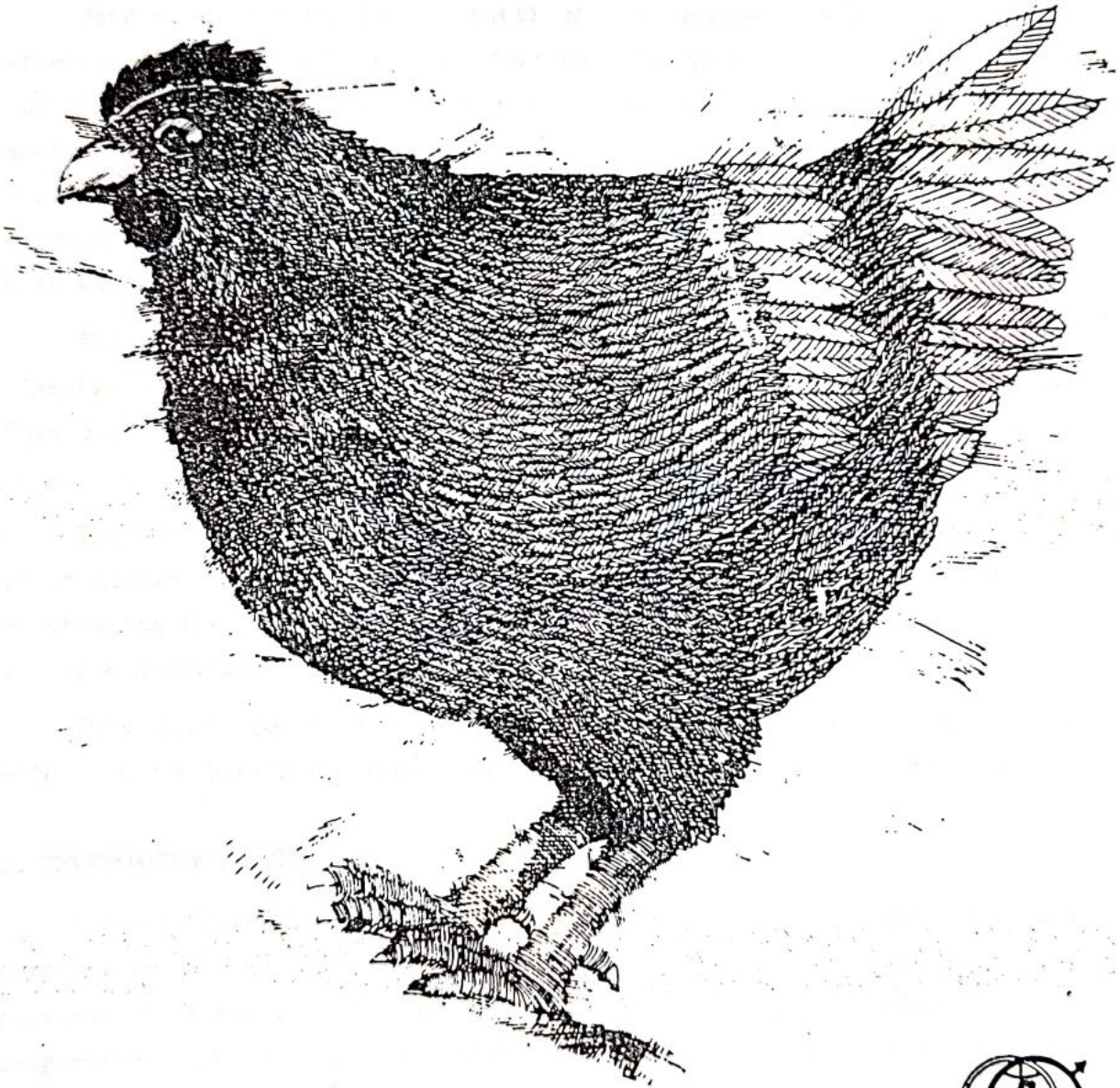
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CLIMATIZATION OF POULTRY HOUSES

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1. INTRODUCTION

Bird's environment is the total of all external conditions that are structural, social and climatic factors. The structural factors indicate the relationship of building and equipment design which are structure materials, sizes of construction and location of feeders, waterers, slatters, nests, cages and floors. The social factors are the numbers of birds per cage, behavior and peak order. The climatic factors are dry-bulb and wet-bulb air temperatures, air movement and radiation.

The agricultural engineers must design poultry houses and their climatic environmental control systems that are economically optimum. This may not always mean optimum in the physiologist's sense but rather in an engineer's sense optimum economically for profitable production.

The climatic environment is of great importance to the agriculturalist in obtaining the fullest genetic expression from domestic birds. The cost of changing the climatic environment in poultry houses must be compensated for by a profitable increase in egg and meat production.

This study pertains to the control of climatic factors and their effect on the bird's regulation and balance of heat production and loss.

2. THERMONEUTRAL ZONE

The environmental temperature should be defined as the effective temperature of the environment, which would inculude all of the variable climatic factors of not only dry-bulb temperature, but also wet-bulb temperature, air movement radiation and temperature of surrounding. The thermoneutral zone is the interval of effective temperature, the bird can maintain its homeothermic state automatically with physical compensations (Fig.1). The bird body is perfectly adjusted and feels neither hot

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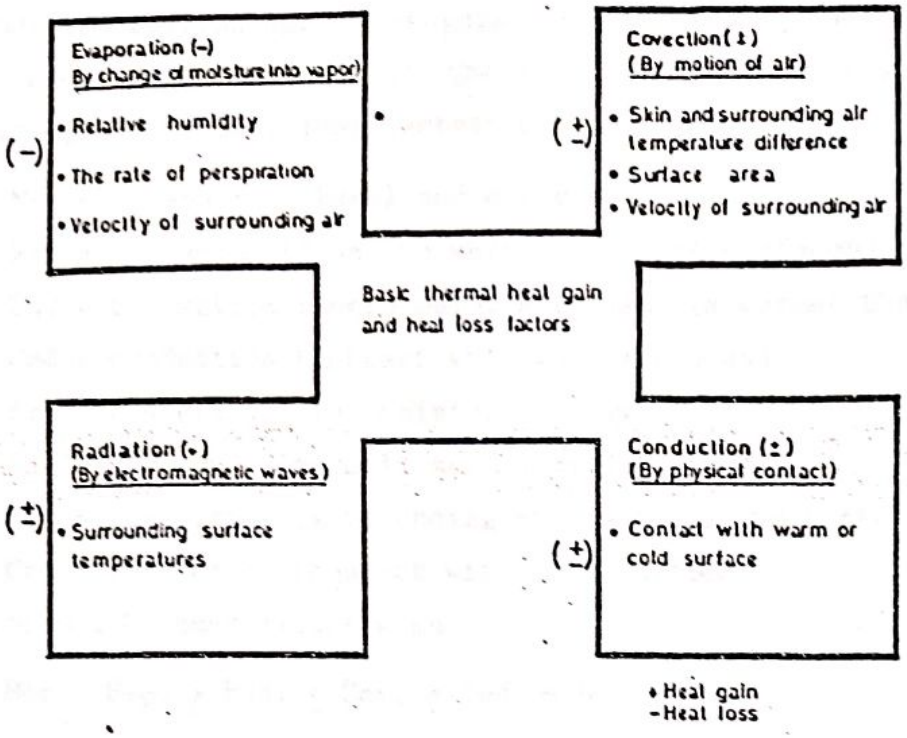


Fig.1. The basic physical thermal heat gain and heat loss factors of birds

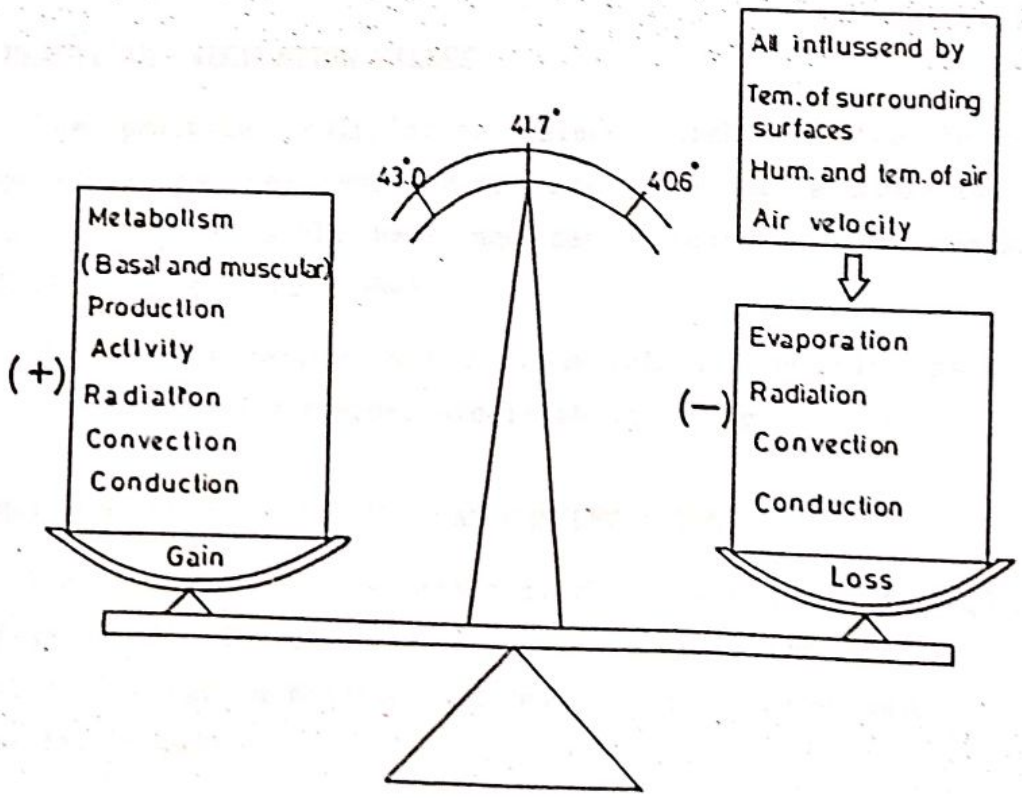


Fig.2. Thermal balance of the birds' body.

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or cold at this effective temperature range. The body of birds can release heat to its environment by evaporation, radiation, convection and conduction. The thermal balance of the bird's body is illustrated in Fig 2. The heat gain and heat loss factors are;

Gain: Met = metabolism (basal and muscular)
Rad = radiation (from the surrounding hot surfaces)
Cnv = convection (surrounding air temp. is warmer than the skin)
Cnd = conduction (contact with warm surfaces)

Loss: Evp = evaporation (of moisture and sweat)
Rad = radiaticn (to cold surrcunding surfaces)
Cnv = convecti.on (surrounding air is cooler than the skin)
Cnd = conduction (contact with cold surfaces)

then thermal balance exists when,

$$Met. - Evp. \pm Rad. \pm Cnv. \pm Cnd. = 0$$

The thermoneutral ranges are for 0-1 week old 34-36°C, for 5 weeks old 32-35°C, for 52 weeks old 18-24°C. The upper and lower optimum housing temperatures of 30°C and 12°C provide the desirable temperature range for summer to winter housing.

3. PRACTICAL CALCULATION VALUES

The practical calculation values which are the lowest practical temperature, assumed temperature, assumed relative humidity, total heat, water vapour, sensible heat and carbondioxide are summarised in Table 1 (CIGR Working Group, 1984).

Recommended maximum and minimum relative humidity as a function of poultry house inside temperature is shown by Fig 3.

4. MAXIMUM ALLOWABLE NOXIOUS GAS CONCENTRATIONS

The noxious gases are carbon dioxide (CO_2), ammonia (NH_3) and hidrogen sulfide (H_2S). Carbon dioxide is produced by the bird's metabolism and exhaled. The carbon dioxide concentration inside the poultry houses should be as low as possible.

Ammonia originates from manure and hidrogen sulphide originates from the anaerobic fermantation of manure. Therefore they are primarily a manure management problem.

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Table 1. Practical calculation values for broilers and laying hens

Type of animal			Broilers (on straw)					Laying hens (in cages)	
Body mass	kg		0.05	0.3	0.5	1.0	1.5	1.5	2.0
Inside house Lowest practical temperature	°C		30	27	24	18	18	12	12
Assumed temperature	°C	Summer	30	30	30	30	30	30	30
	°C	Winter	30	27	24	18	18	18	18
Assumed relative humidity	%	Winter	60	63	66	72	72	72	72
Total heat	W	Summer	1.1	3.9	5.7	9.6	12.6	9.1	11.3
	W	Winter	1.1	4.0	5.9	10	13	9.5	11.8
H_2O vapour	g/h	Summer	1.0	3.9	5.7	9.5	12.9	9.0	11.2
	g/h	Winter	1.0	3.2	3.9	4.6	6.3	4.4	5.4
Sensible heat	W	Summer	0.33	1.3	1.9	3.1	4.3	3.0	3.7
	W	Winter	0.33	1.8	3.3	6.9	9.3	6.5	8.1
CO_2	1/h	Winter	0.17	0.65	0.97	1.6	2.2	1.5	1.9

The assumed calculation value for minimum ventilation requirement is 3000 ppm and outside air contains 300 ppm carbon dioxide.

Recommended maximum gas concentrations are summarised in Table 2 (CIGR Working Group, 1984).

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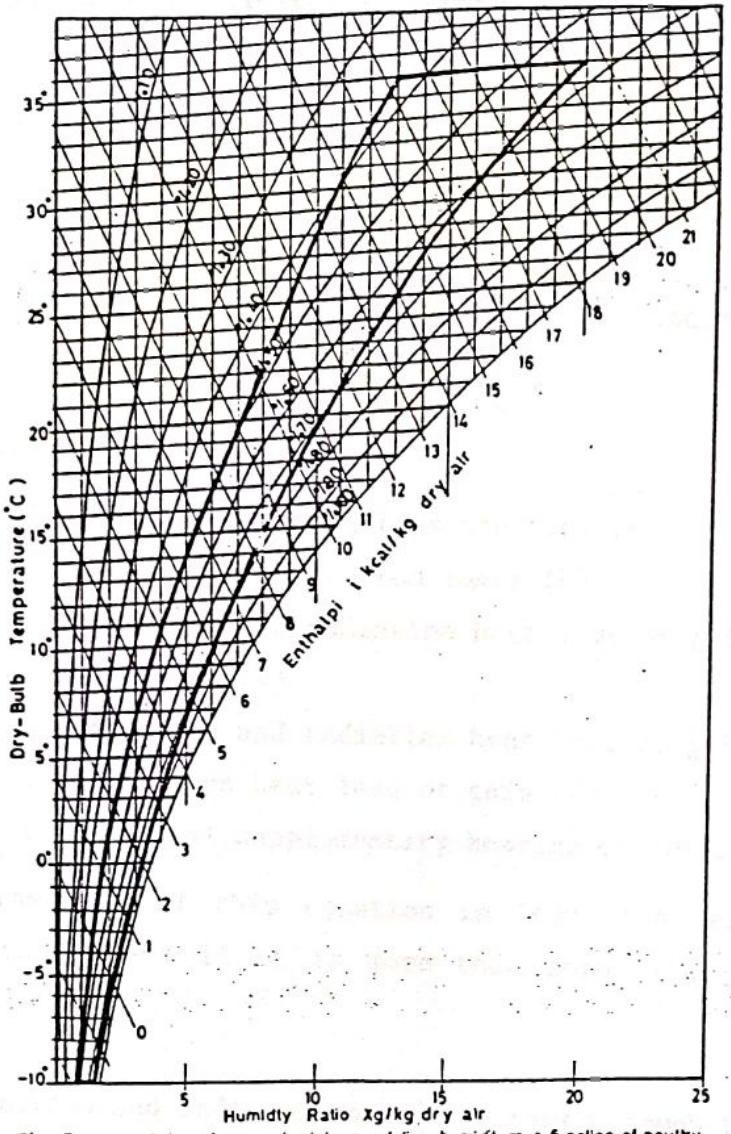


Fig.1 Recommended maximum and minimum relative humidity as a function of poultry house inside temperature

Table 2. Recommendations for maximum gas concentrations

Gas	Maximum concentration, ppm
Carbon dioxide, CO_2	1500[1)]-3000
Ammonia, NH_3	20
Hydrogen sulphide, H_2S	0.5
Carbon monoxide, CO	10

1.Chickens to 4 weeks

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5. HEAT AND MOISTURE BALANCE IN POULTRY HOUSES

The rate of heat loss or heat gain through each building component is proportional to its area, heat transfer coefficient and the difference between the inside and outside temperatures. The heat exchange processes of the building with the out door environment is shown by Figures (4).

The heat and moisture balances of poultry houses are given by;

$$Q_{ti} + Q_i \pm Q_{bcr} \pm Q_{pcr} \pm Q_v \pm Q_{mhc} = 0$$

Where;

Q_{ti} : sensible heat gain from the bird (W)
Q_i : supplemental heat from lamps (W)
Q_{bcr} : conduction and radiation heat loss or gain through the building components (W)
Q_{pcr} : conduction and radiation heat loss or gain through the windows (W)
Q_v : ventilation heat loss or gain (W)
Q_{mhc} : mechanical supplementary heating or cooling (W)

If the Q_{mhc} of this equation is less than zero, the poultry house will be cooled and if it is more than zero, the poultry house will be heated.

5.1. Conduction and radiation heat flow rate through the structure

Conduction and radiation heat loss or gain through the building components of a given area can be described by the equation.

$$Q_{bcr} = \Sigma A_j \cdot k_j \cdot \Delta t_j$$

Where;

Q_{bcr} : conduction and radiation heat flow rate (W)
A_j : surface area (m^2)
k_j : heat transfer coefficient ($W.m^{-2}.K^{-1}$)
Δt_j : temperature difference between both sides of building components (K)

If heat loss from building is considered;

$$\Delta t_j = t_i - t_o$$

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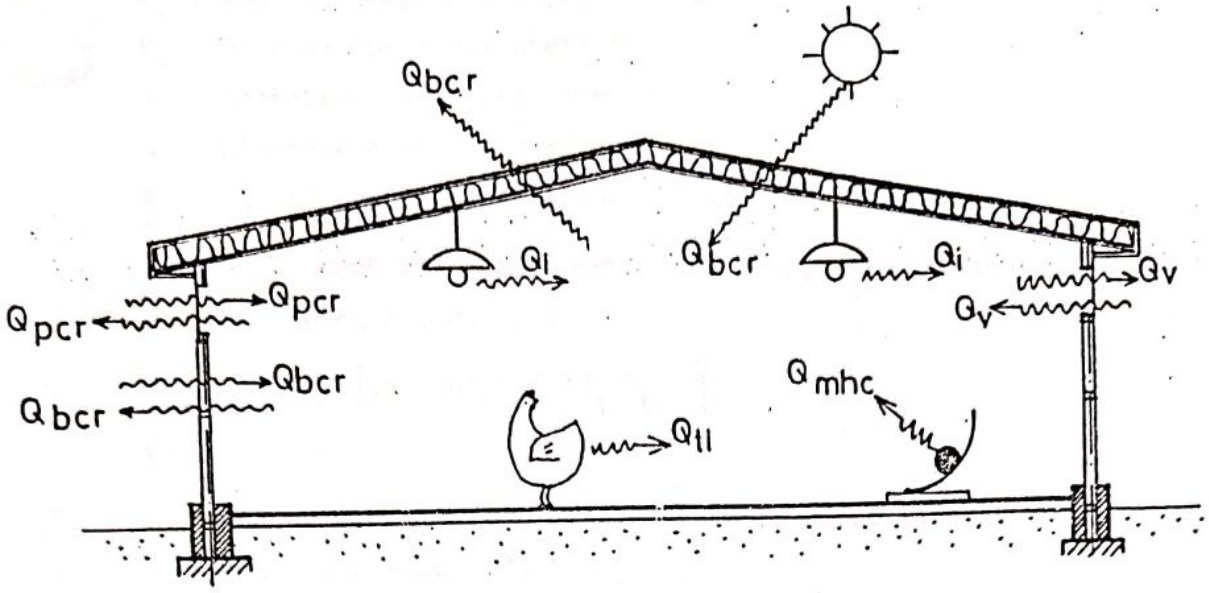


Fig 4 Heat exchange of poultry houses

If heat gain in an air conditioned building is calculated;

$$\Delta t_j = t_o - t_i$$

If a building component surface is also exposed to solar radiation:

$$\Delta t_j = t_s - t_i$$

Where;

t_i : inside air temperature (K)
t_o : outside air temperature (K)
t_s : sol-air temperature (K)

For poultry house design purposes, it is useful to combine the heating effect of radiation incident on a building with the effect of warm air. This can be done by using the sol-air temperature. Sol-air temperature is calculated by the following equation:

$$t_s = t_o + \frac{I \cdot a}{R_o}$$

Where;

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t_s : sol-air temperature (K)

t_o : outside air temperature (K)

I : radiation intensity ($W.m^{-2}$)

a : absorbance of the surface

R_o : outside surface conductance ($W.m^{-2}.K^{-1}$)

Conduction and radiation heat loss or gain through the windows is described by the equation:

$$Q_{pcr} = \Sigma A_j . \left[(k_j . (\Delta t_j) + (I_j . S_{cj}) \right]$$

Where;

Q_{pcr} : conduction and radiation heat flow rate (W)

A_j : surface area (m^2)

k_j : heat transfer coefficient ($W.m^{-2}.K^{-1}$)

Δt_j : temperature difference between both sides of window (K)

I_j : radiation intensity ($W.m^{-2}$)

S_{cj} : shading coefficient

If heat loss from window is considered;

$$\Delta t_j = t_i - t_o$$

If heat gain from window is considered;

$$\Delta t_j = t_o - t_i$$

Shading coefficient (S_c)

Glass with no shading

Single unit ---- 0.90

Double unit ---- 0.81

Glass with shading

Continuous overhang -- 0.25

White courtain ------- 0.40

Dark gray curtain ---- 0.60

5.2. Heat flow rate by ventilation

Heat loss or gain by ventilation can be expressed by the equation:

$$Q_v = \Sigma V_{vj} . C_{pj} . \Delta t_j$$

Where;

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Q_v : heat loss or gain by ventilation (W)

V_{vj} : ventilation rate ($kg.S^{-1}$)

C_{pj} : specific heat of the air ($J.kg^{-1}.K^{-1}$)

Δt_j: temperature difference between inside and outside the building (K)

If heat loss by ventilation

$$\Delta t_j = t_i - t_o$$

If heat gain by ventilation

$$\Delta t_j = t_o - t_i$$

6. CALCULATION METHODS OF VENTILATION

The ventilation rate calculation should be done using mass flows, because they are independent of temperature and pressure.

6.1. Conversion from mass flow (kg dry air.s^{-1}) to volume flow (m^3 moist air.hr^{-1})

The air density can be calculated by the following equation.

$$\rho = \frac{p}{287.T} - 1.32.10^{-5}\,\frac{\phi.P_{vs}}{T}$$

Where;

ρ : air density ($kg.m^{-3}$)

p : atmospheric pressure (101325 pa)

T : absolute temperature (K)

ϕ : relative humidity (%)

P_{vs}: saturated vapour pressure at different temperature (pa)

The air density and the volume flow in $m^3 . hr^{-1}$ per kg dry air s^{-1} are given in Table 3. The relative humidity is assumed to be 70 %, because the other values give a very small deviation. The saturated vapor pressure at different temperature is given in Table 4.

6.2. Ventilation rates

Ventilation is a process for controlling same environmental factors. As air moves through a building its temperature falls or rises and humidity ratio may increase or decrease.

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Table 3. Air density and air volume flow at different temperature and at 70 % relative humidity

Temp.	kg.dry.air. m^{-3} moist air (ρ)	m^3 moist air h^{-1} per kg dry air.S^{-1}	Temp.	kg.dry.air. m^{-3} moist air (ρ)	m^3 moist air h^{-1} per kg dry air.s^{-1}
-20	1.395	2580.65	10	1.244	2893.89
-19	1.389	2591.79	11	1.239	2905.57
-18	1.384	2601.16	12	1.234	2917.34
-17	1.379	2610.59	13	1.230	2926.83
-16	1.373	2622.00	14	1.225	2938.78
-15	1.368	2631.58	15	1.220	2950.82
-14	1.362	2643.17	16	1.216	2960.53
-13	1.357	2652.91	17	1.211	2972.75
-12	1.352	2662.72	18	1.207	2982.60
-11	1.347	2672.61	19	1.202	2995.01
-10	1.341	2684.56	20	1.198	3005.01
- 9	1.336	2694.61	21	1.193	3017.60
- 8	1.331	2704.73	22	1.189	3027.75
- 7	1.326	2714.93	23	1.184	3040.54
- 6	1.321	2725.21	24	1.179	3053.44
- 5	1.316	2735.56	25	1.175	3063.83
- 4	1.311	2746.00	26	1.170	3076.92
- 3	1.306	2756.51	27	1.166	3087.48
- 2	1.301	2767.10	28	1.161	3100.78
- 1	1.296	2777.78	29	1.157	3111.50
0	1.291	2788.54	30	1.152	3125.00
1	1.286	2799.38	31	1.148	3135.89
2	1.281	2810.30	32	1.143	3149.61
3	1.277	2819.11	33	1.139	3160.67
4	1.272	2830.19	34	1.134	3174.60
5	1.267	2841.36	35	1.129	3188.66
6	1.262	2852.61	36	1.125	3200.00
7	1.258	2861.69	37	1.120	3214.29
8	1.253	2873.10	38	1.116	3225.81
9	1.248	2884.62	39	1.111	3240.32

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Table 4. Saturated vapour pressure at different temperature

t (°C)	P_{vs} (pa)	t (°C)	P_{vs} (pa)	t (°C)	P_{vs} (pa)	t (°C)	P_{vs} (pa)
-20	125	-5	421	10	1227	25	3167
-19	137	-4	455	11	1312	26	3361
-18	149	-3	490	12	1402	27	3565
-17	162	-2	528	13	1497	28	3780
-16	176	-1	568	14	1598	29	4006
-15	191	0	611	15	1704	30	4243
-14	208	1	657	16	1817	31	4493
-13	225	2	705	17	1937	32	4755
-12	244	3	758	18	2063	33	5031
-11	264	4	813	19	2196	34	5320
-10	286	5	872	20	2337	35	5624
- 9	310	6	935	21	2486	36	5942
- 8	335	7	1001	22	2643	37	6276
- 7	362	8	1072	23	2809	38	6626
- 6	391	9	1147	24	2983	39	6993

The mass balance of a poultry house can be described as;

$$Q_v = (m_i - m_o)\, V_v$$

Where;

Q_v : mass flow produced internally of the building ($kg.s^{-1}$ or $gr.s^{-1}$)
m_i : material content of the inside air ($kg.kg^{-1}$ or $gr.kg^{-1}$ dry air)
m_o : material content of the outside air ($kg.kg^{-1}$ or $gr.kg^{-1}$ dry air)
V_v : ventilation rate (kg dry $air.s^{-1}$)

6.2.1. Ventilation rate for moisture balance

Minumum ventilation rate according to the moisture balance is given by;

$$V_{vm} = \frac{Q_{mv}}{m_{mi} - m_{mo}}$$

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Where;

V_{vm} : ventilation rate (kg.dry air.s^{-1}. kg^{-1}.live wt.)
Q_{mv} : moisture production of birds (gr.s^{-1})
m_{mi} : absolute humidity of the inside air (gr.kg^{-1} dry air)
m_{mo} : absolute humidity of the outside air (gr.kg^{-1} dry air)

The moisture content of air at saturation is given in Tablo 5.

The ventilation rate ($m^3.s^{-1}$) is found by following equation;

$$V_v = \frac{V_{vm}}{\rho} \ (m^3.s^{-1})$$

Where;

V_{vm} : ventilation rate (kg.dry air.S^{-1})
ρ : air density ($kg.m^{-3}$)

6.2.2. Ventilation rate for carbondioxide balance

Minimum ventilation rate according to the carbondioxide balance is given by;

$$V_{vk} = \frac{Q_{kv}}{m_{ki} - m_{ko}}$$

Where;

V_{vk} : ventilation rate (kg.dry air s^{-1}. kg^{-1}.live wt.)
Q_{kv} : carbon dioxide production of birds ($kg.CO_2.s^{-1}$)
m_{ki} : carbon dioxide content of the inside air (kg CO_2.kg^{-1}dry air)
m_{ko} : carbon dioxide content of the outside air (kg CO_2.kg^{-1}dry air)

Carbon dioxide concentration of the inside air = 3000 ppm or 0.3 %.

$$m_{ki} = \frac{0.3}{100} \cdot 1.529 = 4.587 \cdot 10^{-3} \text{ kg } CO_2 \cdot kg^{-1} \text{dry air}$$

Carbon dioxide concentration of the outside air = 300 ppm or 0.03 %.

$$m_{ko} = \frac{0.03}{100} \cdot 1.529 = 0.459 \cdot 10^{-3} \text{ kg } CO_2 \cdot kg^{-1} \text{ dry air.}$$

Carbon dioxide production = 100 $lt.CO_2.hr^{-1}$

$$Q_{ky} = 0.0005121 \cdot 10^{-3} \text{ kg } CO_2 \cdot s^{-1}$$

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Table 5. Absolute humidity of air at saturation

t (^{o}C)	m_m (gr.kg^{-1} dry air)	t (^{o}C)	m_m (gr.kg^{-1} dry air)	t (^{o}C)	m_m (gr.kg^{-1} dry air)	t (^{o}C)	m_m (gr.kg^{-1} dry air)
-20	0.77	-5	2.60	10	7.63	25	20.07
-19	0.84	-4	2.81	11	8.16	26	21.35
-18	0.92	-3	3.02	12	8.73	27	22.69
-17	0.10	-2	3.26	13	9.33	28	24.11
-16	1.08	-1	3.51	14	9.97	29	25.61
-15	1.18	0	3.77	15	10.64	30	27.19
-14	1.28	1	4.06	16	11.36	31	28.87
-13	1.38	2	4.36	17	12.13	32	30.63
-12	1.50	3	4.69	18	12.93	33	32.51
-11	1.63	4	5.03	19	13.78	34	34.48
-10	1.76	5	5.40	20	14.69	35	36.56
- 9	1.91	6	5.79	21	15.65	36	38.76
- 8	2.06	7	6.21	22	16.66	37	41.08
- 7	2.23	8	6.65	23	17.74	38	43.53
- 6	2.41	9	7.12	24	18.87	39	46.12

6.2.3. Maximum ventilation rate for summer conditions

The determinations of the maximum ventilation rate for summer condition is based on practical experience.

The maximum ventilation rate can be written as:

$$V_{vs} = \frac{Q_{ti} + Q_{bpcr}}{C_p \cdot \Delta t_s}$$

Where;

V_{vs} : maximum ventilation rate (kg dry air.s^{-1} kg^{-1} live wt.)

Q_{ti} : sensible heat production of birds (w.kg^{-1} live wt.)

Q_{bpcr} : conduction and radiation head gain through the building components and windows (w.kg^{-1} .live wt.)

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C_p : specific heat of the air ($J.kg^{-1}.K^{-1}$)

Δt_s: assumed temperature difference between inside and outside the building (K)

Maximum ventilation according to the sensible heat gain

Sensible heat gain from the birds;

$Q_{ti} = 3.7 : 2 = 1.85\ w.kg^{-1}$.live wt. (see Table 1)

The conduction and radiation heat gain through the building components and windows is about 65-68 % of the sensible heat produced by the birds (Drury and Baxter, 1960; Mutaf, 1980);

$Q_{bpcr} = 1.85 . 0.65 = 1.20\ w.kg^{-1}$.live wt

Assumed temperature difference between inside and out side the building;

$\Delta t_s = 2^{o}C$ (Mutaf, 1990)

Specific heat of the air;

$C_p = 1010\ J.kg^{-1}$ dry air.K^{-1}

$$V_{vs} = \frac{1.85+1.20}{1010 . 2} = 1.51 . 10^{-3}\ kg.s^{-1}\ kg^{-1}\ \text{live wt.}$$

Tablo 3 shows that 1 kg dry air.s^{-1} at $30^{o}C$, 70 % R.H = 3125.00 $m^3.hr^{-1}$

$V_{vs} = 1.51 . 10^{-3} . 3125.00 = 4.7\ m^3.hr^{-1}.kg^{-1}$ live wt.

SUMMARY

Bird's environment is the total of all external conditions that are structural, social and climatic factors. The structural factors indicate the relationship of building and equipment design which are such things as structure materials, sizes of construction and location of feeders, waterers, slatters, nests, cages and floors. The social factors are the number of birds per cage, behavior and peck order. The climatic factors are dry-bulb and wet-bulb air temperatures, air movement and radiation.

The basic function of climate modification could take place only in poultry houses. This study pertains primarly to the control of these climatic factors and their effect on bird's regulation and balance of heat production and loss.

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7. LITERATURE

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