulated shelters in extremely cold weather).

Milking barn requirements are similar to those for stall barns, but should be maintained at a temperature between 50 and 75 F for operator comfort. The lower temperature should be used during cold weather. Milk rooms are ventilated by a natural draft system with ventilating fans, and the requirements vary with local milk codes and heat loads from milk coolers. Most milk codes require ventilation in the passageway between the milking area and the milk room.

Summer Cooling

In addition to the summer cooling through air exchange and aspiration provided by winter ventilation systems, some ventilation systems incorporate evaporative cooling devices. One popular system with poultry has been the use of wetted pads in sections of the wall opposite the wall in which fans are mounted. All intake air is drawn through them. Cabinet type evaporative coolers have also been used. Evaporative coolers should be used discreetly, however, as the resulting high humidity may cause the litter to be wet which in turn aids in soiling eggs and may impair bird health. A single-pass system (no recirculation of room air) has a major advantage of reducing the problem of clogging heat exchange surfaces. Except for hatcheries and egg cooling rooms it has been un-