Poultry Laying House Environment Study

Department of Agricultural Engineering
Virginia Polytechnic Institute

Research Report 73 July 1963

Agricultural Experiment Station
Blacksburg, Virginia

Poultry Laying House Environment Study

E. S. Bell and McNeil Marshall*

In January, 1959 plans were developed by agricultural engineer Philip A. Shepherd, Cooperative Seed & Farm Supply Service, Inc., Richmond, Virginia, for an aluminum-covered poultry laying house for 5,000 leghorn hens. The design procedure included the use of Virginia (1,2), USDA (3), and Michigan (4) Experiment Station publications, as well as Mr. Shepherd's own ideas.

The building was constructed and the pullets were housed during the spring of 1959. With the assistance of the Cooperative Seed & Farm Supply Service, Inc., an environmental study was made of the conditions actually existing in this well insulated and equipped house. The object of the study was to obtain temperature and relative humidity records for summer and winter conditions; to relate the maximum and minimum ventilating rates to existing house temperatures; and to evaluate the poultry laying house.

Design conditions:

1. Location - Richmond, Virginia.
2. Space per bird - 1.25 sq. ft.
3. Number layers to be houses - 5,000.
4. Minimum inside temperature - 45^{o} F.
5. Design temperature difference - 30^{o} F. ($T_i - T_o = T_d$).
6. Egg handling and refrigerated storage rooms - 720 sq. ft.
7. Insulated to maintain desirable conditions.
8. Ventilated to maintain desirable conditions.

Figure 1. The A. S. Mistr Poultry Laying House, Richmond, Virginia, August, 1960.

*Associate Professors, Agricultural Engineering Department, Virginia Agricultural Experiment Station, V.P.I., Blacksburg, Virginia.

Size of building required:

A 36'x172' poultry house provided 1.24 sq. ft. of floor space per bird. An added 20' of length would provide the necessary space for handling eggs and for the refrigerated storage room.

Construction:

Pole-type construction was used for the laying house. Nailed trussed rafters of standard design (5) on 4' centers with 2"x4" purlins 24" apart supported the .019" corrugated aluminum sheets. Thirty windows, 10 sq. ft. each, were installed in the side walls equal distances apart.

Insulation:

Double-reflective aluminum insulation was used between the outside aluminum covering and the 3/8", exterior grade plywood inside wall. The U-value for this wall was determined to be 0.18 (6).

A ceiling of the same kind of aluminum sheets used for roofing and side walls was fastened to the underside of 2"x4" rafter chords. Loose-fill fiberglass insulation was used in the attic to the depth of the rafter chords, and was about 3" deep after settling. This construction gave a ceiling U-value of 0.10 (6).

The single-glass window area had a U-value of 1.13 (6).

Heat loss from building:

$$Q = A_U (t_i - t_o)$$

where:

Q = quantity of heat required to maintain design temperature.

A = area in sq. ft. of exposed wall and ceiling areas.

U = factor designating heat transfer through structure walls, ceiling, or windows per sq. ft., per degree F. temperature difference between inside and outside design temperatures.

t_i = inside design temperature.

t_o = outside design temperature.

Available data:

Size of poultry house - 36'x172'x8'
Minimum design temperature - 15^o F (Richmond, Va.)
Roof - aluminum on spaced purlins, attic open
Ceiling - aluminum sheets supporting 3" loose-fill fiberglass insulation
Walls - aluminum sheets, double reflective aluminum insulation, and 3/8" plywood inside
Glass - 30 windows of 10 sq. ft. area each, or 300 sq. ft. single glass
Floor - sand on earthen floor.

Respective U-values, as obtained from National Warm Air Heating and Air Conditioning Association, Manual No. 3, "Calculating Heat Losses," were:

$U_c = .10$ Ref. Table 2a, No. 32(a)
$U_w = .18$ Ref. Table 2a, No. 9(b)
$U_g = 1.13$ Ref. Table 2a, No. 1(a)

Area calculations:

Ceiling = 36'x172' = 6192 sq. ft.
Glass = 30x10 = 300 sq. ft.
Walls = 2(36' + 172') x 8' - 300 = 3028 sq. ft.

Design temperatures:

$T_i = 45^{\circ}$ F
$T_o = 15^{\circ}$ F
$T_d = 30^{\circ}$ F

Heat losses:

$$Q = (6192 \times .10 \times 30) + (300 \times 1.13 \times 30) + (3028 \times .18 \times 30)$$
$$Q = 45{,}097 \text{ B.t.u. per hour}$$

Heat gain estimates:

According to recent calorimeter studies at the Agricultural Research Center, Beltsville, Maryland, (7), 5,000 four-pound leghorn hens provide:

Sensible heat - - - 130,000 to 150,000 B.t.u. per hour
Latent heat - - - 50,000 B.t.u. per hour

The amount of heat produced depends, to a large degree, on the activity of the birds, and considerable differences exist between day and night periods.

Ventilating equipment:

Six electric fan units were installed at window height in the east side of the laying house. They were rated to move 3875 cfm of air at 1/8" static pressure. Each fan was controlled by an individual thermostat and re-cycling timer.

Operation procedure:

During cold weather the exhausted air from the laying house was replaced by fresh air pulled in through the attic. It entered the house through an adjustable metering crack 1'' wide the length of the house. It was assumed that this air would be somewhat warmer than outside air entering the laying house. No. 5 thermocouple, intended to measure temperature of the incoming attic air, was located near the metering crack on the inside of the laying house. It is believed to have been influenced by the air temperature in the house. The temperatures recorded were close to the mean inside laying house temperature during the test period.

At minimum ventilation rate, about 1/10 of the attic air was drawn into the house each minute. Therefore, air remained in the attic an average of 10 minutes before entering the house. With 45^{o} to 55^{o} F temperatures in the laying house, the heat lost through the ceiling must have been partially absorbed by the attic air. It appears evident that the attic air was tempered several degrees before it entered the house, but data to verify this were not recorded. By calculation, the heat loss to the attic could possibly increase the air temperature a maximum of 8^{o}F at the design conditions. However, some studies of ventilating with attic air have indicated that under certain conditions it can possibly become a few degrees cooler than the outside air for brief periods because of radiation losses.

In summer weather the attic ventilating opening in the ceiling was closed, and the attic itself was ventilated naturally. The windows in the west side were opened wide to allow unrestricted air movement through the house. The windows in the east side, where the 6 fans were located, remained closed.

Winter study:

Conditions maintained in the poultry laying house during March 1960 are shown in Table I.

In March there was some cold weather and also some unseasonably warm weather. During March 2-9, the daily maximum outside temperature was 32^{o}F, or below, and the minimum temperature for most of these days was near the 15^{o}F design condition. During this time, the fan thermostat controls were set so the 6 fans would come on at 55^{o}F (off at 50^{o}). The re-cycling timers were adjusted so that the 6 fans were operating at the equivalent of 1 fan running 9 minutes out of every 10. This amounted to a minimum ventilation rate of 3500 cfm. The heat required to warm the ventilating air to design temperature amounted to 120,000 B.t.u. per hour. It was noted that the daily average temperature inside the house was approximately 45^{o}F, the minimum design temperature.

TABLE I - SELECTED WINTER DATA - 1960

Date	Outside Conditions*				Inside Conditions**					
	Temperatures			R.H.	Temperatures			Exhaust Air Relative Humidity		
	Min.	Max.	Avg.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
Mar.										
1	23	39	31							
2	20	32	26	57	42	54	48	59	75	65
3	24	29	27	86	40	54	47	64	75	69
4	21	32	27	45	†	†	†	†	†	†
5	14	31	23	46	†	†	†	†	†	†
6	15	34	25	51	39	53	47	53	70	63
7	12	31	22	66	40	54	47	63	75	69
8	15	32	24	62	38	54	47	59	76	67
9	16	28	22	65	41	54	48	59	81	66
10	18	33	26	83	44	58	51	63	76	69
11	15	33	24	53	39	57	50	55	75	68
12	19	36	28	49	41	58	51	55	72	65
13	15	37	26	49	42	58	51	53	71	64
14	11	42	27	54	43	59	52	43	93	66
15	25	42	34	55	43	59	51	52	93	63
16	26	37	32	80	44	59	51	57	81	70
17	34	47	41	87	44	60	52	63	76	70
18	34	48	41	76	45	59	53	65	72	67
19	32	51	42	68	46	61	53	52	68	62
20	30	49	40	74	47	60	53	57	72	64
21	29	44	37	56	43	58	52	57	76	66
22	31	52	42	40	45	58	52	50	64	58
23	23	47	35	46	41	60	53	43	67	59
24	33	59	46	41	46	64	55	46	65	51
25	26	41	34	37	45	58	52	44	61	56
26	28	54	41	64	44	63	55	52	73	62
27	27	70	49	58	48	75	60	39	68	56
28	39	82	61	49	47	86	67	35	73	54
29	42	82	62	66	50	84	68	43	77	62
30	62	69	65	89	65	74	70	69	82	78
31	52	69	61	81	57	74	68	61	86	73

*Weather Bureau records at Byrd Field, Richmond, Virginia approximately 5 miles from building.

**Average temperature was calculated from 12 locations recorded at 2-hour intervals throughout 24-hour day. Minimum and maximum listed were the extremes of the individual readings.

† Data not valid due to outside door being left open overnight.

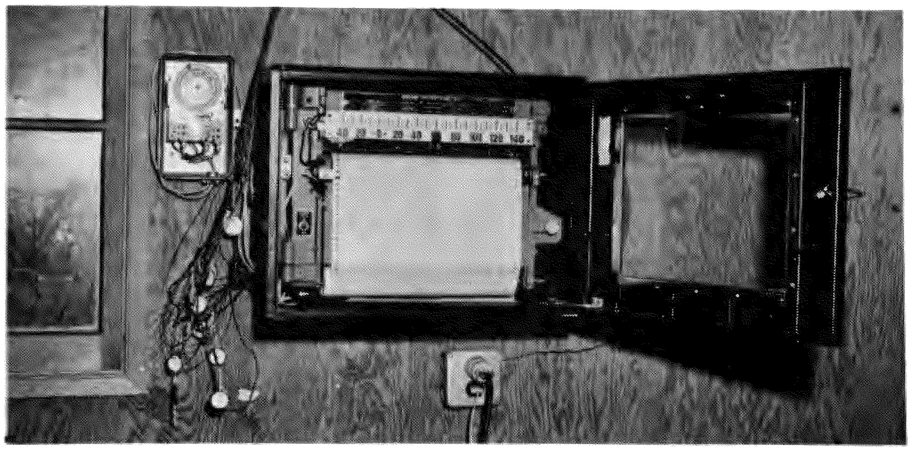

Figure 2. The multi-point temperature recorder used for collecting the data. It was modified to record for 30 minutes out of every 2 hours.

HEAT UTILIZATION @ 3500 cfm MINIMUM VENTILATION RATE

Heat required:

Building Losses	- - - - - - - - -	45,000 B.t.u./hr.
Warming Ventilating Air	- - - -	120,000 B.t.u./hr.
TOTAL		165,000 B.t.u./hr.

Heat Available:

5,000 Layers	Sensible	- - - -	150,000 B.t.u./hr.
	Latent	- - - -	50,000 B.t.u./hr.
	TOTAL		200,000 B.t.u./hr.

At the 3500 cfm minimum ventilation rate, insufficient sensible heat was available to maintain the design conditions. To increase the daily average temperature to above the minimum design temperature, it was necessary to reduce the ventilation rate by adjusting the control settings. On March 9, the fan controls were changed so the fans cut on at 57.5°F and off at 52.5°F. The re-cycling timers were changed to the equivalent of 1 fan running 4 1/2 minutes out of 10. This reduced the minimum ventilation rate to 1750 cfm, 1/2 the previous rate. The heat required for warming the ventilating air was reduced to 60,000 B.t.u. per hour.

HEAT UTILIZATION @ 1750 cfm MINIMUM VENTILATION RATE

Heat required:

Building Losses	- - - - - - - - -	45,000 B.t.u./hr.
Warming Ventilating Air	- - - -	60,000 B.t.u./hr.
TOTAL		105,000 B.t.u./hr.

Heat Available:

5,000 Layers	Sensible	- - - -	130,000 B.t.u./hr.
	Latent	- - -	50,000 B.t.u./hr.
	TOTAL		180,000 B.t.u./hr.

At 1750 cfm minimum ventilation rate, the available sensible heat was sufficient to maintain the minimum design conditions, with approximately 25,000 B.t.u./hr. excess. This heat was probably dissipated in evaporating litter moisture and in the warming of infiltrated air when the ventilating fans were not running.

An indication that environmental conditions inside the building were being controlled by the ventilation system was the response of these conditions to the change of fan control settings. The daily average and daily maximum temperature immediately increased by an amount approximately equal to the change in thermostat setting. The daily minimum temperature showed some increase; however, it was not as pronounced as the daily average or the maximum.

On March 9, Mr. Shepherd collected samples of floor litter from each side of the house for moisture content tests. An independent laboratory testing service found the sample from the exhaust air (east) side of the house contained 19.67% moisture, and that from the air inlet (west) side contained 15.94% moisture. The litter was slightly dusty. Recorded relative humidities indicated that conditions in the laying house were normal and that the environment was favorable during the entire month.

A major point of satisfactory performance of the ventilating system was its ability to maintain desired conditions inside the house when outside weather conditions were extremely variable. On March 28 and 29 the maximum temperature was 82 °F. The ventilating system held the maximum inside temperatures to just about the same as the outside temperature, yet maintained the desired temperature at night when the outside minimum was several degrees below the inside design temperature. These temperatures were maintained with the system operating on a winter schedule, with air inlets restricted and the windows closed.

Summer study:

The fan controls remained the same in the summer as in the winter; however, fan operation was controlled primarily by respective thermostats. Table II provides data on the conditions existing during a selected 6-day period of maximum temperatures during the summer of 1960.

TABLE II - SELECTED SUMMER DATA - 1960

Date	Outside Conditions*				Inside Conditions**					
								Exhaust Air		
	Temperatures			R.H.	Temperatures			Relative Humidity		
	Min.	Max.	Avg.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
Aug.										
1	65	85	75	85	65	87	79	73	91	81
2	69	94	82	78	70	97	83	62	91	79
3	72	95	84	70	72	94	85	58	87	74
4	71	95	83	81	70	93	81	65	96	83
5	70	91	81	84	70	90	81	72	91	82
6	69	90	80	87	69	94	79	75	91	85

*Weather Bureau records at Byrd Field, Richmond, Virginia, approximately 5 miles from building.

**Average temperature was calculated from 12 locations recorded at 2-hour intervals throughout 24-hour day. Minimum and maximum listed were the extreme of these individual readings.

The data indicate that the ventilation system maintained indoor temperatures approximately the same as outdoors. This is all that could be expected of a ventilating system without mechanical cooling devices. In a few instances the data show a very slight cooling effect. This was credited to the evaporation of moisture from the floor litter. The total summer ventilation capacity of the 6 fans was 30,000 cfm free air delivery.

The laying house construction, ventilating system, and thermocouple locations are shown in Figure 3. The recorded temperature values at the respective thermocouple locations show typical winter and summer conditions in the laying house on the dates and at the times noted.

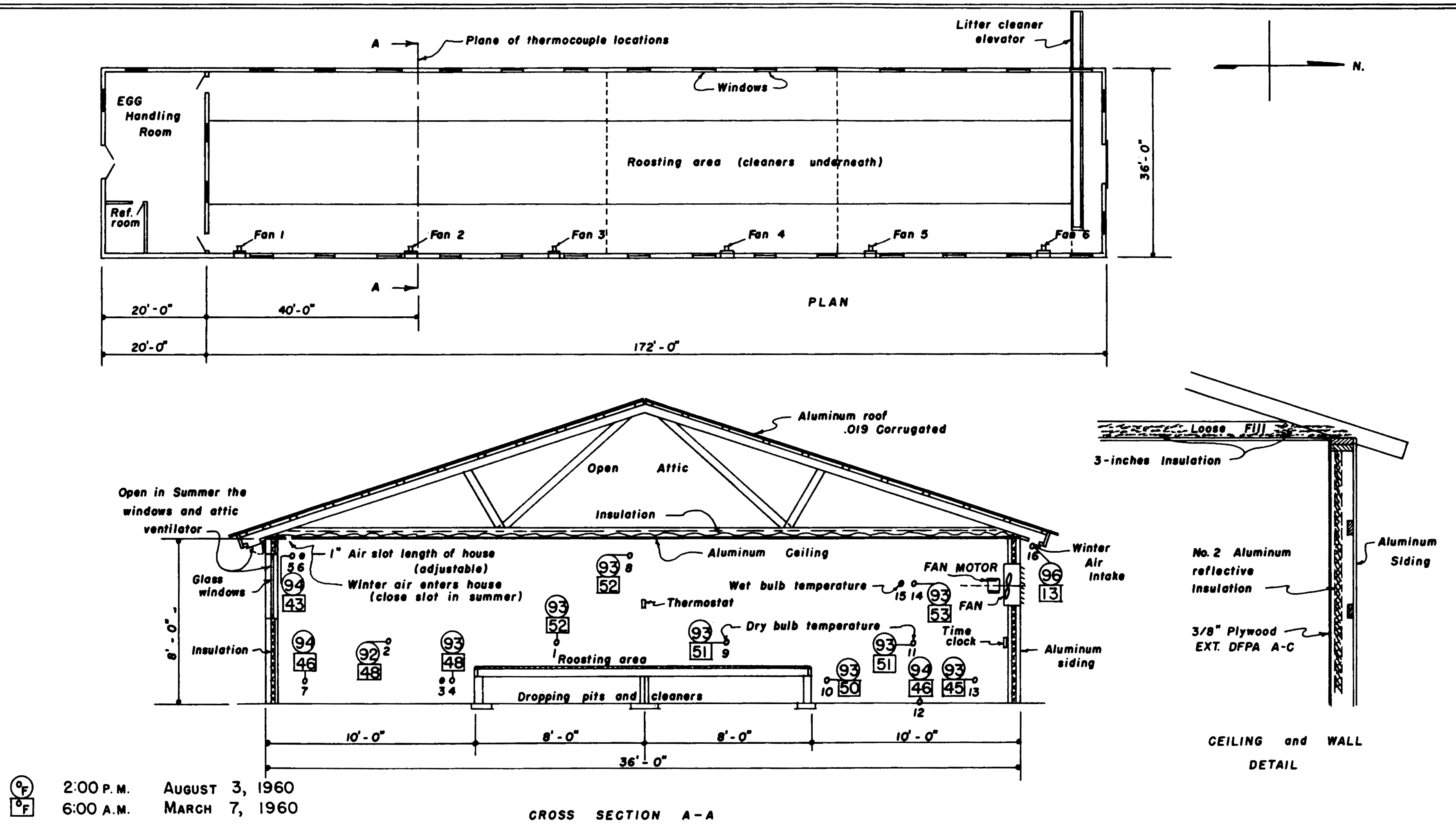

FIG. 3

DIAGRAMATIC DRAWING OF A 5,000 BIRD POULTRY LAYING HOUSE IN WHICH TEMPERATURES WERE RECORDED

Summary:

Typical examples of temperature distribution patterns for winter and summer conditions are recorded on the building cross-section, Figure 3. The winter temperatures were recorded at 6:00 A.M. March 7, 1960, one of the colder days during the test period. These temperatures vary somewhat from the daily averages, or minimums, but show variations over the house at a particular time. Temperatures increase gradually across the house, with no extreme variation. The entire house was maintained in the design temperature range.

The summer temperature record shown on the cross-section was obtained at 2:00 P.M. August 3, 1960, one of the hottest days of the test period. The temperature pattern showed little variation from outside air temperature. There were no apparent "hot spots" across the house.

It was concluded that this was a well designed laying house. With proper supervision and management it is capable of maintaining the desirable environmental conditions in summer and winter. Well designed houses for other conditions could be expected to perform satisfactorily with adept management.

References:

1. Baker, Vernon H., McNeil Marshall, and J. H. Bywaters. Poultry Laying House Ventilation Design Information, Part I - Winter Conditions. Technical Bulletin 131, Virginia Agricultural Experiment Station, June 1957.

2. Baker, Vernon H., McNeil Marshall, and C. E. Howes. Poultry House Ventilation Design Information, Part II - Summer Conditions. Technical Bulletin 134, Virginia Agricultural Experiment Station, August 1958.

3. Ota, Hajime. Houses and Equipment for Laying Hens, Miscellaneous Publication No. 728, ARS, USDA, November 1956.

4. Esmay, Merle L. and James M. More. Poultry Houses. Farm Building Series Circular 736, Michigan State University.

5. V.P.I. Plans for Nailed Trussed Rafter, 36' Span, N-133. Virginia Agricultural Engineering Farm Building Plan Service.

6. National Warm Air Heating and Air Conditioning Association. Manual No. 3, Calculating Heat Losses.

7. Ota, Hajime and E. H. McNally. Poultry Respiration Calorimetric Studies of Laying Hens. ARS, USDA, No. 42-43, June 1961.