

THESIS



This is to certify that the

thesis entitled

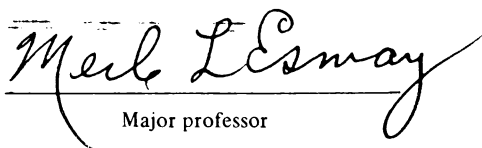
MAXIMIZING POULTRY EXCRETA DEHYDRATION WITH
VENTILATING AIR USING A SIMULATION MODEL

presented by

John Elvin Dixon

has been accepted towards fulfillment
of the requirements for

Ph.D. degree in Agricultural Engineering


Major professor

Date December 1978

PLACE IN RETURN BOX to remove this checkout from your record.
TO AVOID FINES return on or before date due.

DATE DUE	DATE DUE	DATE DUE
JUN 29 2005	AUG 02 2005	

MAXIMIZING POULTRY EXCRETA DEHYDRATION WITH
VENTILATING AIR USING A SIMULATION MODEL

By

John Elvin Dixon

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Agricultural Engineering

1979



ABSTRACT

MAXIMIZING POULTRY EXCRETA DEHYDRATION WITH
VENTILATING AIR USING A SIMULATION MODEL

By

John Elvin Dixon

The shift from an agrarian to an urban society along with chemical fertilizers and high labor costs has focused attention upon the need to manage animal wastes so as not to be offensive or a hazard to the environment. Common methods of animal waste management include use as a fertilizer, aerobic treatment, anaerobic treatment, and composting. Many animal operations do not easily lend themselves to all, and in some cases none, of these waste management systems because of economics, land limitation, or urban encroachment. Some systems are also resource wasteful. Because of these problems other waste management systems such as incineration, pyrolysis, hydroponic culture, and drying are being evaluated by researchers and innovative agriculturalists.

This study was undertaken to provide an analytical tool that would help evaluate the feasibility of drying poultry excreta. The tool was a simulation model designed to estimate the excreta drying potential of mechanical ventilating systems commonly provided for commercial egg production houses. The simulation model was based on

psychrometric calculations in combination with constant-rate drying theory.

The basis of the simulation model and the test facilities for model verification was a commercial-type laying house at the Michigan State University Poultry Science Research and Teaching Center, near East Lansing, Michigan. The laying house had a capacity of approximately 5000 hens and was equipped with a three-tier cage system, dropping boards, and under-cage mechanical scrapers for manure removal. The laying house was fully enclosed, insulated, and equipped with thermostatically controlled mechanical ventilation.

The system was managed as a small commercial unit. Feed and water were provided by hand-filling continuous troughs along each row of cages. Artificial light provided a diurnal photoperiod of 14 hours. The thermostats were set to operate each of the four fans in steps of about two degrees Fahrenheit and to maintain an inside dry-bulb temperature between 55 and 60°F when possible. Manure was scraped from the pens daily.

Psychrometric data collected on three summer days and two winter days were used for verification of the simulation model. Curvilinear regression curves for accumulated total moisture removed from the poultry house and for accumulated moisture evaporated from the manure followed their respective data points closely. Each of the paired set of verification curves had the same general shape and magnitude except for one of the low air flow winter days.

The critical factors for maximizing in-house manure drying were the drying surface area and the manure drying rate. The larger



the surface area the greater the drying. The simulation model indicated that any system that would increase the manure drying surface area would also increase manure drying. The drying rate was a function of no less than seven variables. For a given material such as poultry manure in a given poultry house, these several variables were considered constant.

The variables which influenced the manure drying rate the most were the inside wet-bulb depression and the ventilating rate. The wet-bulb depression in turn was influenced directly by the inside dry-bulb temperature and indirectly by the outside dewpoint temperature. The ventilating rate was limited by the heat available. Maximum drying was possible with a high inside dry-bulb temperature, a low outside dewpoint temperature, and maximum air exchange. The weather determined the outside dewpoint temperature, but management practices and bird heat available influenced the inside dry-bulb temperature.

Approved Mel L Esnay
Major Professor

Approved B. R. Heldman
Department Chairman



ACKNOWLEDGMENTS

The author wishes to express his appreciation to Dr. M. L. Esmay for serving as major professor and for his guidance, encouragement, patience, and personal interest; to Dr. G. L. Park for serving on the doctoral committee and administering a preliminary examination; to Dr. T. C. Surbrook for serving on the doctoral committee; to Dr. C. J. Flegal for serving on the doctoral committee and assisting with the poultry house operation; to Dr. C. C. Sheppard for assistance with the poultry house operation; to Dr. J. B. Gerrish for counsel and assistance with instrumentation of the poultry house; and to Dr. H. C. Zindel for assistance in obtaining funds to carry out the research. Appreciation is also extended to my family for their patience and understanding. Special thanks goes to Winifred for her typing.

This page would not be complete without thanking the Agricultural Engineering Department at the University of Idaho for financial and moral support and the faculty and staff of the Agricultural Engineering Department at Michigan State University for providing physical facilities, financial support, and personal encouragement.

TABLE OF CONTENTS

	Page
LIST OF TABLES	v
LIST OF FIGURES	vii
 Chapter	
1. INTRODUCTION	1
1.1 General Remarks	1
1.2 Objectives	3
1.3 Waste Management Systems	3
2. MODEL DEVELOPMENT	8
2.1 Definition and Explanation of System Modeled	8
2.2 External Environment and System Parameters	12
2.3 Hypothesis for Drying Manure	14
2.3.1 Drying Theory	15
2.3.2 Heat Balance	18
2.3.3 Moisture Balance	21
2.4 Mathematical Models of Subsystems	22
2.4.1 Supplemental Heat, Q_s	22
2.4.2 Heat Flow Through Exterior Building Surfaces, Q_b	22
2.4.3 Sensible Heat of the Animals, Q_a	25
2.4.4 Heat from Evaporated Moisture, Q_e	26
2.4.5 Heat from Mechanical and Lighting Systems, Q_m	26
2.4.6 Heat from Temperature Change in Ventilating Air, Q_v	26
2.4.7 Moisture in Incoming Ventilating Air, M_o	28
2.4.8 Moisture from Animal Respiration, M_r	28
2.4.9 Moisture Evaporated from Manure, M_m	29
2.4.10 Moisture Evaporated from Waterers, M_w	31
2.5 Outline of Computer Program	33
3. MODEL VERIFICATION	39
3.1 Experimental Facilities and Equipment	40
3.2 Experimental Procedure	43
3.2.1 Psychrometric Data Collection and Analysis	43
3.2.2 Simulation Model Evaluation	49

Chapter	Page
3.3 Verification Results	51
3.3.1 Summer Conditions	51
3.3.2 Winter Conditions	51
3.4 Discussion of Verification	52
4. RESULTS FROM MODEL USE	68
5. SUMMARY AND CONCLUSIONS	84
5.1 Summary	84
5.2 Conclusions	86
5.3 Recommendations for Future Research	87
APPENDICES	88
A. COMPUTER PROGRAM LISTING	89
B. EXAMPLES OF INTERMEDIATE COMPARISON GRAPHS	126
C. VERIFICATION MANAGEMENT FACTOR, DESIGN, AND INPUT VALUES	136
LIST OF REFERENCES	142

LIST OF TABLES

Table		Page
2.1	A listing of parameters requiring numeric definition with appropriate units of measurement	15
2.2	Heat production at various levels of ambient temperature for S. C. White leghorn hens (Phillips, 1970)	25
3.1	Accumulated total pounds of moisture removed from the poultry house. A comparison of collected data versus simulation model calculations	66
3.2	Accumulated pounds of moisture evaporated from the manure in poultry house. A comparison of collected data versus simulation model calculations	67
4.1	Manure moisture removed and moisture content for a typical month of January as calculated by the simulation model	78
4.2	Manure moisture removed and moisture content for a typical month of April as calculated by the simulation model	79
4.3	Manure moisture removed and moisture content for a typical month of July as calculated by the simulation model	80
4.4	Manure moisture removed and moisture content for a typical year as calculated by the simulation model . .	81
4.5	Management factor, design, and input values as used for operating the model with average weather data . .	83
C.1	Management factor, design, and input values as used for verifying the model with data collected August 12, 1974	137
C.2	Management factor, design, and input values as used for verifying the model with data collected August 13, 1974	138

Table		Page
C.3	Management factor, design, and input values as used for verifying the model with data collected August 20, 1974	139
C.4	Management factor, design, and input values as used for verifying the model with data collected January 6, 1975	140
C.5	Management factor, design, and input values as used for verifying the model with data collected January 7, 1975	141

LIST OF FIGURES

Figure	Page
2.1 The interrelation of the simulation model inputs and outputs	9
2.2 Floor plan of the commercial-type poultry house used as the base for the simulation. The circled symbols, I1, O1, etc., indicate points of measurement for incoming and outgoing air	10
2.3 Flow chart of computer program	34
3.1 Accumulated total moisture removed from the poultry house during the day of August 12, 1974. The two curves result from curvilinear regression calculations based on the two separate sets of data	56
3.2 Accumulated moisture evaporated from the manure in the poultry house during the day of August 12, 1974. The two curves result from curvilinear regression calculations based on the two separate sets of data .	57
3.3 Accumulated total moisture removed from the poultry house during the day of August 13, 1974. The two curves result from curvilinear regression calculations based on the two separate sets of data	58
3.4 Accumulated moisture evaporated from the manure in the poultry house during the day of August 13, 1974. The two curves result from curvilinear regression calculations based on the two separate sets of data .	59
3.5 Accumulated total moisture removed from the poultry house during the day of August 20, 1974. The two curves result from the curvilinear regression calculations based on the two separate sets of data . .	60
3.6 Accumulated moisture evaporated from the manure in the poultry house during the day of August 20, 1974. The two curves result from curvilinear regression calculations based on the two separate sets of data .	61

Figure		Page
3.7	Accumulated total moisture removed from the poultry house during the day of January 6, 1975. The two curves result from curvilinear regression calculations based on the two separate sets of data . . .	62
3.8	Accumulated moisture evaporated from the manure in the poultry house during the day of January 6, 1975. The two curves result from curvilinear regression calculations based on the two separate sets of data	63
3.9	Accumulated total moisture removed from the poultry house during the day of January 7, 1975. The two curves result from curvilinear regression calculations based on the two separate sets of data.	64
3.10	Accumulated moisture evaporated from the manure in the poultry house during the day of January 7, 1975. The two curves result from curvilinear regression calculations based on the two separate sets of data	65
4.1	The moisture removed from manure during a typical month of January as calculated by the simulation model	70
4.2	The moisture content of manure for a typical month of January as calculated by the simulation model . .	71
4.3	The moisture removed from manure during a typical month of April as calculated by the simulation model	72
4.4	The moisture content of manure for a typical month of April as calculated by the simulation model . . .	73
4.5	The moisture removed from manure during a typical month of July as calculated by the simulation model .	74
4.6	The moisture content of manure for a typical month of July as calculated by the simulation model	75
4.7	Representative daily moisture removal from manure throughout the year as calculated by the simulation model	76
4.8	Representative daily manure moisture content throughout the year as calculated by the simulation model .	77

B.1	An example of a comparison graph used for evaluation during verification of the simulation model with the measured data. This graph showed that the incoming air dry-bulb temperature as used in the model was in fact equal to that of the collected data	127
B.2	An example of a comparison graph used for evaluation during verification of the simulation model with the measured data. This graph showed that the incoming air dewpoint temperature as used in the model was in fact equal to that of the collected data	128
B.3	An example of a comparison graph used for evaluation during verification of the simulation model with the measured data. This graph showed that the incoming air humidity ratio was in fact equal to that of the collected data	129
B.4	An example of a comparison graph used for evaluation during verification of the simulation model with the measured data. This graph showed that the outgoing air dry-bulb temperature as calculated by the simulation model follows very closely to the measured value	130
B.5	An example of a comparison graph used for evaluation during the verification of the simulation model with measured data. This graph showed that the outgoing air dewpoint temperature as calculated by the simulation model follows very closely to the measured value	131
B.6	An example of a comparison graph used for evaluation during the verification of the simulation model with measured data. This graph showed that the humidity ratio of the outgoing air as calculated by the simulation model follows very closely to the measured value	132
B.7	An example of a comparison graph used for evaluation during the verification of the simulation model with measured data. This graph showed that incoming air and outgoing air humidity ratio difference was greater for the measured data than as calculated by the simulation model for all but two hours of the day	133

- B.8 An example of a comparison graph used for evaluation during the verification of the simulation model with measured data. This graph showed that the air flow through the poultry house as calculated by the simulation model follows very closely to the measured value 134
- B.9 An example of a comparison graph used for evaluation during the verification of the simulation model with measured data. This graph showed that the evaporation from the poultry house during one hour as calculated by the simulation model followed the same trend as that which was calculated from measured data. The two curves result from curvilinear regression calculations based on the two separate sets of data 135

1. INTRODUCTION

1.1 General Remarks

The problem of handling, storage, and disposal of animal manure has existed since the beginning of animal husbandry. Until recent years distribution of domestic animals was extensive and the manure along with other wastes was disposed of without problems within the normal habitat of the animal. The earliest husbandrymen were nomadic and the animal waste disposal systems consisted of natural distribution within the pasture and grazing areas. As the history of animal husbandry progressed with the more sophisticated farming systems, the animals were concentrated on more confined land areas. Prior to the mid-twentieth century, the number of animals and the area of the land upon which they were kept was in reasonable balance. The balance was such that the fertilizer value of the waste was considered and treated as a resource for the crops grown on the land.

The general availability and economic feasibility of chemical fertilizers for principal plant nutrients during the twentieth century caused the crop farmers to shun animal manure as the primary source of plant nutrients. At the same time animal production was subjected to higher labor costs and the economy of scale brought about concentration of large herds of animals in confined housing systems. Large concentrations of animals created waste material

handling problems. What had been an asset and resource has now become a disposal problem.

Disposal of animal waste should not, in fact, be the objective. Rather, the raw product should be converted to a stable usable form and removed from the point of production. Removal from the source in an unstable form is often no solution, only a transfer in location. The waste disposal problem with its associated air and water pollution problems still exists, but at a new location.

Historically, raw manure mixed with litter has been stored in open stacks and periodically transported and spread upon the land. Recently, the potential of air and water pollution has caused constraints to be placed on operations of this type. The U.S. Environmental Protection Agency has been established and given authority to regulate operations that have the potential of creating pollution and/or a nuisance.

With the encroachment of urban population onto agricultural land, odors resulting from the storage, transportation, and spreading processes often have been declared a nuisance. Furthermore, the past practice of spreading raw solid or liquid manure upon frozen ground has been curtailed because of stream polluting potential. Frozen ground had the advantage of making fields easily accessible during the winter and the cold weather minimized odors. This curtailment has led to a search for new methods of treatment, storage, and handling which minimize odors and water pollution.

1.2 Objectives

The principal objective of this dissertation was to develop a verified analytical tool for evaluating in-house drying of poultry manure.

The secondary objective was to provide the basis for applying the simulation model tool for maximizing in-house poultry manure drying. The base provided by this secondary objective will allow manipulating design and management parameters such as building insulation, minimum ventilating rate, bird density, and in-house temperature so as to determine maximum in-house drying of manure.

1.3 Waste Management Systems

In their publication pertaining to livestock-waste management, Miner and Smith (1975) discussed various methods for treating, utilizing, or disposing of manure. Commonly accepted methods of utilizing or treating manure are: (1) use as a soil amendment and fertilizer for plants, (2) treatment by an oxidation ditch, (3) treatment by an aerobic lagoon, (4) treatment by an anaerobic lagoon or holding pond, and (5) treatment by composting. Some experimental utilization systems and treatment processes with limited use include: (1) treatment by incineration, (2) treatment by pyrolysis, (3) use in hydroponic culture, (4) treatment by the Barriered Landscape Water Renovation System (BLWRS), and (5) treatment by drying.

Traditionally, as pointed out above, and as noted in these publications, manure has been disposed of or utilized without "treatment" as a soil amendment and fertilizer for plants. With the

increased animal density and larger herds and flocks of recent years, manure treatment necessarily has required serious consideration.

It is possible to treat manure by several methods. Most of these treatments involve some biological process. Sanitary engineers have developed aerobic processes among others for municipal sewage treatment. In the aerobic process oxygen-requiring microorganisms are stimulated through appropriate environmental control to digest the raw manure mixture and change it to a more stable form. Ultimately, however, the various components even though stable, such as water and sludge, must be disposed of some place. Sanitary engineers also have used anaerobic processes. The anaerobic process involves microorganisms too, but an environment must be maintained that excludes oxygen. Again, after this primary treatment there is ultimately a need for disposal of the sludge and impure water.

Both of the two basic biological treatment methods have been and are being used for treatment of animal manure. The most common aerobic systems for liquid manure treatment are oxidation in an aerobic lagoon and oxidation through mechanical mixing. Anaerobic systems being used are the anaerobic digester and the stabilization pond (anaerobic lagoon). Each of these systems was discussed by Miner and Smith (1975).

Composting is another aerobic treatment process. The process differs from those mentioned above because the manure is treated in or near the solid state. Composting of manure was discussed by Singley et al. (1975), and Miner and Smith (1975).

The Barriered Landscape Water Renovation System (BLWRS) treats animal wastes in the near liquid state. The principal objective of this system is to remove nitrogen and phosphorous from the manure. These nutrients along with other solid constituents are removed from the liquid by filtering through a specifically designed and constructed soil profile. Erickson et al. (1971) described this system.

Hydroponic culture has also been tried for removing nutrients from animal wastes in the near liquid state. Systems of this type also were discussed by Miner and Smith (1975). Two other methods of processing manure discussed by Miner and Smith (1975) are incineration and pyrolysis. Incineration involves the complete combustion of the manure. High moisture (above 60 percent) manures require an additional fuel source to sustain the combustion. In their discussion of this subject Davis et al. (1972) noted that it is possible to salvage most of the potash and phosphorous in the ash for use as fertilizer. The nitrogen can be salvaged as ammonia from the flue gases. Sobel and Ludington (1966) noted that in the incineration process the energy tied up in volatile solids is used in the combustion of the organic portions of the manure.

The pyrolysis process involves holding the manure within a temperature range of 480-1830°F in an oxygen-deficient atmosphere. The products are gases (hydrogen, water vapor, methane, carbon dioxide, carbon monoxide, ethylene, etc.), oils, and ash.

Drying of manure also was discussed by Miner and Smith (1975). Drying of poultry excreta in fact has been discussed by several

writers. Ludington (1963) discussed dehydration and its economics. Surbrook (1969) and Surbrook et al. (1971) evaluated drying poultry and other animal excreta with a mechanical drier. Bressler and Bergman (1971) described a system of drying with extra in-house circulating fans located over the excreta collected under a sloping-wire-floor type house. Stirring of manure was also included with the "Bressler" system. With this system, Bressler and Bergman (1971) reduced the manure moisture content in the house to values of from 23.8 percent to 50.5 percent. Gerrish et al. (1973) described an in-house pre-drying system which used only the ventilating air of a cage-type laying house and the periodic waste heat from a mechanical drier and after-burner. Preliminary results from actual tests with this system were presented by Flegal et al. (1974). Conclusions were enumerated in subsequent reports by Sheppard et al. (1974), Esmay et al. (1975a, 1975b), and Zindel et al. (1977).

Mechanical drying of excreta may be too expensive if the amount of water to be evaporated with fossil fuel energy is great. These drying costs can be offset to some extent if the dry manure is processed for a feed supplement. Drying costs can be minimized by removing as much water as possible in the poultry house before the manure is mechanically dried. In-house water removal for poultry manure was described by Esmay et al. (1975a). They showed that drying poultry excreta from its original voided moisture content of approximately 80 percent wet basis (wb) to 12.5 percent wb required the removal of 77.5 pounds of water for each 100 pounds of excreta. (Approximately 100 pounds of excreta per day is produced by 370 hens.)

About one gallon of fuel oil would be required to evaporate the 77.5 pounds of water from the excreta using a typical fuel oil with heating value of 144,000 Btu per gallon and a drier efficiency of 57 percent as found by Surbrook (1969).

Commercial laying operations may be from 100 to 1000 times this size. A commercial egg producer, therefore, would have a daily fuel requirement of from 100 to 1000 gallons per day, if all drying was accomplished by the use of fuel oil. This approach is impractical and not used commercially. Under typical housing conditions some drying of excreta by ventilating air takes place shortly after it is voided and continues within the laying house during normal operations. Results of in-house drying have been reported by Esmay et al. (1975b), Flegal et al. (1974), Lampman et al. (1967), Sobel (1972), Oheimb and Longhouse (1974), Dixon et al. (1976), and Zindel et al. (1977). The drying or removal of water prior to mechanical drying reduces the fuel requirement and thus its treatment cost. Some system of maximizing in-house water removal is, therefore, desirable. A mathematical model or simulation of the pre-drying process would provide an effective analysis tool.

2. MODEL DEVELOPMENT

2.1 Definition and Explanation of System Modeled

The system defined by this study was the environment produced with a 5000 bird egg laying operating unit. The operation unit was defined as the house enclosing the laying hens and the equipment used to manage the operation. Inputs to the system considered to be most important to the model were the manure from the birds, heat, and moisture. Outputs were moisture removed from the manure and manure moisture content. Along with these inputs and outputs there were other related inputs, i.e., feed, water, ventilating air, and hens. Associated outputs were eggs and ventilating air. The interrelation of these inputs and outputs is shown in Figure 2.1.

The simulation was based on a commercial-type, cage, laying house. Figure 2.2 shows a floor plan of the laying house. Hens were confined in wire cages with three hens per cage in alternate rows and four hens per cage in the other rows. The cages were in double rows three tiers high with manure dropping boards under the top two tiers. Periodically the manure was scraped from the dropping boards into the floor-pit beneath the bottom tier. A commercial, cable-operated pit scraper was used to move the manure to a cross conveyor, i.e., a conventional dairy-barn, gutter cleaner. Cleaning was manually controlled on a daily basis for this study.

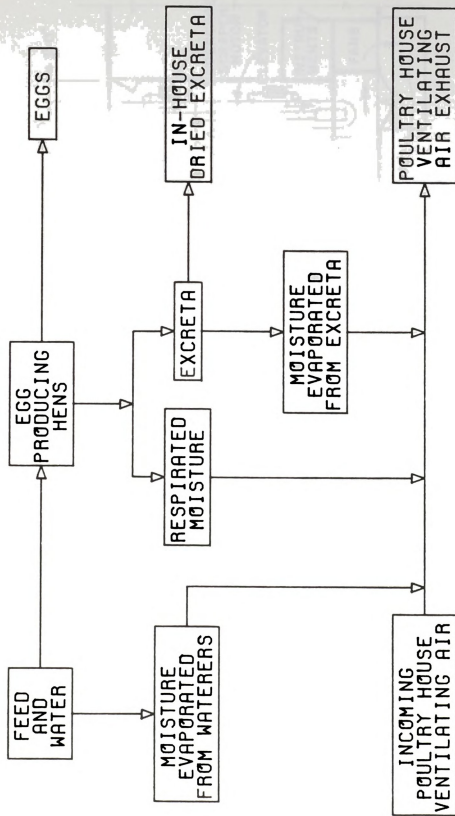


Figure 2.1. The interrelation of the simulation model inputs and outputs.

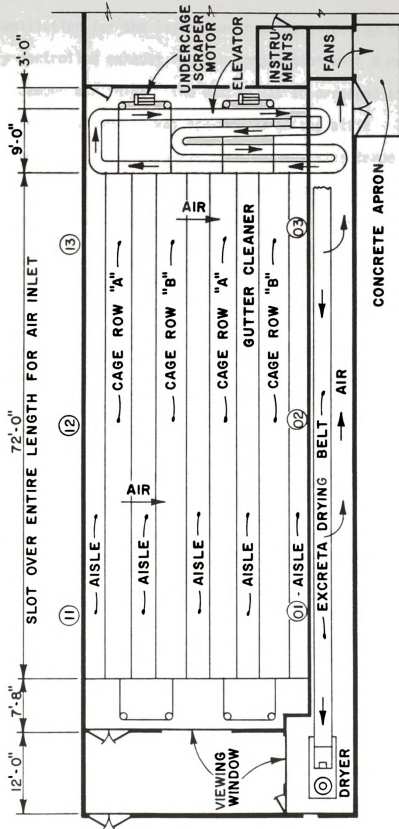


Figure 2.2. Floor plan of the commercial-type poultry house used as the base for the simulation. The circled symbols, 11, 01, etc., indicate points of measurement for incoming and outgoing air.

Ventilation for the laying house was provided by thermostatically controlled exhaust fans in conjunction with a manually controlled damper air inlet. The damper was so arranged that all winter-time ventilating air was drawn through the attic. This arrangement allowed for a relatively constant inside temperature except during summer and extremely cold weather. No supplemental cooling or heating was provided. This system was discussed extensively by Gerrish et al. (1973).

The primary measure of effectiveness was the amount of water removed from the manure in the house by the ventilating air. The moisture removed from the manure is a function of the drying rate, exposed surface area, and the drying time. The effect of the water holding capacity of the ventilating air and the heat energy from the birds was accounted for when calculating the drying rate.

The manure moisture content, which was a function of the moisture removed, was another means of expressing the effectiveness of the simulation. Perry et al. (1973) defined moisture content of a solid as the ratio of the moisture quantity per unit weight of the dry or wet solid. When the wet-solid weight is used as the ratio base, it is referred to as moisture content, wet basis. The moisture content, wet basis, is the quantity used in the simulation.

The manure moisture content (wet basis) was calculated from the above definition by first calculating the water removed from the manure. To calculate the water removed for a given weather condition and cage laying house, the inside dry-bulb temperature and ventilating rate were first determined. For normal operation the

inside temperature was set between 55 and 60°F and the ventilating rate was estimated by solving a heat balance equation. With the inside temperature and ventilating rate known or estimated, the inside wet-bulb temperature was determined and from this the drying rate was calculated. The water removed from the manure was calculated by multiplying the drying rate by the manure surface area and the lapsed time of manure exposure to the ventilating air.

2.2 External Environment and System Parameters

Certain parameters must be known or assumed for the simulation. For the system discussed here these were (a) outside air psychrometrics, (b) the quantity and moisture content of the excreted material, (c) the physical parameters of the building and ventilating system, and (d) the poultry operation management practices including number and weight of hens housed.

Data from the U.S. Weather Service provided the base information for the needed psychrometric data for the outside air used for ventilation. The appropriate weather service data were given as the barometric pressure, the maximum and minimum dry-bulb temperature, and a dewpoint temperature for a day. Average values as prepared by the Weather Service were used as representative of a day in a given month for the analysis of drying within a month. For analysis of annual effects of weather upon drying, average monthly data from the Weather Service were used as a representative day for a given month.

The model was constructed to make calculations based on a fraction of a day. For the simulation calculations it was therefore necessary to make an estimate of the weather situation at various times throughout a given day. Phillips (1970) formulated equations which estimated the temperature function as it varies with time through a day. His function was

for $0 < t \leq 6$

$$T = T_m + R_2 (1 + \cos((t+18)/30)\pi),$$

for $6 < t \leq 15$

$$T = T_m + R_2 (1 + \cos((t-12)/18)\pi),$$

for $15 < t \leq 24$

$$T = T_m + R_2 (1 + \cos((t-30)/30)\pi),$$

where T = outside dry-bulb temperature, °F,

T_m = minimum outside dry-bulb temperature,

R_2 = one-half outside temperature range, and

t = time, hours per 24-hour clock.

Phillips also states that the dewpoint temperature can be considered constant for the day but this was not found to give a reasonable estimate of the dewpoint temperature as measured. A more reasonable estimate of the dewpoint temperature for East Lansing was found by calculating a linear regression equation for the dewpoint temperature based on the dry-bulb temperature. The data used for the regression calculations were the data collected for verification of the model. The results of this calculation were

$$Y_{dp} = 6.48 + 0.8X_{db}$$

where Y_{dp} = dewpoint temperature, °F, and

X_{db} = dry-bulb temperature, °F.

The correlation coefficient for these data was 0.98. With the above equations and pertinent weather data, it was possible to calculate all needed psychrometric quantities for the incoming ventilating air. The equations and data needed for these psychrometric calculations were available through a package of algorithms developed by Bakker-Arkema and Lerew (1972). The psychrometric quantities in this package were: dry-bulb, wet-bulb, and dewpoint temperatures; enthalpy; absolute humidity (humidity ratio); latent heat; actual and saturation vapor pressures; relative humidity; and specific volume.

The moisture content of the freshly voided excreta has been determined by Esmay et al. (1975b) to be 80 percent (wet basis). The excreta produced by laying hens consisted of 0.272 pounds per hen-day of freshly voided excreta at 80 percent moisture content.

The physical and operational parameters will vary with each installation. The needed quantities for the simulation are listed in Table 2.1 along with appropriate units of measurement for use in the simulation model.

2.3 Hypothesis for Drying Manure

The drying rate of a specific material gave a characteristic which was used to estimate the water removed from the substance. As will be noted later, determination of the theoretical drying rate

required knowledge of the drying air temperature, humidity, and velocity plus specific material characteristics. Heat balance theory and the theory of moisture balance in ventilating air lend themselves to estimating the temperature and humidity of the air in the system. The hypothesis was that these theories can be combined through a computer simulation to estimate the water removed from manure in a poultry laying house.

Table 2.1. A listing of parameters requiring numeric definition with appropriate units of measurement.

Parameter	Units of Measurement
bird number	hens
bird weight	pounds
building ceiling height	feet
building length	feet
building width	feet
day, end of	hour
day, start of	hour
excreta moisture content	decimal fraction
excreta production rate	pounds/hen-day
insulation, ceiling "R"	hour-square feet-°F/Btu
insulation, wall "R"	hour-square feet-°F/Btu
lighting energy	watts
ventilating rate, maximum	cubic feet/minute
ventilating rate, minimum	cubic feet/minute
waterer length	feet
waterer surface width	feet

2.3.1 Drying Theory

Perry et al. (1973) presented a discussion of solids-drying fundamentals. From this it was noted there were two principal types

or periods of solids-drying: the constant-rate period and the falling-rate period. As the name implies, the rate at which drying occurs during the first period was constant while that in the second was not. When a plot was made of the drying rate versus time, there was a sharp change from a horizontal line curve to an exponential curve with negative slope at the point of this rate change. This point has been called the critical moisture content.

It was apparent by unit analysis that the amount of water removed from a drying material would be obtained, if the drying rate, m_r , were known, i.e.,

$$\text{water removed} = m_r A \theta,$$

where m_r = constant drying rate, lbs/sq ft - hr

A = surface area, sq ft, and

θ = time span, hr.

If the period of drying were the falling rate period, the equation must be used in its more general form, i.e., as a differential equation, and the term, m_r , can be better represented by $dW/d\theta$, where dW is the differential quantity of water removed in time period, $d\theta$.

Perry et al. (1963, 1973) presented formula to estimate $dW/d\theta$ for the constant-rate period and the falling-rate period. Only the constant-rate period was of interest in this presentation.

Perry et al. (1963, 1973) stated that the constant drying rate can be estimated as

$$dW/d\theta = h_c A (t - t_s') / \lambda = k_g A (p_s - p),$$

where $dW/d\theta$ = drying rate, lb of water/hr,

h_t = total heat transfer coefficient, Btu/hr
-sq ft $^{-\circ}\text{F}$,

A = surface area, sq ft,

λ = latent heat of evaporation at t'_S , Btu/lb,

k_g = mass transfer coefficient, lb/hr-sq ft-atm,

t = dry-bulb temp, $^{\circ}\text{F}$,

t'_S = temperature of evaporating surface, $^{\circ}\text{F}$,

P_S = vapor pressure of water at surface temp,
atm, and

p = partial pressure of water in the air, atm.

Wells (1972) referenced Perry et al. (1963) and stated (Bagnoli contributed to the Chemical Engineers' Handbook by Perry et al.),

"The use of the heat transfer coefficient is preferred in estimating drying rates because they are usually more reliable (Bagnoli et al., 1963). Small errors in temperature have negligible effect on the heat-transfer coefficient, but do introduce relatively large errors in partial pressure estimates and hence in the mass transfer coefficient.

The critical value to determine in evaluating the drying rate was the heat transfer coefficient, h_t . Perry et al. (1963) stated that $h_t = h_c$, the convective heat transfer coefficient, when heat was transferred by convection only. They also gave the formula

$$h_c = \alpha G^n / D_c^m,$$

where h_c = convective heat transfer coefficient, Btu/hr-sq ft $^{-\circ}\text{F}$,

G = mass velocity, lb/hr-sq ft,

D_c = a characteristic dimension, ft, and

α, m, n = constants.

Perry et al. (1963) suggested the value, G , be determined from the relationship: weight rate of flow divided by the cross-sectional area. Perry also pointed out that the value, D_c , for a plate can be represented by the length of drying solid over which the air-stream passes. From the discussion and examples used by Perry et al. (1963) and by Wells (1972) it was apparent that $m = 1-n$ and that these constants along with α were specific to a material and drying conditions.

Wells (1972) ran extensive laboratory tests involving the drying of poultry manure. Although he did not calculate the constants, α and n in the equation for h_c , he provided measured values for the "evaporation heat required," temperatures, velocities, etc. so that these constants could be determined. Dixon et al. (1976) and Dixon et al. (1978) evaluated these data for the constants. For American Engineering Units they found them to be:

$$n = 0.4029 \text{ and } \alpha = 0.1222.$$

2.3.2 Heat Balance

Since the equation, $dW/d\theta' = h_t A(t - t'_s)/\lambda$, was to be the basis for determining the drying rate, a means of estimating the temperatures, t and t'_s , was necessary. The dry-bulb temperature, t , was that of the air passing over the drying manure. The temperature of the evaporating surface, t'_s , can be taken as the wet-bulb temperature of the air according to Perry et al. (1973). Wells (1972), however, in work involving the drying of poultry manure found the surface temperature to be 0.5°C higher than the wet-bulb temperature. Since

the wet-bulb temperature was used for calculating the drying rate parameters, n and α , the wet-bulb temperature was used for t'_s . The dry-bulb temperature was a predetermined inside temperature, between 55 and 60°F, unless the weather was extreme. For extreme weather conditions the dry-bulb temperature was estimated from a heat balance analysis of the laying house. A moisture balance analysis provided a means to estimate the wet-bulb temperature. The assumption was made that the dry-bulb and wet-bulb temperatures of the outgoing ventilating air were representative of the air that passes over the manure being dried within the laying house.

The basic equation for sensible heat balance was given by the Structures and Environment Handbook (1975) as

$$Q_s + Q_b + Q_a + Q_e + Q_m + Q_v = 0,$$

where Q_s = supplemental heat, Btu/hr,

Q_b = heat flow through exterior building surfaces,
Btu/hr,

Q_a = sensible heat from housed animals, Btu/hr,

Q_e = heat from moisture evaporated or condensed,
Btu/hr,

Q_m = heat from mechanical systems and lighting,
Btu/hr, and

Q_v = heat from temperature change in ventilating air,
Btu/hr.

Each of the elements in this equation, except Q_s and Q_m , was a function of the inside temperature. When the physical parameters of the building, the management practices, and flock size were defined, it

was possible to estimate the inside temperature. To make this estimate the exterior environmental temperature and psychrometric characteristics were necessary as well as an iterative technique for an approximate solution of the heat balance equation. The result of the solution to the heat balance equation gave a function from which the temperature was estimated. An appropriate iterative technique, the Newtonian convergence, was used by Phillips (1970). The convergence was based on Newton's method (Smith et al., 1947) for finding roots of a function, $f(x)$. Through some means, an estimate of a root, x_1 , was made. By evaluating the function at x_1 , the equation for the tangent-line through x_1 was written as

$$y - f(x_1) = f'(x_1) (x - x_1).$$

This line intersected the x-axis when $y = 0$. Solving the tangent-line equation for x with $y = 0$ gave

$$x = x_1 - f(x_1)/f'(x_1),$$

a new estimate of the root. The process was repeated until an acceptably small error was obtained. Phillips (1970) adapted Newton's method to a digital computer for evaluation of a heat balance function as follows:

$$t_{n+1} = t_n - \frac{f(t_n)}{f'(t_n)},$$

where t_{n+1} = new approximation to the solution,

t_n = previous approximation value,

$f(t_n)$ = net heat flow across system boundaries at temperature t_n , and

$f'(t_n)$ = first derivative of $f(t_n)$ which was determined

by the following central finite difference

approximation:

$$f'(t_n) = \frac{f(t_n+0.1) - f(t_n - 0.1)}{0.2} .$$

2.3.3 Moisture Balance

The basic equation for moisture balance of the ventilating air was adapted from the Structures and Environment Handbook (1975) as follows:

$$M_o + M_r + M_m + M_w - M_v = 0,$$

where M_o = moisture in incoming ventilating air, lbs/hr,

M_r = moisture from animal respiration, lbs/hr,

M_m = moisture evaporated from manure, lbs/hr,

M_w = moisture evaporated from waterers, lbs/hr,

M_v = moisture in outgoing ventilating air, lbs/hr.

This equation assumes there was no water spillage or other evaporating surfaces.

The equation indicates each element, except M_v , added moisture to the ventilating air. Since the mechanical ventilating system kept the air inside the laying house turbulent, the humidity of the inside air was assumed to be that of the moisture in the outgoing ventilating air, M_v . The equation was, therefore, solved for M_v to obtain the moisture in the outgoing ventilating air in terms of pounds of moisture per hour.

When the ventilating rate was known, the humidity ratio was calculated as follows:

$$H = M_v/V_r,$$

where H = humidity ratio, lbs of water vapor/lb of air,

V_r = ventilating rate, pounds of air/hour, and

M_v = (previously defined).

2.4 Mathematical Models of Subsystems

The following paragraphs present the basis for evaluation of each element in the heat balance and moisture balance equations. Since the element, M_v , in the moisture balance equation was the sum of the other elements, it will not be discussed further. Some elements were determined directly from given data or assumptions. Estimates for others required more rigorous calculations and some required the use of approximation techniques.

2.4.1 Supplemental Heat, Q_s

The system as defined had no supplemental heat. As a result this quantity was assigned the value zero.

2.4.2 Heat Flow Through Exterior Building Surfaces, Q_b

The heat flow through exterior building surfaces, Q_b , was determined from the following sum:

$$Q_b = q_{bw} + q_{bc} + q_{bf},$$

where q_{bw} = heat flow through the building walls, Btu/hr,

q_{bc} = heat flow through the building ceiling, Btu/hr,

and

q_{bf} = heat flow through the building floor, Btu/hr.

Esmay (1969) presented the following equation as a means of estimating a steady state heat flow through a composite of materials:

$$Q = UA(t_i - t_o),$$

where Q = overall heat flow, Btu/hr,

U = overall coefficient of heat transmission, Btu/hr-sq ft-°F,

A = area normal to direction of heat flow, sq ft, and t_i and t_o = inside and outside temperature, °F.

The value, U , was determined from the equation (Esmay, 1969):

$$U = 1 / (1/f_o + L_1/k_1 + L_2/k_2 + \dots 1/a + 1/f_i),$$

where $L_1, L_2, \dots$ = thickness of respective material, inches,

$k_1, k_2, \dots$ = thermal conductivity of respective material, Btu/hr-sq ft-°F/in,

a = thermal conductivity of an air space, Btu/hr-sq ft-°F, and

f_i and f_o = the inside and outside surface conductance, Btu/hr-sq ft-°F.

The general equation was adapted to the poultry building and gave the equations

$$q_{bw} = A_{bw} U_{bw} (t_i - t_o) \text{ and}$$

$$q_{bc} = A_{bc} U_{bc} (t_i - t_o),$$

where the subscripts "bw" and "bc" represent the building walls and building ceiling, respectively.

Phillips (1970) developed an equation to estimate the heat loss from a concrete floor slab in a poultry building, q_{bf} .

The equation was

$$q_{bf} = k_s p A_{bf} (t_{bf} - t_{bo}),$$

where k_s = inside surface heat transfer coefficient,

Btu/hr-sq ft-°F,

p = portion of floor exposed to environment, decimal fraction,

A_{bf} = floor area, sq ft,

t_{bf} = surface temperature of floor, °F, and

t_{bo} = environmental temperature adjacent to floor, °F.

In the presentation of his work, Phillips (1970) found the value of k_s to be 1.65 Btu/hr-sq ft-°F for a concrete floor slab in a poultry house. The variable, p , was more explicitly defined as that portion of the floor not covered by manure. In the development of this equation for use in a simulation he suggested the floor surface temperature, t_{bf} , be assigned an initial value equal to the mean outside temperature for the day plus 5 degrees. This value was approximately equal to the mean expected interior temperature for the day and was intended to eliminate long-term storage effects. Subsequent values were determined by means of the equation

$$(t_{bf})_{\text{new}} = (t_{bf})_{\text{old}} - q_{bf} / (0.25 C A_{bf} m_{bf}),$$

where $(t_{bf})_{\text{new}}$ = slab temperature for next time period,
deg F,

$(t_{bf})_{\text{old}}$ = slab temperature for present time period,
deg F,

C = specific heat of floor, and

m_{bf} = mass of one square foot of slab plus mass
of sufficient fill below the slab to make
up a total thickness of 10 inches.

In evaluating m_{bf} he suggested four inches of concrete plus six inches of sand be assumed for all simulations. This yielded a mass of 120 lbs. per square foot of floor space.

2.4.3 Sensible Heat of the Animals, Q_a

Phillips (1970) developed a mathematical model for the sensible heat, Q_a , from laying hens using data from Ota and McNalley (1961). The data used by Phillips were used for this simulation (see Table 2.2). The data were interpolated by using the computer subroutine entitled TABLI as developed by Llewellyn (1965).

Table 2.2. Heat production at various levels of ambient temperature for S. C. White leghorn hens (Phillips, 1970).

Ambient Temperature °F	Sensible Heat (BTU/Hour (Lb))		Latent Heat (BTU/Hour (Lb))	
	Day	Night	Day	Night
26	11.1	6.9	1.7	1.6
34	8.3	6.8	2.1	2.0
47	7.3	6.1	2.3	1.9
56	6.6	5.3	3.2	2.6
64	6.5	5.1	3.3	2.2
74	---	---	3.4	2.0
84	6.3	3.6	4.2	3.5
94	.2	.6	5.3	4.7

2.4.4 Heat from Evaporated Moisture, Q_e

The heat used to evaporate moisture, Q_e , was determined from the latent heat of vaporization definition (Weast, 1970). This definition yielded the equation

$$Q_e = -Wh_1,$$

where W = weight of evaporated moisture, lbs, and

h_1 = the latent heat of vaporization, Btu/lb.

2.4.5 Heat from Mechanical and Lighting Systems, Q_m

Phillips (1970) calculated the energy added to the laying house system through mechanical and electrical means, Q_m , from the equation

$$Q_m = CAK,$$

where C = the conversion factor 3.413 Btu/watt-hour,

A = the floor area of the laying house, sq ft, and

K = the energy input per unit area, watts/sq ft.

The total lighting energy, AK , was determined by summing the wattage of all the lights. The mechanical energy was small and neglected.

2.4.6 Heat from Temperature Change in Ventilating Air, Q_v

Since all latent heat effects in the ventilating air were accounted for in Q_e , the term Q_v accounted for sensible heat effects only. The sensible heat change in the ventilating air was, therefore, the sum of the change in heat of the air, q_{va} , plus the change in heat of the water vapor within the air q_{vw} , i.e.,



$$Q_V = q_{Va} + q_{VW}$$

The equation for the change in heat energy of the dry ventilating air, q_{Va} , was adapted from the definition of heat capacity as noted by Weast (1970) such that

$$q_{Va} = M_a C_a (t_1 - t_2),$$

where M_a = mass rate of ventilating air, lbs/hr, and

C_a = the heat capacity of air, Btu/lb-°F.

In a like manner the equation for the change in heat energy of the water vapor in the ventilating air, q_{VW} , was determined to be

$$q_{VW} = M_V C_W (t_1 - t_2),$$

where M_V = mass rate of water vapor in ventilating air,
lbs/hr,

C_W = heat capacity of water vapor, Btu/lb-°F, and

$t_1 - t_2$ = temperature change of the air and water vapor
mixture, °F.

The water vapor mass rate, M_V , was calculated from the relationship (Esmay, 1969),

$$M_V = WM_a,$$

where W = humidity ratio of the mixture, lbs of moisture/
lb of dry air, and

M_V and M_a = (as previously defined).

Combining these equations gave

$$Q_V = M_a (C_a + WC_W) (t_1 - t_2).$$

2.4.7 Moisture in Incoming Ventilating Air, M_o

The moisture in the incoming ventilating air, M_o , was determined from given or assumed data about the weather. From these data, a dry-bulb and dewpoint temperature was generated for a specific time of day as discussed earlier. The outside dewpoint temperature was assumed to be constant at the reported value for that day except at times when the dry-bulb temperature was less than this value. For that situation and time the dewpoint temperature was set at the dry-bulb temperature. These temperatures along with the ventilating rate were used to calculate the moisture in the incoming air, M_o , as

$$M_o = M_a W_o,$$

where W_o = the humidity ratio of the incoming air as determined from psychrometric relationships, lbs of moisture/lb of dry air, and

$$M_a = (\text{as previously defined}).$$

2.4.8 Moisture from Animal Respiration, M_r

The latent heat in respired air from laying hens, Q_1 , was determined from data presented by Ota and McNalley and adapted by Phillips (1970). An equation for the moisture from animal respiration, M_r , was written from the definition for latent heat as given by Weast (1970). The equation was

$$M_r = Q_1/h_1,$$

where h_1 = the latent heat of vaporization at the body temperature of a laying hen, Btu/lb, and

Q_1 = latent heat from housed animals, Btu/hr.

2.4.9 Moisture Evaporated from Manure, M_m

The moisture evaporated from the manure, M_m , was calculated from the water removal equation:

$$M_m = A_m m_m \theta + I,$$

where A_m = surface area of the manure, sq ft,

m_m = constant drying rate of manure, lbs/sq ft-hr,

θ = (as previously defined), and

I = moisture evaporated due to manure energy level when voided.

Since the modeled system scraped the manure from the dropping boards daily, the boards were covered with wet manure. The dropping board surface was therefore used as the manure drying surface in the simulation model.

The method for calculating the constant drying rate of manure, m_m , was discussed in section 2.3.1.

The wet-bulb temperature for use in that equation was determined by use of the Newtonian convergence procedure discussed in section 2.3.2. The hypothesis was that the sum of initial ventilating air moisture content plus the moisture added to the air while passing through the poultry house was equal to the final moisture content. The Newtonian convergence equation was

$$F(x) = W_0 + E_m + R - W_i,$$

where W_o = humidity ratio of outside air,

E_m = moisture added per unit weight of ventilating air
from drying manure,

E_w = moisture added per unit weight of ventilating air
from the waterers,

R = moisture added per unit weight of ventilating air
from bird respiration, and

W_i = humidity ratio of the outgoing ventilating air.

The units for all terms were pounds of moisture per pound of dry air.

The moisture evaporated due to the manure energy level as
voided, I , was calculated from the equation

$$I = q_i/h_1,$$

where q_i = heat given up by the manure, Btu, and

h_1 = latent heat of vaporization at average temperature
difference, Btu/lb.

The heat given up by the manure, q_i , was calculated from the equation:

$$q_i = W_m C_m (t_h - t_i)$$

where W = weight of manure produced during one iteration,
lbs.,

C_m = specific heat of manure, Btu/lb-°F,

t_h = hen body temperature, °F, and

t_i = laying house temperature, °F.

The hen body temperature was defined as 107.1°F by Esmay (1969). The specific heat of the manure, C_m , was estimated to be 0.87 Btu/lb-°F. This estimate was made by noting the voided manure moisture content was 80 percent and that water has a specific heat of one. The dry

matter specific heat was estimated at 0.35 Btu/lb-°F by averaging the specific heat values of cellulose, clay sand, silica, wood, sugar, steric acid, and Urea as given by Perry et al. (1973). A weighted average of the two values was then used for the value of C_m .

2.4.10 Moisture Evaporated from Waterers, M_w

The moisture evaporated from the waterers, M_w , was calculated from the water removal equation discussed previously. With appropriate subscripts the equation becomes:

$$M_w = m_w A_w \theta,$$

where m_w = mass flow rate of water from a free surface,
lbs/sq ft-hr,

A_w = surface area of waterers, sq ft, and

θ = (previously defined).

The surface area of the waterers, A_w , was determined by measuring the surface area of each waterer and summing these areas.

Calculation of the mass flow rate of water vapor from a free surface, m_w , was calculated from Stefan's law. Holman (1963) integrated the equation for the law and presented the equation:

$$m_{wt} = \frac{D p_a w_m A}{R_0 T (x_2 - x_1)} \ln(p_2/p_1),$$

where m_{wt} = the total mass flow of water, lb/hr,

D = diffusion coefficient, ft²/hr,

p_a = barometric pressure, psi,

w_m = molecular weight,

- A = area, sq in,
 R_0 = universal gas constant, lb-ft/lb-°R,
 T = temperature of environmental air, °R,
 x_2 = elevation of vessel rim, ft,
 x_1 = elevation of water surface in vessel, ft,
 p_2 = partial pressure of the air outside the vessel,
 psi, and
 p_1 = partial pressure of the air at the water surface,
 psi.

The value for the mass flow rate of water vapor, m_w , was determined by dividing the above equation by the area, A . Weast (1970) gave a value for the diffusion coefficient, D , as 0.239 sq cm/sec at 8°C and Holman (1963) gave a value of 0.256 sq cm/sec at 25°C. The value used for D was that calculated by interpolation using the poultry house dry-bulb temperature. The molecular weight of water and the universal gas constant were given by Holman at 18 and 1545 lb-ft/lb-°R, respectively. Holman (1963) noted the partial pressure of the air at the water surface, p_1 , was the barometric pressure minus saturated water vapor pressure while the air vapor pressure, p_2 , was the barometric pressure minus the ambient air water vapor pressure. The saturated water vapor pressure was determined from the inside dry-bulb temperature and the ambient air water vapor pressure was determined from the inside dry-bulb and wet-bulb temperatures using the psychrometric algorithm discussed earlier. The difference in elevation, $x_2 - x_1$, was estimated from onsite

measurements and the barometric pressure was obtained from weather records.

2.5 Outline of Computer Program

The theory and mathematical algorithms discussed above 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 executive program is shown by Figure 2.3 and a listing of the computer program is presented as Appendix A.

The computer program was set up to either operate in a verification mode based on actually recorded input ventilating air conditions or a simulation mode based on U.S. Weather Service type information. This being the case, the first step of the model determined the mode and number of days to be simulated from input data.

The first operation for starting the simulation of daily drying was to initialize or numerically define the fixed parameters. This was followed by determining the appropriate psychrometric values for the outside air at one-hour intervals for the specific day. The coldest outside temperature at which the inside predetermined temperature can be maintained was then determined. Next, the simulation determined the daily amount of excreta produced. With these data available the simulation started the iterative process and determined the amount of excreta produced up to the time of the specific iteration. The next step was to specify whether it was



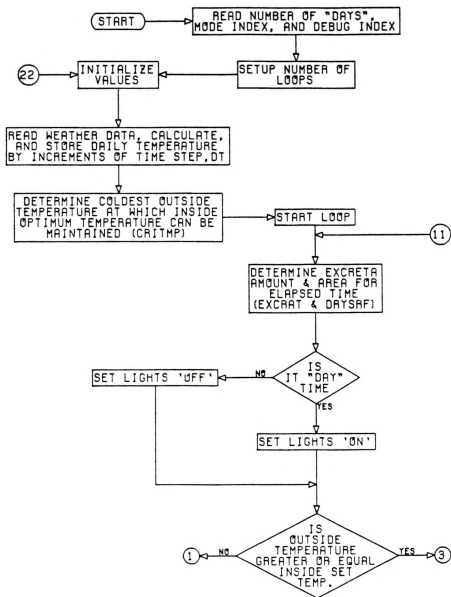


Figure 2.3. Flow chart of computer program.

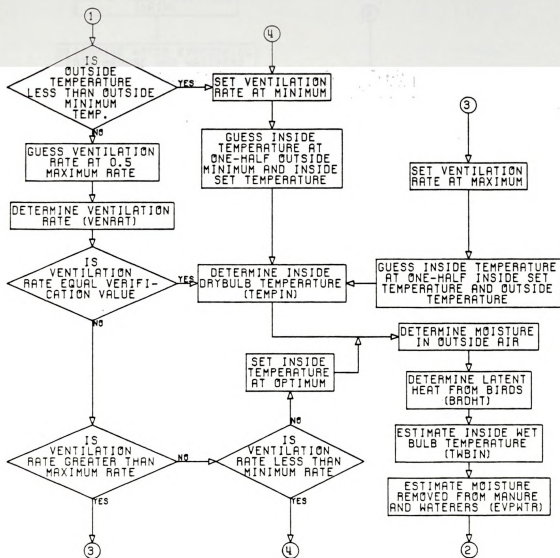


Figure 2.3. Cont'd.

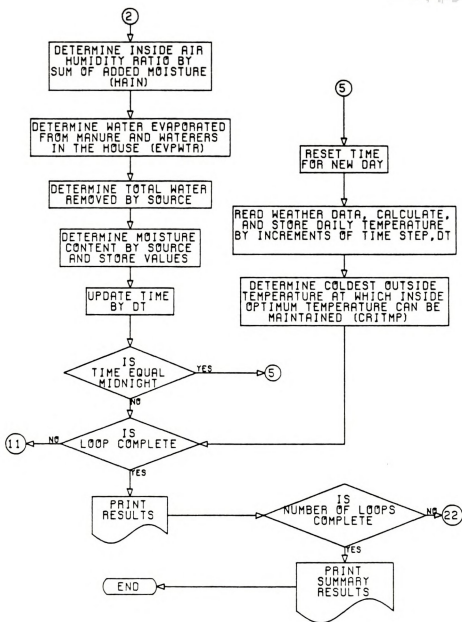


Figure 2.3. Cont'd.

"daytime" (lights on) or "night time" (lights off) for the specific iteration so the correct metabolic and mechanical heat production would be determined.

These operations were followed by two questions of logic involving the outside dry-bulb temperature. With the first the outside dry-bulb was compared with the pre-determined inside temperature. If the outside temperature was higher, an inside higher temperature was calculated. If the outside temperature was lower, a second question of logic determined if the outside temperature was less than the previously calculated outside minimum temperature. When the outside temperature was less than this minimum, a lower inside temperature was calculated. When the outside temperature was between these values, the inside temperature was set at a pre-determined value. Each of these branches in the simulation required a different calculation sequence.

Maintaining the pre-determined inside temperature was done by varying the ventilating rate. This rate was determined for each iteration. An initial guess ventilating rate was made and the calculated rate was determined by the Newtonian convergence procedure.

When the outside temperature was higher than the pre-determined value (summer conditions) the ventilating rate was set at its maximum and the inside temperature was determined. Again the Newtonian convergence technique was used. This required an initial guess for the inside temperature with subsequent determination of the inside temperature.

When the outside temperature was less than the coldest outside temperature which will allow maintenance of the pre-determined inside temperature, the ventilating rate was set at its minimum value. With this ventilating rate (winter conditions) the inside temperature was determined using the same technique as for summer conditions.

With the appropriate inside temperature and ventilating rate, the drying rate was calculated and subsequently the quantity of water evaporated from the manure and waterers for the specific iteration was determined. These values were added to like quantities from previous iterations. The moisture content of the manure at the end of the iteration was calculated also at this time in the simulation sequence. The last regular step of the iterative sequence was to file or store the results of the calculations.

At the end of the iteration the time was checked. If it was midnight, weather data for the next day were read and psychrometric data for the outside air were calculated for the new day. If appropriate, the process was repeated for the next iteration. When the iterative process was complete, results from the moisture content and water removed calculations were printed in tabular form.

3. MODEL VERIFICATION

The model was verified by operating a commercial-type cage laying house from October, 1973, through January, 1975. At various times throughout this period psychrometric data were collected for analysis. The principal data collected were dry-bulb and wet-bulb temperature and the ventilating air-flow rate. Data were collected to make a moisture balance of the ventilating air flowing through the poultry house. The moisture added to the air in the poultry house section of the building was partitioned into respired moisture and moisture added from drying. The moisture from drying was calculated as the difference between the moisture added and respired moisture. As noted earlier, the respired moisture from the chickens can be calculated from the equation:

$$M_r = Q_1/h_1$$

and the latent heat output, Q_1 , from chickens can be found from data by Ota and McNalley (1961). These data (see Table 2.2) were used in conjunction with the latent heat of vaporization, h_1 , to calculate the respired moisture, M_r .

The moisture from drying came from two sources: drying of the manure and evaporation from waterers. Calculations of moisture removed based on psychrometric data were made from data collected every 30 minutes. The purpose of the psychrometric data collection and analysis was to determine the moisture in the ventilation air as

it passed selected locations in the poultry house during a 30-minute period. The moisture added to the air while passing between these locations during the 30-minute period was then calculated by difference.

For verification the water removed from the poultry house as determined from the collected data and as determined by the simulation model were compared.

3.1 Experimental Facilities and Equipment

The floor plan of the experimental facilities is illustrated by Figure 2.2. The operation of the experimental facilities was the same as described earlier.

All temperature and air velocity data were collected with an instrument manufactured by Information Instruments, Inc. The temperatures were measured with thermister sensors; one dry and one with a cotton wick kept wet with distilled water from a continuous source. The air velocity was measured with revolving, 3-cup anemometers. The results of these measurements were transferred electrically to a central point and recorded on paper tape. The equipment was programmed to collect data for about 3 minutes two times each hour, resulting in 5 to 7 data records every 30 minutes of operation. The instrument was designed to record temperatures in degrees Celsius. Since some temperatures for outside air were expected to be below 0°C and the paper tape had no provisions for recording minus temperatures, the instrument was calibrated with an off-set of about 28°C. A special circuit was built to give consistently the electrical

equivalent of 0°C. This circuit was connected to one of the temperature stations and served the following three functions: (1) a defined source for the offset when processing the data, (2) a compensator for minor electrical variations within the instrument, and (3) a known temperature source for checking the equipment during operation.

Raw data from the paper tape were processed and placed on a magnetic tape stored at the Michigan State University Computer Center (Tape No. LTT 5319). The stored data consisted of: (a) clock time of acquisition data, (b) temperature data, (c) anemometer counts for air velocity, and (d) a range factor for the velocity counts. The equipment was capable of measuring the temperature at 60 locations and the air velocity at 8 locations during a 30-second cycle. There were 71 pieces of data stored on the tape for each time designation but only 3 velocity count locations and 12 temperature locations were needed for this study. The date of data acquisition was identified by reference to a name assigned to each file of paper-tape data placed on the magnetic tape. A hard copy listing of the data was made immediately after the data were stored on the magnetic tape. The paper tapes were stored as a back-up data source.

The quantity of ventilating air passing through the poultry building during a 30-minute data-collecting cycle was determined by calibrating the poultry-house ventilating system against the velocity count readings obtained from the recording equipment. The calibration was made by using a hot-wire anemometer to measure the air velocity at 64 locations in the drying tunnel just before the

ventilating air entered the exhaust fans. The velocity measuring procedure followed that recommended by the ASHRAE Guide and Data Book (1965). When making the calibration, one of the five ventilating fans was operated while all other fans were inoperative. During this period the recording velocity-count equipment was operated and the velocity was measured with the hot-wire anemometer. Six sets (replications) of velocity-count records and hot-wire anemometer data were collected. The beginning time and ending time of each data set were noted so that the velocity-count data and the hot-wire anemometer data could be paired. This process was repeated five times, but each time an additional fan was made operative. The velocity-count data collected during the time required to collect the hot-wire anemometer data were averaged and paired with the average velocity as found by the hot-wire anemometer. The final result was five pairs of data with six replications. A linear regression analysis was made of these data pairs. The resulting equation was

$$Y = 54.4838 + 0.2569x,$$

where Y = ventilating air velocity, feet/min, and

x = number of counts as recorded on the paper tape.

Not all of the ventilating air passed by the hot-wire anemometer location because of a clearance hole around the manure removal conveyor. This was accounted for by making a separate calibration. The hole was divided into five representative parts. Each part was measured and its area calculated. The procedure of replications, fan activation, and recording equipment operation was repeated but

only one hot-wire anemometer reading was taken for each area. This reading was multiplied by the respective area, resulting in a flow rate with units of cubic feet per minute. This flow rate was paired to an average of the velocity counts as before. These data pairs were analyzed by a linear regression analysis, which resulted in the equation

$$y = 229.467 + 1.059x$$

where y = flow rate of ventilating air through hole, cfm, and

x = (as previously defined).

3.2 Experimental Procedure

3.2.1 Psychrometric Data Collection and Analysis

Psychrometric data were collected by measuring representative dry-bulb and wet-bulb temperatures of the ventilating air at various locations in the poultry building. These locations are designated on the floor plan in Figure 2.2 as I1, I2, I3 for the incoming air, and O1, O2, and O3 for outgoing air from the laying house. The ventilating air velocity measurements were made at locations O1, O2, and O3. The analysis was based on the premise that all drying was done with the ventilating air. It was also assumed that the difference in total added moisture in the ventilating air between any two measuring locations was added from one or more of the following sources: (a) drying of the manure, (b) respiration from the chickens, and (c) evaporation from the watering troughs. Other sources were assumed negligible. In cases of water spillage from the waterers

or other sources, the collected data were discarded from the analysis. A further assumption was that the data collected at the end of a 30-minute period were representative of the conditions during that period.

The difference in total moisture in ventilating air between two locations expressed as an equation is

$$P_a = P_i - P_j,$$

where P_a = the moisture added to the ventilating air during movement from location j to location i , lbs., and P_i, P_j = moisture in ventilating air at location i and j , respectively, lbs.

The equation for the flow rate of moisture in ventilating air was given by Esmay (1969) and modified to read

$$M_i = M_a W_i,$$

where M_i = the moisture flow rate at location i , lbs. of moisture/hr,

M_a = mass flow rate, lbs of air/hr, and

W_i = the humidity ratio of the air at location i , lbs moisture/lb of dry air.

The results of this equation were multiplied by a lapsed time to yield the total moisture in pounds, i.e.,

$$P_i = M \theta$$

where θ = lapsed time, hours, and

P_i and M_i = (as previously defined).

The collected data were used to estimate the true values of W_i, M_a , and θ . The humidity ratio, W_i , was calculated from algorithms

prepared by Bakker-Arkema and Lerew (1972) using the dry-bulb and wet-bulb temperature data. The processing of these temperature and velocity-count data was done by a computer program prepared for that purpose. Data gathered during a specific 24-hour or longer testing period were treated the same by the program. Minor adjustments in station number designations were sometimes required when processing data from different testing periods because of malfunctions of the temperature-measuring equipment. A data record (71 pieces of data) was read from the magnetic tape and, when appropriate, the clock time set equal to variables defined as the time for data immediately preceding data being processed, the first time reading of the calendar day, and the time of the beginning of the 30-minute programmed cycle of data collection. The readings from those stations recording dry-bulb and wet-bulb temperatures and velocities were combined with another instrument reading cycle and averaged by summing and counting each individual reading. The two instrument recording cycles were combined into one 60-minute calculating cycle by processing only the hour and ignoring the minute portion of the time record. Only those readings not equal to zero were summed and counted. The results of this process yielded an arithmetic average of the readings taken at a specific location during a one-hour cycle. The readings for the electrically preset offset temperature were processed in a like manner. If during data collection or upon reviewing the collected data an equipment malfunction of one of the data-collection stations was observed, the data from that station were set equal to zero. The effect was to eliminate those data

from consideration. The temperature data were collected as paired data; e.g., at Station I1 there was a dry-bulb temperature and a wet-bulb temperature, at Station I2 the same things, etc. These averaged data pairs were checked for the larger value and interchanged if the "wet-bulb" was larger than the "dry-bulb." This switch was necessary to accommodate the idiosyncrasies of the psychrometric algorithms and the data-collecting equipment. In theory the two temperatures can be equal, but the wet-bulb temperature cannot be larger than the dry-bulb temperature. During freezing weather no true wet-bulb temperature of the incoming air was recorded because the water supply would freeze and damage the equipment. Since under freezing conditions the humidity ratio is very low even at 100 percent relative humidity, saturated incoming air was assumed by allowing the dry-bulb and wet-bulb temperatures to be equal. The electronics of the equipment was not precise enough, however, to signal exactly the same temperature to within one-tenth of a degree. The result was that the recorded wet-bulb temperature was sometimes slightly larger than the dry-bulb temperature. After the comparison check and switch, if needed, the dry-bulb temperatures and the wet-bulb temperatures of each location were averaged; i.e., the dry-bulb temperatures at locations I1, I2, and I3 were averaged and the wet-bulb temperatures at locations I1, I2, and I3 were averaged, etc. The result was one dry-bulb and one wet-bulb temperature to represent 10 to 14 readings in the ventilating air stream taken simultaneously at three locations over two time periods of about 3 minutes.



The algorithm for calculation of psychrometric data was prepared for use with American Engineering Units. Because of this, all calculations were made with these units. Since the temperature data were collected in metric units, they were converted to degrees Fahrenheit and degrees Rankine after the offset factor was subtracted from the averaged number representing temperature. The dry-bulb and wet-bulb temperatures, expressed in degrees Rankine, were combined with U.S. Weather Service data for the barometric pressure at East Lansing, Michigan, to determine the humidity ratio of the ventilating air.

The value for the velocity-count, x , for use in the two equations derived by linear regression analysis was obtained by averaging the velocity-count data collected at locations 01, 02, and 03. The processing of the velocity-count data was carried out simultaneously with and similarly to the processing of the temperature data; i.e., the 10 to 14 readings at each location were averaged, then the averages from the three locations were averaged. The result was one arithmetic average velocity-count for those data collected during the one-hour calculating cycle.

The flow rate of the ventilating air through the poultry house for each one-hour cycle was calculated from the equation

$$q = AY + y$$

where q = poultry house air-flow rate, cfm,

A = cross-sectional area of the drying tunnel, sq ft,

and

Y and y = (as previously defined).

To obtain the mass-flow rate, M_a , the volume-flow rate, q , was multiplied by 60 minutes per hour and divided by the specific volume of the ventilation air as calculated from the outgoing dry-bulb and wet-bulb temperatures, i.e.,

$$M_a = 60q/v,$$

where v = specific volume of ventilating air, cu ft/lb,

and

M_a and q = (as previously defined).

The computer program calculated the lapsed time from recorded data thus:

$$\theta = t_m - t_k$$

where t_m = clock time at the end of the currently processed data cycle, hours, and

t_k = clock time at the end of the previously processed data cycle, hours.

For the specific poultry house the area, A , was equal to 49.5 square feet. Combining this area with the above analysis into one function and rounding to 5 significant figures yields

$$P_A = (t_m - t_k)(W_i - W_j)(1/v)(826.53x + 175,580.),$$

where all variables have been previously defined.

This function expresses the moisture added to the ventilating air in terms of the recorded data and psychrometric terms calculated from recorded data.

3.2.2 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 ultimate performance variable to compare was the evaporation from manure during the test day. Another performance variable was the total moisture removed from the poultry house during the test day and a third performance variable was the evaporation from the poultry house during one specific hour of a test day. Of these the total moisture removed from the poultry house during the test day was determined with the least amount of intermediate calculation from the collected data. As a result it was used extensively in the initial verification comparisons.

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 input values and immediately calculated values. All of the comparisons were made graphically by using appropriate peripheral equipment in connection with the computer. The effect of this capability was that appropriate calculated data from the verification measurements could be combined with comparable calculations from the simulation model and plotted to form a graph for review.

The principal input variables for the model were dry-bulb temperature and dewpoint temperature. Other input variables were considered constant for a specific day. Intermediate values of interest were: humidity ratio of incoming air, dry-bulb temperature

of out-going air, dewpoint temperature of out-going air, humidity ratio of out-going air, incoming and out-going humidity ratio difference, and air flow through the poultry house. Examples of comparison graphs for each of these variables versus time are presented in Appendix B. The values calculated for each of the intermediate variables helped evaluate errors in the simulation model. After operating the simulation model and comparing the graphical results, adjustments were made in the model. Following the adjustments it was operated again and compared. This process was continued many times. Each time it was necessary to make comparison graphs for most, if not all validation test days. As noted above, the principal basis of performance evaluation was the graph of total moisture removed from the poultry house during the test day. (See Figure 3.1 for an example.)

The evaporation from manure during the test day for the verification data was calculated by difference. As explained earlier, the psychrometric data and the air flow measurements provided the information to calculate the amount of moisture added to the air as it passed through the poultry house. The results of these calculations provided the total moisture added to the ventilating air. Since the sources of added moisture were the moisture from drying manure, the surface of the waterers, and the respiration from the hens, the moisture from the drying manure could be calculated as the difference from the total added moisture and the other two sources. The estimates used for the moisture from the waterers and from hen respiration were as calculated from the evaporation equation

(section 2.4.10) and the respiration equation (section 2.4.8), respectively. The calculated value for the moisture from the drying manure was further modified by uniformly distributing the error between the verification data and the simulation data among the three sources of added moisture. This modified value was used to prepare the "data" line on the graphs of evaporation from manure during the day. (See Figure 3.2 for an example.)

The simulation model performance acceptability was a qualitative judgment based upon how well the curve of a specific variable versus time matched the shape of the verification (collected data) curve. The individually paired data point values were also considered in the performance acceptability evaluation.

3.3 Verification Results

3.3.1 Summer Conditions

Data collected during three summer days were suitable for use as verification data. These data were obtained August 12, 13, and 20, 1974. For each of the three days, performance variable graphs were prepared. The graphs, prepared with the simulation model in its acceptable form, are presented as Figures 3.1, 3.2, 3.3, 3.4, 3.5, and 3.6. Simultaneously a tabulated graph was made of management factor, design, and input values used in the simulation. These tabulations are presented in Appendix C.

3.3.2 Winter Conditions

Data collected during two winter days were suitable for use as verification data. These data were obtained January 6 and 7, 1975.

As with the summer data, performance variable graphs were prepared. Similarly, tabulations were made of management factor, design, and input values used during the simulation. The graphs are presented as Figures 3.7, 3.8, 3.9, and 3.10. The tabulations are in Appendix C.

It should be pointed out that certain winter condition adjustments were required of the simulation model to accommodate a unique situation of the experimental poultry house. When operating the mechanical dryer it was found necessary to have at least one of the main ventilating fans in operation to prevent combustion gases from entering the laying hen portion of the poultry house. As a result, the minimum ventilating rate in the simulation model was increased to include this effect during the time of mechanical drying on the appropriate verification test dates. This was done by adjusting the minimum ventilating rate to that actually measured on the verification test date.

3.4 Discussion of Verification

A review of the graphs showing the accumulated total moisture removed from the poultry house during the day, i.e., Figures 3.1, 3.3, 3.5, 3.7, and 3.9, showed that the "data" curves and the "simulation" curves followed very closely their respective data points. A comparison of the paired curves also showed the general shape of the curves to be similar. It was noted, however, that the curve shapes were better matched for the summer data than the winter data. When comparing the departure of the paired curves it was noted that the

curves for the date August 13, 1974, had the greatest deviation for the summer data and that for January 6, 1975, for the winter data. For August 13, 1974, the largest deviation occurred at the twenty-fourth hour of the day, i.e., when the ordinate values were the largest and thus the accumulated error was the largest. As noted from Table 3.1, the numerical difference of the plotted data points was 282.09 (2977.10-2695.01) pounds of moisture. For January 6, 1975, the largest difference occurred at the fourteenth hour and was 420.87 (1035.19-614.32) pounds of moisture. With the "data" value as the base, the errors for the two extreme values were 9.5 and 68.5 percent, respectively. There is no known explanation for the large deviation in the January 6, 1975, graph. The only known different management practice on that date was that the mechanical dryer did not operate. Some of the difference might be attributed to measurement error, however.

A review of the graphs showing the evaporation from manure during the day, i.e., Figures 3.2, 3.4, 3.6, 3.8, and 3.10, showed that the "data" and the "simulation" curves followed very closely their respective data points with the possible exception of the "data" curve for January 6, 1975. For this graph there was considerable variation between the plotted points and the curvilinear regression curve. When comparing the paired curves, it was noted that each pair involving the summer data was more nearly the same shape than those of the winter data. Some of this difference in appearance can be explained by noting that the scaled length for the ordinate of the winter data was less than one-half the scaled length

of that for the summer data. It was also noted that the paired curves for the data of January 6, 1975, were not well matched.

Although no reason for this discrepancy was found, it was noted that the data points for the "data" curve for this date seemed more random than all other curves.

Some of the difference in the paired verification curves might be attributed to measurement error. Several factors are involved with measurement error including accuracy, sensitivity, response time, and readability. For the most part, the magnitude of these factors is limited by the specific measuring equipment. Accuracy can be checked by a calibration procedure and can often be adjusted as was the case for the equipment used for this study. The specific measurements made in this study were dry-bulb temperature, wet-bulb temperature, and air speed. The measurement of each contributed to measurement error but this discussion has been limited to the readability of the dry-bulb and wet-bulb temperatures and their effects upon the "data" quantity graphed in Figures 3.1, 3.3, 3.5, 3.7, and 3.9. This quantity is the total moisture removed from the poultry house.

The readability of temperature was limited by the paper tape recording equipment to the equivalent of 1.8°F . Information appropriate for January 7, 1975, was selected to illustrate the extreme effects of an error of one readability unit, i.e., 1.8°F , upon the graphed "data" quantity. For that date the average inside air temperatures were 55.80°F dry-bulb and 50.47°F wet-bulb. The average

incoming air temperatures were 37.00°F dry-bulb and 35.98°F wet-bulb. Also for that date the average ventilating rate was 8388 cubic feet per minute. If the readability error potential is added to or subtracted from these average temperatures to give inside temperatures of 55.62°F dry-bulb and 50.68°F wet-bulb and incoming temperatures of 37.18°F dry-bulb and 35.82°F wet-bulb, the humidity ratio change was the largest possible. For the smallest humidity ratio the dry-bulb and wet-bulb temperatures were 55.98, 50.32, 36.82, and 36.12°F, respectively. For a one-hour period at the average ventilating rate and the large humidity ratio difference, the total moisture added to the air would be 105.7 pounds. For the low humidity ratio difference the total moisture added to the air would be 84.9 pounds per hour. The difference between these two values, 20.8 pounds per hour, can be called the average range of readability effect upon the total moisture removed from the poultry house. The "data" quantity graphed in Figure 3.10, however, accumulates over a 24-hour time period. For the extreme case the readability error would also accumulate over the 24-hour period and be equal to 501.2 pounds of moisture. Table 3.1 shows the difference between the collected data and the simulation model on January 7, 1975, to be 274.7 (1983.50-1708.83) pounds after 24 hours. This is less than 501.2 pounds. Calculations for the data collected on the other dates showed similar relationships. This indicated that the "simulation" quantity graphed by the figures fell within the envelope formed by measurement error variation.

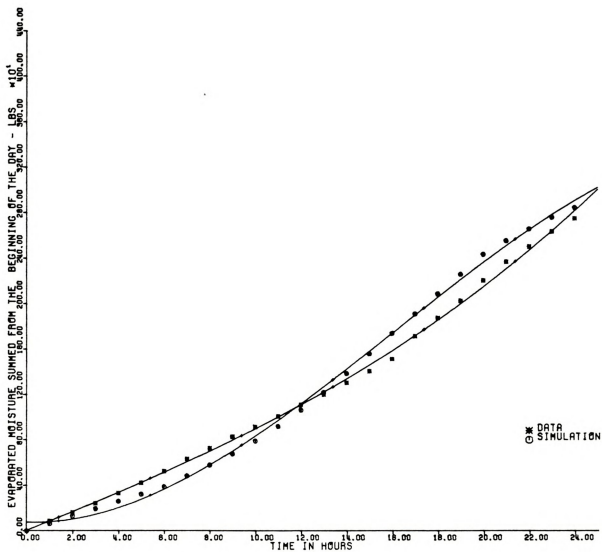


Figure 3.1. Accumulated total moisture removed from the poultry house during the day of August 12, 1974. The two curves result from curvilinear regression calculations based on the two separate sets of data.

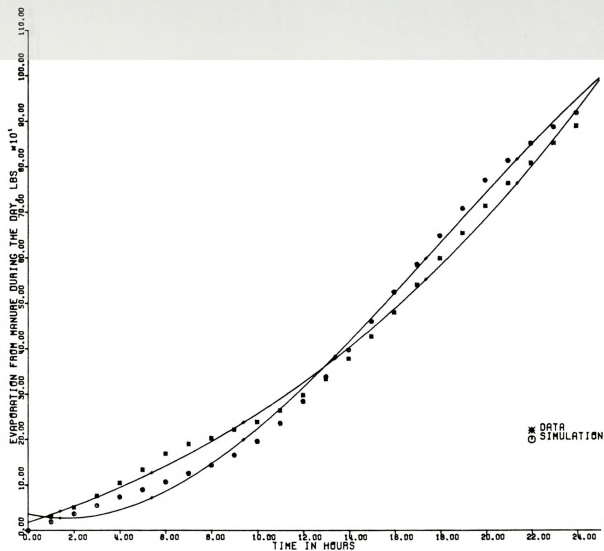


Figure 3.2. Accumulated moisture evaporated from the manure in the poultry house during the day of August 12, 1974. The two curves result from curvilinear regression calculations based on the two separate sets of data.

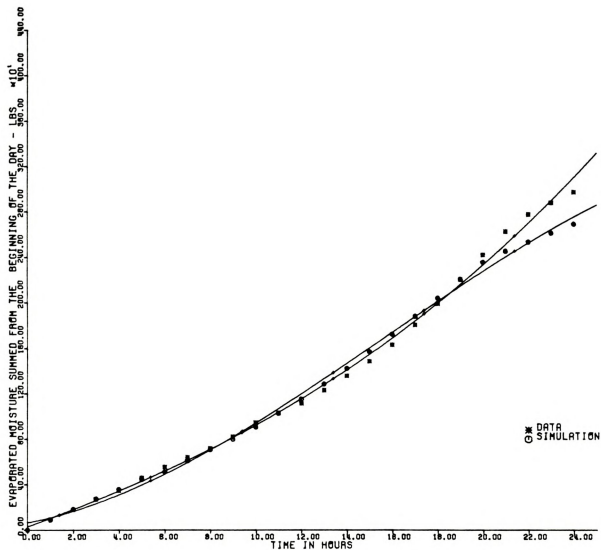


Figure 3.3. Accumulated total moisture removed from the poultry house during the day of August 13, 1974. The two curves result from curvilinear regression calculations based on the two separate sets of data.



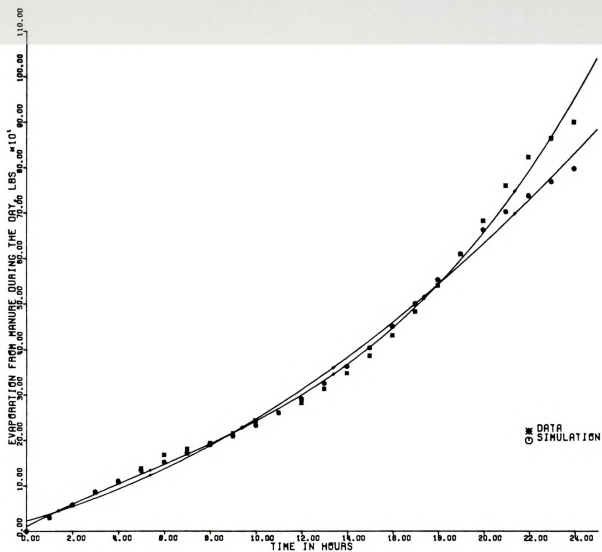


Figure 3.4. Accumulated moisture evaporated from the manure in the poultry house during the day of August 13, 1974. The two curves result from curvilinear regression calculations based on the two separate sets of data.

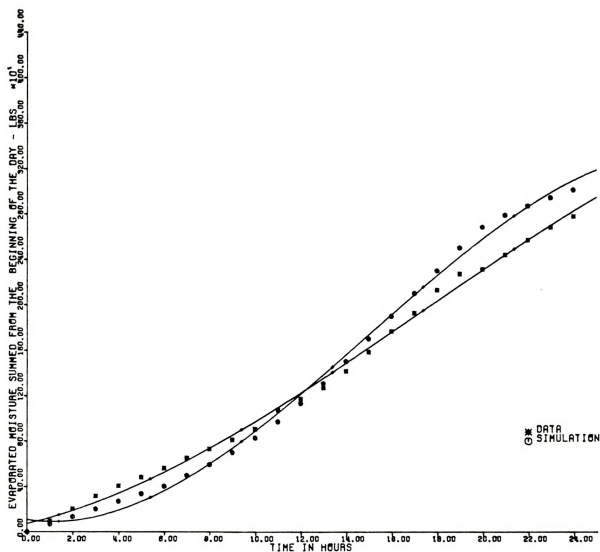


Figure 3.5. Accumulated total moisture removed from the poultry house during the day of August 20, 1974. The two curves result from the curvilinear regression calculations based on the two separate sets of data.

The first part of the paper discusses the importance of understanding the local context in which a project is implemented. This includes a thorough analysis of the social, cultural, and economic factors that may influence the success or failure of the intervention. The second part of the paper describes the methodology used in the study, which involved a combination of qualitative and quantitative data collection methods. The third part of the paper presents the findings of the study, which show that the intervention had a positive impact on the target population. The final part of the paper discusses the implications of the findings for future research and practice.

The study was conducted in a rural area of a developing country, where the majority of the population is engaged in agriculture. The intervention was designed to improve the livelihoods of the target population by providing them with access to credit and technical assistance. The results of the study show that the intervention was successful in achieving its objectives, and that the target population was able to improve their living standards as a result of the intervention.

The findings of the study have important implications for the design and implementation of similar interventions in other rural areas. First, it is important to understand the local context in which the intervention is being implemented. This includes a thorough analysis of the social, cultural, and economic factors that may influence the success or failure of the intervention. Second, it is important to use a combination of qualitative and quantitative data collection methods to gather information about the target population. Finally, it is important to monitor the progress of the intervention and to make adjustments as needed to ensure that it is achieving its objectives.

In conclusion, the study shows that the intervention had a positive impact on the target population, and that the target population was able to improve their living standards as a result of the intervention. The findings of the study have important implications for the design and implementation of similar interventions in other rural areas.

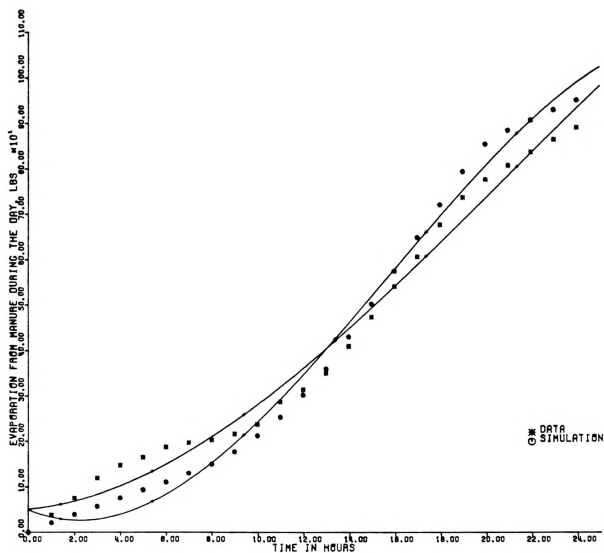


Figure 3.6. Accumulated moisture evaporated from the manure in the poultry house during the day of August 20, 1974. The two curves result from curvilinear regression calculations based on the two separate sets of data.

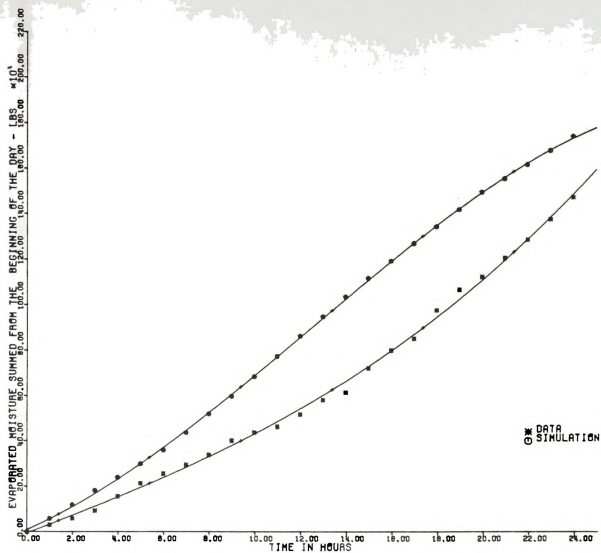


Figure 3.7. Accumulated total moisture removed from the poultry house during the day of January 6, 1975. The two curves result from curvilinear regression calculations based on the two separate sets of data.

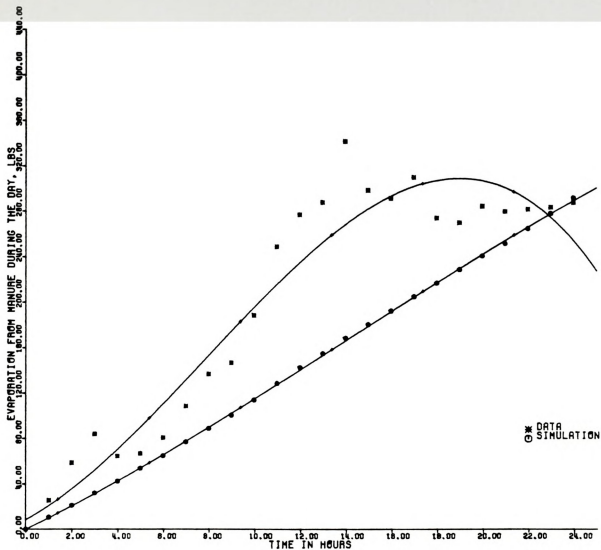


Figure 3.8. Accumulated moisture evaporated from the manure in the poultry house during the day of January 6, 1975. The two curves result from curvilinear regression calculations based on the two separate sets of data.

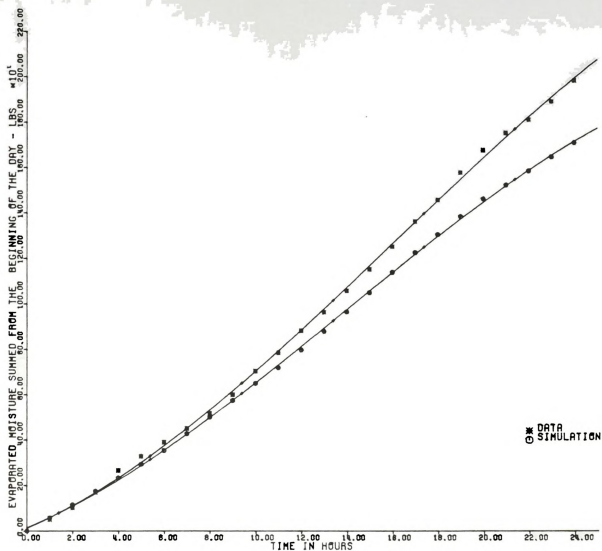


Figure 3.9. Accumulated total moisture removed from the poultry house during the day of January 7, 1975. The two curves result from curvilinear regression calculations based on the two separate sets of data.



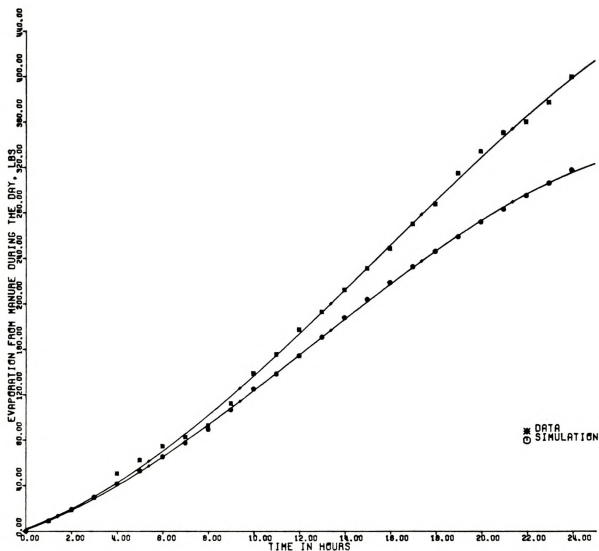


Figure 3.10. Accumulated moisture evaporated from the manure in the poultry house during the day of January 7, 1975. The two curves result from curvilinear regression calculations based on the two separate sets of data.



Table 3.1. Accumulated total pounds of moisture removed from the poultry house. A comparison of collected data versus simulation model calculations.

CLOCK TIME, HOURS	8/12/74			8/13/74			8/20/74			1/6/75			1/17/75		
	COL. DATA	SIM. MODEL		COL. DATA	SIM. MODEL		COL. DATA	SIM. MODEL		COL. DATA	SIM. MODEL		COL. DATA	SIM. MODEL	
0	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
1	88.28	64.33		91.57	89.34		101.51	68.79		31.12	58.66		49.19	56.90	
2	162.91	129.95		177.60	181.95		204.03	135.64		59.95	119.10		101.10	114.78	
3	244.91	195.50		267.95	272.18		316.94	202.15		93.74	181.42		169.15	173.62	
4	332.23	260.88		346.14	356.69		407.67	289.93		156.26	239.98		266.13	233.08	
5	422.23	324.24		456.16	442.56		482.07	337.26		213.66	299.53		328.00	292.80	
6	523.44	388.65		554.87	509.44		563.15	403.11		256.76	360.94		389.35	353.62	
7	632.98	483.92		638.47	606.78		652.28	498.96		295.53	438.07		450.25	427.17	
8	726.37	578.45		719.46	704.37		730.49	595.52		340.13	520.05		517.44	500.43	
9	825.94	677.51		821.77	800.31		811.56	701.47		402.36	598.04		599.87	574.23	
10	912.70	790.07		943.32	906.49		905.04	828.74		438.17	684.52		703.56	649.56	
11	1006.91	919.61		1028.84	1026.40		1074.27	972.00		464.43	773.60		784.56	718.88	
12	1109.38	1063.34		1111.83	1153.62		1173.19	1132.56		517.32	861.72		881.86	796.83	
13	1200.00	1219.48		1230.39	1285.03		1271.61	1309.69		581.66	947.89		962.77	878.70	
14	1305.29	1386.49		1356.28	1423.85		1419.69	1503.36		614.32	1035.19		1057.15	964.49	
15	1407.63	1560.38		1487.56	1570.40		1582.16	1703.32		721.35	1117.16		1151.76	1049.09	
16	1514.06	1741.14		1634.38	1726.07		1766.97	1903.28		799.42	1193.11		1251.44	1138.70	
17	1715.04	1910.79		1808.21	1882.25		1930.28	2104.30		851.10	1269.79		1362.20	1224.44	
18	1875.27	2088.43		1992.28	2043.30		2133.15	2304.24		976.56	1345.03		1457.34	1304.74	
19	2028.14	2259.54		2205.67	2207.65		2275.65	2505.98		1066.53	1419.85		1578.78	1384.16	
20	2205.76	2435.69		2424.74	2358.01		2316.42	2688.64		1123.11	1496.24		1676.52	1462.19	
21	2367.64	2554.87		2628.57	2455.62		2441.05	2793.69		1206.61	1555.41		1753.51	1523.73	
22	2502.12	2659.86		2780.53	2538.29		2573.67	2873.69		1385.52	1617.25		1811.06	1585.43	
23	2635.71	2760.57		2883.57	2617.09		2685.34	2948.40		1375.58	1679.10		1891.36	1647.00	
24	2750.07	2847.24		2977.10	2695.01		2782.39	3016.48		1472.84	1741.73		1983.50	1708.83	



Table 3.2. Accumulated pounds of moisture evaporated from the manure in poultry house. A comparison of collected data versus simulation model calculations.

CLOCK TIME, HOURS	8/12/74			8/13/74			8/20/74			1/6/75			1/7/75		
	COL. DATA	SIM. MODEL		COL. DATA	SIM. MODEL		COL. DATA	SIM. MODEL		COL. DATA	SIM. MODEL		COL. DATA	SIM. MODEL	
0	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
1	30.63	18.98		30.09	29.32		38.32	21.00		25.60	10.68		8.92	9.14	
2	50.64	36.57		56.50	57.81		75.30	39.23		58.64	21.13		18.34	19.07	
3	75.82	54.80		84.66	85.95		119.23	57.01		84.08	31.98		29.38	30.06	
4	104.38	73.31		106.76	109.78		147.52	75.48		64.57	42.46		50.77	41.51	
5	133.00	89.49		137.55	133.17		164.81	93.29		66.82	53.81		62.55	53.08	
6	168.43	106.34		167.67	151.54		187.22	110.37		80.78	64.81		74.77	65.48	
7	189.74	125.16		181.38	171.30		196.79	130.16		108.68	77.13		82.77	77.61	
8	202.32	143.06		194.28	189.98		202.83	150.15		137.04	88.93		93.22	89.71	
9	221.55	165.19		215.07	209.05		215.85	176.92		146.88	100.68		112.60	106.93	
10	238.45	195.68		242.97	232.46		236.53	212.21		188.47	114.14		139.04	125.28	
11	263.94	235.92		260.54	259.92		286.93	253.10		248.79	128.56		155.82	138.71	
12	297.88	284.18		281.98	291.36		314.04	302.17		276.96	142.63		177.79	156.68	
13	333.00	338.17		313.06	325.07		350.46	360.10		287.95	154.86		193.31	171.03	
14	377.90	397.58		348.09	362.80		409.49	429.89		341.36	168.38		212.82	188.20	
15	426.56	459.89		386.13	404.02		474.12	502.39		298.62	180.44		231.70	204.33	
16	479.85	524.40		431.18	451.36		541.16	575.00		291.47	192.29		249.17	219.26	
17	540.53	584.95		483.39	500.87		606.34	649.18		310.10	204.95		270.65	235.14	
18	598.94	648.42		540.82	553.69		677.44	721.59		274.15	217.00		288.22	246.44	
19	654.10	708.54		610.08	610.63		737.65	794.78		270.10	228.87		315.35	259.38	
20	714.27	770.63		683.65	663.55		777.62	855.23		284.77	240.81		334.57	272.35	
21	764.15	813.69		760.88	703.23		808.63	885.63		279.91	251.79		351.09	283.79	
22	808.00	851.75		823.72	738.29		837.72	908.67		282.04	264.93		360.57	295.63	
23	852.26	888.43		865.02	769.30		865.40	930.81		283.68	278.06		377.75	306.57	
24	890.21	919.26		900.51	798.15		891.99	952.43		287.75	291.90		400.08	318.01	

4. RESULTS FROM MODEL USE

The simulation model was operated four times using average weather data. Each simulation operation was selected to typify the amount of manure-drying that might occur in a poultry house near Lansing, Michigan, during (1) winter conditions, (2) summer conditions, (3) spring conditions, and (4) throughout the year.

The data averaged for the first three simulation operations were the dry-bulb and dewpoint temperatures for the 10-year period 1968 through 1977. Weather for the month of January was used to represent winter conditions, the month of July summer conditions, and the month of April represented spring conditions. Since the model calculates the moisture removed from the manure on a daily basis, a dry-bulb and dewpoint temperature was required for each day of the representative month. The 10-year average for the specific day was used and calculated from National Weather Service data (U.S. Department of Commerce, 1977a). For the calculations representing the manure drying throughout the year, representative weather data in each month of the year were selected. The representative data were the average dry-bulb and dewpoint temperatures for each month of the year as determined by the National Weather Service (U.S. Department of Commerce, 1977b) for Lansing, Michigan.

The results from operating the simulation model are presented graphically with two graphs for each operating condition.



The first graph shows the moisture removed from the manure each day of the month as calculated by the simulation model. The same graph also shows the corresponding dry-bulb and dewpoint temperatures as determined from weather data. The second graph shows the manure moisture content for each day of the month and the same corresponding dry-bulb and dewpoint temperatures. The graphs for January are presented as Figures 4.1 and 4.2, for April as Figures 4.3 and 4.4, and for July as Figures 4.5 and 4.6. Graphs for the year as a whole are presented as Figures 4.7 and 4.8. The same basic pattern was used for the year as a whole graphs as those for the individual months. The data from which the graphs were prepared are presented as Tables 4.1, 4.2, 4.3, and 4.4. Table 4.5 lists the management factor, design, and input values used for operating the simulation model.

A review of the graphs indicated more moisture would be removed from the poultry house and more manure drying would occur during summer months than in other seasons. This seemed reasonable and was expected. When comparing the summer conditions to the winter conditions in the poultry house, there was more ventilating air and the air had a larger potential moisture-holding capacity during the summer. For example, the average ventilating rate at noon as calculated by the simulation model for the month of July was 20,400 cubic feet per minute and for January was 5,410 cubic feet per minute. Similarly, the average potential evaporation of the air for July was 103.7 pounds of water and for January was 74.5 pounds of water. (The potential evaporation was calculated as the difference of the



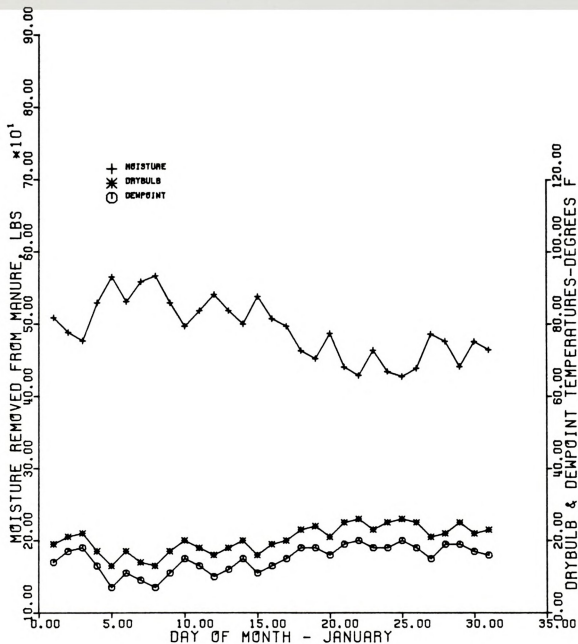


Figure 4.1. The moisture removed from manure during a typical month of January as calculated by the simulation model.



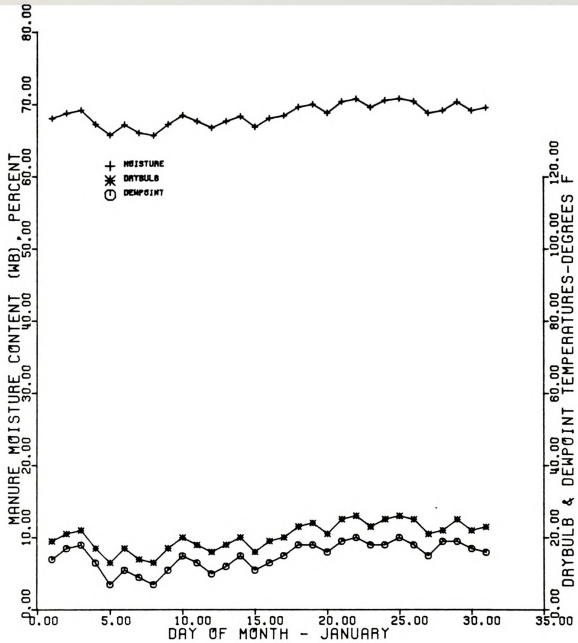


Figure 4.2. The moisture content of manure for a typical month of January as calculated by the simulation model.



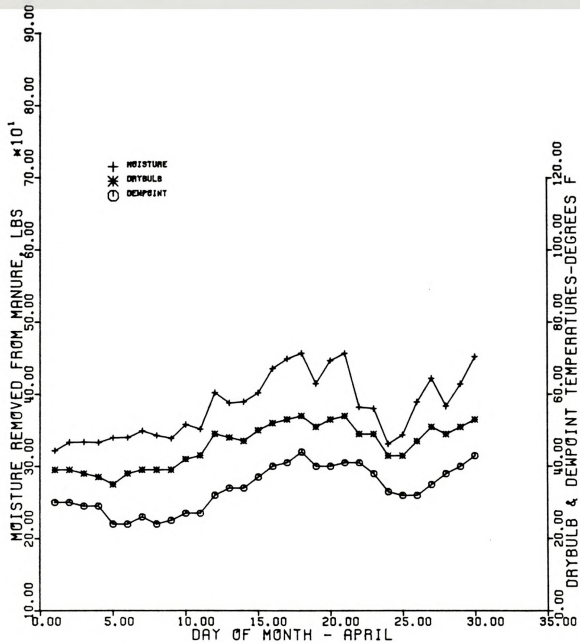


Figure 4.3. The moisture removed from manure during a typical month of April as calculated by the simulation model.



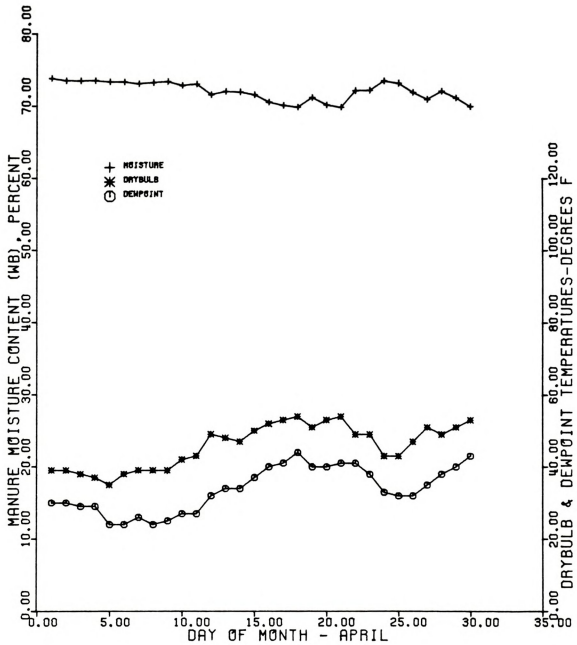


Figure 4.4. The moisture content of manure for a typical month of April as calculated by the simulation model.



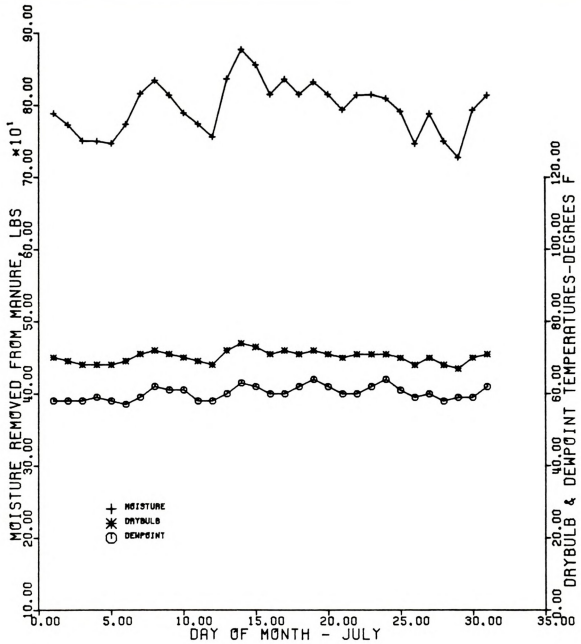


Figure 4.5. The moisture removed from manure during a typical month of July as calculated by the simulation model.



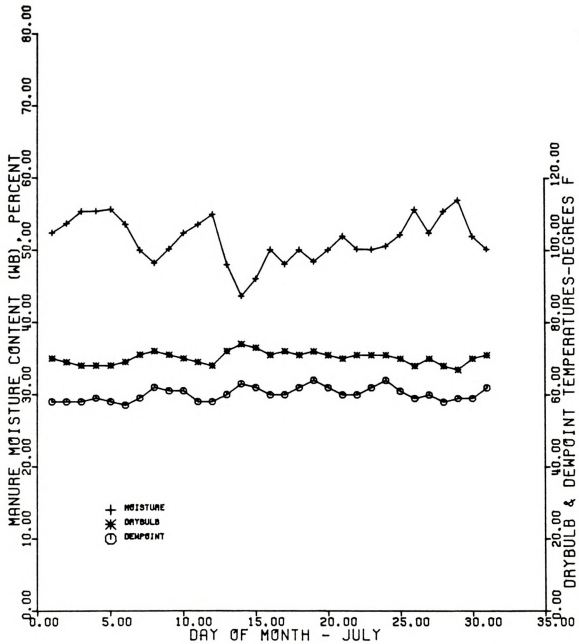


Figure 4.6. The moisture content of manure for a typical month of July as calculated by the simulation model.

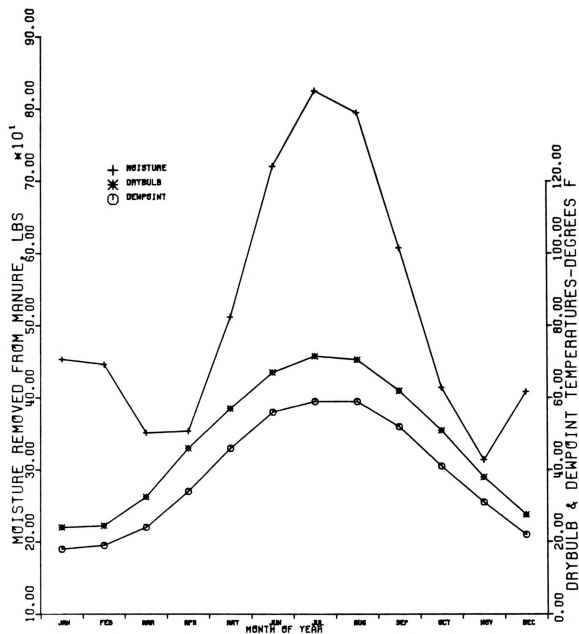


Figure 4.7. Representative daily moisture removal from manure throughout the year as calculated by the simulation model.



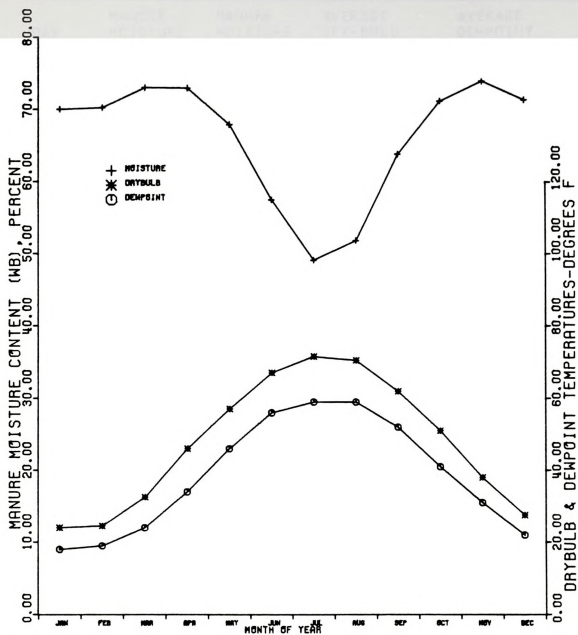


Figure 4.8. Representative daily manure moisture content throughout the year as calculated by the simulation model.



Table 4.1. Manure moisture removed and moisture content for a typical month of January as calculated by the simulation model.

DAY OF MONTH	MANURE MOISTURE REMOVED, POUNDS	MANURE MOISTURE CONTENT, PERCENT	AVERAGE DRY-BULB TEMPERATURE, DEGREES F	AVERAGE DEWPOINT TEMPERATURE, DEGREES F
1	533.4	68.1	19.	14.
2	497.9	68.8	21.	17.
3	476.1	69.2	22.	18.
4	529.1	67.3	17.	13.
5	565.0	65.8	13.	7.
6	530.6	67.2	17.	11.
7	558.4	66.1	14.	9.
8	566.4	65.7	13.	7.
9	529.1	67.3	17.	11.
10	498.4	68.5	20.	15.
11	518.2	67.7	18.	13.
12	540.9	66.8	16.	10.
13	512.4	67.7	18.	12.
14	499.9	68.4	20.	15.
15	539.2	66.9	16.	11.
16	507.3	68.1	19.	13.
17	496.7	68.5	20.	15.
18	462.9	69.7	23.	18.
19	451.9	70.0	24.	18.
20	486.5	68.9	21.	16.
21	440.5	70.4	25.	19.
22	428.8	70.8	26.	20.
23	463.6	69.7	23.	18.
24	434.2	70.6	25.	18.
25	427.1	70.8	26.	20.
26	433.3	70.5	25.	18.
27	406.0	68.9	21.	15.
28	476.0	69.2	22.	19.
29	441.3	70.4	25.	19.
30	475.3	69.2	22.	17.
31	464.5	69.6	23.	16.

Table 4.2. Manure moisture removed and moisture content for a typical month of April as calculated by the simulation model.

DAY OF MONTH	MANURE MOISTURE REMOVED, POUNDS	MANURE MOISTURE CONTENT, PERCENT	AVERAGE DRY-BULB TEMPERATURE, DEGREES F	AVERAGE DEWPOINT TEMPERATURE, DEGREES F
1	321.6	73.6	39.	30.
2	333.1	73.5	39.	30.
3	333.6	73.5	38.	29.
4	332.8	73.5	37.	29.
5	339.4	73.3	35.	24.
6	339.7	73.3	38.	24.
7	349.1	73.1	39.	26.
8	342.6	73.3	39.	24.
9	338.3	73.4	39.	25.
10	357.9	72.9	42.	27.
11	351.5	73.0	43.	27.
12	402.2	71.6	49.	32.
13	388.0	72.0	48.	34.
14	389.6	72.0	47.	34.
15	401.8	71.6	50.	37.
16	435.3	70.6	52.	40.
17	449.1	70.1	53.	41.
18	456.8	69.9	54.	44.
19	414.6	71.2	51.	40.
20	446.6	70.2	53.	40.
21	456.9	69.9	54.	41.
22	382.4	72.2	49.	41.
23	380.5	72.2	49.	38.
24	331.3	73.6	43.	33.
25	343.8	73.2	43.	32.
26	389.5	72.0	47.	32.
27	422.0	71.0	51.	35.
28	383.9	72.1	49.	38.
29	414.5	71.2	51.	40.
30	452.3	70.0	53.	43.

Table 4.3. Manure moisture removed and moisture content for a typical month of July as calculated by the simulation model.

DAY OF MONTH	MANURE MOISTURE REMOVED, POUNDS	MANURE MOISTURE CONTENT, PERCENT	AVERAGE DRY-BULB TEMPERATURE, DEGREES F	AVERAGE DEWPOINT TEMPERATURE, DEGREES F
1	788.3	52.4	70.	58.
2	772.5	53.7	69.	58.
3	750.5	55.4	68.	58.
4	750.0	55.4	68.	59.
5	746.7	55.7	68.	58.
6	773.7	53.6	69.	57.
7	916.1	50.0	71.	59.
8	834.4	49.3	72.	62.
9	813.9	50.2	71.	61.
10	783.9	52.4	70.	61.
11	774.0	53.6	69.	58.
12	756.1	55.0	68.	58.
13	836.6	43.0	72.	60.
14	877.3	43.7	74.	63.
15	855.9	46.0	73.	62.
16	814.9	50.1	71.	60.
17	835.9	48.1	72.	60.
18	815.0	50.1	71.	62.
19	832.3	48.5	72.	64.
20	815.0	50.1	71.	62.
21	793.6	52.0	70.	60.
22	814.0	50.2	71.	60.
23	814.5	50.1	71.	62.
24	809.2	50.6	71.	64.
25	791.3	52.2	70.	61.
26	746.7	55.7	68.	59.
27	788.4	52.4	70.	60.
28	750.0	55.4	68.	58.
29	727.7	57.0	67.	59.
30	793.7	52.0	70.	59.
31	914.0	50.2	71.	62.



Table 4.4. Manure moisture removed and moisture content for a typical year as calculated by the simulation model.

MONTH OF YEAR	MANURE MOISTURE REMOVED, LBS/DAY	MANURE MOISTURE CONTENT, PERCENT	AVERAGE DRY-BULB TEMPERATURE, DEGREES F	AVERAGE DEWPOINT TEMPERATURE, DEGREES F
1	452.8	70.0	24.	18.
2	445.9	70.2	25.	19.
3	351.1	73.0	33.	24.
4	353.6	73.0	46.	34.
5	511.9	67.9	57.	46.
6	720.2	57.5	67.	56.
7	825.4	49.1	72.	59.
8	795.2	51.8	71.	59.
9	607.9	63.8	62.	52.
10	414.4	71.2	51.	41.
11	313.8	74.0	38.	31.
12	408.5	71.4	28.	22.

inside and outside humidity ratios times the ventilating air mass.) Both of these conditions tend to increase moisture removal and manure drying. A high dewpoint temperature would tend to reduce moisture removal and manure drying. Although the dewpoint temperature was high during the summer (see Figures 4.5 and 4.6), it apparently was low enough when combined with other factors, to allow considerable drying in the poultry house according to the simulation model calculations. As a result of this seasonal difference, the simulation model can be expected to calculate manure moisture removal with a seasonal cycle effect. This is in contrast to the situation reported by Esmay et al. (1975). In their presentation they stated the "in-house drying" of poultry manure was not seasonal. However,



their report mentioned four drying phases: in-house drying, movement drying, belt drying, and heated air mechanical drying. The moisture removed from the manure as calculated by the simulation model includes the in-house drying phase and the movement drying phase. Furthermore, the movement drying as reported by Esmay et al. (1975) was influenced by the season of the year. A comparison of the simulation model moisture content calculations for the yearly condition as reported in Figures 4.7 and 4.8 with similar data from Esmay et al. (1975) indicated the simulation model may calculate too much drying, especially during summer conditions.

As the graphs were studied it was noted that the least moisture was removed from the manure and the manure moisture content was highest for the month of April. Although seasonal differences were expected, minimum drying during the spring was not. This difference was found to be more noticeable when the average bird weight was less than the average weight of the birds in the verified system. Since the simulation model has the capability to vary such factors, the difference was emphasized by using a smaller than normal average bird weight as noted by Table 4.5.

At first it was thought the low drying in April was caused by the lower dewpoint temperature and thus the higher potential evaporation of the outside January air. This in itself did not prove to be true. Further study of the simulation model calculations showed that the drying rate in January during the day was about the same as in April but at night the January drying rate was larger



than the April drying rate. For example, the drying rate based on average conditions at noon was 0.0050 pounds of moisture per square foot-hour for January and 0.0051 pounds of moisture per square foot-hour for April. For average conditions at midnight the drying rate for January was 0.0065 pounds of moisture per square foot-hour but only 0.0036 pounds of moisture per square foot-hour for April. The net effect was more drying in January than in April.

Table 4.5. Management factor, design, and input values as used for operating the model with average weather data.

<u>Building</u>	
Length, ft	92.25
Width, ft	38.00
Ceiling height, ft	8.25
Insulation-walls, hr-F-sq ft/Btu	14.11
Insulation-ceiling, hr-F-sq ft/Btu	23.68
Lighting heat, Btu/hr	3242.35
Waterer length, ft	1728.00
Waterer width, ft	0.33
<u>Laying hens</u>	
Number of hens	5000.00
Hen weight, lbs	3.25
Body temperature, F	107.10
Excreta moisture content, percent	80.00
Specific heat of manure, Btu/lb-F	0.87
Excreta production rate, lbs/hen-day	0.27
<u>Ventilation</u>	
Inside design (set) temperature, F	60.00
Maximum ventilating rate, cfm	20421.34
Minimum ventilating rate, cfm	5406.01
<u>Simulation details</u>	
Time increment-DT, hours	1.00
Starting time, clock hours	0.00
Length of run, hours/cycle	24.00
Slab index	1.00
Lighting index	1.00

5. SUMMARY AND CONCLUSIONS

5.1 Summary

A simulation model which calculates the manure moisture removed and the manure moisture content in a poultry laying house was prepared and verified. The simulation model was based on psychrometric calculations in combination with constant-rate drying theory.

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 had a capacity of approximately 5000 hens and used a three-tier cage system with dropping boards and under-cage mechanical scrapers for manure removal. The laying house was fully enclosed, insulated, and used mechanical ventilation with thermostatic control.

The verification system was managed as a small commercial unit at the Michigan State University Poultry Science Research and Teaching Center. Feed and water was provided by hand filling continuous troughs along each row of cages. Eggs were also gathered by hand. Only artificial light was provided to give a photoperiod equal to 14 hours. The thermostats for control of ventilation were set to operate four fans in steps of about two degrees Fahrenheit and to maintain an inside dry-bulb temperature at between 55 and 60°F where possible. Manure was scraped from the pens daily.



Verification data collected on three summer days and on two winter days were satisfactory for comparison with the simulation model generated data. Curvilinear regression curves prepared from the two sources of data for accumulated total moisture removed from the poultry house and for accumulated moisture evaporated from the manure in the poultry house followed their respective data points very closely. Each of the paired curves used for verification purposes had the same general shape and magnitude except one. The exception was for the accumulated moisture evaporated from the manure on January 6, 1975. No known reason was found for this discrepancy. It was noted, however, that the manure moisture evaporation data collected from the laying house were more random on that date than other days of data collection.

The critical factors for maximizing in-house drying of poultry manure were the manure drying rate and the drying surface area. A large surface area provided for maximum drying. Since the manure was removed daily, the scraping of the dropping boards maximized the exposed surface area of manure. The simulation model indicated any system increasing the manure drying surface area would tend to increase manure drying. The drying rate was a function of no less than seven variables. Some of these variables were material specific and some were configuration specific. For a given material, i.e., poultry manure, and a given poultry house, these were considered constant. The variables which influenced the manure drying rate the most were the inside wet-bulb depression and the ventilating rate. The wet-bulb depression in turn was influenced directly



by the inside dry-bulb temperature and indirectly by the outside dewpoint temperature. To maximize manure drying, a high drying rate was desirable. To obtain a high drying rate a high inside dry-bulb temperature and low outside dewpoint was desirable. The weather determined the outside dewpoint temperature, but management practices influenced the inside dry-bulb temperature.

5.2 Conclusions

The following conclusions are the result of preparing and verifying a simulation model to estimate the in-house drying of poultry manure.

1. A computer simulation model based on known drying theory and verified by experimental psychrometric data was formulated to simulate the fecal moisture removed from a poultry house by ventilating air.

2. The data from the simulation model matched the experimental summer psychrometric data closely but the match of the winter data was not as close due to the greater effect of measurement error upon the lower ventilating air movement and smaller wet-bulb depression.

3. The simulation model provided a means of effectively evaluating the controllable management and design factors of a poultry house to maximizing in-house drying of the poultry manure.

4. A simulation run of the model for seasonal variation of moisture evaporation from a poultry house showed the greatest



potential for moisture removal to be in the summer and minimum potential to be during the spring and autumn seasons.

5.3 Recommendations for Future Research

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

1. A better verified model to estimate the outside dewpoint temperature than the one used in this study. The outside dewpoint temperature has considerable impact on the drying rate and thus the moisture removed from manure during in-house drying. An accurate estimate of the outside dewpoint temperature, therefore, is desirable when using the simulation model.

2. A verification study independent of this research using a different approach would be desirable. The collected verification data used for this study were based on the psychrometric characteristics of the ventilating air. Adjustments resulting from verification of the simulation model based on the measurement of the moisture content of the manure and the mass of manure produced by the laying hens could improve the accuracy of the simulation model.

3. Additional laboratory studies be conducted to determine a more suitable mathematical model for the drying rate of manure. The model for the drying rate as used in the simulation model was reported by Perry et al. (1963, 1973). These authors noted the drying rate model was material specific. The objectives of the laboratory studies should be to develop a model specific to manure.

APPENDICES

APPENDIX A

APPENDIX A COMPUTER PROGRAM LISTING

APPENDIX A

```

C *****CINH00010
C CINH00020
C CINH00030
C      PROGRAM DRYLSN CINH00040
C CINH00050
C CINH00060
C CINH00070
C THIS PROGRAM (DRYLSN) SIMULATES THE ENVIRONMENT IN A POULTRY HOUSE CINH00080
C WHEN GIVEN THE MAXIMUM AND MINIMUM OUTSIDE TEMPERATURE, THE CINH00090
C ATMOSPHERIC PRESSURE, THE OUTSIDE DEW POINT, THE NUMBER OF CHICKENS, CINH00100
C THE HOUR TO START SIMULATION AND THE DATE. A VALUE FOR THE MANURE CINH00110
C MOISTURE CONTENT AS FOUND FROM VERIFICATION DATA CAN ALSO BE CINH00120
C INCLUDED, BUT IS NOT REQUIRED. CINH00130
C CINH00140
C THE OUTPUT FROM THE PROGRAM IS A TABLE OF THE MANURE MOISTURE CINH00150
C CONTENT FOR EACH TIME PERIOD (HOUR) THROUGHOUT THE SIMULATED 'DAY' CINH00160
C AND THE MOISTURE REMOVED FROM THE MANURE FOR THAT 'DAY'. FOR EACH CINH00170
C OF THESE 'DAYS', THE INSIDE ENVIRONMENTAL CONDITIONS ARE ALSO CINH00180
C GIVEN. THIS TABLE IS PROVIDED FOR EACH 'CYCLE' OF MANURE REMOVAL CINH00190
C (APPROXIMATELY 24 HOURS). CINH00200
C CINH00210
C AN ADDITIONAL OUTPUT TABLE GIVES A SUMMARY OF END CONDITION OF THE CINH00220
C MANURE FOR EACH 'DAY'. THE SUMMARY TABLE LIST THE MANURE MOISTURE CINH00230
C CONTENT IN PERCENT AND THE WATER REMOVED FROM THE MANURE DURING CINH00240
C THAT PERIOD. APPROPRIATE WEATHER AND OTHER INPUT DATA IS ALSO CINH00250
C SUPPLIED WITH THE LISTING. CINH00260
C CINH00270
C CINH00280
C CINH00290
C TO USE THE PROGRAM THE FOLLOWING DATA CARDS ARE NEEDED: CINH00300
C 1ST CARD- NUMBER OF 'CYCLES' OR DATA-DAY PAIRS (COLUMNS 1 & 2) CINH00310
C DEBUGGING INDEX, MBUG, (1=ON, 0=OFF) COLUMN 4, VERIFICATION INDEX, CINH00320
C NIN, (0=VERIFICATION, 1=SIMULATION) COLUMN 6. CINH00330
C 2ND CARD- NUMBER OF INTERIGNS IN A SPECIFIC 'CYCLE', THE INSIDE CINH00340
C 'SET' TEMPERATURE, DEGREES R, AND THE AVERAGE WEIGHT OF THE HENS, CINH00350
C LBS, A CARD REQUIRED FOR EACH DATA-DAY PAIR (COLUMNS 1 & 2, 3 THRU 8, CINH00360
C AND 9 THRU 14, RESPECTIVELY. CINH00370
C 3RD & 4TH CARD- WEATHER DATA AND OTHER INPUT CONDITIONS FOR A CINH00380
C SPECIFIC DATA-DAY PAIR (SEE FORMAT BELOW). THE 4TH CARD IS FOR THE CINH00390
C SECOND DATE IN THE 24-HOUR CYCLE (A DUPLICATE CARD IS REQUIRED IF CINH00400
C THE CYCLE IS ALL THE SAME DATE). CINH00410
C CINH00420
C      FORMAT FOR CARDS 3 AND 4 (BOTH THE SAME) CINH00430
C CINH00440
C      COLUMNS NOS.      DATA AND UNITS CINH00450
C      1 & 2      MONTH, NO. CINH00460
C      3 & 4      DAY, NO. CINH00470
C      5 & 6      YEAR, NO. CINH00480
C      7,8,9&10      *ATMOSPHERIC PRESSURE, PSI CINH00490
C      11 & 12      *MAXIMUM OUTSIDE TEMPERATURE, DEGREES F CINH00500
C      13 & 14      *MINIMUM OUTSIDE TEMPERATURE, DEGREES F CINH00510
C      15 & 16      *AVERAGE OUTSIDE TEMPERATURE, DEGREES F CINH00520
C      17 & 18      *OUTSIDE DEW POINT TEMPERATURE, DEGREES F CINH00530
C      19,20,21,22      NUMBER OF CHICKENS IN POULTRY HOUSE, NO. CINH00540
C      23 & 24      TIME OF DAY SIMULATION BEGINS, HOURS (24-HR) CINH00550
C      **25,26,27,28      AS MEASURED MANURE MOISTURE CONTENT,PERCENT CINH00560
C      **29 THRU 24      AS MEASURED TOTAL MOISTURE REMOVED FROM HOUSE CINH00570
C                        DURING ONE CYCLE, LBS. CINH00580
C CINH00590
C CINH00600
C * AN ESTIMATE WILL BE CALCULATED IF THE INPUT VALUE EQUALS ZERO. CINH00610
C ** NOT USED IN CALCULATIONS, OUTPUT ONLY CINH00620
C CINH00630
C CINH00640
C *****CINH00650
C CINH00660
C      THE PSYCHROMETRIC FUNCTION SUBROUTINE CINH00670
C PREPARED BY LEREW (1971) INCLUDE THE CINH00680
C FOLLOWING ACRONYMS: CINH00690
C      ENDOOP-ENTHALPY, BTU/LB CINH00700
C      HADRH-HUMIDITY RATION, LB OF H2O/LB OF DA CINH00710
C      HADP-HUMIDITY RATIO      LB OF H2O/LB OF DA CINH00720

```


C	HAPV-HUMIDITY RATIO, LB OF H2O/LB OF DA	CINH00730
C	HL08-LATENT HEAT OF EVAPORATION, BTU/LB	CINH00740
C	PS08-SATURATED VAPOR PRESSURE, PSI	CINH00750
C	PV08WB-VAPOR PRESSURE OF AIR-WATER MIXTURE, PSI	CINH00760
C	PVHA-VAPOR PRESSURE OF AIR-WATER MIXTURE, PSI	CINH00770
C	RH08HA-RELATIVE HUMIDITY, DECIMAL	CINH00780
C	RHSPV-RELATIVE HUMIDITY, DECIMAL	CINH00790
C	VS08HA-SPECIFIC VOLUME, CU.FT./LB	CINH00800
C	WB08HA-WETBULB TEMPERATURE, DEGREES R	CINH00810
C	(AS MODIFIED BY DIXON ET AL, 1976)	CINH00820
C		CINH00830
C	*****	CINH00840
C		CINH00850
C	DEFINITION OF TERMS	CINH00860
C		CINH00870
C		CINH00880
C	AMC-MOISTURE CONTENT OF MATERIAL, WET BASIS, DECIMAL FRACTION	CINH00890
C	AT-ARRAY VALUE FOR ATMOSPHERE PRESSURE, PSI	CINH00900
C	ATAP-ATMOSPHERIC PRESSURE FOR A SPECIFIC DAY, PSI	CINH00910
C	AVSCLT-AVERAGE SOL-AIR TEMPERATURE, DEGREES F	CINH00920
C	AVTO-ARRAY VALUE FOR AVERAGE OUTSIDE DRY BULB TEMPERATURE, DEGREES F	CINH00930
C	AVT08U-AVERAGE OUTSIDE TEMPERATURE, DEGREES F	CINH00940
C	BLTH-BUILDING LENGTH, FEET	CINH00950
C	BR-ARRAY VALUE FOR BIRD NUMBER.	CINH00960
C	BROS-NO. OF BIRDS IN BUILDING	CINH00970
C	BROTMP-BODY TEMPERATURE OF A CHICKEN, DEGREES R	CINH00980
C	BTIM- A HOLD VALUE FOR BTIME	CINH00990
C	BTIME-THE TIME OF DAY THE LOOP IS TO BEGIN, HOURS	CINH01000
C	BTIMEN-ARRAY VALUE FOR BEGINNING TIME, HOURS	CINH01010
C	BTIMN-ARRAY VALUE OF CLOCK TIME FOR BEGINNING OF RUN, HOURS	CINH01020
C	CPA-THERMAL CAPACITY OF AIR, BTU PER LB. DEGREES R	CINH01030
C	CPV-THERMAL CAPACITY OF WATER VAPOR, BTU PER LB. DEGREES R	CINH01040
C	CRITMP-LOWEST OUTSIDE TEMPERATURE AT WHICH INSIDE OPTIMUM (SET)	CINH01050
C	TEMPERATURE CAN BE MAINTAINED, DEGREES R	CINH01060
C	DF - EXCRETA DISTRIBUTION FACTOR, FRACTION OF DAILY EXCRETA PRODUCED	CINH01070
C	DURING PERIOD OF *DT*, LB.	CINH01080
C	DH-INSIDE AND OUTSIDE HUMIDITY RATIO DIFFERENCE, LBS OF H2O PER LB	CINH01090
C	DRY AIR	CINH01100
C	DPF-ARRAY VALUE FOR OUTSIDE DEWPOINT TEMPERATURE, DEGREES F	CINH01110
C	DPHA-DEWPOINT TEMPERATURE, DEGREES R	CINH01120
C	DRPNUM-NUMBER OF DROPPINGS OF EXCRETA AS ACCUMULATED THRU THE DAY	CINH01130
C	DRPSAR-SURFACE AREA OF DROPPINGS, SQ. FEET	CINH01140
C	DRYH- (SEE DRYRTM)	CINH01150
C	DRYRTM-THE DRYING RATE AS CALCULATED, LBS. OF WATER PER HOUR-SQ.FT.	CINH01160
C	DRYSUR-TOTAL SURFACE AREA FOR DRYING, SQ. FEET	CINH01170
C	DRYTW-THE EVAPORATION RATE FROM THE WATERERS, LBS PER HOUR-SQ FT	CINH01180
C	DRYK- (SEE DRYRTW)	CINH01190
C	DT-LENGTH OF ITERATION, HOURS	CINH01200
C	EDRYTM-A VERIFICATION VALUE: END OF MECHANICAL DRYER OPERATING TIME,	CINH01210
C	CLOCK TIME HOURS	CINH01220
C	ELPWAR-AN INDEX FOR LIGHTS, ON=1, OFF=0	CINH01230
C	EVAPDI-WATER EVAPORATED FROM WATERERS AND MANURE PLUS RESPIRED H2O,	CINH01240
C	LBS.	CINH01250
C	EVAPSM-ACCUMULATIVE SUM OF WATERER AND MANURE EVAPORATION, LBS.	CINH01260
C	EVPTTT-TOTAL MOISTURE ADDED TO THE AIR, LBS.	CINH01270
C	EVPH20-WATER EVAPORATED FROM WATERS, LBS. PER HOUR	CINH01280
C	DURING *DT*, LBS	CINH01290
C	EVPH25-ARRAY VALUE FOR SUM OF WATER EVAPORATED FROM WATERS, LBS	CINH01300
C	EVPH2T-SUM OF WATER EVAPORATED FROM WATERS, LBS	CINH01310
C	EVPMRT-SUM OF WATER EVAPORATED FROM MANURE, LBS	CINH01320
C	EVPTTT-ACCUMULATIVE SUM OF POTENTIAL EVAPORATION BASED ON THE	CINH01330
C	VENTILATING AIR CAPACITY, LBS OF H2O.	CINH01340
C	EVPPOT-POTENTIAL EVAPORATION BASED ON THE VENTILATING AIR CAPACITY,	CINH01350
C	LBS OF H2O.	CINH01360
C	EVPMUR-WATER EVAPORATED FROM MANURE, LBS. PER HOUR	CINH01370
C	EVPRM-ARRAY VALUE FOR TOTAL WATER REMOVED FROM MANURE DURING ONE RUN	CINH01380
C	(DAY), LBS	CINH01390
C	EVPSUM-TOTAL WATER REMOVED FROM THE MANURE, LBS	CINH01400
C	EVPT-THE AMOUNT OF WATER EVAPORATED FROM THE MANURE DURING *DT*, LBS.	CINH01410
C	EVPTTL-TOTAL WATER EVAPORATED IN HOUSE, LBS.	CINH01420
C	EXDCMC-THE MOISTURE CONTENT OF MANURE AS DEFICATED, DECIMAL FRACTION	CINH01430
C	EXSMHS-WEIGHT OF MANURE IN THE HOUSE MINUS EVAPORATED MOISTURE, LBS.	CINH01440

C EXHTD-MANURE PRODUCED DURING TIME DT, LBS CINHO1450
 C EXHTD-WEIGHT OF EXCRETA PER DAY, LBS. CINHO1460
 C EXHTSM-WEIGHT OF EXCRETA AS ACCUMULATED THRU THE DAY, LBS CINHO1470
 C FLOW-THE VENTILATION RATE AT THE ITERATION TIME, CFM CINHO1480
 C HA-HUMIDITY RATIO FOR OUTSIDE AIR, LB OF H2O PER LB OF DA CINHO1490
 C HADP-HUMIDITY RATIO, LB OF H2O PER LB OF DA CINHO1500
 C HADPI-INSIDE HUMIDITY RATIO BASED ON INSIDE DEWPOINT TEMPERATURE, LB CINHO1510
 C OF H2O PER LB OF DA. CINHO1520
 C HADPO-OUTSIDE HUMIDITY RATIO BASED ON OUTSIDE DEWPOINT TEMPERATURE, CINHO1530
 C LBS OF H2O PER LB OF DA. CINHO1540
 C HAI-HUMIDITY RATIO FOR INSIDE AIR AS CALCULATED FROM SUMS OF MOISTURECINHO1550
 C SOURCES, LB OF H2O PER LB OF DA CINHO1560
 C HAIN-ABSOLUTE HUMIDITY OF INSIDE AIR, LBS PER LB CINHO1570
 C HEIT-BUILDING HEIGHT, FEET CINHO1580
 C HLD8-LATENT HEAT OF VAPORIZATION, BTU PER LB CINHO1590
 C H7MC-MOISTURE CONTENT OF MANURE ASFOUND FROM EXPERIMENTAL DATA AT MSUCINHO1600
 C H7MN-ARRAY VALUE FOR H7MC CINHO1610
 C I8UG-AN INTEGER CODE USED FOR DEBUGGING THE PROGRAM CINHO1620
 C ID-CALENDAR DAY (DATE) CINHO1630
 C I0N-ARRAY VALUE FOR CALENDAR DAY-FINAL DAY OF RUN. CINHO1640
 C INDIC-AN INDEX TO CHANGE SLAP TEMPERATURE E.G. DAILY RATHER THAN EACHCINHO1650
 C CALCULATION CINHO1660
 C IY-CALENDAR YEAR (DATE) CINHO1670
 C IYN-ARRAY VALUE FOR CALENDAR MONTH CINHO1680
 C K-INTEGER VALUE FOR STARTING PCINTER. CINHO1690
 C L-A POINTER FOR THE CLOCK TIME BEING CALCULATED CINHO1700
 C LTIME- LAST TIME PERIOD OF A RUN (DAY),HOURS CINHO1710
 C MBUG-AN INTEGER CODE USED FOR DEBUGGING THE *MAIN* CINHO1720
 C MID- AHOLD VALUE FOR ID CINHO1730
 C MIDN-ARRAY VALUE FOR CALENDAR DAY-INITIAL DAY OF RUN CINHO1740
 C MM-COUNTER FOR NUMBER OF OUTPUT LINES PER DAY. CINHO1750
 C MMX-DELAYED HOLD VALUE FOR MN, DEGREES F CINHO1760
 C MMXN-DELAYED HOLD VALUE FOR MX, DEGREES F CINHO1770
 C MN-MINIMUM OUTSIDE TEMPERATURE FOR THE DAY,DEGREES F CINHO1780
 C MNIN- OUTPUT VALUE FOR MN, DEGREES F CINHO1790
 C MU-CALENDAR MONTH (DATE) CINHO1800
 C MON-ARRAY VALUE FOR CALENDAR MONTH CINHO1810
 C MTIME-ALAPSED TIME COUNTER DURING RUN, NO. OF DT,S CINHO1820
 C MX-MAXIMUM OUTSIDE TEMPERATURE FOR THE DAY,DEGREES F CINHO1830
 C MXN- OUTPUT VALUE FOR MX,DEGREES F CINHO1840
 C NN-NUMBER OF RUNS (DAYS) FOR WHICH CALCULATIONS ARE DESIRED. CINHO1850
 C NNIN-INDICATOR DESIGNATING THAT WEATHER GENERATED BY *WETHER* IS FOR CINHO1860
 C VERIFICATION (=0) OR FOR SIMULATION (=1). CINHO1870
 C ONEFAN-A VERIFICATION VALUE: THE CAPACITY OF ONE VENTILATING FAN, CFMCINHO1880
 C PATM-ATMOSPHERIC PRESSURE, PSI CINHO1890
 C PCTMCH-THE PERCENT MOISTURE CONTENT AFTER DRYING FOR *DT* AND AS IF CINHO1900
 C IT WERE THE FIRST *DT* CINHO1910
 C PCTMCT-THE PERCENT MOISTURE CONTENT OF THE MANURE AT THE DESIGNATED CINHO1920
 C TIME CINHO1930
 C PC-MOISTURE CONTENT OF MANURE AT END OF RUN, PERCENT CINHO1940
 C POULTRY FARM BLDG NO. 7, PERCENT CINHO1950
 C QAD3D-ACCUMULATED HEAT ADDED TO THE POULTRY HOUSE FROM ALL SOURCES CINHO1960
 C BTU CINHO1970
 C QAH-NET HEAT ADDED TO HOUSE, BTU PER HOUR CINHO1980
 C QCONST-THE SUM OF HEAT BALANCE FACTORS REMAINING CONSTANT DURING CINHO1990
 C CONVERGENCE CALCULATIONS, BTU PER HR. CINHO2000
 C QLTOT-LATENT HEAT PRODUCTION OF BIRDS, BTU PER HOUR CINHO2010
 C QLTOTS-TOTAL RESPIRED MOISTURE FROM BIRDS, LBS CINHO2020
 C QMECH-MECHANICAL HEAT ADDED INSIDE HOUSE, BTU PER HR CINHO2030
 C QS-SENSIBLE HEAT PRODUCTION OF BIRDS, BTU PER HOUR CINHO2040
 C R-INTERMEDIATE VALUE TO DEFINE THE LENGTH OF A RUN. CINHO2050
 C RANGE-OUTSIDE DAILY TEMPERATURE RANGE, DEGREES F CINHO2060
 C RSPWTR-RESPIRATION RATE OF BIRDS, LBS PER HOUR CINHO2070
 C RUNLGT-NUMBER OF INTERACTIONS EACH COMPUTER RUN (CYCLE LENGTH) CINHO2080
 C SDRYTH-A VERIFICATION VALUE: BEGINNING OF MECHANICAL DRYER OPERATING CINHO2090
 C TIME, CLOCK TIME HOURS CINHO2100
 C SOL-ADJUSTED CEILING SOL-AIR TEMPERATURE, DEGREES F CINHO2110
 C ST-ADJUSTED CEILING SOL-AIR TEMPERATURE, DEGREES F CINHO2120
 C TAV-AVERAGE SOL-AIR TEMPERATURE, DEGREES F CINHO2130
 C T3-OUTSIDE DRYBULB TEMPERATURE FOR OUTPUT, DEGREES F CINHO2140
 C TDB-OUTSIDE DRY BULB TEMPERATURE, DEGREES K CINHO2150
 C TDBG2-OUTSIDE WALL SURFACE TEMPERATURE, DEGREES R CINHO2160



```

C TDP-OUTSIDE DEW POINT TEMPERATURE, DEGREES R          CINH02170
C TDPF-OUTSIDE DEWPOINT TEMPERATURE (U.S. WEATHER SERVICE), DEGREES F CINH02180
C TDPI- INSIDE DEWPOINT TEMPERATURE, DEGREES F          CINH02190
C TEMPI-THE INSIDE TEMPERATURE OBTAINED BY CONVERGENCE, DEGREES R    CINH02200
C TGES-AN INTERMEDIATE GUESS VALUE USED FOR CONVERGENCE, DEGREES R    CINH02210
C TI-TEMPERATURE INSIDE HOUSE AS CARRIED BY MAIN PROGRAM, DEGREES R    CINH02220
C TIDP-INSIDE DEWPOINT TEMPERATURE AT "TIME MINUS DT," DEGREES R      CINH02230
C TIME-CLOCK TIME, 24-HOUR CLOCK                                  CINH02240
C TIM-TEMPERATURE, INSIDE HOUSE, DEGREES F(USED IN SUBROUTINES)       CINH02250
C TMIN-A CALCULATED TEMPERATURE WHICH THE MIN. VENTILATION RATE CAN   CINH02260
C HOLD; AN OUTSIDE TEMPERATURE, DEGREES R                      CINH02270
C TDBI-INSIDE DRYBULB TEMPERATURE, DEGREES F                  CINH02280
C TDBO-OUTSIDE DRYBULB TEMPERATURE AS CALCULATED BY *WETHER*, DEGREES F CINH02290
C TDPI-INSIDE DEWPOINT TEMPERATURE, DEGREES F                  CINH02300
C TDPG-OUTSIDE DEW POINT TEMPERATURE AS CALCULATED BY *WETHER*,DEGREE F CINH02310
C TMINR-MINIMUM TEMP FOR THE DAY,DEGREES F                     CINH02320
C TMINR-MINIMUM TEMP FOR THE DAY, DEGREES R                     CINH02330
C TO-OUTSIDE WALL SURFACE TEMPERATURE, DEGREES F              CINH02340
C TP-DEWPOINT TEMPERATURE FOR OUTPUT, DEGREES F, OUTSIDE        CINH02350
C TSET-DESIRED INSIDE TEMPERATURE, DEGREES R                  CINH02360
C TSLAB-TEMPERATURE OF FLOOR SLAB, DEGREES R AND F              CINH02370
C TWBI- INSIDE WETBULB TEMPERATURE, DEGREES R                  CINH02380
C U-FLOATING POINT VALUE OF STARTING POINTER                     CINH02390
C UTEMP-TOTAL WATER EVAPORATED IN UNIT TIME, LBS. PER HOUR       CINH02400
C UXAREA-THE HEAT TRANSMISSION COEFFICIENT FOR THE BLDG., BTU PER HOUR CINH02410
C DEGREE R                                                       CINH02420
C VELMAS-MASS AIR FLOW RATE, LBS/MIN.                           CINH02430
C VENTRT-THE VENTILATION RATE IN THE HOUSE AT TIME OF CALCULATION,   CINH02440
C CFM OUTSIDE AIR                                                CINH02450
C VRMINU-A VERIFICATION VALUE: MINIMUM VENTILATION RATE DURING DRYER CINH02460
C VRGESS-AN INTERMEDIATE GUESS VALUE FOR THE VENTILATION RATE, CFM   CINH02470
C VRMAX-MAXIMUM VENTILATION RATE OF HOUSE, CFM                  CINH02480
C VRMIN-MINIMUM VENTILATION RATE OF HOUSE, CFM                  CINH02490
C WATLGT-LENGTH OF WATERERS, FEET                                CINH02500
C WATSAR-SURFACE AREA OF EXPOSED WATER IN HOUSE, SQ FT          CINH02510
C WATTSQ-ELECTRICAL POWER APPLIED TO BUILDING, WATTS PER SQ. FOOT CINH02520
C WATWDT-WIDTH OF WATERING TROUGHS, WATER SURFACE, FEET         CINH02530
C WBDHA-WET BULB TEMPERATURE, DEGREES R                         CINH02540
C WBRD-AVERAGE BIRD WEIGHT, LBS.                                 CINH02550
C WBTIA-INSIDE WET BULB TEMPERATURE (CALCULATED), DEGREES R      CINH02560
C WIDTH-BUILDING WIDTH, FEET                                     CINH02570
C WMTKTR- SUM OF MANURE EXCRETED, LBS                             CINH02580
C                                                                    CINH02590
C                                                                    CINH02600
C                                                                    CINH02610
C *****CINH02620
C CCMON/BIPOS/WPRD, BRDS                                         CINH02630
C CCMON/BLDG/BLTH,WIDTH,HEIT                                     CINH02640
C CCMON/BUG/IBUG                                                 CINH02650
C CCMON/CARD/RTIME,H7MC,MX,MN,SDRYTH,EDRYTH                     CINH02660
C CCMON/C/EXCDMC,EXWTD,EXWTSN,EVPART,DT                         CINH02670
C CCMON/PRESS/PATM                                                CINH02680
C CCMON/EVP/DRPSAR,WATSAR                                         CINH02690
C CCMON/RATE/DRPNJM                                               CINH02700
C CCMON/DRY/DRYM,DRYW                                             CINH02710
C CCMON/WR/TDOB(48),TDPG(48),TDPI(48),TIME(48),MTIME,TDPI(48)   CINH02720
C CCMON/WR/FLOW(48), EVPT(48), EVPSUM(48), PCTNCH(48),PCTMCT(48) CINH02730
C CCMON/WTHP/AVTDOB,RANGE,ATMP,MC, ID,IY,TDPF,VARDTA            CINH02740
C CCMON/31/EVAPDT(48),EVPDTT(48),EVPH2S(48),CLTOTS(48),DPF(48)  CINH02750
C CCMON/B2/MON( 48),IDN( 48),IDN( 48),LYN( 48),BTIMN( 48)       CINH02760
C CCMON/B3/BT14EN( 48),H7MCN( 48),PC( 48),TB(48),TP(48),EVRMV(48) CINH02770
C CCMON/B4/MXN(48),MMXN(48),MNN(48),MMIN(48),BR(48),AT(48),AVDT(48) CINH02780
C CCMON/CRT/RCL,RWL,SPM,EKRATE                                    CINH02790
C DIMENSION EVPPOT(48),EVPOTT(48),DH(48)                         CINH02800
C INTEGER RUNLGT                                                  CINH02810
C REAL MX,MN                                                      CINH02820
C DIMENSION QADDED(48)                                             CINH02830
C DATA QADDED/48*0./                                             CINH02840
C                                                                    CINH02850
C *****SET PARAMETERS AND INITIALIZE VARIABLES*****CINH02860
C                                                                    CINH02870
C IF I.NW=0, NN SHOULD=1                                          CINH02880

```



```

      READ 22,IN,MBUG,NNH                                INH02890
22  FORMAT(I3,I2)                                         INH02900
      DO 225 M=1,49                                       INH02910
      TDBO(M)=0.                                           INH02920
      TDPD(M)=0.                                           INH02930
      TDBI(M)=0.                                           INH02940
      TIME(M)=0.                                           INH02950
      TDOI(M)=0.                                           INH02960
      FLOW(M)=0.                                           INH02970
      EVPT(M)=0.                                           INH02980
      EVPSUM(M)=0.                                         INH02990
      PCTMCH(M)=0.                                         INH03000
      PCTMCT(M)=0.                                         INH03010
      EVAPDT(M)=0.                                         INH03020
      EVPDIT(M)=0.                                         INH03030
      EVPH2S(M)=0.                                         INH03040
      QLTGTS(M)=0.                                         INH03050
      TS      (M)=0.                                       INH03060
      TP      (M)=0.                                       INH03070
      DPF      (M)=0.                                       INH03080
      EVPRMV(M)=0.                                         INH03090
      BR      (M)=0.                                       INH03100
      AT      (M)=0.                                       INH03110
      AVTD      (M)=0.                                       INH03120
      EVPPOT(M)=0.                                         INH03130
      EVPOTT(M)=0.                                         INH03140
      DH      (M)=0.                                       INH03150
      MDI      (M)=0                                       INH03160
      MIDN      (M)=0                                       INH03170
      IDN      (M)=0                                       INH03180
      IYN      (M)=0                                       INH03190
      BTIMN      (M)=0.                                       INH03200
      BTIMEN(M)=0.                                       INH03210
      H7MCN      (M)=0.                                       INH03220
      PC      (M)=0.                                       INH03230
      MMNN      (M)=0                                       INH03240
      MNN      (M)=0                                       INH03250
      MMXN      (M)=0                                       INH03260
      MXN      (M)=0                                       INH03270
225  CONTINUE                                             INH03280
C                                                                 C INH03290
C *****START LOOP FOR #NN* DAY RUNS*****C INH03300
C                                                                 C INH03310
      DO 3 N=1,NN                                           INH03320
      READ 25,LTIME,TSET,ABRD                                INH03330
25  FORMAT(I2,2F6.2)                                       INH03340
      EXCDAC=0.8                                           INH03350
      EXPATE=.272                                           INH03360
      CALL ABLUCK                                           INH03370
      AVTDBO = 58.+459.67                                   INH03380
      BRDTAP=107.1+459.67                                   INH03390
      BRDS = 4500.                                           INH03400
      BLTH = 92.25                                           INH03410
      DT=1.0                                                 INH03420
      ELPAAP=1.                                              INH03430
      EVPH2S(1)=0.                                           INH03440
      EYPDIT(1)=0.                                           INH03450
      EVPCTT(1)=0.                                           INH03460
      HEIT = 8.25                                           INH03470
      IBUG=1                                                 INH03480
      IBUG=5                                                 INH03490
      IBUG=0                                                 INH03500
      INDIC = 1                                              INH03510
      PATH=14.6                                              INH03520
      QLTGTS(1)=0.                                           INH03530
      SPM=.87                                                INH03540
      TDB=50.+459.67                                         INH03550
      TDP=40.+459.67                                         INH03560
      IF(TSET.EQ.0..OR.TSET.GT.520.) TSET=56.+459.67      INH03570
      TIN=TSET                                               INH03580
      TI=TSET                                                INH03590
      TIOP=TSET-1.                                           INH03600

```



```

VPMAX=(54.4838+0.2569*1270.)*49.5+229.467+1.059*1270. I#NH03610
VRMIN=(54.4838+0.2569* 180.)*49.5+229.467+1.059* 180. I#NH03620
C -IN CALIBRATING THE 4 FANS IT WAS FOUND 3 FANS PRODUCED APPROXIMATELY C#NH03630
C THE SAME FLOW AS 4. THIS IS ATTRIBUTED TO TURBULANCE. C#NH03640
ONEFAN=(VRMAX-VRMIN)/3. I#NH03650
VRMIN=VRMIN+ONEFAN I#NH03660
WATLGT=24.*72. I#NH03670
WIDTH = 33. I#NH03680
WATWDT=4./12. I#NH03690
CALL WETHER(INNR,TMINF) I#NH03700
TSLAB=AVTDBG+459.67+5. I#NH03710
IF(1D.EQ.7.AND.IY.EQ.75) VRMIN=6613.67 I#NH03720
IF(1D.EQ.6.AND.IY.EQ.75) VRMIN=6706.75 I#NH03730
BTIME=0. I#NH03740
DF=(1./24.)*DT I#NH03750
QMECH=2*19*25*3.413 I#NH03760
R=LTIME/DT I#NH03770
RUMLGT=R I#NH03780
U=BTIME/DT+0.5 I#NH03790
K=U I#NH03800
IF(U.LT.1.) K=1 I#NH03810
TIME(1)=BTIME+DT I#NH03820
WATTSQ=(QMECH/(BLTH*WIDTH))/3.413 I#NH03830
MID=1D I#NH03840
BTIM=BTIME I#NH03850
MOR(N)=MO I#NH03860
YIDN(N)=MID I#NH03870
IDN(N)=ID I#NH03880
IYN(N)=IY I#NH03890
ITM(N)=BTIM I#NH03900
BTIMEN(N)=1. I#NH03910
HTMCN(N)=HTMC I#NH03920
MXN(N)=MX I#NH03930
MMXN(N)=MX I#NH03940
MNR(N)=MN I#NH03950
MMNR(N)=MN I#NH03960
BR(N)=BRDS I#NH03970
AT(N)=ATMP I#NH03980
AVTD(N)=AVTDBC I#NH03990
DPF(N)=TDPF I#NH04000
EXWTS=0. I#NH04010
EVPTTL=0. I#NH04020
EVPH2T=0. I#NH04030
EVPMR=0. I#NH04040
EVAPS=0. I#NH04050
TMI=CRITMP(TSET,TDPF +459.67,VRMIN,WATTSQ,0.0) I#NH04060
TGES=TSET I#NH04070
C *****END OF INITIAL VALUES***** C#NH04080
C I#NH04090
CALL HDSTRT(BLTH,WIDTH,FEI,RWL,RCL,QMECH,WATLGT,WATWDT,WBRD,BRDS, I#NH04100
@BRDNO=459.67,EXCMC,DF,SPK,EXPATC, TMIN=459.67, I#NH04120
*DT,BTIME,R,INDIC,ELPHAR,TSET=459.67,VRMAX,VRMIN,TSLAB=459.67) I#NH04130
C I#NH04140
C *****BEGINNING OF LOOP FOR A SPECIFIC DAY***** I#NH04150
C I#NH04160
DO 4 J=1,PUMLGT I#NH04170
TGB=TOBG(J-1+K)+459.67 I#NH04180
TDP=TDPG(J-1+K)+459.67 I#NH04190
TB(J)=TGB-459.67 I#NH04200
TP(J)=TDP-459.67 I#NH04210
C IBUG IBUG IBUG IBUG IBUG IBUG IBUG IBUG IBUG IBUG IBUG IBUG IBUG IBUG IBUG I#NH04220
IF(1BUG.EQ.0) GO TO 999 I#NH04230
PRINT 990,K,TGB,TDP,TIME(MTIME),MTIME I#NH04240
999 EQCAT(1X,5110HOKYHMS /)1UX,*K*,14X,*TGB*, 14X,*TDP*,14X,*TIME* I#NH04250
A,14X, 'MT I#NH04260
1TIME/8X,13,10X,3E14.4,I9) I#NH04270
999 CONTINUE I#NH04280
C IBUG IBUG IBUG IBUG IBUG IBUG IBUG IBUG IBUG IBUG IBUG IBUG IBUG IBUG IBUG I#NH04290
IF(8BUG.EQ.0) GO TO 400 I#NH04300
C I#NH04310
C *****PRINT OUTPUT VALUES AS CALCULATED***** I#NH04320

```



```

J=J-1
DO J=L+1,3
9 PRINT 888, I,I,I,I,I,I,I,I,I,I,I,I,I,I,I,I,I
IF(I.EQ.O) I=1
PRINT 2, TB(1), TP(1),FLOW(1),TDBI(1),TDPI(1),EVP(1),EVSUM(1)
1,PCTMCH(1),PCTMCT(1),TIME(1)
PRINT 4122,TIME(1),EVAPOT(1),EVPPT(1),EVPH2S(1),QLCTIS(1),EVSUM(
@1),EVPOTT(1),EVPOTT(1),CADDSD(1)
888 FORMAT (IX,20(15),30(1HD))
900 CONTINUE
*****DETERMINE THE AMOUNT OF EXCRETA AND THE DRYING SURFACE AREA*
CALL EXCRAT (BRDS,DF,EXWTSN,EXWTD)
EXSHMS=EXWTSN-EVPMRT
CALL DRSRF (EXSHMS,WATLGT,WATWDT,DRPSAR,WATSAR,DRYSUF)
*****DETERMINE IF LIGHTS ARE ON OR OFF AND SET INDEX, ELPWR.
IF(TIME(J).LT.7..OR.TIME(J).GE.21.) GO TO 310
ELPWR=1.
GO TO 311
310 CONTINUE
ELPWR=0.
311 CONTINUE
*****CHECK TO SEE IF ALL FANS RUNNING*****
IF(TDB.GE.TSET)GO TO 10
*****CHECK TO SEE IF OUTSIDE COLDER THAN POSSIBLE TO MAINTAIN TSET
IF(TDB.LT.TMIN)GO TO 20
***** SET UP VENTILATION RATE AND *****
***** SET UP DRYING TEMPERATURE FOR THIS CONDITION *****
VRGESS=.5*(VRMAX +VRMIN)
CALL VENRAT (WATTSQ,ELPWAR,TDB,TSET,TDPI,TDP,AVTDBU,
TSLAB,VRGESS,INDIC,1,QCONST,VENTRT,VRMAX )
IF(TIME(J).GT.SCRYTM.AND.TIME(J).LT.EDRYTM.AND.VENRT.LT.VRMIND) V
IENTPT=VRMIND
IF(VENTRT.EQ.VRMIND) GO TO 30
IF(VENTRT.GT.VRMAX) GO TO 10
IF(VENTRT.LT.VRMIN) GO TO 20
TI=TSET
GO TO 11
*****GUESS DRYING TEMP WITH HIGH OUTSIDE TEMP *****
10 VENTRT=VRMAX
TGES=.5*(TDB+TSET)
GO TO 30
*****GUESS DRYING TEMP. WITH LOW OUTSIDE TEMP.******
20 VENTRT=VRMIN
IF(TIME(J).GT.SCRYTM.AND.TIME(J).LT.EDRYTM) VENTRT=VRMIND
TGES=(TMIN+TSET)*.5
GO TO 30
30 CONTINUE
*****DETERMINE INSIDE TEMPERATURE BY HEAT BALANCE*****
CALL TEMPIN (TGES,VENTRT,WATTSQ,ELPWAR,TSLAB,INDIC,TDB,TDPI,TEMPI
@TDP)
TI=TEMP1
IF(VENTRT.LE.VRMIN.AND.TI.GT.TSET) TI=TSET
11 CONTINUE
HA=HACPI(TDP)
CALL BROHT(TI,ELPWAR,QS,QLIGT)

```



```

CALL TWBIN(TI,VENTRT,TWB1,QLTOT,HA,TDB)      INH05050
CALL EVPNTR (UNTEVP,VENTRT,TI,TWB1,EVPH2C,EVPMUR,1) INH05060
400 CONTINUE                                  INH05070
      HAI=HAIN(QLTOT,TI,VENTRT,UNTEVP,HA)      INH05080
C AS AN ASIDE CALCULATE HEAT ADDED TO POULTRY HOUSE CINH05081
CALL EVPNTR(UNTEVP,VENTRT,TI,HADBHA(TI,HA1),EVPH2C,EVPMUR,1) INH05090
CALL ELHEAT(WATTSQ,ELPHAR,ELHT)              INH05100
CALL CCLHT(TI,TDB,QCTOT)                     INH05110
CALL WALLHT(TI,TDB,QWTOT)                    INH05120
CALL FLORHT(TI,TSLAG,INDIC,QFTOT)            INH05130
QAD=QS +QLTOT*ELHT+QCTOT+QWTOT+QFTOT         INH05140
IF(J.EQ.1) GO TO 503                          INH05150
QADDED(J)=QADQD(J-1)+QAD*DT                  INH05160
GO TO 504                                      INH05170
503 CONTINUE                                  INH05180
QADDED(J)=QAD                                  INH05190
504 CONTINUE                                  INH05200
405 CONTINUE                                  INH05210
C                                              CINH05220
C *****PUT CALCULATED VALUES INTO PRINTOUT ARRAYS*****CINH05230
C                                              CINH05240
      TDP1(J)=DPHA(HAI) -459.67
      HADP1=HADP1(TDP1(J)+459.67)              INH05250
C HADP1 IS THEORETICALLY EQUAL TO HAI BUT IS USED IN LIEU OF HAI TO INH05260
C MINIMIZE ROUNDING ERRORS IN THE PSYCHROMETRIC PACKAGE CREATED WHEN CINH05262
C COMPARING VERIFICATION DATA. THE VERIFICATION DATA FOUND THE CINH05263
C HUMIDITY RATIO COMPARABLE TO HAI DIRECTLY FROM A DEWPOINT TEMPERA- CINH05264
C TURE COMPARABLE TO TDP1.
      HADP2=HADP1(TDP1(J)-1*K)+459.67)         INH05265
      DH(J)=HADP1-HADP2                       INH05270
      WRITE(9,123) IY,MO,JD,TIME(J),HADP1,HADP2 INH05280
123 FORMAT(3I3,3X,FS.2,10X,2F10.6)           INH05290
      TIDP=TDP1(J)+459.67                    INH05300
      FLOW(J)=VENTRT                          INH05310
      TDB1(J)=TI-459.67                      INH05320
      RSPNTR=QLTOT/HLCB(BROTMP)               INH05330
      EVAPDT(J)=DH(J)*VENTRT*DT*60./VSD8HA(TI,HA1) INH05340
      JJ=J-1                                  INH05350
      IF(J.EQ.1) JJ=1                         INH05360
      EVPDTT(J)=EVPDTT(JJ)+EVAPDT(J)          INH05370
      EVPMRT=EVPMRT+EVPMUR*DT                INH05380
      EVPH2T=EVPH2T+EVPH2C*DT                INH05390
      EVPTTL=EVPMRT+EVPH2T                   INH05400
      QLTOTS(J)=QLTOTS(JJ)+RSPNTR*DT          INH05410
      EVPH2S(J)=EVPH2S(JJ)+EVPH2C*DT          INH05420
      EVPT(J)=EVPMUR                          INH05430
      EVAPS=EVAPS+EVPTTL                     INH05440
      EVPSUM(J)=EVPMRT                       INH05450
      VELMAS=VENTRT/VSD8HA(TI,HA1)            INH05460
      EVPPGT(J)=(HAI-HA)*VELMAS*60.*DT        INH05470
      EVPPDT(J)=EVPPDT(JJ)+EVPPGT(J)          INH05480
      PCTMCH(J)=AMC(EVPMUR,EXCDMC,EXWTD)*100. INH05490
      PCTMCT(J)=AMC(EVPMRT,EXCDMC,EXWTS)*100. INH05500
C 1BUG 1BUG 1BUG 1BUG 1BUG 1BUG 1BUG 1BUG 1BUG 1BUG 1BUG 1BUG 1BUG INH05510
      IF(1BUG.EQ.0) GO TO 9999                INH05520
      DRYRTM=DRYM                            INH05530
      DRYTW=DRYW                             INH05540
      PRINT 990,K,TDB,TDP,TIME(MTIME),MTIME  INH05550
      PRINT 9001                             INH05560
9001 FORMAT(9X,'DRPSAR',T25,'DRYRTM',T39,'DRYSUF',T53,'HAI ',T67,'EVPH2INH05580
      A9,'14X,EVPH2T',T95,'EVPMUR',T109,'EVPMRT',T123,'EVPTTL',/10X'TEMP1INH05590
      B,'T26,'TGES', T40,'T1',T54,'TIN',T68,'VENTRT',T82,'VRGESS',T96,'WATTSQINH05600
      ZATSAAR,T110,'QCONST',T123,'TWB1')
      PRINT 9000,DRPSAR,DRYRTM, DRYSUF, HAI, EVPH2C,EVPH2T,EVPMUR INH05610
      1R -EVPMRT,EVPTTL,TEMP1,TGES,TI,TIN,VENTRT,VRGESS,WATSAAR,QCONST INH05620
      3,TWB1
9000 FORMAT(2X,9E14.3,/,2X,9E14.3)           INH05630
      PRINT 9002,DRYRTM                       INH05640
9002 FORMAT(6X,'DRYRTM=',E14.3)              INH05650
      IF(1BUG.EQ.5) 1BUG=0                    INH05660
9999 CONTINUE                                  INH05670
C 1BUG 1BUG 1BUG 1BUG 1BUG 1BUG 1BUG 1BUG 1BUG 1BUG 1BUG 1BUG 1BUG INH05680
      INH05690
      INH05700

```



```

TIME=TIME+1
6 CONTINUE
   TIME(J+1)=TIME(J)+DT
C *****GENERATE WEATHER FOR A NEW DAY IF LOOP PASSES MIDNIGHT. ***
C
IF(TIME(J+1).LE.24.) GO TO 4
TIME(J+1)=TIME(J)+1-24.
K=1-J
CALL WETHER(INNW,TMINF)
ION(N)=ID
BTIME(N)=BTIME
H7MC(N)=H7MC
MN(N)=MN
MX(N)=MX
BR(N)=BRDS
AT(N)=ATMP
AVTD(N)=AVTDBC
DPF(N)=DTPF
TMIN=CRITMP(ITSET,DOPF +459.67,VRAIN,WATTSSQ,0.0)
4 CONTINUE
5 CONTINUE

*****PRINT OUTPUT TABLE AND WRITE DATA FOR PLOT*****
C
C
13 FORMAT(1H1)
CALL HEDING
DO I =1,RUNLGT
PRINT 2,' T(I), TP(I), FLOW(I), TDBI(I), TOP(I), EVPT(I), EVPSUM(I)'
1,PCTMCH(I),PCTMCT(I),TIME(I))
2,FORMAT(1X,E9.3,F4E14.3,I67,4E14.5,5X,F5.2)
WRITE(10,121)IY,MG,ID,TIME(I),EVDPOT(I),EVPSUM(I)
121 FORMAT(3I3,3X,F5.2,F8.2,5XF8.2)
WRITE(6,212)IY,MG,ID,TIME(I),TB(I),TP(I),TDBI(I),TOPI(I),DH(I),FLOW(I)
212 FORMAT(3I3,F5.2,10X,F6.1,F10.6,F9.0)
1 CONTINUE
PRINT 14,AVTDBC,RANGE,ATMP,MG,ID,IY,DTPF,BRDS
14 FORMAT('//1X,"A MINUS SIGN IN COLUMN 8 INDICATES THERE WAS MORE DRY'/'
2ING DURING THAT TIME INCREMENT THAN MANURE MOISTURE PRODUCED '/'
Z' DURING THAT TIME PERIOD.'
$ //1X,"WEATHER DATA FOR THE DAY: AVERAGE TEMPERATURE','F6.1,
11X,'DEGREES F, TEMPERATURE RANGE','F6.1,1X,'DEGREES F, ATMOSPHERIC
2PRESSURE','F6.1,1X,1X,'PSI'/1X,12,'/',12,'/',12,18X,'DEWPOINT TEMPE'
3RATURE','F6.1,X,'DEGREES'," F',5X,'NUMBER OF EIKDS,'"F6.0)
C IBUG IBUG IBUG IBUG IBUG IBUG IBUG IBUG IBUG IBUG IBUG IBUG IBUG IBUG IBUG IBUC
1FM(BMG.EQ.O) GO TO 5000
PRINT 13
MM=(48/2)/DT
FORM 4110
4110 FORMAT(1X,'PARTITIONING OF EVAPORATED MOISTURE AND A COMPARISON OF
2 POTENTIAL EVAPORATION OF VENTILATING AIR.'/)
PRINT 4120
4120 FORMATI(TS,'E V A P O R A T I O N T U T A L','T7,'EVAPURATION',
5T36,16(H)*,T68,14(1H*),T104,'HEAT ADDED',
2T22,'POTENTIAL '/T7,'DURING',T21,'EVAPURATION',T38,'FROM',T52,'FROM'IBUGIBU
#T,'T66,'FROM',T80,'FROM',T91,'VENTILATION'/T11,'DT',T22,'DURING DT'IBUGIBU
Z,T36,'WATERERS',T49,'RESPEARATION',T65,'MANURE ',T77,'ALL SOURCES'IBUGIBU
$,T92,'POTENTIAL',T2,'TIME',T105,' TO AIR')
DO 3125 M=1,MM
PRINT 4122,TIME(M),EVAPDT(M),EVPPDT(M),EVPH2S(M),QLTTOTS(M),EVPSUM(M)
2M,EVPDDTI(M),EVPGDT(M),QADDE(M)
4122 FORMAT(1X,F4.1,E12.5,E13.5,1X,G614.5)
3125 CONTINUE
PRINT 4130,VARDTA
4130 FORMAT(/T55,'HOUSE T EVAPGRATION',T76,E12.5)
PRINT 14,AVTDBC,RANGE,ATMP,MG,ID,IY,DTPF,BRDS
C IBUG IBUG IBUG IBUG IBUG IBUG IBUG IBUG IBUG IBUG IBUG IBUG IBUG IBUG IBUG IBUC
5000 CONTINUE
EVPMV(I)=EVPSUM(RUNLGT)
PC(N)=PCTMCT(RUNLGT)
3 CONTINUE

```


[illegible]


```

      FUNCTION AMC(H2ORMV,ORIGMC,DRIGWT)                                INH07100
C *****CINH07110
C CINH07120
C CINH07130
C THIS SUBROUTINE CALCULATES THE MOISTURE CONTENT OF A MATERIAL ON A    CINH07140
C WET BASIS WHEN GIVEN ORIGINAL MOISTURE CONTENT AND WATER REMOVED.    CINH07150
C IF WATER IS ADDED, H2G REMOVED SHOULD BE NEGATIVE.                  CINH07160
C CINH07170
C *****CINH07180
C *****CINH07190
C CINH07200
C CINH07210
C      DEFINITION OF TERMS                                           CINH07220
C CINH07230
C      SEE MAIN PROGRAM FOR ACRONYMS NOT                               CINH07240
C      LISTED HERE                                                    CINH07250
C CINH07260
C *****CINH07270
C CINH07280
C AMC=MOISTURE CONTENT OF MATERIAL, WET BASIS, DECIMAL FRACTION      CINH07290
C DRYWT=DRY WEIGHT, CNE UNIT                                          CINH07300
C H2ORMV=WATER WEIGHT REMOVED FROM MATERIAL, UNIT AS INPUT           CINH07310
C IBUG=AN INTEGER CODE USED FOR DEBUGGING THE PROGRAM.              CINH07320
C ORIGMC=ORIGINAL MOISTURE CONTENT OF MATERIAL                       CINH07330
C DRIGWT=ORIGINAL WEIGHT OF MATERIAL,LBS                             CINH07340
C WATDRD=WEIGHT OF WATER REMOVED BY DRYING, UNITS AS INPUT           CINH07350
C WATRWI=WEIGHT OF WATER ORIGINALLY IN MATERIAL, UNITS AS INPUT      CINH07360
C WTCOMB=WET WEIGHT OF MATERIAL AFTER DRYING, UNITS AS INPUT         CINH07370
C CINH07380
C CINH07390
C *****CINH07400
C      COMMON/BUG/BUG                                                INH07410
C      DRYWT=(1.-ORIGMC)*DRIGWT                                       INH07420
C      WATRWI=ORIGMC*DRIGWT                                           INH07430
C      WATDRD=WATRWI-H2ORMV                                           INH07440
C      WTCOMB=WATDRD+DRYWT                                             INH07450
C      AMC=WATDRD/WTCOMB                                              INH07460
C      IF(DRYWT.GT.0..AND.WATDRD.GT..0.AND.AMC.GT.0.) GO TO 2        INH07470
C      PRINT 3,DRYWT,WATDRD,AMC                                       INH07480
C 3  FORMAT (/1X,130(1HK)/1X'NEGATIVE VALUE FOR DRY WEIGHT, FINAL   INH07490
C    WATER WEIGHT OR RESULTING MOISTURE CONTENT. THESE VALUES ARE    INH07500
C    2RESPECTIVELY '/1X3G21.8/1X'IF WATER IS ADDED H2ORMV SHOULD BE NEGATIVE')
C      IF(BUG.EQ.0) BUG=2                                             INH07510
C      PRINT 5                                                         INH07520
C      IF(BUG.EQ.0) BUG=2                                             INH07530
C 2  CONTINUE                                                         INH07540
C      IF(BUG.EQ.0) GO TO 88                                           INH07550
C      PRINT 5                                                         INH07560
C 5  FORMAT(/1X,10(1HK),'AMC',10(1HK))                                INH07570
C      PRINT 55                                                        INH07580
C 55 FORMAT(1H0,10(10HMC))                                           INH07590
C      PRINT 1,DRYWT,WATRWI,WATDRD,WTCOMB,AMC,H2ORMV,DRIGWT,ORIGMC   INH07600
C 1  FORMAT (8X,'DRYWT',9X,'WATRWI',8X,'WATDRD',7X,'WTCOMB',8X,'AMC',  INH07610
C    211X,'H2ORMV',8X,'DRIGWT',8X,'ORIGMC',/1X#E14.3)              INH07620
C 88 CONTINUE                                                         INH07630
C      IF(BUG.EQ.2) BUG=0                                             INH07640
C      RETURN                                                         INH07650
C      END                                                            INH07660
C      INH07670

      SUBROUTINE BRDHT (T,DALYI,QS,QL)                                INH07680
C *****CINH07690
C CINH07700
C CINH07710
C THIS SUBROUTINE DETERMINES THE SENSIBLE AND LATENT                 CINH07720
C HEAT OUTPUT FROM CHICKENS FOR VARIOUS TEMPERATURES                CINH07730
C AND DAY OR NIGHT ACTIVITY BY TABLE LOOK-UP.                     CINH07740
C CINH07750
C CINH07760
C *****CINH07770
C CINH07780
C CINH07790

```



```

C      DEFINITION OF TERMS                                CINH07800
C      SEE MAIN PROGRAM FOR ACRONYMS NOT                  CINH07810
C      LISTED HERE                                         CINH07820
C      CINH07830
C      CINH07840
C      *****CINH07850
C      ARG1-AN ARRAY OF TEMPERATURES CORRESPONDING TO THE ARRAYS *VLDAY* CINH07860
C      AND *VLNITE*, DEGREES F                             CINH07870
C      ARG5-AN ARRAY OF TEMPERATURES CORRESPONDING TO THE ARRAYS *VSDAY* AND CINH07880
C      *VSNITE*, DEGREES F                                 CINH07900
C      BRDS-NO. OF BIRDS IN BUILDING                       CINH07910
C      DALYT-AN INDEX FOR DAY=1, FOR NITE=0                CINH07920
C      IBUG-AN INTEGER CODE USED FOR DEBUGGING THE PROGRAM CINH07930
C      QL-LATENT HEAT PRODUCTION OF BIRDS, BTU PER HOUR    CINH07940
C      QS-SENSIBLE HEAT PRODUCTION OF BIRDS, BTU PER HOUR CINH07950
C      T-INSIDE TEMPERATURE, DEGREES R AND F               CINH07960
C      TAB1-A TABLE LOOKUP FUNCTION SUBROUTINE            CINH07970
C      54321 CONTINUE                                       CINH07980
C      VLDAY-AN ARRAY OF DAYTIME LATENT HEAT PRODUCTION VALUES, BTU PER CINH07990
C      HOUR-BIRD                                           CINH08000
C      VLNITE-AN ARRAY OF NITETIME LATENT HEAT PRODUCTION VALUES, BTU PER CINH08010
C      HOUR-BIRD                                           CINH08020
C      VSDAY-AN ARRAY OF DAY TIME SENSIBLE HEAT PRODUCTION VALUES, BTU PER CINH08030
C      HOUR-BIRD                                           CINH08040
C      VSNITE-AN ARRAY OF NITE TIME SENSIBLE HEAT PRODUCTION VALUES, BTU CINH08050
C      PER HOUR-BIRD                                       CINH08060
C      W3RD-AVERAGE BIRD WEIGHT, LBS.                     CINH08070
C      WT-AVERAGE BIRD WEIGHT, LBS                       CINH08080
C      CINH08090
C      CINH08100
C      *****CINH08110
C      DIMENSION ARG5(7),ARG1(8),VSDAY(7),VSNITE(7),      CINH08120
C      1 VLDAY(8),VLNITE(8)                                CINH08130
C      EQUIVALENCE (WT,WBRD)                               CINH08140
C      COMMON/BUG/IBUG                                     CINH08150
C      COMMON/BIRDS/WBRD,BRDS                              CINH08160
C      DATA ARG5 /26.,34.,47.,56.,64.,84.,94./           CINH08170
C      DATA ARG1 /26.,34.,47.,56.,64.,74.,84.,94./       CINH08180
C      DATA VSDAY /11.1,8.3,7.3,6.6,6.5,6.3,6.2/        CINH08190
C      DATA VSNITE /6.9,6.8,6.1,5.3,5.1,3.6,6./         CINH08200
C      DATA VLDAY /1.7,2.1,2.3,3.2,3.3,3.4,4.2,5.3/     CINH08210
C      DATA VLNITE /1.6,2.0,1.9,2.6,2.2,2.0,3.5,4.7/     CINH08220
C      T=459.67                                             CINH08230
C      IF (DALYT.EQ. 0.) GO TO 2                            CINH08240
C      DAYTIME HEAT PRODUCTION CALCULATIONS                CINH08250
C      1 QS=WT*BRDS*TAB11(VSDAY,ARG5,T,7)                 CINH08260
C      QL=WT*BRDS*TAB11(VLDAY,ARG1,T,8)                   CINH08270
C      T=459.67                                             CINH08280
C      33 CONTINUE                                          CINH08290
C      IF (IBUG.EQ.0) GO TO 9999                            CINH08300
C      PRINT 6                                              CINH08310
C      6 FORMAT(/1X,10(1H), 'BRDHT',10(1H))               CINH08320
C      PRINT 9030                                           CINH08330
C      9030 FORMAT (1X, 'BRDHT', /9X, 'T', T53, 'DALYT', T39, 'QS', T53, 'CL') CINH08340
C      PRINT 9031, T, DALYT, QS, QL                       CINH08350
C      9081 FORMAT(2X,E14.2)                                CINH08360
C      9999 CONTINUE                                       CINH08370
C      RETURN                                              CINH08380
C      NIGHT TIME HEAT PRODUCTION CALCULATIONS            CINH08390
C      2 QS=WT*BRDS*TAB11(VSNITE,ARG5,T,7)                CINH08400
C      QL=WT*BRDS*TAB11(VLNITE,ARG1,T,8)                  CINH08410
C      T=459.67                                             CINH08420
C      GO TO 33                                             CINH08430
C      END                                                 CINH08440
C      SUBROUTINE CEILHT(TIN,TDB,Q)                        CINH08450
C      *****CINH08460
C      CINH08470
C      CINH08480
C      CINH08490
C      THIS SUBROUTINE DETERMINES THE BUILDING HEAT LOSS CINH08490

```



```

C THROUGH THE CEILING                                CINH06500
C                                                    CINH06510
C                                                    CINH06520
C *****CINH06530
C                                                    CINH06540
C                                                    CINH06550
C           DEFINITION OF TERMS                      CINH06560
C                                                    CINH06570
C           SEE MAIN PROGRAM FOR ACRONYMS NOT        CINH06580
C           LISTED HERE                               CINH06590
C                                                    CINH06600
C *****CINH06610
C                                                    CINH06620
C ACL--DEFINED IN CRITMP                             CINH06630
C BLTH-BUILDING LENGTH, FEET                         CINH06640
C HEIT-BUILDING HEIGHT, FEET                         CINH06650
C IBUG-AN INTEGER CODE USED FOR DEBUGGING THE PROGRAM CINH06660
C Q--HEAT TRANSFER THROUGH CEILING,BTU PER HOUR      CINH06670
C RCL--DEFINED IN CRITMP                             CINH06680
C TDB--DEFINED IN MAIN                               CINH06690
C TIN--DEFINED IN MAIN                              CINH06700
C WIDTH-BUILDING WIDTH, FEET                        CINH06710
C                                                    CINH06720
C                                                    CINH06730
C                                                    CINH06740
C *****CINH06750
C   COMMON/BUG/IBUG                                  INH06760
C   COMMON/BLDG/BLTH,WIDTH,HEIT                     INH06770
C   ACL=9LTH*WIDTH                                  INH06780
C   RCL=23.68                                         INH06790
C   Q=(TDB-TIN)*ACL/RCL                             INH08800
C   IF(TIN.LT.519.67) Q=0.                           INH08810
C *** DURING WINTER CEILING HEAT LOSS GOES TO ATTIC & IS RETURNED IN THE INH08820
C VENTILATING AIR OF MSU HOUSE #7. INSUMMER(TIN>519.67) AIR COMES CINH08830
C DIRECTLY FROM THE OUTSIDE.                        CINH08840
C   IF(1BUG.EQ.0) GO TO 9999                          INH08850
C   PRINT 7                                             INH08860
C   7 FORMAT(1X,10(1HW),'CEILHT',10(1HW))             INH08870
C   PRINT 9090                                         INH08880
C 9090 FORMAT(1X,'CEILHT',9X,'TIN',T25,'TDB',T39,'Q',T53,'ACL',T67,'RCL',INH08890
C       1T81,'BLTH',T95,'WIDTH')                     INH08900
C       PRINT 9091,TIN,TDB,Q,ACL,RCL,BLTH,WIDTH      INH08910
C 9091 FORMAT (2X,8E14.3)                             INH08920
C 9999 CONTINUE                                       INH08930
C       RETURN                                       INH08940
C       END                                           INH08950

                                                    INH08960
FUNCTION CPA(TDB)                                     INH08970
C *****CINH08980
C                                                    CINH08990
C                                                    CINH09000
C THIS SUBROUTINE FINDS THE APPROPRIATE VALUE FOR THE THERMAL CAPACITY CINH09010
C OF AIR                                              CINH09020
C                                                    CINH09030
C                                                    CINH09040
C *****CINH09050
C                                                    CINH09060
C                                                    CINH09070
C           DEFINITION OF TERMS                      CINH09080
C                                                    CINH09090
C           SEE MAIN PROGRAM FOR ACRONYMS NOT        CINH09100
C           LISTED HERE                               CINH09110
C                                                    CINH09120
C *****CINH09130
C CPA-THERMAL CAPACITY OF AIR, BTU/LB-F ---- OR DEGEES R CINH09140
C HTCPA-ARRAY VALUES OF THERMAL CAPACITIES, BTU/LB-F CINH09150
C TABLI-A TABLE LOOKUP FUNCTION SUBROUTINE         CINH09160
C TDB-INPUT DRY BULB TEMPERATURE, DEGREES R        CINH09170
C TEMP-ARRAY VALUES OF TEMPERATURE, DEGREES R     CINH09180
C TF-TEMPERATURE, DEGREES F                          CINH09190

```



```

1.67,1459.67,1959.67/
DATA HTC PW / .448,.493,.493,.476,.472,.477,.483,.498,.517,.564/
MBUG=18UG
DO 33 I=1,10
33 TF(I)=TEMPR(I)-459.67
IF(TDP-GT.529.67) GO TO 1
CPW=.448
IF(MBUG.NE.1) GO TO 8
PRINT 9
PRINT 55
PRINT 333,(TF(J),J=1,10),(HTCPW(K),K=1,10)
PRINT 200,TDP,CPW
9 CONTINUE
9 FORMAT(/IX,10(1HW),'CPW',10(1HW))
RETURN
1 CONTINUE
CPW=TABLE1(HTCPW,TEMPR,TDP,10)
IF(M3UG.EQ.0) GO TO 88
PRINT 55
55 FORMAT(1H0,10(1HCPW))
PRINT 333,(TF(J),J=1,10),(HTCPW(K),K=1,10)
333 FORMAT(4X,'TF',10F10.2/IX,'HTCPW',10F10.3)
PRINT 200,TDP,CPW
200 FORMAT(1X,'TDP, CPW,', 2E23.4)
88 CONTINUE
RETURN
END

```

```

FUNCTION CRITMPTSET,TOP,VRMIN,WATTSQ,ELPWAR)
C *****
C CRITMPTSET
C
C THIS SUBROUTINE CALCULATES THE MINIMUM OUTSIDE EQUALIBRIUM TEMPER-
C TURE TO MAINTAIN THE INSIDE TEMPERATURE AT THE SET VALUE.
C
C *****
C DEFINITION OF TERMS
C
C SEE MAIN PROGRAM FOR ACRONYMS NOT LISTED HERE
C
C *****
C ACL-EFFECTIVE WALL SURFACE AREA, SQ FT
C ALTH-BUILDING LENGTH, FEET
C CRITMPT-OUTSIDE TEMPERATURE AT WHICH HOUSE GENERATED HEAT IS IN BALANCE
C FOR THE GIVEN "MSET" INSIDE TEMPERATURE, DEGREES R
C ELHT- HEAT EQUIVALENT OF ELECTRIC POWER, BTU PWR HR
C ELPW-AN INDEX FOR LIGHTS, DN=1, OFF=0
C HEIT-BUILDING HEIGHT, FEET
C IBUG-AN INTEGER CODE USED FOR DEBUGGING THE PROGRAM
C QLTOT-LATENT HEAT PRODUCTION OF BIRDS, BTU PER HOUR
C QSTOT-SEE MAIN
C RCL-THERMAL RESISTIVITY OF THE CEILING, SQ FT-DEGREES F-HOUR PER BTU
54321 CONTINUE
C RWL-THERMAL RESISTIVITY OF THE WALL, SQ FT-DEGREES F-HOUR PER BTU
C TOP-OUTSIDE DEW POINT TEMPERATURE, DEGREES R
C TSET-DESIRED INSIDE TEMPERATURE, DEGREES R
C UXAREA-THERMAL AREA-RESISTIVITY RATIO FOR BUILDING, BTU PER HOUR-
C VRMIN-MINIMUM VENTILATION RATE OF HOUSE, CFM
C VS-MINIMUM MASS VENTILATION RATE, LB PER HOUR
C WATTSQ-ELECTRICAL POWER APPLIED TO BUILDING, WATTS PER SQ. FOOT
C WIDTH-BUILDING WIDTH, FEET
C *****

```



```

4.01582,.01697,.01819,.01948,.02086,.02233,.02389,.02555,.02731, INH11290
5.02919,.03118,.0333,.03556,.03795,.04049,.04319,.04606,.04911, INH11300
6.05234,.05578,.05944,.06333,.06746,.07185,.07652,.08149,.08678, INH11310
7.09262,.09841,.1049,.1116,.1189,.1267,.135,.1439,.1534,.1636, INH11320
8.1745,.1862,.1989,.2125,.2271,.243,.2602,.2788,.299,.3211,.3452, INH11330
9.3716,.4007,.4327,.4682,.5078,.5519,.6016,.6578,.7218,.7953,.8805, INH11347
2.9802,1.1,1.241,1.416,1.635,1.917,2.295/ INH11350
DATA TEMPF / INH11360
10.,5.,10.,15.,20.,25.,30.,32.,34.,36.,33.,40.,42.,44.,46.,48.,50., INH11370
252.,54.,56.,58.,60.,62.,64.,66.,68.,70.,72.,74.,76.,78.,80.,82., INH11380
384.,86.,88.,90.,92.,94.,96.,98.,100.,102.,104.,106.,108.,110.,112., INH11390
4,114.,116.,118.,120.,122.,124.,126.,128.,130.,132.,134.,136.,138., INH11400
5140.,142.,144.,146.,148.,150.,152.,154.,156.,158.,160.,162.,164., INH11410
6166.,168.,170.,172.,174.,176.,178.,180.,182.,184.,186.,188.,190., INH11420
7192.,194.,196.,198.,200./ INH11430
DATA ATMP/-1./ INH11440
IF(PATH.EQ.ATMP) GC TO 1 INH11450
DO 2 I=1,92 INH11460
2 HRATIO(I)=HADP(TEMPF(I)+459.67) INH11470
1 CONTINUE INH11480
DP =TABLI(TEMPF,HRATIO,HA,92) INH11490
DPHA=DP+459.67 INH11500
ATMP=PATH INH11510
RETURN INH11520
END INH11530

SUBROUTINE DRYHET (VENTRT,TIN,TDP,QEVAP,ELPHAR,TDE) INH11540
C ***** INH11550
C INH11560
C INH11570
C THIS SUBROUTINE CALCULATES THE HEAT USED FOR ALL EVAPORATION. INH11580
C INH11590
C INH11600
C ***** INH11610
C INH11620
C INH11630
C DEFINITION OF TERMS INH11640
C INH11650
C SEE MAIN PROGRAM FOR ACRONYMS NOT INH11660
C LISTED HERE INH11670
C INH11680
C ***** INH11690
C INH11700
C BLTH-BUILDING LENGTH, FEET INH11710
C DPT-DEWPOINT TEMPERATURE BASED ON CALCULATE INSIDE HUMIDITY RATIO, INH11720
C DEGREES R INH11730
C DRPSAR-SURFACE AREA OF DROPPINGS, SQ. FEET INH11740
C EVAPH2O-WATER EVAPORATED FROM WATERS, LBS. PER HOUR INH11750
C EVPMUR-WATER EVAPORATED FROM MANURE, LBS. PER HOUR INH11760
C HA-THE ABSOLUTE HUMIDITY AT THE OUTSIDE DEW POINT TEMPERATURE, LBS INH11770
C PER LB. INH11780
C HAINI-HUMIDITY RATIO OF INSIDE AIR AS FOUND FOR *DRYHET* CONDITIONS, INH11790
C LBS OF H2O PER LB OF DA INH11800
C HEIT-BUILDING HEIGHT, FEET INH11810
C I9UG-AN INTEGER CODE USED FOR DEBUGGING THE PROGRAM INH11820
C PATH-ATMOSPHERIC PRESSURE, PSI INH11830
C PS-SATURATED VAPOR PRESSURE AT THE DRY BULB TEMPERATURE, PSI INH11840
54321 CONTINUE INH11850
C QEVAP-THE HEAT TO EVAPORATE THE WATER FROM MANURE AND WATERS, BTU INH11860
C TDP-OUTSIDE DEW POINT TEMPERATURE, DEGREES R INH11870
C TIN-TEMPERATURE, INSIDE HOUSE, DEGREES (USED IN SUBROUTINES) INH11880
C TWB-WET BULB TEMPERATURE BASED ON CALCULATED INSIDE HUMIDITY RATIO, INH11890
C DEGREES R INH11900
C TWBI- INSIDE WETBULB TEMPERATURE, DEGREES R INH11910
C UNTEVP-TOTAL WATER EVAPORATED IN UNIT TIME, LBS. PER HOUR INH11920
C VENTRT-VENTILATION RATE THROUGH HOUSE AT TIME OF CALCULATION, CFM INH11930
C WATSAR-SURFACE AREA OF EXPOSED WATER IN HOUSE INH11940
C WIDTH-BUILDING WIDTH, FEET INH11950
C INH11960
C INH11970
C ***** INH11980

```



```

COMMON/BUG/IBUG
COMMON/BLDG/BLTH,WIDTH,HEIT
COMMON/EVP/DRPSAR,WATSAR
COMMON/PRESS/PATH
HA=HADD(TOP)
CALL BRDHT(TIN,ELPWAR,CSTOT,CLTGT)
CALL TWBINT(TIN,VENTRT,TWB1,CLTGT,HA,TDR)
CALL EVPKTR(UNTEVP,VENTRT,TIN,TWB1,EVPH20,EVPMUR,1)
HAIN1=HAIN1,CLTGT,TIN,VENTRT,UNTEVP,HA)
IF(HAIN1.GT..0007872) GO TO 3
PRINT 10,HAIN1
10 FORMAT(1X,15(7H DRYHET 1/1X,'ABSOLUTE HUMIDITY INSIDE IS:',G21.7)
1,' THE RETURNED VALUE IS: 0.0007872')
HAIN1=.0007872
IF(1BUG.EQ.0) IBUG=2
3 CONTINUE
DPI=DPHA(HAIN1)
IF(DPI.LT.TIN) GO TO 2
TWO=TIN
PRINT 9,DPI,TWO
9 FORMAT(1X,20(6H DRYHET)1X,'INSIDE DEWPOINT GREATER THAN DRYBULB.
10 DEWPOINT =',G21.7,' WETBULB SET AT:',G21.7)
GO TO 1
2 CONTINUE
TWO=WDPHA(TIN,HAIN1)
1 CONTINUE
CALL EVPKTR(UNTEVP,VENTRT,TIN,TWO,EVPH20,EVPMUR,1)
QEVAP=UNTEVP*HLD8(TIN)*(-1.)
IF(1BUG.EQ.0) GO TO 9999
PS=PSDB(TIN)
DRY=-9.
PRINT 11
11 FORMAT(1X,10(1HW),' DRYHET',10(1HW))
PRINT 9030
9030 FORMAT(1X,' DRYHET',9X,' VENTRT',T25,' TIN',T39,' TDP',T53,' DRPSAR',T67,
1,' WATSAR',T91,' EVPMUR',T95,' EVPH20',T109,' DEY',T123,' QEVAP',/10X
2,' BLTH',T26,' HA',T40,' HAIN1',T54,' PS',T68,' UNTEVP',T82,' DPI ')
PRINT 9031,VENTRT,TIN,TDP,DRPSAR,WATSAR,EVPMUR,EVPH20,DRY
10 EVAP,BLTH,HA,HAIN1,PS,UNTEVP,DPI
9031 FORMAT(2X,9E14.3/2X,6E14.3)
IF(1BUG.EQ.2) IBUG=0
9999 CONTINUE
RETURN
END

```

```

SUBROUTINE DRYRATE(VENTRT,TIN,TWO,DRYRT,DRYRTW,ME)
C *****
C C1NH12440
C C1NH12450
C C1NH12460
C THIS SUBROUTINE CALCULATES THE DRYING RATE USING THE HEAT TRANSFER COEFFICIENT
C C1NH12480
C AS OUTLINED BY PERRYS HANDBOOK PAGE 15-35. PARAMETERS ARE CALCULATED
C C1NH12490
C FROM DATA
C C1NH12500
C IN WELLS THESIS. (PERRYS 4TH ED 1963)
C C1NH12510
C C1NH12520
C C1NH12530
C *****
C C1NH12540
C C1NH12550
C C1NH12560
C DEFINITION OF TERMS
C C1NH12570
C C1NH12580
C SEE MAIN PROGRAM FOR ACRONYMS NOT
C C1NH12590
C LISTED HERE
C C1NH12600
C C1NH12610
C *****
C C1NH12620
C C1NH12630
C ALPHA-CONSTANT DETERMINED BY EXPERIMENT FOR DETERMINING THE HEAT
C C1NH12640
C TRANSFER COEFFICIENT.
C C1NH12650
C BDAAREA - AREA OF ONE BIRD IN CROSS SECTION, SQ. FT.
C C1NH12660
C BLTH-BUILDING LENGTH, FEET
C C1NH12670
C HMITMP-TEMPERATURE AT WHICH *DIFMNM* IS APPROPRIATE, DEGREES C
C C1NH12680

```



```

C CKAREA - APPROX. CROSS SECTIONAL AREA BLOCKED FOR AIR FLOW BY BIRDS, CINH12690
C SQ FT. CINH12700
C CRCTMP-TEMPERATURE AT WHICH *DIFCR* IS APPROPRIATE, DEGREES C CINH12710
C DC-CHARACTERISTIC DIMENSION OF THE DRYING SURFACE, FEET CINH12720
C (THE LENGTH OF THE AIR PATH OVER THE DRYING SURFACE) CINH12730
54320 CONTINUE INH12740
C DELTA-X-DIFFERENCE IN ELEVATION OF WATER SURFACE AND WATERER RIM, FT. CINH12750
C DIFCR-DIFFUSION COEFFICIENT AS FOUND IN CRC HANDBOOK, SQ.CM./SEC CINH12760
C DIFHMN-DIFFUSION COEFFICIENT AS FOUND IN HEAT TRANSFER BY HOLMAN, SQ CINH12770
C DIFSN-DIFFUSION COEFFICIENT, SQ CM/SEC. CINH12780
C DRYW-ALTERNATE VALUE FOR *DRYRTM* CINH12790
C DRYRTM-THE DRYING RATE AS CALCULATED, LBS. OF WATER PER HOUR-SQ.FT. CINH12800
C COEFFICIENT CINH12810
C DRYRTM-THE DRYING RATE AS CALCULATED FOR WATER SURFACES, LBS OF WATER CINH12820
C PER HOUR-SQ FT CINH12830
C DRYW-ALTERNATE VALUE FOR *DRYRTM* CINH12840
C EXPN-A CONSTANT DETERMINED BY EXPERIMENT FOR DETERMINING THE HEAT TRANS CINH12850
C G-MASS VELOCITY, WEIGHT RATE OF FLOW PER CROSSSECTIONAL AREA, LBS./HR.CINH12860
C SQ FT CINH12870
C HEIT-BUILDING HEIGHT, FEET CINH12880
C HT-HEAT TRANSFER COEFFICIENT, BTU/HR.-SQ.FT.-F CINH12890
C LAMBDA-LATENT HEAT OF VAPORIZATION FOR WATER AT TEMPERATURE OF MATERIA CINH12900
C MBUG-CODED FACTOR FOR DESIRED PRINTOUT AS NOTED ELSEWHERE CINH12910
C ME-A CODED INDEX TO SHOW FROM WHICH SOURCE *DRYRTM* IS CALLED,2=TWB CINH12920
C 1=OTHER CINH12930
C MDTM-MASS FLOW RATE OF WATER VAPOR, LBS/HR-SQ. FT. CINH12940
C MW-MOLECULAR WEIGHT OF WATER CINH12950
54321 CONTINUE INH12960
C ONELG-THE ONE-HALF CIRCUMFERENCE OF A 2 CM DROPPING, CM CINH12970
C PA1-THE DIFFERENCE BETWEEN BAROMETRIC PRESSURE AND SATURATED VAPOR CINH12980
C PRESSURE OF THE AIR, PSI CINH12990
C PA2-THE DIFFERENCE BETWEEN BAROMETRIC PRESSURE AND THE VAPOR PRESSURE CINH13000
C OF THE AIR, PSI CINH13010
C PATM-ATMOSPHERIC PRESSURE,PSI CINH13020
C PI-THE CONSTANT RATIO OF CIRCUMFERENCE TO DIAMETER CINH13030
C RQ-UNIVERSAL GAS CONSTANT, LB.FT./LR DEGREEES R CINH13040
C ROWS - NUMBER OF ROWS OF CAGES THRU HOUSE CINH13050
C TEMRT-RATE OF CHANGE FOR DIFFUSION WITH TEMPERATURE, SQ CM/SEC. C CINH13060
C TIN-THE TEMPERATURE OF THE DRYING AIR, DEGREEES R CINH13070
C TS-TEMPERATURE OF MATERIAL BEING DRIED (WELLS P. 70) DEGREEES R CINH13080
C TWB-WET BULB TEMPERATURE OF VENTILATING AND/OR DRYING AIR, DEGREEES R CINH13090
C VEL-VELOCITY OF DRYING AIR OVER MATERIAL ON BELT, FT/MIN CINH13100
C VENTRT-THE VENTILATION RATE IN THE HOUSE AT TIME OF CALCULATION, CINH13110
C CFM OUTSIDE AIR CINH13120
C WATW-T-NOTH OF WATERERS, FEET CINH13130
C WB - WET BULB TEMPERATURE USED TO CALCULATE DRYRTM. CINH13140
C WIDTH-BUILDING WIDTH, FEET CINH13150
C CINH13160
C CINH13170
C *****CINH13180
C COMMON/PRESS/PATM INH13190
C COMMON/LOG/BLTH,WIDTH,HEIT INH13200
C COMMON/DRY/DRYM,DRYW INH13210
C COMMON/BIRDS/WBRD,BRDS INH13220
C COMMON/BUG/IBUG INH13230
C REAL LAMBDA,MDTM INH13240
C WB=TWB INH13250
C IF(TWB.LE.TIN) GO TO 2 INH13260
C WB=TIN-.91 INH13270
C WRITE(3,12) INH13280
C INH13290
12 FORMAT(1X,10(1H),,'DRYRTM',10(1H)) INH13300
C WRITE(3,10) VEL,TIN,WB,DC,G,HT,TS,LAMBDA,DRYRTM,DRYRTM INH13310
C WRITE(3,1) TWB,TIN,WB INH13320
C 1 FORMAT(1X,13(1H),1X,'WET BULB LARGER THAN DRY BULB TEMPERATURE. INH13330
C 1 TWB=',G21.8,10X,'TIN=',G21.8,10X,'DEGREEES RANKINE'/ INH13340
C 21X,'WET BULB RESET TO:',G21.8) INH13350
C 2 CONTINUE INH13360
C PI=355./113. INH13370
C EXPN=.40202222 INH13380
C ALPHA=.1222427622 INH13390
C ONELG=PI*.2/.2. INH13400
C DC=(ONELG/(2.54*12.))

```



```

C  WELLS SAYS TS SHOULD BE WB+.9 BUT ALPHA AND EXPN ARE DETERMINED USING
  TS=WB
  LAMBDA=LDB(TS)
  ROWS=4.
  BDAREA=0.2
  CKAREA=(BRDS/RCWS)*BDAREA
  VEL=ABS(VENTRT)/((HEIT*3LTH)-CKAREA)
  G=(VEL/VSD3HA(TIN,HAPV(PVDBWD(TIN, WB))) )*.60.
  HT=(ALPHA*(G**EXPN))/(DC*(1.-EXPN))
  DRYRTM=(HT/LAMBDA)*(TIN-TS)
C  FROM HEAT TRANSFER BY HOLMAN P. 260
  DIFCRC=.239
  DIFHMN=.256
  CRCTMP=.8.
  HMNTHP=.25.
  TEMRTE=(DIFHMN-DIFCRC)/(HMNTHP-CRCTMP)
  DIFSN=(DIFCRC+TEMRTE*((TIN-459.67)-32.)*5./9.)*3600.*1.07639E-3
  MW=18.
  RD=1545.
  DELTAX=2./12.
  PA2=PATH-PVDBWD(TIN, WB)
  PA1=PATH-PCB(TIN)
  MDOTW=((DIFSN*PATH*MW)/(RD*TIN*DELTAX))*ALOG(PA2/PA1)
  DRYRTW=MDOTW*144.
  DRY4=DRYRTM
  DRY4=DRYRTW
  IF(BUG.EQ.0) GO TO 88
  PRINT 55
55  FORMAT(1H0,10(10HDRYRATE ))
  PRINT 10,VEL,TIN, WB,DC,G,HT,TS,LAMBDA,DRYRTM,DRYRTW
10  FORMAT(/7X'VEL',T21,'TIN',T35,' WB ',T48,'DC',T62,'G',T76,'HT',T91,
  'TS',T104,'LAMBDA',T1X,8E14.4/T7,'DRYRTM',T21,'DRYRTW',T2E14.4)
98  CONTINUE
  RETURN
  END

```

SUBROUTINE DRYSRF (EXSMHS, WATLGT, WATWDT, DRPSAR, WATSAR, DRYVSUF) INH13790

***** INH13770

C INH13780

C INH13790

C THIS SUBROUTINE FINDS INH13800

C THE SURFACE AREA OF WATERERS AND MANURE FOR DRYING INH13810

C INH13820

C INH13830

***** INH13840

C INH13850

C INH13860

C INH13870

C INH13880

C SEE MAIN PROGRAM FOR ACRONYMS NOT INH13890

C LISTED HERE INH13900

C INH13910

***** INH13920

C INH13930

C DRPNUM=NUMBER OF DROPPINGS OF EXCRETA AS ACCUMULATED THRU THE DAY INH13940

C DRPSAR=SURFACE AREA OF DROPPINGS, AS ACCUMULATED THRU THE DAY, SQ. FT. INH13950

C DRYVSUF=TOTAL SURFACE AREA FOR DRYING, SQ. FEET INH13960

C IBUG=AN INTEGER CODE USED FOR DEBUGGING THE PROGRAM INH13970

C PLYWTH=THE WIDTH OF THE DROPPING BOARDS, FT. INH13980

C WATLGT=LENGTH OF WATERERS, FEET INH13990

C WATSAR=SURFACE AREA OF EXPOSED WATER IN HOUSE , SQ. FEET. INH14000

C WATWDT=WIDTH OF WATERING TROUGHS, WATER SURFACE, FEET INH14010

C INH14020

C INH14030

***** INH14040

C CMNCK/BUG/IBUG INH14050

C COMMON/RATE/DRPNUM INH14060

C DRPSAR=DRPNUM*.0067573 INH14070

C PLYWTH=10./12 INH14080

C DRYSRF=PLYWTH*WATLGT INH14090

C WATSAR=WATLGT*WATWDT INH14100


```

DRYSUF=DRPSAR+WATSAR
IF (IBUG.EQ.0) GO TO 9999
PRINT 13
13 FORMAT (/1X,10(1HW),'DRYSRF',10(1HW))
PRINT 9020
9020 FORMAT (1X'DRYSRF'/9X'EXSMHS',T25,'WATLGT',T39,'WATWDT',T53,'DRPSAR',
1,'T67','WATSAR',T81,'DRYSUF',T95,'DRPNUM')
PRINT 9021, EXSMHS,WATLGT,WATWDT,DRPSAR,WATSAR,DRYSUF
1,DRPNUM
9021 FORMAT (1X,7E14.3)
9999 CONTINUE
RETURN
END

```

```

INNH14110
INNH14120
INNH14130
INNH14140
INNH14150
INNH14160
INNH14170
INNH14180
INNH14190
INNH14200
INNH14210
INNH14220
INNH14230

```

```

SUBROUTINE ELHEAT(WATTSQ,ELPWR,ELHT)
C *****
C INNH14240
C INNH14260
C INNH14270
C THE PURPOSE OF THIS SUBROUTINE IS TO COMPUTE THE HEAT ADDED BY
C ELECTRIC LIGHTS. AKWATT IS APPLIED POWER IN THE POULTRY BUILDING.
C WATTSQ IS THE WATTAGE PER SQUARE FOOT. ELPWR IS AN INDEX
C INDICATING POWER IS ON OR OFF. 3413 IS THE WATTAGE TO DTU
C CONVERSION FACTOR
C INNH14300
C INNH14340
C INNH14350
C *****
C INNH14360
C INNH14370
C DEFINITION OF TERMS
C INNH14380
C INNH14390
C SEE MAIN PROGRAM FOR ACRONYMS NOT
C LISTED HERE
C INNH14400
C INNH14420
C *****
C INNH14430
C INNH14440
C AKWATT-ELECTRIC POWER APPLIED IN THE BUILDING, KILOWATTS
C BLTH-BUILDING LENGTH, FEET
C ELHT- HEAT EQUIVALENT OF ELECTRIC POWER, BTU PER HR
C ELPWR-AN INDEX INDICATION LIGHTS ARE ON OR OFF
C HEIT-BUILDING HEIGHT, FEET
C IBUG-AN INTEGER CODE USED FOR DEBUGGING THE PROGRAM
C WATTSQ-ELECTRICAL POWER APPLIED TO BUILDING, WATTS PER SQ. FOOT
54321 CONTINUE
C WIDTH-BUILDING WIDTH, FEET
C INNH14520
C INNH14530
C INNH14540
C INNH14550
C *****
C INNH14560
C COMMON/BUG/IBUG
C COMMON/BLDG/BLTH,WIDTH,HEIT
C AKWATT=WATTSQ*BLTH*WIDTH/1000.
C ELHT=AKWATT*3413./ELPWR
C IF (IBUG.EQ.0) GO TO 9999
PRINT 15
15 FORMAT (/1X,10(1HW),'ELHEAT',10(1HW))
PRINT 9050
9050 FORMAT (1X,'ELHEAT',/9X,'WATTSQ',T25,'ELPWR',T39,'ELHT',T53,
1AKWATT')
PRINT 9051, WATTSQ,ELPWR,ELHT,AKWATT
9051 FORMAT (9X,4E14.3)
9999 CONTINUE
RETURN
END

```

```

INNH14240
INNH14250
INNH14260
INNH14270
INNH14280
INNH14290
INNH14300
INNH14310
INNH14320
INNH14330
INNH14340
INNH14350
INNH14360
INNH14370
INNH14380
INNH14390
INNH14400
INNH14410
INNH14420
INNH14430
INNH14440
INNH14450
INNH14460
INNH14470
INNH14480
INNH14490
INNH14500
INNH14510
INNH14520
INNH14530
INNH14540
INNH14550
INNH14560
INNH14570
INNH14580
INNH14590
INNH14600
INNH14610
INNH14620
INNH14630
INNH14640
INNH14650
INNH14660
INNH14670
INNH14680
INNH14690
INNH14700
INNH14710

```

```

SUBROUTINE EVPKTR (UNTEVP,VENTRT,TIN,TWB,EVPH2O,EVPMUR,MEI)
C *****
C INNH14730
C INNH14740
C INNH14750
C THIS SUBROUTINE CALCULATES WATER REMOVED FROM THE WATERERS, THE
C MANURE AND THE SUM OF THESE TWO.
C DRYING WATER IS ADDED TO AIR FROM MANURE AND WATERERS(ASSUME NO

```

```

INNH14720
INNH14730
INNH14740
INNH14750
INNH14760
INNH14770
INNH14780

```



```

C SPILLS H2O REMOVED FROM MANURE IN UNIT TIME          CINH14790
C                                                         CINH14800
C                                                         CINH14810
C ***** CINH14820
C                                                         CINH14830
C                                                         CINH14840
C          D E F I N I T I O N   U F   T E R M S          CINH14850
C                                                         CINH14860
C          S E E   M A I N   P R O G R A M   F O R   A C R O N Y M S   N U T
C          L I S T E D   H E R E                           CINH14870
C                                                         CINH14880
C ***** CINH14890
C                                                         CINH14900
C          C B R D T M P - B O D Y   T E M P E R A T U R E   O F   A   L A Y I N G   H E N ,   D E G R E E S   R          CINH14910
C          C D R P S A R - S U R F A C E   A R E A   O F   D R O P P I N G S ,   S Q .   F E E T          CINH14920
C          C D R Y R T M - T H E   D R Y I N G   R A T E   A S   C A L C U L A T E D ,   L B S .   O F   W A T E R   P E R   H O U R - S Q . F T . CINH14930
C          C D R Y R T W - T H E   D R Y I N G   R A T E   A S   C A L C U L A T E D   F O R   W A T E R   S U R F A C E S ,   L B S   O F   W A T E R CINH14950
C          C P E R   H O U R - S Q   F T          CINH14960
C          C D T - L E N G T H   O F   I T E R A T I O N ,   H O U R S          CINH14970
C          C E V P H 2 O - W A T E R   R E M O V E D   F R O M   W A T E R S ,   L B S   P E R   H O U R          CINH14980
C          C E V P M F T - T O T A L   W A T E R   E V A P O R A T E D   I N   H O U S E   F R O M   M A N U R E ,   L B S .          CINH14990
C          C E V P M U R - W A T E R   E V A P O R A T E D   F R O M   M A N U R E ,   L B S .   P E R   H O   R          CINH15000
C          C E V P I S T - T H E   M O I S T U R E   E V A P O R A T E D   F R O M   M A N U R E   A S   A   R E S U L T   O F   I T S   I N I T I A L CINH15010
C          T E M P E R A T U R E   B E I N G   G R E A T E R   T H A N   A M B I E N T   T E M P . ,   L B S   P E R   H O U R          CINH15020
C          54321   C O N T I N U E          I N H I 5030
C          C E X C D M C - T H E   M O I S T U R E   C O N T E N T   O F   M A N U R E   A S   D E F I C A T E D ,   D E C I M A L   F R A C T I O N CINH15040
C          C E X H T S M - W E I G H T   O F   E X C R E T A   A S   A C C U M U L A T E D   T H R U   T H E   D A Y ,   L B S          CINH15050
C          C H L I S T - L A T E N T   H E A T   O F   E V A P O R A T I O N   E S T I M A T I O N   W H I L E   D R Y I N G   M A N U R E   W I T H          CINH15060
C          C          I N I T I A L   B O D Y   H E A T ,   B T U / L B          CINH15070
C          C I B U G - A N   I N T E G E R   C O D E   U S E D   F O R   D E B U G G I N G   T H E   P R O G R A M          CINH15080
C          C M E - A   C O D E D   I N D E X   T O   S H O W   F R O M   W H I C H   S O U R C E   * D R Y K A T *   I S   C A L L E D , 2 = T W B I CINH15090
C          C          1 = C T H E R          CINH15100
C          C Q I S T - T H E   E X T R A   H E A T   I N   T H E   M A N U R E   A S   A   R E S U L T   O F   I T S   I N I T I A L          CINH15110
C          C          T E M P E R A T U R E   B E I N G   G R E A T E R   T H A N   A M B I E N T ,   B T U   P E R   H O U R          CINH15120
C          C S P M - T H E   S P E C I F I C   H E A T   O F   M A N U R E , B T U / L B - D E G R E E   F          CINH15130
C          C T I N - T E M P E R A T U R E ,   I N S I D E   H O U S E ,   D E G R E E S   R ( U S E D   I N   S U B R O U T I N E S )          CINH15140
C          C T W - W E T   B U L B   T E M P E R A T U R E   B A S E D   O N   C A L C U L A T E D   I N S I D E   H U M I D I T Y   R A T I O ,          CINH15150
C          C          D E G R E E S   R          CINH15160
C          C U N T E V P - T O T A L   W A T E R   E V A P O R A T E D   I N   U N I T   T I M E ,   L B .   P E R   H O U R          CINH15170
C          C V E N T R T - T H E   V E N T I L A T I O N   R A T E   I N   T H E   H O U S E   A T   T I M E   O F   C A L C U L A T I O N ,          CINH15180
C          C          C F M   O U T S I D E   A I R          CINH15190
C          C W A T S A R - S U R F A C E   A R E A   O F   E X P O S E D   W A T E R   I N   H O U S E   S Q .   F T .          CINH15200
C          C          C F M          CINH15210
C          C          CINH15220
C ***** CINH15230
C          C O M M O N / C R T / K C L , R W L , S P M , E X R A T E          I N H I 5240
C          C O M M O N / B U G / I B U G          I N H I 5250
C          C C M H D R / C / E X C D M C , E X H T D , E X H T S M , E V P M F T , D T          I N H I 5260
C          C O M M O N / E V P / D R P S A R , W A T S A R          I N H I 5270
C          C A L L   D R Y R A T I V E N T R T , T I N , T W B , D R Y R T M , D R Y R T W , M E I          I N H I 5280
C          C B R D T M P = 1 0 7 . 1 + 4 5 9 . 6 7          I N H I 5290
C          C Q I S T = E X H T D * S P M + ( B R D T M P - T I N ) / D T          I N H I 5300
C          C H L I S T = H L D R I ( 9 9 0 T M P + T I N ) / 2 . )          I N H I 5310
C          C E V P I S T = Q I S T / H L I S T          I N H I 5320
C          C E V P M U R = D R Y R T M * D R P S A R + E V P I S T          I N H I 5330
C          C R W T R W T = E X H T S M * E X C D M C - E V P M F T          I N H I 5340
C          C I F ( K W T R W T * . 9 - E V P M U R / D T ) 1 , 2 , 2          I N H I 5350
C          C          1   E V P M U R = . 9 * R W T R W T / D T          I N H I 5360
C          C          W R I T E ( I , 3 )   E V P M U R          I N H I 5370
C          C          3   F O R M A T ( I X , I 2 0 ( I H W ) , 5 X , ' E V P M U R ' / I X , ' D R Y I N G   B E L O W   C O N S T A N T   R A T E   W A T E R I N H I 5380
C          C          1 R   R E M O V E D   L I M I T E D   T O : ' , 6 2 1 . 7 )          I N H I 5390
C          C          I F ( I B U G . E Q . 0 )   I B U G = 2          I N H I 5400
C          C          2   C O N T I N U E          I N H I 5410
C          C          H 2 O   R E M O V E D   F R O M   W A T E R S   I N   U N I T   T I M E          CINH15420
C          C          E V P H 2 O = D R Y R T W * W A T S A R          CINH15430
C          C          T O T A L   H 2 O   E V A P O R A T E D   I N   U N I T   T I M E          CINH15440
C          C          U N T E V P = E V P M U R + E V P H 2 O          I N H I 5450
C          C          I F ( I B U G . E Q . 0 )   G O   T O   9 9 9 9          I N H I 5460
C          C          P R I N T   1 6 ,   D F Y R T W          I N H I 5470
C          C          1 6   F O R M A T ( I X , I 0 1 ( I H W ) , ' E V P M U R ' , I 0 1 ( I H W ) , 1 0 X , ' D R Y R T W = ' , E 1 4 . 4 )          I N H I 5480
C          C          P R I N T   4 0 4 0          I N H I 5490
C          C          9 0 4 0   F O R M A T ( I X ' E V P M U R ' / 9 X ' D R Y R T M ' , I 2 5 , ' D R P S A R ' , I 3 9 , ' W A T S A R ' , I 5 3 , ' E V P M U R I N H I 5500

```



```

SUBROUTINE EXCRTA (BIRDNO,DF,EXWTSY,EXWTD)
C *****
C INH15580
C ***** CINH15590
C CINH15600
C CINH15610
C THIS SUBROUTINE CALCULATES DAILY MANURE PRODUCTION. CINH15620
C MANURE PRODUCTION RATE TAKEN FROM ESMAY, ET. AT ISLW,1975 CINH15630
C MANURE PRODUCTION = 0.272 LBS/DAY - HEN CINH15640
C CINH15650
C CINH15660
C ***** CINH15670
C CINH15680
C CINH15690
C D E F I N I T I O N   O F   T E R M S CINH15700
C CINH15710
C SEE MAIN PROGRAM FOR ACRONYMS NOT CINH15720
C LISTED HERE CINH15730
C CINH15740
C ***** CINH15750
C CINH15760
C BIRDNO= NC. OF BIRDS IN BUILDING CINH15770
C DF = EXCRETA DISTRIBUTION FACTOR, FRACTION OF DAILY EXCRETA PRODUCED CINH15780
C DURING PERIOD OF *DT*, LB. CINH15790
C EGRT=EGG PRODUCTION RATIO, DECIMAL CINH15800
C EXRATE=RATE OF MANURE EXERTION, LBS OF MANURE PER BIRD-DAY CINH15810
C EXWTD=MANURE PRODUCED DURING TIME DT, LBS CINH15820
C EXWTS=WEIGHT OF EXCRETA AS ACCUMULATED THRU THE DAY, LBS CINH15830
C EXWTD=WEIGHT OF EXCRETA PER DAY, LBS. CINH15840
C IBUG=AN INTEGER CODE USED FOR DEBUGGING THE PROGRAM CINH15850
C CINH15860
C CINH15870
C ***** CINH15880
C CMMCN/CRT/RCL,RWL,SPM,EXRATE INH15890
C COMMON/BUG/IBUG INH15900
C EXWTDY=EXRATE*BIRDNO INH15910
C EXWTD=EXWTDY*OF INH15920
C EXWTS=EXWTSM+EXWTD INH15930
C IF (IBUG.EQ.0) GO TO 9999 INH15940
C EGRT= 0.69 INH15950
C PRINT 14 INH15960
C 14 FORMAT(1X,10(1HW),'EXCRAT',10(1HW)) INH15970
C PRINT 9010 INH15980
C 9010 FORMAT(1X,EXCRAT,'/9X',BIRDNO,'T25,'EGRT',T39,'EXWTD',T53,'EXWTDY') INH15990
C PRINT 9011,BIRDNO,EGRT,EXWTC,EXWTDY INH16000
C 9011 FORMAT (2X,5E14.3) INH16010
C 9999 CONTINUE INH16020
C RETURN INH16030
C END INH16040

```

```

SUBROUTINE FLHRT (T,TSLAB,INDIC,Q)                                INH16050
C *****                                                    INH16060
C                                                    INH16070
C THIS SUBROUTINE DETERMINES THE BUILDING HEAT LOSS              INH16080
C THROUGH THE FLOOR SLAB.                                       INH16090
C                                                    INH16100
C                                                    INH16110
C                                                    INH16120
C *****                                                    INH16130
C                                                    INH16140
C                                                    INH16150
C           D E F I N I T I O N   O F   T E R M S              INH16160
C                                                    INH16170
C           SEE MAIN PROGRAM FOR ACRONYMS NOT                   INH16180

```



```

C          LISTED HERE                                CINHI6190
C          CINHI6200
C ***** CINHI6210
C          CINHI6220
C          BLTH-BUILDING LENGTH, FEET                CINHI6230
C          CAMU-PRODUCT OF FLOOR UTILIZATION, AREA, SPECIFIC HEAT, AND MASS CINHI6240
C          HEIT-BUILDING HEIGHT, FEET                CINHI6250
C          HTFLO-HEAT TRANSFER PER UNIT FLOOR AREA, BTU PER HOUR-SQ. FT.  CINHI6260
C          IBUG-AN INTEGER CODE USED FOR DEBUGGING THE PROGRAM CINHI6270
C          54321 CONTINUE                             INHI6280
C          C INDIC-AN INDEX TO CHANGE SLAB TEMPERATURE E.G. DAILY NOT EACH CINHI6290
C          CALCULATION                                CINHI6300
C          Q-HEAT TRANSFER THROUGH FLOOR, BTU PER HOUR CINHI6310
C          T-INSIDE TEMPERATURE, DEGREES R AND F     CINHI6320
C          TSLAB-TEMPERATURE OF FLOOR SLAB, DEGREES R AND F CINHI6330
C          UTILIZ-PORTION OF FLOOR NOT COVERED BY MANURE, SQ FT CINHI6340
C          WIDTH-BUILDING WIDTH, FEET                CINHI6350
C          CINHI6360
C          CINHI6370
C ***** CINHI6380
C          COMMON/BUG/IDUG                             INHI6390
C          COMMON/BLOG/BLTH,WIDTH,HEIT              INHI6400
C          COMMON/WTHR/AVTOBO,RANGE,ATMP,MC,IO,IY,TDPF,VARDTA INHI6410
C          T=T+459.67                                  INHI6420
C          TSLAB=TSLAB+459.67                        INHI6430
C          UTILIZ=.25                                  INHI6440
C          HEAT FLOW PER SQ FT                        CINHI6450
C          HTFLO=1.65*(TSLAB-(T+AVTOBO)/2)           INHI6460
C          TOTAL HEAT FLOW                            CINHI6470
C          Q=HTFLO*BLTH*WIDTH*UTILIZ                INHI6480
C          IF (INDIC .NE. 1) GO TO 2                 INHI6490
C          NEW SLAB TEMPERATURE                      CINHI6500
C          SPECIFIC HEAT=0.156, PERRY P.3-136        CINHI6510
C          CAMU=UTILIZ*0.156*BLTH*WIDTH*(10./12.)*120. INHI6520
C          1 TSLAB=TSLAB+.5*HTFLO/CAMU              INHI6530
C          INDIC=0                                     INHI6540
C          2 CONTINUE                                 INHI6550
C          T=T+459.67                                  INHI6560
C          TSLAB=TSLAB+459.67                        INHI6570
C          IF (IGUG.EQ.0) GO TO 9999                 INHI6580
C          PRINT 17                                    INHI6590
C          17 FORMAT(1X,10(1HW),'FLORHT',10(1HW))    INHI6600
C          PRINT 9110                                  INHI6610
C          9110 FORMAT (1X,'FLORHT',/9X,' T',T25,'TSLAB',T39,'INDIC',T53,'C',T67,'INHI6620
C              1HTFLO')                                INHI6630
C              PRINT 9111,T,TSLAB,INDIC,Q,HTFLO      INHI6640
C          9111 FORMAT (2X2E14.3,114,2E14.3)         INHI6650
C          9999 CONTINUE                             INHI6660
C          RETURN                                      INHI6670
C          END                                          INHI6680

C          FUNCTION HAIN(IGTOT,TIN,VENTRT,UNTEVP,H4)  INHI6690
C ***** CINHI6700
C          CINHI6710
C          CINHI6720
C          THIS SUBROUTINE CALCULATES THE INSIDE ABSOLUTE HUMIDITY CINHI6730
C          CINHI6740
C          CINHI6750
C ***** CINHI6760
C          CINHI6770
C          CINHI6780
C          DEFINITION OF TERMS                       CINHI6790
C          SEE MAIN PROGRAM FOR ACRONYMS NOT         CINHI6800
C          LISTED HERE                                CINHI6810
C          ***** CINHI6820
C          ***** CINHI6830
C          ***** CINHI6840
C          ***** CINHI6850
C          AIRLBI-AN ESTIMATE OF THE MASS RATE OF VENTILATION, LBS OF AIR CINHI6860
C          PER MINUTE                                  CINHI6870
C          AIRLBY-AIR FLOW RATE, LBS PER MIN          CINHI6880

```



```

C BROTMP-BODY TEMPERATURE OF A CHICKEN, DEGREES R                CINH16890
C HA-ABSOLUTE HUMIDITY OF INCOMING AIR, LBS PER LB                CINH16900
C HAIEST - AN ESTIMATE OF THE INSIDE ABSOLUTE HUMIDITY, LBS PER LB CINH16910
C HAIN-ABSOLUTE HUMIDITY OF INSIDE AIR, LBS PER LB                CINH16920
C HL-LATENT HEAT OF EVAPORATION AT CHICKEN BODY TEMPERATURE, BTU PER LBCINH16930
C IBUG-AN INTEGER CODE USED FOR DEBUGGING THE PROGRAM            CINH16940
C QL-LATENT HEAT FROM THE HENS, BTU/HR                            CINH16950
C QLTOT-LATENT HEAT PRODUCTION OF BIRDS, BTU PER HOUR            CINH16960
54321 CONTINUE                                                    INH16970
C RESPI- AN ESTIMATE OF THE MASS MOISTURE RESPIRATION RATE PER UNIT OF CINH16980
C VENTILATION AIR, LB OF MOISTURE PER LB OF VENTILATED AIR        CINH16990
C RESPIR-MOISTURE ADDED TO AIR BY BIRD RESPIRATION, LBS OF WATER PER CINH17000
C LB OF AIR                                                        CINH17010
C TIN-TEMPERATURE, INSIDE HOUSE, DEGREES RIUSED IN SUBROUTINES) CINH17020
C UEVPM-UNIT EVAPORATION RATE, LBS OF WATER PER MIN.              CINH17030
C UNT-TOTAL WATER EVAPORATED IN UNIT TIME (SAME AS UNTEVP), BL/HR CINH17040
C UNTEVP-TOTAL WATER EVAPORATED IN UNIT TIME, LBS. PER HOUR       CINH17050
C VENTRT-THE VENTILATION RATE IN THE HOUSE AT TIME OF CALCULATION,CFM CINH17060
C                                                                    CINH17070
C                                                                    CINH17080
C *****CINH17090
C COMMON/PRESS/PATH
COMMON/BUG/IBUG
AIRLB1=VENTRT/V$DBHA(TIN,HA)
UEVPM=UNTEVP/60.
BROTMP=107.1+455.67
HL=HLDB(BROTMP)
RESPI=(QLTOT/(HL*60.))/AIRLB1
HAIEST=HA+RESPI
AIRLBM=VENTRT/V$DBHA(TIN,HAIEST)
RESPIR=(QLTCT/(HL*60.))/AIRLBM
HAIN=HA+UEVPM/AIRLB1+RESPIR
IF(BUG.EQ.0) GO TO 9999
PRIIT 5
5 FORMAT (1X,10(HAIN,RW40.))
PRINT 55,TIN,RESPIR,QLTOT,AIRLBM,HAIN,HA,UEVPM,UNTEVP,VENTRT
55 FORMAT(7X,'TIN',T21,'RESPIR',T35,'QLTCT',T48,'AIRLB1',T62,'HAIN',
176,'HA',T90,'UEVPM',T104,'UNTEVP',T118,'VENTRT'/1X9E14.4)
9999 CONTINUE
RETURN
END
INH17100
INH17110
INH17120
INH17130
INH17140
INH17150
INH17160
INH17170
INH17180
INH17190
INH17200
INH17210
INH17220
INH17230
INH17240
INH17250
INH17260
INH17270
INH17280
INH17290

SUBROUTINE HEAD                                                    INH17300
C *****CINH17310
C                                                                    CINH17320
C THIS SUBROUTINE WRITES THE HEADING FOR A TABLE                 CINH17330
C                                                                    CINH17340
C                                                                    CINH17350
C                                                                    CINH17360
C                                                                    CINH17370
C *****CINH17380
C PRINT 13
13 FORMAT (1H1)
PRINT 14
14 FORMAT(1X,'TABLE 2 COMPARISON OF WEATHER AND POULTRY HOUSE EXPERIMINH17420
ENTAL CONDITIONS WITH EXPERIMENTAL AND CALCULATED MANURE MOISTURE INH17430
2CONTENT.')
```



```

13 FORMAT (IHL)
PRINT 1
1 FORMAT( 9X,'THEORETICAL WATER REMOVAL AND MOISTURE CONTENT (WET
2 BASIS) OF POULTRY MANURE AFTER DRYING WITH UNHEATED',/
3 9X,'VENTILATING AIR. THE MANURE IS AS DROPPED IN A CAGE LAYING
46 HOUSE WITH DROPPING BOARDS.',/9X,'INSIDE VALUES ARE THEORETICAL
5 EXHAUST AIR')
PRINT2
2 FORMAT (//1X ,T73,'MANURE', T98,'MANURE'/1X
1 ,TOUTSIDE',T16,'OUTSIDE', T30,'FLOW RATE', T44,'INSIDE', T58
2 ,TINSIDE',T73,'WATER REMOVED - LBS',T96,'MOISTURE CONTENT - PERCENT
AT TIME', /1X 'DRY BULB', T16,'DEW POINT', T30,'CFM',
1T129,'HRS',
BT44,'DRY BULB', T58,'DEW POINT', T72,'ONE HOUR', T86,'LISTED',
CT100,'AT END', T114,'AT END',/1X,'DEGREES F', T16,'DEGREES F',
DT44,'DEGREES F', T58,'DEGREES F', T72,'CF DRYING', T86,'HOURS
EF', T100,'OF ONE', T114,'OF LISTED',/1X,T86,'DRYING', T100,INH17750
F'HOUR',T114,'HOURS',/4X,'(1)',T20,'(2)',T34,'(3)',T48,'(4)',T62,'(5)',
G5),T74,'(6)',T88,'(7)',T102,'(8)',T115,'(9)',T128,'(10)',/
RETURN
END
INH17590
INH17600
INH17610
INH17620
INH17630
INH17640
INH17650
INH17660
INH17670
INH17680
INH17690
INH17700
INH17710
INH17720
INH17730
INH17740
INH17750
INH17760
INH17770
INH17780
INH17790

SUBROUTINE HDSTR(ELTH,WIDTH,HEIT,RWL,RCL,QMECH,WATLGH,WATWDT, INH17800
-WBFD,BRDS,BRDTMF,EXDCMC,DF,SPN,EXRATE, TMINF,DT, INH17810
-BTIME,RUMLGT,INDIC,ELPWAR,TSETF,VRMAX,VRMIN,TSLABF) INH17820
C ***** INH17830
C THIS SUBROUTINE PRINTS A TABLE GIVING THE DATE, DESIGN PARAMETERS, INH17840
C MANAGEMENT CONDITIONS, WEATHER, AND SIMULATION DETAILS FOR THE INH17860
C SPECIFIC COMPUTER RUN AND DATE. INH17870
C INH17880
C ***** INH17890
C DEFINITION OF TERMS INH17900
C INH17910
C SEE MAIN PROGRAM FOR ACRONYMS NOT INH17920
C LISTED HERE INH17930
C INH17940
C ***** INH17950
C COMMON/WTNR/AVTDBC,RANGE,ATMP,HG,ID,IY,TDPF,VARDTA INH17960
PRINT 1,MG,IC,IY INH17970
1 FORMAT(IHL,1X,'DESIGN VALUES USED DURING SIMULATION FOR DATA OF', INH17990
212,'/1',12,'/1',12/) INH18000
PRINT 2,BLTH,WIDTH,HEIT,RWL,RCL,QMECH INH18010
2 FORMAT(1X,'BUILDING: /5X,LENGTH, FT',T45,F10.2/5X,'WIDTH, FT', INH18020
T45,F10.2/5X,'CEILING HEIGHT, FT',T45,F10.2/5X,'INSULATION-WALLS, INH18030
#HF-F=SQ FT/STU',T45,F10.2/5X,'INSULATION-CEILING, HR-F=SQ FT/STU',INH18040
T45,F10.2/5X,'LIGHTING HEAT, BTU/HR',T45,F10.2) INH18050
PRINT 20,WATLGH,WATWDT INH18060
20 FORMAT(5X,'WATERER LENGTH, FT',T45,F10.2/5X,'WATERER WIDTH, FT',T45,INH18070
T5,F10.2) INH18080
PRINT 3,BRDS,WBFD,BRDTMF,EXDCMC,DF,SPN,EXRATE INH18090
3 FORMAT(1X,'LAYING HENS: /5X,'NUMBER OF HENS',T45,F10.2/5X,'HEN WEIGH INH18100
-IGHT, LBS',T45,F10.2/5X,'BODY TEMPERATURE, F',T45,F10.2/5X, INH18110
/'EXCRETA MOISTURE CONTENT, %',T45,2PF10.2/5X,'EXCRETA DISTRIBUTION INH18120
# FACTOR',T45,OPF10.2/5X,'SPECIFIC HEAT OF MANURE, BTU/LB-F', INH18130
T45,F10.2/5X,'EXCRETA PRODUCTION RATE, LBS/HEN-DAY',T45,F10.2) INH18140
PRINT 4,TSETF,VRMAX,VRMIN,TSLABF INH18150
4 FORMAT(1X,'VENTILATION: /5X,'INSIDE DESIGN(SET) TEMPERATURE, F',TINH18160
T45,F10.2/5X,'MAXIMUM VENTILATING RATE, CFM',T45,F10.2/5X,'MINIMUM INH18170
SUBM VENTILATING RATE, CFM',T45,F10.2/5X,'INITIAL SLAB TEMPERATURE, INH18180
F',T45,F10.2) INH18190
PRINT 5,ATMP,AVTDBC,RANGE,TMINF INH18200
5 FORMAT(1X,'WETBULB: /5X,'ATMOSPHERIC PRESSURE, PSI',T45,F10.2/ INH18210
-5X,'AVERAGE OUTSIDE TEMPERATURE, F',T45,F10.2/5X,'OUTSIDE TEMPERATURE INH18220
DURE RANGE, F',T45,F10.2/5X,'CRITICAL LOW OUTSIDE TEMPERATURE, F', INH18230
BT45,F10.2) INH18240
PRINT 6, DT,BTIME,RUMLGT,INDIC,ELPWAR INH18250
6 FORMAT(1X,'SIMULATION DETAILS: /5X,'TIME INCREMENT-DT, HOURS', INH18260
T45,F10.2/5X,'STARTING TIME, CLOCK HOURS',T45,F10.2/5X, INH18270
T5,'LENGTH OF RUN, HOURS',T45,F10.2/5X,'SLAG INDEX',T45,18 /5X, INH18280

```



```

**LIGHTING INDEX*,T45,F10.2/1H1)
PUNCH 11,MO,10,1Y
11 FORMAT( 'DESIGN VALUES USED DURING SIMULATION FOR DATA OF',
  212,' ',12,' ',12)
PUNCH 2,BLTH,WIDTH,HEIT,KWL,FCL,QMECH
PUNCH 3,BFDS,WORD ,BRDTMF,EXCDMC,DF,SPM,EXRATE
PUNCH 4,TSETF,VRMAX,VRMIN,TSLABF
PUNCH 5,ATMP,AVTDBO,RANGE,TMINF
PUNCH 6,DT,BTIME,RUNLGT,INDIC,ELPHAR
PUNCH 7
7 FORMAT(33(2H- ),' -1')
RETURN
END
INHI8290
INHI8300
INHI8310
INHI8320
INHI8330
INHI8340
INHI8350
INHI8360
INHI8370
INHI8380
INHI8390
INHI8400
INHI8410

SUBROUTINE TEMCES (WATTSQ,ELPHAR,ST,TAV,TO,TOAVE,TSLAB,INDIC,
  IVENTRT,TCB,TOP,TI,QNETT,TIDP)
*****CINHI8420
C *****CINHI8430
C *****CINHI8440
C *****CINHI8450
C *****CINHI8460
C *****CINHI8470
C *****CINHI8480
C *****CINHI8490
C *****CINHI8500
C *****CINHI8510
C *****CINHI8520
C *****CINHI8530
C *****CINHI8540
C *****CINHI8550
C *****CINHI8560
C *****CINHI8570
C *****CINHI8580
C *****CINHI8590
C *****CINHI8600
C *****CINHI8610
C *****CINHI8620
C *****CINHI8630
C *****CINHI8640
C *****CINHI8650
C *****CINHI8660
C *****CINHI8670
C *****CINHI8680
C *****CINHI8690
C *****CINHI8700
C *****CINHI8710
C *****CINHI8720
C *****CINHI8730
C *****CINHI8740
C *****CINHI8750
C *****CINHI8760
C *****CINHI8770
C *****CINHI8780
C *****CINHI8790
C *****CINHI8800
C *****CINHI8810
C *****CINHI8820
C *****CINHI8830
C *****CINHI8840
C *****CINHI8850
C *****CINHI8860
C *****CINHI8870
C *****CINHI8880
C *****CINHI8890
C *****CINHI8900
C *****CINHI8910
C *****CINHI8920
C *****CINHI8930
C *****CINHI8940
C *****CINHI8950
C *****CINHI8960
C *****CINHI8970
C *****CINHI8980
C *****CINHI8990
C *****CINHI9000
COMMON/PRESS/PATH
COMMON/BUG/BUG
CALL ELHEAT (WATTSQ,ELPHAR,ELHT)
CALL BROHT (TI,ELPHAR,QSTOT,QLTCT)
CALL CEILHT (TI,TDB,QCTOT)
CALL WALLHT (TI,TDB,QWTOT)
CALL FLORHT (TI,TSLAB,INDIC,CFTOT)
CALL DRYHET (VENTRT,TI,TOP,QEVAP,ELPHAR,TDB)

```



```

C      THE HEAT PICKED UP BY THE VENTILATING AIR
VS=VSDHAI(TI,HADP(TIDP))
QVENT=(VENTRT/VS)*(CPA(TI)+CPW(TIDP))*HADP(TIDP)*(TDB-TI)*60.
QNETT=ELHT+QSTOT+QLTOT+QLTOT+QWTOT+QFTOT+QVENT+QEVAP-QLTOT
30 CONTINUE
IF(18UG.EQ.0) GO TO 9999
PRINT 20
20 FORIAT/1X,10(1HW),'TEMGES',10(1HW))
PRINT 9120
9120 FORMAT (1X,'TEMGES',/T10,'WATTSQ',T24,'ELPHAR',T38,'ST',T52,'TAV',
1T66,'TO',T80,'TOAVE',T94,'TSLAB',T108,'INDIC',/10X,'VENTRT',T26
2,'TDB',T38,'TDP',T52,' I ',T66,'QNETT',T80,'ELHT',T94,'QSTOT'
3,T108,'QLTOT',/10X,'QWTOT',T24,'QFTOT',T38,'QVENT',T52,'QEVAP',
4T66,'QCTOT')
PRINT 9121,WATTSQ,ELPHAR,ST,TAV,TO,TOAVE,TSLAB,INDIC,VENTRT,
1 TDB,TDP,TI,QNETT,ELHT,QSTOT,QLTOT,QWTOT,QFTOT,QVENT,CEVAP,
2QCTOT
9121 F6MAT (2X7E14.3,114/2X3E14.3/2X5E14.3)
9999 CONTINUE
RETURN
END
CINH18990
CINH19000
CINH19010
CINH19020
CINH19030
CINH19040
CINH19050
CINH19060
CINH19070
CINH19080
CINH19090
CINH19100
CINH19110
CINH19120
CINH19130
CINH19140
CINH19150
CINH19160
CINH19170
CINH19180
CINH19190

SUBROUTINE TEMPI (TGES,VENTRT,WATTSQ,ELPHAR,TSLAB
1,INDIC,TDB,TDP,TEMPI,TIDP)
C *****
C
C THIS SUBROUTINE DETERMINES THE INSIDE TEMPERATURE BY A HEAT BALANCE.
C
C *****
CINH19200
CINH19210
CINH19220
CINH19230
CINH19240
CINH19250
CINH19260
CINH19270
CINH19280
CINH19290
CINH19300
CINH19310
CINH19320
CINH19330
CINH19340
CINH19350
C *****
C
C DQNETT-DIFFERENCE DIFFERENTIAL OF QNETT, BTU/(HR-DEGREE R)
C ELPHAR-AN INDEX FOR LIGHTS, ON=1, OFF=0
C GES-INPUT VALUE OF TGES
C 18UG-AN INTEGER CODE USED FOR DEBUGGING THE PROGRAM
C INDIC-AN INDEX TO CHANGE SLAB TEMPERATURE E.G. DAILY NOT EACH
C CALC.
C JT-COUNTER USED FOR NEWTONIAN CONVERGENCE
54321 CONTINUE
C QNETTM-NET HEAT FOR FUNCTION MINUS ONE, BTU PER HR.
C QNETTN-NET HEAT FOR FUNCTION, BTU PER HR.
C QNETTP-NET HEAT FOR FUNCTION PLUS ONE, BTU PER HR.
C ST-ADJUSTED CEILING SOL-AIR TEMPERATURE, DEGREES F
C TAV-AVERAGE SOL-AIR TEMPERATURE, DEGREES F
C TDB-OUTSIDE DRY BULB TEMPERATURE, DEGREES R
C TDP-OUTSIDE DEW POINT TEMPERATURE, DEGREES R
C TEMPI-THE INSIDE TEMPERATURE OBTAINED BY CONVERGENCE, DEGREES R
C TGES-AN INTERMEDIATE GUESS VALUE USED FOR CONVERGENCE, DEGREES R
C TO-OUTSIDE WALL SURFACE TEMPERATURE, DEGREES F
C TOAVE-AVERAGE OUTSIDE TEMPERATURE, DEGREES R AND F
C TP-AN ARRAY OF TEMPERATURES USED FOR NEWTONIAN CONVERGENCE, DEGREES F
C TSLAB-TEMPERATURE OF FLOOR SLAB, DEGREES R AND F
C VENTRT-THE VENTILATION RATE IN THE HOUSE AT TIME OF CALCULATION, CFM
C WATTSQ-ELECTRICAL POWER APPLIED TO BUILDING, WATTS PER SQ. FOOT
C
C *****
CINH19360
CINH19370
CINH19380
CINH19390
CINH19400
CINH19410
CINH19420
CINH19430
CINH19440
CINH19450
CINH19460
CINH19470
CINH19480
CINH19490
CINH19500
CINH19510
CINH19520
CINH19530
CINH19540
CINH19550
CINH19560
CINH19570
CINH19580
CINH19590
CINH19600
CINH19610
CINH19620
CINH19630
C
DIMENSION TP(10)
C4MGN/BUS/18UG
DATA ST,TAV,TOAVE,TO/4*-9./
GES=TGES
C BEGIN NEWTONIAN CONVERGENCE
CINH19640
CINH19650
CINH19660
CINH19670
CINH19680

```



```

      DO 500 JT=1,9
      TP(JT)=TGES-1.
      CALL TEMGES (WATTSQ,ELPWAR,ST,TAV,TC,TOAVE,TSLAB,INDIC,VENTRT,TDB,
1      TTOP,TP(JT),QNETTM,TIDP)
      TP(JT)=TGES+1.
      CALL TEMGES (WATTSQ,ELPWAR,ST,TAV,TC,TOAVE,TSLAB,INDIC,VENTRT,TDB,
1      TTOP,TP(JT),QNETTP,TIDP)
      CALL TEMGES (WATTSQ,ELPWAR,ST,TAV,TC,TOAVE,TSLAB,INDIC,VENTRT,TDB,
1      TTOP,TP(JT),QNETTP,TIDP)
      QNETT=(QNETTP-QNETTM)/2.
      TP(JT+1)=TP(JT)-QNETTM/QNETT
      IF (TP(JT+1)-TP(JT)).LE.1.) GO TO 502
      TGES=TP(JT+1)
500 CONTINUE
      PRINT 1500
1500 FORMAT (1X'SUBROUTINE TEMPIN ERROR NOT LESS THAN 1 DEGREE F')
502 CONTINUE
      TEMPI=TGES
      IF (IBUG.EQ.0) GO TO 9999
      IF (TEMPI.GT.120+459.67)IBUG=2
      PRINT 21
      21 FORMAT (/1X,10(1HW),'TEMPIN',10(1HW))
      PRINT 9130
9130 FORMAT (1X,'TEMPIN',/9X,'GES',T25,'VENTRT',T39,'WATTSQ',T53,'
      1ELPWAR',T67,'ST',T81,'TAV',T95,'TOAVE',T109,'TSLAB',T123,'INDIC',
      2/10X,'TDB',T26,'TDP',T40,'TEMPI',T54,'TP(JT)',T68,'QNETT',T82
      3,'QNETTM',T96,'QNETTP',T110,'QNETTN')
      PRINT 9131,GES,VENTRT,WATTSQ,ELPWAR,ST,TAV,TOAVE,TSLAB,INDIC,TDB,
      1 TDP,TEAPI,TP(JT),QNETT,QNETTM,QNETTN
9131 FORMAT (2X8E14.3,114/2X8E14.3)
      IF (IBUG.EQ.2) IBUG=0
9999 CONTINUE
      RETURN
      END
      SUBROUTINE TWBIN(TIN,VENTRT,TkBI,QL ,HA,TDB)

```

```

C *****CINH20050
C CINH20060
C CINH20070
C THIS SUBROUTINE DETERMINES THE WETBULB TEMPERATURE BY EQUATING THE CINH20080
C SUM OF AIR VAPOR SOURCES TO THE PSYCHROMETRICALLY DETERMINED ABSOLUTE CINH20090
C HUMIDITY THRU A NEWTONIAN CONVERGENCE. CINH20100
C CINH20110
C CINH20120
C *****CINH20130
C CINH20140
C CINH20150
C      D E F I N I T I O N   O F   T E R M S
C CINH20160
C      SEE MAIN PROGRAM FOR ACRONYMS NOT
C      LISTED HERE
C CINH20170
C CINH20180
C CINH20190
C CINH20200
C *****CINH20210
C CINH20220
C DFX - DERIVATIVE OF *FX *, (LBS OF H2O/LBS OF AIR)/DEGREE R
C CINH20230
C FXM, FXH, FXP - A FUNCTION OF *VB* EQUAL TO ZERO WITH THE CORRECT
C CINH20240
C      VALUE OF WBOS
C CINH20250
C HA-HUMIDITY RATIO FOR OUTSIDE AIR,LB OF H2O PER LB OF DA
C CINH20260
C TWBI- INSIDE WETBULB TEMPERATURE, DEGREES R
C CINH20270
C WB(I)-INTERMEDIATE WETBULB TEMPERATURE, DEGREE R
C CINH20280
C WBGS-A GUESS WETBULB TEMPERATURE FOR USE WITH NEWTONIAN CONVERGENCE,
C CINH20290
C      DEGREE R
C CINH20300
C WBGS1-FIRST GUESS FOR WB, DEGREES R
C CINH20310
C CINH20320
C CINH20330
C *****CINH20340
C CINH20350
C CMMCA/BUG/IBUG
C CMMCA/PRESS/PATM
C DIMENSION WB(10)
C WBOS=TIN
C CINH20360
C CINH20370
C CINH20380

```



```

      IF(TIN.LT.492.) GO TO 492
      WBG5=WBDBHA(TIN,HADBRH(TIN,0.5))
492  CONTINUE
      WBG51=WBG5
      DO 50 I=1,9
      WB(I)=WBG5+1.
400  CONTINUE
      CALL EVPWTR(UNT , VENTRT, TIN, WB(I),EVPH20,EVPMUR,2)
      FXP=HAIN(QL/2.,TIN,VENTRT,UNT/2.,HA)-HAPV(PVDBWB(TIN,WB(I)))
      WB(I)=WBG5-1.
      CALL EVPWTR(UNT , VENTRT, TIN, WB(I),EVPH20,EVPMUR,2)
      FXM=HAIN(QL/2.,TIN,VENTRT,UNT/2.,HA)-HAPV(PVDBWB(TIN,WB(I)))
      WB(I)=WBG5
      CALL EVPWTR(UNT , VENTRT, TIN, WB(I),EVPH20,EVPMUR,2)
      FXM=HAIN(QL/2.,TIN,VENTRT,UNT/2.,HA)-HAPV(PVDBWB(TIN,WB(I)))
      DXF=(FXP-FXM)/2.
      WB(I+1)=WB(I)-FXM/DXF
      IF(WB(I+1)-WB(I)).LE.1.1.AND.WB(I+1)-WB(I).GE.0.)GO TO 52
      WBG5=ABS(WB(I+1))
50  CONTINUE
      PRINT 1500
1500 FORMAT (1X,'SUBROUTINE TW3IN ERROR NOT LESS THAN 1 DEGREE F')
52  CONTINUE
      TWBI=WBG5
      IF(1BUG.EQ.0) GO TO 9999
      PRINT 21
21  FORMAT(1X,10(1HW),' TWBIN ',10(1HW))
      PRINT 23,TIN,VENTRT,TWBI,WBG51
23  FORMAT(9X,'TIN',T25,'VENTRT',T39,'TWBI',T53,'WBG51'/2X,4E14.5)
      PRINT 22,FXP,FXM,FXM,DXF
22  FORMAT(5X,' FXP',T23, 'FXM',T37, 'FXM',T55,'DXF'/2X,4E14.5)
9999 CONTINUE
      RETURN
      END
      SUBROUTINE VENTRAT(WATTSQ,ELPWR, TDB ,TIN ,TDP ,DPI,
      1AVTDBO,TSAB,VENTG,INDIC,IND, 2CONST,VENTR,VRMAX)
C *****
C
C
C THIS SUBROUTINE DETERMINES THE VENTILATION RATE BY A HEAT BALANCE.
C
C
C *****
C
C
C D E F I N I T I O N O F T E R M S
C
C
C SEE MAIN PROGRAM FOR ACRONYMS NOT
C LISTED HERE
C
C *****
C
C
C AVSCLT-AVERAGE SOL-AIR TEMPERATURE, DEGREES F
C AVTDBO-AVERAGE OUTSIDE TEMPERATURE, DEGREES F
C DNET -DIFFERENCE DIFFERENTIAL OF JNET
C DPI-INSIDE DEWPOINT TEMPERATURE (SAME AS TIDPI), DEGREES F
C DRPSAR-SURFACE AREA OF DROPPINGS, SQ. FEET
C ELHT- HEAT EQUIVALENT OF ELECTRIC POWER, BTU PER HR
C ELPWR-AN INDEX INDICATION LIGHTS ARE ON OR OFF
C IND-AN INDICATOR TO BY PASS CONVERGENCE
C INDIC-AN INDEX TO CHANGE SLAB TEMPERATURE E.G. DAILY RATHER THAN EACH MINUTE
C JK-COUNTER USED FOR NEWTONIAN CONVERGENCE
C QCONST-THE SUM OF HEAT BALANCE FACTORS REMAINING CONSTANT DURING CONVCN
C , BTU PER HR.
54321 CONTINUE
C OCTOT-HEAT TRANSFER THROUGH CEILING, BTU PER HOUR
C OFTUT-HEAT TRANSFER THROUGH FLOOR, BTU PER HOUR
C QLTOT-LATENT HEAT PRODUCED BY SIKOS, BTU PER HOUR
C QNET-MET HEAT FOR FUNCTION MINUS ONE, BTU PER HR.
C QNETN-NET HEAT FOR THE FUNCTION, BTU PER HR.

```



```

C QNETP-NET HEAT FOR FUNCTION PLUS ONE, BTU PER HR. CINH21090
C QSTCT-SENSIBLE HEAT PRODUCED BY BIRCS, BTU PER HOUR CINH21100
C QWTOT-HEAT TRANSFER THROUGH WALLS, BTU PER HOUR CINH21110
C SOLT-ADJUSTED CEILING SOL-AIR TEMPERATURE, DEGREES F CINH21120
C TDB-OUTSIDE DRY BULB TEMPERATURE, DEGREES R CINH21130
C TDBO2-OUTSIDE WALL SURFACE TEMPERATURE, DEGREES R CINH21140
C TOP-OUTSIDE DEW POINT TEMPERATURE, DEGREES R CINH21150
C TIN-TEMPERATURE, INSIDE HOUSE, DEGREES R (USED IN SUBROUTINES) CINH21160
C TSLAB-TEMPERATURE OF FLOOR SLAB, DEGREES R AND F CINH21170
C V-THE ERROR IN VENTILATING RATE AT END OF CONVERGENCE, CFM CINH21180
C VENTG-AN INTERMEDIATE GUESS VALUE FOR VENTILATION RATE (SUBROUTINE VACINH21190
C VENTR-THE VENTILATION RATE IN THE HOUSE AT GIVEN TIME (SUBROUTINE VALCINH21200
C , CFM CINH21210
C VR-AN ARRAY OF VENTILATION RATES USED FOR NEWT. CONVERGENCE. CFM CINH21220
C VRMAX-MAXIMUM VENTILATION RATE OF HOUSE, CFM CINH21230
C WATSAR-SURFACE AREA OF EXPOSED WATER IN HOUSE CINH21240
C WATTSQ-ELECTRICAL POWER APPLIED TO BUILDING, WATTS PER SQ. FOOT CINH21250
C CINH21260
C CINH21270
C *****CINH21280
C DIMENSION VR(22) INH21290
C COMMON/EVP/DRPSAR,WATSAR INH21300
C COMMON/BUG/IBUG INH21310
C DATA AVSOLT,SOLT,TDBO2/3*-9./ INH21320
C CALL ELHEAT(WATTSQ, ELPWR,ELHT) INH21330
C CALL BROHT (TIN,ELPWR,QSTCT,QLTOT) INH21340
C CALL CEILHT (TIN,TDB,QCTOT) INH21350
C CALL WALLHT (TIN,TDB,QWTCT) INH21360
C CALL FLOORHT (TIN,TSLAB,INDIC,QFTOT) INH21370
C QCONST=ELHT+QSTCT+QLTOT+QCTOT+QWTCT+QFTOT -QLTOT INH21380
C IF(IND.EC.2) GO TO 2 INH21390
C BEGIN NEWTONIAN CONVERGENCE OF VENTILATION RATE CINH21400
DO 400 JK=1,20 INH21410
VR(JK)=VENTG-.01*VENTG INH21420
CALL VNTNET (VP(JK),TDB,TOP,TIN,QCONST,QNETM,ELPWR,DPI) INH21430
VR(JK)=VENTG+.01*VENTG INH21440
CALL VNTNET (VR(JK),TDB,TOP,TIN,QCONST,QNETP,ELPWR,DPI) INH21450
VR(JK)=VENTG INH21460
CALL VNTNET (VR(JK),TDB,TOP,TIN,QCONST,QNETN,ELPWR,DPI) INH21470
QNET=(QNETP-QNETM)/(+.02*VENTG) INH21480
VR(JK+1)=VR(JK)+QNETN/QNET INH21490
VENTG=VP(JK+1) INH21500
IF(VR(JK+1)-VR(JK)).LE..01*VRMAX.AND.VR(JK+1)-VR(JK).GE.0.) GO TO CINH21510
1 402 INH21520
400 CONTINUE INH21530
V=VR(JK+1)-VR(JK) INH21540
PRINT 1000 ,V INH21550
1000 FORMAT(1X,'AN ERROR IN SUBROUTINE VENFATE,THE VENTILATION RATE NOT INH21560
1 LESS THAN .01 X VRMAX,V-ERROR=',E14.5) INH21570
GO TO 20 INH21580
402 CONTINUE INH21590
IF(VENTG.LT.0.) IBUG=2 INH21600
VENTR=ABS(VENTG) INH21610
2 CONTINUE INH21620
IF(IBUG.EQ.0) GO TO 9999 INH21630
20 CONTINUE INH21640
PRINT 240,VENTG INH21650
240 FORMAT(1X,2(7HVENRAT ),'VENTG=',G20.9) INH21660
PRINT 22 INH21670
22 FORMAT(1X,10(1HW),'VENFAT',10(1HW)) INH21680
PRINT 9060 INH21690
9060 FORMAT (2X,'VENRATE',/9X,'WATTSQ',T25,'ELPWR',T39,'TDB',T53,'TIN',INH21700
1T67,'TOP',T51,'SOLT',T95,'AVSOLT',T105,'TDBO2',T123,'AVTDB',/ INH21710
210X,'TSLAB',T26,'VENTG',T40,'INDIC',T54,'QCONST',T68,'QCONST', INH21720
3T82,'VENTR',T92,'VRMAX',T105,'DRPSAR',T124,'WATSAR'/11X,'QNETM',T27 INH21730
4,'QNETP',T41,'QNETN',T55,'QNET',T69,'VR(JK)') INH21740
PRINT 9061,WATTSQ,ELPWR,TDB,TIN,TOP,SOLT,AVSOLT,TDBO2,AVTDBO, INH21750
TSLAB,VENTG,INDIC,QCONST,QCONST,VENTR,VRMAX,DRPSAR,WATSAR,QNETM, INH21760
QNETP,QNETN,QNET,VR(JK) INH21770
9061 FORMAT (2X9(14.3/2X)E14.3,114,6E14.3/2X)E14.3) INH21780
IF(1E05.EQ.2) IBUG=0 INH21790
9999 CONTINUE INH21800

```



```

4 CONTINUE
RETURN
END
INM21810
INM21820
INM21830

SUBROUTINE VNTNET (VENTG,TDB,TDP,TIN,QCONST,QNET,ELPWAR,DPI) INM21840
C ***** INM21850
C INM21860
C INM21870
C THIS SUBROUTINE CALCULATES THE HEAT USED INM21880
C FOR VENTILATION,QVENT, AND THE INM21890
C NET HEAT BALANCE, QNET, INM21900
C IN THE HEAT BALANCE EQUATION. C INM21910
C INM21920
C INM21930
C ***** INM21940
C INM21950
C INM21960
C DEFINITION OF TERMS C INM21970
C INM21980
C SEE MAIN PROGRAM FOR ACRONYMS NOT C INM21990
C LISTED HERE C INM22000
C INM22010
C ***** INM22020
C INM22030
C DPI=INSIDE DEWPOINT TEMPERATURE (SAME AS TIDP), DEGREES R C INM22040
C DRPSAR=SURFACE AREA OF DRIPPINGS, SQ. FEET C INM22050
C EVAPH2O=WATER EVAPORATED FROM WATERS, LBS. PER HOUR C INM22060
C EVPMUR=WATER EVAPORATED FROM MANURE, LBS. PER HOUR C INM22070
C QCONST=THE SUM OF HEAT BALANCE FACTORS REMAINING CONSTANT DURING C INM22080
C CONVERGENCE CALC., BTU PER HR. C INM22090
C QEVAP=THE HEAT TO EVAPORATE THE WATER FROM MANURE AND WATERS, BTU C INM22100
C PER HR C INM22110
C QNET=NET HEAT FLOW FROM HEAT BALANCE AND USED FOR CONVERGENCE, C INM22120
C IDEALLY ZERO, BTU PER HOUR C INM22130
C QVENT= HEAT EXCHANGED BY VENTILATING AIR, BTU/HR C INM22140
54321 CONTINUE INM22150
C TDB=OUTSIDE DRY BULB TEMPERATURE, DEGREES R C INM22160
C TDP=OUTSIDE DEW POINT TEMPERATURE, DEGREES R C INM22170
C TIN=TEMPERATURE, INSIDE HOUSE, DEGREES RIUSED IN SUBROUTINES) C INM22180
C VENTG=AN INTERMEDIATE GUESS VALUE FOR VENTILATION RATE,CFM C INM22190
C VS=AN ESTIMATE OF THE SPECIFIC VOLUME OF THE VENTILATING AIR, CU.FT. C INM22200
C PER LB C INM22210
C WATSAR=SURFACE AREA OF EXPOSED WATER IN HOUSE C INM22220
C C INM22230
C C INM22240
C ***** C INM22250
C COMMON/RESS/PATH C INM22260
C COMMON/EVP/DRPSAR,WATSAR C INM22270
C COMMON/BUG/IBUG C INM22280
C VS=VSDBA(TIN,HADP(DPI)) C INM22290
C QVENT=(VENTG/VS)*(CPA(TIN)+CPW(TDP)*HADP(DPI))*(TDB-TIN) *60. C INM22300
C CALL DRYHET (VENTG,TIN,TDP,QEVAP,ELPWAR,TDB) C INM22310
C QNET=QCONST+QVENT+QEVAP C INM22320
C IF(IBUG.EQ.0) GO TO 9999 C INM22330
C PRINT 23 C INM22340
23 FORMAT (1X,10(1HW),'VNTNET',10(1HW)) C INM22350
C DRY =-7. C INM22360
C EVPMUR=-1. C INM22370
C EVPH2O=-1. C INM22380
C DPHA=HADP(TDP) C INM22390
C PRINT 9070 C INM22400
9070 FORMAT (1X,'VNTNET',/9X,'VENTG',T25,'TDB',T39,'TDP',T53,'TIN',T67, C INM22410
1'DRY ',T81,'DRPSAR',T95,'WATSAR',T109,'QCONST',T123,'QNET', C INM22420
2'10X,'QVENT',T26,'HADP',T40,'EVPMUR',T54,'EVPH2O',T68,'DRY ', C INM22430
3T81,'QEVAP') C INM22440
C PRINT 9071,VENTG,TDB,TDP,TIN,DRY ,DRPSAR,WATSAR,QCONST,QNET, C INM22450
1 QVENT,DPHA, EVPMUR,EVPH2O,DRY ,QEVAP C INM22460
9071 FORMAT (2X9E14.3/2X6E14.3) C INM22470
9999 CONTINUE C INM22480
RETURN C INM22490
END C INM22500

```



```

      SUBROUTINE WALLHT(TIN,TDB,Q)                                INH22510
C *****CINH22520
C CINH22530
C CINH22540
C THIS SUBROUTINE DETERMINES THE BUILDING HEAT LOSS            CINH22550
C THROUGH THE WALLS                                           CINH22560
C *** SINCE END OF ROOM WITH BIRDS NOT EXPOSED DIRECTLY TO OUTSIDE, CINH22570
C *** ASSUME 1/2 HEAT LOSS.                                  CINH22580
C CINH22590
C CINH22600
C *****CINH22610
C CINH22620
C CINH22630
C      D E F I N I T I O N   O F   T E R M S                CINH22640
C CINH22650
C      SEE MAIN PROGRAM FOR ACRONYMS NOT                      CINH22660
C      LISTED HERE                                           CINH22670
C *****CINH22680
C *****CINH22690
C AWL--DEFINED IN CRITMP                                     CINH22700
C BLTH--BUILDING LENGTH, FEET                               CINH22710
C HEIT--BUILDING HEIGHT, FEET                               CINH22720
C 54321 CONTINUE                                             CINH22730
C INH22740
C IBUG--AN INTEGER CODE USED FOR DEBUGGING THE PROGRAM      CINH22750
C Q--HEAT TRANSFER THROUGH WALLS,BTU PER HOUR              CINH22760
C RKL--DEFINED IN CRITMP                                     CINH22770
C TDB-- DEFINED IN MAIN                                       CINH22780
C TIN-- DEFINED IN MAIN                                       CINH22790
C WIDTH--BUILDING WIDTH, FEET                                CINH22800
C *****CINH22810
C *****CINH22820
C *****CINH22830
C      COMMON/BUG/IBUG                                         INH22840
C      COMMON/BLDG/BLTH,WIDTH,HEIT                            INH22850
C      AWL=HEIT*.2*(BLTH+WIDTH/2.)                            INH22860
C      RKL=14.11                                               INH22870
C      Q=(TDB-TIN)*AWL/RKL                                     INH22880
C      IF (IBUG.EQ.0) GO TO 9999                               INH22890
C      PRINT 7                                                  INH22900
C 7 FORMAT(1X,10(1HW),'WALLHT',10(1HW))                      INH22910
C      PRINT 9090                                              INH22920
C 9090 FORMAT(1X,'WALLHT',9X,'TIN',T25,'TDB',T39,'Q',T53,'AWL',T67,'RKL', INH22930
C      1T81,'HEIT',T95,'BLTH',T109,'WIDTH')                  INH22940
C      PRINT 9091,TIN,TDB,Q,AWL,RKL,HEIT,BLTH,WIDTH          INH22950
C 9091 FORMAT (2X,BE14.3)                                       INH22960
C 9999 CONTINUE                                                INH22970
C      RETURN                                                  INH22980
C      END                                                    INH22990

      SUBROUTINE WETHER(AN,TMINW)                                INH23000
C *****CINH23010
C CINH23020
C CINH23030
C THIS SUBROUTINE GENERATES A DAILY WEATHER PATTERN, I.E. DRYGULB CINH23040
C AND DEWPOINT TEMPERATURES, BASED ON U.S. WEATHER SERVICE DATA (NN=1) CINH23050
C OR ON VERIFICATION DATA (NN=0).                             CINH23060
C CINH23070
C *****CINH23080
C *****CINH23090
C *****CINH23100
C      D E F I N I T I O N   O F   T E R M S                CINH23110
C CINH23120
C      SEE MAIN PROGRAM FOR ACRONYMS NOT                      CINH23130
C      LISTED HERE                                           CINH23140
C *****CINH23150
C *****CINH23160
C *****CINH23170
C *****CINH23180
C A-A CONSTANT USED TO CALCULATE THE BAROMETRIC PRESSURE BASED ON THE CINH23190

```



```

M2=15*K
M3=24*K
I2=1
IDP=0
IF(TDPF.EQ.0.) TDPF=MN
IF(AVTD80.EQ.0.) AVTD80=(MN+MX)/2.
IF(ATMP.NE.0.) GO TO 13
CD=(5./9.)*(AVTD80-32.)
C 27070. IS THE ELEVATION OF E. LANSING , MI IN CM
A=27070./(1600000.*(1+.004*CD))
ATMP=14.696*(1.-A)/(1.+A)
13 CONTINUE
RANGE=MX-MN
PATM=ATMP
C CALCULATE DRY BULB TEMPS FOR THE DAY (PHILLIPS P. 6)
RNG2=RANGE/2.
TM1N=AVTD80-RNG2
IF(TDPF.LT.TM1N) GO TO 7
IDP=1
7 CONTINUE
DO 8 I=12,M1
N=2*I/K
TDBO(I)=TM1N+RNG2*(1.+COS(((FLCAT(N)+18.)/30.)*PI))
TPOC(I)=6.47+.8*TDBO(I)
6 CONTINUE
I2=M1+1
DO 9 I=12,M2
N=2*I/K
TDBO(I)=TM1N+RNG2*(1.-COS(((FLCAT(N)-12.)/18.)*PI))
TPOC(I)=6.47+.8*TDBO(I)
9 CONTINUE
I2=M2+1
DO 10 I=12,M3
N=2*I/K
TDBO(I)=TM1N+RNG2*(1.+COS(((FLCAT(N)-30.)/30.)*PI))
TPOC(I)=6.47+.8*TDBO(I)
10 CONTINUE
C
C WEATHER DETERMINED FROM HOUSE 7 DATA
C
100 CONTINUE
IF(MN.GT.0) GO TO 777
PATM=ATMP
N=0
BX=0.
DN=100.
AB=0.
DO 710 J=1,24
READ(5,760) DTIME(J),BO(J),PO(J),TDBI(J),TDPI(J)
760 FORMAT(12X,F5.2,10X,F6.2)
710 CONTINUE
DO 770 K=1,24
4K
TDSG(K)=BO(K)
TDPG(K)=PO(K)
TDPG(K+24)=HADP(PO(K)+459.67)
IF(K.GT.0) GO TO 745
M=(FLOCAT(K)/20.+5)
IF(M.NE.N) GO TO 750
TIME(M)=FLOCAT(M)
IF(TIME(M).LT.DTIME(1)) GO TO 610
IF(TIME(M).GT.DTIME(48)) GO TO 620
TDBO(M)=TABLI(BO,DTIME,TIME(M),48)
TPOC(M)=TABLI(PO,DTIME,TIME(M),48)
745 CONTINUE
750 CONTINUE
B=BO(K)
IF(B.GT.BX) BX=B
IF(B.LT.DN) DN=B
AB=AB+B
N=N+1
770 CONTINUE

```

```

INH23920
INH23930
INH23940
INH23950
INH23960
INH23970
INH23980
INH23990
C INH24000
INH24010
INH24020
INH24030
INH24040
INH24050
C INH24060
INH24070
INH24080
INH24090
INH24100
INH24110
INH24120
INH24130
INH24140
INH24150
INH24160
INH24170
INH24180
INH24190
INH24200
INH24210
INH24220
INH24230
INH24240
INH24250
INH24260
INH24270
INH24280
C INH24290
C INH24300
C INH24310
INH24320
INH24330
INH24340
INH24350
INH24360
INH24370
INH24380
INH24390
INH24400
INH24410
INH24420
INH24430
INH24440
INH24450
INH24460
INH24470
INH24480
INH24490
INH24500
INH24510
INH24520
INH24530
INH24540
INH24550
INH24560
INH24570
INH24580
INH24590
INH24600
INH24610
INH24620
INH24630

```



```

AVTDBC=A8/48.                                INH24640
RANGE=BX-BN                                  INH24650
777 CONTINUE                                  INH24660
NN=NN+1                                       INH24670
IF (IDP.EQ.0) GO TO 12                       INH24680
PRINT 26                                     INH24690
PRINT 6,TDPF,TMIN4                           INH24700
6 FORMAT(1X,'DEWPOINT TEMPERATURE GREATER THAN MINIMUM TEMPERATURE F INH24710
   10R THE DAY. DEWPOINT INPUT AS',G21.7/1X,'BUT RESET AS SHOWN') INH24720
GO TO 27                                     INH24730
12 CONTINUE                                  INH24740
IF (DT.EQ..5.0P.DT.EQ.1.) GO TO 99          INH24750
PRINT 26                                     INH24760
90 PRINT 900,DT                               INH24770
903 FORMAT(1X,'DT NOT EQUAL .5 OR 1. NOTE VALUES FOR TDBO BELOW. RETU INH24780
   10RNEO VALUE FOR DT IS:',G20.5)          INH24790
GO TO 27                                     INH24800
99 CONTINUE                                  INH24810
IF (IBUG.EQ.0) GO TO 9999                   INH24820
PRINT 26                                     INH24830
26 FCORMAT(1X,10(1HW),8(10H WETHER      ),10(1HW)) INH24840
27 CONTINUE                                  INH24850
PRINT 9000,MTIME,I2,K,M1,M2,M3, AVTDBC,RANGE,TDPF,RNG2,TMINM INH24860
9000 FORMAT(1X,'MTIME',15X,'I2',18X,'K',19X,'M1',18X,'M2',18X,'M3' / INH24870
   A 1X'AVTDBC',14X,'RANGE',15X,'TDPF',16X,'RNG2 ',15X,'TMINN' / INH24880
   11X,I2,5(I20)/1X,E11.4,G20.4)           INH24890
PRINT 9005,SDRYTM,EDRYTM                    INH24900
9005 FORMAT(1X,'DRYER START AND END TIME - WINTER MONTHS',2F10.2/) INH24910
PRINT 9010,M0,ID,IY                          INH24920
9010 FCORMAT (1X,'CATE',I2,'/',I2,'/',I2) INH24930
PRINT 9090,TDBO                              INH24940
9090 FORMAT (1H0,10(10HWETHER      ),/1X' TDBC(J)',/8(6E20.4/)) INH24950
PRINT 9091,TDPO                              INH24960
9091 FCORMAT(1X'TDPC(J)'/1X,8(6E20.4/)) INH24970
PRINT 9092 ,TDBI                              INH24980
9092 FCORMAT (1X'TDBI(J)'/1X,8(6E20.4/)) INH24990
PRINT 9093,TDPI                              INH25000
9093 FCORMAT (1X'TDPI(J)'/1X,8(6E20.4/)) INH25010
PRINT 9094,TIME                              INH25020
9094 FCORMAT (1X'TIME(J)'/1X,8(6E20.4/)) INH25030
9999 CONTINUE                                INH25040
RETURN                                         INH25050
613 TDBO(M)=BC(K)                            INH25060
TDPO(M)=PC(K)                                INH25070
GO TO 750                                     INH25080
620 TDBO(M)=BC(48)                           INH25090
TDPO(M)=PC(48)                               INH25100
GO TO 750                                     INH25110
END                                            INH25120

```



APPENDIX A
EXAMPLES OF INTERMEDIATE COMPARISON GRAPHS

APPENDIX B
EXAMPLES OF INTERMEDIATE COMPARISON GRAPHS

APPENDIX B EXAMPLES OF INTERMEDIATE COMPARISON GRAPHS

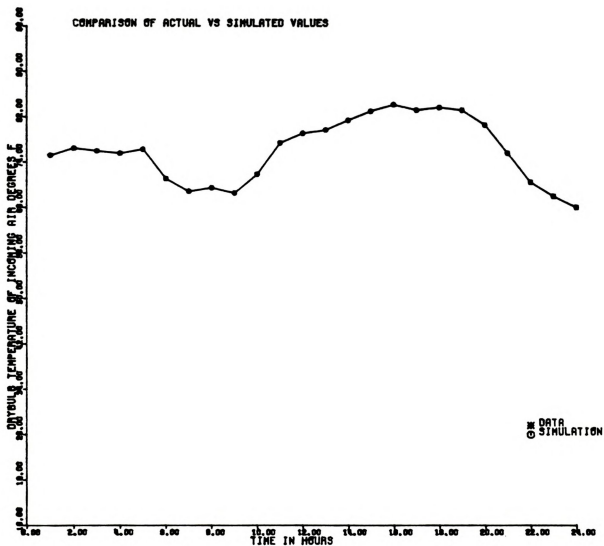


Figure B.1. An example of a comparison graph used for evaluation during verification of the simulation model with the measured data. This graph showed that the incoming air dry-bulb temperature as used in the model was in fact equal to that of the collected data.



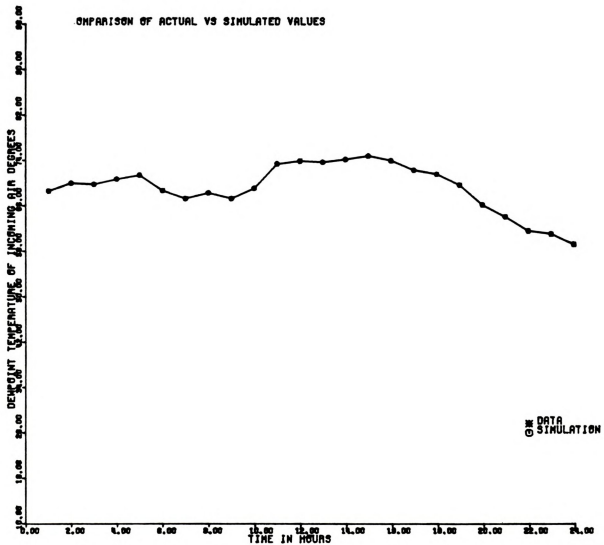


Figure B.2. An example of a comparison graph used for evaluation during verification of the simulation model with the measured data. This graph showed that the incoming air dewpoint temperature as used in the model was in fact equal to that of the collected data.



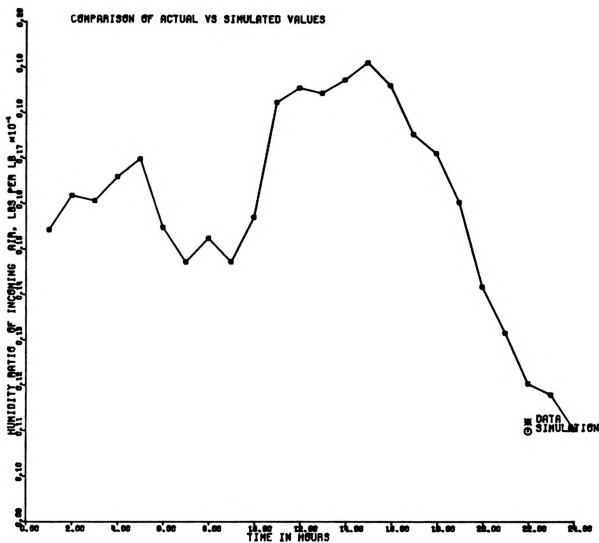


Figure B.3. An example of a comparison graph used for evaluation during verification of the simulation model with the measured data. This graph showed that the incoming air humidity ratio was in fact equal to that of the collected data.

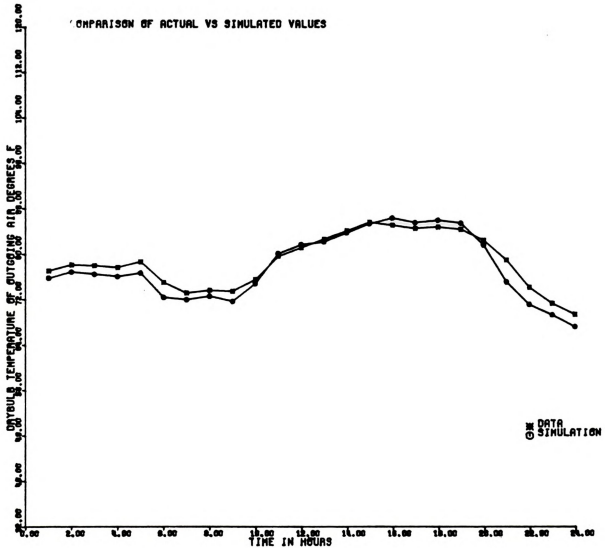


Figure B.4. An example of a comparison graph used for evaluation during verification of the simulation model with the measured data. This graph showed that the outgoing air dry-bulb temperature as calculated by the simulation model follows very closely to the measured value.

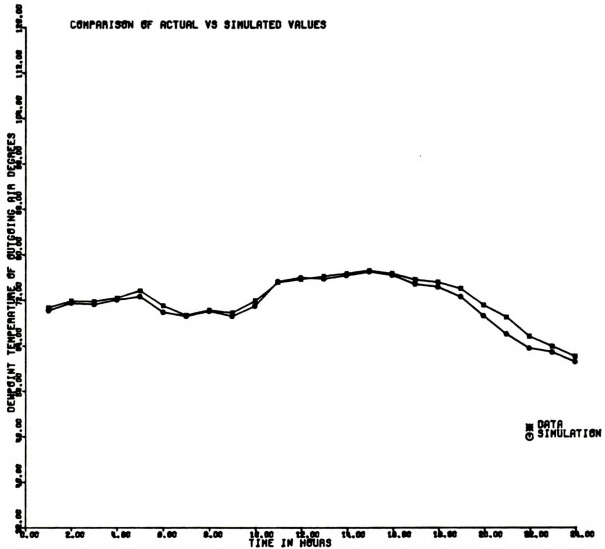


Figure B.5. An example of a comparison graph used for evaluation during the verification of the simulation model with measured data. This graph showed that the outgoing air dewpoint temperature as calculated by the simulation model follows very closely to the measured value.

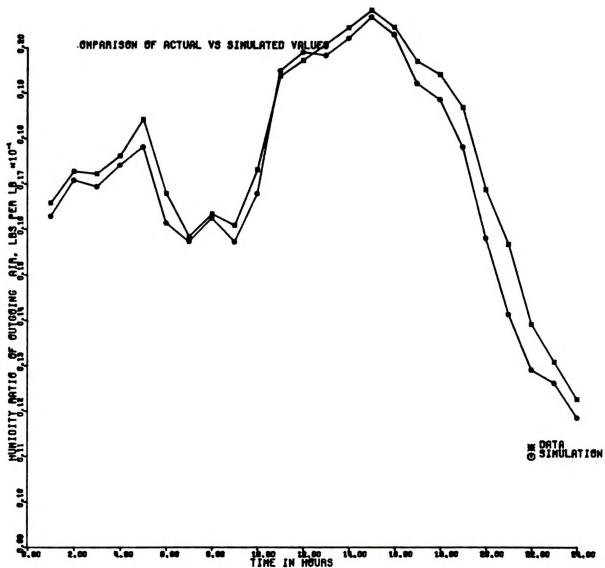


Figure B.6. An example of a comparison graph used for evaluation during the verification of the simulation model with measured data. This graph showed that the humidity ratio of the outgoing air as calculated by the simulation model follows very closely to the measured value.

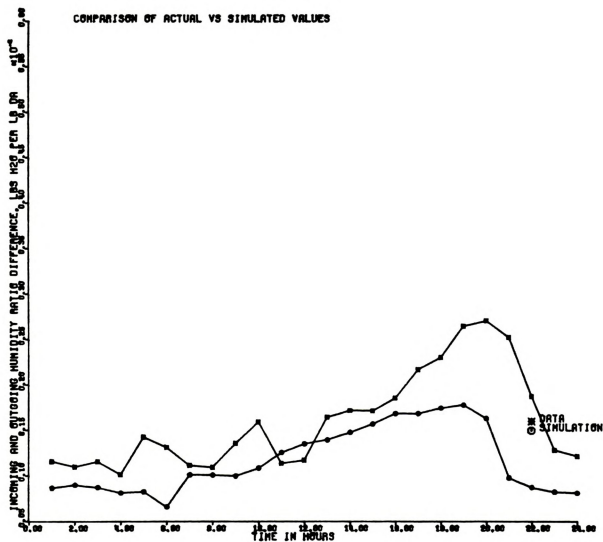


Figure B.7. An example of a comparison graph used for evaluation during the verification of the simulation model with measured data. This graph showed that incoming air and outgoing air humidity ratio difference was greater for the measured data than as calculated by the simulation model for all but two hours of the day.



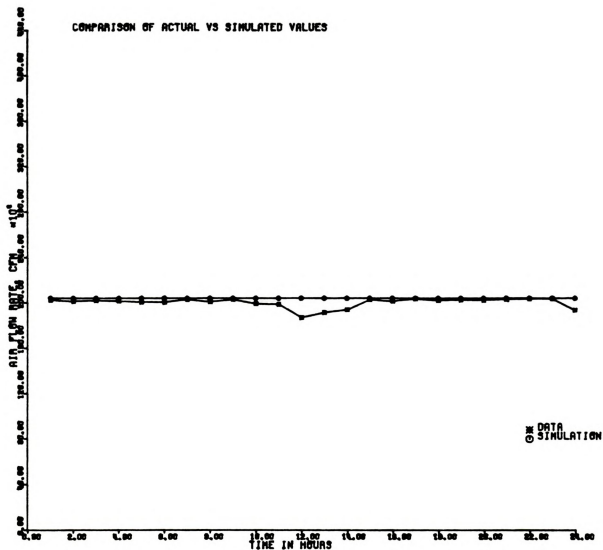


Figure B.8. An example of a comparison graph used for evaluation during the verification of the simulation model with measured data. This graph showed that the air flow through the poultry house as calculated by the simulation model follows very closely to the measured value.



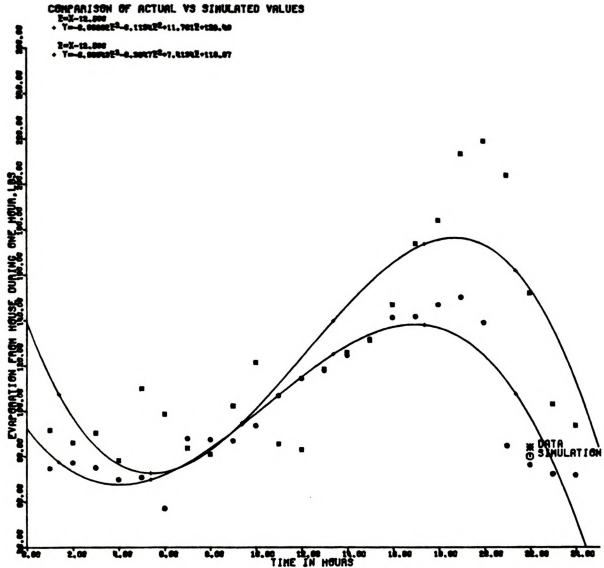


Figure B.9. An example of a comparison graph used for evaluation during the verification of the simulation model with measured data. This graph showed that the evaporation from the poultry house during one hour as calculated by the simulation model followed the same trend as that which was calculated from measured data. The two curves result from curvilinear regression calculations based on the two separate sets of data.



APPENDIX C

VERIFICATION MANAGEMENT FACTOR, DESIGN,
AND INPUT VALUES



APPENDIX C

VERIFICATION MANAGEMENT FACTOR, DESIGN,
AND INPUT VALUES

Table C.1. Management factor, design, and input values as used for verifying the model with data collected August 12, 1974.

BUILDING:	
LENGTH, FT	92.25
WIDTH, FT	38.00
CEILING HEIGHT, FT	8.25
INSULATION-WALLS, HR-F-SQ FT/BTU	14.11
INSULATION-CEILING, HR-F-SQ FT/BTU	23.68
LIGHTING HEAT, BTU/HR	3242.35
LAYING HENS:	
NUMBER OF HENS	5239.00
HEN WEIGHT, LBS	4.25
BODY TEMPERATURE, F	107.10
EXCRETA MOISTURE CONTENT, %	80.00
EXCRETA DISTRIBUTION FACTOR	0.04
SPECIFIC HEAT OF MANURE, BTU/LB-F	0.87
EXCRETA PRODUCTION RATE, LBS/HEN-DAY	0.27
VENTILATION:	
INSIDE DESIGN(SET) TEMPERATURE, F	56.00
MAXIMUM VENTILATING RATE, CFM	20421.34
MINIMUM VENTILATING RATE, CFM	5406.01
INITIAL SLAB TEMPERATURE, F	42.89
WEATHER:	
ATMOSPHERIC PRESSURE, PSI	14.28
AVERAGE OUTSIDE TEMPERATURE, F	37.89
OUTSIDE TEMPERATURE RANGE, F	25.18
CRITICAL LOW OUTSIDE TEMPERATURE, F	36.29
SIMULATION DETAILS:	
TIME INCREMENT-DT, HOURS	1.00
STARTING TIME, CLOCK HOURS	0.0
LENGTH OF RUN, HOURS	24.00
SLAB INDEX	1
LIGHTING INDEX	1.00

Table C.2. Management factor, design, and input values as used for verifying the model with data collected August 13, 1974.

BUILDING:	
LENGTH, FT	92.25
WIDTH, FT	38.00
CEILING HEIGHT, FT	8.25
INSULATION-WALLS, HR-F-SQ FT/BTU	14.11
INSULATION-CEILING, HR-F-SQ FT/BTU	23.68
LIGHTING HEAT, BTU/HR	3242.35
LAYING HENS:	
NUMBER OF HENS	5237.00
HEN WEIGHT, LBS	4.25
BODY TEMPERATURE, F	107.10
EXCRETA MOISTURE CONTENT, %	80.00
EXCRETA DISTRIBUTION FACTOR	0.04
SPECIFIC HEAT OF MANURE, BTU/LB-F	0.87
EXCRETA PRODUCTION RATE, LBS/HEN-DAY	0.27
VENTILATION:	
INSIDE DESIGN (SET) TEMPERATURE, F	56.00
MAXIMUM VENTILATING RATE, CFM	20421.34
MINIMUM VENTILATING RATE, CFM	5406.01
INITIAL SLAB TEMPERATURE, F	43.02
WEATHER:	
ATMOSPHERIC PRESSURE, PSI	14.29
AVERAGE OUTSIDE TEMPERATURE, F	38.02
OUTSIDE TEMPERATURE RANGE, F	18.12
CRITICAL LOW OUTSIDE TEMPERATURE, F	36.32
SIMULATION DETAILS:	
TIME INCREMENT-DT, HOURS	1.00
STARTING TIME, CLOCK HOURS	0.0
LENGTH OF RUN, HOURS	24.00
SLAB INDEX	1
LIGHTING INDEX	1.00



Table C.3. Management factor, design, and input values as used for verifying the model with data collected August 20, 1974.

BUILDING:	
LENGTH, FT	92.25
WIDTH, FT	38.00
CEILING HEIGHT, FT	8.25
INSULATION-WALLS, HR-F-SQ FT/BTU	14.11
INSULATION-CEILING, HR-F-SQ FT/BTU	23.68
LIGHTING HEAT, BTU/HR	3242.35
LAYING HENS:	
NUMBER OF HENS	5222.00
HEN WEIGHT, LBS	4.25
BODY TEMPERATURE, F	107.10
EXCRETA MOISTURE CONTENT, %	80.00
EXCRETA DISTRIBUTION FACTOR	0.04
SPECIFIC HEAT OF MANURE, BTU/LB-F	0.87
EXCRETA PRODUCTION RATE, LBS/HEN-DAY	0.27
VENTILATION:	
INSIDE DESIGN(SET) TEMPERATURE, F	56.00
MAXIMUM VENTILATING RATE, CFM	20421.34
MINIMUM VENTILATING RATE, CFM	5406.01
INITIAL SLAB TEMPERATURE, F	43.58
WEATHER:	
ATMOSPHERIC PRESSURE, PSI	14.34
AVERAGE OUTSIDE TEMPERATURE, F	38.58
OUTSIDE TEMPERATURE RANGE, F	31.85
CRITICAL LOW OUTSIDE TEMPERATURE, F	36.44
SIMULATION DETAILS:	
TIME INCREMENT-DT, HOURS	1.00
STARTING TIME, CLOCK HOURS	0.0
LENGTH OF RUN, HOURS	24.00
SLAB INDEX	1
LIGHTING INDEX	1.00



Table C.4. Management factor, design, and input values as used for verifying the model with data collected January 6, 1975.

BUILDING:	
LENGTH, FT	92.25
WIDTH, FT	38.00
CEILING HEIGHT, FT	8.25
INSULATION-WALLS, HR-F-SQ FT/BTU	14.11
INSULATION-CEILING, HR-F-SQ FT/BTU	23.68
LIGHTING HEAT, BTU/HR	3242.35
LAYING HENS:	
NUMBER OF HENS	4944.00
HEN WEIGHT, LBS	4.25
BODY TEMPERATURE, F	107.10
EXCRETA MOISTURE CONTENT, %	80.00
EXCRETA DISTRIBUTION FACTOR	0.04
SPECIFIC HEAT OF MANURE, BTU/LB-F	0.87
EXCRETA PRODUCTION RATE, LBS/HEN-DAY	0.27
VENTILATION:	
INSIDE DESIGN(SET) TEMPERATURE, F	56.00
MAXIMUM VENTILATING RATE, CFM	20421.34
MINIMUM VENTILATING RATE, CFM	6706.75
INITIAL SLAB TEMPERATURE, F	23.45
WEATHER:	
ATMOSPHERIC PRESSURE, PSI	14.23
AVERAGE OUTSIDE TEMPERATURE, F	18.45
OUTSIDE TEMPERATURE RANGE, F	10.37
CRITICAL LOW OUTSIDE TEMPERATURE, F	40.85
SIMULATION DETAILS:	
TIME INCREMENT-DT, HOURS	1.00
STARTING TIME, CLOCK HOURS	0.0
LENGTH OF RUN, HOURS	24.00
SLAB INDEX	1
LIGHTING INDEX	1.00



Table C.5. Management factor, design, and input values as used for verifying the model with data collected January 7, 1975.

BUILDING:	
LENGTH, FT	92.25
WIDTH, FT	38.00
CEILING HEIGHT, FT	8.25
INSULATION-WALLS, HR-F-SQ FT/BTU	14.11
INSULATION-CEILING, HR-F-SQ FT/BTU	23.68
LIGHTING HEAT, BTU/HR	3242.35
LAYING HENS:	
NUMBER OF HENS	4942.00
HEN WEIGHT, LBS	4.25
BODY TEMPERATURE, F	107.10
EXCRETA MOISTURE CONTENT, %	80.00
EXCRETA DISTRIBUTION FACTOR	0.04
SPECIFIC HEAT OF MANURE, BTU/LB-F	0.87
EXCRETA PRODUCTION RATE, LBS/HEN-DAY	0.27
VENTILATION:	
INSIDE DESIGN (SET) TEMPERATURE, F	56.00
MAXIMUM VENTILATING RATE, CFM	20421.34
MINIMUM VENTILATING RATE, CFM	6613.67
INITIAL SLAB TEMPERATURE, F	23.48
WEATHER:	
ATMOSPHERIC PRESSURE, PSI	14.25
AVERAGE OUTSIDE TEMPERATURE, F	18.48
OUTSIDE TEMPERATURE RANGE, F	12.42
CRITICAL LOW OUTSIDE TEMPERATURE, F	40.67
SIMULATION DETAILS:	
TIME INCREMENT-DT, HOURS	1.00
STARTING TIME, CLOCK HOURS	0.0
LENGTH OF RUN, HOURS	24.00
SLAB INDEX	1
LIGHTING INDEX	1.00



LIST OF REFERENCES



LIST OF REFERENCES

- ASHRAE Guide and Data Book, 1965. American Society of Heating, Refrigerating and Air-Conditioning Engineers, New York, N.Y. 880 pp.
- Bakker-Arkema, F. W., and L. E. Lerew, 1972. A psychrometric package. Mimeo: Agricultural Engineering Department, Michigan State University, East Lansing, Michigan.
- Bressler, G. O., and E. L. Bergman, 1971. Solving the poultry manure problem economically through dehydration. Proceedings International Symposium on Livestock Wastes, Ohio State University. ASAE Publication PROC-270: 81-84.
- Davis, E. G., I. L. Field, and J. H. Brown, 1972. Combustion disposed of manure wastes and utilization of the residue. United States Department of the Interior, Bureau of Mines, Solid Wastes Research Program Technical Progress Report 46.
- Dixon, J. E., J. B. Gerrish, T. S. Chang, C. J. Flegal, C. C. Sheppard, and H. C. Zindel, 1976a. Poultry environment system model for drying manure. ASAE paper 76-4039, ASAE, St. Joseph, MI 49085.
- Dixon, J. E., G. D. Wells, and M. L. Esmay, 1976b. Convective heat transfer coefficient for poultry manure. ASAE paper 76-4511, ASAE, St. Joseph, MI 49085.
- Dixon, J. E., G. D. Wells, and M. L. Esmay, 1978. Convective heat transfer coefficient for poultry excreta. Transactions of the ASAE 21(3):534-536.
- Erickson, A. E., J. M. Tiedje, B. G. Ellis, and C. M. Hanson, 1971. A barriered landscape water renovation system for removing phosphate and nitrogen from liquid feedlot waste. Proceedings International Symposium on Livestock Wastes, Ohio State University, ASAE Publication PROC-271: 232-234.
- Esmay, M. L., 1969. Principles of Animal Environment. AVI Publishing Co., Westport, Conn. 325 pp.
- Esmay, M. L., C. J. Flegal, J. B. Gerrish, J. E. Dixon, C. C. Sheppard, H. C. Zindel, and T. S. Chang, 1975a. Poultry manure dehydration by air-drying and machine in a caged-layer house handling system. Research Report No. 269, Agricultural Experiment Station, Michigan State University, East Lansing, pp. 2-14.



- Esmay, M. L., C. J. Flegal, J. B. Gerrish, J. E. Dixon, C. C. Sheppard, H. C. Zindel, and T. S. Chang, 1975b. In-house handling and dehydration of poultry manure from caged-layer operations: A project review. Proceedings Third International Symposium on Livestock Waste, University of Illinois, ASAE Publication PROC-275: 468-473, 477.
- Flegal, C. J., M. L. Esmay, J. B. Gerrish, J. E. Dixon, C. C. Sheppard, H. C. Zindel, and T. S. Chang, 1974. A complete system for collecting, handling, air-drying and machine dehydration of poultry manure in a caged-layer production unit. Cornell Agricultural Waste Management Conference Proceedings, Rochester, New York, March 25-27, pp. 122-131.
- Forsht, R. Gar, C. R. Burbee, and W. M. Crosswhite, 1974. Recycling poultry waste as a feed: Will it pay? Agricultural Economic Report 254. Economic Research Service, United States Department of Agriculture, Washington, D.C. 51pp.
- Gerrish, J. B., J. E. Dixon, M. L. Esmay, G. H. Quebe, C. J. Flegal, C. C. Sheppard, and H. C. Zindel, 1973. Engineering aspects of handling and dehydrating poultry excreta: A progress report. ASAE Paper 73-4560. ASAE, St. Joseph, MI 49085.
- Holman, J. P., 1963. Heat Transfer. McGraw-Hill Book Company, Inc., New York, N.Y. 289 pp.
- Hummel, J. W., and G. B. Willson, 1975. High-rate mechanized composting of dairy manure. Proceedings Third International Symposium on Livestock Wastes, University of Illinois, ASAE Publication PROC-275: 481-484.
- Lampman, C. E., J. E. Dixon, C. F. Petersen, and R. E. Black, 1967. Environmental control for poultry housing. Idaho Agricultural Experiment Station Bulletin 456, University of Idaho, Moscow, Idaho. 27 pp.
- Llewellyn, R. W., 1965. Fordyn--An Industrial Dynamics Simulator. Privately published by R. W. Llewellyn, Box 5353, Raleigh, North Carolina. 150 pp.
- Longhouse, A. D., H. Ota, and W. Ashby, 1960. Heat and moisture design data for poultry housing. Agricultural Engineering 41: 567-576.
- Ludington, D. C., 1963. Dehydration and incineration of poultry manure. Proceedings National Symposium on Poultry Waste Management. May 13-15.



- Miner, J. R., and R. J. Smith, 1975. Livestock Waste Management with Pollution Control. Northcentral Regional Research Publication 222, Midwest Plan Service, Ames, Iowa, June. 89 pp.
- Oheimb, Rainer A. von, and A. D. Longhouse, 1974. Partial drying of poultry manure using in-house air. West Virginia University Agricultural Experiment Station Bulletin 633T, Morgantown. 16pp.
- Ota, H., and E. H. McNally, 1961. Poultry respiration calorimetric studies of laying hens--single comb white leghorns, Rhode Island reds, and New Hampshire X Cornish Cross. United States Department of Agriculture ARS 42-43. 34 pp.
- Perry, Robert H., and Cecil H. Chilton, 1963. Chemical Engineers' Handbook. 4th edition. McGraw-Hill Book Company, New York. 1663 pp.
- Perry, Robert H., and Cecil H. Chilton, 1973. Chemical Engineers' Handbook. 5th edition. McGraw-Hill Book Company, New York. 1962 pp.
- Phillips, R. E., 1970. A systems analysis of summer environment for laying hens. Unpublished Ph.D. thesis, Agricultural Engineering Department, Michigan State University, East Lansing, Michigan.
- Sheppard, C. C., C. J. Flegal, M. L. Esmay, J. B. Gerrish, J. E. Dixon, H. C. Zindel, and T. S. Chang, 1974. A complete system for collecting, handling, air-drying and machine dehydration of poultry manure in a caged-layer production unit. XV World's Poultry Congress, New Orleans, LA., June.
- Singley, M. E., Martin Decker, and S. J. Toth, 1975. Composting of swine waste. Proceedings Third International Symposium on Livestock Wastes, University of Illinois, ASAE Publication PROC-275: 492-496.
- Smith, E. S., Meyer Salkover, and H. K. Justice, 1947. Unified Calculus. John Wiley and Sons, New York. 534 pp.
- Sobel, A. T., 1972. Undercage drying of laying hen manure. Proceedings of the 1972 Cornell Agricultural Waste Management Conference, pp. 187-200.
- Structures and Environment Handbook, 1975. Midwest Plan Service, MWPS 1, Ames, Iowa. 412 pp.
- Surbrook, T. C., 1969. Evaluation of an animal excreta dryer. Unpublished MS Thesis, Agricultural Engineering Department, Michigan State University, East Lansing, Michigan.

- Surbrook, T. C., C. C. Sheppard, J. W. Boyd, H. C. Zindel, and C. J. Flegal, 1971. Drying poultry waste. Proceedings International Symposium on Livestock Wastes, Ohio State University. ASAE Publication PROC-271, pp. 192-194.
- Weast, Robert C., 1970. Handbook of Chemistry and Physics. 51st edition. Chemical Rubber Company, Cleveland, Ohio.
- Wells, Grant DeWitt, 1972. Simulation of in-house drying of chicken excreta. Unpublished Ph.D. Thesis, Department of Agricultural Engineering, Michigan State University, East Lansing, Michigan.
- U.S. Department of Commerce, 1968. Climatic Atlas of the United States. Environmental Science Services Administration, Environmental Data Service, Asheville, North Carolina.
- U.S. Department of Commerce, 1977a. Local Climatological Data--monthly summary for Lansing, Michigan. National Weather Service, National Oceanic and Atmospheric Administration, National Climatic Center, Asheville, North Carolina.
- U.S. Department of Commerce, 1977b. Monthly Weather Data. National Weather Service, National Oceanic and Atmospheric Administration, National Climatic Center, Asheville, North Carolina.
- Zindel, H. C., T. S. Chang, C. J. Flegal, D. Polin, C. C. Sheppard, B. A. Stout, J. E. Dixon, M. L. Esmay, and J. B. Gerrish, 1977. Poultry excreta dehydration and utilization: System development and demonstration. U.S. Environmental Protection Agency, Environmental Research Laboratory, Athens, Georgia, Report EPA-600/2-77-221.





MICHIGAN STATE UNIV. LIBRARIES



31293011092693