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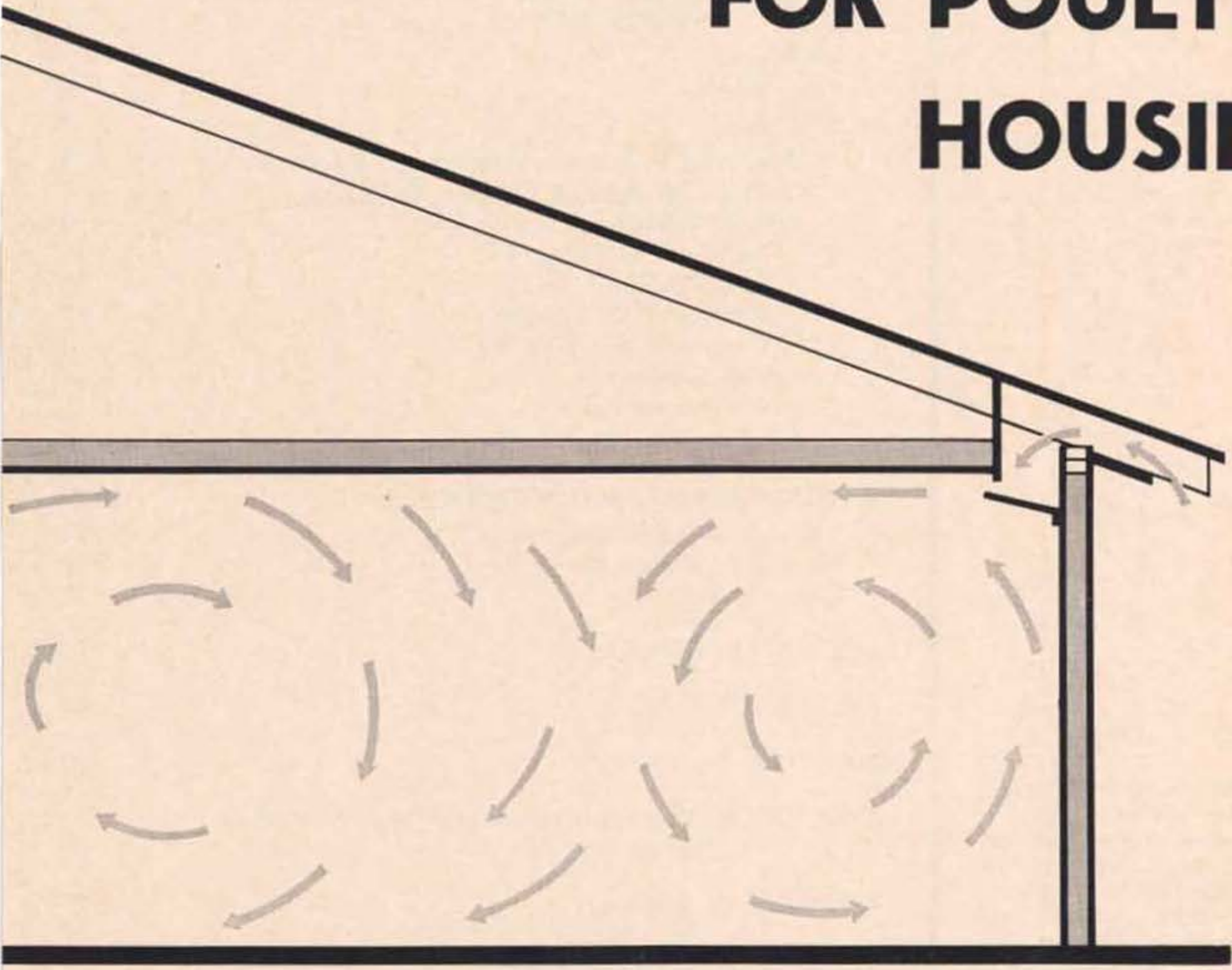
ENVIRONMENTAL CONTROL FOR POULTRY HOUSING



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ENVIRONMENTAL CONTROL FOR POULTRY HOUSING

by C. E. Lampman, J. E. Dixon, C. F. Petersen and R. E. Black

The control of temperature and humidity has long been a major objective in controlling the environment in poultry houses. More recently other factors, including air movements, ammonia concentration, noxious odors, dust and controlled lighting, have been considered. All of these become increasingly important with high bird concentration and highly specialized large scale operations. Odors, fly control and manure disposal are major problems with all large scale operations, particularly when located near urban or residential areas. For extensive reviews of literature in the area of environmental control, see Longhouse, Ota and Ashby (5) and Longhouse *et al* (6).

Standards for and benefits of controlled environment apply generally to all sizes of enterprises and to all geographic areas. Specific problems and their solution differ with the size of operation and the locality. This bulletin presents standards of environment and shows how these standards can be accomplished through use of functional design, insulation, controlled ventilation, bird concentration, controlled lighting and essential ventilation management practices. The information will apply more specifically to the northern states where climatic conditions vary from sub-zero temperatures in winter to hot weather during summer.

The benefits of controlled environment are physiological—to obtain maximum performance of the birds, and economic—to realize maximum returns on the investment in housing, equipment and labor.

The specific benefits of environmental control include:

1. Maintaining inside temperature within the desired range by eliminating stress caused by fluctuating outside temperatures;
2. Removing excess moisture during cold weather;
3. Removing excess ammonia, objectional odors and dust;
4. Maximizing performance in growth, egg production and hatchability;
5. Maximizing bird concentration;
6. Minimizing morbidity and mortality;
7. Improving the over-all environmental conditions in which poultry products are produced for human consumption.

Suggested poultry house environmental standards are given in Tables 1 and 2 for layers and broilers, respectively.

TABLE 1. **Suggested Poultry House Environmental Standards for Layers.**

1. TEMPERATURE °F	Winter		Summer
	Floor Mgt.	Cages	Floor and Cages
Desirable	50 to 55	55 to 60	65 to 70
Satisfactory	50	55	70 to 75
Min. or Max.	45 min.	50 min.	85 max.

2. RELATIVE HUMIDITY—Percent		
Desirable	65	60
Satisfactory	70	50
Min. or Max.	75 max.	40 min.*

*Dust becomes a problem below 50% relative humidity and more serious at 40% and below.

3. AIR EXCHANGE

Installed fan capacity in cfm per bird—Leghorns 5; heavy breeders 6; for fan and pad evaporative cooling 7.

Guide for operation—varies with outside temperature and humidity, insulation of building and bird density. Average rate for cfm per bird—winter 0.75 to 2.0; summer maximum installed capacity as specified above.

Installed intake area for maximum ventilation rate in summer—250 sq. in. per 1,000 cfm fan capacity, except with light traps for controlled lighting 300 sq. in. per 1,000

Guide for operation—winter 150 to 200 sq. in. per 1,000 cfm; summer maximum as specified above.

4. **INSULATION (R values)**—walls 8 to 10; ceiling 12 to 15.

5. **AMMONIA CONCENTRATION**—Desirable: Not over 20 ppm for prolonged periods. Injurious to birds over 50 ppm for prolonged periods. Excessive ammonia is associated with the accumulation of droppings and inadequate ventilation.

6. **LIGHT INTENSITY**—more critical in cage operations. Desirable—1 to 3 foot candles at feed trough level. Higher intensities increase the hazards of cannibalism.

7. **LITTER MOISTURE FOR WOOD SHAVINGS**—Desirable—not over 25%; satisfactory—30 to 33%.

8. **BIRD DENSITY**—Leghorns—1 to 1¼ sq. ft. per bird with floor management. ½ sq. ft. of cage space per bird.

Heavy breeders—2 to 2½ sq. ft. per bird with floor management. Cage management not recommended.

TABLE 2.–Suggested Poultry House Environmental Standards for Broilers and Replacement Stock.

1. TEMPERATURE °F

Bird Age	Winter To 4 wks.	Winter 4 to 8 wks.	Summer To 4 wks.	Summer 4 to 8 wks.
Desirable	70	65 to 70	70 to 75	65 to 70
Satisfactory	70	65	75	75
Min. or Max.	65 min.	60 min.	85 max.	85 max.

2. RELATIVE HUMIDITY–Percent

	Winter	Summer
Desirable	60 to 65	60
Satisfactory	70	50 to 70
Min. or Max.	75 max.	45 min.*; 75 max.

*Dust becomes a problem at and below 50%; higher humidity favors better feathering, growth and feed conversion.

3. AIR EXCHANGE

Installed fan capacity–at the maximum ratio of 3 cfm per bird for summer ventilation rate.

Installed intake area–at the ratio of 250 to 300 square inches per 1,000 cfm fan capacity –the maximum required for summer.

Following is an illustration of average air exchange (cfm) needed to remove the moisture produced by the birds when the outside air is about 30°F and 90% relative humidity.

Age	Average body weight	cfm per bird
2 weeks	0.45	0.15
4 weeks	1.30	0.30
8 weeks	3.75	0.50

See tables 8 and 9 to calculate air exchange requirements for various ages of birds and outside temperature conditions.

4. **INSULATION (R values)**–walls 8 to 10; ceiling 12 to 15.

5. **AMMONIA CONCENTRATION** – Desirable: Less than 20 ppm for prolonged periods. Satisfactory: Not over 30 ppm for short periods. Objectionable: Continuous exposure to more than 20 ppm results in damage to the respiratory tract and increased susceptibility to respiratory diseases.

6. **LIGHT INTENSITY**–1 ft. candle at feed level is adequate. Higher intensities increase the hazard of cannibalism.

7. **BIRD DENSITY**–0.75 to 1.0 sq. ft. of floor space per bird; 0.5 sq. ft. or less of cage space per bird, depending upon age, for replacement stock.

Physiological Factors Influencing Poultry House Environment

The principles for obtaining controlled environment involve the input and output of heat, water and air. A practical understanding of the basic information in this section will help the reader understand the standards of environment outlined in Tables 1 and 2. For detailed results of heat and moisture balance studies, see Ata, Garver and Ashby (7), and Ota and McNally (8, 10, 11).

LAYING HENS (Adult Birds)

Heat Input

Heat production varies with age, body weight, breed, activity of the bird, house temperature and with humidity at temperatures of 80 F and above. The adult hen is an efficient source of heat. Although 40 BTU per bird-hour is a value commonly used for heat output calculations, 9 BTU of total heat per hour for each pound of live weight for Leghorns and 7.9 BTU for heavy hens (5) are more accurate. For example:

A 3-lb. Leghorn pullet will produce approximately 27 BTU per hour.

A 4½-lb. Leghorn hen will produce approximately 40 BTU per hour.

A 5¼-lb. heavy hen will produce approximately 41 BTU per hour.

Not all of the total heat produced is available for warming the air in the house. A portion of the heat along with vaporized moisture is respired in the breath. This portion is called **latent heat.** Each pound of water vaporized at body temperature requires about 1,000 BTU. The remaining heat is given off by radiation and convection and is, therefore, available for warming the surrounding air. This is called **sensible heat.** The production of sensible heat is increased at low temperatures, remains quite constant between 45 and 60 F and is greater during the day than at night (8). At 55 F, sensible heat will comprise from 72 to 75 percent of the total heat produced.

Bird-generated heat in combination with high bird density and insulated houses provides a basis for maintaining the desired house temperature and moisture control during cold weather. It also creates the problem of heat removal during hot weather.

Water Input

The consumption and elimination of water by laying hens varies widely and is influenced by age, weight, temperature, ration, rate of egg production and type of management.

Longhouse, Ota and Ashby (5) report basic information on the relationships of water to feed consumption and water plus feed consumption to feces produced. They also give the water content of feces as influenced by different temperatures. This information is presented in part in Table 3.

Ota and McNally (10) have incorporated basic information from their calorimetric determinations tabulating the heat and moisture produced by 1,000 Leghorn hens at different temperatures. This is presented in part in Table 4.

Temperature is only one of several factors influencing water consumption and water content of droppings. The energy, fiber and salt content of the ration are also influencing factors. Hens drink less with high energy rations containing a low salt content. Contamination of the water by microorganisms accumulating in the watering equipment will cause excessive water content of droppings. Frequent cleaning of the watering equipment will help prevent this problem.

When feeders and waterers are located above the roosting racks, approximately 75 percent of the droppings and all the waste water is deposited in the droppings pit.

TABLE 3.—Constants for Determining Water Consumption and Fecal and Water Elimination in Relation to Feed Consumption (weight basis).

	Ambient (House) Temperature		
	40-60 F	60-80 F	80-100 F
Ratio of water to feed consumption	1.7 to 2.0	2.0 to 2.5	2.5 to 5.0
Ratio of water and feed consumed to feces produced— Leghorns	2.0	2.1	2.2
Heavy Breeds	1.7	1.8	1.9
Water content of feces (%)	75	77	80

Example: At 60 to 80 F, Leghorn hens will drink 2.0 to 2.5 lb. of water to each pound of feed consumed; feed and water consumed will be at the ratio of 2.1 lb. to each pound of feces eliminated, and the feces will contain 77% water.

TABLE 4—Heat and Moisture Production by Laying Hens at Various Temperature Levels. 1,000 S. C. White Leghorns—4.3 lb. Avg. Wt., 75% Egg Production.

Temperature (°F)	Total heat from hens (BTU per hour)	Water from hens		Total water input in house*	
		Respired (lb./hr.)	In droppings (lb./hr.)	(lb./hr.)	(lb./day)
25	46,000	6.3	14.5	22.8	547
35	45,000	8.3	14.5	24.8	595
45	38,700	8.4	12.9	23.7	569
55**	38,700	10.4	12.8	25.5	612
60	38,700	11.4	12.7	26.4	634
80	38,500	14.3	14.4	31.6	758
95	24,500	20.0	10.3	33.7	809

*Total includes water wasted by hens while drinking—estimated at 10% of water consumed as wasted by the hens from 25 to 80F and 15% at 95F.

**The values for 55 were interpolated from the data presented in reference 10.

Layers in cages usually drink more water than those on the floor. This additional water consumption often results in a semi-liquid consistency of the droppings which makes removal difficult and mechanical loading by elevator-conveyors practically impossible.

These factors all influence the total water output by hens, especially the water content of droppings. Higher concentrations of ammonia and noxious odors are associated with moisture buildup.

The detailed information in Tables 3 and 4 has been included to provide a quantitative evaluation of the moisture-input problem within the house. Efficient controlled ventilation for adequate air exchange is the first approach to the removal of excess water. Problem I, Appendix C, shows that about one-half of the moisture produced by laying hens can be removed by ventilation.

The information also points out the limitations of ventilation in the removal of moisture from accumulated droppings and, therefore, indicates the added advantages of mechanical equipment for droppings removal when the size of enterprise justifies the investment.

GROWING CHICKS — HEAT, WATER AND FECAL PRODUCTION

Ota and McNally (11) and Ota (personal communication, 1966) have made extensive calorimetric determinations on the production of heat, moisture and fecal material by growing broilers at different temperatures. Their data show that age, size of bird, ambient temperature and other factors including rate of growth, strain differences, relative humidity, air movement and the progressive reduction of temperature during the growing period influence heat, water and fecal production. Table 5 has been developed from their basic information as a guide for evaluating the heat, water and droppings produced by growing broilers in relation to the problems of ventilation and management.

These values show that both the heat and moisture produced by chicks become important contributing factors at and beyond four weeks of age. This also emphasizes the need for less brooder heat and more ventilation to remove the moisture as the birds become larger. During cold weather supplementary room heat may be required, of course.

The calculations in Problem II, Appendix C, point out that ventilation for 1,000 broilers will need to remove about 8 tons of water during an 8-week growing period. Water produced by gas brooders, during the brooding period, also contributes to the atmospheric moisture in the house. Ota and McNally (9) state that about 1.6 pounds of water is produced in the combustion of 1 pound of propane gas. The water produced by gas brooders for brooding 1,000 young chicks can amount to 9.6 pounds per day.

Observations at the Idaho Agricultural Experiment Station indicate that excellent growth, feathering and chick behavior are obtained when the brooder house is maintained at 70F and 60 to 65 percent relative humidity during the first 3 to 4 weeks of age. Ota (per-

TABLE 5.—Average Heat, Moisture and Fecal Production per 1,000 Broilers at Different Ages at Brooder House Temperatures of 68 to 70F.

Age of birds	Avg. body wt. (lbs.)	Heat output per hour*		Water output** (lb. per day per 1,000 birds)	Fecal output*** (lb. per day per 1,000 birds)
		(BTU per lb. live wt.)	(BTU per 1,000 birds)		
2 weeks	.45	26	11,700	130	70
3 weeks	.75	23	17,250	200	110
4 weeks	1.30	18	23,400	280	170
5 weeks	1.75	14	24,500	350	215
6 weeks	2.40	13	31,200	400	260
7 weeks	3.00	10	30,000	470	315
8 weeks	3.75	10	37,500	500	370

*From data furnished by Ota (personal communication, 1966).

**Approximately 40% is respired moisture and 60% is water in droppings. Approximately 10% should be added to include water wasted from waterers.

***At 65 to 70F droppings contain 80 to 82% water.

sonal communication, 1966) suggests that accelerated reduction in brooding temperatures hastens feather growth, and probably the development of the homo-ethermic mechanism which enables the chick to be comfortable at temperatures lower than commonly used.

The temperature and velocity of the air over the floor are extremely important factors during the early brooding period. Floor drafts associated with leakage around windows and doors and poor ventilation management during cold weather can be harmful to the extent of contributing to respiratory diseases and a high condemnation rate of broilers. On the other hand, during hot weather, positive air movement at floor level will help to remove bird heat and make the chicks more comfortable.

AMMONIA BUILD-UP

The concentration of ammonia in poultry houses is influenced by bird concentration, the ventilation rate and by the frequency of droppings removal. During cold weather, an excessive build-up of ammonia and humidity within the house occurs during periods of restricted ventilation. Higher concentrations of ammonia are also found in laying houses when droppings are allowed to accumulate for prolonged periods either in the droppings pit or on the floor under cages.

In the case of winter broiler production, high levels of ammonia concentration are more frequently found in poorly insulated houses that are under-ventilated because of insufficient supplementary heat. These high levels have detrimental effects on the birds and are discomforting to the operator. Watery eyes, due to irritation, are usually the first symptoms observed in birds. Increased susceptibility to respiratory diseases follows if excessive ammonia is present for prolonged periods of time.

A brief summary of the research on ammonia concentration in broiler houses is given by Longhouse *et al* (6) who state that 15 ppm can be detected by the caretaker and that a ventilation rate of 1/3 cfm per pound of chicken was sufficient to maintain the ammonia in the air below 25 ppm.

Anderson, Beard and Hamon (1), working with young birds in ammonia exposure chambers, found that chickens and turkeys exposed continuously to 20 ppm of ammonia showed gross or histopathological signs of damage to the respiratory tract after six weeks of exposure. Further, exposure to 20 ppm for 72 hours and exposure to 50 ppm for 48 hours significantly increased the infection rate of chickens subsequently exposed to an aerosol of Newcastle disease virus. Results of these experiments indicate that the toxic effects of ammonia are related to both concentration and length of time of exposure.

Research at the Idaho Experiment Station has also been concerned with levels of ammonia concentration as influenced by frequency of droppings removal in floor-managed layers during cold weather. Table 6 presents data on ammonia concentrations during the months of January and February while ventilation was restricted.

When droppings were allowed to accumulate in the pits under the roosting and feeding rack, the ammonia content of the air was twice the amount as when droppings were removed twice a week in House A and three times as much in House B.

The high levels of ammonia during these two winter months had no adverse effects on either egg production or mortality. This does not agree with the work of Anderson *et al* (2), but it is possible the adult laying hen has a higher tolerance than young chicks for high levels of ammonia concentration.

TABLE 6.—Ammonia Concentration as Influenced by Frequency of Droppings Removal and Fan Capacity Per Bird During Two Winter Months.

	Frequency of Droppings Removal			
	Twice Weekly	Seasonally	Twice Weekly	Seasonally
	(House A: Pressurized Ventilation)		(House B: Exhaust Ventilation)	
Number of birds	406	406	240	240
Floor space—sq. ft. per bird	1.25	1.25	1.50	1.50
Ventilation (measured capacity cfm per bird)	2.53	2.49	3.4	3.0
Ammonia concentration—ppm in air 6" above roosting racks				
January sampling No. 1	22.1	32.2	9.6	33.3
January sampling No. 2	21.2	32.8	9.5	25.8
January sampling No. 3	20.0	40.8	10.6	29.4
January average	21.1	35.3	9.9	29.5
February sampling No. 1	18.2	35.6	10.7	28.2
February sampling No. 2	14.4	32.8	13.3	35.8
February sampling No. 3	15.2	29.8	10.0	29.3
February average	15.9	32.7	11.3	31.1
January and February average	18.5	34.0	10.6	30.3
Average litter moisture—% Sampled January 30	25.5	28.0	37.1	37.2
Average egg production—% 10/10/63 to 7/15/64	79.3	79.5	78.9	81.1
Average mortality for same period—%	10.3	10.1	6.7	3.7

LIGHTING EFFECTS

The influence of light as it affects the physiological activity of birds of all ages is an important phase of environmental control. The length of the lighting period (day length) affects the activity of the reproductive system and the intensity of light influences the behavior of the birds.

Research by Wilson (15) and others has established the basic principle: light passing through the eye via the optic nerve and central nervous system to the anterior pituitary gland triggers the release of hormones which stimulate the ovaries to increased activity.

Increasing periods of light (longer days) stimulate the rate of sexual development in growing pullets and increases egg production in laying hens. On the other hand, decreasing periods of light delay sexual maturity of growing pullets and restrict egg production to less than the maximum potential of laying hens.

The influence of light intensity on the behavior of birds of all ages is an important economic aspect of environmental control in poultry housing and management. High intensities stimulate activity, nervousness or flightiness and cannibalistic tendencies. With low intensities, birds appear more contented. They are quieter, more easily managed and less inclined to cannibalism. Recommended light intensities are given in Tables 1 and 2.

Physical Factors Involved in Controlling Environment

The following factors are the most important in controlling the environment of a poultry house: (a) insulation, (b) vapor barrier, (c) ventilation, (d) management and (e) light control. Each of these factors will be discussed in the sections which follow, with major emphasis given to ventilation and its management.

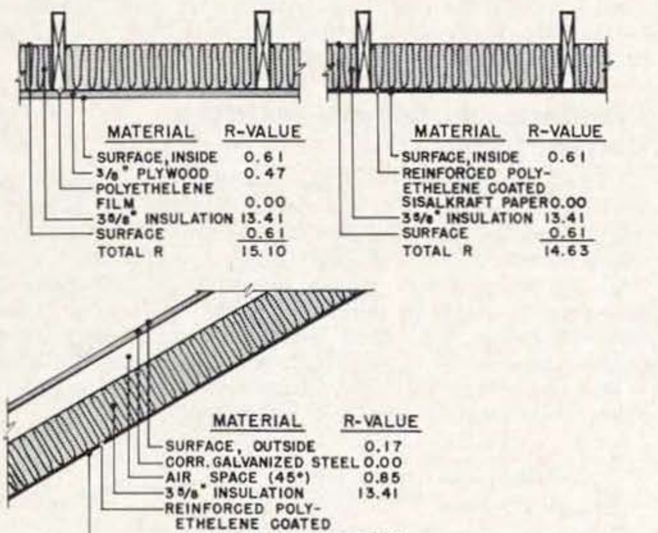

Fig. 1.—Various combinations of building materials in ceilings, roofs and walls will provide "R values" which meet recommendations of Tables 1 and 2.

INSULATION

Insulation is needed to conserve the inside heat during cold weather and to keep out the outside heat during hot weather.

During winter, insulation is needed to conserve and utilize the heat produced by the birds in order to maintain uniform temperatures of 50 to 55F (for layers) and still have adequate ventilation for moisture removal. At this temperature, the moisture-holding capacity of the inside air is sufficient to hold the moisture produced until it is carried out by the ventilating system. Insulation also prevents the condensation of moisture on the walls and ceiling. In other words, an insulated building is necessary for satisfactory moisture control by ventilation during cold weather. Insulation in the brooder house will also reduce the amount of supplementary heat required during winter to maintain a temperature of 70F.

The efficiency of insulation is measured by the resistance of heat transfer (thermal resistance) through the material or the combination of materials used in the walls or ceiling. This is called the "R-value." The "R-value" of various materials is given in Appendix B.

The amount of insulation needed depends upon the temperature extremes to which the particular area is subject. In northern states, an "R-value" of 8 to 10 for the walls and 12 to 15 for the ceiling is considered necessary. These values represent the total of all materials and the air space between them. This usually requires the equivalent of 2 to 3 inches of fiber glass in the walls and 3 to 3⅝ inches in the ceiling. Combined "R-values" for typical wall and ceiling construction are illustrated by Fig. 1.

For more information about insulation, see Bragg and Lambert (3) and Walpole, D'Armi and Lloyd (14).

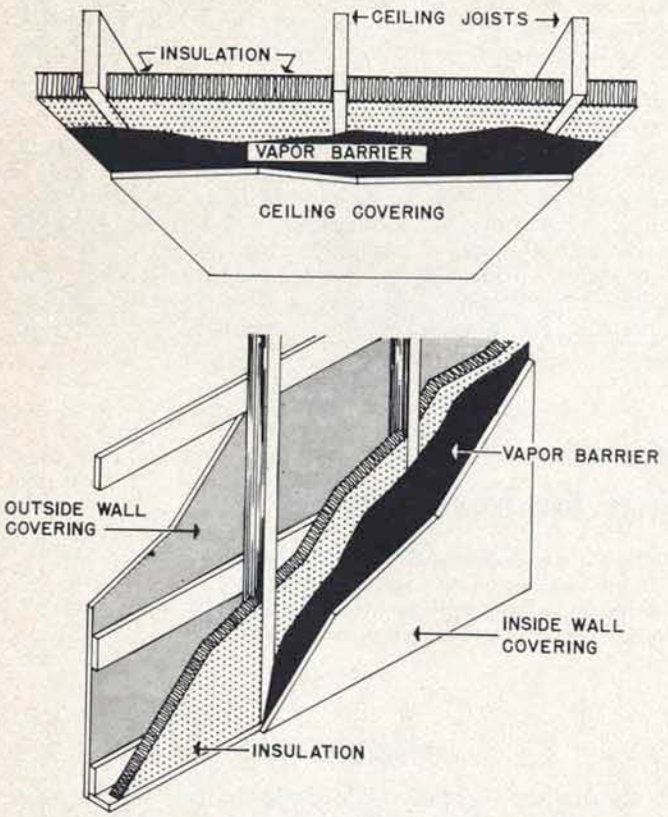

Fig. 2.—Ceiling and wall construction showing installations of insulation and vapor barrier.

VAPOR BARRIER

The effectiveness of any insulating material is associated with dryness; the penetration of moisture reduces the insulating value and causes deterioration. To prevent this, a vapor barrier is required unless the insulation is a waterproof material. The vapor barrier should be placed between the insulation and the inside wall covering (Fig. 2). To be effective, the vapor barrier must be sealed at all joints and mechanical service openings by adequately lapping the material or taping around the opening with plastic tape.

Several kinds and types of materials are available. Selection depends upon the function intended. If the material is to serve only as a vapor seal, 4 mil polyethylene or equivalent will be satisfactory and inexpensive. On the other hand, if the material is to serve as both a vapor seal and the interior surface, a stronger and more durable material is needed, such as reinforced sisalkraft paper coated with polyethylene. This material is often attached to the under side of the rafter to serve as the ceiling. A solid covering over the vapor barrier is recommended in an area which is apt to receive physical damage by puncture or abrasion.

VENTILATION

Controlled mechanical ventilation is a fundamental requirement for regulating air exchange in poultry housing. For adequately insulated houses, it is the basis for providing the desired environmental conditions outlined in Tables 1 and 2.

Adequate air exchange is a basic necessity for windowless housing. From the standpoint of ventilation, all poultry houses should be operated as windowless houses during the winter season.

Major considerations include the removal of excess moisture and ammonia while still maintaining the desired temperature inside the house during cold weather. In summer, removal of excess heat and dust is a major problem with high bird densities.

Ventilation to Remove Moisture During Winter

The principle used in the removal of moisture by ventilation during cold weather is that the water holding capacity of air is approximately doubled with each temperature increase of 20F (Table 7). Outside air at 30F and 90 percent relative humidity which contains 0.25 pounds of water per 1,000 cubic feet when it enters the house, will hold twice as much water (0.54 pounds per 1,000 cubic feet) when warmed to 50F. When warmed to 70F, it will hold four times as much water (1.04 pounds per 1,000 cubic feet).

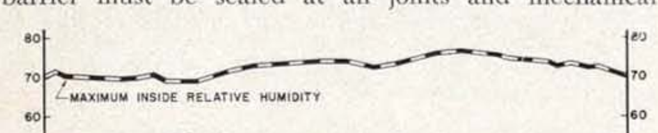

Fig. 3.—Desirable uniform temperature and humidity can be maintained in a laying house during extremely cold weather. (Idaho Agricultural Experiment Station data.)

Fig. 4.—Uniform brooder house temperature and humidity were maintained during this period of fluctuating outside temperature. Controlled ventilation and a balanced regulation of both fan and brooder thermostats made this possible.

TABLE 7.—Pounds of Water that 1,000 Cubic Feet of Air Will Hold at Various Temperatures and Relative Humidities.

Air Temperature (°F)	Relative Humidity 90%	70%	50%
30	0.25	0.19	0.14
40	0.37	0.29	0.21
50	0.54	0.42	0.30
60	0.75	0.58	0.42
70	1.04	0.81	0.58

Therefore, as incoming air is warmed to the house temperature, the increased capacity to hold water makes it possible to take up moisture and carry it out through the ventilating system. The amount of ventilating air required to remove moisture at various outside temperatures is given in Tables 8 and 9 for growing and adult birds. The values given in these tables show the quantity of air which must be exchanged in one hour. These values are not the capacity of the ventilation system. They are the sum of the required ventilated air volumes during one hour obtained with restricted ventilation resulting from intermittent fan operation during winter months.

Bird heat combined with insulation and controlled ventilation will maintain satisfactory conditions in the laying house (Fig. 3). The addition of supplementary heat will maintain satisfactory conditions in the brooder house (Fig. 4).

Control — The Basis for Efficient Ventilation

Fundamentally, controlled ventilation is a regulated rate of air exchange. This involves more than controlled fan operation. It also involves control of incoming air in the case of exhaust ventilation or outgoing air in pressurized ventilation. To explain and illustrate the principles involved, discussion deals specifically with exhaust ventilation. The fundamental principle of controlling both incoming and outgoing air applies also to pressurized ventilation which is discussed later in the text.

Several systems of ventilation give satisfactory results when properly installed and operated. Even with the automatic controls available today, **the human element — evaluation, judgment and the extent to which the operator applies himself to the management of the system — is an indispensable factor.**

Exhaust Ventilation

Automatic control of fans by thermostats and timers is an accepted practice and is reasonable in cost. On the other hand, automatic control of the intake area and incoming air is still in the developmental state. This is especially true in the case of the perimeter continuous-slot type intake. For the present, regulation of intakes is done manually by the operator. Some poultrymen have reduced their labor routine by developing a system of control by cables and pulleys operated by centrally located winches. Automatic controls operated by thermostatically controlled electric motors are available but costly. Experiment stations and equipment manufacturers are presently working to develop automatic intake control mechanisms that are practical and reasonable in cost.

The ridge ventilator shown in Fig. 13 operates as an intake when the wall fans are positioned to exhaust the air. In a windowless house or with all windows closed a negative pressure is created which opens the side flaps. The width of the opening and amount of air pulled in increases as the fan operating capacity increases. This provides some automatic control of intake area. The same principle could be incorporated with wall intakes.

The ventilating system that is properly installed and regulated to provide automatic fan control and the proper ratio of intake area to ventilation rate will:

1. Respond quickly to outside temperature changes;
2. Provide the desired rate of air exchange in relation to the outside temperature;
3. Maintain a balance between heat input and outgo during cold weather;
4. Maintain the desired inside temperature within a reasonably narrow range (Figs. 3 and 4);
5. Remove excess moisture, ammonia, objectionable odors and dust and the carbon monoxide produced by gas brooders;
6. Minimize the stratification of air and, therefore, reduce the temperature range between floor and ceiling (Fig. 12);
7. Maintain drier litter in floor-type housing for birds of all ages;

TABLE 8.—Ventilation Required at Various Ages and Outside Temperatures to Eliminate Moisture Produced by Growing Birds.*

Age of Birds (weeks)	Cubic feet of air exchange needed per hour for each 1,000 birds with outside temperature and relative humidity of: 0F 90%	15F 90%	30F 90%	50F 90%	50F 70%
		inside temperature—70F			
2	6,800	8,100	9,750	18,700	13,120
3	10,510	12,500	15,080	28,900	20,300
4	14,580	17,330	20,840	40,000	28,150
		inside temperature—65F			
5	17,990	21,390	25,790	49,400	34,700
6	20,420	24,350	29,340	56,200	39,420
7	24,000	28,500	34,350	65,900	46,400
8	25,320	30,150	36,250	69,600	48,800

*Based on moisture output as given in Table 5.

TABLE 9.—Ventilation Required to Eliminate Moisture for Two Weights of Adult Birds at Various Outside Temperatures*.

	Cubic feet of air exchange needed per hour for each 1,000 birds with the inside air at 55F and 70% relative humidity and with outside temperature and relative humidity of:			
Bird weight (lb.)	0F 90%	15F 90%	30F 90%	50F 90%
4.3 (Leghorns)	30,950	36,000	53,900	161,500
7.0 (Heavies)	38,600	44,850	67,000	201,000

*Based on moisture output as computed from material given in Table 4.

8. Maintain inside temperatures several degrees below that outside when combined with "fan and pad" or "fogger" systems of evaporative cooling during hot weather.

Installed Fan Capacity

The total **installed** fan capacity should provide the maximum rate of air exchange required during hot weather. Table 1 shows the recommended ratio of cubic feet per minute for each adult bird: 5 cfm per bird for Leghorns and 6 for the heavy broiler breeders. When the fan and pad combination is used for evaporative cooling in areas with prolonged high temperatures, at least 7 cfm per bird should be considered. If ducts are a part of the system, as in pressurized ventilation, an experienced authority should be consulted. The total installed fan capacity recommended for broilers is at a ratio of 3 cfm per bird as shown in Table 2.

Higher ratios of installed fan capacity are not recommended. Forcing in excessive amounts of outside air at temperatures above 90F is not the solution for removing bird heat; additional circulating fans inside the house are more effective for moderate summer weather, and some type of evaporative cooling is required for areas with prolonged temperatures in excess of 90F.

Installed Intake Area

The total installed intake area should allow maximum air exchange during hot weather when fans are operating at full capacity.

Tables 1 and 2 show a ratio of 250 to 300 square inches of intake area per 1,000 cfm fan capacity. This ratio is based upon the fact that an opening 1 x 12 in. or 12 square inches will admit 50 cubic feet of air per minute at a pressure difference of 0.04 inches (3, 14). This pressure difference of 0.04 inches is extremely low and allows the fans to operate at almost full capacity.

These basic figures (12 square inches and 50 cfm) multiplied by 20 give a ratio of 240 square inches per 1,000 cfm fan capacity—for practical purposes, 250 square inches per 1,000 cfm or the ratio of 1 square inch per 4 cfm of installed fan capacity. When the air is restricted through an offset in the intake opening and especially when light traps are installed for controlled lighting, 300 square inches per 1,000 cfm should be used.

As a general guide a width of 3 inches is suggested for the continuous slot type intake.

The average velocity of incoming air at the intake opening is approximately 720 feet per minute. When

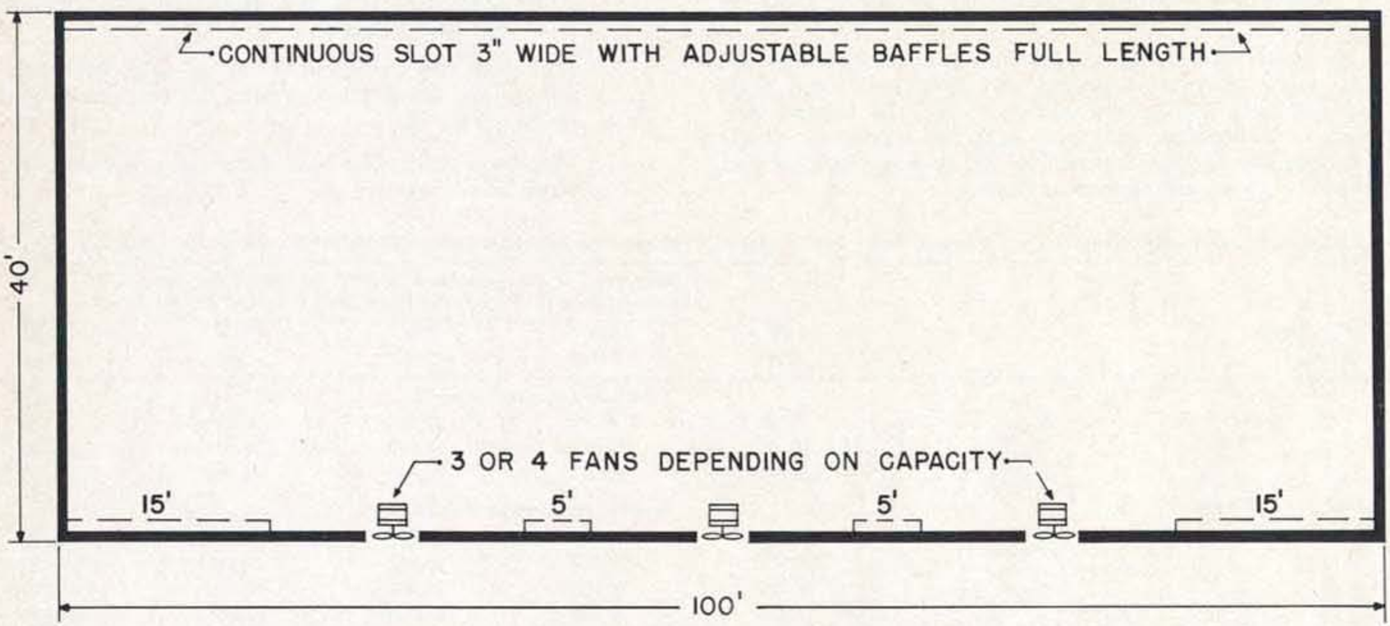

Fig. 5.—This slot-type intake is designed to give the proper ratio of installed intake area to installed fan capacity. Note continuous slot of 100 feet on one wall and total of 40 feet on opposite wall.

the pressure difference is increased from 0.04 to 0.125 (1/8) inch static pressure, as could be the case with increased fan operation, the average velocity and amount of air passing through the intake is approximately doubled.

The following illustration will serve to apply the above information for installing the perimeter-slot type intake in a laying house:

> Assume a house 40 x 100 feet providing 4,000 square feet of floor space for 4,000 Leghorn hens housed at 1 square foot per bird. Exhaust wall fans are installed in one side wall to provide 5 cfm per bird or a total installed fan capacity of 20,000 cfm. At the ratio of 1 square inch of intake per 4 cfm of fan capacity, the house will require 5,000 square inches of intake area.
>
> Then: 5,000 square inches divided by 3-in. intake width equals 1,667 lineal inches or about 140 lineal feet of intake area. This requires a continuous slot 3 inches wide the full length of the wall opposite the fans plus 40 feet on the fan side. This is located as shown in Fig. 5. Intakes should be at least 8 and preferably 10 feet from the fans to avoid short circuiting the incoming air.
>
> The installed intake area will allow maximum air exchange for summer temperatures. Adjustable baffles such as illustrated in Figs. 6 and 7 will be needed to restrict the incoming air during the winter.

Patterns of Air Circulation

Field observations repeatedly show that improper installation and poor management of ventilating equipment are partly due to lack of understanding of air circulation inside the poultry house. This is especially critical during winter weather because the incoming cold air is heavier than the warm inside air and, therefore, settles rapidly to the floor unless a directional control

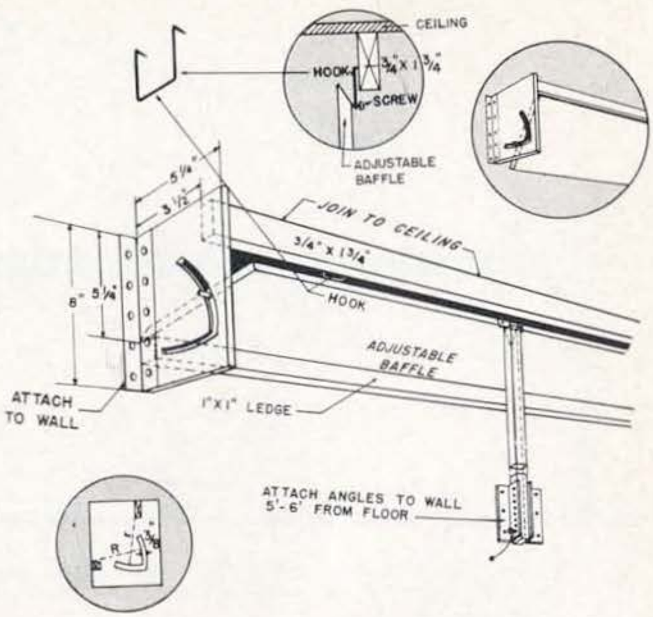

Fig. 6.—Details of construction of an intake box with an adjustable baffle. The main drawing shows the baffle adjusted to direct incoming air upward along the ceiling. The insert at top right shows the baffle adjusted to direct the air downward as might be desired during summer operation. To hold the baffle in this position, construct a hook as shown in the insert at top center. The hook is bent from 1/16-inch wire and driven into the 3/4 x 1 3/4-inch board to serve as a support for the baffle-mounted screw. The insert at lower left shows details of construction of the 3/4-inch plywood end board. The radii are as follows: "R" = 4 1/4 inches; "r" = 3 5/8 inches. The slot is 3/8-inch wide.

Fig. 7.—Smoke sticks show the patterns of air flow, mixing and diffusion when the intake area is restricted and the baffle adjusted to direct incoming air into the house at ceiling level. Black paper is used here for background. The lighter shading shows blended air gradually settling to the floor as shown graphically in Fig. 8a.

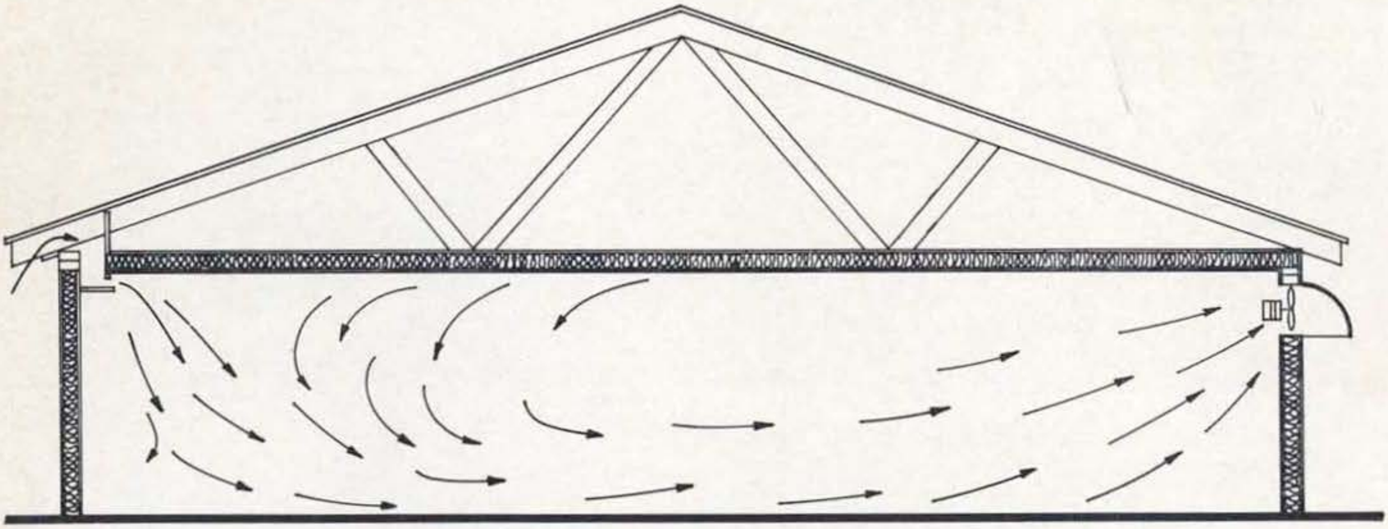

Fig. 8.—General pattern of air circulation with wall-fan and slot-type intake located in opposite walls. During cold weather, the large volume of air entering at a low velocity drops rapidly to the floor with less blending of the inside warm air than occurs in Fig. 8a.

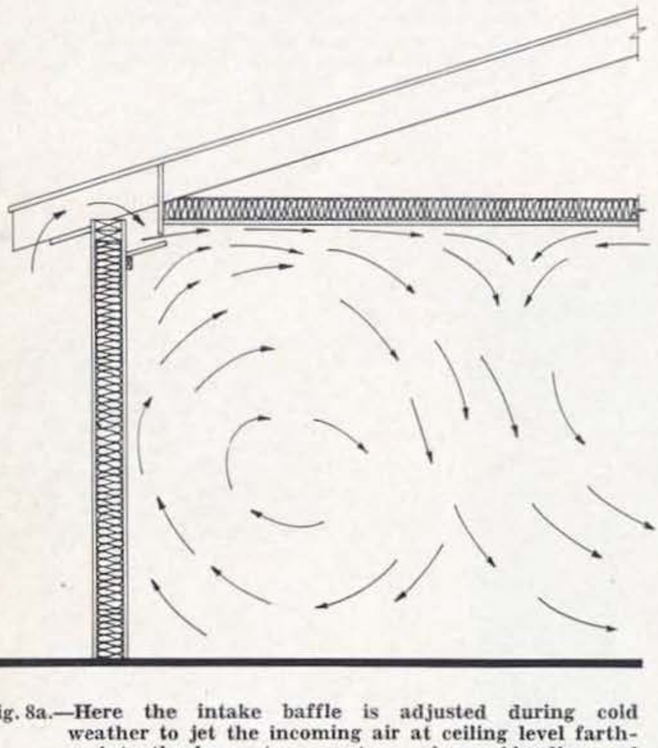

Fig. 8a.—Here the intake baffle is adjusted during cold weather to jet the incoming air at ceiling level farther into the house to promote maximum blending and diffusion of outside and inside air.

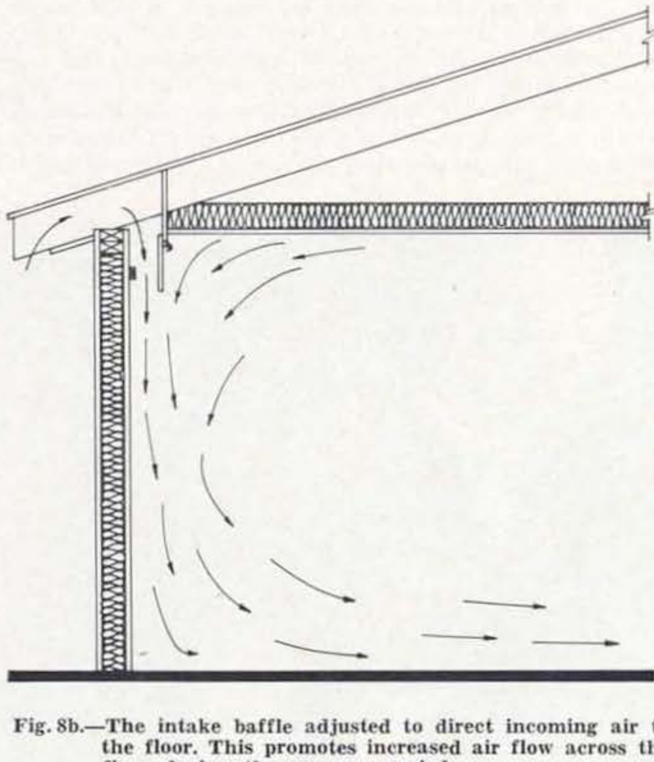

Fig. 8b.—The intake baffle adjusted to direct incoming air to the floor. This promotes increased air flow across the floor during the summer period.

Fig. 9.—The pattern of smoke travel here shows incoming cold air falling rapidly to the floor from an intake as originally installed in a brooder house at the Idaho Experiment Station.

promotes circulation. In the exhaust system of ventilation, the **location of the intakes** and the **ratio of intake area to fan operation** exert the major influence in establishing the pattern of air circulation inside the house.

The following explanation and accompanying figures apply to patterns of **inside** air circulation when the **outside** air temperature is lower than the inside temperature. The patterns of air circulation illustrated have been established by the use of several types of "smoke guns" and "smoke sticks" in research at this station and in field observations (Figs. 7, 9, and 10).

Control of Incoming Air

Controlling incoming air involves control of the amount of air, its velocity and directional flow.

During **cold** weather, fan operation will be restricted automatically by thermostats when outside temperatures drop. The amount of cold air drawn in while the fans are operating influences the length of time the fans are on and off. If intakes are **not** restricted, the large volume of incoming cold air will cause the fans to be off for long periods of time so that even with adequate fan capacity, the house may be under-ventilated and the air inadequately mixed. This is more likely to happen during cold nights. Furthermore, cold air coming in through the unrestricted intake is at a low velocity so that it falls rapidly to the floor. (Fig. 8).

When the intake area is restricted: (a) the fans operate for longer periods of time, (b) the volume-rate (cfm) of incoming air is decreased, (c) the air passes through the intake area at a higher velocity so that it jets further into the house (Figs. 7, 8a and 10) and (d) the warm inside air is syphoned or drawn into the mainstream of incoming air (Figs. 8a and 11).

The rapid movement of air at ceiling level and the mixing of the incoming and inside air slows the rate of fall and raises the temperature of the mixed air close to that of the inside air. Control of the air flow, blending and recirculation affects the pattern of air circulation in the entire house. It breaks up stratification to the extent that there is only a few degrees difference between ceiling and floor temperatures. This program of restriction, directional control and blending of incoming air was the basis for maintaining the small difference between floor and ceiling temperatures in the brooder house as shown in Fig. 12.

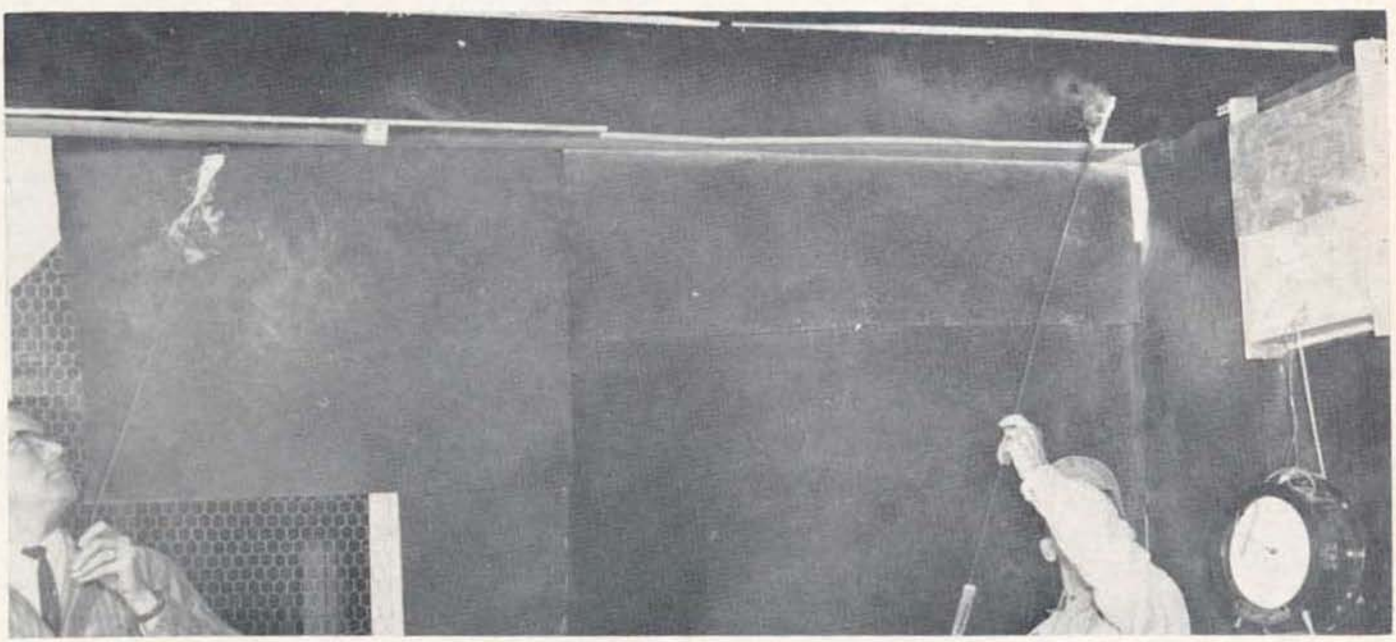

Fig. 10.—The pattern of smoke travel from the same intake shown in Fig. 9 after a shield has been attached to change the intake opening to within 2½ inches from the ceiling. Black paper was attached to the wall and ceiling to give black background. Note that the air gets into the house at ceiling level. The lighter shading indicates blended air slowly settling to the floor. This pattern of air flow was obtained while the ceiling fan shown in Fig. 14 was operating.

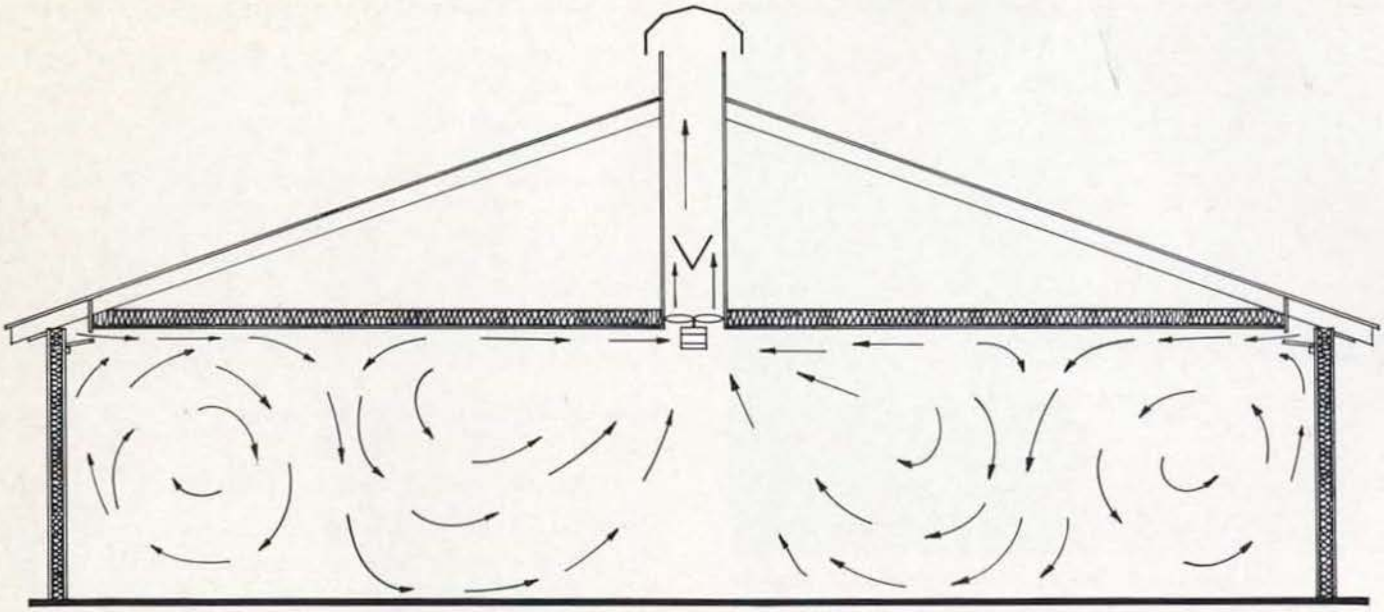

Fig. 11—This is the general pattern of air circulation with a combination of ceiling exhaust fan and the slot-type intake in both side walls and when baffles are adjusted to direct incoming cold air into the pen at ceiling level.

The intake box in Fig. 6 functions in two ways: (a) it makes it possible to reduce the amount of air, and (b) it provides for directional control and the desired mixing patterns (Figs. 8 and 11). It is designed primarily for the perimeter-slot type intake. Even though the slot is continuous, the length of the baffle should be limited to 6 or 8 feet to facilitate manual regulation.

The pattern of air circulation for the ridge ventilator serving as an intake is shown in Fig. 13.

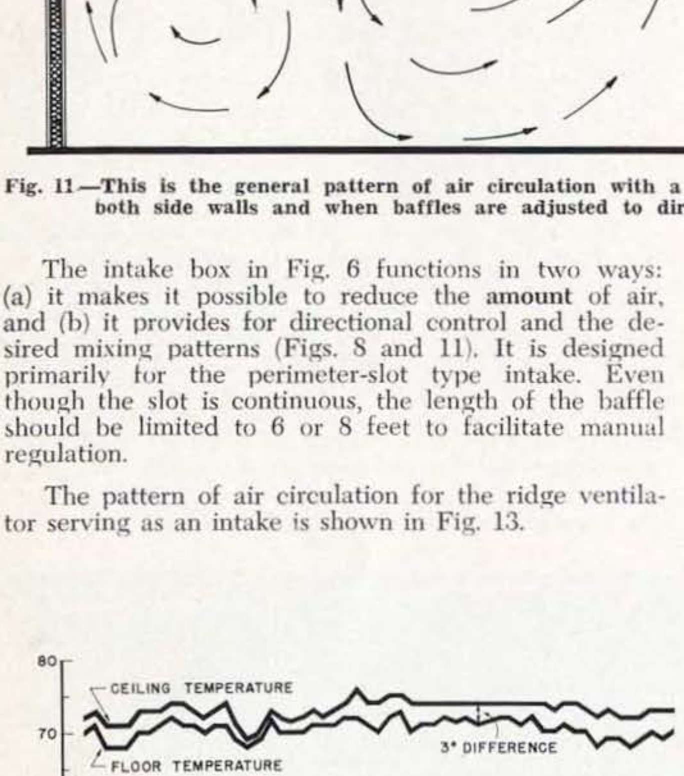

Fig. 12.—Ceiling and floor temperatures in a brooder house during a period of fluctuating outside temperatures. The ceiling temperature record was obtained from the recorder at ceiling level as shown in Fig. 14; the floor temperature was recorded by the recorder shown in Fig. 10 with the cable extended to within 2 inches of the floor at the side wall under the intake.

Fan Selection

Many types and sizes of fans are available for ventilating poultry buildings. These include single-speed, two-speed, reversible side-wall fans, high-speed (1725 rpm) and low-speed, high-volume fans. The capacity of the fan depends upon the diameter, number and pitch of the blades and the speed (rpm) at which the fan operates. The rated capacity is given in cfm of air delivered at various static pressures, for example 0", 0.05", 0.10" and 0.125" (⅛") of static pressure (water gage). The actual delivery will vary according to the pressure against which the fan must operate.

Fans should be selected at a static pressure (S.P.) of 0.10" or 0.125", with the capacity based upon ratings certified by AMCA (Air Moving and Conditioning Association). The listings in Table 10 illustrate the variety of propeller-type fans available and items to look for in the specifications of the manufacturer. Fan motors should be dust proof and totally enclosed with permanently lubricated ball bearings and overload protection. Adequate wire size for the selected motors is essential (see Appendix D). The fan assembly should include antibackdraft dampers or shutters. Motor operated shutters are available for larger fans at extra cost.

From the standpoint of initial investment and electricity used, the larger fans are less expensive. The size selected should be consistent with the size of house and the desired flexibility or range needed in ventilating rate. As a specific example, broiler growers find it desirable to have low capacity fans controlled by both timer and thermostat in opposite walls near each end of the house for restricted operation during cold weather.

Fans with the blades mounted directly on the motor shaft require less maintenance. In the case of belt driven fans, the tension of the belt requires periodic

TABLE 10.—Information to consider in determining specifications when selecting fans.

Fan Blades Diameter	No.	Motor Size (hp)	Fan Speed* (rpm)	Capacity (cfm at ⅛ in. S.P.)	Remarks
18"	4	¼	1725	2700	single speed
18"	5	⅓	1100	3300	single speed
18"	3 or 4	¼	1400 low 1700 high	1600 low 2700 high	two-speed
24-42"	3 to 6	⅓ to ½	800 to 1200	5000 to 10,000	low-speed high-volume direct drive
24-48"	3 to 6	⅓ to ¾	600 to 1200	5000 to 12,000	low-speed high-volume belt driven

*The rpm and cfm shown are approximate; specific ratings will be given by the manufacturer or equipment company.

checking. This is especially important with new installations and during any initial period of operation after the fans have been idle. Proper tension to avoid belt slippage is essential for efficient operation. Follow the manufacturer's recommendations.

Controls for Fans

Fans are automatically controlled by thermostats and timers (usually a 10-minute timer). Dual control of some fans by both a thermostat and timer provides greater flexibility in the control of air exchange. (Fig. 14).

Thermostats operate according to temperature change, and the calibration should be checked with an accurate thermometer. Thermostats should be located away from the outside walls and out of the flow of incoming air, preferably near the center of the house as shown in Fig. 15 and about 5 feet above the floor. When more than one thermostat is involved in the control of fans, there should be a difference of 2 to 3 degrees in the temperature settings of the several thermostats so that additional fans will operate as the house temperature rises and automatically go off when the temperature is lowered.

The function of the timer is to turn the fans on periodically regardless of house temperature, which will assure a minimum rate of ventilation for moisture and ammonia removal. This is important during cold weather. During a cold night the house temperature could drop below the thermostat setting and the fans would remain off if there was no timer. This is less likely to happen with a proper range of thermostat settings in multiple fan installations.

Panel control assemblies which control two or more fans are available from equipment companies. The number of fans controlled by one control panel will depend upon the size of the operation and the number of fans involved. The wiring and planning of the circuits should be done by a qualified electrician.

An illustration of fan selection, location and control for a brooder house accomodating 10,000 broilers is given in Problem III, Appendix C.

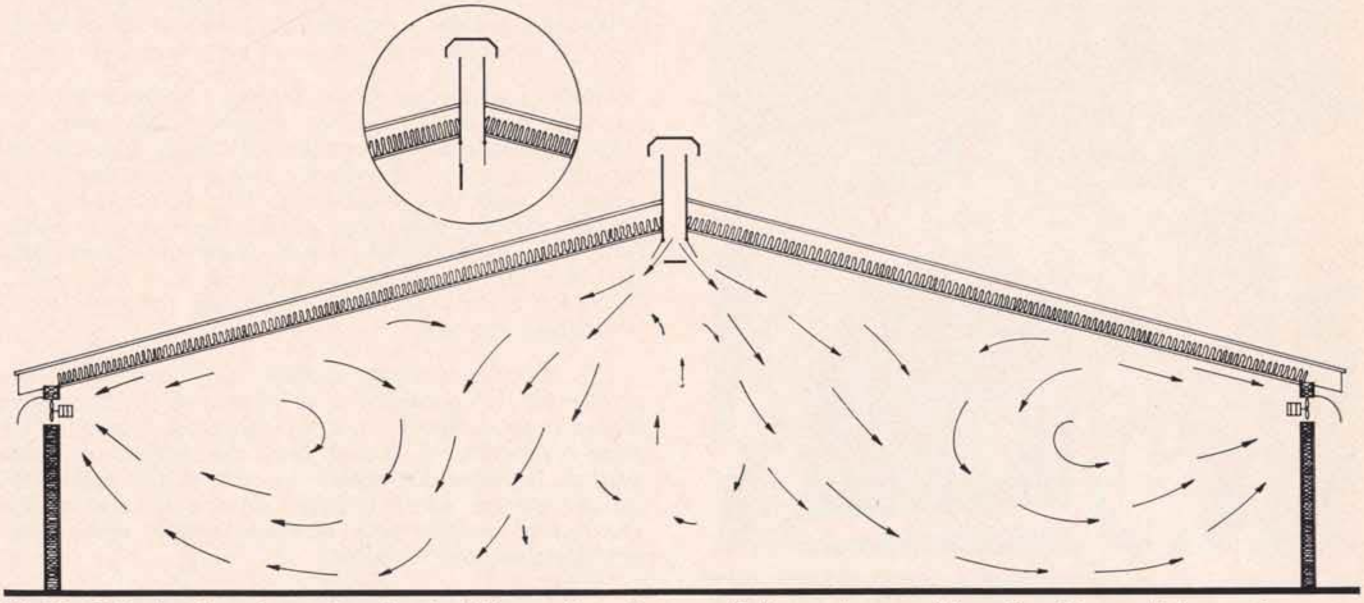

Fig. 13.—This drawing shows the air circulation pattern in a ventilating system consisting of a ridge ventilator serving as an intake and wall fans positioned to exhaust the air. The insert shows the hinged bottom of the ridge ventilator dropped to increase the intake (outtake) area as needed during summer operation. If the fans are reversed to force air into the house during summer operation, the air pattern will be different.

Pressurized Ventilation

In this system fans force air into the house through ducts usually located at ceiling level. A slight positive pressure is developed within the house which causes the air to be exhausted through outtakes.

Research on pressurized ventilation at this station has included the use of two slightly different systems over a period of several years. The "pilot plant" studies were made in a well-insulated laying house 24 x 48 feet, divided into two pens by an insulated partition.

During the first years of operation the following ventilating system was used:

(1) A high speed fan, located in the rear wall of each pen, brought air into the pen through a duct 8 feet long with a V-shaped deflector at the end to direct the air toward each front corner. Each fan was controlled by a thermostat and timer.

(2) Out-takes extending 18 inches below the ceiling were located at the front plate. A study of the pattern of air circulation showed that this length was necessary to promote the desired recirculation of air and to prevent excessive loss of warm air during cold weather.

Leghorn hens were housed with floor-type management at a bird density rate varying in different years from 1 to 1¼ square feet of floor space per bird.

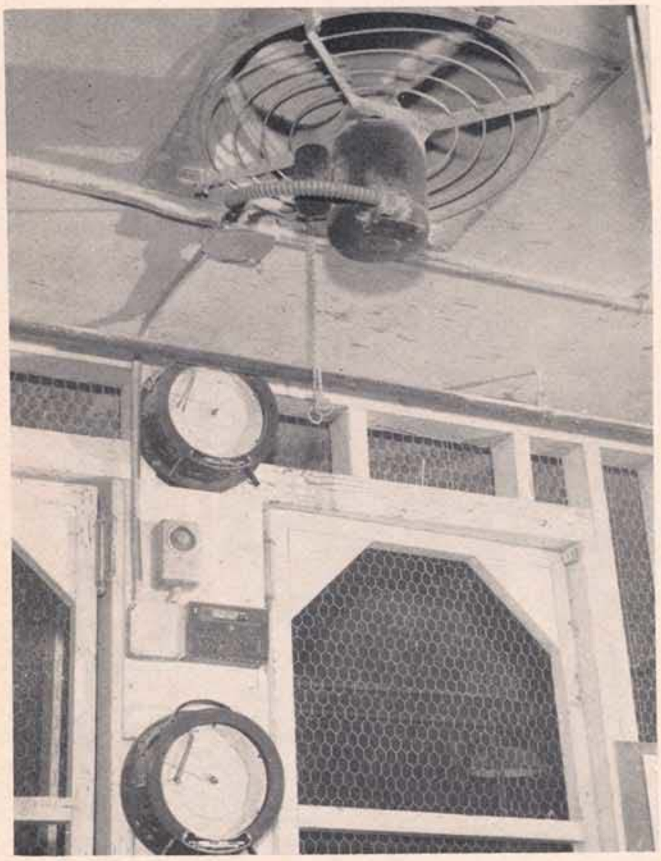

Fig. 14.—This ceiling fan, controlled by thermostat and timer, was used in the same brooder house as the intakes shown in Figs. 9 and 10. Note the thermohumidigraphs used to record temperature and humidity at mid-pen and ceiling levels.

Environmental conditions were excellent as measured by uniform temperatures, low humidity, dry litter, desirable pattern of air circulation and bird performance. The favorable environment shown in Fig. 3 during a period of low and fluctuating outside temperature was obtained with pressurized ventilation in this experimental laying house.

The detailed data shown in Table 11 during a 3-day period of moderate winter weather was also obtained in this experimental house while pressurized ventilation was being used for floor-type housing.

Later, laying cages were installed in this experimental house and the pressurized ventilation was modified. In one pen (installation A) the high speed fan and intake duct were retained, but two-way grills were attached to the openings on each side of the duct (Fig. 16) to direct the incoming air both vertically and horizontally as desired. Controls for regulating the flow of outgoing air were incorporated at the bottom of the outtakes by providing self-operating aluminum side flaps and an adjustable hinged bottom (Fig. 17).

A velometer and smoke sticks to check air circulation demonstrated that in some areas the velocity was higher than desirable for birds in cages. This condition was corrected by installing baffles to deflect the air from the birds in these areas. The results have been very satisfactory. The general pattern of air circulation with this type of installation is shown in Fig. 18.

In the other pen (installation B) a low-speed, high volume, two-speed propeller-type fan, controlled by both a thermostat and timer, forced air through a duct extending through the center of the pen (Fig. 19). Adjustable dampers in the sides of the duct regulated the amount and directed the flow of incoming air as desired. The remodeled outtakes used in this pen (Fig. 20) also extended 18 inches below the ceiling to promote recirculation of the air and were equipped with counterbalanced dampers. Leghorn hens were in cages at the ratio of one half square foot of cage area per bird.

Results as measured by uniform temperature, low humidity and patterns of air circulation have been extremely satisfactory. Adequate ventilation with positive air movement at low velocity and without drafts was obtained with this installation. This is especially important for cage-type operations. The over-all evaluation of this installation would justify the conclusion that the slow-speed high-volume type of fan with a distributing duct is highly desirable for pressurized ventilation systems.

To date pressurized systems have not been used extensively by poultrymen or promoted by equipment manufacturers. Since ducts are required, this system is more expensive to install than the wall-fan exhaust system. It compares closely in cost to the ceiling-fan exhaust system which requires ducts and cupolas. The pressurized system gives excellent results when properly installed and operated.

With the increased use of large, low-speed, high-volume fans in large enterprises it is reasonable to expect more widespread use of this system in the future.

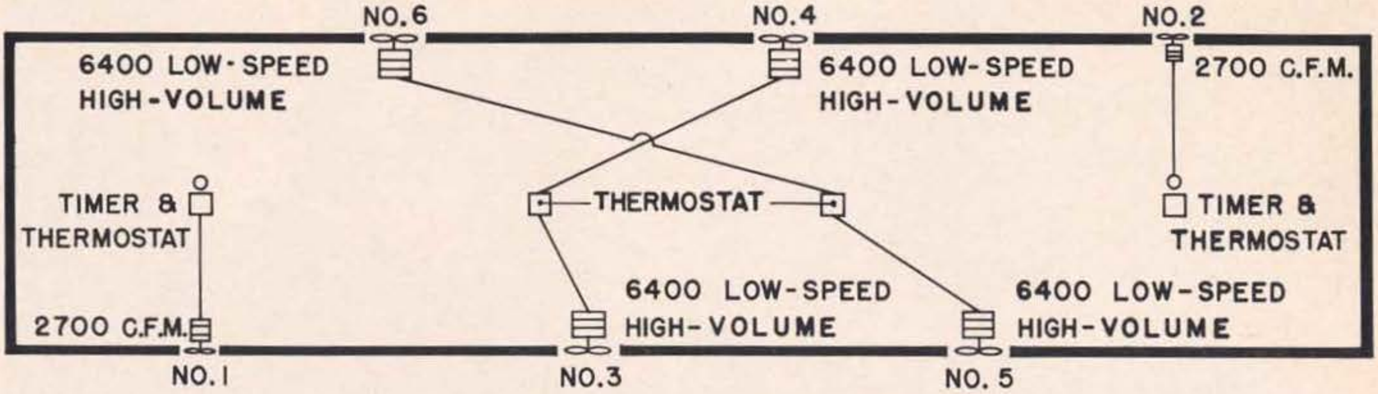

Fig. 15.—A system for controlling fans in a 40' x 212' brooder house. The two smaller capacity fans are controlled by timers and thermostats while the four larger capacity fans are controlled by thermostats only.

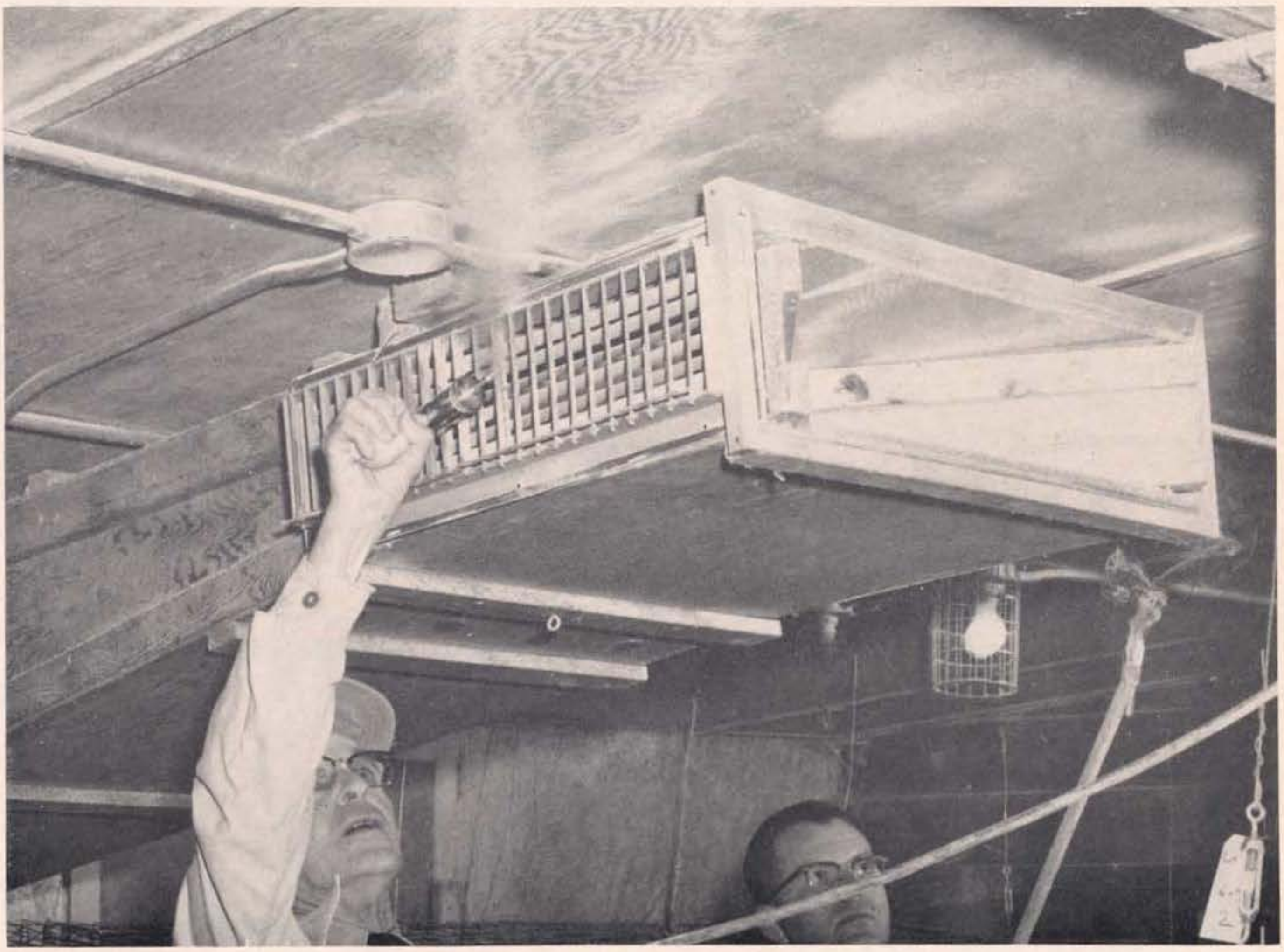

Fig. 16.—The duct system in installation A of the experimental poultry house using pressurized ventilation. This duct is insulated on the inside.

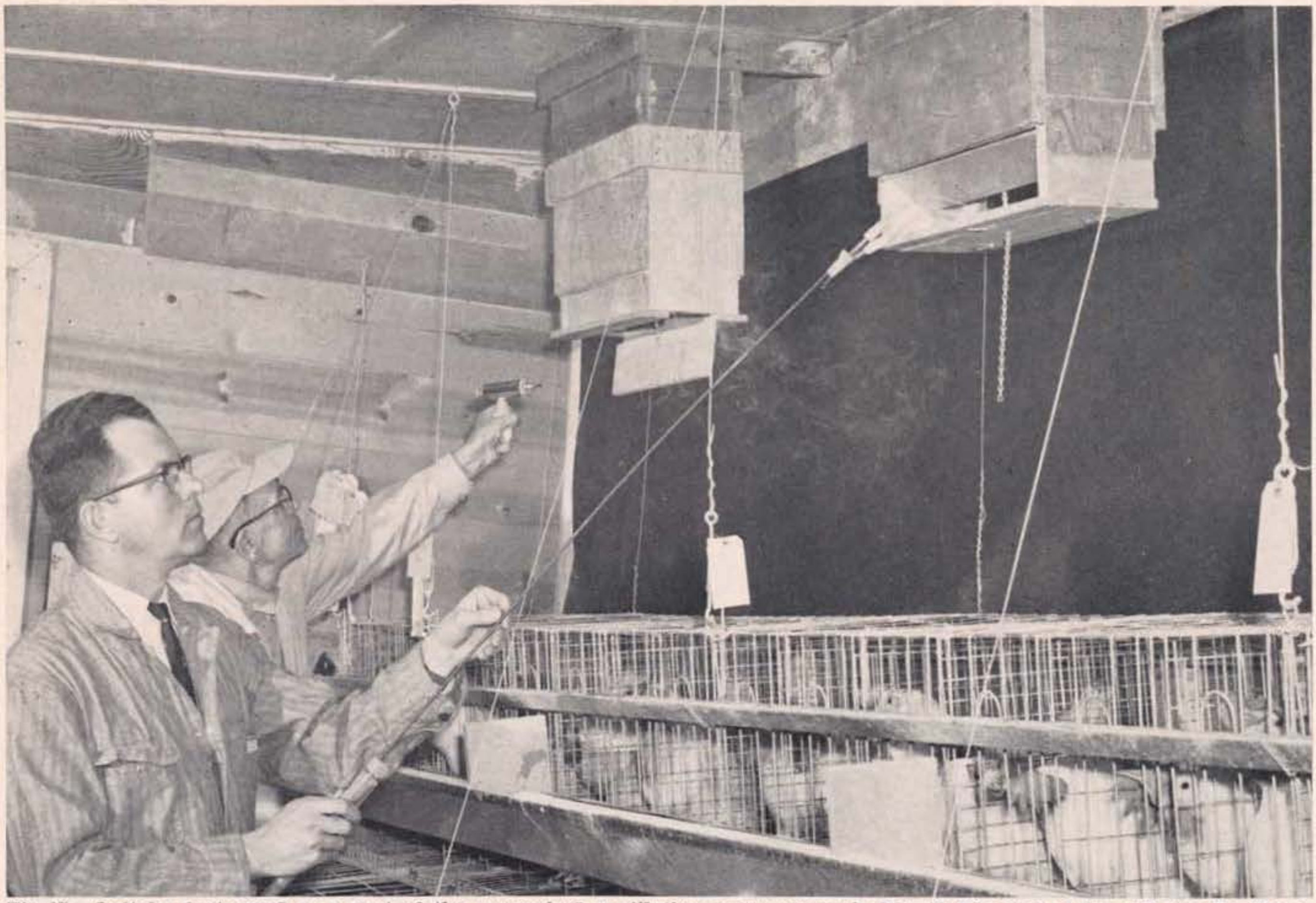

Fig. 17.—Outtake ducts used as a part of the pressurized ventilation system shown in Fig. 16. The duct at the left has the hinge bottom dropped as would be the adjustment for moderate and warm weather operation. The duct at the right has the hinged aluminum damper opened by the positive pressure created by the fan as it would be operated during cold weather.

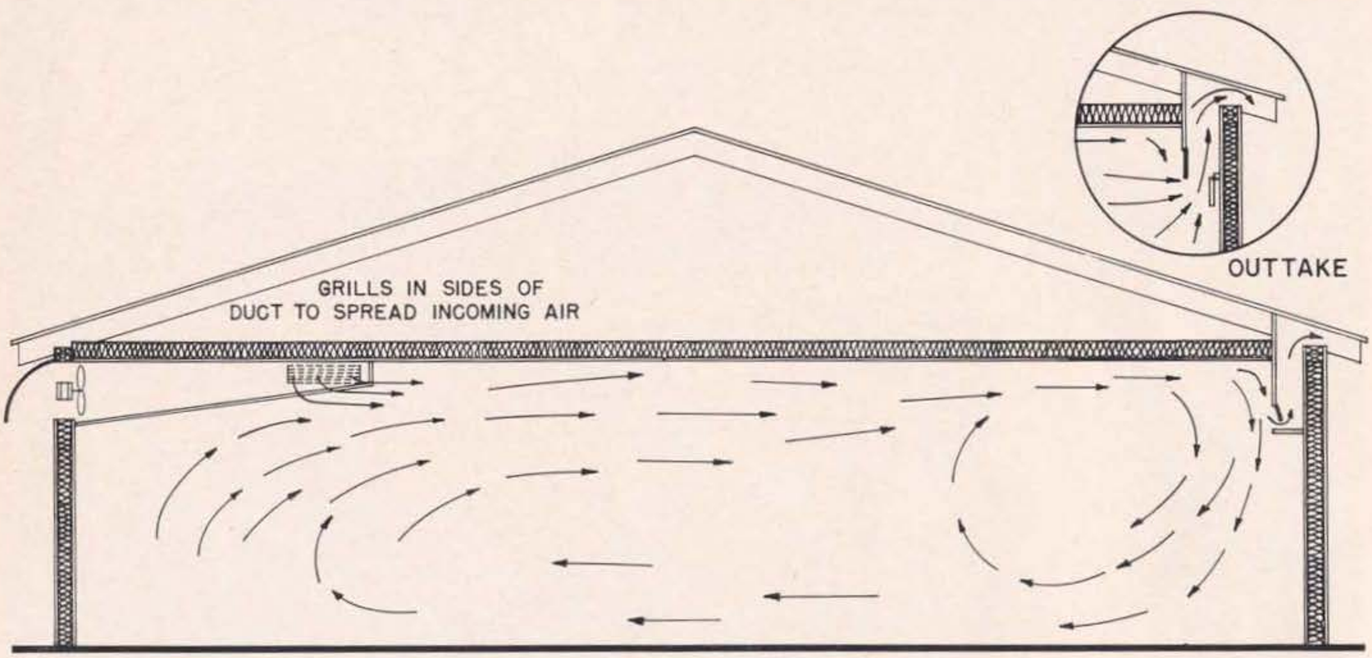

Fig. 18.—The duct system in Fig. 16 produces this general pattern of air circulation. Positive air pressure opens the hinged damper in the outtake for cold weather operation. The insert shows the hinged bottom of the outtake opened to allow a greater volume of air to be exhausted during moderate and hot weather operation.

Fig. 19.—The duct system in installation B of the experimental poultry house using pressurized ventilation. The duct is covered with a black-colored insulating board and has adjustable outlet openings evenly spaced along each side to give suitable air distribution. Two of these outlets are pointed out in the picture by a smoke stick and a smoke gun.

There are several advantages and some disadvantages to be evaluated in considering pressurized ventilation.

Advantages: (1) Maximum recirculation and mixture of incoming air with the inside air makes it possible for air to take up the maximum amount of moisture before it is exhausted. (2) Air is forced out any and all cracks around windows and doors which eliminates cold drafts from such sources during cold weather. (3) Directional control of incoming air is possible when deflectors are properly installed and regulated. (4) Use of low-speed high-volume fans in combination with a properly designed intake duct affords the possibility of positive air movement at a low speed without drafts.

Disadvantages: (1) The pressurized system is more expensive than the exhaust system. (2) Positive pressure will force moist air during winter and dust during summer through any cracks or breaks in the vapor seal. (3) The pressurized system is more complicated than the wall-fan type of exhaust ventilation system and requires the services of a qualified engineer in the planning and installation of the equipment.

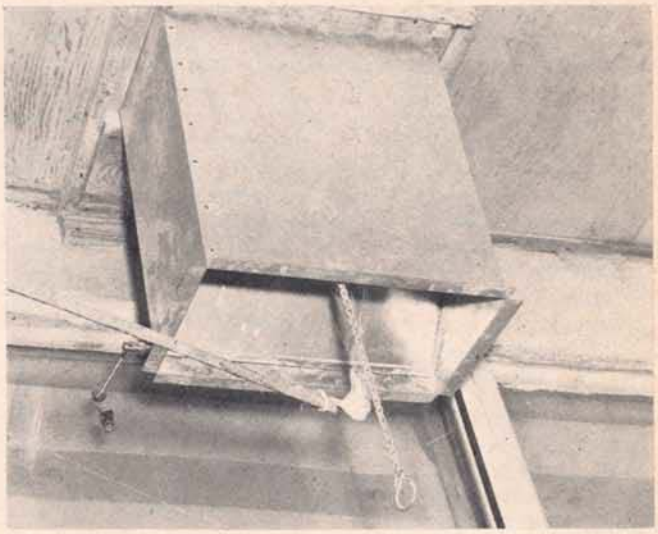

Fig. 20.—The counterbalanced aluminum damper in the outtake flue opens and closes automatically with fan operation. The outtake flue is used in combination with the duct shown in Fig. 19. During hot weather, additional weights are added to hold the dampers fully open.

Environmental Management

Field visits to poultrymen and evaluation of the problems as they are found in their poultry houses repeatedly point to the need for better management of the ventilation program. In some instances improper installation is the major problem. However, many cases could be cited where poor ventilation is found even with good equipment. The poultryman is not obtaining the maximum potential efficiency of his equipment because he has failed to evaluate the conditions and make the necessary adjustments to improve the ventilation.

Some poultrymen assume too much from the automatic controls. Thermostats and timers are mechanical robots. The poultryman must decide (1) the temperature setting of the thermostats, (2) the length of time the timer operates the fan(s) independently of the thermostat, and (3) what manual adjustments he should make of the intakes (or outtakes in case of a pressurized system) to control the amount of air admitted in relation to the outside temperatures and marked changes in the weather.

It is highly recommended that poultrymen use a smoke gun or smoke sticks to observe the pattern of air circulation and the velocity of air travel. The authors have found these to be indispensible in evaluating ventilation.

Excessive dust accumulation on the fans, antiback-draft louvers and hoods covering the fans are often major factors limiting the efficiency of the ventilating system. If dust build-up prevents antiback-draft louvers from opening fully while the fans are operating, air exchange is reduced and the house is underventilated. Periodic cleaning is necessary for any system to operate at maximum efficiency.

WINTER VENTILATION MANAGEMENT

General guides for ventilation rates for winter conditions are given in Tables 1 and 2. Although less air is required for moisture removal during cold weather (Tables 8 and 9), there is a general tendency to underventilate all types of poultry houses during winter. This is especially true in the case of brooder and broiler houses when supplementary heat (heat other than brooder heat) is not sufficient to maintain the temperatures needed for the chicks and still allow for adequate ventilation. In too many cases poultrymen underventilate rather than provide the necessary supplementary heat because of fuel costs. This generally proves to be false economy because it results in the build-up of excessive moisture and ammonia, wet litter and increased disease problems.

As poultrymen become better informed on the importance of good environment in assuring economical gains and reducing disease hazards, they appreciate the need for insulation, supplementary heat and adequate ventilation management.

More attention to the following details constitutes good management that will result in good economy:

1. Coordinate temperature settings of the thermostats for the fans, brooder, and the supplementary heating system so that the fan thermostat operates only when the house temperature rises above that desired according to the age of the chicks. This is especially important when gas brooders are used.

2. Adjust the time interval on the timers to operate the fans for the minimum rate of air exchange.

3. In multiple fan installations stagger the temperature settings of the thermostats with a range of 2 to 3 degrees as explained on page 15.

4. While chicks are small or weather is cold restrict intake openings to reduce the volume of incoming air. Adjust for more air as the chicks become larger or as the outside temperature moderates.

In laying houses, managing ventilation requires conserving and utilizing the bird heat by restricting the air exchange to maintain the desired house temperature and still provide the necessary ventilation. Good environment can be obtained in laying houses by restricted ventilation in relation to outside temperature. For example, the data in Table 11 was obtained during a 3-day test period in one of the experimental houses at this station.

In this experimental house, Leghorn hens were housed using floor management. Shavings litter comprised 65 per cent of the floor area and automatic feeders and waterers were located on the roosting rack. Pressurized ventilation was used with the fan operation controlled by a thermostat set at 52F and a 10-minute timer set to operate the fan 2 minutes out of 10.

Note that the minimum inside temperature was less than the thermostat setting. This resulted from timer controlled fan operation. During winter conditions it is often necessary to sacrifice house temperature in order to provide adequate ventilation to maintain moisture and ammonia levels within a desirable range.

TABLE 11.—Environmental Conditions Maintained During a 3-Day Winter Period.

Conditions

Outside temperature range: 19 to 38 F.
Insulated house (R-values): side walls 9.8; ceiling 12.
Bird density: 1¼ sq. ft. of floor space per bird.
Outtake area during the period: 150 sq. in. per 1,000 cfm of fan capacity.

Results

Percent of time fan operated during the 3-day period	55%
Percent of time fan operated in daytime	86%
Percent of time fan operated at night	32%
Average ventilating rate for the 3-day period (cfm per bird)	1.4
Minimum inside temperature	51F
Maximum inside temperature	58F
Maximum relative humidity of inside air	72%
Moisture content of litter	28%

SUMMER VENTILATION MANAGEMENT

Environmental control during the summer is primarily concerned with the removal of heat, ammonia, other odors and dust. These problems are critical with high bird densities.

In Table 1, 85 F is suggested as the maximum temperature for layers. Even at this temperature, the poultryman may have serious problems with shell quality, egg production and excessive water consumption. Ability of the layers to tolerate high daytime temperatures is influenced by the extent that laying house temperatures are lowered at night.

The amount of body heat produced by birds is given in Tables 4 and 5. Removing this heat becomes a real problem.

Brooders are another source of problem heat when young chicks are grown during the summer. As a general rule, the brooder temperature can be several degrees lower in summer than is required for winter brooding. Brooder thermostats should be adjusted for lower temperatures as rapidly as possible. This is especially important in the case of gas brooders. The brooder thermostat settings should be coordinated with those operating the ventilating fans so that the fan operation does **not** increase the brooder heat output.

The total installed fan capacity for maximum summer ventilation was given in Tables 1 and 2. The ratio of 5 cfm per bird (Leghorn hens) is the maximum recommended. Higher ventilating rates may actually be a disadvantage when outside temperatures go above 90 F. Inside circulating fans will better serve the purpose of increased air movement. Another practice is to reverse some or all of the sidewall fans on the cool side of the building.

Evaporative cooling is an effective and economical method of holding down inside temperatures during periods of extremely hot weather.

The ratio of installed intake area to fan capacity in order to permit fans to operate at full capacity is given in Tables 1 and 2, illustrated in Fig. 5, and discussed on page 11. This is especially important for windowless houses.

Air circulation over the floor is another means of providing bird comfort during the summer. This is especially helpful for broilers after the brooding period. The adjustable baffle for the continuous slot-type intake illustrated in Fig. 6 should be installed in lengths of 6 to 8 feet. If every other baffle is adjusted to direct the air down to the floor (Fig. 8b), it will promote air circulation over the floor.

Dust inside the poultry house is a serious problem in the summer when outside relative humidity is low. Excessive ventilation rates with high velocity fans intensify the dust problem. Low-speed, high-volume fans which move a large volume of air at a low velocity will reduce the agitation of dust inside the house.

LIGHT CONTROL

Light intensity and controlled lighting periods are a part of controlled environment. The optimum intensity of light has been a controversial issue. It is agreed, however, that absolute light control is necessary for out-of-season (October through March) hatched pullets except when the step-down program of lighting is used. Absolute black-out houses are not as essential for layers as for pullet growing. For detailed information on light control systems and windowless housing, see Wilson and Rooney (15) and Dixon and Lampman (4).

When using a controlled lighting program, it is essential to have light traps at ventilation openings. Two important principles are involved in the design of light traps. These are (a) light travels in a straight line and (b) light intensity decreases with the square of the distance from the light source.

The light trap illustrated in Fig. 21 should be adequate when inside surfaces are painted dull black. To assure fan operation at full capacity a ratio of 300 square inches of intake area to each 1,000 cfm fan capacity is recommended.

Windowless houses with light traps for controlled lighting are becoming more popular for year-around operations. If houses have windows, the number and size should be limited.

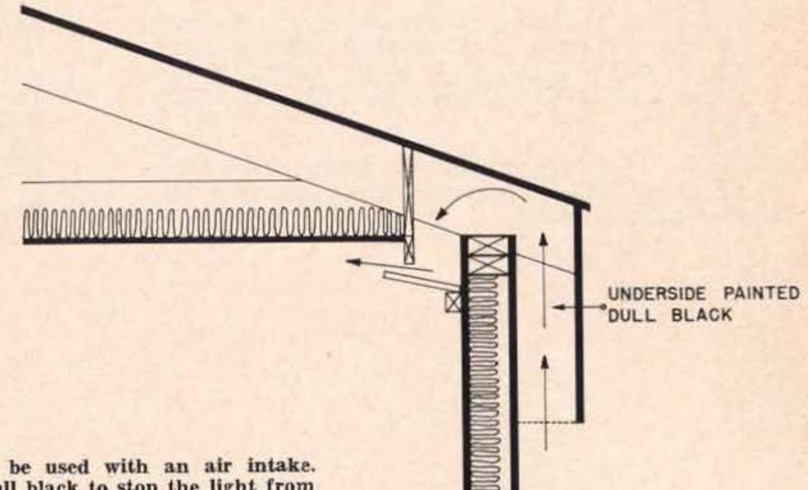

Fig. 21.—This light trap might be used with an air intake. The inside is painted dull black to stop the light from getting into the house by reflection.

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References

1. American Society of Agricultural Engineers. 1966. Design of Ventilation Systems for Poultry and Livestock Shelters, p. 307-314. ASAE D 270. *In* Agricultural Engineering Year Book. St. Joseph, Mich.

2. Anderson, D. P., C. W. Beard and R. P. Hamon, 1964. The Adverse Effects of Ammonia on Chickens Including Resistance to Infection with Newcastle Disease Virus. Avian Diseases 8:369-379.

3. Bragg, D. D. and A. J. Lambert, 1964. Improved Poultry House Environment. Virginia Agr. Ext. Ser. Bull. 269.

4. Dixon, J. E. and C. E. Lampman, 1963. Effect of Windowless-type Poultry Housing on Physical and Egg-production Factors. Amer. Soc. Agr. Eng., Trans. 6:335-337.

5. Longhouse, A. D., H. Ota and W. Ashby, 1960. Heat and Moisture Design Data for Poultry Housing. Agr. Engineering 41:567-576.

6. Longhouse, A. D., G. O. Bressler, C. S. Shaffner and H. W. Garver, 1963. Poultry Housing—Basic Data Useful for Design Purposes in the Northeastern States. West Virginia Agr. Exp. Sta. Bull. 486T.

7. Ota, H., H. L. Garver and W. Ashby, 1953. Heat and Moisture Production of Laying Hens. Agr. Engineering 34:163-167.

8. Ota, H., and E. H. McNally, 1961. Poultry Respiration Calorimeter Studies of Laying Hens. ARS 42-43, USDA.

9. Ota, H., and E. H. McNally, 1961. Engineering in Broiler Housing. Agr. Engineering 42:616-617, 623.

10. Ota, H., and E. H. McNally, 1963. Design Criteria for Laying House Moisture and Temperature Control. Paper presented at Commercial Egg Clinic, Texas A & M, College Station, Texas.

11. Ota, H., and E. H. McNally, 1965. Preliminary Broiler Heat and Moisture Data for Designing Poultry Houses and Ventilation Systems. Am. Soc. Agr. Eng. Paper No. 65-411.

12. Petersen, C. F., D. H. Conrad, D. H. Lumijarvi, E. A. Sauter, and C. E. Lampman, 1960. Studies on the Calcium Requirements of High Producing White Leghorn Hens. Idaho Agr. Exp. Sta. Res. Bull. 44.

13. Turner, C. N. and H. R. Davis, 1965. Ventilation for Poultry Houses. Cornell Ext. Ser. Bull. 1140.

14. Walpole, E. W., F. A. D'Armi and R. Lloyd, 1964. Insulation and Mechanical Ventilation of Delmarva Broiler Houses. Delaware Agr. Ext. Ser. Coop. Bull. 2.

15. Wilson, W. O., and W. F. Rooney, 1964. Artificial Lighting for Poultry. California Agr. Ext. Circ. 529.

Appendix A

Glossary

Bird Concentration (bird density)—An expression of the ratio of the floor area per hen or broiler, usually expressed as square feet per bird.

BTU—British thermal unit, the amount of energy required to raise the temperature of one pound of water one degree Fahrenheit.

Cage Management—A system of housing poultry wherein the bird or a small number of birds is housed within a small wire-floored coop. The coop or cage is within a poultry building and is supplied with water, feed, etc.

cfm—Cubic feet per minute, a measurement of the rate of air flow in a ventilating system. It means that the volume of one cubic foot passes a fixed point during a period of one minute.

Controlled Lighting—A system used in the poultry industry to control the sexual maturity and production of growing birds and laying hens by subjecting the birds to light (usually artificial) for a specified period each day. The length of the lighted period may change in a regulated sequence as the birds become older.

Environment—The aggregate of all the external conditions, surroundings and influences affecting the life and development of poultry. The most important of these appear to be space, temperature, humidity, light, air movement and composition, feed and water.

Exhaust System—A ventilating system in which the fan blows air from the house creating a negative pressure so that the outside air is pulled into the house through intake openings.

Fan and Pad System—A system of poultry house ventilation used during hot weather periods wherein air is drawn or forced into the poultry house through fiber matting which has been saturated with water. The effect is to cool the air entering the poultry house by evaporation.

Floor Management—A system of housing poultry wherein the birds are loose and free to move anywhere within the poultry house.

Foot Candle—A unit of illumination equivalent to the intensity of light one foot from one standard candle.

Heavy Breeder Chickens—Laying hens of breeds, varieties and strains used as sources of eggs for broiler production, which weigh more than birds used for market egg production.

Insulation—A building material which has a low rate of heat transfer and is used to reduce the amount of heat that passes through a wall or ceiling.

Intake—An opening in the wall or ceiling of a poultry building designed to let outside air enter the building in a controlled manner. This type opening is used with an exhaust ventilating system.

Latent Heat—A form of heat energy associated with changing the state of a material such as ice to water or water to vapor. This type of energy is involved in the evaporation of water from poultry droppings and is not available to keep the poultry building warm. (See Sensible Heat and Respired Moisture).

Leghorn Hens (White)—The breed of laying hens most commonly used in the production of market eggs.

Low Speed - High Volume—A ventilating fan of the propeller-type which is capable of delivering large quantities of air (usually in excess of 5,000 cfm) while running at a speed of less than 1,700 rpm.

Mil—A mil is a unit of measurement used to designate the thickness of thin materials. One mil is equal to 0.001 inch.

Outtake (Outlet)—An opening in the wall or ceiling of a poultry building designed to allow inside air to escape to the outside in a controlled manner. This type of opening is used with a pressurized ventilating system.

Physiological—Factors or characteristics which affect or pertain to the functioning or performance of an organism; applied to poultry in this bulletin.

ppm (parts per million)—A unit used to designate low concentration of a material when mixed with another. For example, 30 ppm of ammonia in air would mean 30 milliliters of ammonia in one million milliliters of air.

Pressurized System—A ventilating system used in poultry houses which is arranged so that a fan blows air from the outside into the house creating a slight pressure and thereby forcing the inside air out through outlet openings.

Relative Humidity—A measure of the relative saturation of moisture in air expressed as a percentage ratio of partial pressures. From a practical viewpoint within the range of temperatures used in poultry housing, it can be expressed as a percentage ratio of the amount of moisture in the air compared to that which the air could hold at the specified temperature.

Respired Moisture—The water given off by a chicken as part of the exhaled breath. Heat used to vaporize this moisture is termed latent heat.

rpm (revolutions per minute)—A unit measuring the speed of a rotating shaft which tells the number of complete turns a shaft makes during a period of one minute.

R-Value, Thermal Resistance—A measure of the ability of a material to resist the flow of heat. Materials with large values are better insulators than those with small values.

Sensible Heat—A form of heat energy which is available for heating the air in the poultry house. It can also be converted into latent heat by evaporation of water. (See Latent Heat).

Smoke Gun — A device used to trace air circulation which emits a smoke-like vapor or a very fine, lightweight powder from a nozzle.

Smoke Stick—A glass tube with gauze wrapped around one end containing titanium chloride which when broken emits a smoke-like vapor. It is used to trace air circulation in the same manner as the smoke gun.

Static Pressure—The force per unit area exerted on a surface by an operating fan but involving no movement of air. If air is moving, velocity pressure is involved. The sum of static pressure and velocity pressure equals total pressure.

Step-Down Lighting—A system of controlled light duration used in the poultry industry to control sexual maturity where the length of the lighting period is made progressively shorter. (See Controlled Lighting)

Thermal Resistance—See R-Value.

Total Heat—A term used to designate all of the heat liberated by poultry. It amounts to the sum of the sensible and latent heat given off by the birds. (See Sensible and Latent Heat).

Vapor Barrier—A membrane which limits or stops the flow of water vapor. In poultry housing this barrier is placed near the inside wall and ceiling surface to prevent condensation of water vapor in the insulation.

Water-Gage Pressure—A unit of pressure measurement used for low pressure values. One inch of water-gage pressure exists when pressure exerted by a fan will raise the water level in a tube one inch. (1 inch of water = 0.036 pounds per square inch).

Windowless Housing—A method of poultry housing where all natural light is excluded and all ventilation is by mechanical equipment.

Appendix B

Thermal Resistance (R-Value) Of Various Building Materials

The total thermal resistance of a wall or ceiling is the sum of the appropriate values given in the table. If the value for thickness is marked (X), multiply the R-value listed in the table by the thickness (in inches) of the material in the wall or ceiling. See examples in text of bulletin and Fig. 1. Be sure to include appropriate values for surface and air space resistances.

Material and Remarks*	Thickness (inches)	Resistance, R (for thickness listed)
Air Space:		
Std. building mat'l, nonreflective vertical, with heat flow horizontal	3/4 to 4	0.92**
Horizontal with heat flow up	3/4 to 4	0.80**
45° slope with heat flow up	3/4 to 4	0.85**
Building boards:		
Asbestos-cement	1/8	0.03
Plywood	1/4	0.31
Plywood	3/8	0.47
Plywood	1/2	0.63
Plywood	5/8	0.78
Plywood	3/4	0.94
Blanket and Batt Insulation:		
Cotton fiber fill	X	3.85
Mineral wood; processed from slag, rock or glass	X	3.70
Wood fiber	X	4.00
Loose Fill Insulation:		
Mineral wool, glass, slag or rock	X	3.70
Sawdust or shavings (dry)	X	2.22
Vermiculites (expanded)	X	2.18
Woodfiber, redwood, hemlock or fir	X	3.33
Boards and Slab Insulation:		
Glass fiber	X	4.00
Wood or cane fiberboard	3/4	1.78
Masonry Material:		
Sand and gravel concrete	X	0.03
Concrete blocks, sand and gravel 3 hole core	4	0.71
Concrete blocks, sand and gravel 3 hole core	8	1.11
Concrete blocks, sand and gravel 3 hole core	12	1.28
Concrete blocks, pumice 3 hole core	4	1.50
Concrete blocks, pumice 3 hole core	8	2.00
Concrete blocks, pumice 3 hole core	12	2.27
Plastic Film:	—	negligible
Roofing Material:		
Asbestos-cement shingles	—	0.21
Asphalt shingles	—	0.44
Built-up roofing	3/8	0.33
Metal sheets	—	negligible
Wood shingles	—	0.44
Siding Material (on flat surface):		
Asbestos-cement	1/4	0.21
Asphalt insulating siding	1/2	1.45
Wood drop, 1 x 8	—	0.79
Wood: fir, pine	X	1.25
Surface:		
Inside, still air vertical surface	—	0.68
Inside, still air horizontal surface	—	0.61
Outside, 15 mph wind any position	—	0.17
Windows, outdoor exposure:		
Single pane	—	0.89***
Two panes 1/4" air space	—	1.64***
Two panes, 1/2" air space	—	1.82***
Two panes 1" or larger air space	—	1.89***

*Extracted by permission from ASHRAE Guide and Data Book 1965. American Society of Heating, Refrigerating and Air Conditioning Engineers, New York, N. Y.

**These values apply for all thicknesses between 3/4" and 4".

***These are total thermal resistance (R) values and no additions for surface coefficients should be made.

Appendix C

Problems

Problem I—Moisture Removal by Ventilation in Laying Houses

Assume 1,000 Leghorn hens with an average weight of 4.3 pounds, laying at 75 percent and housed at 55F.

From Table 4, it can be noted that 1,000 hens will generate a total of 612 pounds of water daily. This represents a total from the following sources:

a. Water present in droppings (75% water content)	307 pounds
b. Water respired from the hens	249 pounds
c. Water from spillage (10% of 556)	56 pounds
	612 pounds

Assume 15 percent of fecal water and spilled water is removed by evaporation (15% of 307 + 56). This amounts to 54 pounds. All of the 249 pounds of respired moisture can be removed by adequate ventilation.

The total amount of water then that can be expected to be removed by ventilation is 303 pounds daily, or about one-half the total amount produced.

Problem II—Moisture Removal by Ventilation in Broiler Houses

The following calculated information is an estimate of the amount of water that may be removed by adequate ventilation for each 1,000 broilers during an **8-week period.** Bird concentration is figured at 0.7 sq. ft. per bird.

Approximately 10,650 pounds of droppings averaging 80% water are produced during the period (from table 5).

Dry shavings with 15 percent moisture are used at a depth of 3½ inches at the start.

At the end of 8 weeks, the moisture content of the litter plus droppings is assumed to be about 35 percent.

From the above, it is calculated that from 85 to 88 percent of the water deposited in the litter from the droppings and from spillage has been removed by evaporation and ventilation in order to keep the litter moisture at 30 to 40 percent. This amounts to appromimately 9,000 pounds of water.

Assume that all of the respired moisture (40 percent of the total) can be removed by ventilation. This is approximately 6,600 pounds (Table 5).

The total amount of water removed by adequate ventilation per 1,000 broilers during 8 weeks is approximately 15,600 pounds. (This does not include water produced by gas brooders.)

This is indeed a large quantity of water—nearly 8 tons—and emphasizes the need for adequate ventilation and the importance of other factors such as insulation, supplementary heat in cold weather and good management.

Problem III—Fan Selection, Location and Control

The following example illustrates fan selection and location with controls for a wide range of ventilating rates for a brooder house accommodating 10,000 broilers.

Assume a building 40 feet wide and 212 feet long providing 0.85 square feet of floor space per bird.

Assume the ventilating system to consist of wall fans in both side walls with ridge type ventilators serving as intakes.

Fan selection and location is as shown in Fig. 15. (Note that the fans are not located opposite each other). Six fans are shown on the basis of 3 cfm per bird providing a total installed capacity of 31,000 cfm, with each of the two end fans (No. 1 and No. 2) having a capacity of 2,700 cfm. These two are controlled by 10-minute timers and thermostats.

The four low-speed high-volume fans (Nos. 3, 4, 5 and 6) have a capacity of 6,400 cfm each. One thermostat controls two fans as shown in the diagram. These four fans are selected because they move a large volume of air at a low velocity which reduces possibility of floor drafts.

The number of ridge ventilators is selected on the following basis:

$$\frac{\text{31,000 cfm total fan capacity}}{\text{ratio of 4 cfm}} = \text{7,750 square inches}$$

per square inch intake area.

Assume ridge intakes are 13 inches wide and 60 inches long. Each provides 780 square inches. Thus, 10 intakes are required.

For an example of the minimum rate of ventilation, assume the timers for fans No. 1 and No. 2 are set to operate the fans 3 minutes out of 10. This gives an average ventilating rate of 1620 cfm, equivalent of 0.16 cfm per bird. (See Table 2 for recommendation for low ventilating requirements.)

As another example, assume the timers are set for 5 minutes out of 10. The average ventilating rate would be 2,700 cfm, equivalent to 0.27 cfm per bird.

The timer control assures a minimum rate of ventilation regardless of house temperature.

If the four thermostats are set with a temperature difference of 2 to 3 degrees, the rate of ventilation will increase with a rise in house temperature and decrease as the temperature is lowered. This arrangement provides sufficient flexibility in the ventilating system to maintain both the temperature desired and the rate of ventilation needed as long as the outside temperature is below inside temperature. With higher summer temperatures all fans will be operating and the bottom of the ridge ventilator will be open to permit maximum air exchange.

Appendix D

Electrical Requirements for Ventilating Fans

Each fan should be individually fused with a time-delay fuse of the proper rating, as shown in Table D-1. These fuses will protect against burned-out motors and electrical overloads. When the equipment is automatically controlled, this type of protection is most important.

Deteriorated or defective wiring for ventilating fans should be replaced in accordance with recommendations in Table D-2. Follow the same recommendations for new wiring. This table gives the recommended wire size to use for various lengths of wire. To use the table, measure the distance from the power supply panel to the fan along the path the wiring will take. This will be the length to use in the table. If the measured length is not in the table, go to the next longer length listed. From the fan, find the horsepower rating and rated voltage. With this information, enter the table and read the wire size. Example: Measured wire length 179 feet; fan horsepower 1/4 and voltage 115v. Use No. 10 wire. If the voltage were 230v, the wire size should be No. 14. For information about alarms to warn of fan failure, see Idaho Farm Electrification Leaflet No. 63.

TABLE D-1. Ampere Rating for Time-Delay Fuses.

Hp	115 Volts	230 Volts
1/6	5	2.5
1/4	7	3.5
1/3	9	4.5
1/2	12	5.6
3/4	15	8
1	20	10
1 1/2	25	12

TABLE D-2.—Wire Sizes for Individual Single-Phase Motors (Based on 3 percent Voltage Drop)

Motor Hp	Voltage	Full-load Current*	Length of Run in Feet					
			50	75	100	150	200	250
1/6	115	4.4	14	14	14	12	10	10
1/4	115	5.8	14	14	12	10	10	8
1/3	115	7.2	14	12	12	10	8	8
1/2	115	9.8	14	12	10	8	8	....
3/4	115	13.8	12	10	8	8	....	....
1/6	230	2.2	14	14	14	14	14	14
1/4	230	2.9	14	14	14	14	14	14
1/3	230	3.6	14	14	14	14	14	14
1/2	230	4.9	14	14	14	14	14	12
3/4	230	6.9	14	14	14	12	12	10
1	230	8.0	14	14	14	12	12	10
1 1/2	230	10.0	14	14	14	12	10	10

*Table 430-148, National Electrical Code 1965.