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SIMULATION OF WINTER ENVIRONMENTAL
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SIMULATION OF WINTER ENVIRONMENT

AND PRODUCTION FOR LAYING HENS

By

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ABSTRACT

SIMULATION OF WINTER ENVIRONMENT
AND PRODUCTION FOR LAYING HENS

By

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A chicken will eat to meet its energy needs. Temperature directly and significantly influences its energy need and feed intake. A ambient temperature goes beyond the thermal neutral zone (the range at which chicken's performance is at its best), the bird makes adjustments to keep its body temperature normal. Feed consumption and required nutrient decrease as the ambient temperature increases, while energy needs may be met, intake of other essential nutrients may be inadequate. In turn, growth and egg production are decreased. Therefore, it is important that chickens be housed and cared for so as to provide an environment that enables them to maintain their thermal balance and allows them to convert feed to product (eggs and body growth) more efficiently.

This study was undertaken to provide an analytical tool that would help evaluate environmental conditions under different management strategies and climatic

conditions. The tool was a simulation model designed to predict hourly temperature, average daily temperature for inside, and management information, including feed consumption, feed costs, metabolizable energy, egg production, electricity cost, bodyweight, mortality rate using lower ventilation rate to evaluate poultry house. The simulation model was based on psychrometric and biological relationships for laying hens.

The basis of the simulation model and the test facilities for model verification was a commercial-type laying house near East Lansing, Michigan. The laying house has a capacity of 4,100 birds in each room. The system was managed as a small commercial unit at Michigan State University Poultry Science Research and Training Center.

Verification data were collected on five winter days and compared satisfactorily with simulated data. The carbon dioxide ventilation rate control was used as minimum ventilation rate in cool days to replace the moisture control ventilation rate commonly used in poultry houses. Carbon dioxide and ammonia levels were well under control with a ventilation rate of 0.2 m^3/hr/bird.

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CHAPTER I

INTRODUCTION

In the broad sense, environment may be interpreted as all external conditions that might affect animals. The concept of "environment" can be divided into social, physical, chemical, and biological components. The social factors pertain to animal behavior, such as crowding and the social or "pecking" order. The physical factors pertain to all of the surroundings, such as lighting, sound, cages, floor, and other equipment. The thermal factors pertain to air temperature, humidity, and movement.

Chemical factors pertain to all gases, such as oxygen, carbon dioxide, carbon monoxide, ammonia, and other gases, and also to water and feed. Some are necessary for life, while others are toxic and irritating.

In this study there will be emphasis on physical and chemical environment factors.

From a manager's and engineer's point of view, it is necessary to know both the optimal temperatures, and

CO_2 and NH_3 concentrations to be able to provide optimal management. To do so, the manager should know about the poultry environment and its effect on production and feed consumption. Chickens, being warm blooded, have the ability to maintain a rather uniform temperature of their internal organs. However, the mechanism (homeostasis) is efficient only when the ambient temperature is within certain limits. The thermoneutral zone is the range at which chickens' performance is at their best (21-25 C). Inside temperature below this range will increase the feed intake.

A chicken will eat to meet its energy needs. Ambient temperatures directly and significantly influences its energy needs and feed intake. As temperature go beyond the thermal neutral zone, the bird must make more effort to make adjustments to keep its body temperature normal. Feed consumption decreases as the ambient temperature increases. While energy needs may be met, intake of other essential nutrients may be inadequate. In turn, growth and egg production are decreased. As an approximate guide within the range of 15 C to 31 C, when the ambient temperature goes up 1 C, the energy requirement goes down approximately 2 Kcal/kg of body weight and feed consumption goes down about 0.7 g/bird/day (North, 1979). As the temperature goes down, the reverse is true. Therefore, it is important that chickens be housed and cared for so as to provide an environment that enables them to maintain their thermal balance, and allows them to convert feed to product (eggs and body growth) most efficiently.

Not only is thermal environment important, but there are other factors which effect egg production, such as the chemical environment. Concentration of carbon dioxide and ammonia could also effect egg production, and it may cause a high mortality rate.

Winter ventilation rates commonly used is set to control moisture. Sometimes this ventilation rate is too high to maintain inside temperature in the optimal range. Without using supplemental heat, this means a drop in inside temperature, which also means an increase in feed consumption and may effect egg production (Ariel, 1980).

Using ventilation rates below that commonly used for moisture control could help solve the problem of maintaining inside temperature in the optimal range. Moisture level could increase to the level that water condensation may occur inside the house on the walls or equipment. If this situation occurs for a short duration and infrequently, corrosion of cages and other equipment or any health problems may not be a problem.

The relative humidity may sometimes exceed 85% in this situation, but according to Hellickson et al. (1983), an increase in humidity will decrease production only at higher air temperature. Therefore, in general, humidity changes would not effect the response of nearly mature animals, such as laying hens for environmental temperatures below 24 C.

For pullets just starting production, maintaining the temperature below the thermal neutral zone could mean a delay in egg laying, which could mean a serious cash flow problem.

There was more than one alternative to be tested or used in egg production. For example, to keep the inside temperature in the optimal range, producers may think about adding more insulation to the interior of the building, or using supplemental heat in cool days, or using lower ventilation rates beelow the commonly used moisture venntilation rate.

Because the trade off between these alternatives, fuel input, increase in feed intake insulating the building, and short-time below the ideal environment are not clear or unknown. Therefore, there is a need to construct a simulation model to evaluate these alternatives.

1.1 Objectives

The objectives of this study are:

Objective 1: To develop a simulation model that will predict inside air temperature, relative humidity, ventilation rate and CO_2 concentration on an hourly and a daily basis within a laying house and the influence of these environmental conditions upon daily feed consumption, energy use, egg production, as well as feed and energy costs and income from egg sales.

Objective 2: To demonstrate the use of this model in providing input for a decision analysis to evaluate various cost control strategies.

1.2 Literature Review

Growers and scientists have tried to find optimal conditions to grow chickens for both meat and egg production. The first reported investigation of critical temperature of the chickens appears to be that of Regnault and Reiset (1850).

Mitchell and Haines (1927) studied the critical temperature of chickens in 36 experiments with 12 Rhode Island hens, which involved 137 determinations of carbon dioxide production during fasting and quiescence at different temperatures. It was found that the average lower critical temperature was 16.7 C. This value applied to winter-feathered birds in an environment of low humidity with an air flow of 3 liters per minute. Some of the individual birds appeared to exhibit distinct differences in their reaction to change in environmental temperature.

Results from Barott and Prince (1941) were quite different from those by Mitchell and Haines (1927). Mitchell and Haines (1972) found a lower critical temperature (the temperature at which the metabolism is at minimum) at 16.7 C. Barott and Prince's analysis gives a very different temperature for the minimum metabolism. They studied the metabolic rate during the experimental period, as measured by both heat and CO_2 elimination and oxygen consumption over the temperature range of 10 to 35 C on the metabolic rate during each 24 hour period. It showed that the typical diural rhythm in the metabolism of the hen had a maximum value in the morning (8 a.m.) and minimum value in the evening (8 p.m.). The minimum metabolism of the hen occurred at 25.6 C. The maximum metabolism occurred at 16.1 C. The rate at 16.1 C is approximately 8% higher than at 25.6 C.

Helback and Casterline (1963) studied the effect of high CO_2 atmosphere on the laying hens. Four Hy-Line laying hens were kept in an enclosed 6.5 ft^3 plastic-covered chamber to which a 5% CO_2 and 95% gas mixture was metered at 4 liters per minute for a 19-hour period. The temperatures was 21 C 2 C. Excess moisture was removed with sulfuric acid. The chamber resembled a closed system. Results indicated that during exposure to high CO_2, the shell thickness rose above pretreatment levels. However, there was no drop in egg size following the exposure.

Anderson et al. (1964) found 5,000 to 6,000 ppm of CO_2 in a commercial poultry house. In studies reported by Longhouse (1967), CO_2 was as high as 10,000 ppm. Hiestand et al. (1941) reported that chickens (no age and breed given) would withstand up to 6% (60,000 ppm) CO_2 concentration with slight inhibition off breathing, while at a 10% level, there was increased amplitude, but not an increased rate of breathing.

Kotula et al. (1957) reported that concentrations, as high as 20%, failed to immobilize birds in 75 seconds in a slaughtering study. Longhouse et al. (1968) published information for growing and studying broilers. Some experimental data on levels of NH_3, and CO gas levels were:

CO_2	860	to	10,000 ppm
CO	0	to	62 ppm
NH_3	0	to	50 ppm

They stated that exposure to variable concentrations of CO, in the presence of CO_2 may have a serious physiological effect on growing broilers in winter.

Charles and Payne (1965) reported the effects of ammonia on the performance of White Leghorn hens housed in various environments of defined temperature and humidity. At 18 C and 67% relative humidity, the use of atmospheres containing 105 ppm of ammonia by volume significantly reduced egg production after a 10-week exposure. No effects in egg quality were observed. However, voluntary feed intake was reduced in ammoniated atmospheres and live weight gain was lower. No recovery in production occurred when the treated groups were maintained for a further 12 weeks in an atmosphere free of ammonia.

When White Leghorn hens were housed at an environmental temperature of 28 C and various ammonia concentrations, a decrease in body weight occurred. The decrease in live weight was greatest at ammonia concentration of 102 ppm, and was significant after only one week of exposure to ammonia. Feed intake of controls was approximately 25% lower at 28 C than at 18 C. The presence of 100 ppm of ammonia further reduced feed intake by more than 10%. In one experiment at 28 C, egg production was significantly reduced after 7 weeks' exposure to ammonia.

Deaton et al. (1981) studied the effect of temperature cycles on egg shell quality and layer performance. Laying hens exposed to 24 hour linear temperature cycle ranging from 16.7 C to 35 C had significantly poorer egg shell breaking strength, and significantly greater body weight change than hens exposed to temperature cycles of 21 to 35 C and 15.6 to 35 C. No significant difference in performance existed in hens exposed to 24 hour linear temperature cycles of 21 to 35 C and 15.6 to 35 C. Egg shell quality deteriorated when the laying hen was exposed to high environmental temperatures.

Bray and Gesell (1961) studied the environmental temperature as a factor affecting performance of pullets fed diets suboptimal (11.5, 12.0, and 14.0% protein levels. White Leghorn pullets 29 to 31 weeks were used. Diets contained a mixture of corn and soybean oil meal, in which corn provided 45% of the protein. Chambers were maintained at 5.6 C and 24.4 C in one experiment and at 24.4 C and 30 C in a second experiment for a 8-week period.

Temperature extremes of 5.6 C and 30 C altered feed intake, but did not appear to affect rate of lay, with the protein provided. Intake remained above a minimum throughout the period. The rate of decline in egg production of pullets fed a given suboptimal protein diet was greater at higher temperatures. An inverse relationship existed between temperature and egg production at suboptimal protein levels.

Arad et al. (1981) studied the effect for 7 months of daily exposures to increasing ambient temperature on egg production for different breeds, including the White Leghorn.

Egg weight of Leghorns was stable up to 40 C, but decreased at higher temperatures. The laying rate decreased consistently from 35 C to 44 C. They concluded that the White Leghorn breed is highly tolerant of heat compared with other conventional breeds, shown by its long survival time, its moderate increase in metabolic rate, body temperature, and its accelerated evaporation.

DeShazer et al. (1970) reported on the effect of acclimation on partitioning of heat loss by the laying hen (White Leghorn). Hens acclimated to a 35 C environment reduced their total metabolic rate which included decreasing body weight by 15% and decreasing egg production by approximately 30%.

Weiss et al. (1963) also observed that the body weight of hens acclimated to a 32.2 C environment was significantly lower than the controls at 22.8 C. They also showed that the shell conductance of the hens acclimated to 23.9 C temperature environment decrease significantly when exposed to a 35 C environment as compared to a 25 C and 30.6 C.

Cowan and Michie (1980) studied the effect of increasing the environmental temperature late in lay and the performance of the hens. Their hens, ranging in age from 333 to 500 days, were fed on a conventional diet (161 g crude protein). Those kept at 27 C had a significantly lower egg output than at 21 C. Birds fed on the higher protein diet (192 g cp) kept at 27 C had a significantly lower egg output than those kept at 21 C. They also clearly noticed that for birds fed on a conventional diet (161 g cp) and an increased environmental temperature (27 C) at an age of 333 days still resulted in a depressed rate of egg output compared with hens maintained at 21 C.

Vohra et al. (1979) studied egg production, feed consumption, and maintenance energy requirements of Leghorn hens as influenced by energy content at 15.6 C and 26.7 C. They reported that the hens reduced their feed intake significantly at both ambient temperatures as the energy content of the diet increased from 1,980 to 2,830 Kcal/kg. Also the intake of low and high diets was significantly less at 26.7 C than at 15.6 C. The decrease in feed consumption was about 13% and 15.3% at ambient temperature of 15.6 and 26.7 C as the median of the diets increased form 1,980 to 2,830 Kcal/kg, respectively. Within this temperature range the feed intake decreased by 1.2% and 1.41% per 1 C rise in ambient temperature for the low and high diets, respectively.

Neither egg production nor shell thickness was influenced by the treatments, but egg weight was significantly depressed at 26.7 C as compared to those at 15.6 C.

The maintenance energy requirements were significantly lower at the two ambient temperatures when hens were fed the low diet as compared with the high diet. The energetic efficiency was increased for the conversion of maintenance energy intake to egg energy either by increasing the ambient temperature or by lowering the dietary maintenance energy.

Valencia et al. (1980) studied the energy utilization in laying hens and the effect of dietary protein level at 21 C and 32 C. They investigated White Leghorn housed at either 21 or 32 C and the effects of dietary protein level on energy utilization. Protein levels 12, 14, 16, 18 and 20% were used in this study for 21 days. They reported that maintenance metabolizable energy (was estimated at 134 and 121 kcal/kg physiological body weight ($BW^{0.75}$) was 21% higher at the lower temperature (89 vs. 70 kcal). Estimates of energetic efficiencies at 21 C varied from 60.9% for the 12% protein diet to 72.4% for the 18% protein diets.

Egg weights were significantly higher at lower environmental temperatuare, and at each temperature they were increased with feeding the higher protein diets. The average feed efficiency (g of egg/ g of feed) was significantly higher at higher environmental temperature (.46 vs. .53).

Henken et al. (1982) studied the effect of environmental temperature on some aspects of energy and protein metabolism of 3 to 6 week old pullets, at low temperatures. Feed conversion (g feed/g growth) was higher at lower temperature ($p < .25$) and 10.5% (at 10 to 20 C) compared to intake at 25 C. Growth rate and protein gains were not significantly affected by low temperatures.

Higher temperatures reduced ($p < .05$) feed intake 15.9% at 35 C and 14.9% at 30 to 40 C and growth rate 12.3% at 35 C and 12.5% at 30 to 40 C compared to 25 C.

Protein gains and fed conversion were not significantly affected by high temperatures.

Prince et al. (1965) studied the response of chickens to temperature and relative humidity environments. White Plymouth Rock male chicks 4 to 8 weeks old were subjected to environment temperatures of 12 C and 23.8 C and supplied with relative humidity 52,70 and 90%. They found that the feed consumption was significantly higher in the 12.6 C than in the 23.8 C.

Difference in feed consumption, due to relative humidity, were not significant. The difference in weight gains due to temperature was significant. Weight gain in the 12.6 C was 53 grams/bird greater than in the 28.8 C. No differences in weight gain were observed which would be attributable to relative humidity. The feed efficiency in 12.6 C was significantly lower than in 23.8 C.

Hellickson et al. (1983) in their book <u>Ventilation of Agricultural Structures</u> summarized the literature about the effects of humidity on heat loss for domestic animals. White Leghorn chickens at high air temperature of 30 C and 35 C an increased relative humidity from approximately 40 to 90% resulted in an overall decline of 77% in the respiratory evaporative heat loss. This lowered the ability of the hen to dissipate its total heat dissipation by 15% at environmental temperature 35 C and by 7% in a 30 C environment. At 20 C an increase in relative humidity from 55 to 88% caused a 3% increase in the total heat production and a 25% decrease in the respiratory evaporative heat loss.

Increases in humidity decreased production only at high air temperature. In general, humidity changes did not affect the responses of growing laying animals for environmental temperatures below 24 C.

North (1979) reported that the most important factor which had the greatest affect on layer feed intake was the ambient temperature. At extremes, daily feed consumption varied up to 50%. Layers ate more feed as ambient temperature decreased, and ate less as it increased. Variations in feed intake were not uniform. With 11.7 kg of feed consumed per 100 layers at 5 C as the base, they ate 46% less at 38 C. If 6.312 kg/100 layers per day at 38 C is used as the base, the flock ate 85.7% more at 5 C.

He concluded that birds adjust their energy intake to compensated for fluctuations in ambient temperature. At higher temperatures, the birds still consumed enough feed to meet their energy needs, but the diet becomes inadequate because of inadequate intake of other dietary constituents.

Greninger et al. (1982) developed a simulation model for poultry energetics for developing environmental recommendations. The model was based on the general relationship that the total metabolizable energy intake required by the hen is equal to the summation of maintenance energy, used in production of an egg, and the energy used for body weight gain. The actual metabolizable energy intake was assumed to be equal to the required feed intake. The necessary amount of protein in the diet was assumed to be provided for required maintenance of the hen, egg content, and egg development.

Mueller (1961; 1967) developed a method to estimate egg weight and production for an energy laying cycle.

Greninger et al. concluded that based on feed efficiency for egg output, the environmental temperature in layer house should be between 21 C to 25 C. However, economic parameters dictated that the temperature should be controlled at higher or lower temperatures, depending on protein cost, energy cost, fuel cost, insulation cost, and marketing situations.

Phillips and Esmay (1973) applied the systems approach to the analysis of summer environment for laying hens and developed a simulation model to be used in studying parameters affecting the environment. A mathematical model was developed to predict system temperature and humidity as a function of heat and mass transfer rates across system boundaries at discreet points of time at half-hour intervals throughout the day.

They studied six different constant ventilation rates in 1 cfm increments ranging from 2.5 to 7.5 cfm per 4.5 lb bird. Housing density was .7 ft^2 per bird and artificial day was from 6 a.m. to 8 p.m. The conclusion was that higher ventilation rates were not effective in reducing system temperatures during night hours when outside temperatures were lower. Density effects were most noticeable during the 11 a.m. to 6 p.m. period when outside temperatures were in the maximal area of the diural cycle. Summer ventilation rates in excess of 1.0 cfm per pound of body weight did not significantly reduce maximum system temperature.

Dixon and Esmay (1979) studied the feasibility of maximizing poultry excreta dehydration with ventilation air using a simulation model. The study was undertaken to provide an analytical tool that would help evaluate the feasibility of drying poultry excreta. The simulation model was designed to estimate the drying potential of excreta using mechanical ventilation systems commonly provided for commercial egg production houses. The simulation model was based on psychrometric calculations in combination with constant rate drying theory.

The critical factors for maximizing in-house manure drying were the drying surface area and the manure drying rate. The larger the surface are, the greater the drying. The variables which influenced the manure drying rate the most were the inside wet-bulb depression and the ventilations rate. Maximum drying was possible with a high inside dry-bulb temperature, a low outside dewpoint temperature, and maximum air exchange.

Timmons and Gates (1985) studied a stochastic method for synthetic weather generation which is combined with a layer production model to illustrate the utility of risk analysis applied to animal housing. Daily mean temperatures are generated based on previous day's temperatures, the expected mean daily temperatures, and random fluctuation.

Based on simulations of layer housing and egg production using either a deterministic simulation or stochastic simulation. They conclude that large differences occur in predictions of egg production parameters depending on the type of weather simulation model used. More reasonable predictions of egg production parameters are possible using a stochastic approach.

The use of stochastic evaluation indicates that evaporative cooling can be justified in a cool climate based on increased returns of \$.43 and \$.32 per hen per year for flock placement dates of January 1 and July 1, respectively. A minimum of 50 years of simulated production data should be used to predict expected production results

There were large differences between the two methods in predicted savings, caused by the small, but highly significant periods, when the stochastically generated outside temperature exceeded the deterministic outside temperature. Differences in predicted production occur when the higher outside stochastic temperature, caused house temperatures to significantly affect production.

CHAPTER II

METHODOLOGY

2.1 Model Development

This study was conducted at Michigan State University Poultry Research and Teaching Farm in a commercial-type egg research facility.

The system in this study was the environment produced within a 4,100 hen operating unit. The operating unit was the house enclosing the laying hens and the equipment used to manage the operation.

The house contained two identical laying rooms. Each room was 5.5m x 31m x 2.37m. Each room contained one row of deep pyramid reverse cages 30.5 cm x 40.6 cm. These cage rows were a modified stair-step, four-tier design that contained eight lines of cages per row and 60 cages per line. Figure 2.1 shows the general cage designs for the shallow and deep cage system. Performance of different colony sizes and different bird densities was one of the other studies in the room studied. Five and six bird colonies were placed in the deep cages in alternating lines, and

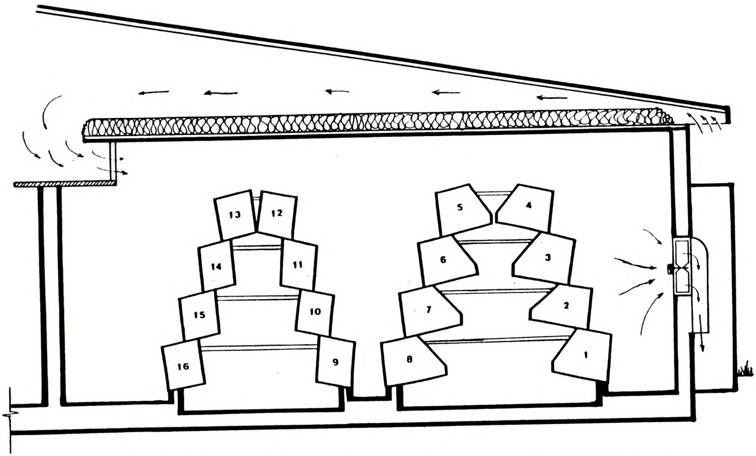


Figure 2.1. Shallow and deep cage systems labeled by line from House Seven green room.

three- and four-bird colonies were placed in the reverse cages in alternating lines. The end result was a total of two rows of deep cages with five or six birds per cage and two rows of reverse cages with three or four birds per cage and a total of 32 lines.

Figure 2.2 presents a general layout of the laying chambers. Ventilation in each room was provided by two 45 cm variable speed fans (4588 m^3/hr), four 60 cm (4950 m^3/ hr), and one 90 cm (8411 m^3/hr), fan. The 45 cm variable speed fans operated continuously and provided a total minimum air exchange of 840 cubic meters per hour (.2 m^3/hr/bird). The variable speed fans were fixed on that rate. When the room temperature rose above 26 C, one 60 cm fan was turned on to attempt to maintain target temperatures. The in-house target temperature range was 22 to 26 C. This was regulated by thermostat controlling ventilation fans. The 90 cm fan operated only during hot weather conditions. Air inlets located near the ceiling along the north wall of the south (White) room were adjusted by an automatic system sensing static pressure. No supplemental heat was used.

Lights were provided by 33 (25 watt) white, incandescent bulbs. Intensity was adjusted to .75 foot candles as measured from the bottom tier of cages. Feed was delivered three time per day to the birds by

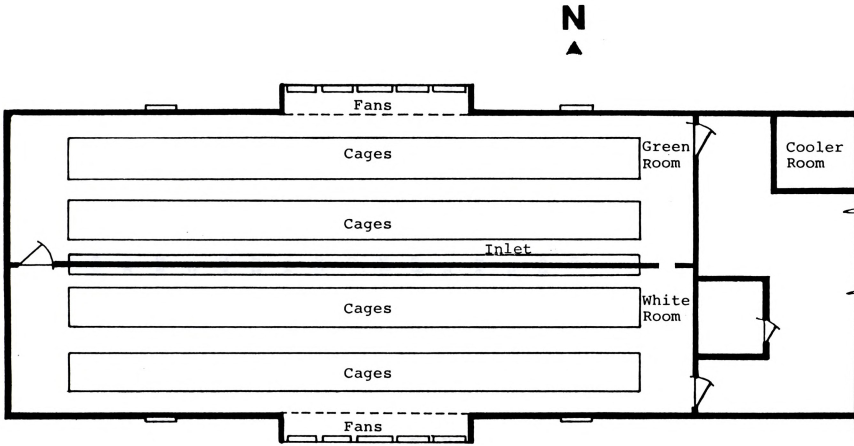


Figure 2.2 General layout of House Seven.

four automatic feed carts. One cart serviced one row of cages. Each cart was filled twice a day from separate bulk storage tank. Load cells placed under the carts at "home position" made it possible to weigh the carts before and after each feeding. Spouts from the feed cart led into each feed trough and could be adjusted separately.

Feed consumption was calculated every week. The bird inventory at the beginning of the week and at the end of the week, were used to get the average number of birds in the house during the week. The average number of birds was divided by the weight of feed disappearance (delivered) to the chickens. No feed loss adjustments were made.

Carts were controlled with time clocks and ran 1/2 hour after lights were turned on in the morning, in the early afternoon, and three hours before the lights were turned off in the evening. Water was provided from water cups placed on the side of every other cage so that one cup serviced two cages.

Average egg weight was calculated weekly. A 30 eggs flat is collected from randomly chosen cages for each line. The 30 egg flat was weighted, the empty flat also weighted in the same time. The difference in weight was the weight of 30 eggs, then this number was divided by 30 to get the average egg weight of the line.

Manure droppings were contained in shallow pits under the cage rows. The pits were scrapped twice a day into a cross gutter at one end of the laying rooms and moved to a conventional manure spreader outside.

Birds (Hy-line variety W-36 pullets) were housed in the facility at 18 weeks of age. All the birds were from one source and had been raised according to commercial practices.

2.2 Weather Model

The objectives of the weather model were to give reasonable estimates of average daily and hourly outside temperature and dewpoint temperature. These were used as inputs to the laying house environmental model.

Data from both the United States Department of Commerce/National Oceanic and Atmospheric Administration/National and the Weather Service (USDC/NOHA/NWS), station for Lansing, Michigan, were used to prepare values needed for the model. Daily averages, maximum and minimum temperatures from 1941 to 1970 were used to calculate yearly average ambient temperature and yearly ambient temperature amplitude.

Diural dry bulb temperature fluctuation can be closely approximated by a sinusoidal function with amplitude varying equally about the daily mean temperature. During winter in Michigan, the minimum daily temperature can be expected at approximately 7 a.m. and the maximum about 3 p.m. Hill (1983) used this procedure in his paper to estimate average daily and average hourly temperatures, and found this to be a good estimation. For the prevailing conditions in this study, the following equation was used to generate the daily average ambient air temperature for any day of the year based on Hill (1983).

$$DTEMP = TA + TYRAMP * SIN\,[.0172142\,(Day-DAV)] \quad (2.1)$$

where:

DTEMP = average daily ambient air temperature C

TA = yearly average air temperature = 8.6 C

TYRAMP = yearly ambient amplitude = -3.9 C

Day = day of year (January 1 = 1)

DAV = day of year which first reaches the annual average temperature = 107

The hourly ambient air temperature for a given day of the year is calculated as follows (Hill, 1983):

$$TEMPC = DTEMP + TDYAMP\ [\sin(.2617994\ (HOUR + 13)) + \sin\ (.2617924\ (Hour + 13)2)/3] \quad (2.2)$$

where:

TEMPC = hourly air temperature C

TDYAMP = daily ambient temperature amplitude (winter only) = -13.5 C

HOUR = hour of day

Data from USDA/NOHA/NWS for Lansing from 1965-1984 provided the base information for the daily needed dewpoint temperature. The hourly dewpoint temperatures for each month--January, February, March, November, and December--were used to fit a regression equation for each month. Several candidate equations were evaluated. These included linear exponential, logarithmic, and power equations. The linear equations were used because the correlation coefficients were about the same as the more complex equations. These equations were used to estimate hourly dewpoint temperatures to calculate all needed psychometric properties for the incoming ventilating air. The hourly ambient dewpoint temperature for a given day during the winter were:

$$DEWPT = -1.3258 + .803381 * TEMPC \quad \text{For January } R = 0.93 \qquad (2.3)$$

$$DEWPT = -2.8242 + .834888 * TEMPC \quad \text{For February } R = 0.89 \qquad (2.4)$$

$$DEWPT = 4.9466 + .605923 * TEMPC \quad \text{For March } R = 0.76 \qquad (2.5)$$

$$DEWPT = 11.6864 + .533961 * TEMPC \quad \text{For November } R = 0.75 \qquad (2.6)$$

$$DEWPT = -3.6047 + .942597 * TEMPC \quad \text{For December } R = 0.92 \qquad (2.7)$$

where:

DEWPT = hourly dewpoint temperature F.

Hourly relative humidity for outside air were calculated by using the hourly dry bulb temperature and dewpoint temperature for each day, by use of psychrometric equations, ASAE Standards (1984).

2.3 Sensible Heat Balance

The basic equations are obtained by a heat and moisture balance during short time periods considering the building as an open system. Hinkle and Good (1970) suggested that the heat balance can be represented as

Change in heat = heat entering system - heat leaving system

$$\Delta q = q_{in} - q_{out} \tag{2.8}$$

Several simplifying assumptions were made to develop the model. No heat storage in the building. Complete mixing of the air within the building and constant heat and moisture production of chickens during the time interval.

The systems defined by this research are the environment surrounding the layers and enclosed by interior surfaces of the animal shelter. A sensible heat balance equation can be written as

$$q = q_s + q_e + q_{sup} \pm q_w - q_b - q_{sv} - q_m \qquad (2.9)$$

where:

q_s = sensible heat produced by the animals kJ/hr

q_e = sensible heat produced by equipment such as lights, motors kJ/hr

q_{sup} = sensible heat from supplemental sources kJ/hr

q_w = heat needed to change water at room temperature to water vapor at the same temperature, heat also released when water condenses kJ/hr

q_b = conductive heat loss through the building, walls, floor, and ceiling kJ/hr

q_{sv} = sensible heat leaving with the dry exhausted ventilation air kJ/hr

q_m = sensible heat leaving with the moisture in the ventilated air kJ/hr

Sensible heat lost with the dry portion of the ventilation air, q_{sv}, can be expressed as

$$q_{sv} = q_{vi} - q_{vo} = C_p M (t_i - t_o) \qquad (2.10)$$

where:

C_p = specific heat of dry air (1.0035) kJ/kg. C

M = ventilation mass air flow kg/hr

t_i = inside air temperature C

t_o = outside air temperature C

The equation for ventilation mass air flow rate (M) can be written as

$$M = \frac{Q_s}{V_s} \qquad (2.11)$$

where:

Q_s = ventilation volumetric flow rate m^3/hr

V_s = specific volume of inside air m^3/kg

Ventilation rate needed to remove the available sensible heat and thus maintain the inside temperature at t_i calculated as

$$Q_s = \frac{V_s}{C_p\ (t_i - t_o)} * (q_s + q_e + Q_{sup} \pm q_w - q_b) \qquad (2.12)$$

Specific volume of inside air V_s is given by ASAE 1984 standard as

$$V_s = \frac{R * T}{P_{at} - P_v} \qquad (2.13)$$

where:

T = absolute temperature of the dry air K

R = gas constant of dry air = .287 kJ/kg.K

P_{at} = atmospheric pressure = 101.325 kPa

P_v = vapor pressure kPa

Vapor pressure P_v is also given by ASAE 1984 standards as

$$P_v = \frac{\phi * P_s}{100} \qquad (2.14)$$

where:

= relative humidity %

P_s = saturated vapor pressure kPa

Saturated vapor pressure is calculated by two equations for temperatures ranged -18 to -0 C as

$$\ln P_s = 31.9602 - \frac{627.3605}{T} - 4.06057 * \ln(T) \qquad (2.15)$$

and for temperatures range 0 to 110 C as

$$\ln\left(\frac{P_s}{R}\right) = \frac{A + BT + CT^2 + DT^3 + ET^4}{FT - GT^2} \qquad (2.16)$$

where:

A = -27405.526

B = 97.5413

C = -.146244

D = $.12558 \times 10^{-3}$

E = $-.48502 \times 10^{-7}$

F = 4.34903

G = 0.39381×10^{-2}

R = 22105649.25

The enthalpy of water vapor as a function of temperature is given by ASHRASE (1967) as:

$$h = 2501 + 1.84T \qquad kJ/kg\ H_2O \qquad (2.17)$$

Then change in enthalpy due to change in both the temperature and moisture content of the incoming (h_{im}) and outgoing (h_{om}) water vapor would be

$$h_{im} = (W_i\ (2501 + 1.84\ t_i)) \qquad (2.18)$$

and

$$h_{om} = (W_0\ (2501 + 1.84\ t_o)) \qquad (2.19)$$

where:

W = humidity ratio in kg H_2O/kg d.a.

i = incoming

0 = outgoing

Then humidity ratio for outside or inside air is calculated based on ASAE 1984 standards

$$W = \frac{.619 * P_v}{P_{at} - P_v} \qquad (2.20)$$

Therefore, the sensible heat q_m lost with the moisture in the ventilation air is

$$q_m = M[2501 (W_i - W_o) + 1.84 (W_i t_i - W_o t_o)] \quad (2.21)$$

where:

q_m = change in heat in kJ/hr

W_o = humidity ratio of outside air kg H_2O/kg d.a

W_i = humidity ratio of inside air kg H_2O/kg d.a

2.3.1 Sensible Heat Production of Animals

Poultry produce various quantities of metabolic heat, depending on type of bird, body weight, amount of feed consumed, and environmental conditions. Data for sensible heat production published by Esmay and Dixon (1986) are used to predict the sensible heat for the model (Table 2.1). A linear regression equation has been fitted to the data. The equations are:

$$q_s = 16.4533 - .3108 * t_i \quad \text{in darkness } R = 0.97 \quad (2.22)$$

and

$$q_s = 23.4309 * ti^{-.1558} \quad \text{in light } R = 0.96 \quad (2.23)$$

Table 2.1 Heat Production from Chickens

In Darkness		In Light	
Temp C	Sensible Heat kJ/hr. kg	Temp C	Sensible Heat kJ/hr. kg
-33.0	16.49	-33.3	25.52
0.56	16.02	1.67	19.48
8.33	44.40	8.33	17.17
12.22	12.78	12.22	15.30
17.78	12.31	17.22	15.30
27.78	8.82	22.22	15.08
34.44	3.96	27.78	13.68

2.3.2 Heat From Mechanical Lighting System

Use of electricity for artificial lighting and to power materials handling equipment provides a direct source of sensible heat to the system. The amount of electrical energy added during the hours of artificial daylight was estimated at 38.7 kJ/hr. m^2 (1 watt/ft^2) by Phillips (1970). Then the amount of heat added is

q_e = A * 38.7 (2.24)

where:

A = area of the floor m^2

38.7 = heat produced by the lights $kJ/hr.m^2$

Heat from the electrical motors, such as fans motors and scaper motor was assumed to be insignificant.

2.3.3 Conductive Heat Loss Through the Building Shell

The fundamental equation for steady-state heat conduction through the solid building boundaries is

q_b = - kA (dt/dx) (2.25)

where:

q_b = heat flow in one direction in Watts or J/sec

k = thermal conductivity in $W.m/m^2K$

A = cross-sectional area in m^2

dt/dx = temperature gradient in K/m

Overall, heat flow through ceilings, walls, and windows may be calculated for each component

$$q = U A (t_i - t_o) \tag{2.26}$$

where:

U = overall coefficient of heat transfer $W/m^2.K$

A = area normal to direction of heat flow m^2

t_i, t_o = air temperature inside and outside C

The overall coefficient of heat transfer may be calculated as follows:

$$U = \left[\frac{1}{f_i} + \sum_{n}^{x=1} \frac{L_x}{k_x} + \frac{1}{f_o} \right]^{-1} \tag{2.27}$$

where:

fi,fo = film or surface conductance inside and outside $W/m^2.K$

L_x = length of the path of heat flow m

k_x = coefficient of conduction of specific material W/m.K

n = number of materials needing a designation

x = a specific material designation

Heat loss through the floor is based on an equation suggested by ASHRAE (ASHRAE, 1981 Handbook of Fundamentals).

$$q_{F_1} = (A_{F_1} - A_m) * U_{F_1} \qquad (2.28)$$

where:

A_{F_1} = floor area m^2

U_{F_1} = average value of heat transfer = 3.155 W/m^2

A_{ml} = area covered with manure m^2

q = heat loss through the floor in W

Then the total heat loss through the building would be:

$$q_b = q_{w_1} + q_{c_1} + q_{F_1} + q_{op} \qquad (2.29)$$

where:

q_b = heat loss through the building shell W

q_{wl} = heat loss through the walls W

q_{c_1} = heat loss through the ceiling W

q_{F_1} = heat loss through the floor W

q_{op} = heat loss through windows or fans not operating W

Substituting the components of heat balance equation and rearranging

$$q = q_s + q_e + q_{sup} + q_w - q_b - q_{sv} - q_m \qquad (2.30)$$

Then the difference in rate of heat flow is

$$q = M(1.0035\ (t_o - t_i) + 2501\ (w_o - w_i) + 1.84 * (W_o t_o - w_i t_i)) + 2431 * W_m + q_s + q_e - q_b \qquad (2.31)$$

To calculate the temperature at a point in time, therefore, the change in heat content q over a small time increment is desired. This can be obtained by multiplying the heat change equation by time increment T as follows:

$$q = h/ T$$

$$\Delta h = \Delta T\ [M(1.0035(t_o - t_i) + 2501(w_o - w_i) + 1.84 * (w_o t_o - w_i t_i)) + 2431 * W_m + q_s + q_e - q_b \qquad (2.32)$$

2.4 Moisture Balance

The moisture balance for the system is as follows:

$$W_{ot} + W_c + W_m - W_v = 0 \quad (2.33)$$

where:

W_{ot} = moisture in incoming ventilating air kg/hr

W_c = moisture from animal respiration kg/hr

W_m = moisture evaporated from manure and spilled water kg/hr

W_v = moisture in outgoing ventilating air kg/hr

The moisture in incoming ventilating air is calculated by

$$W_{ot} = M * W_o \quad (2.34)$$

where:

M = ventilation flow air mass kg d.a/hr

W_o = humidity ratio of outside air kg H_2O/kg.d.a

The moisture in outgoing ventilating air is calculated by the following equation

$$W_v = M * W_i \quad (2.35)$$

where:

W_i = humidity ratio of inside air kg H_2O/kg.d.a.

Air mass in the building, Ma, is calculated by the relationship

$$Ma = \frac{V_b}{V_s} \qquad (2.36)$$

where:

V_b = volume of the floor m^3

V_s = specific volume of inside air m^3/kg

The moisture in the incoming ventilating air was determined from estimated data from the weather model. Dry bulb and dewpoint temperature was generated for a specific time of day.

2.4.1 Moisture from Animals

The latent heat in respired air from laying hens, q_l, was determined from data presented by Esmay (1986) (Table 2.2), were used to fit a linear regression equation for latent heat production during dark hours and light. The equations were:

$$q_l = 4.4649 + .2122 * t_i \quad \text{for light kJ/hr.kg}$$

$$R = 0.98 \qquad (2.37)$$

$$q_l = 3.8085 + .1685 * t_i \quad \text{for darkness kJ/hr. kg}$$

$$R = 0.92 \qquad (2.38)$$

Table 2.2. Latent Heat from Chickens

In Darkness		In Light	
Temperature C	kJ/kg. hr	Temperature C	kJ/kg.hr
-3.33	3.71	-3.33	3.71
0.56	4.86	1.67	5.33
8.33	4.39	8.33	5.58
12.22	5.80	12.22	7.67
17.78	5.33	17.22	8.14
27.78	8.14	27.78	9.97
34.44	10.91	33.33	12.31

Then the moisture production W_c from respiration of the chickens was calculated from:

$$W_c = \frac{q_l}{h_{fg}} \tag{2.39}$$

where:

q_l = latent heat produced by the chickens kJ/hr

h_{fg} = latent heat of vaporation of water at saturation kJ/kg

Latent heat of vaporization of water at saturation based on ASAE 1984 standards is:

$$h_{fg} = 2502.535259 - 2.38576\ (T - 273.16) \qquad (2.40)$$

where:

T = temperature in Kelvin

2.4.2 Moisture from Manure and Spilled Water

The moisture evaporated from the manure W_m, and the drinking water that spilled into the manure, and evaporated with manure water was calculated from the free water evaporation from the surfaces developed by Kadlec (1969) as follows

$$W_m = KA_m\ (P_m - P_p) \qquad (2.41)$$

where:

W_m = water evaporated from manure kg/hr

K = coefficient of evaporation $kg/m^2/hr$

A_m = area covered with manure m^2

P_m = partial pressure of moisture in the air near manure mm.Hg

P_p = partial pressure of the moisture in the air away from the manure mm.Hg

b = barometric pressure mm.Hg

The coefficient of evaporation was calculated from the following relationship:

$$K = .018 + .015 * V \tag{2.42}$$

where:

V = air velocity near the manure m/s

Partial pressure near the manure was calculated by the following relationship

$$P_m = P_{sm} * Rh_m \tag{2.43}$$

where:

P_{sm} = saturated vapor pressure near the manure mm.Hg

Rh_m = relative humidity near the manure

Relative humidity near the manure was assumed equal to the relative humidity inside based on measurements taken during winter months. The saturated vapor pressure then calculated for the temperature near the manure, which assumed less than the inside temperature by small fraction based on measurements taken in the building.

The difference in partial pressures was then calculated and used for further calculations to determine the amount of water evaporated from the manure.

The total amount of water added to the air over a small time increment ΔT was calculated by summing the amount of water produced from the chickens' respiration, air entering the system and the amount of water evaporated from the manure, minus the moisture leaving the system.

The moisture balance can be stated as

change in moisture content = (moisture entering the building - moisture leaving the building) /building air mass

$$\frac{\Delta W}{\Delta \bar{T}} = (M\ W_o + W_c + W_m - MW_i)/Ma \tag{2.44}$$

$$\Delta W = \Delta T[MW_o + W_c + W_m - MW_i)/Ma] \tag{2.45}$$

From the basic equations for the new heat content, the change in heat, new moisture content and the change in moisture of the air in the building, at the end of time increment, the new heat and moisture content can be found.

By substituting the new values of heat content, and moisture content in the following equation, the new temperature inside the building can be calculated at the end of time increment. The new heat and moisture content is calculated as follows:

$$h_{new} = h_{old} + \Delta q \qquad (2.46)$$

$$W_{new} = W_{old} + \Delta W \qquad (2.47)$$

By using the relationship between enthalpy $h = q_{new}/Ma$, temperature and moisture content, new values of inside temperature can be calculated as follows:

$$t_i = \frac{h_{new}/Ma - 2501 * W_{new}}{1.0035 + 1.84 * W_{new}} \qquad (2.48)$$

where:

q_{new} = new heat content kJ

W_{new} = new moisture content kg H_2O/kg d.a

Ma = air mass in the building kg

Inside relative humidity is calculated from the relationship:

$$\phi = \frac{P_v}{P_s} \times 100 \qquad (2.49)$$

where:

P_v = existing vapor pressure kPa

P_s = saturated vapor pressure kPa

The dry bulb temperature and moisture content are known, the saturated vapor pressure P_s, and existing vapor pressure P_v are calculated as previously discussed.

2.5 Carbon Dioxide Balance

Mitchel and Haines (1927) published early concerns about the critical temperature for hens and the carbon dioxide production of hens at different temperatures. Later in 1941, Barott and Pringle (1941) also published paper on energy and gaseous metabolism of hens. Carbon dioxide eliminated ranges from .46cm^3 per hour per gram live weight at 10 C to .49 cm^3 per hour per gram live weight at 16.7 C.

Rous et al. (1971) estimated carbon dioxide production for hen ranges from .415 cm^3/hr for body weight of 450 g to .678 cm^3/hr for body weight of 1,350 g (heavy breed).

Carbon dioxide balance equation could be written as:

$$C_c + C_m + C_g = C_{ve} - C_{vo} \qquad (2.50)$$

where:

C_c = CO_2 produced by the chickens

C_m = CO_2 produced from manure

C_g = CO_2 from other sources (gas furnace)

C_{ve} = CO_2 in exhaust ventilation air

C_{vo} = CO_2 in ventilation air from outside

For this study, carbon dioxide from the manure and from other sources, e.g., heating and equipment assumed to be zero. The only carbon dioxide production used is from the hens.

$$\frac{\Delta C_c}{\Delta T} = C_{ve} - C_{vo} \qquad (2.51)$$

The carbon dioxide in exhaust ventilation air is set to the maximum allowable concentration offo 0.35%. This value was an average of different locations concentration. To calculate ventilation rate for carbon dioxide control, the rate of CO_2 production is needed in m^3/hr, and calculated from following equations. This rate then divided by the difference of maximum allowable CO_2, and CO_2 in atmosphere.

Three different equations used to estimate CO_2 production in different temperatures based on data from Barott and Pringle (1941):

$$P_{co2} = .3434 * ti^{.1317} \quad \text{for temperatures 10 C - 17 C} \quad R = 0.99 \qquad (2.52)$$

$$P_{co2} = .8961 * ti^{-.213} \quad \text{for temperatures 18 C - 26 C} \quad R = 0.97 \qquad (2.53)$$

$$P_{co2} = .222 * ti^{.2201} \quad \text{for temperatures 27 C - 34 C} \quad R = 0.98 \qquad (2.54)$$

where:

P_{co2} = carbon dioxide production per gram body weight cm^3/gr.hr.

The carbon dioxide picked up by ventilation is calculated by this formula based on Kadlec (1969):

$$C_v = \frac{\Sigma P_{co2}}{CO_{2max} - CO_{2atm}} \qquad (2.55)$$

where:

C_v = ventilation rate for CO_2 m^3/hr

ΣP_{co2} = total production of CO_2 m^3/hr

CO_{2max} = maximum CO_2 allowable = 0.35%

CO_{2atm} = CO_2 concentration in the air = .0003%

2.6 Bodyweight

Bodyweight of the chickens was calculated as a function of age. Data used were from the DeKalb XL-Link Pullet and Layer Management Guide, 2nd edition. A linear regression equations was fitted to the data and the following equation found to be best fit.

$$BW = .39883 * Age^{.400275} \quad \text{for age 19-40 weeks} \qquad R = 0.94 \qquad (2.56)$$

$$BW = 1.68548 * Age^{.011659} \quad \text{for age 41-78 weeks} \qquad R = 0.99 \qquad (2.57)$$

where

BW = bodyweight of the chickens kg

Age = age of chickens weeks

Change in weight was also estimated according to the same source. An average value was used to determine the change in weight because it was not significant to use otherwise. The change in weight was estimated as:

Age (Weeks)	Gain (g/day)	S.D.
18 - 23	8.3	1.60
24 - 28	3.8	1.30
29 - 40	1.5	0.42
41 - up	.5	0.00

Mortality was estimated from the management experience, of house seven, was .8% per month or 2.67×10^{-4} per day.

2.7 Feed Consumption

Marsden and Morris (1980) fitted a third order polynomial equation to describe the response of energy intake, of white egg layers to dry bulb temperature, within the cage, from 30 experiments. Temperature within the cage were assumed the same as room temperature.

$$Y_1 = 1584.3 - 33.47 * t_i + 1.562\, t_i^2 - .0349\, t_i^3 \qquad (2.58)$$

At a given temperature, energy intake increases slightly if dietary energy concentration is increased, even though feed intake decreases (Morris, 1968). In

34 experiments, the average increase in energy intake was 46 kJ/day per bird for each MJ/kg increase in dietary energy concentration. Therefore, assuming that the previous equation gives the energy intake for birds eating a typical diet containing 11.3 MJ/kg of energy, then the following equation estimates the energy intake adjusted for any dietary energy level, E (MJ/kg)

$$Y_2 = Y_1 + 46.0 * E - 519.8 \qquad (2.59)$$

Feed intake was estimated by

$$F = Y_2/E \qquad (2.60)$$

where:

Y_1 = metabolizable energy intake, kJ/d per bird, layers feed a diet containing 11.3 MJ/kg, for white egg layers only

Y_2 = metabolizable energy intake, kJ/d per bird, for white egg layers

E = metabolizable energy content of diet, MJ, ME/kg

F = feed intake, g/d per bird

Feed intake also changes with age (Charles, 1984). Table 2.3 gives values of another multiplier, f_1 age factor, also taken from ADAS data archives.

Feed intake estimation was taken a step further, for adjustment of feeding equipment. Many designs of feeding equipment which are standard in both

Table 2.3 Values of Factor f_1, which adjusts feed intake for age.

Period	Week of Age	White Birds
1	20-24	0.764
2	24-28	0.917
3	28-32	0.987
4	32036	1.006
5	36-40	1.022
6	40-44	1.024
7	44-48	1.052
8	48-52	1.044
9	52-56	1.053
10	56-60	1.053
11	60-64	1.030
12	64-68	1.020
13	68-72	1.032

Note: Calculated from Gleadthorpe data for 17 flocks feed 17 g/day per bird GRP, at 24°C.

the industry and in nutrition experiments have been found to be substantially wasteful (Elson, 1980). Therefore, a second adjustment factor, f_2, was used. Values taken from the data of Elson (1980) are given in Table 2.4. Allowing for the two adjustments F_f can be finally estimated as:

$$F_f = (Y_2 * f_1 * f_2)/E \qquad (2.61)$$

where:

F_f = final estimate of feed intake g/day per bird

f_1 = age factor adjustment

f_2 = feeding system design factor adjustment

Table 2.4. Values of the Factor f_2, which Adjusts Feed Intake for Wastage using Various Feeding Operations

Type of Feeder	f_2
Hopper and trough	1.000
Chain	0.965
Hopper and trough plus grid	0.958
Spiral	0.948
Sleeve	0.986

2.8 Egg Production

Fisher, Morris, and Jennings (1973) presented the most fundamental model for predicting the egg output response to nutrient intake. The model was deliberately limited to a few relatively simple algebric functions. An attempt was therefore made to find a simple function, which would simulate the shape of the responses curve described by Fisher et al. (1973).

Charles (1984) found a satisfactory approximation for protein content within the normal commercial range of feed, and for experiments carried out at optimum house temperature, using an inverse polynomial.

$$e_1 = P^2/(4.446 - 0.417P + 0.0309P^2) \qquad (2.62)$$

where:

e_1 = egg output response to protein (g/b/d)

P = standard protein intake g/d per bird

The standard protein intake P was adjusted from the original form to conform to the protein standard used in Charles's equation. Then the equation for the standard protein intake would be

$$P = F*C/100 \quad (2.63)$$

where:

C = protein content in the feed %

F = feed intake g/d per bird

The protein content in the feed was 16% used for this study. No attempt was made to adjust the egg output response to photoperiod. The photoperiod used in this study was considered to be near optimum.

There is insufficient evidence to make estimates with confidence about the effect of temperature upon egg production on a daily bases (Personal Communication, Flegal, 1985). The effect of temperature was used when the temperature was above to 30 C. The depression was given by subtracting the following equation from the first estimate e_1.

$$D_1 = 10.98 + 2.14t_{ia} - 0.2335t_{ia}^2 + 0.00522t_{ia}^3 \quad (2.64)$$

where

D_1 = depression factor for temperature g/d per bird

t_{ia} = average daily inside temperature C

Morris (1968) reviewed the effects of light on poultry and described the response in egg production, on a hen-hosed basis, H, eggs per bird in 336 days, to light intensity, I, as

$$H = 232.4 + 15.18 \, Log_{10}(I) - 4.256 \, (Log_{10}(I))^2 \qquad (2.65)$$

For this function, the maximum value of H occurs when I = 60.4 Lux, for which H = 245.9 eggs per 336 days. The depression factor for light intensity, D_2 was calculated if the light intensity were below the 60.4 Lux. Assuming a mean egg weight of 60g, and adjusting to 364 days:

$$D_2 = 2.41 - 2.711 \, log_{10} \, (I) + .76 \, (log_{10}(I))^2 \qquad (2.66)$$

where:

H = egg production per hen housed per year

I = light intensity LX

D^2 = depression term for light intensity g/b/d

For this model light intensity was assumed optimal, and I = 60.4.

Egg output was also adjusted for age factor A, which calculated from Gleadthorpe data for 17 flocks fed 17 g/d per gird GRP, at 24 C. Table 2.5 gives the values of A factor.

The predicted egg output e_3 (g/d per bird), was therefore:

TABLE 2.5. Values of Age Factor A, which Adjusts Egg Output.

Period	Weeks of Age	White Birds
1	20-24	0.32
2	24-28	0.93
3	28-32	1.09
4	32-36	1.12
5	36-40	1.11
6	40-44	1.11
7	44-48	1.11
8	48-52	1.09
9	52-56	1.06
10	56-60	1.05
11	60-64	1.02
12	64-68	1.00
13	68-72	0.97

$$e_3 = (e_1 - D_1 - D_2)*A \qquad (2.67)$$

where:

e_3 = egg output, final estimate g/b/d

A = egg output adjustment factor for age

2.9 Cost Calculations

This includes fuel, electricity, feed cost and egg revenue.

2.9.1 Fuel Cost

Supplemental heat was used as an option in the model. The supplemental heat needed was calculated from heat balance equation. It could be written as shown in the following:

$$q_{sp} = q_b + q_v - q_s - q_e \qquad (2.68)$$

where:

q_b = sensible heat from chickens kJ/hr

q_v = sensible heat from lights at day time kJ/hr

q_s = sensible heat loss by ventilation kJ/hr

q_e = sensible heat loss by building kJ/hr

$$q_v = q_{vi} - q_{vo} = C_p\ M\ (t_i - t_o)$$
$$= 1.0035 * M * (t_i - t_o) \quad (2.69)$$

where:

q_{vi} = sensible heat leaving the room kJ/hr

q_{vo} = sensible heat entering the room kJ/hr

M = ventilation air mass kg/hr

$$q_{sp} = A * U\ (t_i - t_o) + 1.0035 * M\ (t_i - t_o)$$
$$- q_s - q_e \quad (2.70)$$

Fuel cost was then calculated by multiplying the supplemental heat needed by its price and divided by the energy content of the fuel used:

$$F_{uc} = (q_s * P_f)/E_f \quad (2.71)$$

where:

P_f = fuel price $\$/m^3$

E_f = energy content in fuel kJ/m^3

2.10 Electricity Cost

The two 45 cm variable speed fans were fixed at constant rate, and they operated continuously as minimum ventilation rate. Minimum ventilation rate cost was calculated by measuring power in watts consumed at low air flow rate on the variable speed fan and multiplied by electricity price in dollars per kilowatt hour for each fan.

$$E_c = (E_p * .135) * N \qquad (2.72)$$

where:

E_c = electricity cost \$/hr

E_p = electricity price \$/kW hr

0.135 = power measured at min. vent. rate kW

N = number of fans operating N=2

For fans operated to control the temperature, electricity cost calculated according to information supplied by the fan manufactures performance tables, it was 11.81 cubic feet per min, per watt was used to calculate electricity usage per hour, which then multiplied by electricity price. The daily electricity cost was calculated by summing the cost for every hour for both fans during one day.

$$KWH = (Vrate \times Eusag)/1000 \qquad (2.73)$$

where:

Vrate = ventilation rate above minimum ventilation rate cfm

Eusag = electricity consumption = 0.0847 W/cfm

KWH = electricity usage in kw

2.11 Feed Cost

Feed cost was calculated by multiplying feed intake by feed price.

$$F_{dc} = (F_{in} * F_{dp}) \times 1000 \quad (2.74)$$

where:

F_{dc} = feed cost 1,000 $/day

F_{in} = feed intake kg/day

F_{dp} = feed price $/kg

2.12 Egg Revenue

Average egg weight was estimated from data published by Hy-Line management guide, third edition, for variety W 36. Two equations were used to estimate average egg weight based on age of the bird.

$$Egw = 13.5203 * Age^{.4087} \quad \text{for age 22 to 40 weeks} \quad R = 0.98 \quad (2.75)$$

$$Egw = 36.1114 * Age^{.1371} \quad \text{for age 41 to 80 weeks} \quad R = 0.99 \quad (2.76)$$

where:

Egw = average egg weight gr

Age = Age of birds weeks

The number of eggs was determined by dividing egg production estimated from the model by the average weight calculated from the standards and then calculated per 1,000 chickens. Number of dozens was also calculated by dividing number of eggs for (1,000 chickens) by 12. Then the revenue was calculated by multiplying number of dozens by nest run price.

Cost was estimated for that day by summing the electricity cost, feed cost, and fuel cost (if used). Then this amount was subtracted from the revenue for the same day, and reported as (revenue margin).

2.13 Outline of Computer Program

The mathematical algorithms discussed early were incorporated into subroutines for computer computation. In the simulation these subroutines were activated and controlled by a main or executive program. A flow chart of the main program and the subroutines are shown by Figures 2.3 to 2.26.

The computer program was set up to either operate in a verification mode based on actually recorded(measured) input ventilation rate, inside and outside average daily temperature or a simulation mode based on Weather model.

The input routine was designed to be used interactively to enter all information needed to run the main program. The input routine may use old files stored on a disk, change some parameters from an old

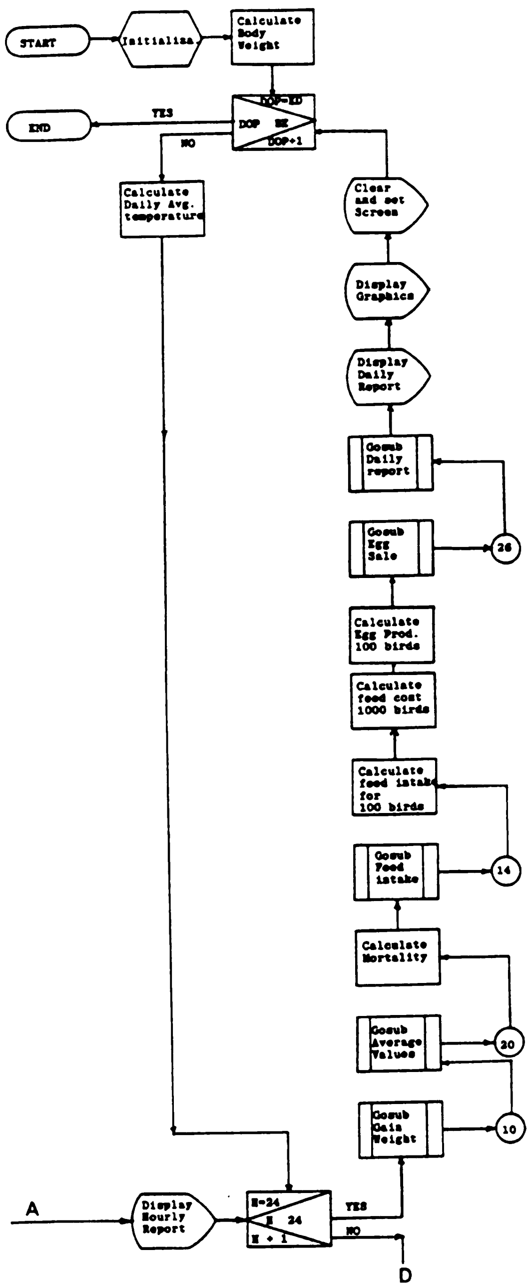


Figure 2.3 Main Program

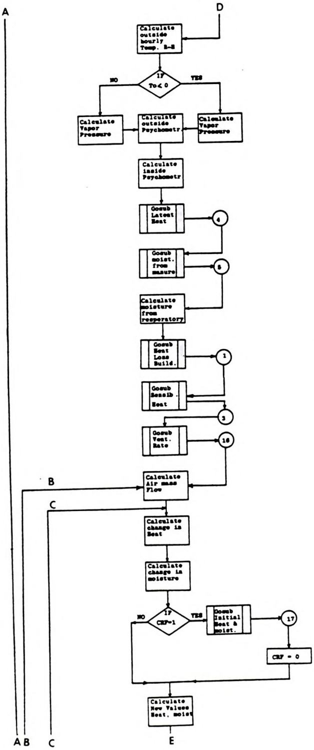


Figure 2.3. Continued

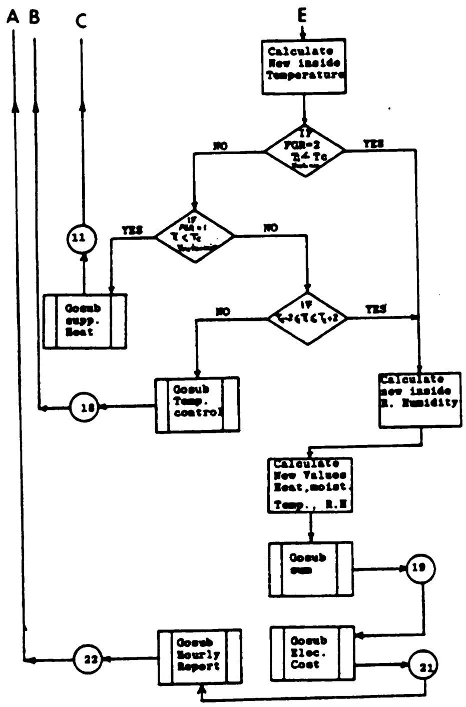


Figure 2.3. Continued.

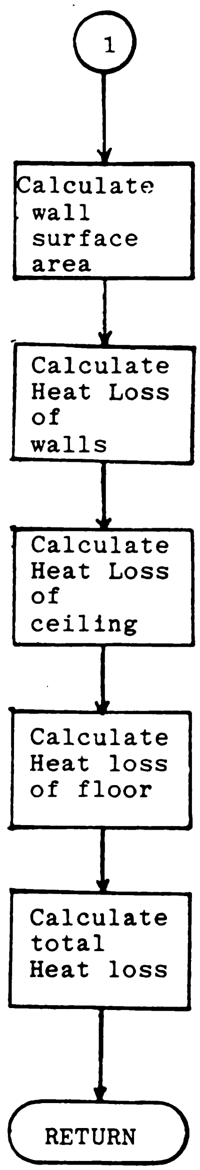


Figure 2.4. Subroutine Number 1--Heat Loss Through Building.

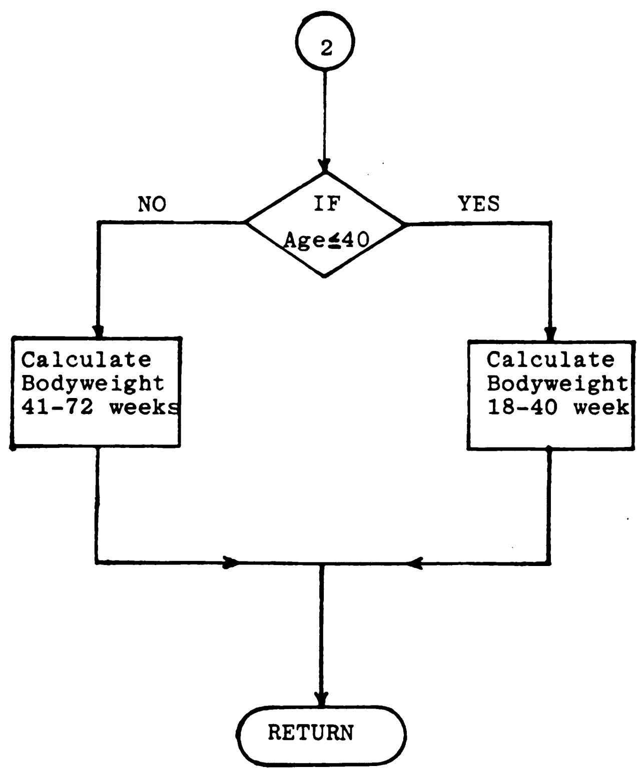


Figure 2.5. Subroutine Number 2--Body Weight of Chickens.

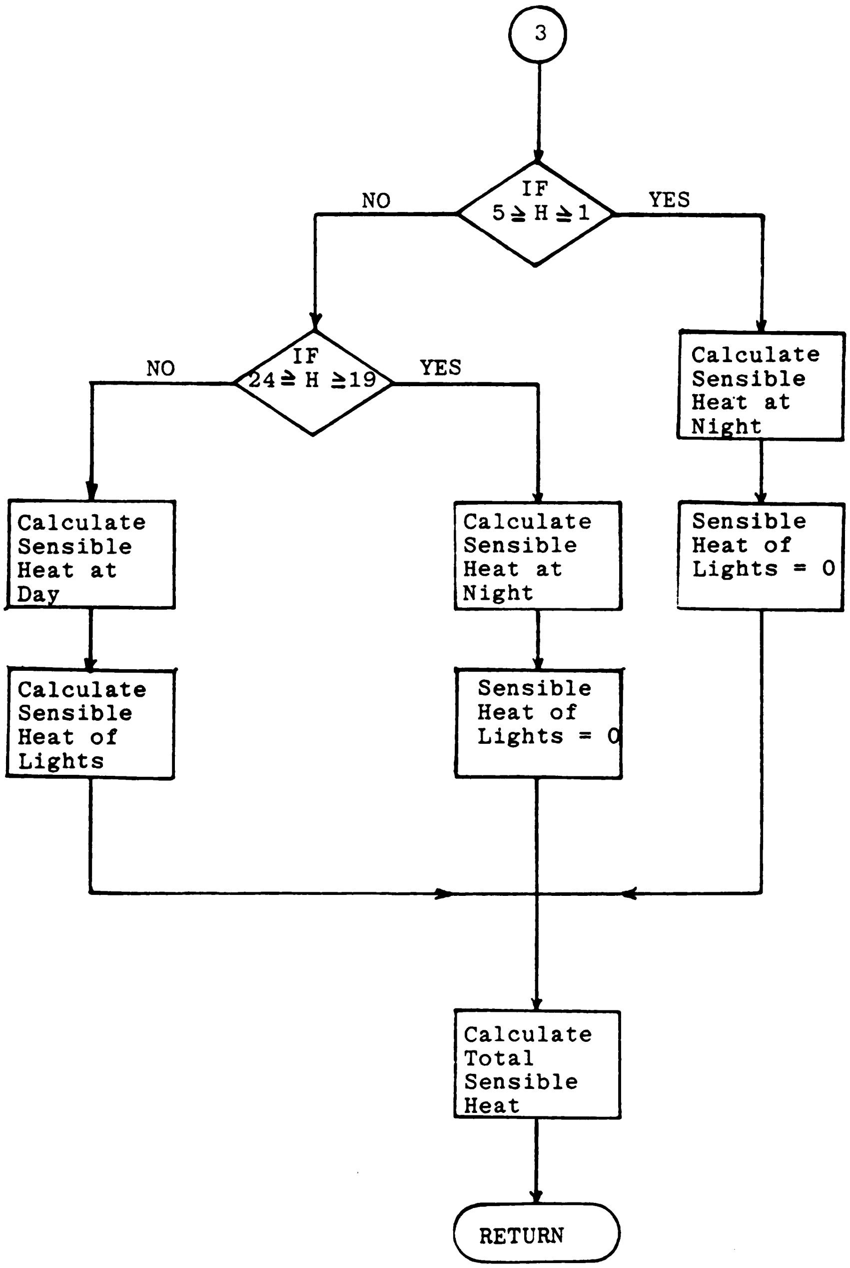


Figure 2.6. Subroutine Number 3--Sensible Heat from Chickens.

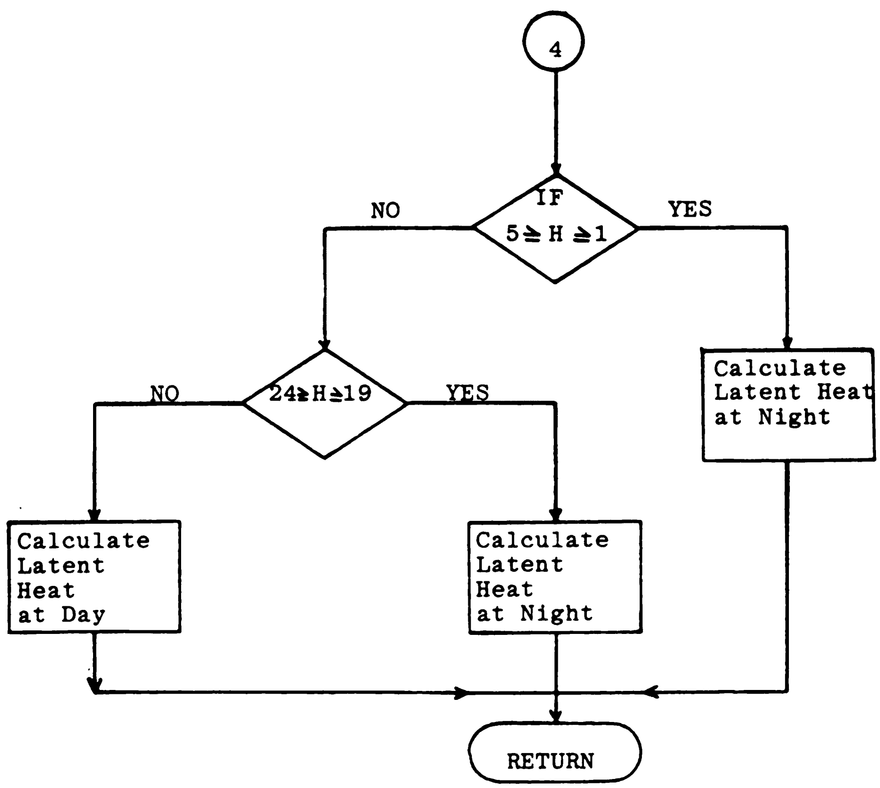


Figure 2.7. Subroutine Number 4--Latent Heat from Chickens.

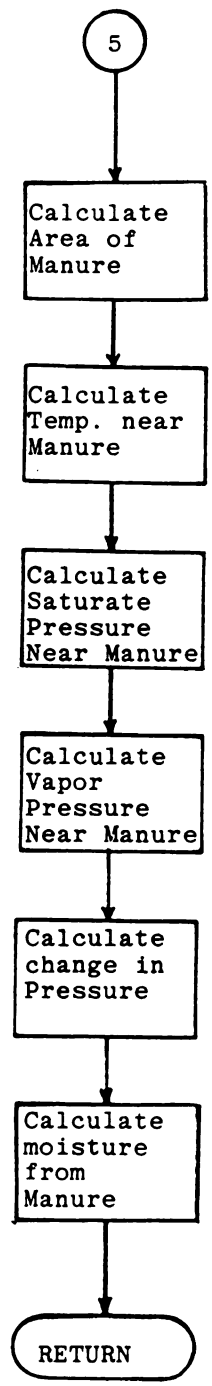


Figure 2.8. Subroutine Number 5--Water Evaportation from Manure.

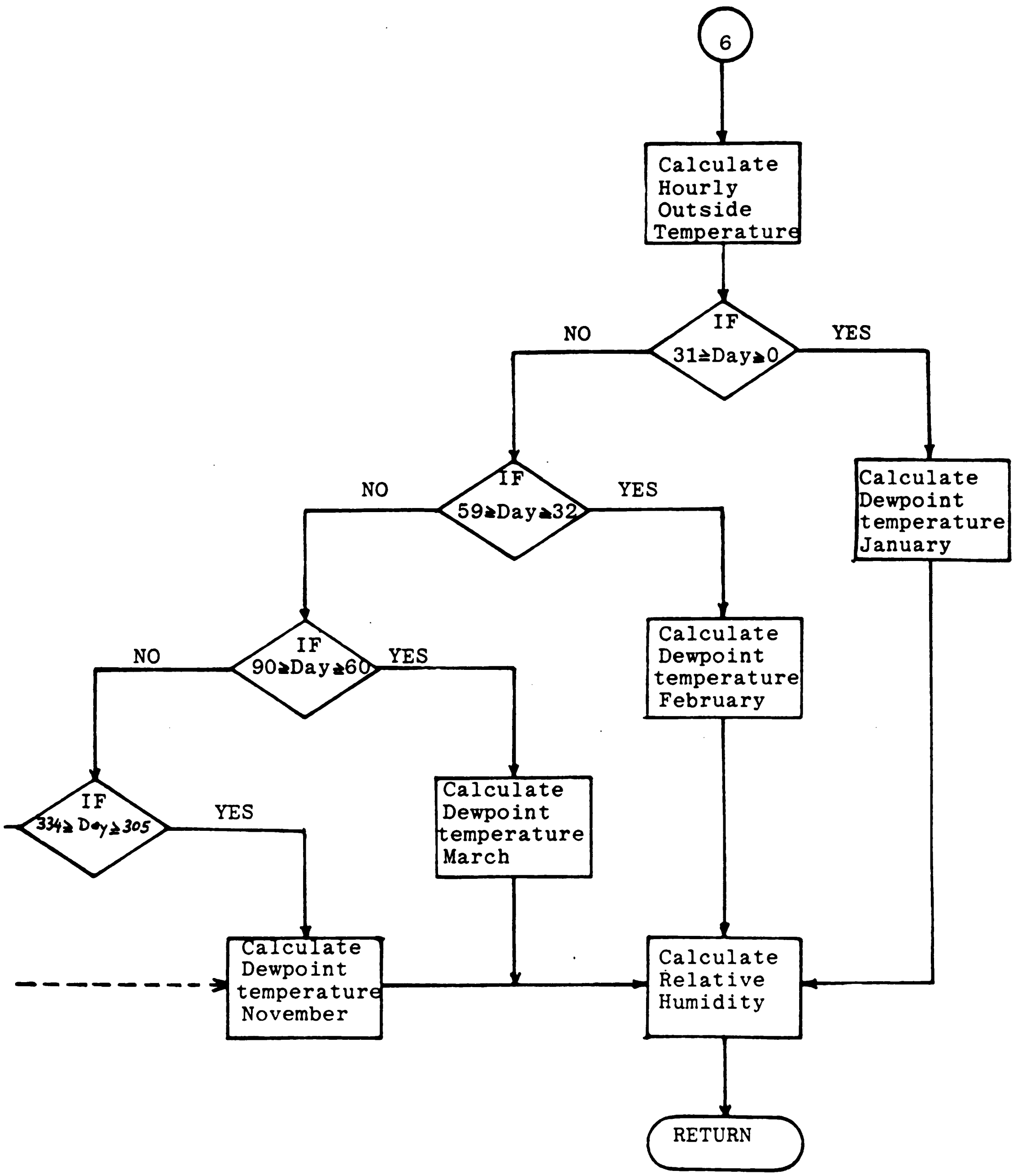


Figure 2.9. Subroutine Number 6--Outside Hourly Ambient Temperature and Relative Humidity.

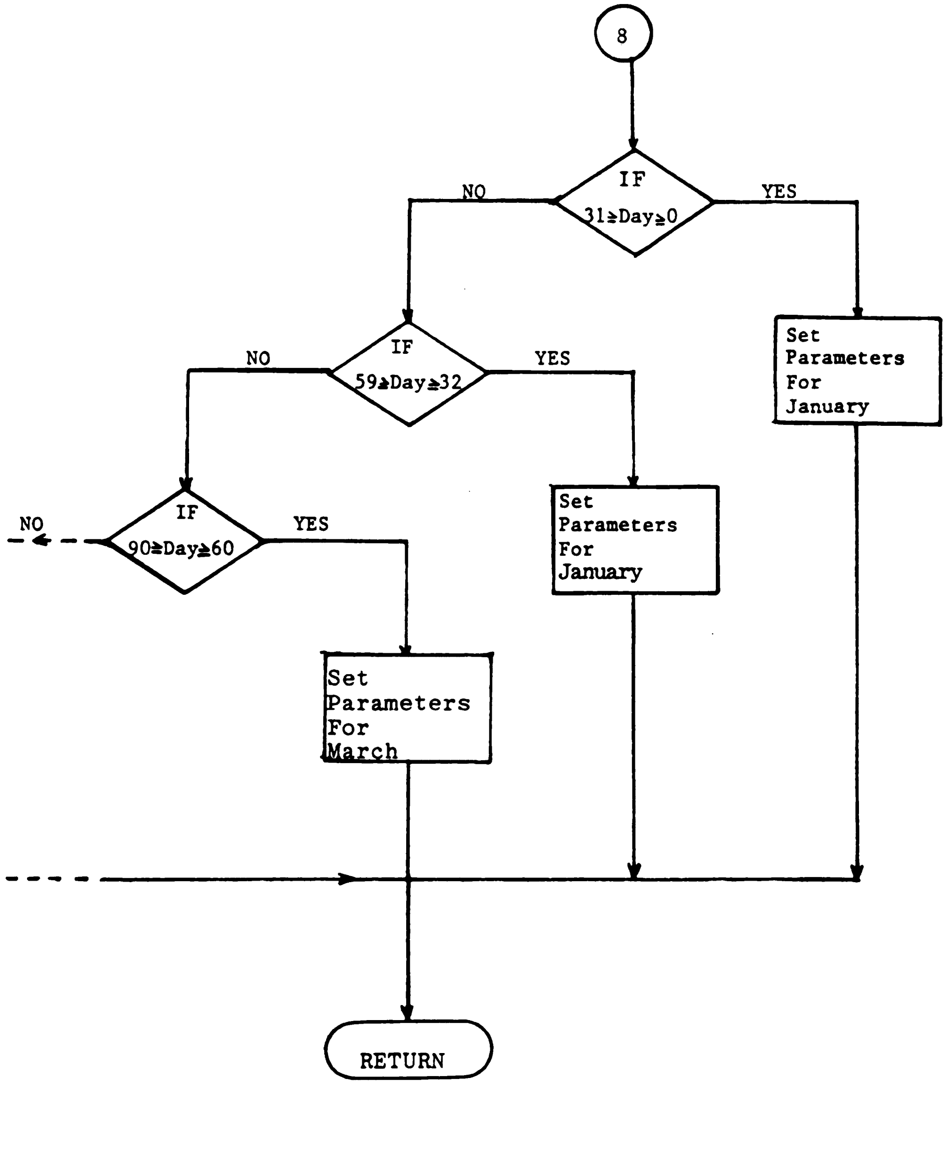


Figure 2.10. Subroutine 8: Julian Day (Calendar)

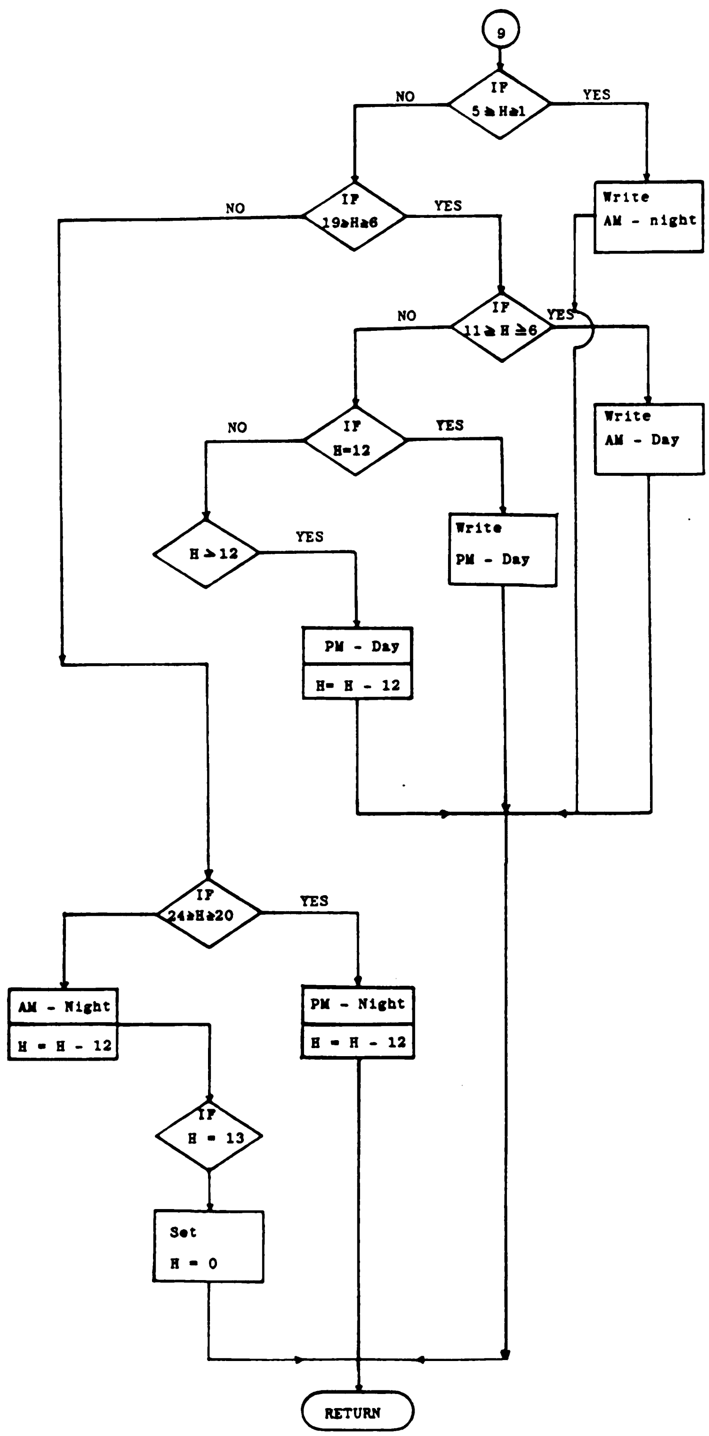


Figure 2.11. Subroutine Number 9--Day and Night.

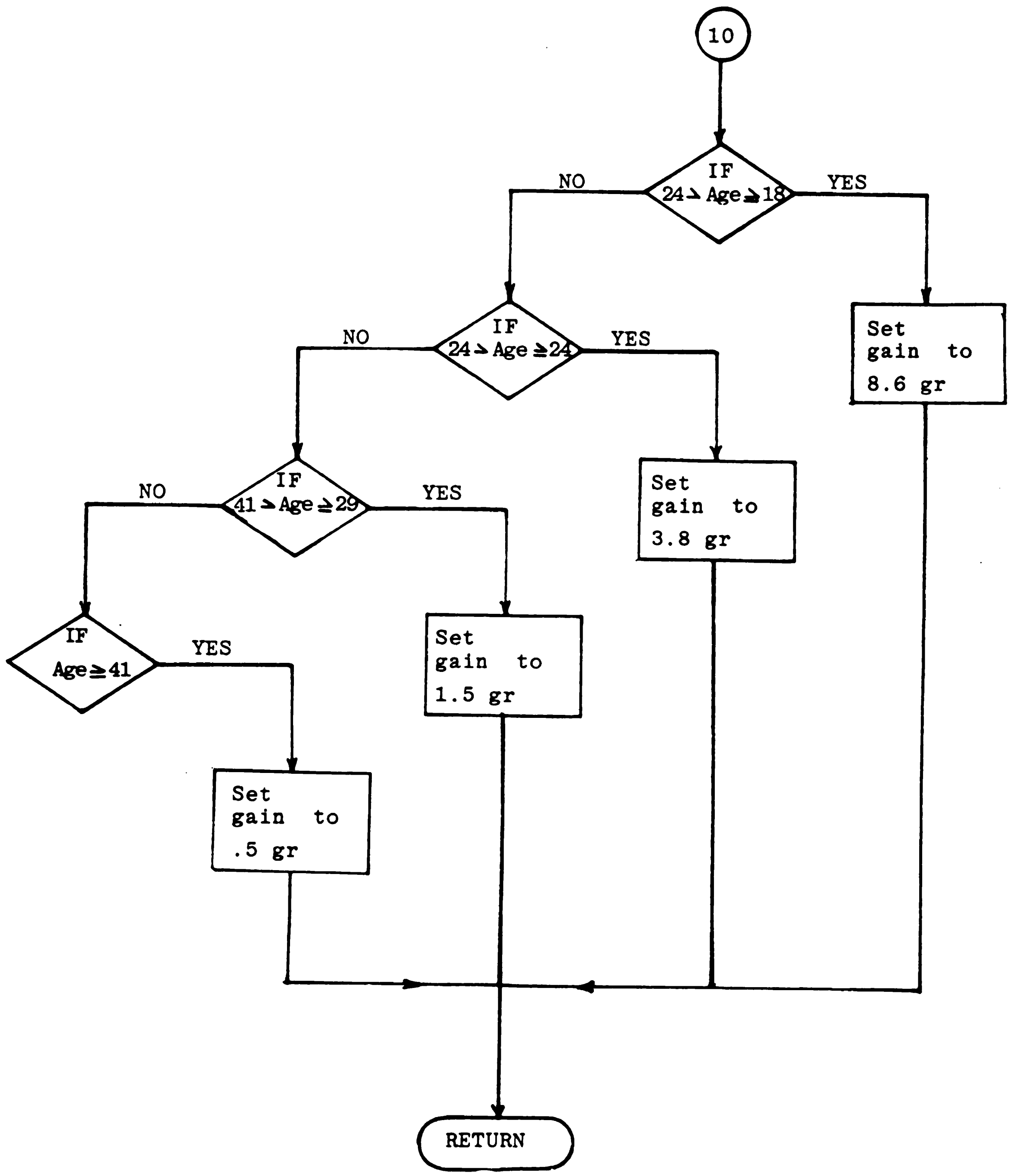


Figure 2.12. Subroutine Number 10--Gain in Weight.

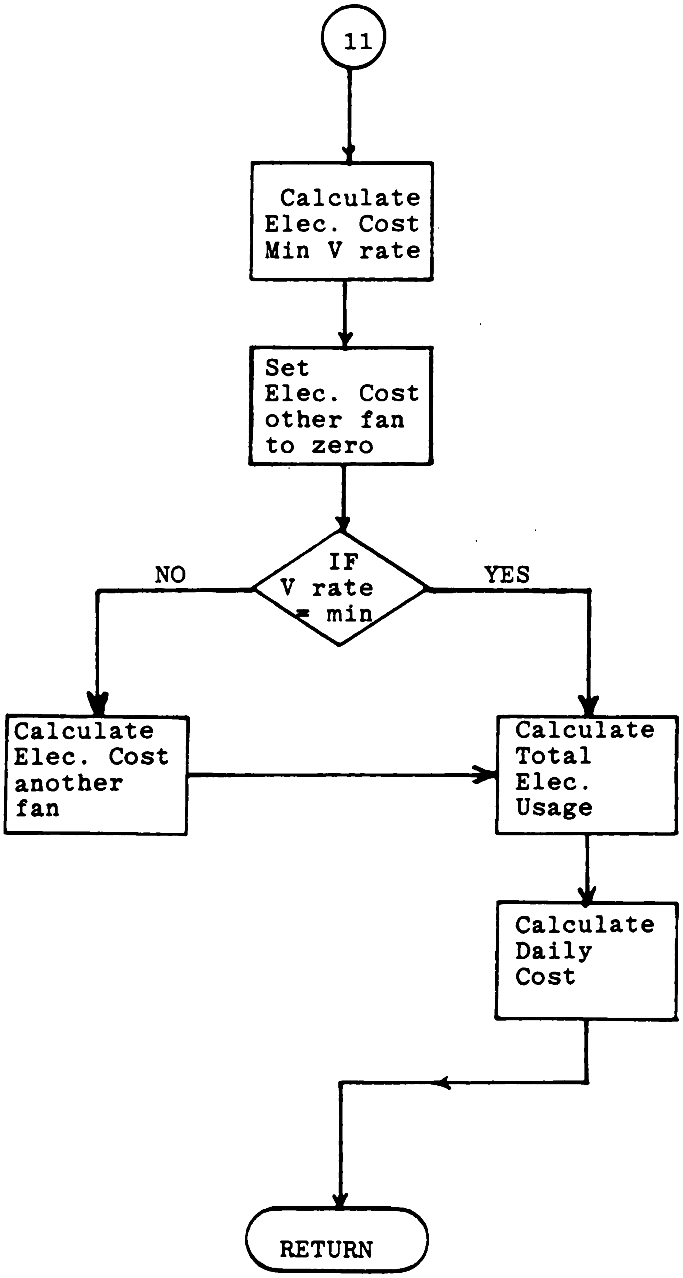


Figure 2.13. Subroutine Number 11--Electricity Cost.

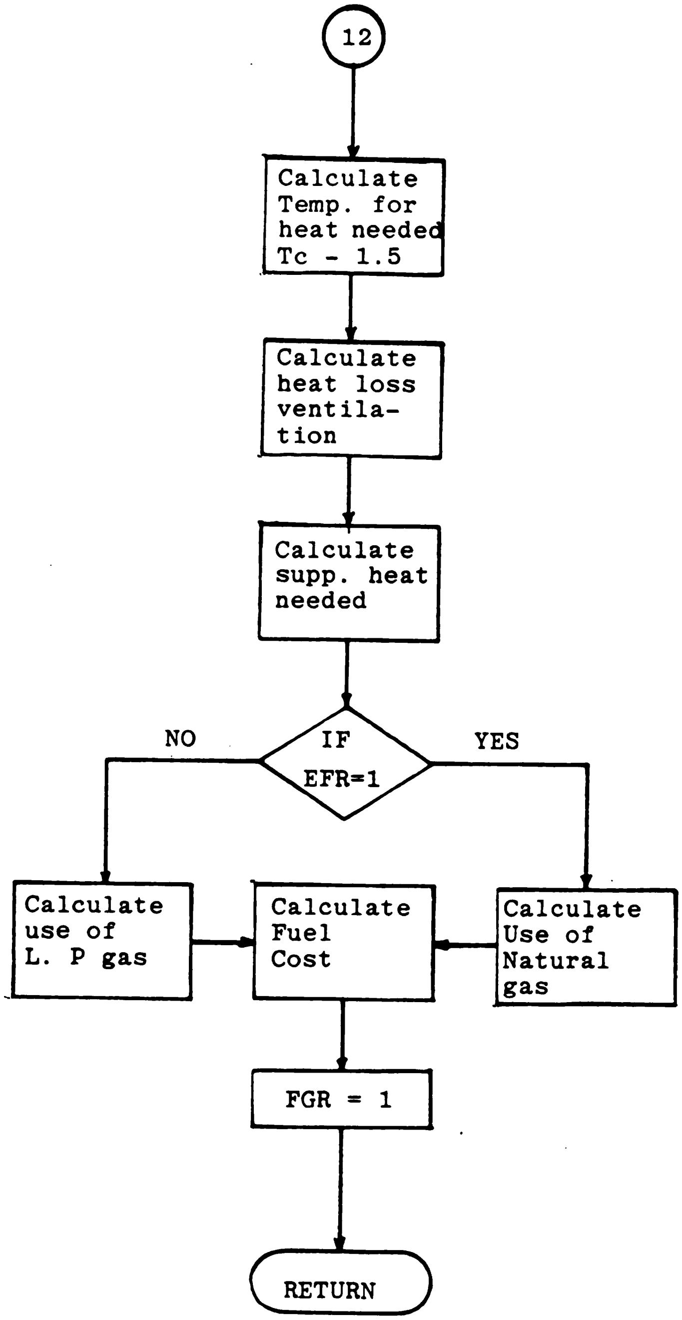


Figure 2.14. Subroutine Number 12: Supplemental Heat Needed.

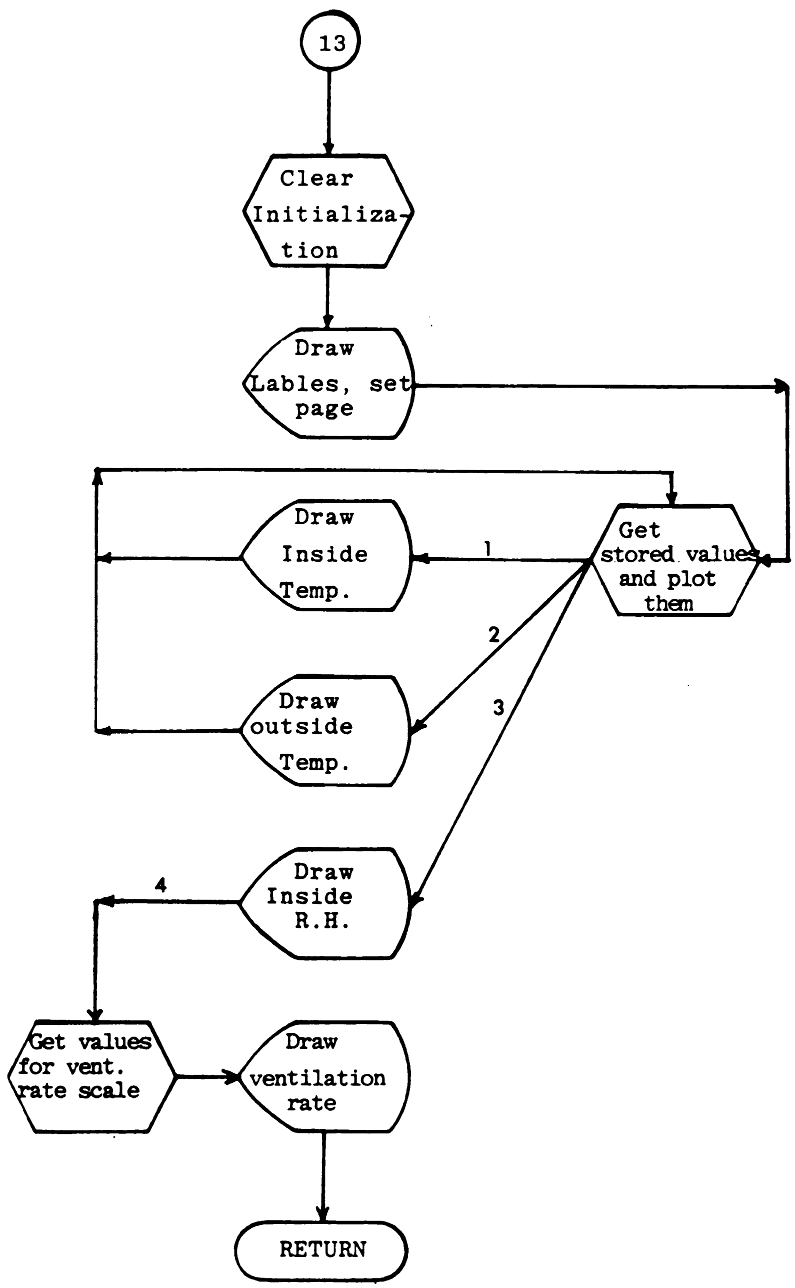


Figure 2.15. Subroutine Number 13: Graphics Presentation.

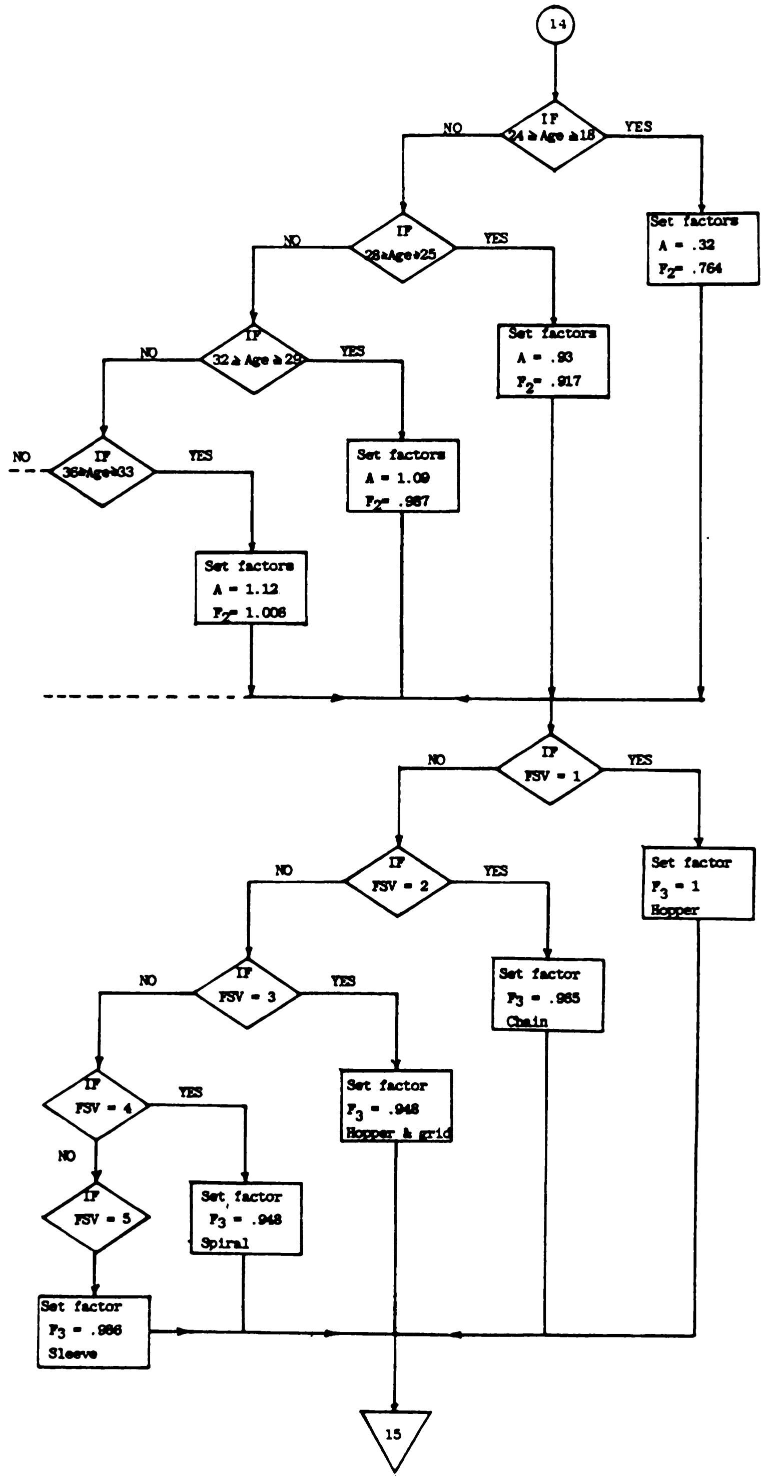


Figure 2.16. Subroutine Number 14: Estimate of Age and Feed System Factors.

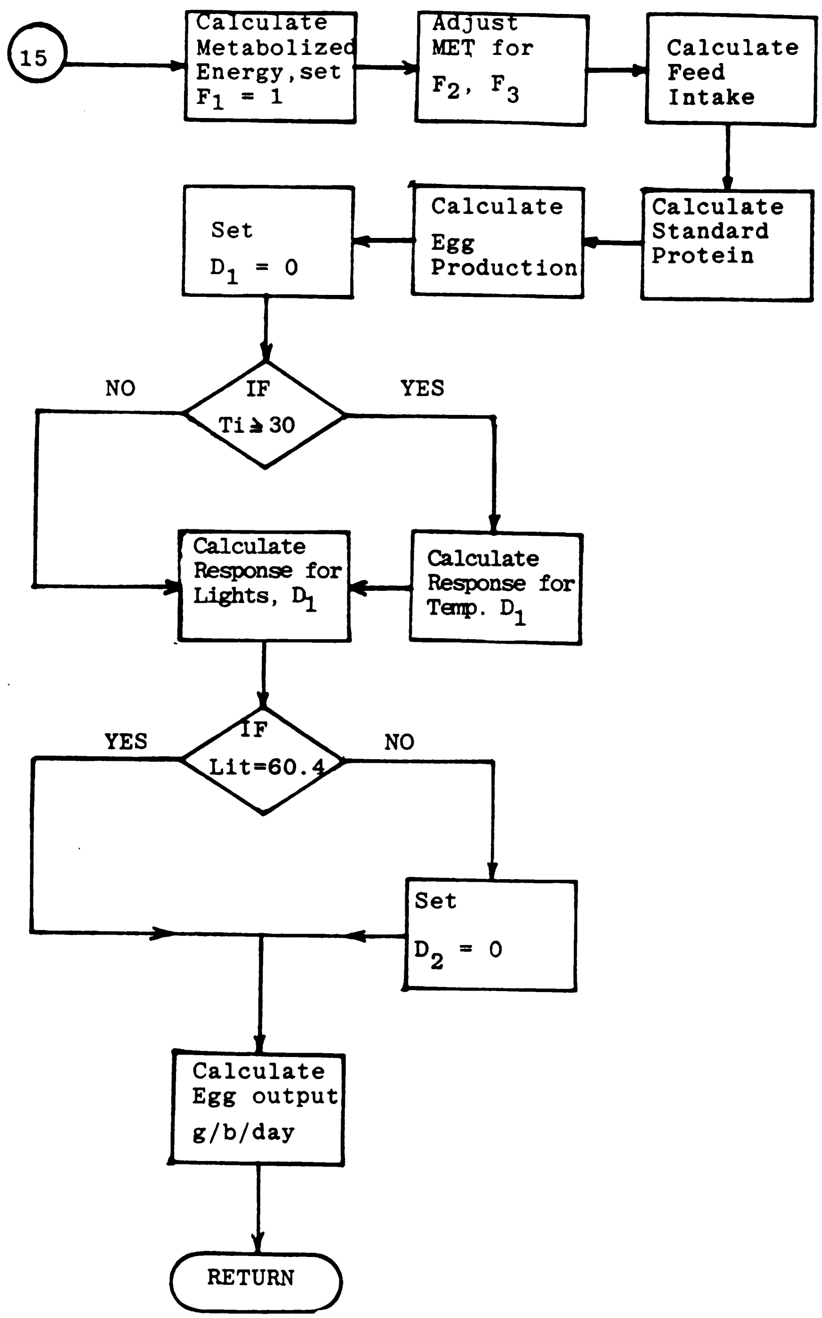


Figure 2.17. Subroutine Number 15: Feed Intake and Egg Production.

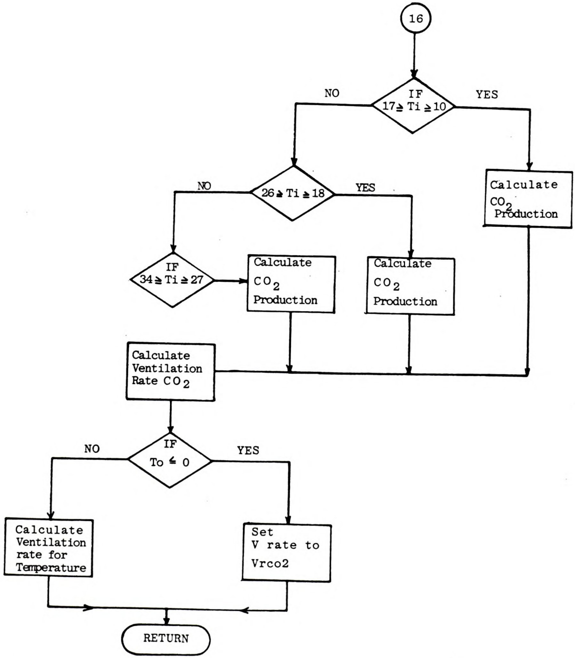


Figure 2.18. Subroutine Number 16: Ventilation Rate.

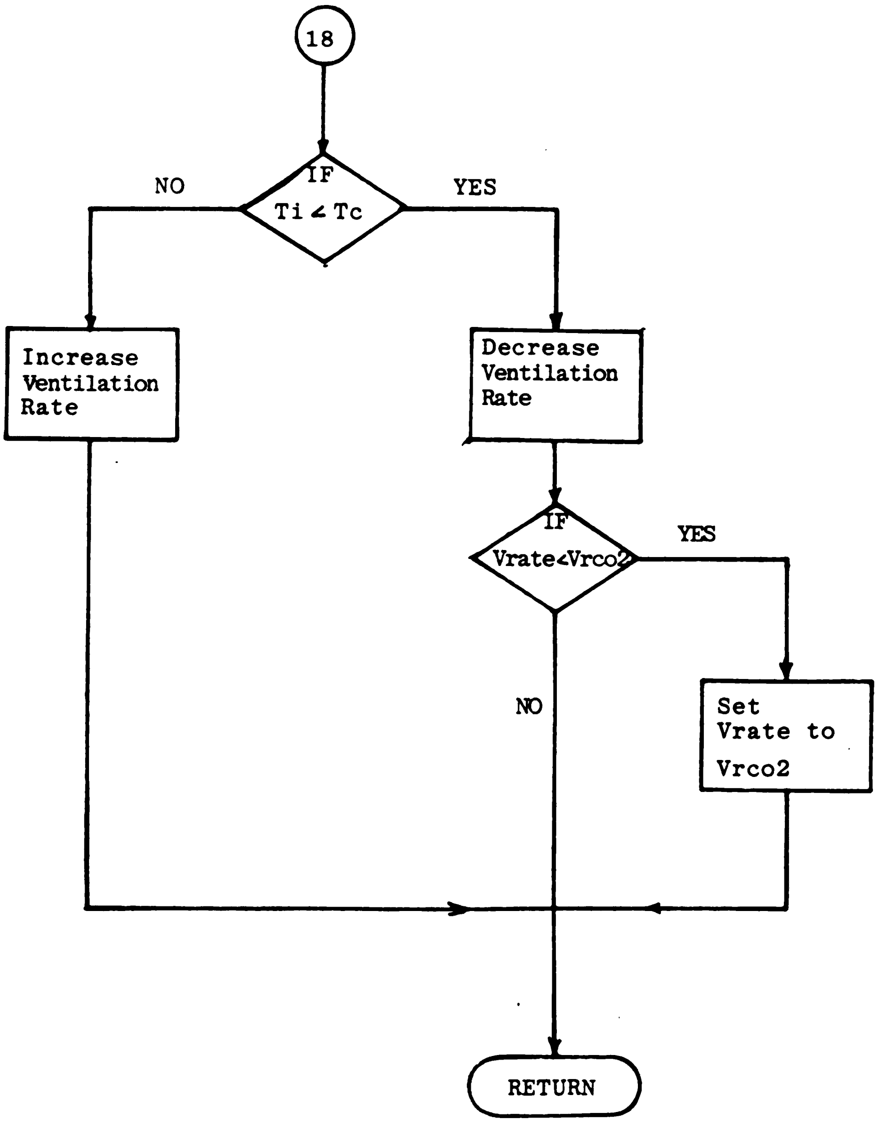
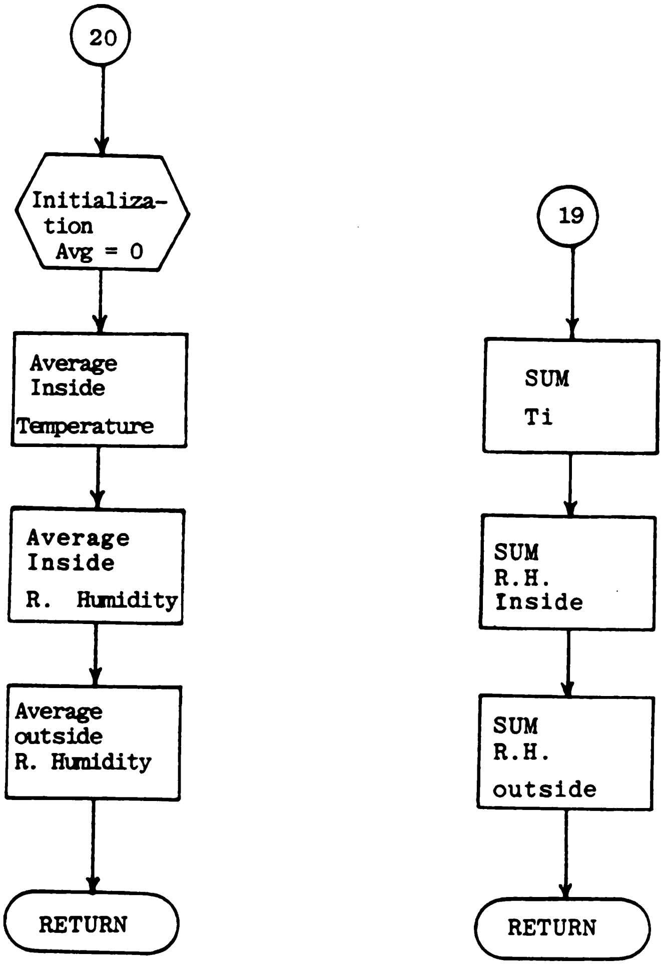


Figure 2.19.--Subroutine Number 18: Control Inside Temperature.



Subroutine Number 20
Averaging the Values

Subroutine Number 19
Summing the Values.

Figure 2.20. Subroutine Number 19: Summing the Values.

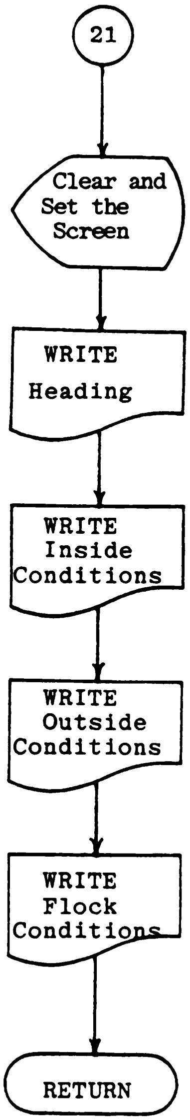


Figure 2.21. Subroutine Number 21: Design Hourly Output Page.

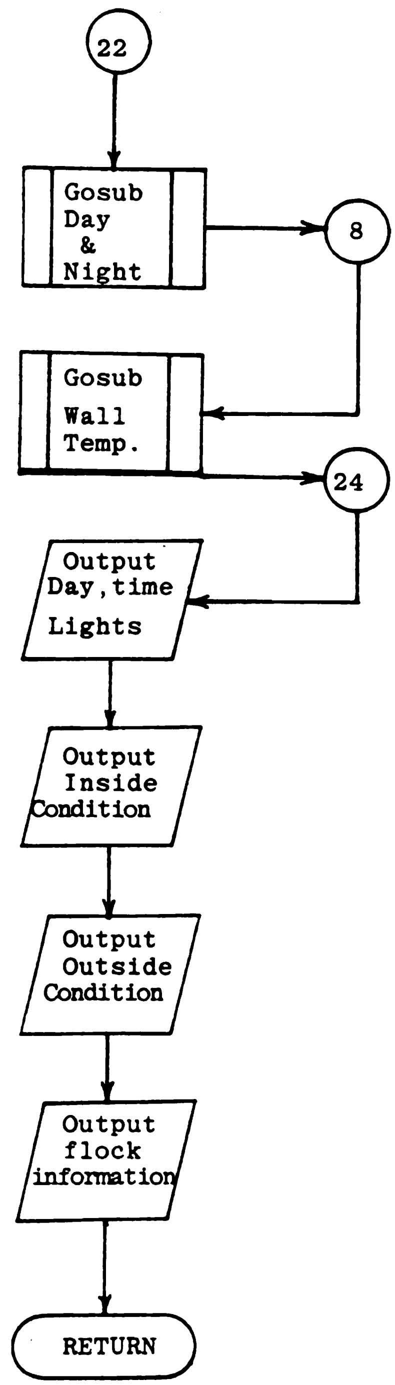


Figure 2.22. Subroutine Number 22: Hourly Report.

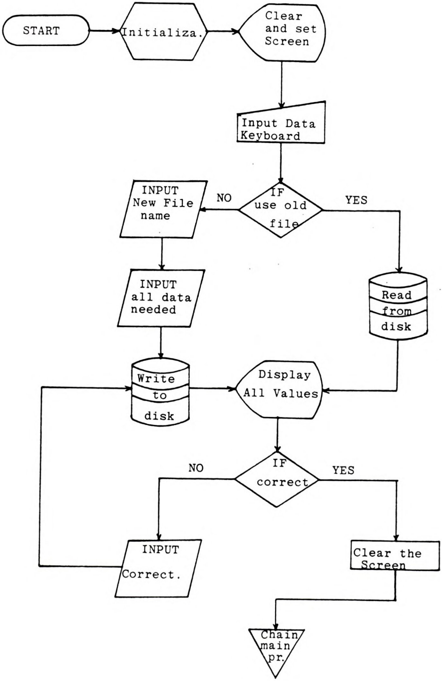


Figure 2.23. Subroutine Number 23--Input Program.

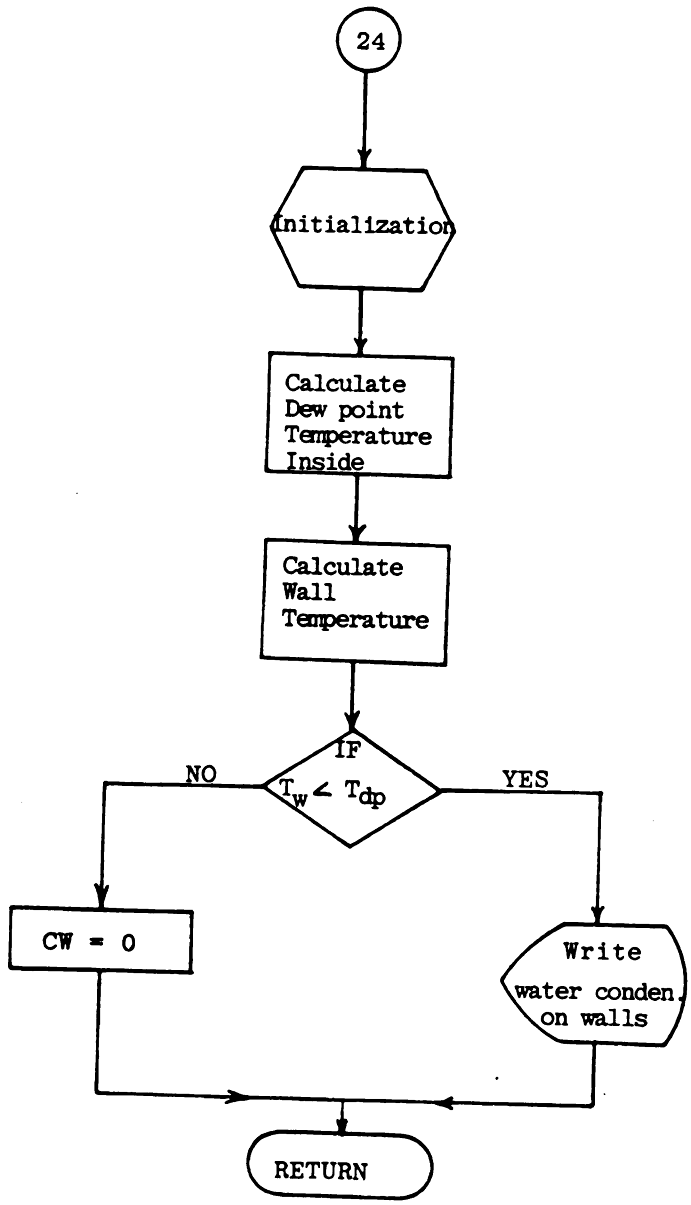


Figure 2.24. Subroutine Number 24: Wall Temperature.

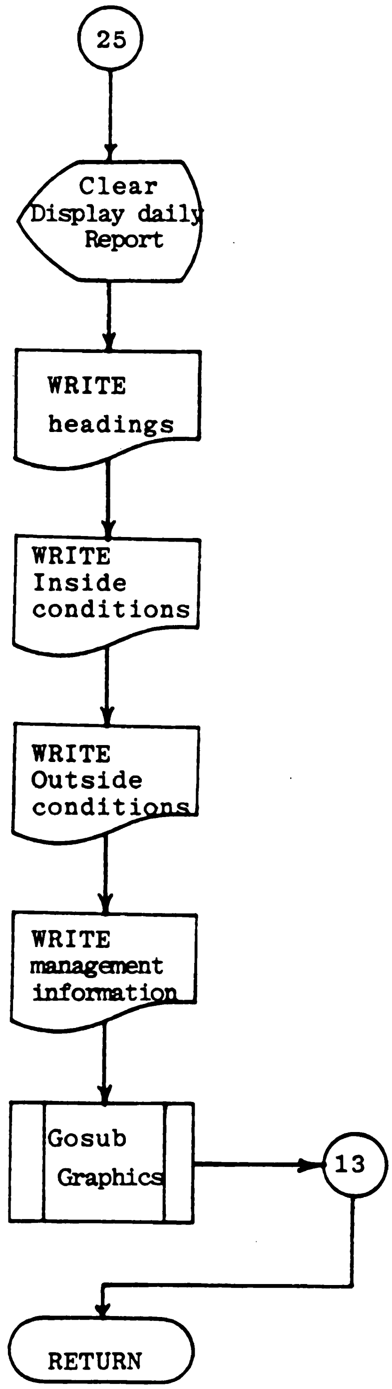


Figure 2.25. Subroutine Number 25: Daily Report.

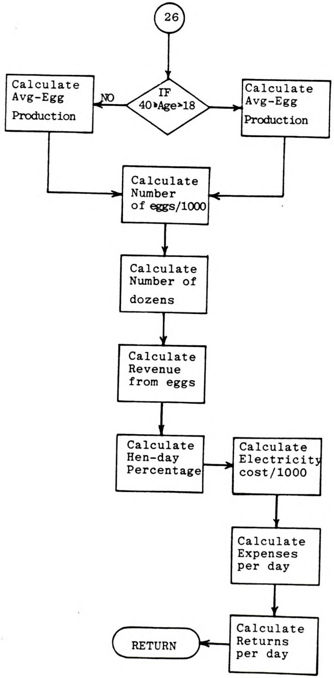


Figure 2.26. Subroutine Number 26: Costs.

file or allow the user to create new files. After all the information have been entered, the input routine will activate the simulation model (main program).

The first operation for starting the simulation on a daily bases was to initialize the fixed parameters. First, the body weight of chickens is calculated based on age of bird. Then the daily simulation started for the period needed. The screen is cleared, and the hourly report displayed (see Figure 2.27), and prepared for further calculations. Average daily temperature for outside was then calculated using the weather model. This was followed by determining the appropriate psychometric properties for the outside air for that hour for the specific day.

The appropriate psychometric properties for the inside air for that hour and day also was calculated.

Heat loss through the building, sensible heat from birds, and if the lights were on, the heat from lights was estimated, then the total sensible heat calculated.

The ventilation rate for temperature control was determined, and the minimum ventilation rate to control carbon dioxide is calculated, if outside hourly temperature were below 0 C. For temperatures above 0 C, ventilation rate is calculated from equation derived from heat balance equation. Before using any ventilation rate, the ventilation rate was checked, and not allowed to be less than the ventilation rate for carbon dioxide control.

The change in heat and moisture was calculated and added to initial values, then the new heat and moisture content of air was used to determine the new inside temperature. This value was checked, if it was in the range previously set, then it was passed for further calculations and to determine the new relative humidity. If it was not, a control subroutine was used to increase or decrease ventilation rate, and checked against the minimum allowed, then returned to the main program to calculate a new inside temperature.

The new values of heat, moisture, inside temperature, and relative humidity were set to be initial values for the next hour, and stored in an array for further use in graphics.

The wall temperature and dewpoint temperatuare inside was calculated and compared to determine if water condensation may occur. Then the inside and outside conditions were displayed on a previously prepared screen.

After 24 hours of calculations, the age of chickens was determined, the gain in bodyweight was estimated and mortality per day calculated. Feed intake was then calculated based on average daily inside temperature and feed cost for 1,000 birds was calculated. Egg production and egg sale for 1,000 bird was also calculated. Figures 2.27 and 2.28 show a typical output.

The daily report then displayed, included average inside temperature and relative humidity, maximum and minimum temperature that occurred on that day, the outside conditions, average daily temperature, and relative humidity.

The management information was also displayed, which included feed intake per 100 birds, metabolizable energy intake per bird, estimated egg production per 100 bird, percent of hen day production, feed cost, electricity cost, fuel cost if used, and egg revenue for 1,000 bird was calculated and displayed.

The flock information also displayed. That included number of birds, age in weeks, average body weight, and mortality rate calculated on that day.

Then the model will clear the screen and draw the graphics for inside, outside hourly temperature, the relative humidity inside, and ventilation rate on hourly base was also displayed.

```
DATE :                  TIME:                 FARM NANE:
                   HOURLY REPORT                 LIGHTS:

INSIDE CONDITIONS:                 OUTSIDE CONDITIONS:

1-Previous  temperature     C      1-Avg daily temperature     C
2-New       temperature     C      2-Previous  temperature     C
3-Previous rel humidity     %      3-New       temperature     C
4-New      rel humidity     %      4-Previous rel humidity     %
5-Ventilation      rate  m3/hr     5-New      rel humidity.    %

FLOCK INFORMATION:
1-Number of  birds         Birds
2-Age    of  birds         Weeks
3-Avg   bodyweight         kg
4-Feed consumption         g/d/b
5-Egg   production         g/d/b
6-H D   production         %
```

Figure 2.27. Typical Hourly Report Output.

```
DATE :                                          FARM NANE:
                        DAILY  REPORT

INSIDE CONDITIONS:                     MANAGEMENT INFORMATION:

1-Avg   temperature       C            1-Feed intake   /100        kg/day
2-Avg  rel humidity       %            2-MET energy   /bird        kJ/day
3-Maximum        temp     C            3-H D     production        %
4-Minimum        temp     C            4-Est    egg prd/100        kg/day
                                       5-Feed     cost  /100       $/day
OUTSIDE CONDITIONS:                    6-Elec     cost /1000       $/day
1-Avg  daily    temp      C            7-Fuel     cost /1000       $/day
2-Avg  rel humidity       %            8-Egg revenue /1000         $/day
                                       9-Revenues   -   cost       $/day
FLOCK INFORMATION:
1-Nunber of birds     Birds
2-Age     of birds    Weeks
3-Avg  bodyweight     kg               # Hours of water condenzation
4-Bird  mortality     Birds
```

Figure 2.28. Typical Daily Report Output.

After a pause of about 30 seconds, a new hourly report displayed, and all the calculations repeated for new conditions of outside and inside.

2.14 Model Calibration and Verification

The model was calibrated during winter months, and especially adjusted on February 8. This day was used as calibration of the model. Other days selected for validation were February 13, 16, 27, and March, 3 days only.

The model was verified by operating a commercial-type cage laying houses from January 1986 through March 1986. At various time throughout this period, psychometric data were collected for analysis. The principal data collected were dry-bulb, wet-bulb temperature and ventilation rate. Carbon dioxide and ammonia were measured during minimum ventilation rate.

Management information also collected by the poultry department for the same period, and that includes bodyweight, feed consumption, egg production, feed energy, and also prices for feed, egg, and electricity

2.15 Experimental Facilities and Equipment

The floor plan of experimental facilities is illustrated by Figure 2.29. Dry and wet bulb temperature data were collected with CR-21 instrument manufactured by Campbell Scientific, Inc. The temperature was measured with thermister sensors: one dry and one with a cotton wick kept wet with distilled water from a continuous source. The results of these measurements were transferred to the CR-21 and then to a tape recorder. The data loger was programmed to collect data for every 10 minutes. The instrument was set to recover temperatures in degrees Celsius. Since some temperatures for outside air were expected to be below O C, relative humidity measured directly by special sensor design for this purpose (201 sensor).

Wet bulb temperature for inside air was measured by temperature probe (101 sensor) covered with a cotton wick kept wet by an instrument designed in Agricultural Engineering Department at Michigan State University, and a special circuit was built to turn the wet bulb fan on 5 minutes before the reading and turn it off after that.

A 5 volt pulse from CR-21 to transistor 2N2222 turns on LED in OPTO-ISOLATOR which turns on trigger triac. This turns on 1 amp 200 volt triac which

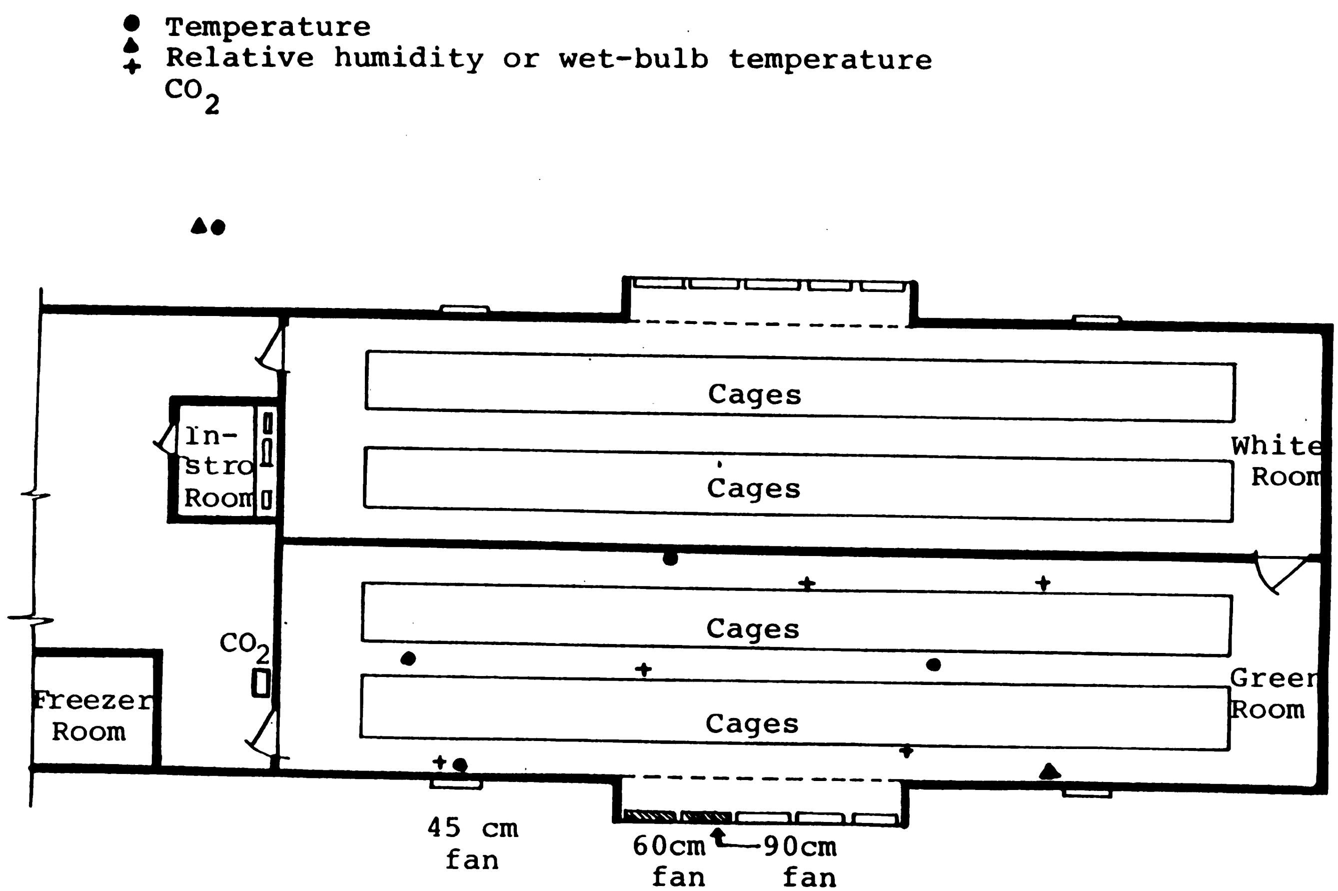


Figure 2.29 Floor plan of the commerical-type poultry house used as base for the simulation.

controls fan motor (see Figure 2.30) holding it on for as long as 5 volt output for CR-21 is present.

For air flow measurements, the variable fans (45 cm) were fixed on fixed rate of 900 cubic meters per hour. Air velocity were measured near the inlet openings and the area of the inlet was measured, then the airflow was calculated by multiplying the area by air velocity. This procedure was repeated several times until the appropriate ventilation rate was achieved.

This ventilation rate was the minimum ventilation rate and for ventilation rate above that, two pieces of equipment designed to interface the fan circuit. The first circuit was the current sensor which connected to circuit breaker of 60 cm fan (see Figure 2.31 for each fan).

When any current passes through Diode resistor assembly, a constant AC voltage is presented to OPTO-ISOLATOR and external LEDs. This causes output triac to switch on feeding 120 VAC to input of CR-21 logic interface.

The second device was the logic interface, Figure 2.32, which connected to the data loger CR-21 input channels. Current sensor (in 240 V fan power line) senses fan "ON" condition and causes 120 VAC

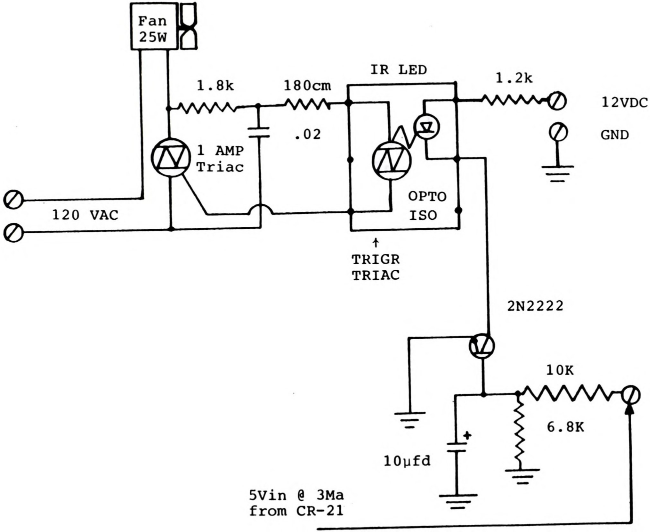


Figure 2.30. Psychrometric Fan Control Circuit.

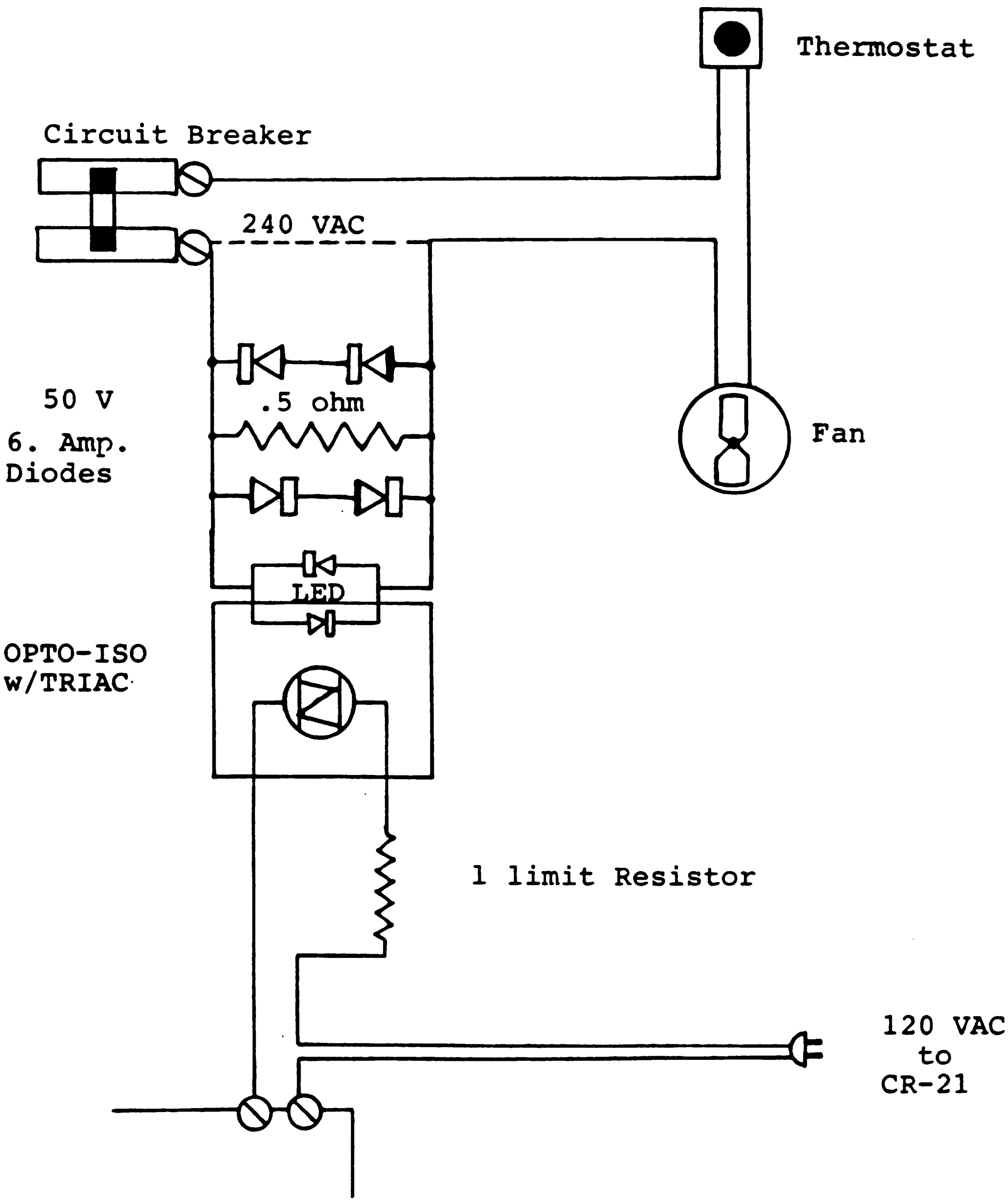


Figure 2.31 Current (I) Sensor circuit.

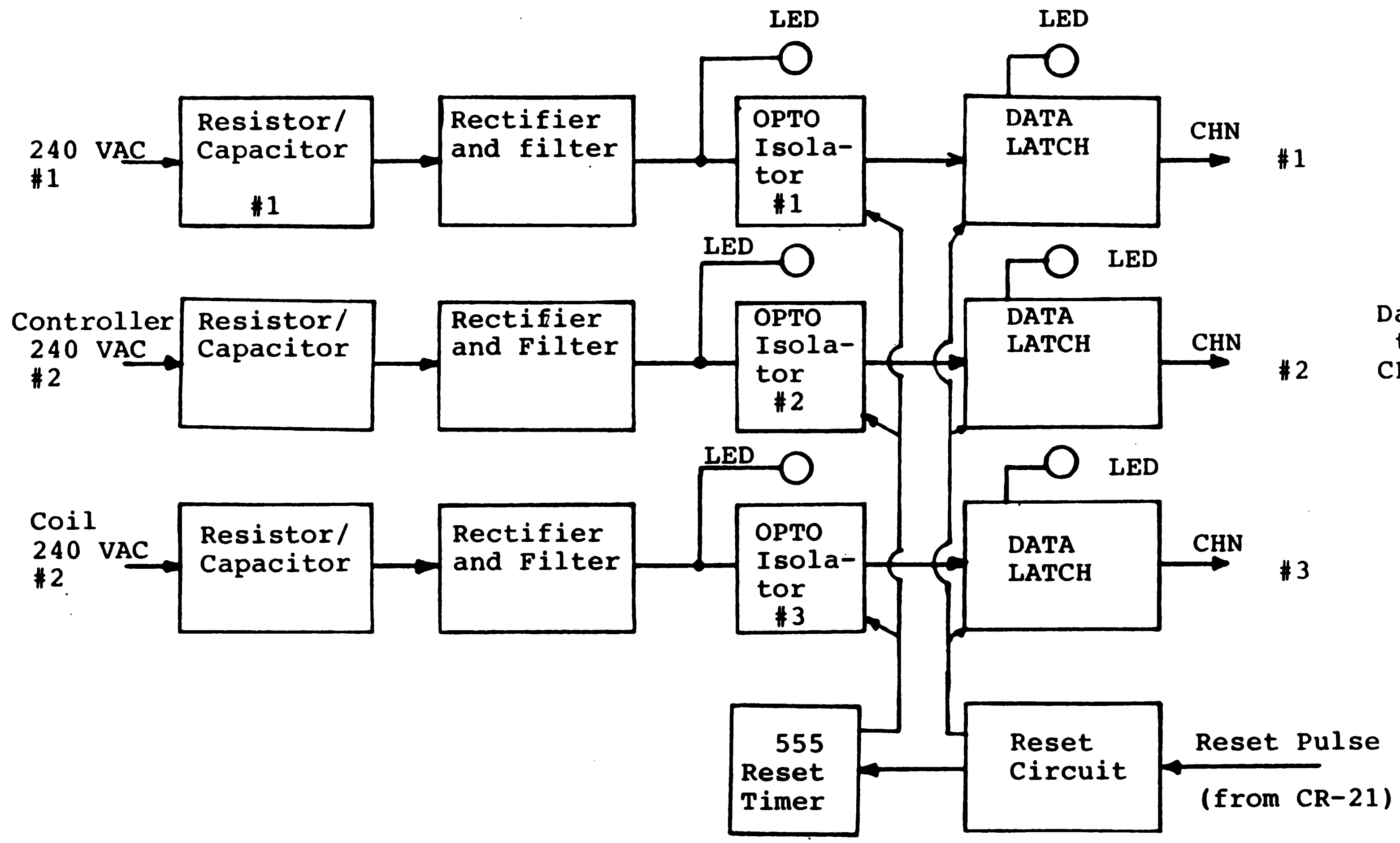


Figure 2.32 Current (I) to CR-21 interface diagram.

(approximately) to appear at the Attenuator inputs (numbers 1 through 3). This voltage is then rectified and filtered, then it is applied (as low voltage, DC) to both on light Emitting Diode and the input of an OPTO- ISOLATOR. The output of the OPTO-ISO is a small pulse (from a capacitor) to the data latch, which holds the (PULSE/information) condition until the CR-21 scans latches for present/absent of fan "ON" condition. At the end of the scan, the CR-21 pulses to "RESET CIRCUIT" causing the "LATCHES" to return to the wait state (Yellow Led ON).

The reset pulse also starts a "555" timer which holds any information that may be present in the OPTO-ISO for approximately 10 seconds. If the fan is still on or comes on during the time period (after reset) then the information is not lost, but is passed on to the latches after "time out" of the reset timer (555).

The 60 cm fan, when it was on, assumed to operate on maximum capacity of 4950 cubic meter per hour. That was the same for the 90 cm fan. Both fans were connected to the CR-21 circuit.

To measure carbon dioxide concentration in the poultry house at the minimum ventilation rate, a gas system collection was designed and built in the poultry house. There was a set of filters (5) placed in different locations and different heights on the cases (see Figure 2.33). Every filter was connected to a P.V.C. tube which then connected to a main panel with valves, each valve controls one filter. All five tubes led to outside the room. A vacuum compressor was connected to the main valve panel through a fine filter. The compressor then pumps the air to an aquarium (see Figure 2.34), which puts upside down. Another tube was placed on the base of the aquarium to allow taking the samples.

There was flush filter placed outside the poultry room to flush the system after each sample.

2.16 Data Collection and Analysis

Dry bulb and wet bulb temperatures were measured at various locations in the poultry house (see Figure 2.29). Data were collected every ten minutes. Temperature at each hour calculated by two data sets, at the end of each hour and the reading from the ten minutes before were averaged and used as representative temperature of that hour.

Wet bulb temperature was measured in two ways: by using a thermostor prob manufactured by Campbell Scientific, Inc., covered with wet wick and a thermocouple sensor covered with the same wick as a back up sensor. Both sensors placed in the same

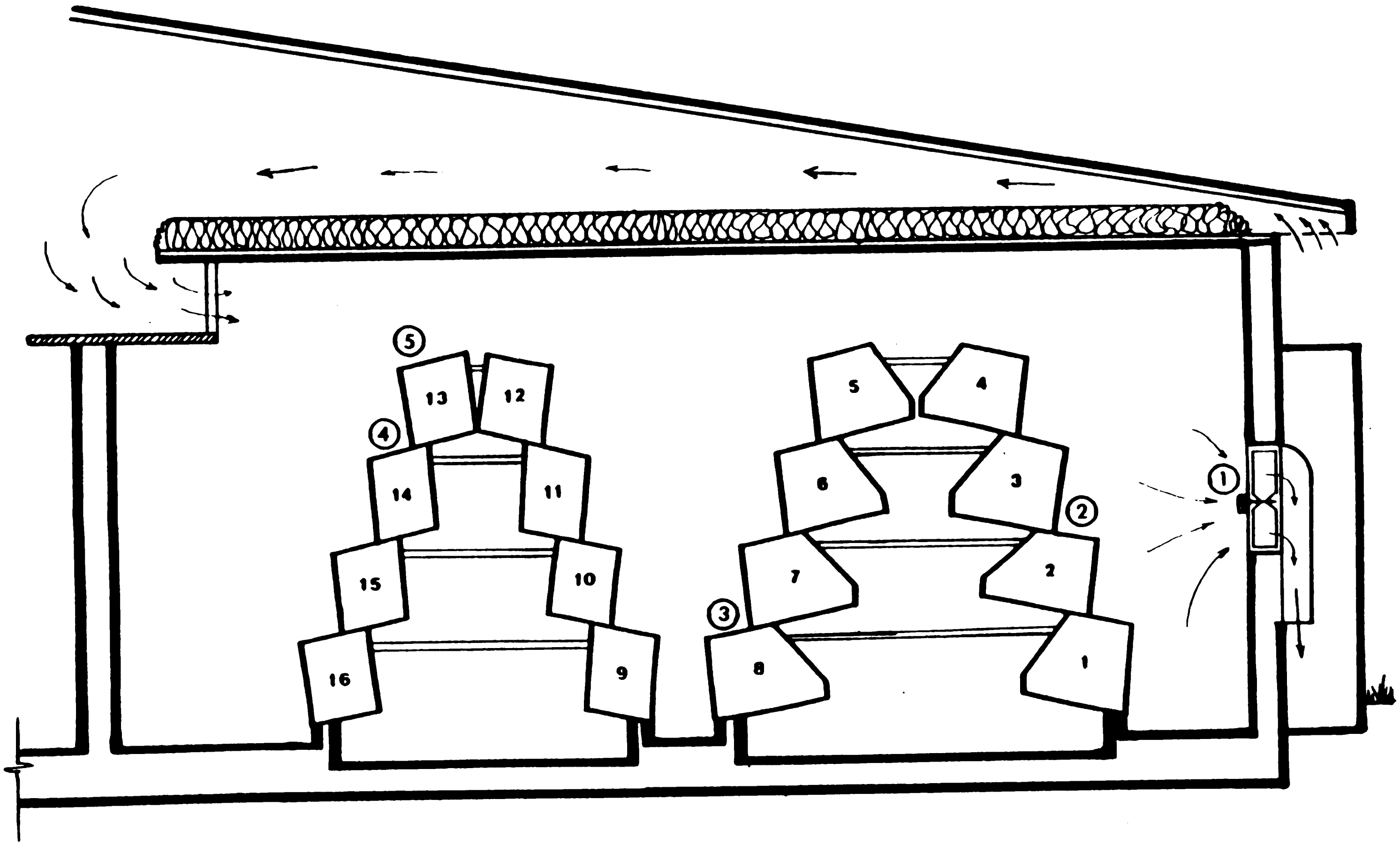


Figure 2.33. Carcon Dioxide Sampling Locations.

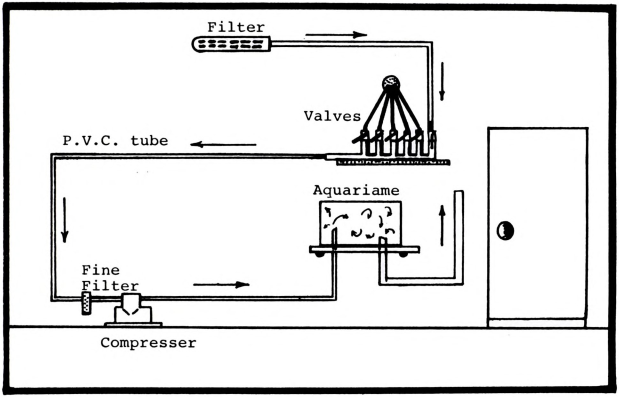


Figure 2.34. Carbon Dioxide Sampling Instrumentation.

location close to exhaust fan. Readings were taken twice a day for the back up sensor manually at 8 a.m. in the morning and 4 p.m. in the afternoon.

Because of the failure in some channels of data loger not registered, specially for the outside temperature and relative humidity and the wet bulb temperature for inside. The back-up data for wet bulb temperature then was used to calculate the average daily inside relative humidity.

Outside temperatuare and relative humidity data were taken from the National Oceanic and Atmospheric Administration (NDAA), from Lansing, Michigan, during February and March 1986. The average daily temperature and the amplitude of the daily temperature were calculated and used in the weather model to predict the hourly outside temperature and relative humidity. The dewpoint temperature first calculated and then by using the dry bulb temperature on that hour, the relative humidity calculated from psychrometrics. The hourly temperature and relative humidity were used as inputs to the main model to calculate psychometric data needed to complete the calculation for outside conditions.

Carbon dioxide was measured on different days of January 17 and 31, and several days in February, 11, and 21, for coldest days. Samples were taken several times a day from 9 a.m. in the morning, 3 p.m. in the afternoon, and from 6 p.m. until 7 a.m. of the next day, every three hours. It takes one hour to complete a scan of all five locations (see Figure 2.33 for carbon dioxide and ammonia locations). The interval between each scan was about 15 minutes. The emphasis was on night hours when the poultry house was in stable conditions almost all the time and the ventilation rate was a minimum 0.2 m^3/hr bird.

During working hours, it is difficult to control or measure exact amount of airflow because of the workers and other researchers which who should do their jobs. Several times the doors were opened which could effect the carbon dioxide concentration.

The samples were analyzed by using a commercial colorometer (chemically). The instrument was manufactured by Matheson (Model No. 8014-400a) using carbon dioxide tube model 126SA ranges from 0.1 - 2.6%. The ammonia tube model 105SC ranges from 5 to 260 PPM.

After each sample, the system was flushed with clean air from the outside room for about 8 minutes and then proceeded to the next location (see Figure 2.34). Measurements with very low readings were repeated and the average of the two were considered as representative value of that sample.

To estimate moisture from the manure, 4 to 5 samples each time of manure has been taken on a time interval of 3 p.m., 8 p.m., 12 midnight, and 6 a.m. The samples were weighed in aluminum cans. The cans were cleaned, dried, numbered, and weighted empty. This was the empty can weight. Then the sample was placed in each can and immediately sealed and then weighed. This weight was the weight of the can full of manure. A preheated oven for 103 C used to dry the cans for 24 hours. Then the samples were taken from the oven, cooled, and weighed again. This weight was the weight of the dried manure with the can. The dry manure weight was calculate by subtracting the weight of the can empty from the weight of the can plus manure dried. Then the moisture content in percent was calculated for all 22 samples This process was repeated for other days for more data.

Electricity consumption also was measured for the 45 cm fan and assumed to be constant for all day. For the 60 cm fan, data from the manufacturing company were used to calculate electricity consumption, which was based on the number of minutes the fan was operating.

CHAPTER III

VERIFICATION

3.1 Simulation Model Evaluation

The model was evaluated by comparing a performance variable as determined from measured data to that same variable as calculated by the simulation model. The important variables to compare were the hourly inside temperature during the test day, average daily inside temperature ventilation rates and average daily inside relative humidity. Another performance variable was the feed intake of 100 chickens and egg production. Intermediate calculation from the model were compared, for example, bodyweight.

The verification measurements were combined with comparable calculations from the simulation model and plotted to form a graph for review.

The principal input variables for the model, for inside conditions, were initial dry-bulb temperature, relative humidity, age of the birds, number of chickens, building parameters, insulation values of the walls and ceiling, feed metabolizable energy and length, width of manure pit. Inputs for outside conditions were average daily dry-bulb temperature and amplitude of outside temperature. Other input variables were considered constant; for example, feeding system, feed prices, electricity prices, egg sale price, and ventilation rate (Tables 5A to 7A in the Appendix).

3.2 Results and Discussion

Actual and predicted outside and inside temperatures are plotted in Figures 3.1 through 3.4. Output information for all runs are tabulated (Tables 3.1 to 3.5). The input information is tabulated in Appendix A.

The absolute mean deviation between actual and predicted hourly inside temperature for February 13 was 0.148 C and standard deviation of 1.758; for February 16 was 0.077 C and standard deviation of 1.884; for February 27 it was 0.016 C and standard deviation of 1.776; and on March 3 was 0.204 C and standard deviation of 1.954.

The average daily inside relative humidity, (Table 3.1) measured was 72% and the simulated was 71%, average daily relative humidity for outside, measured was 78% and the simulated was 79%. The mean daily inside temperature simulated and measured were 24.61 and 24.46 C, respectively. The daily average for outside temperature was -11.46 C, which was the same used to

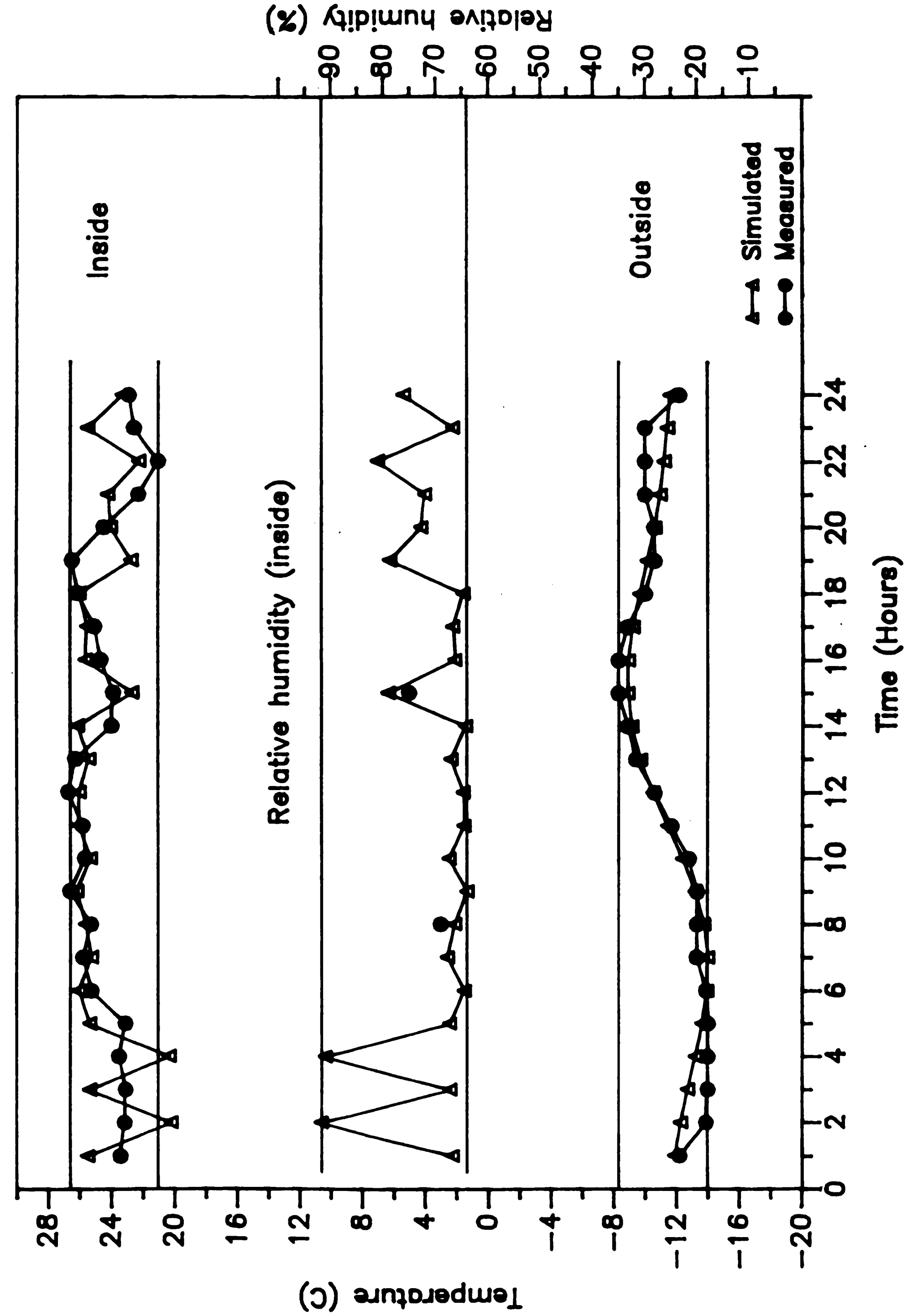


Figure 3.1. Simulated vs. measured temperature, and relative humidity February-13-1986.

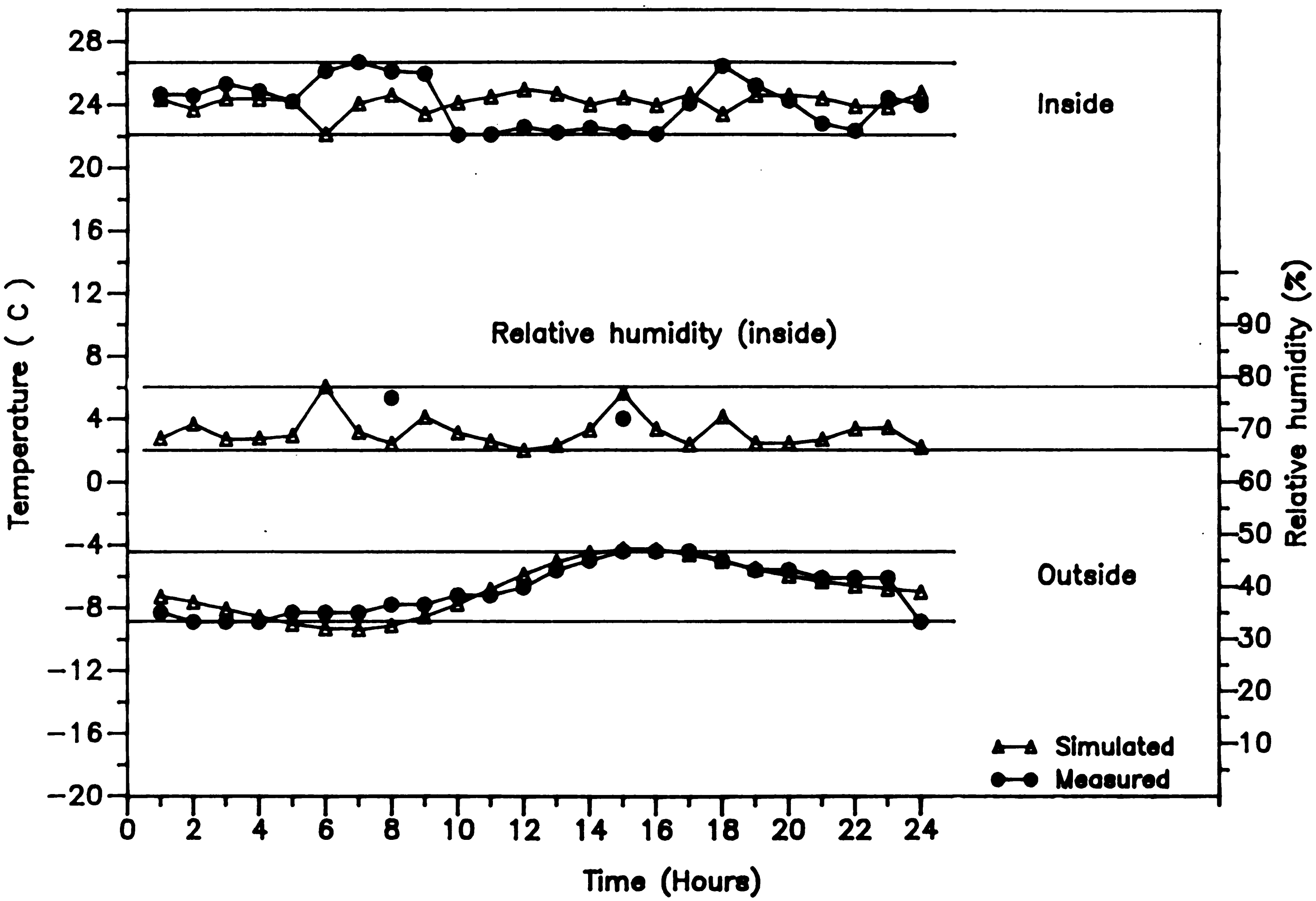


Figure 3.2. Simulated vs. measured temperature, and relative humidity February−16−1986.

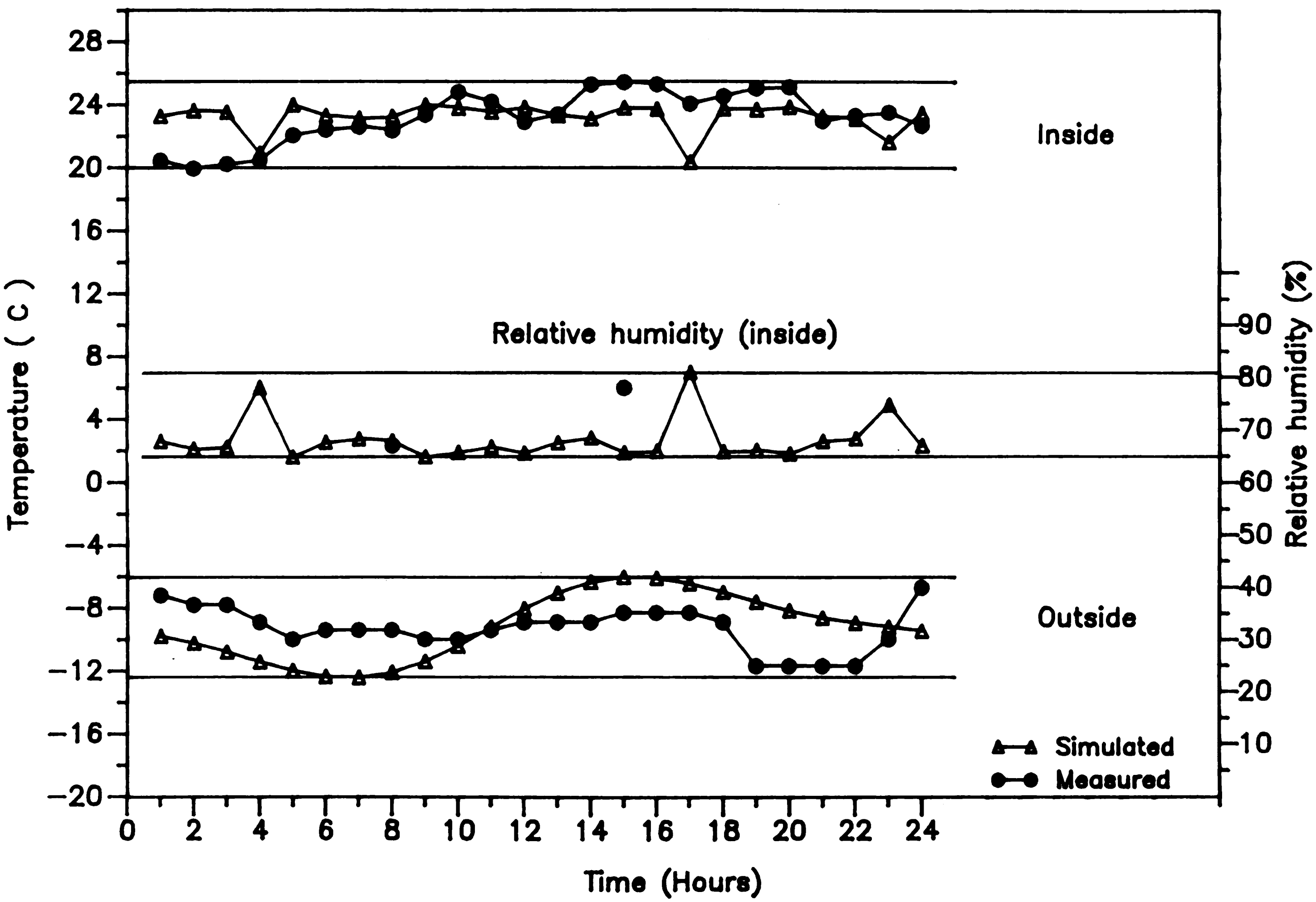


Figure 3.3. Simulated vs. measured temperature, and relative humidity February-27-1986.

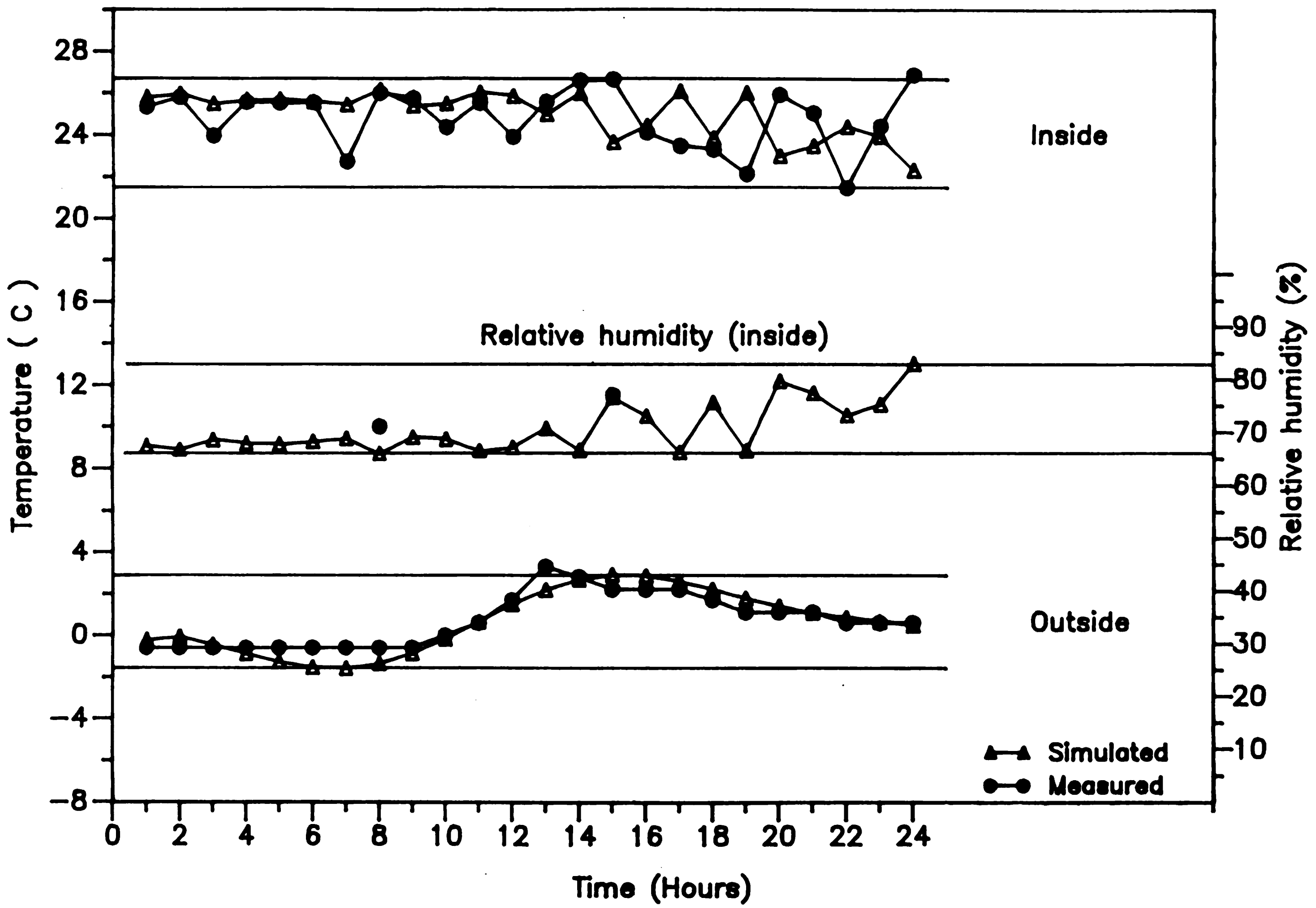


Figure 3.4. Simulated vs. measured temperature, and relative humidity March-3-1986.

Table 3.1. Output Values Simulated and Measured on February 13, 1986

Time Hours	Temperature in Degree C			
	Inside		Outside	
	Measured	Simulated	Measured	Simulated
1am	12.41	25.49	-12.2	-11.93
2	23.14	20.20	-13.9	-12.29
3	23.09	25.37	-14.0	-12.74
4	23.51	20.33	-14.0	-13.23
5	23.09	25.35	-14.0	-13.68
6	25.25	26.06	-13.9	-13.97
7	25.78	25.24	-13.3	-14.02
8	25.28	25.60	-13.3	-13.77
9	26.62	26.20	-13.3	-13.21
10	25.66	25.31	-12.8	-12.40
11	25.81	26.06	-11.7	-11.46
12pm	26.73	26.02	-10.6	-10.51
1	26.27	25.41	- 9.4	- 9.70
2	23.97	26.14	- 8.9	- 9.14
3	23.86	22.66	- 8.3	- 8.89
4	24.66	25.61	- 8.3	- 8.94
5	25.05	25.51	- 8.9	- 9.23
6	26.13	26.02	-10.0	- 9.68
7	26.48	22.72	-10.6	-10.17
8	24.48	24.05	-10.6	-10.62
9	22.28	24.21	-10.0	-10.99
10	21.04	22.24	-10.0	-11.25
11	22.57	25.51	-10.0	-11.46
12	22.89	23.28	-12.2	-11.66

Avg. inside temperature simulated	24.61 C
Avg. inside temperature measured	24.46 C
Avg. inside relative humidity simulated	70.72 %
Avg. inside relative humidity measured	72.00 %
Avg. outside temperature simulated	-11.46 C
Avg. outside temperature measured	-11.46 C
Avg. outside relative humidity simulated	78.94 %
Avg. outside relative humidity measured	78.00 %
Feed intake simulated (100 birds)	10.84 kg/d
Feed intake measured (100 birds)	9.92 kg/d
Percent hen - day production simulated	81.56 %
Percent hen - day production measured	74.51 %
Avg. egg weight simulated	61.77 gr
Avg. egg weight measured	59.70 gr
Avg. bodyweight simulated	1.77 kg
Avg. bodyweight measured	1.71 kg

Table 3.2. Output Values Simulated and Measured on February 16, 1986

Time Hours	Temperature in Degree C			
	Inside		Outside	
	Measured	Simulated	Measured	Simulated
1am	24.66	24.34	-8.3	-7.30
2	24.58	23.68	-8.9	-7.66
3	25.31	24.38	-8.9	-8.11
4	24.84	24.33	-8.9	-8.60
5	24.20	24.21	-8.3	-9.05
6	26.13	22.10	-8.3	-9.34
7	26.70	24.06	-8.3	-9.39
8	26.09	24.60	-7.8	-9.14
9	25.95	23.38	-7.8	-8.58
10	22.06	24.10	-7.2	-7.77
11	22.09	24.47	-7.2	-6.83
12pm	22.56	24.92	-6.7	-5.88
1	22.22	24.66	-5.6	-5.08
2	22.50	23.96	-5.0	-4.52
3	22.24	24.42	-4.4	-4.26
4	22.11	23.92	-4.4	-4.31
5	24.07	24.64	-4.4	-4.61
6	26.44	23.36	-5.0	-5.05
7	25.18	24.58	-5.6	-5.54
8	24.24	24.57	-5.6	-5.99
9	22.80	24.40	-6.1	-6.34
10	22.35	23.90	-6.1	-6.62
11	24.44	23.84	-6.1	-6.83
12	24.00	24.78	-8.9	-7.03

Avg. inside temperature simulated	24.07 C
Avg. inside temperature measured	24.15 C
Avg. inside relative humidity simulated	69.09 %
Avg. inside relative humidity measured	74.00 %
Avg. outside temperature simulated	-6.83 C
Avg. outside temperature measured	-6.83 C
Avg. outside relative humidity simulated	77.68 %
Avg. outside relative humidity measured	87.00 %
Feed intake simulated (100 birds)	10.86 kg/d
Feed intake measured (100 birds)	10.67 kg/d
Percent hen - day production simulated	81.39 %
Percent hen - day production measured	74.61 %
Avg. egg weight simulated	61.93 gr
Avg. egg weight measured	60.15 gr
Avg. bodyweight simulated	1.77 kg
Avg. bodyweight measured	1.71 kg

Table 3.3. Output Values Simulated and Measured on February 27, 1986

Time Hours	Temperature in Degree C			
	Inside		Outside	
	Measured	Simulated	Measured	Simulated
1am	20.45	23.25	- 7.2	- 9.82
2	19.95	23.61	- 7.8	-10.27
3	20.24	23.51	- 7.8	-10.82
4	20.49	20.91	- 8.9	-11.45
5	22.06	23.98	-10.0	-12.01
6	22.41	23.28	- 9.4	-12.38
7	22.60	23.12	- 9.4	-12.44
8	22.35	23.22	- 9.4	-12.12
9	23.36	23.97	-10.0	-11.42
10	24.79	23.76	-10.0	-10.42
11	24.18	23.50	- 9.4	- 9.23
12pm	22.89	23.80	- 8.9	- 8.05
1	23.38	23.29	- 8.9	- 7.04
2	25.28	23.07	- 8.9	- 6.34
3	25.42	23.78	- 8.3	- 6.03
4	25.28	23.70	- 8.3	- 6.09
5	24.04	20.33	- 8.3	- 6.46
6	24.54	23.72	- 8.9	- 7.01
7	25.03	23.67	-11.7	- 7.63
8	25.12	23.84	-11.7	- 8.20
9	22.97	23.23	-11.7	- 8.65
10	23.31	23.11	-11.1	- 8.98
11	23.51	21.62	-10.0	- 9.23
12	22.69	23.46	- 6.7	- 9.49

Avg. inside temperature simulated	23.20 C
Avg. inside temperature measured	23.18 C
Avg. inside relative humidity simulated	68.01 %
Avg. inside relative humidity measured	73.00 %
Avg. outside temperature simulated	-9.23 C
Avg. outside temperature measured	-9.23 C
Avg. outside relative humidity simulated	80.71 %
Avg. outside relative humidity measured	69.71 %
Feed intake simulated (100 birds)	11.10 kg/d
Feed intake measured (100 birds)	10.23 kg/d
Percent hen - day production simulated	79.13 %
Percent hen - day production measured	76.56 %
Avg. egg weight simulated	62.26 gr
Avg. egg weight measured	60.80 gr
Avg. bodyweight simulated	1.77 kg
Avg. bodyweight measured	1.71 kg

Table 3.4. Output Values Simulated and Measured on March 3, 1986

Time Hours	Temperature in Degree C			
	Inside		Outside	
	Measured	Simulated	Measured	Simulated
1am	23.33	25.80	-0.6	-0.24
2	25.80	25.96	-0.6	-0.08
3	23.96	25.49	-0.6	-0.47
4	25.57	25.66	-0.6	-0.90
5	25.52	25.69	-0.6	-1.29
6	25.56	25.57	-0.6	-1.55
7	22.73	25.43	-0.6	-1.60
8	26.01	26.15	-0.6	-1.37
9	25.75	25.38	-0.6	-0.88
10	24.35	25.48	0.0	-0.18
11	25.52	26.02	0.6	0.65
12pm	23.90	25.85	1.7	1.48
1	25.59	24.97	3.3	2.18
2	26.61	26.00	2.8	2.67
3	26.66	23.64	2.2	2.90
4	24.10	24.43	2.2	2.85
5	23.47	26.09	2.2	2.59
6	23.30	23.85	1.7	2.20
7	22.13	26.02	1.1	1.77
8	25.93	22.99	1.1	1.38
9	25.05	23.47	1.1	1.06
10	21.47	24.40	0.6	0.83
11	24.44	23.93	0.6	0.65
12	26.90	22.31	0.6	0.47

Avg. inside temperature simulated	25.02 C
Avg. inside temperature measured	24.82 C
Avg. inside relative humidity simulated	70.62 %
Avg. inside relative humidity measured	74.00 %
Avg. outside temperature simulated	0.65 C
Avg. outside temperature measured	0.65 C
Avg. outside relative humidity simulated	68.74 %
Avg. outside relative humidity measured	92.00 %
Feed intake simulated (100 birds)	10.78 kg/d
Feed intake measured (100 birds)	9.81 kg/d
Percent hen - day production simulated	78.58 %
Percent hen - day production measured	75.36 %
Avg. egg weight simulated	62.26 gr
Avg. egg weight measured	61.10 gr
Avg. bodyweight simulated	1.77 kg
Avg. bodyweight measured	1.77 kg

Table 3.5. Average Daily Inside Temperatures Measured and Simulated from February 13 to March 3, 1986

Date	Average Daily Temperature °C	
	Measured	Simulated
February 13	24.46	24.61
16	24.15	24.07
27	23.18	23.20
March 3	24.82	25.02
Mean	24.15	24.22
SD	0.704	0.786

Average hourly deviation = 0.11

Average daily deviation = 0.18

Percent of error for hourly deviation = 0.5%

predict the hourly outside temperature and relative humidity. Ventilation rate calculated from the model (February 13) for early morning hours (1 a.m. to 5 a.m.) was between 0.2 and 0.29 m^3/hr/bird, the measured was fixed on 0.2 m^3/hr/bird, but the air infiltration could add to it and increase the air flow. The maximum air flow predicted at 4 p.m. was 0.5 m^3/hr/bird.

The model had a tendency to fluctuate in the morning hours, especially on day February 13, Figure 3.1, which may be caused by the model's trying to adjust the temperature inside while the temperature outside was going down (simulated). The control routine of the model has a fixed increment to control the air flow, which may not be good for all the times to adjust the ventilation rate to keep the inside temperature in the specified range. So the temperature was allowed to drop to the minimum allowed. This air flow rate was assumed to occur for the entire hour. However, the real temperature (measured) was about constant for about 5 hours. Otherwise, the model predicted very good estimates of hourly inside temperatures after that.

On day March 3, Figure 3.4, the model and the measured data followed each other until 3 p.m. (hour 15) which then the measured and the simulated starts to fluctuate. The measured data could be effected by the thermostat setting when outside temperature is high. But the fluctuation of the model is still in the range of the measured data, Table 3.4, the daily average of inside temperature measured and simulated were 25.02 C and 24.82 C, respectively, with a difference of 0.2 C. The average relative humidities were 74.00% and 70.62% measured and simulated, respectively.

Mean deviation between actual and predicted average daily inside temperature for all runs was 0.18 C with standard deviation of 0.43. Table 3.5 shows the average daily temperatures measured and simulated for the period from February 13 to March 3.

Percent of error for the same period for the average hourly deviation was 0.5%, compared to 5% from Phillips (1970). The results also statistically tested by paired comparison, for all runs and found that the means of these examples were not significantly different.

The model predicting very accurate average daily temperatures compared to the actual average temperatures. This will support the prediction of feed consumption which is calculated based on the daily average temperature.

It was necessary to adjust the simulation model to give results similar to the collected data. During this period of evaluation, it was found useful to compare initial inputs values and intermediately calculated values. Special adjustment made on day February 8, an increase in moisture evaporation from the manure made the model predict inside temperatures more closely to the actual.

The inputs for this model were average daily temperatures and the temperature amplitude. To evaluate the model's ability to predict inside conditions, these inputs were taken from the NOAA for Lansing, Michigan, and used to predict hourly outside temperature and relative humidity. The weather model was predicting very close to data. The curve shape matched the actual data closely in Figure 3.1, 3.2, and 3.4.

The feed consumption and egg production models (management model), which include prediction of feed consumption based on 100 bird per day in kg, metabolizable energy per bird in kJ per day, hen-day production in percent, estimated egg production for 100 bird in kg per day. The second part of this model is the cost calculations and that includes feed cost per 1,000 bird as a common base, electricity cost/1,000 bird in dollars per day, and egg sale calculated based on nest run price for that day, then the revenue margin (revenues-cost) for that day is calculated and the value is displayed in \$/day.

The above parameters were compared to measured data or supplied by the management manual for Hy-Line chickens breed W-36. Tables 3.1 to 3.4 shows the simulated values and the measured values for each day.

Feed intake for February 13, Table 3.2, (age 50 weeks) was 10.83 kg/day/100 bird simulated, the measured was 9.92 kg/day/100 birds, and comparing with the management manual was 9.9 kg/day/100 bird. The percent hen per day production was 81.56% simulated comparing to 74.51% measured on 50th week, and the manual estimated it to be 80%. Egg production prediction from the model was 61.77 g/da/bird, the measured was 59.70 g/day/bird, and the management manual for this breed estimate was 61.70 g/day/bird.

Bodyweight was also calculated based on age of the chickens. The simulated value was 1.77 kg, comparing with 1.71 kg according to the management manual. Electricity costs were calculated based on number of hours the fans were operated. The simulated value was 0.134 $/day/1,000 bird, the measured was 0.10 $/day. No fuel costs were calculated.

The mean deviation for all runs between measured and simulated were, for feed intake 0.796 kg/100 bird, egg weight 1.708 g/day/bird and for the bodyweight 0.06 kg.

Some of the differences in the management information could be caused by conditions that may have occurred that week; for example, health, stress, feed, and management practices. In general, the model is a useful tool to evaluate different parameters, for instance, inside temperature, ventilation rate, feed intake, and egg production. The model gives very accurate average daily inside temperatures.

Carbon dioxide concentration could vary by using different ventilation rates. Allowable concentration of CO_2 in hen houses were discussed in Kadlec (1969). Concentrations in the range 0.25% to 0.5% have no harmful effect on production. Concentration between 0.5% to 2.5% have a small effect on production between 2.5%, and above 5%, CO_2 concentration is dangerous and will effect health, production, and may increase mortality, especially with combination of other gases and high temperature.

The minimum ventilation rate for carbon dioxide control was 0.2 m^3/hr/bird. When air flow was reduced below that necessary for control of moisture (0.43 m^3/hr/bird), uniform distribution of fresh air throughout the room may not be achieved. Measurement of CO_2 in various locations were made to determine the adequacy of

CO_2 removal from all locations of the room, and to appraise the air distribution.

For February 13, Figure 3.5, CO_2 concentration in location #2, ranged from 0.41% to 0.70%. Location #3 from 0.42% to 0.55%, location #4 from 0.30% to 0.52%, and location #5 from 0.5% to 0.6%. All these ranges fall in the allowable concentration of CO_2, where no effect on health or production would be anticipated. Other day, Figure 3.6 has similar patterns.

The sudden drop in CO_2 level in location #2, Figure 3.5, was caused by operation of second phase fan in the adjacent room (white) at 4 a.m.

Carbon dioxide could be deadly in case of electricity failure or stoppage of fans. Figure 3.7 shows the quick increase in CO_2 concentration reaching the harmful level of 2% in about 2 hours and 20 minutes. The rate of CO_2 production calculated was 714 cm^3/hr/bird measured and the simulated was 734 cm^3/hr/bird. A combination of high levels of CO_2 from 2% to 5% and high temperature (30 C) in tight buildings will contribute to very high mortality. The highest level of CO_2 was in location #5, and the lowest at location #3 at 10 p.m.

Ammonia concentration was constant about all the time during the test days, and it was always below the maximum limit of 50 PPM. This could be effected by the

kind of feed used, and the two time cleaning the manure pit.

Using low ventilation rate of 0.2 m^3/hr/bird in winter as ventilation rate for carbon dioxide control (minimum ventilation rate) will give better manipulation of air exchange in the poultry house, and to maintain the temperature in the thermoneutral zone, without exceeding the maximum allowable concentration of CO_2.

The mean deviation between the average hourly carbon dioxide concentration measured for both days Figures 3.5 and 3.6, and the simulated were 10.05%. The prediction of carbon dioxide for both days was satisfactory and fell in the range of CO_2 measured.

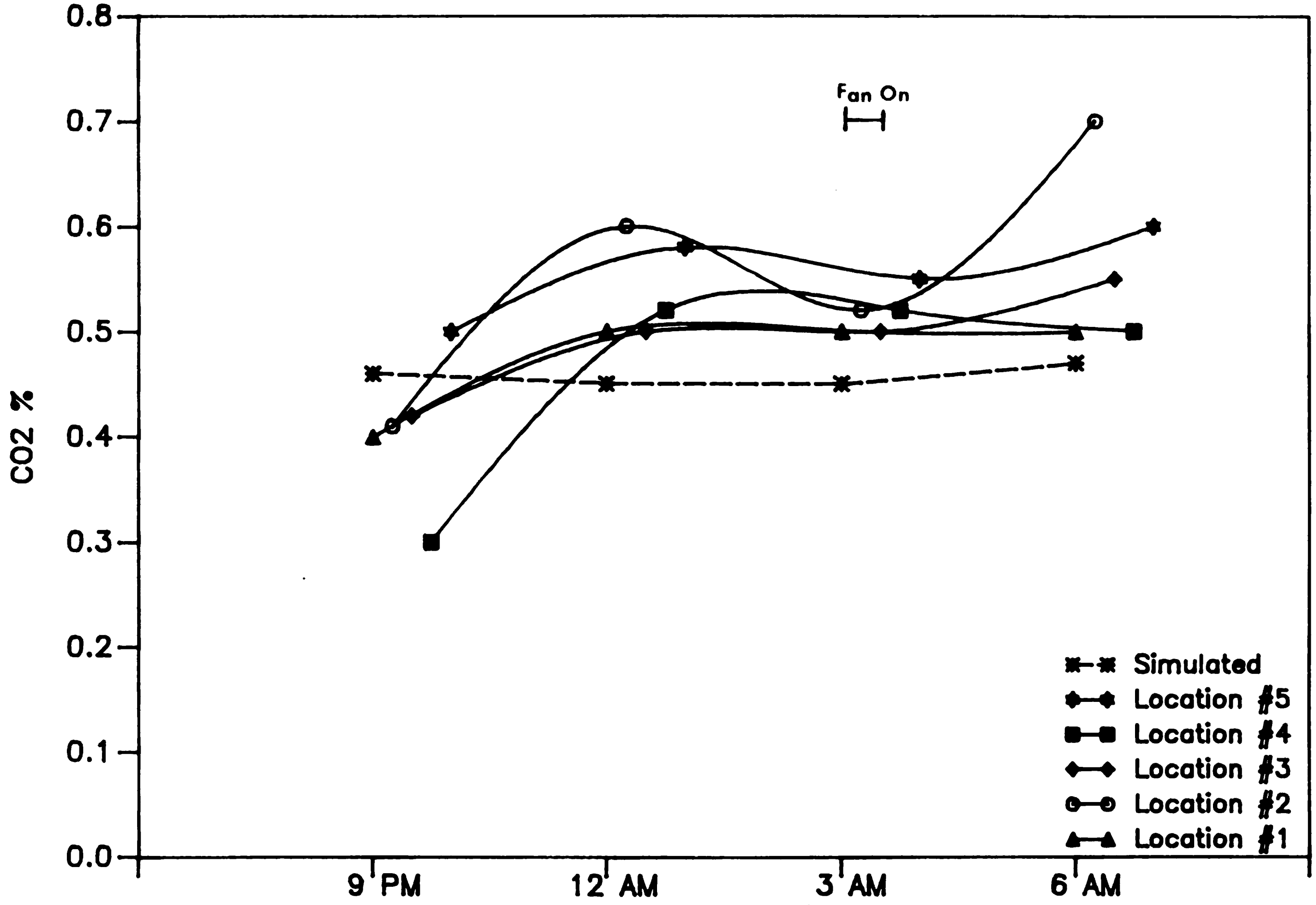


Figure 3.5. Carbon dioxied concentration vs. time February-11-1986

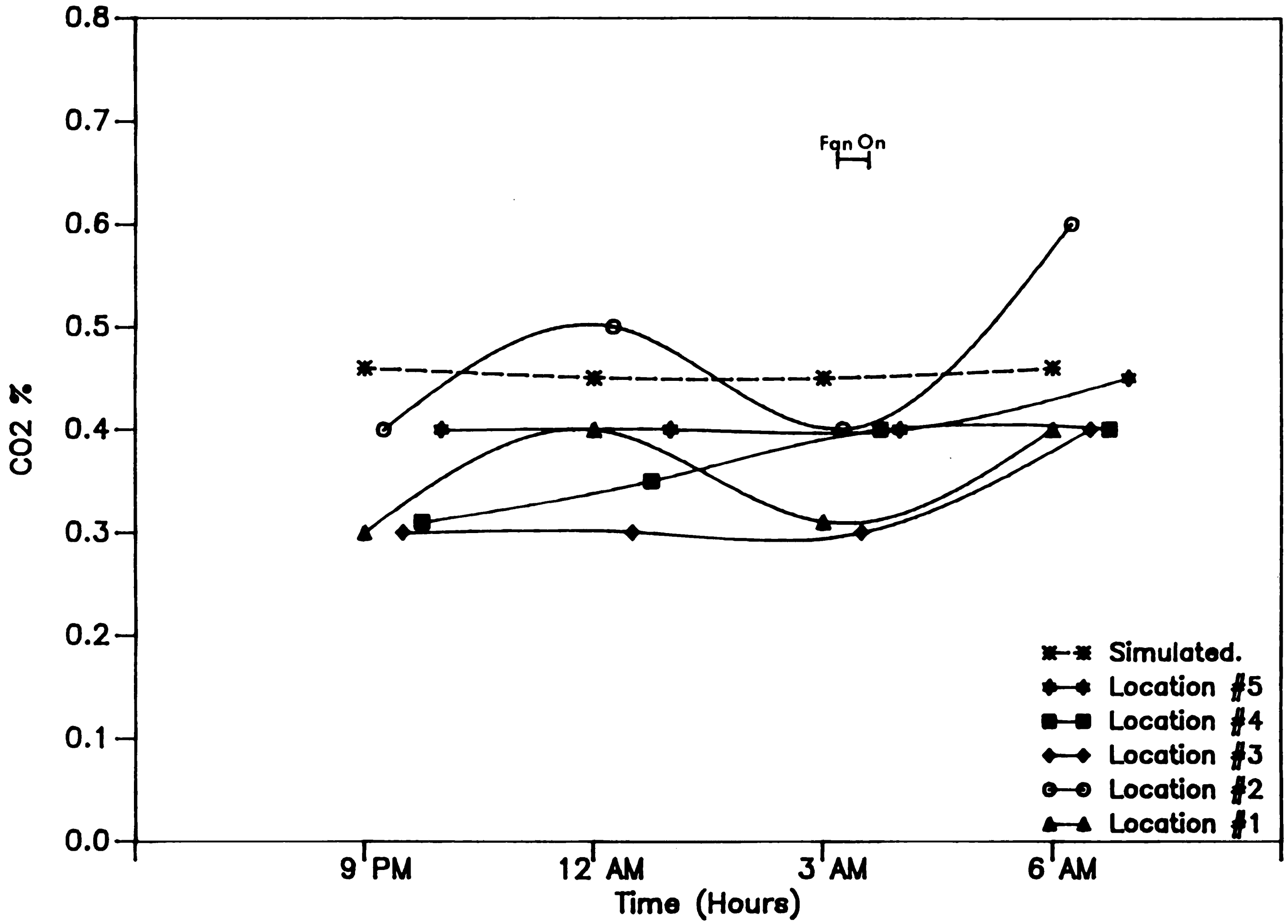


Figure 3.6. Carbon dioxide concentration vs. time
February–21–1986

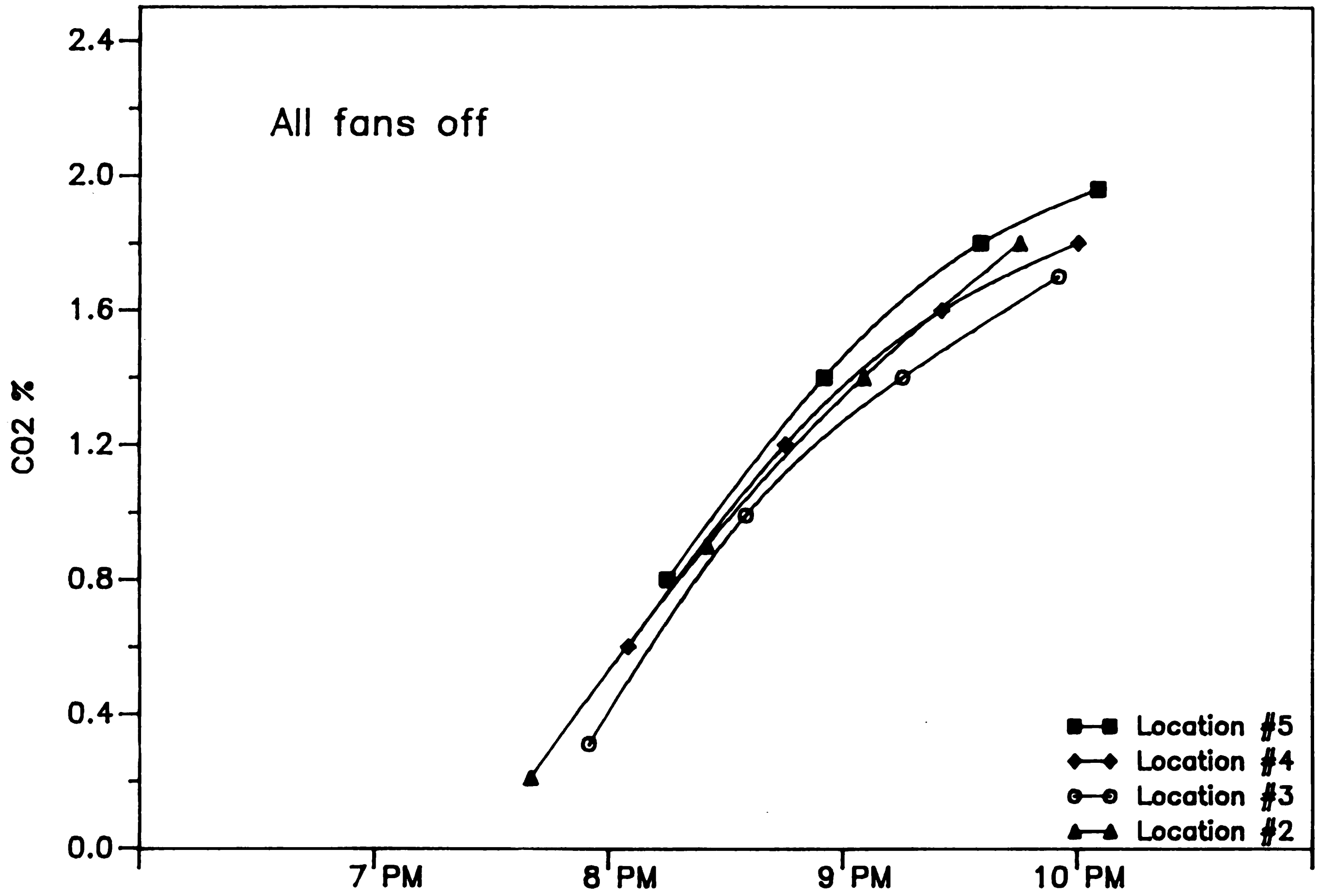


Figure 3.7. Carbon dioxide concentration vs. time
February–18–1986

CHAPTER IV

RESULTS FROM MODEL USE

One of the applications of the model is to decide what ventilation rate should be used to maximize revenues over costs when the outside temperature is very low. Two alternatives that may be considered are:

1. Ventilate at a rate to control carbon dioxide.
2. Ventilate at a rate that will control moisture. (Fixed ventilation rate.)

The simulation model was used to estimate and evaluate differences in revenue margins between the two control strategies. A common base for expressing financial performance measures in the commercial egg industry is per 1,000 bird units. This base will be used in calculating and presenting the evaluation criterion. The revenue margin (RM) is defined as value of egg sales minus feed and electricity costs per 1,000 birds.

$$RM = ES - (FC + EC) \tag{4.1}$$

where

FC = Feed cost \$/day

ES = Egg sale \$/day

EC = Electricity cost \$/day

Decision analysis has become an important technique in the solution of business problems of this type. The decision analysis method is accomplished by listing available courses of action, expressing subjective variables quantitatively, and determining possible economic returns.

When the data are put in order, the result is that decision analysis becomes a powerful tool for determining optimal courses of action. The returns of laying hen operation is dependent on the biological response of chickens to their environment and to market conditions.

The evaluation criterion used for this application is the Expected Value (EV). This criterion incorporates the probability of an event (state of nature) occurring into the decision or evaluation process. The probability is a quantitative measurement of the degree of certainty associated with the occurrence of an event. The evaluation decision rule is to select the alternative that has the greatest revenue margin. A decision tree is a graphic presentation that shows a sequence of strategic decisions and the expected consequences under each possible state of nature or circumstances. A decision is symbolized by a square and noncontrollable events by a circle. The revenue margin of each branch is multiplied by its joint probability of possible state of nature and then summed with other branches to get the expected value (EV) of each age, and each strategy. The equation of EV would be as follows:

$$EV = \sum_{i=1}^{n} Pi \times Vi \qquad (4.2)$$

where

Pi = Probability of event Vi occurring.

Then the expected value for age 25 weeks will be calculated as:

$$EV_{25} = (0.03 \times 14.93) + (0.24 \times 15.03) + (0.73 \times 15.07)$$
$$= 15.06 \ \$/day$$

A summary of E.V. calculations is in Table 4.1 and the decision analysis is in Figures 4.1. and 4.2.

The usual laying period for the hens is about 76 weeks, when pullets are put in production from 18 weeks of age. Some assumptions have been made for the duration

Table 4.1. Output Values for Decision Analysis for Expected Values (E V)

Ventilation Rate m^3/hr	Age Weeks	Avg. Temperature C		Expected Values	Total
		Outside	Inside		
Carbon Dioxide Ventilation Rate (840)	25	-20	19.70	0.45	
		-15	22.05	3.61	
		-10	23.45	11.00	
					15.06
	40	-20	22.88	0.44	
		-15	24.28	3.59	
		-10	24.58	10.92	
					14.95
Moisture Control Ventilation Rate (1394)	25	-20	17.94	0.44	
		-15	21.42	3.58	
		-10	22.99	10.92	
					14.97
	40	-20	19.45	0.43	
		-15	22.43	3.51	
		-10	24.36	10.86	
					14.80

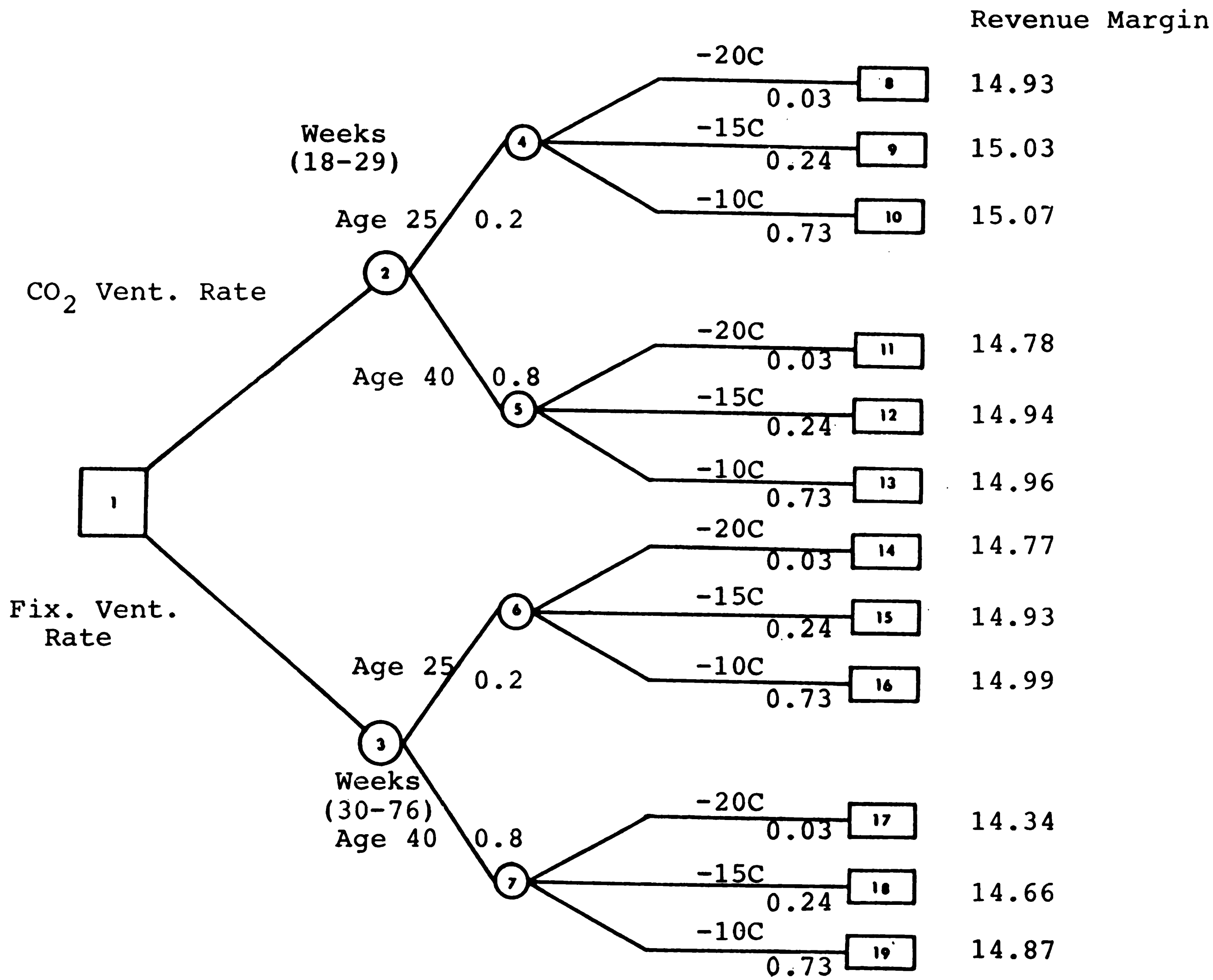


Figure 4.1. Decision Analysis Inputs, Revenue Margins and Probabilities.

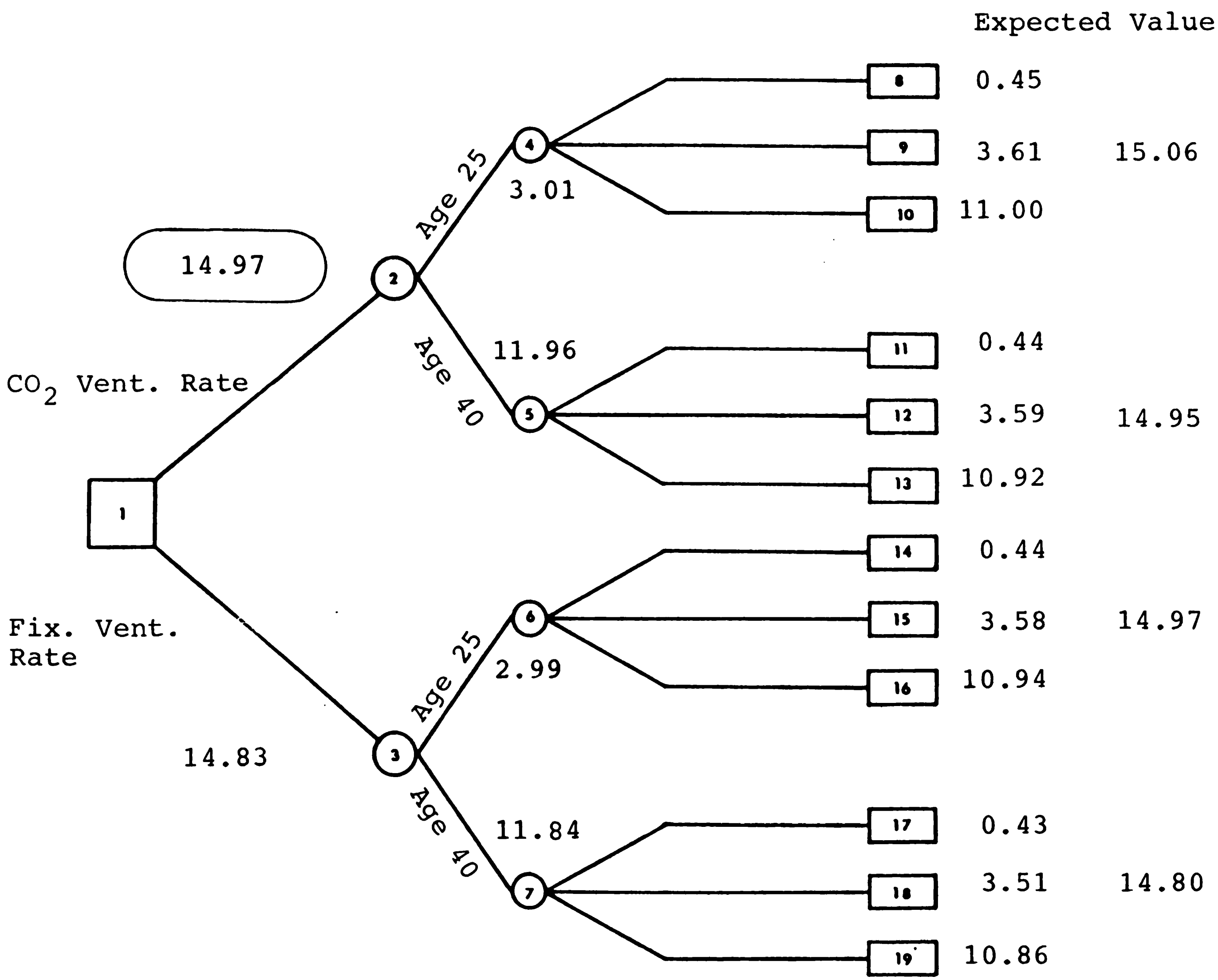


Figure 4.2. Decision Analysis Expected Values

of age. The laying period is divided into two periods. First period from age 18 through 29 weeks, which encompasses 11 weeks of production. In this period the chickens are small in size, their bodyweight is not reached the standard (growing) and they are not mature. A representative age is chosen for this period (18 to 29 weeks) and that is 25 weeks. This age reflects the variability in bodyweight and production. The second period, 30 to 78 weeks, when the chickens reach their stable bodyweight, maturity, and they are well adapted to production conditions. The representative age chosen for this period (47 weeks) is 40 weeks.

The duration proportions calculated for each period are as follows:

29 - 18 = 11 weeks first period duration

76 - 30 = 47 weeks second period duration

11 + 47 = 58 weeks production period duration

then

$\frac{11}{58} = 0.19 \simeq 0.2$ duration proportion for first period

$\frac{47}{58} = 0.81 \simeq 0.8$ duration proportion for second period

These duration proportions will be used to weight the two alternatives selected as representative production situations.

The weather data used in this evaluation are based on 83 years (1889 - 1980) for Jackson, Michigan, supplied by NOAA and NWS, Table 4.2 is used to calculate the probabilities for outside temperatures.

Three ranges of temperatures were chosen to represent outside conditions. They are from >0 to <-10 C, from -10 to <-20 and from -20 to -30. The representative temperature for each range used in the model were -10, -15, and -20 C, respectively. The probability for each range then calculated by dividing the total number of days for each range by the number of winter days in 83 years for the period from November through March (5 months).

Number of days = 151 x 83 = 12,533 days

For -20 C range, the probability is calculated as:

$$\frac{(328 + 42)}{12,533} = 0.0296 \simeq 0.03$$

The same procedure is used to calculate other range probabilities. They are 0.03, 0.24, and 0.73 from the lowest to the highest range.

Assumptions were also made for the market price of product and input factors. A representative price level for egg, feed, and electricity were used: 0.45 $/doz for

Table 4.2. Weather Information Used in Decision Analysis 1889-1980 (83 Years)

Ranges C	Jan.	Feb.	Mar.	Nov.	Dec.	Total
	Frequencies of Occurrences					Days
> 0 to <-5	697	612	1061	1055	886	4311
- 5 to <-10	771	755	700	418	816	3460
-10 to <-15	645	561	307	83	469	2065
-15 to <-20	373	332	76	7	214	1002
-20 to <-25	141	122	15	2	48	328
-25 to -30	18	23	0	0	1	42
	Number of Years with Hits					Years
> 0 to <-5	79	81	82	82	82	83
- 5 to <-10	82	82	82	79	82	83
-10 to <-15	82	82	72	37	81	83
-15 to <-20	72	69	34	6	55	82
-20 to <-25	49	44	11	2	26	65
-25 to -30	13	13	0	0	1	23

nest run egg price, 0.16 \$/kg for feed, and 0.06 \$/kWh for electricity.

The expected values for the two strategies being evaluated in this application are 14.97 \$/day for carbon dioxide control ventilation rate, and 14.83 \$/day for moisture control ventilation rate. The maximum expected value revenue margin (MEVRM) of 14.97 \$/day was achieved by using or implementing the carbon dioxide control ventilation rate. The difference of the two strategies in RM is 0.14 \$/day. This value becomes more significant in a large production operation, where a 100,000 bird house capacity or greater may be utilized. The number of cool days in the winter season has an important impact on choosing the appropriate ventilation rate. Other factors that could be listed in this discussion are: age of chickens, production level, feed prices, egg and other inputs which the manager must take into consideration.

To evaluate this problem for different conditions, egg sale price was fixed as 0.45 \$/dozen nest run price for all following runs. The feed and electricity prices were doubled and then the model used to predict the new revenue margins. The expected values were calculated by using equation (4.2). When the price of the feed doubled to 0.32 \$/kg, both strategies lost money. The minimum losses were with using lower ventilation rates to control

carbon dioxide, with minimum expected value of -1.50 \$/day, compared to -1.64 \$/day. The difference between both values was 0.14 \$/day.

Another run was made to evaluate the two strategies under electricity price change only. The price of electricity was doubled to 0.12 \$/kW hr. The expected values also calculated, and the final evaluation was to use lower ventilation rates to control carbon dioxide instead of moisture control ventilation rate. The maximum expected value achieved with low ventilation rate was 14.88 \$/day, compared to 14.74 \$/day, and the difference was 0.14 \$/day, the same as previous runs.

Using lower ventilation rates (0.2 m^3/hr/bird) could cause water condensation on the walls or equipment, but this problem was not serious from the observations made during the data collection and also from the model prediction. Hours of water condensation predicted for the runs from February 13 through March 3 were 10, 1, 3, and 0 hours, respectively. The water condensation usually occurred in early morning hours and in the night. From the observation made, water condensation occurred on the lower part of the walls and outside door. No water condensation was as noted on the cages or other equipment in the poultry house.

Higher ventilation rates (0.43 m^3/hr/bird) did not prevent water condensation on the walls; predicted hours of water condensation were between 6 and 4 hours.

Lower ventilation rates based on controlling carbon dioxide in poultry houses could be used to achieve higher temperatures, and savings without effecting egg production, or creating health problems.

However, for prudent management at low ventilation rates of 0.2 m^3/hr/bird, monitoring CO_2 is mandatory. The width of commercial layer houses are typically more than the 17 m width structure used in this study. With low ventilation rates, it is possible that the carbon dioxide levels in the middle of the poultry house could exceed allowable levels. This may result in increased mortality or reduced performance levels unless special provisions are made for effective air distribution at these low air flow rates.

Table 4.3. Output Values from the Model Used in Decision Analysis

Ventilation rate m^3/hr	Age Weeks	Avg. Temperature C		Feed Intake kg/day/100 b
		Outside	Inside	
Carbon Dioxide Control Ventilation Rate (840)	25	-20	19.70	10.138
		-15	22.05	9.878
		-10	23.45	9.693
	40	-20	22.88	10.678
		-15	24.28	10.459
		-10	24.58	10.407
Moisture Control Ventilation Rate (1394)	25	-20	17.94	10.304
		-15	21.42	9.953
		-10	22.99	9.756
	40	-20	19.45	11.105
		-15	22.43	10.742
		-10	24.36	10.444

CHAPTER V

SUMMARY AND CONCLUSIONS

5.1 Summary

A simulation model which predicts hourly temperature, relative humidity, maximum, minimum temperatures, average daily temperature for inside and outside conditions, and management information, including feed consumption, feed costs, metabolizable energy, egg production, and electricity costs, bodyweight, mortality rate, and ventilation rates used in evaluation of poultry laying house was prepared and verified. The simulation model was based on psychrometric and biological relationships for laying hens.

The basis of the simulation model and the test facilities for model verification was a commercial-type laying house near East Lansing, Michigan. The laying house has a capacity of approximately 4,100 hens in each room: system was managed as small commercial unit at Michigan State University Poultry Science Research and Training Center.

Verification data collected on five winter days compared satisfactorily with the simulation.

The carbon dioxide ventilation rate control was used as minimum ventilation rate in cool days to replace the ventilation rate for moisture control. Carbon dioxide and ammonia were under control with a ventilation rate of 0.2 m^3/hr/bird (0.12 CFM/bird).

The model gives very close predictions of feed consumption, H-D production, metabolizable energy, and egg production compared with the measured data and management manual for the Hy-Line breed W-36.

5.2 Conclusions

The following conclusions are the result of preparing and verifying the simulation model of estimate the hourly inside, outside dry-bulb temperature and relative humidity, and management information.

1. Ventilating at 47% of the rate commonly used for moisture control to provide adequate environmental conditions was accomplished successfully under the climatic conditions that existed.

2. Lower ventilation rates helped maintain higher inside temperature which lowered feed consumption and improved revenue margins for cooler days.

3. The data from the simulation model matched the experimental winter psychrometric data satisfactorily.

4. Ammonia concentrations were well below maximum allowable concentrations (<35 PPM) even with low ventilation rate which was used in this study.

5. For the climatic conditions studied, water condensation occurred only for short durations, but it did not last all day.

6. At the low air flow rate, mixing of outside air with the inside was very good, and adequate, based on uniformity of CO_2 and temperature in various locations.

7. Carbon dioxide did not exceed the maximum allowable level in any location.

8. The simulation model provided a means of effectively evaluating the controllable management and design factors for the environment in a poultry house.

9. Data generated from the simulation model is useful in making economical analysis to evaluate different strategies or situations.

5.3 Recommendations for Further Research

The results of this research suggests the need for additional work in the following areas:

1. This model was not tested or evaluated for options already built in the simulation. It is recommended to explore this simulation model for different conditions.

2. Additional studies be conducted to determine and improve the egg production model.

3. Investigation of bird heat production under conditions of diurally varying temperatures.

4. Develop a single function which can make a smoother transition between day and night rates than the two separate linear interpolations used in this study.

5. Expansion of the model so that it could be used to simulate environment conditions, feed consumption and egg production responses throughout an entire year. This would allow evaluation of alternative energy and environmental management strategies for any period of time.

APPENDICES

APPENDIX A

TABLES

Table A.1. Carbon Dioxide and Ammonia Concentration Measured on February 11, 1986

Time	Location	CO_2%	NH_3 ppm	Temperature C
9:00 pm	1	0.40	20	22.92
9:15 pm	2	0.41	15	22.52
9:30 pm	3	0.42	15	22.87
9:45 pm	4	0.30	20	21.85
10:00 pm	5	0.50	15	22.48
12:00 am	1	0.50	30	23.66
12:15 am	2	0.60	20	23.56
12:30 am	3	0.50	20	23.66
12:45 am	4	0.52	20	23.71
1:00 am	5	0.58	15	23.56
3:00 am	1	0.50	30	23.41
3:15 am	2	0.52	23	23.41
3:30 am	3	0.50	23	23.46
3:45 am	4	0.52	23	23.56
4:00 am	5	0.55	23	23.66
6:00 am	1	0.50	25	24.39
6:15 am	2	0.70	18	25.21
6:30 am	3	0.55	18	25.20
6:45 am	4	0.50	18	24.70
7:00 am	5	0.60	18	24.63

Table A.2. Carbon Dioxide and Ammonia Concentration Measured on February 21, 1986

Time	Location	CO_2%	NH_3ppm	Temperature C
9:00 pm	1	0.30	20	22.83
9:15 pm	2	0.40	20	23.16
9:30 pm	3	0.30	20	23.26
9:45 pm	4	0.31	20	23.35
10:00 pm	5	0.40	20	23.04
12:00 am	1	0.40	20	24.42
12:15 am	2	0.50	20	24.07
12:30 am	3	0.30	20	24.17
12:45 am	4	0.35	20	23.98
1:00 am	5	0.40	20	23.04
3:00 am	1	0.31	--	23.80
3:15 am	2	0.40	--	23.84
3:30 am	3	0.30	--	24.04
3:45 am	4	0.40	--	24.07
4:00 am	5	0.40	--	24.19
6:00 am	1	0.40	--	25.77
6:15 am	2	0.60	--	26.11
6:30 am	3	0.40	--	26.39
6:45 am	4	0.40	--	25.99
7:00 am	5	0.45	--	26.06

Table A.3. Carbon Dioxide and Ammonia Concentration Measured on February 18, 1986 (All fans off)

Time	Location	CO_2%	NH_3 ppm	Temperature C
7:40 pm	2	0.21	20	23.21
8:20 pm		0.90		28.90
9:00 pm		1.40		31.45
9:40 pm		1.80		33.47
7:50 pm	3	0.31	20	26.78
8:30 pm		0.99		29.73
9:10 pm		1.40		31.83
9:50 pm		1.70		33.88
8:00 pm	4	0.60		27.03
8:40 pm		1.20		30.46
9:20 pm		1.60		32.61
9:55 pm		1.80		33.90
8:10 pm	5	0.80	20	28.09
8:50 pm		1.40		31.00
9:30 pm		1.80		33.07
10:00 pm		1.96		34.22

Table A.4 Management Factors, Design, and Input Values as Used for Verifying the MOdel on February 13, 1986

Building:	
Length, m	31.00
Width, m	5.50
Height, m	2.37
Insulation:	
Walls, $W/m^2.C$	0.54
Ceiling, $W/m^2.C$	0.32
Simulation Period:	
Beginning day	44.00
Ending day	45.00
Initial Inside Conditions:	
Average daily temperature, C	24.20
Average daily rel. humidity, %	72.00
Initial Outside Conditions:	
Average daily temperature, F	11.38
Amplitude temperature, F	4.00
Flock Information:	
Number of chickens	4038.00
Age of chickens	50.00
Feed Information:	
Feed metabolized energy, MJ/da	11.532
Crude protein content, %	0.16
Manure Pit:	
Length, m	25.00
Width, m	3.44
Lights:	
Lights intensity, Lx	60.40
Feeding System:	
Hopper and trough system	
Prices:	
Feed, $/kg	0.16
Electricity, $/kW.hr	0.06
Egg Prices:	
Nest run price, $	0.45

Table A.5. Management Factors, Design, and Input Values as Used for Verifying the Model on February 16, 1986

Building:	
Length, m	31.00
Width, m	5.50
Height, m	2.37
Insulation:	
Walls, $W/m^2.C$	0.54
Ceiling, $W/m^2.C$	0.32
Simulation Period:	
Beginning day	47.00
Ending day	48.00
Initial Inside Conditions:	
Average daily temperature, C	23.00
Average daily rel. humidity, %	74.00
Initial Outisde Conditions:	
Average daily temperature, F	19.71
Amplitude temperature, F	4.00
Flock Information:	
Number of chickens	4031.00
Age of chickens	51.00
Feed Information:	
Feed metabolized energy, MJ/da	11.532
Crude protein conten, %	0.16
Manure Pit:	
Length, m	25.00
Width, m	3.44
Lights:	
Lights intensity, Lx	60.40
Feeding System:	
Hopper and trough system	
Prices:	
Feed, $/kg	0.16
Electricity, $/kW.hr	0.06
Egg Prices:	
Neat run price, $	0.45

Table A.6. Management Factors, Design, and Input Values as Used for Verifying the Model on February 27, 1986

Building:	
Length, m	31.00
Width, m	5.50
Height, m	2.37
Insulation:	
Walls, $W/m^2.C$	0.54
Ceiling, $W/m^2.C$	0.32
Simulation Period:	
Beginning day	58.00
Ending day	59.00
Initial Inside Conditions:	
Average daily temperature	22.00
Average daily rel. humidity, %	73.00
Initial Outside Conditions:	
Average daily temperature, F	15.38
Amplitude temperature, F	5.00
Flock Information:	
Number of chickens	4020.00
Age of chickens	53.00
Feed Information:	
Feed metabolized energy, mJ/da	11.532
Crude protein content, %	0.16
Manure Pit:	
Length, m	25.00
Width, m	3.44
Lights:	
Lights intensity, Lx	60.40
Feeding System:	
Hopper and trough system	
Prices:	
Feed, $/kg	0.16
Electricity, $/kW.hr	0.06
Egg Prices:	
Nest run price, $	0.45

Table A.7. Management Factors, Design, and Input Values as Used for Verifying the Model on March 3, 1986

Building:	
Length, m	31.00
Width, m	5.50
Height, m	2.37
Insulation:	
Walls, $W/m^2.C$	0.54
Ceiling, $W/m^2.C$	0.32
Simulation Period:	
Beginning day	62.00
Ending day	63.00
Initial Inside Conditions:	
Average daily temperature, C	24.20
Average daily rel. humidity, %	74.00
Initial Outside Conditions:	
Average daily temperature, F	33.17
Amplitude temperature, F	3.50
Flock Information:	
Number of chickens:	4009.00
Age of chickens	53.00
Feed Information:	
Feed metabolized energy, mJ/da	11.532
Crude protein content, %	0.16
Manure Pit:	
Length, m	25.00
Width, m	3.44
Lights:	
Lights intensity, Lx	60.40
Feeding System:	
Hopper and trough system	
Prices:	
Feed, $/kg	0.16
Electricity, $/kW.hr	0.06
Egg Prices:	
Nest run price, $	0.45

APPENDIX B

LIST OF THE MODEL

```
10 ':-----------------------------------------------------------:
20 ':       SUBROUTINE TO INPUT INITIAL DATA FOR SIMULATION     :
30 ':       MODEL AND TO DRAW HEN PICTURE (INTRODUCTION)        :
40 ':       AL-CHALABI DHIA 1985                                :
50 ':       SUBROUTINE    023                                   :
60 ':-----------------------------------------------------------:
70  CLS:SCRN$="HENS.SCR":REM Name of file to Load in
80  SCRNF$="R":REM set screen function to "R" for Read
90  GOSUB 110
100  FOR LOOP=1 TO 5000:NEXT LOOP:CLS:GOSUB 160
110  OPEN"R",1,"SAVESCR.ADR",2:FIELD 1,2 AS SCRNADR$:GET 1:
115  SCRNADR=CVI(SCRNADR$):CLOSE:
120 REM SCRN$=FILE NAME OF SCREEN YOU WANT TO READ IN OR WRITE OUT
130 REM SCRNF$=FUNCTION YOU WISH TO DO "R" FOR READ  "W" FOR WRITE
140  DEF SEG=SCRNADR:CALL 256,SCRN$,SCRNF$
150  RETURN
160 CLS :DIM XX(27)
170 'DRAW THE BOUNDRY OF THE PAGE
180 LOCATE 2,2 :PRINT CHR$(201)
190 'Upper line
200 '
210      FOR X=3 TO 78
220      IF X=40 THEN 230 ELSE 250
230      LOCATE 2,X:PRINT CHR$(203)
240      GOTO 260
250      LOCATE 2,X :PRINT CHR$(205)
260      NEXT X :LOCATE 2,78:PRINT CHR$(187)
270 '
280 'Right line
290 '
300     FOR Y=3 TO 22
310     LOCATE Y,78:PRINT CHR$(186)
320     NEXT Y :LOCATE 23,78 :PRINT CHR$(188)
330 '
340 ' Lower line
350 '
360     FOR X=77 TO 3 STEP -1
370     IF X=40 THEN 380 ELSE 400
380     LOCATE 23,X:PRINT CHR$(202)
390     GOTO 410
400     LOCATE 23,X:PRINT CHR$(205)
410     NEXT X
420     LOCATE 23,2 :PRINT CHR$(200)
430 '
440 'Left line
450 '
460     FOR Y=22 TO 3 STEP -1
470     LOCATE Y,2 : PRINT CHR$(186)
480     NEXT Y
490     LOCATE 8,3
500 '
```

```
510 'Middel line
520 '
530      FOR Y=3 TO 22
540      LOCATE Y,40 :PRINT CHR$(186)
550      NEXT
560 '
570 'Write the headings
580    GOSUB 3650 :GOSUB 3530
590    IF M=1 THEN 2160 ELSE 600
600 'BEGINING OF DATA INPUT
610    ROW =4
620    FOR I=1 TO 22
630    IF I=1 THEN 640 ELSE 680
640    COLOR 3:LOCATE 3,4:PRINT "Building features"
650    LOCATE 4,4:PRINT "------------------" :COLOR 2
660    LOCATE ROW+I,4 :INPUT "1-Length in m ¦ ";LENG: XX(1)=LENG
670 NEXT
680    IF I=2 THEN 690 ELSE 720
690    LOCATE ROW+I,4
700    INPUT "2-Wiedth in m ¦ ";WEDT: XX(2)=WEDT
710 NEXT
720    IF I=3 THEN 730 ELSE 760
730    LOCATE ROW+I,4
740    INPUT "3-Hight  in m ¦ ";HIGT: XX(3)=HIGT
750 NEXT
760    IF I=4 THEN 770 ELSE 810
770    COLOR 3:ROW=7:LOCATE 9,4 :
775    PRINT "Thermal conductivity (U-value) of"
780    LOCATE 10,4:PRINT "---------------------------------" :COLOR 2
790    LOCATE ROW+I,4:
795    INPUT "4-Walls      in W/m2xC ¦";UWALL:XX(4)=UWALL
800 NEXT
810    IF I=5 THEN 820 ELSE 850
820    LOCATE ROW+I,4
830    INPUT "5-Ceilling   in W/m2xC ¦";UCEIL:XX(5)=UCEIL
840 NEXT
850    IF I=6 THEN 860 ELSE 910
860    COLOR 3:ROW=10:LOCATE 8+I,4:
865    PRINT "Simulation period (Julian days)"
870    LOCATE 15,4:PRINT "------------------------------" :COLOR 2
880    LOCATE ROW+I,4
890    INPUT "6-Beging  day ¦";BG :XX(6)=BG
900 NEXT
910    IF I=7 THEN 920 ELSE 950
920    ROW=12:LOCATE 10+I,4:INPUT "7-Endding  day ¦";ED :XX(7)=ED
930    COLOR 2
940 NEXT
950    IF I=8 THEN 960 ELSE 1000
960    COLOR 3:LOCATE 19,4 :PRINT "Initial inside conditions"
970    LOCATE 20,4 :PRINT "--------------------------" :COLOR 2
980    LOCATE 21,4 :INPUT "8-Avg.  daily temperature ¦";TINS:XX(8)=TINS
```

```
990 NEXT
1000     IF I=9 THEN 1010 ELSE 1040
1010     LOCATE 22,4
1020     INPUT "9-Avg.  relative humidity ¦";RHIN :XX(9)=RHIN
1030 NEXT
1040     IF I=10 THEN 1050 ELSE 1090
1050     COLOR 3:LOCATE 3,42:PRINT "Flock informations"
1060     LOCATE 4,42:PRINT "----------------------" :COLOR 2
1070     LOCATE 5,42:
1075     INPUT "10-Number of chickens   ¦";NCHKN :XX(10)=NCHKN
1080 NEXT
1090     IF I=11 THEN 1100 ELSE 1130
1100     LOCATE 6,42
1110     INPUT "11-Age    of chickens   ¦";AGE :XX(11)=AGE
1120 NEXT
1130     IF I=12 THEN 1140 ELSE 1190
1140     COLOR 3:LOCATE 8,42:PRINT "Feed informations"
1150     LOCATE 9,42:PRINT "-------------------" :COLOR 2
1160     LOCATE 10,42
1170     INPUT "12-Feed MET.   energy          ¦";MEDIT :XX(12)=MEDIT
1180 NEXT
1190     IF I=13 THEN 1200 ELSE 1230
1200     LOCATE 11,42
1210     INPUT "13-Crude protein content %  ¦";NSCP :XX(13)=NSCP
1220 NEXT
1230     IF I=14 THEN 1240 ELSE 1330
1240 LOCATE 13,42:COLOR 3:PRINT"14-Supplemental heat  "
1250 LOCATE 14,42:PRINT "----------------------":COLOR 2
1260 LOCATE 15,42:PRINT "1-Natural   gas    ¦"
1270 LOCATE 16,42:PRINT "2-L.P       gas    ¦"
1280 LOCATE 17,42:PRINT "3-No suppl.  heat   ¦"
1290 LOCATE 19,42:INPUT "Choose one option please";FGR
1300 XX(14)=FGR
1310 IF FGR<=0 OR FGR>=4 GOTO 1290
1320 NEXT
1330     IF I=15 THEN 1350 ELSE 1410
1340 'Clean the screen
1350     GOSUB 3540
1360     COLOR 3:LOCATE 3,4 :PRINT "Information about manure area"
1370     LOCATE 4,4:PRINT "--------------------------------" :COLOR 2
1380     LOCATE 5,4
1390     INPUT "15-Length of pit in m ¦";LENM :XX(15)=LENM
1400 NEXT
1410     IF I=16 THEN 1420 ELSE 1450
1420     LOCATE 6,4
1430     INPUT "16-Wiedth of pit in m ¦";WEDM :XX(16)=WEDM
1440 NEXT
1450     IF I=17 THEN 1460 ELSE 1500
1460     COLOR 3:LOCATE 8,4:PRINT "Information about Lights"
1470     LOCATE 9,4:PRINT "---------------------------":COLOR 2
1480     LOCATE 10,4:INPUT "17-Light intensity in Lx ¦";LIT :XX(17)=LIT
```

```
1490 NEXT
1500    IF I=18 THEN 1510 ELSE 1620
1510    COLOR 3:LOCATE 12,4 :PRINT "18-Feeding systems "
1520    LOCATE 13,4 :PRINT "-------------------" :COLOR 2
1530    LOCATE 14,4 :PRINT "1-Hopper and trough system ¦"
1540    LOCATE 15,4 :PRINT "2-Chain system             ¦"
1550    LOCATE 16,4 :PRINT "3-Hopper and trough + grid ¦"
1560    LOCATE 17,4 :PRINT "4-Spiral system            ¦"
1570    LOCATE 18,4 :PRINT "5-Sleeve system            ¦"
1580    LOCATE 20,4 :INPUT "Choose one feed system Please ";FSV
1590    XX(18)=FSV
1600    IF FSV<=0 OR FSV>=6 GOTO 1580
1610 NEXT
1620    IF I=19 THEN 1630 ELSE 1670
1630    COLOR 3:LOCATE 3,42:PRINT "Information about costs"
1640    LOCATE 4,42 :PRINT "-----------------------":COLOR 2
1650    LOCATE 5,42 :INPUT "19-Feed cost  $/Kg   ¦";FPRIC:XX(19)=FPRIC
1660 NEXT
1670    IF I=20 THEN 1680 ELSE 1710
1680    LOCATE 6,42
1690    INPUT "20-Electricity cost  ¦";ELPRC:XX(20)=ELPRC
1700 NEXT
1710    IF I=21 THEN 1720 ELSE 1740
1720    LOCATE 7,42:INPUT "21-Fuel cost  $/m3   ¦";FUPRC:XX(21)=FUPRC
1730 NEXT
1740    IF I=22 THEN 1750 ELSE 1800
1750    COLOR 3:LOCATE 9,42
1760    PRINT "Information about egg prices"
1770    LOCATE 10,42:PRINT "---------------------------------":COLOR 2
1780    LOCATE 11,42:
1785    INPUT "22-Nest run price           ¦";VEGG1:XX(22)=VEGG1
1790 NEXT
1910 '
1920    OPEN "O", 1,N$+".SIM"
1930    FOR I=1 TO 22
1940    WRITE  1,XX(I)
1950 NEXT I
1960    CLOSE  1
1970 '
1980    LOCATE 17,42:PRINT "Are these values correct (Y/N) ?"
1990    LOCATE 17,75:QQ$=INKEY$ :IF QQ$="" THEN 1990
2000    IF QQ$="Y" OR QQ$="y" THEN  CHAIN "HOUSIMUL",,ALL
2010 'Correct the wrong values
2020 '
2030    OPEN "O", 1,N$+".SIM"
2040    LOCATE 18,42:INPUT"Enter number,new value ";I,XX(I)
2050    FOR I=1 TO 22
2060    WRITE  1,XX(I)
2070    NEXT I
2080    CLOSE  1
2090 '
```

```
2100    OPEN "I", 2,N$+".SIM"
2110    GOSUB 3540
2120    INPUT  2,XX(I)
2130    GOSUB 2250
2140    CLOSE  2
2150    GOTO 1980
2160 'Read the old file from the disk
2170    LOCATE 1,30:PRINT "WAIT loading file ";N$
2180    OPEN "I", 1,N$+".SIM"
2190    FOR I=1 TO 22
2200    INPUT  1,XX(I)
2210    NEXT I
2220    CLOSE  1
2230    LOCATE 1,30:PRINT"                              ":
2235    GOSUB 2250:GOTO 1980
2240 'Write the data to the screen
2250    ROW =4
2260    FOR I=1 TO 22
2270    IF I=1 THEN 2280 ELSE 2320
2280    COLOR 3:LOCATE 3,4:PRINT "Building features"
2290    LOCATE 4,4:PRINT "-----------------" :COLOR 2
2300    LOCATE ROW+I,4 :PRINT "1-Length in m ¦ ";XX(1)
2310 NEXT
2320    IF I=2 THEN 2330 ELSE 2360
2330    LOCATE ROW+I,4
2340    PRINT "2-Width  in m ¦ ";XX(2)
2350 NEXT
2360    IF I=3 THEN 2370 ELSE 2400
2370    LOCATE ROW+I,4
2380    PRINT "3-Hight  in m ¦ ";XX(3)
2390 NEXT
2400    IF I=4 THEN 2410 ELSE 2450
2410    COLOR 3:ROW=7:LOCATE 9,4 :
2415    PRINT "Thermal conductivity (U-value) of"
2420    LOCATE 10,4:PRINT "---------------------------------" :COLOR 2
2430    LOCATE ROW+I,4:PRINT "4-Walls      in W/m2xC ¦";XX(4)
2440 NEXT
2450    IF I=5 THEN 2460 ELSE 2490
2460    LOCATE ROW+I,4
2470    PRINT "5-Ceilling   in W/m2xC ¦";XX(5)
2480 NEXT
2490    IF I=6 THEN 2500 ELSE 2550
2500    COLOR 3:ROW=10:LOCATE 8+I,4:
2505    PRINT "Simulation period (Julian days)"
2510    LOCATE 15,4:PRINT "-------------------------------" :COLOR 2
2520    LOCATE ROW+I,4
2530    PRINT "6-Beging   day ¦";XX(6)
2540 NEXT
2550    IF I=7 THEN 2560 ELSE 2590
2560    ROW=12:LOCATE 10+I,4:PRINT "7-Endding  day ¦";XX(7)
2570    COLOR 2
```

```
2580 NEXT
2590    IF I=8 THEN 2600 ELSE 2640
2600    COLOR 3:LOCATE 19,4 :PRINT "Initial inside conditions"
2610    LOCATE 20,4 :PRINT "---------------------------" :COLOR 2
2620    LOCATE 21,4 :PRINT "8-Avg.  daily temperature ¦";XX(8)
2630 NEXT
2640    IF I=9 THEN 2650 ELSE 2680
2650    LOCATE 22,4
2660    PRINT "9-Avg.  relative humidity ¦";XX(9)
2670 NEXT
2680    IF I=10 THEN 2690 ELSE 2730
2690    COLOR 3:LOCATE 3,42:PRINT "Flock information "
2700    LOCATE 4,42:PRINT "----------------------" :COLOR 2
2710    LOCATE 5,42:PRINT "10-Number of chickens   ¦";XX(10)
2720 NEXT
2730    IF I=11 THEN 2740 ELSE 2770
2740    LOCATE 6,42
2750    PRINT "11-Age    of chickens   ¦";XX(11)
2760 NEXT
2770    IF I=12 THEN 2780 ELSE 2830
2780    COLOR 3:LOCATE 8,42:PRINT "Feed information "
2790    LOCATE 9,42:PRINT "------------------" :COLOR 2
2800    LOCATE 10,42
2810    PRINT "12-Feed MET.   energy        ¦";XX(12)
2820 NEXT
2830    IF I=13 THEN 2840 ELSE 2870
2840    LOCATE 11,42
2850    PRINT "13-Crude protein content %  ¦";XX(13)
2860 NEXT
2870    IF I=14 THEN 2880 ELSE 2950
2880 LOCATE 13,42:COLOR 3:PRINT"14-Supplemental heat  "
2890 LOCATE 14,42:PRINT "----------------------":COLOR 2
2900 LOCATE 15,42:PRINT "1-Natural   gas    ¦"
2910 LOCATE 16,42:PRINT "2-L.P       gas    ¦"
2920 LOCATE 17,42:PRINT "3-No suppl.  heat   ¦"
2930 LOCATE 19,42:PRINT "Your choise is   ";XX(I)
2940 NEXT
2950    IF I=15 THEN 2970 ELSE 3030
2960 'Clean the screen
2970    GOSUB 3590: GOSUB 3540
2980    COLOR 3:LOCATE 3,4 :PRINT "Information about manure area"
2990    LOCATE 4,4:PRINT "-------------------------------" :COLOR 2
3000    LOCATE 5,4
3010    PRINT "15-Length of pit in m ¦";XX(15)
3020 NEXT
3030    IF I=16 THEN 3040 ELSE 3070
3040    LOCATE 6,4
3050    PRINT "16-Width  of pit in m ¦";XX(16)
3060 NEXT
3070    IF I=17 THEN 3080 ELSE 3120
3080    COLOR 3:LOCATE 8,4:PRINT "Information about Lights"
```

```
3090    LOCATE 9,4:PRINT "--------------------------":COLOR 2
3100    LOCATE 10,4:PRINT "17-Light intensity in Lx ¦";XX(17)
3110 NEXT
3120    IF I=18 THEN 3130 ELSE 3220
3130    COLOR 3:LOCATE 12,4 :PRINT "18-Feeding systems "
3140    LOCATE 13,4 :PRINT "-------------------" :COLOR 2
3150    LOCATE 14,4 :PRINT "1-Hopper and trough system ¦"
3160    LOCATE 15,4 :PRINT "2-Chain system             ¦"
3170    LOCATE 16,4 :PRINT "3-Hopper and trough + grid ¦"
3180    LOCATE 17,4 :PRINT "4-Spiral system            ¦"
3190    LOCATE 18,4 :PRINT "5-Sleeve system            ¦"
3200    LOCATE 20,4 :PRINT "Your choise is   ";XX(I)
3210 NEXT
3220    IF I=19 THEN 3230 ELSE 3270
3230    COLOR 3:LOCATE 3,42:PRINT "Information about costs"
3240    LOCATE 4,42 :PRINT "-----------------------":COLOR 2
3250    LOCATE 5,42 :PRINT "19-Feed cost  $/Kg   ¦";XX(19)
3260 NEXT
3270    IF I=20 THEN 3280 ELSE 3310
3280    LOCATE 6,42
3290    PRINT "20-Electricity cost  ¦";XX(20)
3300 NEXT
3310    IF I=21 THEN 3320 ELSE 3340
3320    LOCATE 7,42:PRINT "21-Fuel cost  $/m3   ¦";XX(21)
3330 NEXT
3340    IF I=22 THEN 3350 ELSE 3400
3350    COLOR 3:LOCATE 9,42
3360    PRINT "Information about egg prices"
3370    LOCATE 10,42:PRINT "----------------------------------":COLOR 2
3380    LOCATE 11,42:PRINT "22-Nest run price            ¦";XX(22)
3390 NEXT
3510 '
3520    RETURN
3530 'Clean the screen
3540          SR=0
3550          FOR J=3 TO 22:LOCATE J,4+SR
3560          PRINT "                                      "
3570          NEXT :IF SR=38  THEN RETURN
3580          SR =38 : GOTO 3550
3590 'This subroutine will wait for input to continue
3600          COLOR 0,5:LOCATE 22,47:PRINT" Hit space bar to continue "
3610          FOR D=1 TO 1500:NEXT :COLOR 2,0
3620          LOCATE 22,47:PRINT "                           "
3630          QQ$=INKEY$:IF QQ$="" THEN 3630
3640          IF QQ$=" " THEN RETURN
3650 'This subroutine will aske the user if he wants to use an old file
3660     COLOR 7
3670     LOCATE 3,4:INPUT "Enter Farm name ¦";FARM$
3680     LOCATE 22,4:PRINT"OLD files on this disk are¦-"
3690     LOCATE 24,4:ON ERROR GOTO 3760 :FILES"*.SIM"
3700     LOCATE 5,4:PRINT "Do you want an old file (Y/N)?"  :LOCATE 5,34
```

```
3710     Q$=INKEY$:IF Q$=""  THEN 3710
3720     IF Q$="Y" OR Q$="y" THEN 3730 ELSE 3760
3730     LOCATE 6,4:INPUT "OLD file name (8 Chr.)";N$:LOCATE 24,4
3740     FOR FG=4 TO 80:PRINT" ";:NEXT
3750     COLOR 2:M=1:RETURN
3760     COLOR 5:LOCATE 5,42:
3765     INPUT"NEW file name (8 Chr.)";N$:LOCATE 24,4
3770     COLOR 2:M=0:FOR FG=4 TO 80:PRINT" ";:NEXT :RETURN
```

```
1 ':-----------------------------------------------------------:
2 ':    THIS IS THE MAIN  PROGRAM TO CALCULATE PSYCHROMETRIC   :
3 ':               PARAMETERS AND CONTROL THE MODEL            :
4 ':                                                           :
5 ':               WRITTEN BY DHIA AHMED AL-CHALABI 1985-1986  :
6 ':-----------------------------------------------------------:
7 CLS:DIM Y1(26),Y2(26),Y3(26),Y4(26),VRATE(26),TINS(26)
8     DIM TOUT(26),RHIN(26),RHOUT(26)
10    A =-27405.526       :NRPRC= XX(22)
12    B = 97.5413         :LENG=XX(1)  :WEDT=XX(2)   :HIGT=XX(3)
14    C =-.146244         :UCEIL=XX(5):BG =XX(6)    :ED =XX(7)
16    D = .00012558       :RHIN =XX(9):NCHKN=XX(10):AGE=XX(11)
18    E =-.000000048502 :NSCP=XX(13):FGR =XX(14)  :LENM=XX(15)
20    F = 4.34903         :LIT=XX(17)  :FSV=XX(18)   :FPRIC=XX(19)
22    G = .0039381        :FUPRC=XX(21):UWALL=XX(4):TINS=XX(8)
25    R = 22105649.25     :MEDIT=XX(12):WEDM=XX(16):ELPRC=XX(20)
30 '
44    TINEW=TINS :MEANT=TINS:ELSUM=0:CW=0:COUNT=0:QSUPL=0:FLAG=0:FGR=2
160 'Calculate body weight of chickens       subroutine   2      in kg
180      GOSUB 12000
200 'Starting DAILY simulation  *.*.*.*.*.*.*.*.*.*.*.*.*.*.*.*.*.*.*
210 '
220      FOR DOP =BG TO ED
225      TISUM=0 :RHSUM=0 :VRSUM=0 :CRF=1 :QMOLD=0 :
226      QHOLD=0 :RHOSM=0:COUNT=0
230      GOSUB 31000
240 'Calculate daily average temperature     subroutine   7      in C
250 '
260      GOSUB 17000
270 '
280 'Calculate body weight in kg and change in gaine in gr
290      GOSUB 20000
300      BWEIT=(BWEIT + DTW/1000)
310      BODYW=BWEIT* NCHKN
320 'Starting HOURLY simulation .*.*.*.*.*.*.*.*.*.*.*.*.*.*.*.*.*.*.*
330 '
340      FOR H=1 TO 24
350 '
360 'Calculate outside hourly temperature      subrotine   6     in C
370 ' and relative humidity
380      GOSUB 16000
390 '
400      TOUT=TEMPC    :TOUT(H)=TOUT  :RHOUT(H)=RHOUT
410 '
420 'Psychrometric calculation                               in SI units
430 'for outside conditions
520 '
530 'Calculate outside absolute temperature                  in Kelvin
540 '
550      TOKVN=TOUT+273.16
560 '
```

```
570 'Atmospheric pressure                                          in kPa
580 '
590     PATMO= 101.325
600 '
610 'Calculate saturated vapor pressure temp.  range (-18 - 0)    in kPa
620 '
630     IF TOUT <=0 AND TOUT >=-18 THEN 640 ELSE 690
640        LTOK=LOG(TOKVN)
650     PSOUT=EXP(31.9602-(6270.3605 /TOKVN)-(4.6057*LTOK))
660        GOTO 710
670 '
680 'Calculate saturated vapor pressur temp.  range  (0 - 110)    in kPa
690 '
700     Z =(A +(B *TOKVN)+(C *(TOKVN^2))+(D *(TOKVN^3))+(E *(TOKVN^4)))
703     Y =((F *TOKVN)-(G *(TOKVN^2)))
705     L =Z /Y   :PSOUT=R *CDBL(EXP(L ))
710     PSOUT=PSOUT/1000
720 'Calculate actual vapor pressure                                in kPa
730 '
740     PVOUT=(RHOUT*PSOUT)/100
750 '
760 'Calculate humidity ratio of outside air                   in kg/kg da
770 '
780     HOUT=(.6219*PVOUT)/(PATMO-PVOUT)
790 '
800 'Calculate specific volume of outside air                     in m3/kg
810 '
820     VSOUT=(.287*TOKVN)/(PATMO-PVOUT)
830 '
840 'CALCULATE INSIDE CONDITIONS *.*.*.*.*.*.*.*.*.*.*.*.*.*.*.*
850 'Calculate absolute inside temperature                      in Kelvin
860 '
870     TNKVN=TINS+273.16
880 '
890 'Calculate saturation vapor pressure                            in kPa
900 '
903     K =(A +(B *TNKVN)+(C *(TNKVN^2))+(D *(TNKVN^3))+(E *(TNKVN^4)))
906     M =((F *TNKVN)-(G *(TNKVN^2)))
910     S =K /M    :PSINS=R *CDBL(EXP(S ))
920     PSINS=PSINS/1000
930 'Calculate vapor pressure                                       in kPa
940 '
950     PVINS=(RHIN*PSINS)/100
960 '
970 'Calculate humidity ratio of inside air                in kg/kg d.a.
980 '
990     HINS=(.6219*PVINS)/(PATMO-PVINS)
1000 '
1010 'Calculate specific volume of inside air                     in m3/kg
1020 '
1030     VSINS=(.287*TNKVN)/(PATMO-PVINS)
```

```
1040 '
1050 'Calculate air mass in the building                               in kg
1055 '
1060     VOLUM=HIGT*LENG*WEDT-(BODYW/1000)-5.599
1070     AMI=VOLUM/VSINS
1080 '
1090 'Calculate latent heat of vaporization                          in kJ/kg
1100 'of water at saturation
1110     HFG=2502.535259 -2.38576*(TNKVN-273.16)
1120 '
1130 'Calculate  latent heat from birds     subroutine   4         in kJ/hr
1140 '
1150     GOSUB 14000
1160 '
1170 'Calculate moisture from manure         subroutin   5         in kg/hr
1180 '
1190     GOSUB 15000
1200 '
1210 'Calculate moisture production from respiration               in kg/hr
1220 '
1230     WECHK=QLATB/HFG
1240 '
1250 'Calculate total moisture  added to the air                    in kg/hr
1260 '
1270     WETOT=WECHK+WEMNR
1273 '
1275 'Calculate building heat loss           subroutine   1         in kJ/hr
1280 '
1285     GOSUB 11000
1287 '
1290 'Calculate sensible heat from birds     subroutine   3         in kJ/hr
1300 '
1310     GOSUB 13000
1320 '
1330 'Calculate ventilation rate             subroutine  16         in m3/hr
1340 '
1350     GOSUB 26000
1360 '
1370 'Calculate ventilation air flow                                in kg/hr
1380 '
1390     MAV=VRATE/VSINS
1400 '
1410 'Calculate rate of change for heat content inside               in kJ
1420 'Change in time =1 hour                                         in hr
1430 '
1440     DTIME=1
1450     DAH=1.0035*(TOUT-TINS)
1453     MAH=2501*(HOUT-HINS)+1.775*((HOUT*TOUT)-(HINS*TINS))
1455     LHA=2430 * WECHK
1457     QHCHG=DTIME*((MAV*(DAH+MAH))+LHA-QTOTB+QSNCL+QSUPL)
1460 '
```

```
1470 'Calculate rate of change for moisture content        in kg/kg d.a
1480 '
1490     QMCHG=DTIME*(((MAV*HOUT+WETOT)-(MAV*HINS))/AMI)
1500 '
1502      IF CRF=1 THEN 1504 ELSE 1550
1504      TOUT(0)=TOUT :TINS(0)=TINS :RHIN(0)=RHIN :RHOUT(0)=RHOUT
1506 '
1510 'Calculate initial values for            subroutine   17
1520 'heat and moisture
1530     GOSUB 27000
1540 '
1550 'Calculate new values for heat and moisture content
1560 '
1570     QHNEW=QHOLD+QHCHG
1580     QMNEW=QMOLD+QMCHG
1590 '
1600 'CALCULATE NEW INSIDE TEMPERATURE                              in C
1610 '
1620     TINEW=((QHNEW/AMI)-(2501* QMNEW))/(1.0035+1.775* QMNEW)
1630 '
1640 'Check temperature range inside
1650 '
1671    IF FGR=2 AND TINEW<MEANT-2 AND VRATE<1100  THEN 1710 ELSE 1672
1672    IF FGR=1 AND TINEW<MEANT-2 AND VRATE<1100  THEN 1673 ELSE 1677
1673 '  GOSUB 22000
1674 '  GOTO 1410
1675 '
1677    IF TINEW <=MEANT+2 AND TINEW >=MEANT-2 THEN 1710 ELSE 1680
1678 '
1680 'GO to the control subroutine   18
1690     GOSUB 28000
1700     GOTO 1390
1710     TINS(H)=TINEW  :VRATE(H)=VRATE/3600
1720 'Calculate inside relative humidity
1730 'Calculate absolute temperture for new inside
1740 'temperature in Kelvin
1750     TNEWK=TINEW+273.16
1760 '
1770 'Calculate actual vapor pressure                              in kPa
1780 '
1790     PVACT=(HINS*PATMO)/(HINS+.6219)
1800 '
1810 'Calculate saturated vapor pressure                           in kPa
1820 '
1830   NE =(A +(B *TNEWK)+(C *(TNEWK^2))+(D *(TNEWK^3))+(E *(TNEWK^4)))
1833   PW =((F *TNEWK)-(G *(TNEWK^2)))
1836   UA =NE /PW
1840   PSNEW=R *CDBL(EXP(UA ))  : PSNEW=PSNEW/1000
1850 'Calculate new relative humidity inside  %
1860 '
1870     RHNEW=(PVACT/PSNEW)*100
```

```
1875     IF RHNEW >99 THEN RHNEW=95
1880     RHIN(H)=RHNEW
1890 'Exchange the values
1900 '
1910     QHOLD=QHNEW
1920     QMOLD=QMNEW
1930     TINS =TINEW
1940     RHIN =RHNEW
1950 '
1960 'Calculate the sum of values            subroutine   19
1970 '
1980     GOSUB 29000
1990 'Save the data in array
2000     Y1(H)=TINS(H)
2010     Y2(H)=TOUT(H)
2020     Y3(H)=RHIN(H)  :Y4(H)=VRATE(H)  :QSUPL=0
2022     TOLD=TOUT(H-1):TILD=TINS(H-1)  :RHILD=RHIN(H-1)  :
2023     RHOLD=RHOUT(H-1)
2025     GOSUB 21000   : GOSUB 32000   :'Print out hourly report
2030     NEXT H        :'Next hour  *.*.*.*.*.*.*.*.*.*.*.*.*.*.*.*.*.*.*
2040 'Calculate age of the birds in weeks
2050     AGE=AGE+(1/7)
2056 'Calculate maximum and minimum temperatures
2058 '
2060     TIMIN=TINS(1)
2062     FOR H=1 TO 24
2064     IF TINS(H)>=TIMIN THEN 2068
2066     TIMIN=TINS(H)
2068     NEXT H
2070     TIMAX=TINS(1)
2072     FOR H=1 TO 24
2074     IF TINS(H)<=TIMAX THEN 2078
2076     TIMAX=TINS(H)
2078     NEXT H
2080 'Calculate change in body weight      subroutine   10     in gr/da
2090 '
2100     GOSUB 20000 :GOSUB 30000
2110 '
2120 'Calculate mortality of the birds per day (assumed .008/month)
2150 '
2155     MORCH=NCHKN * .0003 :MORCH=INT(MORCH)
2160     NCHKN=NCHKN - MORCH
2165 '
2170 'Calculate feed intake and egg prodution   subroutine   14 & 15
2180 '
2190     GOSUB 24000
2200 '
2300 'Calculate feed intake for 1000 birds                     in kg/day
2310 '
2320     FE100= FETAK*1000
2330 '
```

```
2340 'Calculate feed cost consumed by 1000 birds          in $/day
2350 '
2360     FCOST=(FPRIC*FE100)/1000
2370 '
2380 'Calculate total egg production                        in kg/day
2390 '
2400     EGTOT=(E30FE*NCHKN)/1000
2410 '
2420 'Calculate egg production for 100 birds                in kg/day
2430 '
2440     EG100= E30FE*100
2445 'Calculate egg sale and display daily report
2447   GOSUB 40000 : GOSUB 39000
2450 NEXT DOP
2460 END
2470 '
2480 ' Where|-----------------------------------------------------
2490 ' QLATB ---------------- latent heat production     in kJ/hr   |
2500 ' QTOTB ---------------- heat loss through buliding in kJ/hr   |
2510 ' QSNCL ---------------- total sensible heat prod.   in kJ/hr   |
2515 ' QSUPL ---------------- suplemental heat needed    in kJ/hr   |
2520 ' PRCO2 ---------------- carbon dioxide production  in m3/g/hr|
2530 ' VRCO2 ---------------- ventilation rate for CO2   in m3/sce  |
2540 ' MWATR ---------------- rate of water production   in kg/hr   |
2550 ' WEMNR ---------------- water vaopr from manure    in kg/hr   |
2560 ' VRMIS ---------------- venti.  rate for moisture   in m3/sce |
2570 ' VSINS ---------------- specific volume in air     in m3/kg   |
2580 ' VRTMP ---------------- venti.rate for temperature in m3/sce  |
2590 ' HINS  ---------------- humidity ratio inside air  in kg/kg   |
2600 ' HOUT  ---------------- humidity ratio outside air in Kg/Kg   |
2610 ' TINS  ---------------- inside temperaturet        in C       |
2620 ' TOUT  ---------------- outside temperaturet       in C       |
2630 ' HFG   ---------------- latent heat of evaporation in kJ/kg   |
2640 ' DAH   ---------------- heat of dry air flow       in kJ      |
2650 ' MAH   ---------------- heat from moisture change  in kJ      |
2655 ' LHA   ---------------- heat from moisture of hens in kJ      |
2660 '       |-----------------------------------------------------
2670 ' End of subroutine
11000 ':-----------------------------------------------------------:
11010 ':       SUBROUTINE OF HEAT LOSS THROUGH THE BUILDING kJ/hr  :
11020 ':                   AL-CHALABI DHIA                          :
11030 ':                                                            :
11040 ':       SUBROUTINE    01                                     :
11050 ':-----------------------------------------------------------:
11060 '
11070 'Calculate surface area of the walls in m2
11080 '
11090         AWALL=2*HIGT*(LENG+WEDT)
11100 '
11110 'Calculate heat loss through the walls   QWALL  in W
11120 '
```

```
11130         QWALL=AWALL*UWALL*(TINS-TOUT)
11140 '
11150 'Calaulate heat loss through the ceiling QCEIL  in W
11160 '
11170         QCEIL=(LENG*WEDT)*UCEIL*(TINS-TOUT)
11180 '
11190 'Calculate heat loss through the floor   QFLOR  in W
11200         UFLOR=3,155
11210         QFLOR=((LENG * WEDT)-(LEMN * WEDM))* UFLOR
11220 '
11230 'Calculate total heat loss through the building in kJ/hr
11240 '
11250         QTOTB=QWALL+QCEIL+QFLOR
11260         QTOTB=QTOTB * 3.6
11270        RETURN
11280 '
11290 ' Where¦---------------------------------------------------
11300 ' AWALL ---------------- surface area of the walls  in m2     ¦
11310 ' HIGT  ---------------- hight of the building      in m      ¦
11320 ' WEDT  ---------------- width of the building      in m      ¦
11330 ' LENG  ---------------- length of the building     in m      ¦
11340 ' UWALL ---------------- wall coef.of heat trans.    in W/m2.C ¦
11350 ' UCEIL ---------------- ceiling coef.of heat trans.in W/m2.C ¦
11355 ' UFLOR ---------------- flor heat loss coef.        in W/m2   ¦
11360 ' QWALL ---------------- heat loss through walls    in W      ¦
11370 ' QCEIL ---------------- heat loss through ceiling  in W      ¦
11380 ' QFLOR ---------------- heat loss through floor    in W      ¦
11385 ' QTOTB ---------------- heat loss through building in kJ/hr  ¦
11390 '      ¦---------------------------------------------------
11400 ' End of subroutine
12000 ':-----------------------------------------------------------:
12010 ':       SUBROUTINE OF BODY WEIGHT CALCULATION in kg         :
12020 ':                     AL-CHALABI DHIA                        :
12030 ':                                                            :
12040 ':       SUBROUTINE    02                                     :
12050 ':-----------------------------------------------------------:
12060 '
12070 'Calculate body weigth for hens from age 19 - 40 weeks in kg
12080 '
12090         IF AGE >=19  AND AGE <=40 THEN 12100 ELSE 12130
12100         BWEIT=.41583 * (AGE^ .400275)      :'R=.94
12110     GOTO 12180
12120 '
12130 'Calculate body weight for hens from age 41 - 78 weeks in kg
12140 '
12150         BWEIT=1.68548 * (AGE^ .011659)     :'R=1.0
12160 '
12170 '
12180     RETURN
12190 '
12200 '
```

```
12210 ' Where¦-----------------------------------------------------
12220 ' AGE    ---------------- age of the hens          in weeks  ¦
12230 ' BODYW  ---------------- body weight of the hens   in kg     ¦
12240 ' R      ---------------- correlation coef.  of dody           ¦
12250 '                         weight and age                      ¦
12260 '       ¦-----------------------------------------------------
12270 ' End of subroutine
13000 ':-------------------------------------------------------------:
13010 ':       SUBROUTINE TO CALCULATE SENSIBLE HEAT in kJ/hr        :
13020 ':              AL-CHALABI DHIA                                :
13030 ':                                                             :
13040 ':       SUBROUTINE    03                                      :
13050 ':-------------------------------------------------------------:
13060         H=INT(H)
13070 'Calculate sensible heat from the hens at night    in kJ/hr
13080 '
13090         IF H <5 AND H >=1  THEN 13100 ELSE 13122
13100         QSNSB=(16.4533 - .3108 * TINS) * BODYW     :'R=.97
13110         FLAG=0 :  QSNSL=0  :GOTO 13230
13120 '
13122         IF H <=24 AND H>=19  THEN 13124 ELSE 13130
13124         QSNSB=(16.4533 - .3108 * TINS) * BODYW     :'R=.97
13126         FLAG=0 :  QSNSL=0  :GOTO 13230
13128 '
13130 'Calculate sensible heat from the hens at day time in kJ/hr
13140 '
13150         IF H <19 AND H >=5 THEN 13160
13160         QSNSB=(23.4309 * (TINS^-.1558 ))* BODYW    :'R=.96
13170         FLAG=1 :'LIGHTS ON
13180 '
13190 'Calculate sensible heat from the lights          in kJ/hr
13200 '
13210         QSNSL=(LENG*WEDT) * 38.744
13220 '
13230 'Calculate total sensible heat                    in kJ/hr
13240 '
13250         QSNCL=QSNSB + QSNSL
13260 '
13270         RETURN
13280 '
13290 '
13300 ' Where¦-----------------------------------------------------
13310 ' QSNSB ---------------- sensible heat production   in kJ/hr  ¦
13320 ' QSNSL ---------------- sensible heat from lights  in kJ/hr  ¦
13330 ' QSNCL ---------------- total sensible heat        in kJ/hr  ¦
13340 ' TINS  ---------------- inside temperaturet        in C      ¦
13350 ' H     ---------------- time of the day            in Hours  ¦
13360 ' R     ---------------- correlation coef.  of sensible        ¦
13365 '                        heat and inside temperature          ¦
13370 ' 38.744---------------- heat generated by lights in kJ/hr.m2 ¦
13380 '      ¦-----------------------------------------------------
```

```
13390 ' End of subroutine
14000 ':-------------------------------------------------------------:
14010 ':       SUBROUTINE TO CALCULATE LATENT HEAT in kJ/hr          :
14020 ':                  AL-CHALABI DHIA                            :
14030 ':                                                             :
14040 ':       SUBROUTINE    04                                      :
14050 ':-------------------------------------------------------------:
14060 '
14070 'Calculate latent heat from the hens at night    in kJ/hr
14080 '
14090       IF H>=1 AND H <5  THEN 14100 ELSE 14120
14100       QLATB=(3.8085 +.1685 * TINS) * BODYW      :'R=.92
14110       FLAG=0:  GOTO 14190
14120 '
14122       IF H<=24 AND H>=19 THEN 14124 ELSE 14140
14124       QLATB=(3.8085 +.1685 * TINS) * BODYW
14126       FLAG=0:  GOTO 14190
14128 '
14130 'Calculate latent heat from the hens at day time in kJ/hr
14140 '
14150       IF H >=5 AND H <19 THEN 14160
14160       QLATB=(4.4649 +.2122 * TINS) * BODYW      :'R=.97
14170       FLAG=1 :'Lights ON
14180 '
14190 '
14200       RETURN
14210 '
14220 '
14230 ' Where¦-----------------------------------------------------
14240 ' QLATB ---------------- latent heat production     in kJ/hr  ¦
14250 ' TINS  ---------------- inside temperature         in C      ¦
14260 ' H     ---------------- time of the day            in Hours  ¦
14270 ' R     ---------------- correlation coef.  of latent         ¦
14280 '                        heat and inside temperature          ¦
14290 '      ¦-----------------------------------------------------
14300 ' End of subroutine
15000 ':-------------------------------------------------------------:
15010 ':       SUBROUTINE OF WATER EVAPORATION FROM MANURE in kg/hr:
15020 ':                  AL-CHALABI DHIA                            :
15030 ':                                                             :
15040 ':       SUBROUTINE    05                                      :
15050 ':-------------------------------------------------------------:
15060 'This subroutine will calculate water from manure in kg/hr
15070 'Calculate area covered with manure                  in m2
15080       RFTOR=1.5
15090       ARAM=LENM * WEDM *RFTOR
15100 '
15110 'Calculate temperature near the manure               in C
15120 '
15130       CHTMP=.09
15140       TMNR=TINS-CHTMP
```

```
15150 '
15160 'Calculate absolute temperature near the manure      in Kelvin
15170 '
15180        TMNRK=TMNR+273.16
15190 '
15200 'Calculate saturated vapor pressure near the manure  in torr
15210 '
15220   P =(A +(B *TMNRK)+(C *(TMNRK^2))+(D *(TMNRK^3))+(E *(TMNRK^4)))
15225   Q =((F *TMNRK)-(G *(TMNRK^2)))
15230   V =P /Q  :        PSMNR=R *CDBL(EXP(V ))
15240   PSMNR=PSMNR/133.322
15250 '
15260 'Calculate partial vapor  pressure near the manure    in torr
15270        RHMNR=RHIN/100
15280        PVMNR=PSMNR * RHMNR
15290 '
15300 'Calculate partial pressure in the house             in torr
15310 '
15320        PVINT=PVINS/.1333
15330 '
15340 'Calculate change in pressure                        in torr
15350 '
15360        DPSSR=PVMNR - PVINT
15370 '
15380 'Calculate barometric pressure                       in torr
15390 '
15400        BPRSS=PATMO*(760/101.325)
15410 '
15420 'Calculate evaporation coefficient in kg/m2/hr
15430        AVELC=.06
15440        SIGMA=.018 + .015 * AVELC
15450 '
15460 'Calculate water evaporation from the manure         in kg/hr
15470 '
15480        WEMNR=SIGMA * ARAM * DPSSR *(760/BPRSS)
15490 '
15500 '
15510        RETURN
15520 '
15530 '
15540 ' Where|----------------------------------------------------
15550 ' LENM  ---------------- length of the manure area  in m      |
15560 ' WEDM  ---------------- wedth of the manure arae   in m      |
15570 ' ARAM  ---------------- area covered with manure   in m2     |
15580 ' TMNR  ---------------- temperature near manure    in C      |
15590 ' TINS  ---------------- inside temperaturet        in C      |
15600 ' TMNRK ---------------- absolute temp.  near manure in K     |
15610 ' DTEMP ---------------- change in temperature      in C      |
15620 ' PSMNR ---------------- saturated pres.near manure in torr   |
15630 ' PVMNR ---------------- partial pres.  near manure  in torr  |
15640 ' PVINT ---------------- partial pres.  in the house in torr  |
```

```
15650 ' DPSSR ---------------- change in pressure         in torr   |
15660 ' BPRSS ---------------- barometric pressuer        in torr   |
15670 ' SIGMA ---------------- coefficient of evaporation in kg/m2/h|
15680 ' AVELC ---------------- air velocity near manure   in m/sce  |
15690 ' WEMNR ---------------- water evapo.  from manure   in kg/hr  |
15700 ' RFTOR ---------------- manure roughness factor              |
15710 ' UNITS ----------------   1 torr =.1333  kPa =   1 mm Hg abs |
15720 '                        760 torr =101.325 kPa=   1 atm       |
15730 '        |-----------------------------------------------------
15740 ' End of subroutine
16000 ':------------------------------------------------------------:
16010 ':        SUBROUTINE OF TEMPERATURE & REL.HUM.  OUTSIDE in C   :
16020 ':                      AL-CHALABI DHIA                        :
16030 ':                                                             :
16040 ':        SUBROUTINE    06                                     :
16050 ':------------------------------------------------------------:
16060 'Calculate hourly ambient air temperature in F
16070 '
16080         TDAMP= 7.71
16090 TEMPF= DTEMP+TDAMP*(SIN(.261799*(H+13))+SIN(.261792*(H+13)*2)/3)
16100 '
16110 KD= TEMPF
16120 TEMPC=(KD-32)*5/9    :'Convert to C
16130 'Dew point temp Vs Dry bulb Temperature (1965-1984)
16140 '
16150 IF DOP>=0   AND DOP<=31  THEN 16160 ELSE 16190  :'FOR JANUARY
16160  DEWPT= -1.3258+(.803381*KD) :'LINEAR EQUATION(R=.93) FOR January
16170  GOTO 16340
16180 '
16190 IF DOP>=32  AND DOP<=60  THEN 16200 ELSE 16230  :'FOR FEBRUARY
16200  DEWPT= -2.8242+(.834888*KD):'LINEAR EQUATION(R=.89) FOR February
16210  GOTO 16340
16220 '
16230 IF DOP>=61  AND DOP<=90  THEN 16240 ELSE 16270  :'FOR MARCH
16240    DEWPT= 4.94659+(.605923*KD) :'LINEAR EGUATION(R=.76) FOR March
16250    GOTO 16340
16260 '
16270 IF DOP>=305 AND DOP<=334 THEN 16280 ELSE 16310  :'FOR NOVEMBER
16280  DEWPT= 11.6864+(.533961*KD):'LINEAR EQUATION(R=.75) FOR November
16290       GOTO 16340
16300 '
16310 IF DOP>=335 AND DOP<=365 THEN 16320 ELSE 16480  :'FOR DECEMBER
16320  DEWPT= -3.6047+(.942594*KD):'LINEAR EQUATION(R=.92) FOR December
16330 '
16340  'CALCULATE RELATIVE HUMIDITY OUTSIDE
16350 '
16360 TDPO=459.69+DEWPT
16370       PDP=EXP(23.3924-(11286.6489 /TDPO)-.46057*LOG(TDPO))
16380 '
16390 TDBO=459.69+KD
16400       PDB=EXP(23.3924-(11286.6489 /TDBO)-.46057*LOG(TDBO))
```

```
16410 '
16420 'Calculate relative humidity outside in %
16430 '
16440       RHOUT=(PDP/PDB)*100
16450 '
16460 IF RHOUT>=100 THEN RHOUT=99
16470 '
16480 RETURN
16490 '
16500 '  WHERE¦------------------------------------------------------
16510 '  TEMPC --------------- hourly ambient air temperature  in C    ¦
16520 '  TDAMP --------------- daily ambient temp.  amplitude   in F    ¦
16530 '  DTEMP --------------- average daily ambient air temp.  in F    ¦
16540 '  DEWPT --------------- dew point temperature outside   in F    ¦
16550 '  TDPO  --------------- absolute temperature            in R    ¦
16560 '  DOP   --------------- day of production of the year   in day  ¦
16570 '  RHOUT --------------- relative humidity outside       in %    ¦
16580 '  X     --------------- outside temperature converted   in F    ¦
16590 '        -------------------------------------------------------
16600 '  END OF SUBROUTINE
17000 ':---------------------------------------------------------------:
17010 ':       SUBROUTINE OF AVERAGE DAILY TEMPERATURE in C           :
17020 ':                      AL-CHALABI DHIA                          :
17030 ':                                                               :
17040 ':       SUBROUTINE    07                                        :
17050 ':---------------------------------------------------------------:
17060 'Calculate daily average ambient air temperature in C
17070          YTA= 47.5
17080        TYAMP= 25
17090 DTEMP=YTA + TYAMP * SIN(.017214 *(DOP-107))
17100 DTMPC=(DTEMP-32)*5/9
17110 '
17120 RETURN
17130 '
17140 '  WHERE¦------------------------------------------------------
17150 '  TYAMP --------------- yearly ambient amplitude temp.   in F    ¦
17160 '  DTEMP --------------- average daily ambient air temp.  in F    ¦
17165 '  DTMPC --------------- average daily ambient air temp.  in C    ¦
17170 '  YTA   --------------- yearly average air temperature  in F    ¦
17180 '        -------------------------------------------------------
17190 '  END OF SUBROUTINE
18000 ':---------------------------------------------------------------:
18010 ':       SUBROUTINE TO CALCULATE DAY OF THE YEAR in DAYS         :
18020 ':                      AL-CHALABI DHIA                          :
18030 ':                                                               :
18040 ':       SUBROUTINE    08                                        :
18050 ':---------------------------------------------------------------:
18060 'This subroutine convert the julian day to a calender day
18070 '
18080 '
18090      IF DOP>=0 AND DOP<=31 THEN 18100 ELSE 18120
```

```
18100          GOSUB 19000 :S$="JANUARY ":SDOP=DOP
18110       GOTO 18550
18120       IF DOP>=32 AND DOP<=59 THEN 18130 ELSE 18160
18130          GOSUB 19000 :S$="FEBRUARY "
18140         SDOP=DOP-31
18150       GOTO 18550
18160       IF DOP>=60 AND DOP<=90 THEN 18170 ELSE 18200
18170          GOSUB 19000 :S$="MARCH "
18180         SDOP=DOP-59
18190      GOTO 18550
18200      IF DOP>=91 AND DOP<=120 THEN 18210 ELSE 18240
18210         GOSUB 19000 :S$="APRIL "
18220        SDOP=DOP-90
18230      GOTO 18550
18240      IF DOP>=121 AND DOP<=151 THEN 18250 ELSE 18280
18250         GOSUB 19000 :S$="MAY "
18260        SDOP=DOP-120
18270      GOTO 18550
18280      IF DOP>=152 AND DOP<=181 THEN 18290 ELSE 18320
18290         GOSUB 19000 :S$="JUNE "
18300        SDOP=DOP-151
18310     GOTO 18550
18320     IF DOP>=182 AND DOP<=212 THEN 18330 ELSE 18360
18330        GOSUB 19000 :S$="JULY "
18340       SDOP=DOP-181
18350     GOTO 18550
18360     IF DOP>=213 AND DOP<=243 THEN 18370 ELSE 18400
18370        GOSUB 19000 :S$="AUGUST "
18380       SDOP=DOP-212
18390     GOTO 18550
18400     IF DOP>=224 AND DOP<=273 THEN 18410 ELSE 18440
18410        GOSUB 19000 :S$="SEPTEMBER "
18420       SDOP=DOP-243
18430     GOTO 18550
18440     IF DOP>=274 AND DOP<=304 THEN 18450 ELSE 18480
18450        GOSUB 19000 :S$="OCTOBER "
18460       SDOP=DOP-273
18470     GOTO 18550
18480     IF DOP>=305 AND DOP<=334 THEN 18490 ELSE 18520
18490        GOSUB 19000 :S$="NOVEMBER "
18500       SDOP=DOP-304
18510     GOTO 18550
18520     IF DOP>=335 AND DOP<=365 THEN 18530
18530        GOSUB 19000 :S$="DECEMBER " :SDOP=DOP-334
18540 '
18550     RETURN
18560 '
18570     WHERE|---------------------------------------------
18580 '   DOP    --------------------- day of production in the year    |
18590 '   SDOP   --------------------- calender day assocíaated with     |
18600 '                                the day of production.           |
```

```
18610 '        ----------------------------------------------------------
18620 '
18630 '   END OF SUBROUTINE
19000 ':------------------------------------------------------------:
19010 ':        SUBROUTINE TO CALCULATE DAY AND NIGHT TIME           :
19020 ':                       AL-CHALABI DHIA                       :
19030 ':                                                             :
19040 ':        SUBROUTINE    09                                     :
19050 ':------------------------------------------------------------:
19060 '
19070 '
19080          SDF=H
19090       IF SDF>=1 AND SDF<=5 THEN 19100 ELSE 19110
19100          D$=" AM-Night"                            :RETURN
19110       IF SDF>=6 AND SDF<=19 THEN 19120 ELSE 19170
19120       IF SDF>=6 AND SDF<=11 THEN 19130 ELSE 19140
19130          D$=" AM-Day  "                            :RETURN
19140       IF SDF= 12  THEN D$=" PM-Day" ELSE 19150  :RETURN
19150       IF SDF> 12  THEN SDF=SDF-12
19160          D$=" PM-Day  "                            :RETURN
19170       IF SDF>=20 AND SDF<=23 THEN 19180 ELSE 19190
19180          D$=" PM-Night":SDF=H-12                   :RETURN
19190          D$=" AM-Night":SDF=H-12
19200      IF SDF=13 THEN SDF=0 : D$="        "          :RETURN
19210 '
19220 'END OF SUBROUTINE
20000 ':------------------------------------------------------------:
20010 ':        SUBROUTINE TO CALCULATE CHANGE IN WEIGHT  in grams  :
20020 ':                       AL-CHALABI DHIA                       :
20030 ':                                                             :
20040 ':        SUBROUTINE    010                                    :
20050 ':------------------------------------------------------------:
20060 '
20070      IF AGE> 18 AND AGE<24 THEN 20080 ELSE 20090
20080      DTW=8.6 :GOTO 20160
20090      IF AGE>=24 AND AGE<29 THEN 20100 ELSE 20110
20100      DTW=3.8 :GOTO 20160
20110      IF AGE>=29 AND AGE<41 THEN 20120 ELSE 20130
20120      DTW=1.5 :GOTO 20160
20130      IF AGE>=41 THEN 20140
20140      DTW=.5
20150 '
20160 '
20170 RETURN
20180 '
20190 '  Where|-----------------------------------------------------
20200 '  DTW    ------------------------- change in weight in gr   |
20210 '  AGE    ------------------------- bird's age       in weeks|
20220 '         -----------------------------------------------------
20230 '
20240 'END OF SUBROUTINE
```

```
21000 ':-------------------------------------------------------------:
21005 ':       SUBROUTINE TO CALCULATE ELECTRICITY COST               :
21010 ':                     AL-CHALABI DHIA                          :
21020 ':                                                              :
21030 ':       SUBROUTINE    011                                      :
21040 ':-------------------------------------------------------------:
21060 '
21080 'Calculate cost for minimum ventlation rate
21082      ELCS1=ELPRC*(.135*2)       :ELCS2=0
21084      IF VRATE <1050 THEN GOTO 21094 ELSE 21086
21086      CFMRT=VRATE*.589           :'Convert to CFM
21088      KWHRC=((CFMRT*.0847)/1000)
21090 'Calculate electricity cost per day
21092      ELCS2=KWHRC*ELPRC
21094      ELTOT=ELCS1+ELCS2
21096      ELSUM=ELTOT+ELSUM
21098 '
21120 '
21130  RETURN
21140 '  Where|-----------------------------------------------------
21150 '  VRATE ------------------------- ventilation rate in m3/hr   |
21160 '  CFMRT ------------------------- ventilation rate in CFM     |
21170 '  KWHRC ------------------------- electr.  consum.   in kW/h    |
21180 '  ELCST ------------------------- electr.  cost     in $/day   |
21190 '  ELPRC ------------------------- electr.  price    in $/kW.hr |
21200 '        -----------------------------------------------------
21210 '
21220 'END OF SUBROUTINE
22000 ':-------------------------------------------------------------:
22010 ':       SUBROUTINE TO CALCULATE SUPPLEMENTAL HEAT              :
22020 ':                     AL-CHALABI DHIA                          :
22030 ':                                                              :
22040 ':       SUBROUTINE    012                                      :
22050 ':-------------------------------------------------------------:
22060 'Calculate heat loss though ventilation               in kJ/hr
22070 '
22080     TSUPL=MEANT -1.5
22090     QHVRT=1.0035 * MAV * (TSUPL - TOUT)
22100 '
22110 'Calculate supplement heat needed
22120 '
22130     QSUPL=(QHVRT + QTOTB) - QSNCL
22140 '
22150 'Calculate fuel cost                                  in $/hr
22160     IF EFR=1 THEN FENRG=37252!  ELSE FENRG=25529138
22170     FCOST=(QSUPL * FPRIC)/FENRG
22220 '
22230 RETURN
22240 '
22250 '  Where|--------------------------------------------------
22260 '  QHVRT ------------------------- heat loss in ventilation |
```

```
22270 '  TSUPL ------------------------ temperature needed       ¦
22280 '  QSUPL ------------------------ supplemental heat  kJ/hr ¦
22290 '      ¦-----------------------------------------------------
22300 'END OF SUBROUTINE
23000 ':------------------------------------------------------------:
23010 ':       SUBROUTINE TO DRAW A GRAPH FROM THE DATA             :
23020 ':                     AL-CHALABI DHIA                        :
23030 ':                                                            :
23040 ':       SUBROUTINE    013                                    :
23050 ':------------------------------------------------------------:
23060 '
23070 'This subroutine will plot the data into line graph
23080 '
23090       CLS:'Clear the screen
23100 '
23110       WINDOW(0,0)-(639,459):VIEW(0,0)-(639,199)
23120       DATA 1,2,3,4,5,6,7,8,9,10,11,12,1,2,3,4,5,6,7,8,9,10,11,12
23130 '
23140 'Draw lables and axis
23150 '
23160        GOSUB 23430
23170 '
23180 'Draw inside temperature in deg.  F
23190 '
23200        FOR H=1 TO 24:Y1(H)=((Y1(H)  * 9/5)+32):NEXT H
23210            K=3:Z=0:N$="Tin" :CLR=1
23220        GOSUB 23670
23230 '
23240 'Draw outside temperature in deg.  F
23250        FOR H=1 TO 24:Y1(H)=Y2(H):NEXT H
23260        FOR H=1 TO 24:Y1(H)=((Y2(H)  * 9/5)+32):NEXT H
23270            Z=55:N$=",Tout" :CLR=2
23280        GOSUB 23670
23290 '
23300 'Draw relative humidity  in %
23310        FOR H=1 TO 24:Y1(H)=Y3(H):NEXT H
23320        FOR H=1 TO 24:Y1(H)=(Y3(H)):NEXT H
23330            Z=145:N$=",R.H" :CLR=3
23340        GOSUB 23670
23350 '
23360 'Draw ventilation rate   in m3/sec
23370 '
23380        FOR H=1 TO 24:Y1(H)=(Y4(H)*15):NEXT H
23390            Z=210:N$=",Vrt" :CLR=4
23400        GOSUB 23810
23410        FOR JJ=1 TO 5000:NEXT
23420 RETURN
23430 ' Draw lables and axis
23440       SYMBOL (1,350)," Out -In Temp.  R.H",2,2,3,3
23450       SYMBOL(35,400),"A.M.            Hours            P.M.",1,2,5
23460       FOR C= 7 TO 77 STEP 3
```

```
23470             LOCATE 20,C :PRINT "¦";
23480             LOCATE 21,C-1 :READ M :PRINT M ;
23490         NEXT C:L=0
23500         LINE (50,359)-(146,364),1,BF
23510         LINE (148,359)-(482,364),6,BF
23520         LINE (484,359)-(605,364),1,BF
23530         LOCATE 3,10:PRINT S$;" / ";SDOP
23540         FOR Y=352 TO 44 STEP -30
23550             SYMBOL (32,Y),CHR$(196),1,1,2
23560             SYMBOL (630,Y),CHR$(196),1,1,2
23570         NEXT Y
23580         LOCATE 3,2:PRINT "100"
23590         LOCATE 12,3:PRINT "50"
23600         LOCATE 20,3:PRINT "0"
23610         SYMBOL(80,8 ),"AVERAGE HOURLY TEMPERATURE & R.H ",2,2,5
23620         SYMBOL(82,10),"AVERAGE HOURLY TEMPERATURE & R.H ",2,2,7
23630         LINE (35,30)-(35,356):LINE-(630,356):LINE-(630,30)
23640         RESTORE
23650          RETURN
23660 '
23670 'Plot the data
23680 '
23690         LINE(48,(356-Y1(1)*K)-2)-(52,(356-Y1(1)*K)+2),CLR,B
23700         C=1:M=1
23710         SYMBOL(300+Z,30),N$,2,2,CLR
23720         PSET(50,356-Y1(1) * K )
23730         FOR X=78 TO 654 STEP 24
23740             C=C+1  :M=M+1
23750         FOR I=C TO M
23760             IF X=630 THEN GOTO 23800
23770             LINE-(X,356-Y1(I)*K),CLR
23780             LINE(X-2,(356-Y1(I)*K)-2)-(X+2,(356-Y1(I)*K)+2),CLR,B
23790         NEXT I:NEXT X
23800  RETURN
23810             CC=-1 :MM=-1
23820             SYMBOL(300+Z,30),N$,2,2,CLR
23830             PSET(50,356-Y1(1) * K )
23840         FOR X=78 TO 654 STEP 24
23850            CC=CC+1  :MM=MM+1
23860         FOR I=CC TO MM
23870             IF X=630 THEN GOTO 23930
23880             IF X=78  THEN GOTO 23900
23890             LINE-(X-24 ,356-Y1(I+1)*K),CLR
23900 '****
23910             LINE -(X,356-Y1(I+1)*K),CLR
23920         NEXT I:NEXT X :CLR=3
23930  RETURN
24000 ':----------------------------------------------------------:
24010 ':      SUBROUTINE TO ESTIMATE FACTORS EFFECTING FEED INTAKE :
24020 ':                    AL-CHALABI DHIA                        :
24030 ':                                                           :
```

```
24040 ':       SUBROUTINE    014                                           :
24050 ':----------------------------------------------------------------:
24060     AGEI=INT(AGE)
24070 'Values of factor f2 ,which adjusts  feed intake for age ,and
24080 'values of factor A ,which adjusts egg output for age.
24090 '
24100 'Bird's age 20-72 weeks                                       Period
24110 '
24120     IF AGEI>=20 AND AGEI<=24 THEN 24130 ELSE 24150    :'  1
24130            F2FCT=.764      :AEFCT=.32
24140            GOTO 24550
24150     IF AGEI>=25 AND AGEI<=28 THEN 24160 ELSE 24180    :'  2
24160            F2FCT=.917      :AEFCT=.93
24170            GOTO 24550
24180     IF AGEI>=29 AND AGEI<=32 THEN 24190 ELSE 24210    :'  3
24190            F2FCT=.987      :AEFCT=1.09
24200            GOTO 24550
24210     IF AGEI>=33 AND AGEI<=36 THEN 24220 ELSE 24240    :'  4
24220            F2FCT=1.006     :AEFCT=1.12
24230            GOTO 24550
24240     IF AGEI>=37 AND AGEI<=40 THEN 24250 ELSE 24270    :'  5
24250            F2FCT=1.002     :AEFCT=1.11
24260            GOTO 24550
24270     IF AGEI>=41 AND AGEI<=44 THEN 24280 ELSE 24300    :'  6
24280            F2FCT=1.024     :AEFCT=1.11
24290            GOTO 24550
24300     IF AGEI>=45 AND AGEI<=48 THEN 24310 ELSE 24330     :'  7
24310            F2FCT=1.052     :AEFCT=1.11
24320            GOTO 24550
24330     IF AGEI>=49 AND AGEI<=52 THEN 24340 ELSE 24360    :'  8
24340            F2FCT=1.044     :AEFCT=1.09
24350            GOTO 24550
24360     IF AGEI>=53 AND AGEI<=56 THEN 24370 ELSE 24390    :'  9
24370            F2FCT=1.046     :AEFCT=1.06
24380            GOTO 24550
24390     IF AGEI>=57 AND AGEI<=60 THEN 24400 ELSE 24420    :'  10
24400            F2FCT=1.053     :AEFCT=1.05
24410            GOTO 24550
24420     IF AGEI>=61 AND AGEI<=64 THEN 24430 ELSE 24450    :'  11
24430            F2FCT=1.03      :AEFCT=1.02
24440            GOTO 24550
24450     IF AGEI>=65 AND AGEI<=68 THEN 24460 ELSE 24480    :'  12
24460            F2FCT=1.02      :AEFCT=1
24470            GOTO 24550
24480     IF AGEI>=69  THEN 24490                           :'  13
24490            F2FCT=1.032     :AEFCT=.97
24500 '
24510 '          end of values f2
24520 'Values of factor f3 ,which adjusts feed consumption for wastage
24530 'in various feeding systems .
24540 '
```

```
24550 '
24560 'Hopper and trough system
24570       IF FSV=1 THEN F3FCT=1   ELSE 24590
24580 '
24590 'Chain system
24600       IF FSV=2 THEN F3FCT=.965 ELSE 24620
24610 '
24620 'Hopper and trough plus grid system
24630       IF FSV=3 THEN F3FCT=.948 ELSE 24650
24640 '
24650 'Spiral system
24660       IF FSV=4 THEN F3FCT=.948 ELSE 24680
24670 '
24680 'Sleeve system
24690       IF FSV=5 THEN F3FCT=.986
24700 '
25000 ':------------------------------------------------------------:
25010 ':      SUBROUTINE TO ESTIMATE EGG OUTPUT in g/b/day          :
25020 ':                     AL-CHALABI DHIA                        :
25030 ':                                                            :
25040 ':      SUBROUTINE    015                                     :
25050 ':------------------------------------------------------------:
25060 'This subroutine will estimate feed consumption and egg
25070 'production for the white breed chickens
25080 '
25090 'Breed factor for white birds
25100 '
25110       F1FCT=1
25120 '
25130 'Calculate metabolizable energy intake for white egg layer fed
25140 '11.3 MJ/kg                              in kJ/d per bird
25150 '
25160     METAK=1584.3 - 33.47*TIAVG + 1.562*(TIAVG^2)- .0349*(TIAVG^3)
25170 '
25180 'Adjust the energy intake for any dietary energy level
25190 '
25200      ADJFD=METAK + 46 * MEDIT - 519.8
25210 '
25220 'Calculate feed intake for the chickens in g/d per bird
25230 '
25240      FETAK=(F1FCT*F2FCT*F3FCT*ADJFD)/MEDIT
25250 '
25260 'Calculate the standard protein intake          g/day
25270 '
25280      STRDP=FETAK *(NSCP/100)
25290 '
25300 'Calculate egg output response to protein       g/b/day
25310 '
25320      E1ORP=(STRDP^2)/(4.446-(.417*STRDP)+(.0309*(STRDP^2)))
25330 '
25340 'Calculate egg output response to temperature    g/b/day
```

```
25350      D1ORT=0
25360       IF TIAVG>=30 THEN 25370 ELSE 25400
25370 '
25380    D1ORT=10.98-(2.14*TIAVG)-(.02335*(TIAVG^2))+(.00522*(TIAVG^3))
25390 '
25400 'Calculate egg output response to light intensity g/b/day
25410 '
25420  D2ORL=2.41-(2.711*LOG(LIT)*.434294)+(.76*((LOG(LIT)*.434294)^2))
25430 '
25440       IF LIT=60.4 THEN D2ORL=0
25450 '
25460 'Calculate egg output the final estimet          g/b/day
25470 '
25480     E3OFE=(E1ORP-D1ORT-D2ORL) * AEFCT
25490 '
25500 RETURN
25510 '
25520 '  WHERE|----------------------------------------------------
25530 '  F1FCT --------------- breed factor for white chickens        |
25540 '  F2FCT --------------- adjust feed intake for age f2          |
25550 '  F3FCT --------------- adjust feed intake for wastage in      |
25560 '  FETAK --------------- feed intake in g/b/day                 |
25570 '  METAK --------------- metabolizable energy intake in kJ/b/da |
25580 '  AEFCT --------------- adjust egg output for age   A          |
25590 '  MEDIT --------------- metabolizable energy of diet in MJ/kg  |
25600 '  STRDP --------------- standard protein intake                |
25610 '  E1ORP --------------- egg output response to protein g/b/da  |
25620 '  D1ORT --------------- egg output response to temp.    g/b/da |
25630 '  D2ORL --------------- egg output response to light   g/b/da |
25640 '  E3OFE --------------- egg output final estimate              |
25650 '        -----------------------------------------------------
25660 '  END OF SUBROUTINE
26000 ':-----------------------------------------------------------:
26010 ':       SUBROUTINE TO CALCULATE VENTILATION RATE  m3/hr      :
26020 ':               AL-CHALABI DHIA                              :
26030 ':                                                            :
26040 ':       SUBROUTINE    016                                    :
26050 ':-----------------------------------------------------------:
26060 '
26070 'Calculate ventilation rate for carbon dioxide
26120 'Check for inside temperature and calculate CO2 production
26130 'for hens (10-17 C)                                    in cm3/gr.hr
26140     IF TINEW>=10 AND TINEW<=17 THEN 26150 ELSE 26180
26150        PRCO2=.34344 * (TINEW^.1317)                    :'R=.99
26160        GOTO 26290
26170 '
26180 'Calculate CO2 production for hens (18-26 C)          in cm3/gr.hr
26190 '
26200     IF TINEW>=18 AND TINEW<=26 THEN 26210 ELSE 26240
26210        PRCO2=.8961 * (TINEW^-.213)                     :'R=.97
26220        GOTO 26290
```

```
26230 '
26240 'Calculate CO2 production for hens (27-34 C)       in cm3/gr.hr
26250 '
26260     IF TINEW>=27 AND TINEW<=34 THEN 26270
26270        PRCO2=.222 * (TINEW^.2201)                   :'R=.98
26280 '
26290 'Calculate total CO2 production in the house      in m3/hr
26300 '
26310     TPCO2=PRCO2 * .001 * BODYW
26320 '
26330 'Calcuate ventilation rate for carbon dioxide     in m3/hr
26340 '
26350     VRCO2=TPCO2/(.0035-.0003)
26360     IF TOUT<= 0 THEN 26400 ELSE 26660
26400     VRATE=VRCO2
26410 'Go back to maine program
26420 '
26430     RETURN
26440 '
26450 'Check for relative humidity inside
26460 '
26470     IF RHIN > 90 THEN 26490 ELSE 26660
26480 '
26490 'Calculate ventilation rate for moisture          in m3/hr
26500 '
26600     VRMIS=(VSINS * WETOT)/(HINS-HOUT)
26605 '
26610     VRATE=VRMIS
26620 'Go back to maine program
26630 '
26640     RETURN
26650 '
26660 'Calculate ventilation rate for temperature       in m3/hr
26700 '
26710     VRTMP=(VSINS/(1.0035 *(TINS -TOUT))) * (QSNCL-QTOTB)
26720     VRATE=VRTMP
26730 'Go back to maine program
26740 '
26750     RETURN
26760 '
26770 '
26780 ' Where|--------------------------------------------------------
26790 ' QLATB ---------------- latent heat production     in kJ/hr   |
26800 ' QTOTB ---------------- heat loss through building in kJ/hr   |
26810 ' QSNCL ---------------- total sensible heat prod.   in kJ/hr  |
26820 ' PRCO2 ---------------- carbon dioxide production  in m3/kghr|
26830 ' VRCO2 ---------------- ventilation rate for CO2   in m3/hr   |
26840 ' WETOT ---------------- rate of water production   in kg/hr   |
26860 ' VRMIS ---------------- venti.  rate for moisture   in m3/hr  |
26870 ' VSINS ---------------- specific volume of air     in m3/kg   |
26880 ' VRTMP ---------------- venti.rate for temperature in m3/hr   |
```

```
26890 ' HINS  ---------------- humidity ratio inside air  in kg/kg  |
26900 ' HOUT  ---------------- humidity ratio outside air in kg/kg  |
26910 ' TINS  ---------------- inside temperature         in C      |
26920 ' TOUT  ---------------- outside temperature        in C      |
26930 ' HFG   ---------------- latent heat of evaporation in kJ/kg  |
26940 ' R     ---------------- correlation coef.  of CO2            |
26950 '                        production and inside temperature    |
26960 '       |-----------------------------------------------------
26970 ' End of subroutine
27000 ':----------------------------------------------------------------:
27010 ':     SUBROUTINE TO CALCULATE INITIAL  HEAT & MOISTURE           :
27020 ':         CONTENT                                                :
27030 ':                   AL-CHALABI DHIA                              :
27040 ':                           SUBROUTINE   017                     :
27050 ':----------------------------------------------------------------:
27060 '
27070 'Calculate initial value for heat content           in kJ
27080 '
27090      IF CRF=1 THEN 27100 ELSE 27200
27100 '
27110      QHOLD=AMI* (TINS * (1.007 + 1.84* HINS) + 2501* HINS - .026)
27120 '
27130 'Calculate initial value for moisture content    in kg H20/kg d.a
27140 '
27150      QMOLD=HINS
27160 '
27170 'Go back to maine program
27180      CRF=0
27190 '
27200      RETURN
27210 '
27220 ' Where|-----------------------------------------------------
27230 ' QHOLD ---------------- initial heat contentn      in kJ     |
27240 ' QMOLD ---------------- initial moisture content   in kg     |
27250 ' HINS  ---------------- humidity ratio inside air  in kg/kg  |
27260 ' TINS  ---------------- inside temperature         in C      |
27270 ' AMI   ---------------- air mass in the building   in kg     |
27290 ' CRF   ---------------- flag                                 |
27300 '       |-----------------------------------------------------
27310 ' End of subroutine
28000 ':----------------------------------------------------------------:
28010 ':       SUBROUTINE TO CONTROL INSIDE TEMP.,MOISTURE & CO2        :
28020 ':                AL-CHALABI DHIA                                 :
28030 ':                                                                :
28040 ':       SUBROUTINE    018                                        :
28050 ':----------------------------------------------------------------:
28060 '
28170 'Decrease  ventilation rate for low temperatures
28180 '
28190    IF TINEW <MEANT-2 THEN 28200 ELSE 28280
28200    VRTMP=VRTMP -153.83
```

```
28210    VRATE=VRTMP
28220 '
28230 'Check for CO2 level
28240 '
28250     IF VRATE < VRCO2 THEN 28260 ELSE 28270
28260     VRATE=VRCO2
28270     RETURN
28280 '
28290 'Increase  ventilation rate for high temperatures
28300 '
28310     VRTMP=VRTMP +12
28320     VRATE=VRTMP
28330     RETURN
28340 '
28350 'CONTROL FOR MOISTURE (RELATIVE HUMIDITY)
28360 '
28370     IF RHIN <=95 THEN 28380 ELSE 28400
28380     RETURN
28390 '
28400 'Increase ventilation rate
28410 '
28420     VRMIS=VRMIS +15
28430     VRATE=VRMIS
28440 '
28450 'Go back to maine program
28460 '
28470 RETURN
28480 '
28490 ' Where|-----------------------------------------------------
28500 ' VRCO2 ---------------- ventilation rate for CO2   in m3/hr  |
28510 ' VRMIS ---------------- venti.  rate for moisture   in m3/hr  |
28520 ' VRTMP ---------------- venti.rate for temperature in m3/hr  |
28530 ' MEANT ---------------- temp.  to be controled      in C      |
28540 ' TINS  ---------------- inside temperature         in C      |
28550 ' TOUT  ---------------- outside temperature        in C      |
28560 '      |-----------------------------------------------------
28570 ' End of subroutine
29000 ':-----------------------------------------------------------:
29010 ':       SUBROUTINE TO SUM THE VALUES TO CALCULATE MEANS      :
29020 ':              AL-CHALABI DHIA                               :
29030 ':                                                            :
29040 ':       SUBROUTINE    019                                    :
29050 ':-----------------------------------------------------------:
29060 '
29070 'Temperature summation
29080 '
29090    TISUM=TISUM+TINS
29100 '
29110 'Realtive humidity sumation
29120 '
29130    RHSUM=RHSUM+RHIN
```

```
29140    RHOSM=RHOSM+RHOUT
29150 'Ventilation rate summation
29160 '
29170    VRSUM=VRSUM+VRATE
29180 '
29190    RETURN
29200 '
29210 ' Where|--------------------------------------------------------
29220 ' RHNEW ---------------- new inside relative humidity in %    |
29230 ' TINEW ---------------- new inside temperature      in C     |
29240 ' VRATE ---------------- ventilation rate            in m3/hr |
29250 '      |--------------------------------------------------------
29260 ' End of subroutine
30000 ':-------------------------------------------------------------:
30010 ':       SUBROUTINE TO CALCULATE HOURLY AVERAGES               :
30020 ':              AL-CHALABI DHIA                                :
30030 ':                                                             :
30040 ':       SUBROUTINE    020                                     :
30050 ':-------------------------------------------------------------:
30060 TIAVG=0 :RHAVG=0 :VRAVG=0 :RHOVG=0
30070 'Temperature mean
30080 '
30090    TIAVG =TISUM/24
30100 '
30110 'Realtive humidity mean
30120 '
30130    RHAVG=RHSUM/24
30140    RHOVG=RHOSM/24
30150 'Ventilation rate mean
30160 '
30170    VRAVG=VRSUM/24
30180 '
30190    RETURN
30200 '
30210 ' Where|-------------------------------------------------------
30220 ' RHAVG --------------- hourly average relativ humi.  in %      |
30230 ' TINS  --------------- hourly average temperature   in C      |
30240 ' VRAVG --------------- hourly average venti.  rate   in m3/hr |
30250 '      |--------------------------------------------------------
30260 ' End of subroutine
31000 ':-------------------------------------------------------------:
31010 ':       SUBROUTINE TO DESIGN OUTPUT HOURLY REPORT             :
31020 ':              AL-CHALABI DHIA                                :
31030 ':                                                             :
31040 ':       SUBROUTINE    021                                     :
31050 ':-------------------------------------------------------------:
31060 CLS:WINDOW(0,0)-(639,459):VIEW(0,0)-(639,199)
31070 'Draw the boundry of the page
31080 '
31090 LOCATE 2,2 :PRINT CHR$(201)
31100 '
```

```
31110 'Upper line
31120 '
31130       FOR X=3 TO 78
31140       LOCATE 2,X :PRINT CHR$(205)
31150       NEXT X :LOCATE 2,78:PRINT CHR$(187)
31160 '
31170 'Right line
31180 '
31190      FOR Y=3 TO 22
31200       IF Y=8 THEN 31210 ELSE 31230
31210       LOCATE Y,78:PRINT CHR$(185)
31220       GOTO 31240
31230       LOCATE Y,78:PRINT CHR$(186)
31240      NEXT Y :LOCATE 23,78 :PRINT CHR$(188)
31250 '
31260 ' Lower line
31270 '
31280      FOR X=77 TO 3 STEP -1
31290       IF X=40 THEN 31300 ELSE 31320
31300       LOCATE 23,X:PRINT CHR$(202)
31310       GOTO 31330
31320       LOCATE 23,X:PRINT CHR$(205)
31330      NEXT X
31340 LOCATE 23,2 :PRINT CHR$(200)
31350 '
31360 'Left line
31370 '
31380      FOR Y=22 TO 3 STEP -1
31390       IF Y=8 THEN 31400 ELSE 31420
31400       LOCATE Y,2:PRINT CHR$(204)
31410       GOTO 31430
31420       LOCATE Y,2 : PRINT CHR$(186)
31430      NEXT Y
31440 LOCATE 8,40 :PRINT CHR$(203)
31450 LOCATE 8,3
31460 '
31470 'Upper middel line
31480 '
31490      FOR X=3 TO 77
31500       IF X=40 THEN 31510 ELSE 31520
31510       GOTO 31530
31520       LOCATE 8,X :PRINT CHR$(205)
31530      NEXT X
31540 LOCATE 9,40
31550 '
31560 'Middel line
31570 '
31580      FOR Y=9 TO 22
31590       LOCATE Y,40 :PRINT CHR$(186)
31600      NEXT
31610 '
```

```
31620 'Write the headings
31630 '
31640 LOCATE 4,4 :PRINT "DATE:":LOCATE 4,20 :PRINT "/"
31650 LOCATE 4,26:PRINT "TIME:"
31660 LOCATE 4,45:PRINT "FARM NAME:"
31670 SYMBOL(50,100)," HOURLY REPORT",3,3,5 :COLOR 2,0
31675 SYMBOL(52,101)," HOURLY REPORT",3,3,7 :COLOR 2,0
31680 LOCATE 6,65:PRINT "LIGHTS:"
31690 LOCATE 9 ,4:COLOR 3,4:PRINT " INSIDE CONDITIONS:    ":COLOR 2,0
31700 LOCATE 10,4:PRINT "1-Previous  temperature"
31710 LOCATE 11,4:PRINT "2-New       temperature"
31720 LOCATE 12,4:PRINT "3-Previous rel humidity"
31730 LOCATE 13,4:PRINT "4-New      rel humidity"
31740 LOCATE 14,4:PRINT "5-Ventilation      rate"
31750 LOCATE 15,4:PRINT "                       "
31760 LOCATE 16,4:COLOR 0,5:PRINT " FLOCK INFORMATION :":COLOR 2,0
31770 LOCATE 17,4:PRINT "1-Number of  birds"
31780 LOCATE 18,4:PRINT "2-Age    of  birds"
31790 LOCATE 19,4:PRINT "3-Avg   bodyweight"
31800 LOCATE 20,4:PRINT "4-Feed consumption"
31810 LOCATE 21,4:PRINT "5-Egg   production"
31820 LOCATE 22,4:PRINT "6-H D   production"
31830 'Write outside conditions
31840 '
31850 LOCATE 9 ,42:COLOR 4,6:PRINT " OUTSIDE CONDITIONS:   ":COLOR 2,0
31860 LOCATE 10,42:PRINT "1-Avg daily temperature"
31870 LOCATE 11,42:PRINT "2-Previous  temperature"
31880 LOCATE 12,42:PRINT "3-New       temperature"
31890 LOCATE 13,42:PRINT "4-Previous rel humidity"
31900 LOCATE 14,42:PRINT "5-New      rel humidity"
31910 '
31920  RETURN
31930 '
31940 '
31950 'END OF SUBROUTINE
32000 ':-----------------------------------------------------------:
32010 ':       SUBROUTINE TO OUTPUT HOURLY REPORT                  :
32020 ':                AL-CHALABI DHIA                            :
32030 ':                                                           :
32040 ':       SUBROUTINE    022                                   :
32050 ':-----------------------------------------------------------:
32060 'This subroutine will print out the digits for the simulation
32070 'go to subroutine  8 to calculate the calender day and to
32080 'subroutine   24 to calculate wall temperature if there is
32081 'condenzation
32090 GOSUB 18000 :GOSUB 38000
32100 '
32110 'Write the month's name ,time ,day and hour
32120 '
32130 LOCATE 4,10:COLOR 1:PRINT S$:LOCATE 4,21:COLOR 5:
32135 PRINT SDOP:COLOR 2
```

```
32140 LOCATE 4,32:COLOR 7:PRINT SDF:LOCATE 4,35:COLOR 4 :PRINT D$
32150 COLOR 2:LOCATE 4,56:COLOR 3:PRINT FARM$
32160 IF FLAG=0 THEN 32170 ELSE 32190
32170 LOCATE 6,73:COLOR 0,5:PRINT " OFF":COLOR 2
32180 GOTO 32200
32190 LOCATE 6,73:COLOR 1,6:PRINT " ON ":COLOR 2,0
32200 '
32210 IF CW=1 THEN 32220 ELSE 32250
32220 LOCATE 19,43:COLOR 6,1
32230 PRINT " WATER CONDENZATION ON THE WALLS " :COLOR 2,0
32240 GOTO 32260
32250 COLOR 2,0:LOCATE 19,43:PRINT "                                  "
32260 KK$="  .    m3/hr"
32270 DD$="  .    m3/s"
32280 FF$="   .     C"
32290 SS$="   .   %"
32300 COLOR 4,0
32310 LOCATE 10,28:PRINT USING FF$;TILD :LOCATE 10,35:PRINT CHR$(248)
32320 LOCATE 11,28:PRINT USING FF$;TINEW :LOCATE 11,35:PRINT CHR$(248)
32330 LOCATE 12,28:PRINT USING SS$;RHILD
32340 LOCATE 13,28:PRINT USING SS$;RHNEW
32350 LOCATE 14,28:PRINT USING DD$;VRATE/3600
32360 '
32370 COLOR 3,0
32380 LOCATE 17,24:PRINT USING "      Birds";NCHKN
32390 LOCATE 18,24:PRINT USING "      Weeks";AGE
32400 LOCATE 19,24:PRINT USING " .    Kg";BODYW/NCHKN
32410 LOCATE 20,24:PRINT USING "   .  g/d/b ";FETAK
32420 LOCATE 21,24:PRINT USING "  .   g/d/b ";EGADJ/100
32425 LOCATE 22,24:PRINT USING "  .   %      ";HDPOD
32430 COLOR 5,0
32440 LOCATE 10,67:PRINT USING FF$;DTMPC :LOCATE 10,74 :PRINT CHR$(248)
32450 LOCATE 11,67:PRINT USING FF$;TOLD  :LOCATE 11,74 :PRINT CHR$(248)
32460 LOCATE 12,67:PRINT USING FF$;TOUT  :LOCATE 12,74 :PRINT CHR$(248)
32470 LOCATE 13,67:PRINT USING SS$;RHOLD
32480 LOCATE 14,67:PRINT USING SS$;RHOUT
32490 COLOR 2,0
32500 CW=0
32510 RETURN
32520 '
32530 'END OF SUBROUTINE
38000 ':-------------------------------------------------------------:
38010 ':       SUBROUTINE TO CALCULATE DEW POINT TEMPERATURE in C   :
38020 ':                    AL-CHALABI DHIA                          :
38030 ':                                                             :
38040 ':       SUBROUTINE    24                                      :
38050 ':-------------------------------------------------------------:
38060 'Calculate Dew point temperature for inside conditions in deg.C
38070      TDB=TINS:RH=RHIN :USFC=2.46
38072      GOSUB 38130
38080 'Calculate wall surface temperature in deg.  C
```

```
38090      WALTP=TINS-((UWALL * (TINS-TOUT))/USFC)
38100      IF WALTP+1 <TDP  THEN CW=1 ELSE CW=0
38110      IF WALTP+1 <TDP  THEN COUNT=COUNT+1
38120 RETURN
38130 '----------SUBROUTINE HUMIDT--------------------------------
38140      PATM = 101.325
38150      P = PATM
38160     JR = .28705
38170 'CALCULATE SATURATION VAPOR PRESSURE FOR DRY BULB TEMPERATURE
38180      TDBK = TDB + 273.16
38190      T = TDBK
38200      GOSUB 38400
38210      PSDB = PRES
38220      WSDB = .62198 * PSDB / (P - PSDB)
38230 'CALCULATE PROPERTIES AT DESIRED STATE POINT
38240      RH = RH / 100
38250      PW = RH * PSDB
38260      W = .62198 * PW / (P - PW)
38270      DEGSAT = W / WSDB
38280      ENTH = 1.006 * TDB + W * (2501 + 1.775 * TDB)
38290      SPVOL =JR * TDBK * (1 + 1.6078 * W) / P
38300      ALFA = LOG(PW)
38310      IF PW > .611 THEN GOTO 38340
38320      TDP = 5.994 + 12.41 * ALFA + .4273 * ALFA^2
38330      GOTO 38390
38340      IF PW > 8.08 THEN GOTO 38370
38350      TDP = 6.983 + 14.38 * ALFA + 1.079 * ALFA^2
38360      GOTO 38390
38370      TDP = 13.8 + 9.478 * ALFA + 1.991 * ALFA^2
38380      TWB = TEMP
38390      RETURN
38400 '--------- SUBROUTINE PRESSURE -----------------------------
38410      IF T > 273.16 THEN GOTO 38440
38420      PRES = EXP(24.2779 - 6238.64 / T - .344438 * LOG(T))
38430      GOTO 38450
38440      PRES = EXP(-7511.52/T+89.6312+.023999*T-.000011654551 *T^2-
           .000000012810336 *T^3+2.0998405D-11*T^4-LOG(T)*12.1507992 )
38450      RETURN
38460 '
38470 '   Where |--------------------------------------------------------
38480 '   WALTP  ----------------------   Wall temperature      in C    |
38490 '   USFC   ----------------------   Heat transf.coeffi.   in W/m2C|
38500 '   RHIN   ----------------------   Relative humidity     in %    |
38510 '   TINS   ----------------------   Inside temperature    in C    |
38520 '   TDP    ----------------------   Dew point temperature in C    |
38530 '          ---------------------------------------------------------
38540 '
38550 'END OF SUBROUTINE
38560 '
39000 ':---------------------------------------------------------------:
39010 ':        SUBROUTINE TO PRINT OUT DAILY REPORT                    :
```

```
39020 ':              AL-CHALABI DHIA                                    :
39030 ':                                                                 :
39040 ':       SUBROUTINE    025                                         :
39050 ':-----------------------------------------------------------------:
39060 'This subroutine will print out daily report
39070 'Write the headings
39080 FF$="   .     C   ":SS$="  .     %   ":DD$="  .    m3/s "
39090 LOCATE 4,26:PRINT "                         "
39095 LINE  (50,100)-(455,125),0,BF :COLOR 2,0
39100 SYMBOL(50,100)," DAILY REPORT ",3,3,1 :COLOR 2,0
39105 SYMBOL(52,101)," DAILY REPORT ",3,3,6 :COLOR 2,0
39110 LOCATE 6,65:PRINT "              "
39120 LOCATE 9, 4:COLOR 1,3:PRINT " INSIDE CONDITIONS:      ":COLOR 2,0
39130 LOCATE 10,4:PRINT "1-Avg  temperature     ":LOCATE 10,28:
39135 PRINT USING FF$;TIAVG:LOCATE 10,35:PRINT CHR$(248)
39140 LOCATE 11,4:PRINT "2-Avg rel Humidity     ":LOCATE 11,28:
39145 PRINT USING SS$;RHAVG
39150 LOCATE 12,4:PRINT "3-Maximum     temp     ":LOCATE 12,28:
39155 PRINT USING FF$;TIMAX:LOCATE 12,35:PRINT CHR$(248)
39160 LOCATE 13,4:PRINT "4-Minimum     temp     ":LOCATE 13,28:
39165 PRINT USING FF$;TIMIN:LOCATE 13,35:PRINT CHR$(248)
39170 LOCATE 14,4:COLOR 3,1:PRINT " OUTSIDE CONDITIONS:     ":COLOR 2,0
39175 LOCATE 14,29:PRINT "           ":COLOR 2,0
39180 LOCATE 15,4:PRINT "1-Avg  daily  temp     ":LOCATE 15,28:
39185 PRINT USING FF$;DTMPC:LOCATE 15,35:PRINT CHR$(248)
39190 LOCATE 16,4:PRINT "2-Avg rel humidity   ":LOCATE 16,28:
39195 PRINT USING SS$;RHOVG
39200 LOCATE 17,4:PRINT "                                   "
39210 LOCATE 18,4:COLOR 0,7:PRINT "FLOCK INFORMATION:       ":COLOR 2,0
39215 LOCATE 18,28:PRINT "           ":COLOR 2,0
39220 LOCATE 19,4:PRINT "1-Number of  birds         ":LOCATE 19,28:
39225 PRINT USING "      Birds";NCHKN
39230 LOCATE 20,4:PRINT "2-Age    of  birds         ":LOCATE 20,28:
39235 PRINT USING "      Weeks";AGE
39240 LOCATE 21,4:PRINT "3-Avg   bodyweight         ":LOCATE 21,28:
39245 PRINT USING " .    Kg";BODYW/NCHKN
39250 LOCATE 22,4:PRINT "4-Bird   mortality         ":LOCATE 22,28:
39255 PRINT USING "      Birds";MORCH
39260 '
39270 'Write management information
39280 '
39290 LOCATE 9 ,42:COLOR 4,6:PRINT " MANAGEMENT INFORMATION: ":
39295 COLOR 2,0
39300 LOCATE 10,42:PRINT "1-Feed intake /100   ":LOCATE 10,63:
39305 PRINT USING "   .    kg/day";FE100/10000
39305 LOCATE 11,42:PRINT "2-MET energy /bird   ":LOCATE 11,63:
39306 PRINT USING "        kJ/day";METAK
39310 LOCATE 12,42:PRINT "3-H D  production   ":LOCATE 12,63:
39315 PRINT USING "    .  %     ";HDPOD
39320 LOCATE 13,42:PRINT "4-Est  egg prd/100   ":LOCATE 13,63:
39325 PRINT USING "   .    kg/day";EGADJ/1000
```

```
39340 LOCATE 14,42:PRINT "5-Feed  cost /1000   ":LOCATE 14,63:
39345 PRINT USING "    .   $/day ";FCOST
39350 LOCATE 15,42:PRINT "6-Elec  cost /1000   ":LOCATE 15,63:
39355 PRINT USING "    .   $/day";ELSUM
39360 LOCATE 16,42:PRINT "7-Fuel  cost /1000   ":LOCATE 16,63:
39365 PRINT USING "    .   $/day";FUCOST
39380 LOCATE 17,42:PRINT "8-Egg revenue/1000   ":LOCATE 17,63:
39385 PRINT USING "    .   $/day";EGGSL
39385 LOCATE 18,42:PRINT "9-Revenues - costs   ":LOCATE 18,63:
39387 PRINT USING "    .   $/day";PROFT:ELSUM=0
39388 LOCATE 19,42:PRINT "                                   ":
39389 LOCATE 21,43:COLOR 0,7 : PRINT COUNT
39390 LOCATE 21,46:COLOR 4,7:PRINT " Hours of water condenzation" :
39391 COLOR 2,0
39392  FOR X=1 TO 10000 :NEXT:GOSUB 23000 : RETURN
39400 'END OF SUBROUTINE
40000 ':------------------------------------------------------------:
40010 ':        SUBROUTINE TO CALCULATE EGG PRODUCTION                :
40020 ':               AL-CHALABI DHIA                                :
40030 ':                                                              :
40040 ':        SUBROUTINE    026                                     :
40050 ':------------------------------------------------------------:
40060 'Calculate average egg weight                     in gr
40070 '
40080      IF AGE>=22 AND AGE<=40 THEN 40090 ELSE 40110
40090      EGGWT=13.5203*(AGE^.4087)  :'For age 22-40 weeks (R2=.98)
40100      GOTO 40120
40110      EGGWT=36.1114*(AGE^.1371)  :'For age 41-80 weeks (R2=.99)
40120 'Calculate number of eggs for 1000 birds          in gr
40130      EGNBR=(EG100 /EGGWT)*10
40140 'Calculate number of dozens                       in dozens
40150      DOZNO=EGNBR/12
40160 'Calculate returns from eggs sale                 in $/100 birds
40170      EGGSL=DOZNO*NRPRC
40180 'Calculate hen/day production                     in %
40190      HDPOD=EGNBR/10
40195      EGADJ=(EG100/HDPOD)*100
40200 'Calculate electricity cost/1000 birbs            in $/day
40202      ELSUM= (ELSUM/NCHKN)*1000
40204 'Calculate sum of      cost/1000 birds            in $/day
40206      PRCOST=ELSUM+FUCOST+FCOST
40210 'Calculate revenues over cost                     in $/day
40212      PROFT=EGGSL-PRCOST
40220  RETURN
40230 'Where:-------------------------------------------
40240 'E3FKG --------------- egg weight /100 birds         |
40250 'NRPRC --------------- nest run price   in $         |
40260 'EGNBR --------------- egg number                    |
40270 'EGGWT --------------- egg weight       in gr        |
40280 'EGGSL --------------- egg sale         in $/100 bird|
40290 'DOZNO --------------- dozen number                  |
```

```
40300 'HDPOD --------------- hen/day production in %       ¦
40310 '--------------------------------------------------------------
40320 'END OF SUBROUTINE
*EOS
*EOP
----- hen
```

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REFERENCES

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