COMPUTERIZED HEAT LOSS EVALUATION of FARROWING HOUSES

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INTRODUCTION

The declining energy supply and the generally increasing cost of energy have made it essential that producers emphasize the reduction of heating losses in livestock buildings. Large reductions can and have been made in the heat loss (energy cost) through ventilating system management and structural modifications.

Energy cost is most intensive in the farrowing to weaning portion of swine production. Kansas Extension publication MF-263 points out that utility costs make up 7 percent(%) of the variable cost in the farrowing operation or 5.6 percent(%) of the total cost of raising feeder pigs (up to 40 lb).

This report and accompanying computer program is an attempt to help producers evaluate farrowing house heating cost and show how increasing insulation and controlling ventilation can aid in reducing this expense.

OBJECTIVES

The objective of this report is to provide information on an accurate method of evaluating the heat losses of farrowing houses by Kansas agricultural advisors, consultants and producers. Equations for calculating and evaluating energy losses are widely available, however the background of these professionals is in areas other than engineering where they were not exposed to the technology.

Computer programs available for public use in this area, expect the user to have knowledge of the thermal resistance values for each of the materials in the structure. Programs for inexperienced users must be written with the user in mind. The language and terminology should be similar to that of the user.

1. The information should be presented in a non-technical nature so that all users might understand the instructions and choices.

2. Inputs should require a minimum amount of calculations and leave the calculating to the computer.

3. Terms should be common to the user's language.

4. Inputing of information should not exceed the user's knowledge of buildings or his experience with computers.

5. The program must be "friendly" or "forgiving" of typing errors during input.

6. The program must be resilient enough not to "die" if invalid input is entered.

7. Output should be self explanatory, brief and in a narrative form whenever possible.

8. Program output must be accurate.

LITERATURE REVIEW

An excellent list of the steps for calculating livestock building heat loss is given in the ASHRAE Handbook of Fundamentals, 1981.

ASHRAE (1981) indicates that to calculate a designed heating load, detailed information about building design, weather data and the designed operating conditions are required as follows:

1. Select outdoor design weather conditions: temperature, wind direction, and speed.

2. Select the indoor air temperature to be maintained in each space during the coldest weather.

3. Select or compute heat transfer coefficients for the outside walls and ceilings, doors, and foundations.

4. Determine the net area of outside wall, glass, and roof next to unheated spaces. Such determinations are made from building plans, or from the actual building, using the inside dimensions.

5. Compute the heat transmission losses for each kind of wall, glass, floor, ceiling and roof in the building by multiplying the heat transfer coefficient in each case by the area of the surface and the temperature difference between indoor and outdoor air, or adjacent unheated spaces.

6. Compute the heat loss from basement or grade-level slab floors.

7. Select unit values and compute the energy associated with infiltra-

tion of cold air around doors, windows, and other openings. These values depend upon the kind or size of cracks, wind speed and the temperature difference between indoor and outdoor air. An alternate method is the use of air changes per hour.

8. Using positive ventilation, outdoor air provided by an air-heating or air-conditioning unit must be warmed or cooled to the inside temperature. The principle for calculation of this load component is identical to that for infiltration.

9. The sum of the transmission losses (heat transmitted through the combined walls, floors, ceiling, glass and other surfaces) plus the energy associated with heating the cold air, entering by infiltration or replaced by mechanical exhaust, represents the total heating load.

10. In buildings that have a reasonably steady internal heat release from sources other than the heating system, (e.g. heat produced by animals) a computation of this heat release under design conditions should be made and deducted from the heat loss computed earlier.

11. Consideration should be given to pick-up loads that may be required in intermittently heated buildings or in buildings utilizing night thermostat setback. Pick-up loads frequently necessitate an increase in the heating equipment capacity in order to bring the temperature of the structure and contents to the specified temperature.

(Taken from ASHRAE Handbook of Fundamentals,1981 Pg. 25.1)

HEAT TRANSFER DEFINITIONS AND SYMBOLS

In livestock buildings, heat is lost or gained by conduction, convection, radiation, or evaporation. Insulation is the general term for the group of materials which have a high resistance to heat flow. Increasing the insulation level of an enclosure resists heat gain and loss.

Installing insulation conserves animal heat or supplemental heat added to maintain the operating temperature. Insulation also assists in reducing the heat gain when outside temperatures exceed the building operating temperature. Insulation can help prevent the temperature difference between the warm building air temperature and the internal siding surface temperature that could result in condensation on the walls.

The following are definitions of terms used to discuss and describe heat transfer.

Transmission losses = Heat transfer through the confining wall, glass, ceiling, floor, or other surfaces.

q = Thermal transmission or rate of heat flow; the quantity of heat flowing due to all mechanisms in unit time under the conditions prevailing at the time.

Btu/h or (W)

k = thermal conductivity the thermal transmission by conduction only, in unit time through unit area of an infinite slab in a direction perpendicular to the surface, when unit difference in temperature is established between the surfaces.

Btu · in./ (h · ft^2 · ^oF) or (W/ (m · K))

r = thermal resistivity; the reciprocal of thermal conductivity.

ft^2 · ^oF · h/(Btu · in) or (m · K/M)

C = thermal conductance; the thermal transmission in unit time through unit area of a particular body or assembly having defined surfaces, when unit average temperature difference is established between the surfaces.

Btu/(h · ft^2 · ^oF) or (W/(m^2 · K))

R = thermal resistance; the reciprocal of thermal conductance.

ft^2 · ^oF · h/Btu or (m^2 · K/W)

U = thermal transmittance; the thermal transmission in unit time through unit area of a particular body or assembly, including its boundary films, divided by the difference between the environmental temperatures on either side of the body or assembly.

Btu/(h · ft^2 · ^oF) or (W/(m^2 · K))

(Taken from ASHRAE 1981 FUNDAMENTALS HANDBOOK, pg 23.1)

A more simplified set of definitions for these heat transfer terms (in British Thermal Units) is found in Midwest Plan Service Structure & Environment Handbook, MWPS 1.

k = is the heat per hour that passes through a piece of material 1" thick and 1' square, when the temperature difference between the sides is 1 ^{o}F.

$$k = \frac{1}{R/\text{in. material}}$$

C = is the heat that passes through a material (total thickness) per hour through an area 1' square when the difference in the temperature is 1 ^{o}F.

$$C = \frac{1}{R_{\text{material}}}$$

U = is the heat that passes through a wall, ceiling or other sections of the building enclosure per hour for each square foot of area when the temperature difference between the sides is 1 ^{o}F. The U-value includes the insulating value of the boundary film layers.

(overall coefficient of heat transfer)

$$U = \frac{1}{R_t}$$

R-values will be referred to throughout the program because of the ease of calculation and because many insulating materials are marked with R-value.

The program is designed for Kansas conditions and Kansas swine producers, therefore the British units (e.g. Btu) rather than Metric units.

FUEL COST COMPARISON

For calculations of fuel costs, each fuel can be converted to a common unit of measure such as \$/MBtu (million Btu). The conversion values are included in the following table by Holmes and Tucker (1981).

```
Natural Gas - Therm = 100,000 Btu
                    = 100 cu ft
              65% Efficiency
              $/MBtu = 15.38 x $/Therm
              $/MBtu = 1.538 x $/1000 cu ft

LP Gas      - 93,000 Btu/gallon
              65% Efficiency
              $/MBtu = 16.54 x $/gallon

Fuel Oil    - 138,000 Btu/gallon
              65% Efficiency
              $/MBtu = 11.15 x $/gallon

Electricity - 3412 Btu/KWH
              100% Efficiency
              $/MBtu = 293 x $/KWH

Coal        - 12,500 Btu/lb
              60% Efficiency
              $/MBtu = $/Ton ÷ 15

Mixed Hardwoods- 24 MBtu/cord
              50% Efficiency
              $/MBtu = $/cord ÷ 12
```

PROCEDURES AND DISCUSSION

A computer program was written to accomplish heat loss analysis of the farrowing houses. The programing language used was Fortran 77 within a Unix operating system.

STEPS OF THE PROGRAM

This program uses a series of questions about the building and its materials to calculate the total R-value of each of the building components. The questions about the building materials are used for the ease of the user to prevent the need to know R-values of those materials. Information about size, operating temperature, stocking rate, ventilating rate, and location within the Kansas are provided by the user. A list of the available answers are provided for the user. This list (menu) allows the user to enter a single digit or character to make most inputs.

The main body of this program is relatively short and contains data statements to fill all the arrays, (except the delta t array which is filled in the subroutine "cycle"). It handles the call of all the subroutines except "conver" which is called throughout the remainder of the program to verify the numeric inputs. The subroutine "conver" is called approximately 50 times in the remainder of the program, however it might be called more or less, depending upon the looping required to obtain the input values.

The subroutine "rfact" is used in debugging to check the R-values assigned to each of the materials. It is not commonly available to the user but could be provided with the information sheet if later requested.

The two subroutines "ask" and "wall" are question and answer (I/O) type subroutines, very few calculations are done. Their objective is to obtain the values needed for the later calculations.

The subroutine "output" does the major calculations. The entire subroutine is for calculating and formating of the output. The individual calculations will be discussed later.

The subroutine "cycle" calculates the delta T for each of the 24 hours of the diurnal cycle. The Sine function is used to approximate the daily temperature fluctuations.

The appendix contains documentation of the program using the line numbers as a locator.

CALCULATIONS FOR THE PROGRAM

Principles presented in heat transfer analysis are used to calculate overall coefficients for thermal resistance. The total thermal resistance to heat flow through a flat ceiling, floor, or wall is assumed to be numerically equal to the sum of the resistances in series.

$$R_t = R_1 + R_2 + R_3 + R_4 + \ldots + R_n \qquad [1]$$

where

R_t is the total thermal resistance of the wall.

R_1, R_2, ... are the individual resistances of the wall components

One major factor of heat flow depends upon the temperature gradient between the air inside and air outside of the building components.

$$\Delta t = t_i - t_o \qquad [2]$$

where

t_i = inside air temperature

t_o = outside air temperature

Heat loss from any building component can be expressed as:

$$q_{ceiling} = \frac{\Delta t \cdot A_{ceiling}}{R_{ceiling}} \qquad [3]$$

where

$A_{ceiling}$ is the area of the ceiling

$R_{ceiling}$ is the R-value for the ceiling

$q_{ceiling}$ is the heat loss through the ceiling

Calculating the total heat loss from the building can be simplified by finding the exposure factors of each of the building components which will be later summed (e.g. exposure $factor_{wall}$).

$$\text{exposure factor}_{wall} = \frac{A_{wall}}{R_{wall}} \qquad [4]$$

The exposure factors of each of the building components (the $\frac{A}{R}$'s) can be summed and expressed as the exposure factor for the building.

$$\text{exposure factor}_{building} = \frac{A_{ceil}}{R_{ceil}} + \frac{A_{wall}}{R_{wall}} + \ldots. \qquad [5]$$

Transmission loss from the building can then be calculated as;

$$q_{building} = \text{exposure factor}_{bldg} \times \Delta t \qquad [6]$$

where

$$q_{building} = \text{the transmission heat loss}$$

$q_{building}$ is quite useful as it can be used in heat balance equations. To maintain a constant temperature within a structure, an equal amount of heat must be added (or removed) from the structure, as it moves through the walls, ceiling etc.

Total heat production from animals occurs in two forms:

1. Sensible heat which is transferred by conduction, convection, or radiation.

2. Latent heat which is transferred through evaporation.

Sensible heat is transferred because of a temperature difference within or between materials. Heat transfers in effort to neutralize the temperature difference. The greater the temperature difference, the greater the heat transfer.

Latent heat is the result of the phase change of water. Water evaporation resulting from clean-up or manure removal can effect this heat transfer rate. This form of heat transfer has not been considered other than by the level of the minimum ventilation rate which is designed to maintain moisture and odor levels within the building (e.g. 15 CFM/sow). The minimum ventilation rate required is dependent upon animal size and stocking density.

Values for animal sensible heat production are (q_s) arrived through heat balance research in both animal science and engineering areas.

Mount (1968) expressed the basal metabolic rate of swine to be:

$$q_s = 68.1 \text{ Kcal/day} \cdot W^{0.75} \qquad [7]$$

where

4.41 Btu = 1 Kcal

q_s = Kcal/day

W = weight (Kg)

Robbins and Spillman (1982) reported the sensible heat production of sows with litters in a commercial farrowing house to be:

$$q_s = 104 + .068 \cdot A^2 \text{ Watt/hr} \qquad [8]$$

where

A = age of the litter in days

1 Watt = 3.413 Btu

Bond et al. (1952) also computed the sensible heat production of the sow and litter. Their values are higher than those by Robbins and Spillman. Bond et al. collected their information from a farrowing house environment quite different from that used by most Kansas producers. The straw bedded farrowing pen used by Bond et al. does not fit the current farrowing environment as well as the slotted floor farrowing crate environment used by Robbins and Spillman.

For the purpose of the program q_s = 600 Btu/hr. This is equivilent to assuming the average age of the pigs is 32 days using the equation by Robbins and Spillman.

When calculating the ventilating rates for sows, many of the values have been calculated or assigned by now.

$$Q = \frac{V}{60 \cdot C_p \cdot \Delta t} \left(q_s - \frac{A}{R} \Delta t \right) \quad [9]$$

where

V = specific volume of air moved by the fan (ft^3/lb).

C_p = specific heat of air (Btu/lb)

Δt = temperature difference (^oF)

q_s = sensible heat production of the sows (Btu/hr).

$\frac{A}{R}$ = exposure factor of the building (Btu/hr/^{o}f).

When outside temperatures increase to the point that supplemental heat is not required, ventilating rates are increased to maintain a constant temperature. These ventilating rates increase as the outside temperature increase to within 5 - 15 ^oF of the inside temperatures. As outside temperatures approach inside temperatures, ventilation rates increase dramatically to the point they equal the 'Maximum Ventilation Rate' (e.g. 200 CFM/sow).

Heat loss of ventilation air, q_v, depend on the psychrometric properties of the air. The value for the specific volume of the air is considered at a constant 14 cu ft/lb dry air.

$$q_v = M_a \cdot C_p \cdot \Delta t = \frac{Q \cdot C_p \cdot \Delta t}{V} \quad [10]$$

where

M_a = mass of the air (lb/hr)

C_p = specific heat of air (.24 Btu/ lb)

Q = ventilation rate (CFM)

V = specific volume of the air (assumed 14 cu ft/lb)

The supplemental heat (q_{sr}) which must be supplied can be calculated by subtracting the heat produced by the animals q_s) from the amount of heat which is transmitted through the building components (q_b) plus the heat removed by the ventilation air (q_v).

$$q_{sr} = q_b + q_v - q_s \quad [11]$$

When selecting the size of the furnace for a structure, the maximum heating load must be considered. The coldest outside conditions regulate the minimum size unit capable of heating the building.

The most common method for selecting the furnace size is to calculate the heat loss, including ventilation heat loss, during the designed coldest hour. Select a heater which will meet or exceed this heat demand.

An alternate method is to select a heater which will meet the heating demands of the structure at a pre-assigned temperature for the area, (not the extreme low temperature), and increase this by a given percentage e.g. 20%. For many livestock buildings the additional percentage may not be added, allowing the building to cool a few degrees in those extreme conditions.

For the purpose of the program, a minimum temperature was set to -10 ^{o}F knowing the temperature within the building will decrease when the effective outside temperature is below -10 ^{o}F.

Fuel prices are converted to $/MBtu (million Btu). The conversions are made according to the fuel conversion values by Holmes and Tucker (1981).

WORKSHEET FOR USERS

A worksheet was developed to assist the user in collecting the inputs. The worksheet is be used to gather information to be entered. A copy of the worksheet is included in the appendix. The following is a discussion of the worksheet.

OWNER

The information about the owner or the building is entered here. The information is not checked for any validity and is written directly to the output files. This information is mostly a record keeping aid when running more than one program in a short period of time.

BUILDING SIZE

The length and width information is used throughout the program. The length and width (ft) is used to calculate area of the ceiling, area of the wall and foundation, and the length of the perimeter. The program considers all buildings to be rectangular.

The number of sows housed or the number of stalls in the building is included in this subdivision of the information sheet. Number of sows is used to calculate the heat generated within the building. The ventilation rates are calculated from this stocking rate.

The thermometer setting is used to calculate the Δt between the inside and the outside of the building in determining the supplemental heat required and heat loss values.

LOCATION

The location is used to localize the weather condition. The program uses the average daily maximum and minimum temperature per month for representative sites within each of the nine (9) climatalogical regions of Kansas (30 yr average, 1951-1980). These values are used by the sine function to approximate the diurnal temperature variations.

HEAT SOURCE

The four most common sources of heat for livestock buildings are included in the menu of choices. The user selects the fuel and then must enter the price per unit. This value is then converted to a cost/million Btu and used to figure the fuel cost throughout the program.

DOORS

The menu for doors includes those commonly used in agricultural structures. Other type doors may be used, however, the user must provide the total R-value. All doors are considered to have a common area of 20 ft^2. The total number of doors is used to check the accuracy of the inputs if the doors are of different types.

WINDOWS

The menu for windows contains those that are those commonly available to builders. Other types of windows can be entered, but, the user must provide the R-value of the window desired. The area of the windows are calculated by the length and width (ft) values entered.

WALLS

The first question asks if the walls are of similar material and have approximately the same amount of wall height exposed. The "yes" (true) choice for the question shortens this section greatly by asking about each part of the wall (from outside to inside) one time. The "no" (false) choice for the question is the long route which continues to run through the information until the number of walls equals 4 (four). In the "no" choice for the question, the $\frac{\text{Awall section}}{\text{R-value}}$ of the walls are summed and a total exposure of the wall is thus calculated.

Each of the areas listed below present a menu of materials.

Exterior Siding
Rigid Insulation (between siding and studs)
Wall Insulation
Interior Siding

As with the doors and windows, materials other than those listed can be used if the user is willing to enter the R-value of the material.

FOUNDATIONS

The average height of the foundation is used to calculate the area of the foundations. The area for doors is removed by subtracting (2.5 ft x number of doors X height of the foundation) to get the total foundation area.

The menu for foundations lists concrete and block type construction materials. The user must enter the thickness if a concrete wall is desired.

The menu for external foundation insulation includes the commonly used materials. Formaldehyde materials are not included but it or any other material can be entered.

Often when exterior foundation insulation is used, a protective material such as cement asbestos board or similar material is used. If these materials are used, the foundation R-value is increased by .25 $ft^2 \cdot {}^oF \cdot hr/Btu$.

Below grade insulation of the foundation is used to reduce heat loss. If the perimeter (below soil level portion of the foundation) is insulated, the R-value is assigned to be 2.22, otherwise the uninsulated perimeter is assigned R-value of 1.23 $ft^2 \cdot {}^oF \cdot hr/Btu$.

CEILING

The menu of ceiling insulation includes those materials commonly used by producers, other materials may be used if the user can enter the R-value of the desired material. The total R-value of other materials must be entered if other materials are desired. The thickness of the insulation must be entered if the material is included in the menu.

MINIMUM VENTILATING RATE

The minimum ventilating rate (CFM/sow) to control odors and/or moisture can be set at any desired level. Ventilating rates less than 15 CFM/sow should be discouraged.

DISCUSSION OF OUTPUT

(sample of the output is included in the appendix)

Output from the program is written in order that producers will be capable of reading and interpreting the analysis.

The name and address of the producer serves to personalize the output and to assist in the return of output to the proper producer. Additional descriptive information may be added to the name and address line.

Monthly Average Values

This figure is the month by month values for the heat loss from the structure.

Temp The mean monthly temperature (^{o}F) for the area specified is calculated by $\frac{\text{avg. daily max.} + \text{avg. daily min.}}{2}$. The value is the 30 year historic average (1951-1980) of the nine (9) climatalogical regions of Kansas. A map outlining the regions is included in the appendix.

The values shown in the output is rounded to the nearest whole number.

Bldg loss This transmission loss is calculated by multiplying the exposure factor for the building times the Δt (temperature difference). The value is labeled as Btu/hr .

Supp Heat The amount of supplemental heat is calculated according to equation #6 having units of Btu/hr . This value does not consider the heat used for creep or other localized heating. Any creep heat during periods when the supplemental heat is required would reduce this required level.

Ventilation Both total ventilation rate and the ventilation rate/sow (CFM) are calculated. The minimum rate to control odor and moisture is set at 15 CFM/sow, while the maximum rate is set at 200 CFM/sow. The rates between the maximum and the minimum are calculated according to equation #9.

Cost The heating cost of the building is the cost ($) to provide the supplemental heat at the price of the fuel entered.

Projected Total Cost   The sum of the monthly costs is reported as total fuel cost.

Temperature and Ventilation Guide

This table is a calculation of the supplemental heat rate (Btu/hr) and the total ventilation rate and ventilation rate/sow for each 5 ^{o}F increase in temperature between 0 - 100 ^{o}F.

The table is useful to illustrate when ventilation rates should be increased above the minimum ventilation rate.

Heat Loss From Each Building Component

These values are the exposure factors for each building component and it's respective percentage of the total transmission losses. The building exposure factor is included in the table.

The equivalent exposure factor of the ventilation air is calculated (Btu/hr/^{o}F). The total exposure factor for the building and ventilation air is included as well as the percentage of the total exposure factor represented by the ventilation air. All these values should be compared with the values from the modified heat loss values to be discussed later.

Current R-Values

This figure is a comparison of the recommended R-values to their respective current values for the doors, windows etc.

Modified Heat Loss Values

This figure is of the greatest economic value for the producers as it can be used to assist in determining when increasing the insulation levels of any building component might be economical. The previous figures are valuable to explain the values of this figure.

Btu/hr/^{O}F This value would be the exposure factor if the building were modified or insulated according to the currently recommended levels.

% Bldg Loss This is the percentage the modified building exposure factor would be provided by each of the of the building components.

Btu/hr/^{O}F Saved This value is the difference between the current exposure factor and the modified exposure factor of the respective building components.

$ Saved The actual dollar savings is calculated for January to show the reductions in the January fuel bill by modifying each building component.

Annual Savings The amount of the savings for each of the modified building components is calculated for the entire year. This demonstrates the annual savings and cannot be found by simple multiplying times 12 months.

Note: Total Btu/hr/^{O}F, Btu/hr/^{O}F saved, $ Saved (January) and

Annual Savings are the sums of the columns except for annual savings. The values for the annual savings cannot react as a summation because when any combination of of values which reduces the supplemental heat requirement to 0.0, further improvement cannot be considered as savings.

The equivalent ventilation exposure factor does not change (provided the recommended ventilation rate is used). If the building shows a reduction in heat loss with the recommended levels the ventilation will therefore reflect a greater percentage of the total exposure factor. In most conditions ventilation represents 55-65 % of the total heat loss when the buildings are insulated and ventilated as recommended.

Minimum Ventilating Rates

Ventilation is the largest source of winter heat loss in a well insulated and well managed building. Research by Robbins and Spillman (1982) indicate that past minimum ventilation rate recommendations may need to be reduced in slotted floor farrowing houses. This reduction is made possible by the improved waste control and the increased temperatures maintained in the newer farrowing houses. The value reported is the cost of warming the 5 CFM of ventilation air. This is the cost for each 5 CFM over-ventilated.

Selecting Heating and Ventilating Equipment

Minimum ventilating fan rates should be maintained continuously. Maximum ventilating fan capacity is designed to be used during hot weather. It is desirable to have these summer ventilating fans operating with either variable speed or with a combination of two or more fans to allow for choices in the ventilation rate at any given temperature.

Furnace output is the output required from the furnace to provide a constant temperature in the structure at an effective outside temperature of -10 ^{o}F. Any creep heat or localized heating used would reduce this level. Temperatures below -10 ^{o}F would cause a reduction in the inside temperature during continuous operation of the furnace.

Condensation Caution

A special note is included, if necessary, to bring attention to parts of the building on which condensation might occur. Increasing the R-value of the building component would help to prevent the problem.

CONCLUSION

Many of the farrowing houses throughout Kansas are losing much more heat than necessary. These buildings can be improved by additions of insulation. Often the must economical location to reduce heat loss is the ceiling because additional insulation can be placed in the attic. Adding the insulation to the walls can reduce the heat loss just as effectively as insulating the ceiling, however, the cost of installing the insulation will be more costly thus less cost effective. In many structures the foundations will lose greater heat than expected. Insulating the foundation can be done after the structure is in operation, although the soil must be removed from along the foundation to allow for its installation.

Currently it is not and probably will never be economically sound to insulate structures to a level where the animals' heat can provide all the heat required in the coldest of times, but as fuel costs continue to increase, insulating structures to greater levels will become more economical.

This program can be useful in considering additional insulation when designing new structures where the retro-fitting costs are not necessary.

SUGGESTIONS FOR FURTHER WORK

Just as this program is designed for the less experienced user, more programs need to be written with the agriculture producer in mind. These non-technical programs require more inputs (each easier to answer), but can be used both by the producer and professional. Often the inputs to the more non-technical programs are less confusing and will obtain the more correct result upon occasional use. Computers will become more available to agricultural users and these less technical programs will speed the acceptance.

A concern when writing this type of program is to enter weather data which can accurately predict the true environmental conditions. Diurnal temperatures are difficult to accurately calculate. The monthly sine function, as used in this program, fits the curve more-closely than the mean monthly temperature used in other programs. Attempts to find accurate methods of estimating the diurnal temperatures variations need investigating.

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APPENDIX A: AGRICULTURAL COMPUTER DEVELOPMENT

AGRICULTURAL COMPUTER DEVELOPMENT

Interest in computers and software for agricultural uses has greatly increased over the recent years. The large number of articles in agricultural newspapers and magazines on the topic is only one sign of the interest. However there is currently little being done to write software which can be used by inexperienced operators.

One of the problems with writing this type of software is the need to be very informal and non-technical in the request of the input values. When working with the less technical inputs, the program may need to request many more values. This allows or requires the computer to do the actual calculations. When writing this less technical software, the programer spends a greater amount of time writing input and output (I/O) in order to obtain the values for later calculations.

From the literature review, programs of this type are rare in the agriculture area. Computer networks such as AG-Net in Nebraska use this type program; however, few programs are being written in the non-technical style as attempted here. Computers will gain even greater acceptance throughout agriculture as more programs of the less technical nature become available publicly.

The growth of businesses providing consultation and newsletters aimed toward agricultural computer use is another indication of the interest. Examples of these businesses are as follows:

AgriComp
1101 E. Walnut
Suite 201
Columbia, Mo. 65201
(314) 443-4316

Agricultural Computing
Doane-Weatern, Inc.
8900 Manchester Road
St. Louis Mo 64144
(314) 968-1000

Agricultural Microcomputing
Ridgetown College of
Agricultural Technology
Ridgetown, Ontario
Canada NOP 2CO
(519) 674-5456

Compu-Farm
Alberta Agriculture
Box 2000
Olds, Alberta
Canada TOM 1PO
(403) 556-8421

Farm Computer News
Successful Farming Magazine
1716 Locust Street
Des Moines, IA 50336
(515) 284-3000

Strain and Fieser (1982) published an "Updated Inventory of Agricultural Computer Programs Available for Extension Use". This latest listing attempts to categorize the programs which are available to the public into subject matter areas as well as by the machine for which they were written. Nearly 1500 programs and the author or contact person(s) are listed.

Efforts similar to those by Strain and Fieser (1982) will be necessary to prevent duplication of work.

In the near future, a common universal language should be selected, as well as a common operating system to make the programs more transferable. As the "new" computer users check into available software, one of their inevitable questions is "Will this program run for me on my machine". Few of the agricultural operators can revise a program to make it compatible with their machine.

To increase the portability of software, Texas has adopted the CP/M operating system (developed and marketed by Digital Research of Pacific Grove, California) as the operating system for their work. This has not eliminated the transferability problem, however it is the first step. Producers can purchase this operating systems adaptated for Apple, TRS-80 or most any other machine.

Producers will find more uses and greater needs for programs as time and experience progress. The use of one beneficial program only leads to the need for other associated software. If no uniform computer language or operating system is developed, computers will remain remote to the agricultural producer and the consulting companies and the computer companies will dominate this decision making tool and keep the "mystique" of the computer prevalent.

Producers can and will learn the price of accurate and proper decisions, but to date only a small percentage are regularly using computers. Many more producers are looking to consultants or specialists for decisions which they feel need computer analysis. This may be the present day answer to the portability of programs. This may well make the distribution of computers similar to the tractor business; the computer in an area will tend to be the same as their local extension service or the nearest computer consultant, just as the brand of tractors in an area tends to be the same as the one with the best service man in the area.

APPENDIX B : WORKSHEET FOR PRODUCERS

WORKSHEET FOR FARROWING HOUSE HEAT LOSS *

OWNER

Name and address____

BUILDING SIZE

______ft 1. Building length

______ft 2. Building width

________ 3. How many sow stalls will be in the building?

______°F 4. What will be the thermostat setting for the furnace in the winter?

LOCATION

5. Which section of Kansas is the building located?

____ NW Kansas
____ NC Kansas
____ NE Kansas
____ WC Kansas
____ C Kansas
____ EC Kansas
____ SW Kansas
____ SC Kansas
____ SE Kansas

HEAT SOURCE

6. Which fuel are you using for heating?

_____ Electricity
_____ Natural Gas
_____ Propane or butane
_____ Fuel oil

7. What is the price of the fuel per unit?
$____.___ / unit (KWH, gal, 1000 cf)

DOORS

(ENTER the number of doors of each type which opens to the outside)

____ Solid Core wood 1 3/4 inch
____ + Wood Storm
____ + Metal Storm
____ Metal, urethane core 1 3/4 inch
____ Metal, polystyrene core 1 3/4 inch
__.__ Other <==specify Total R-Value

________ 8. Total number of doors

WINDOWS

(ENTER the number of each type of window to the outside)

____ Single glass
____ + storm
____ Twin glazed
____ Triple glazed
__.__ Other <== specify Total R-Value

________ 9. Total number of windows

____.__ft 9a. Average window width?

____.__ft 9b. Average window length?

WALL Mark (X) the material used or the thickness of insulation for each of the four walls. If there are walls of similar type, only complete one wall, but circle the names of the similar walls. Include the R-Value of materials used but not listed.

NOTE ==> Circle the wall(s) of the same type.

North,	East,	South,	West,	

Exterior Siding : (mark (X) one per wall)

____	____	____	____	Wood, 8 inch beveled siding
____	____	____	____	Wood, 8 inch drop siding
____	____	____	____	Metal, farm building (unbacked)
____	____	____	____	Metal, residential (hollow backed)
____	____	____	____	Metal, residential (insulation backed)
___.__	___.__	___.__	___.__	Other <== specify Total R-Value

Insulation (installed between siding and studs) :
ENTER thickness (inches)

__.__	__.__	__.__	__.__	Extruded Polystyrene
__.__	__.__	__.__	__.__	Molded Polystyrene
__.__	__.__	__.__	__.__	Fiber glass
__.__	__.__	__.__	__.__	Exp. Polyurethane (aged), 1.5#/cu ft
___.__	___.__	___.__	___.__	Other <== specify Total R-Value

Insulation (installed between the studs) :
ENTER thickness (inches)

				Blanket or Batt
__.__	__.__	__.__	__.__	Glass wool, mineral wool or fiber glass
				Loose fill
__.__	__.__	__.__	__.__	Glass or Mineral wool
__.__	__.__	__.__	__.__	Vermiculite
__.__	__.__	__.__	__.__	Shavings or sawdust
__.__	__.__	__.__	__.__	Milled paper or wood pulp
___.__	___.__	___.__	___.__	Other <== specify Total R-Value

Interior Siding : (mark (X) one per wall)

____	____	____	____	Plaster or Gypsum board
____	____	____	____	Plywood, 3/8 inch
____	____	____	____	1/2 inch
____	____	____	____	Fiber board sheathing 25/32 inch
____	____	____	____	Particle board, med. density
____	____	____	____	Metal, farm building (unbacked)
___.__	___.__	___.__	___.__	Other <== specify Total R-Value

Wall Size

__.__	__.__	__.__	__.__	(ft) Length of the wall
__.__	__.__	__.__	__.__	(ft) Heigth of the wall

_____ft 10. What is the average height of the foundation above soil level?

FOUNDATIONS : (mark (X) one)

____ Concrete, inches thick ____

Concrete blocks

____	Sand and Gravel	8 inch
____		12 inch
____	Lightweight	8 inch
____		12 inch
____	+ Vermiculite in cores	8 inch
____	+ Vermiculite in cores	12 inch

Exterior foundation insulation :
ENTER thickness (inches)

__.__ Extruded Polystyrene
__.__ Molded (bead board) Polystyrene
__.__ Glass fiber
___.__ Other <== specify Total R-Value

Y or N 11. Is the exterior foundation insulation covered with a protective material?

Y or N 12. Is the foundation below soil level insulated?

CEILING : (mark (X) one)

____ Plaster or Gypsum board
____ Plywood, 3/8 inch
____ 1/2 inch
____ Fiber board sheathing 25/32 inch
____ Particle board, med. density
____ Metal, farm building (unbacked)
___.__ Other <== specify Total R-Value

Ceiling Insulation :
ENTER thickness (inches)

Blanket or Batt

__.__ Glass wool, mineral wool or fiber glass

Loose fill

__.__ Glass or Mineral wool
__.__ Vermiculite
__.__ Shavings or sawdust
__.__ Milled paper or wood pulp
___.__ Other <== specify Total R-Value

_____ CFM 13. Enter the minimum Winter ventilation rate you desire.

APPENDIX C: SAMPLE OUTPUT

SAMPLE OUTPUT

Farrowing house "1 inch insulation in walls & ceiling"

MONTHLY AVERAGE VALUES

Month	Temp deg F	Bldg Loss Btu/Hr	Supp Heat Btu/Hr	Ventilation CFM	Ventilation CFM/sow	Cost $/Mo.
January	27	62052.21	64943.10	435.00	15.00	$ 267.70
February	33	53500.38	53594.83	435.00	15.00	$ 199.55
March	41	42759.25	39341.38	435.00	15.00	$ 162.17
April	54	25039.81	17787.05	820.96	28.31	$ 70.96
May	63	13140.31	6768.43	2465.23	85.01	$ 27.90
June	75	4355.27	296.12	4019.94	138.62	$ 1.18
July	80	1618.79	0.00	5044.24	173.94	$ 0.00
August	78	2605.77	0.00	4576.02	157.79	$ 0.00
September	68	9123.55	3873.38	3162.59	109.05	$ 15.45
October	57	20934.93	14680.95	1757.35	60.60	$ 60.52
November	41	42348.75	38796.67	435.00	15.00	$ 154.77
December	31	55621.22	56409.19	435.00	15.00	$ 232.53

Projected total fuel cost = $ 1192.72

TEMPERATURE & VENTILATION GUIDE

Temp	Supp Heat	CFM	CFM/sow
0	113332.15	435.00	15.00
5	104253.53	435.00	15.00
10	95174.91	435.00	15.00
15	86096.29	435.00	15.00
20	77017.66	435.00	15.00
25	67939.05	435.00	15.00
30	58860.42	435.00	15.00
35	49781.80	435.00	15.00
40	40703.18	435.00	15.00
45	31624.55	435.00	15.00
50	22545.94	435.00	15.00
55	13467.31	435.00	15.00
60	4388.69	435.00	15.00
65	0.00	1086.38	37.46
70	0.00	5800.00	200.00
75	0.00	5800.00	200.00
80	0.00	5800.00	200.00
85	0.00	5800.00	200.00
90	0.00	5800.00	200.00
95	0.00	5800.00	200.00
100	0.00	5800.00	200.00

This 90 X 30 farrowing house with 29 sows has an average January heat loss of 62052.2 Btu/Hr at the desired temperature of 72.0 degrees (F).

The heat loss from each building component is:

doors	= 53.6 Btu/Hr/F	or	3.9 % of total
windows	= 0.0 Btu/Hr/F	or	0.0 % of total
walls	= 414.7 Btu/Hr/F	or	30.3 % of total
ceiling	= 555.6 Btu/Hr/F	or	40.6 % of total
foundations	= 149.3 Btu/Hr/F	or	10.9 % of total
perimeters	= 195.1 Btu/Hr/F	or	14.3 % of total
TOTAL	= 1368.3 Btu/Hr/F		
Ventilation	= 447.4 Btu/Hr/F		
TOTAL Heat loss	= 1815.7 Btu/Hr/F		
Ventilation	= 24.6% of the total heat loss.		

Located in NC Kansas, this building would have a heating cost of $1192.72 /year, using a fuel price of $ 3.50 for Natural Gas per 1000 cubic ft.

If all areas were insulated at the recommended rate of:

		current R-Value
6.0	R-value for all doors	2.6
3.0	R-value for all windows	0.0
20.0	R-value for all walls	5.4
30.0	R-value for all ceilings	4.9
8.0	R-value for all foundations	1.5
2.22	R-value for all perimeters	1.23

The new values would lead to a average January heat loss of 16388.5 Btu/Hr at the desired temperature.

Modified heat loss values

		Btu/Hr/F	% Bldg Loss	Btu/hr/F Saved	$ Saved	Annual Savings
doors	=	23.33	6.5	30.3	5.66	$ 28.41
windows	=	0.00	0.0	0.0	0.00	$ 0.00
walls	=	112.13	31.0	302.6	56.56	$ 282.95
ceiling	=	90.00	24.9	465.6	87.03	$ 432.89
foundations	=	27.81	7.7	121.5	22.72	$ 114.02
perimeter	=	108.11	29.9	87.0	16.27	$ 81.64
TOTAL	=	361.38 Btu/Hr/F		1006.9	188.23	$ 912.39

Ventilation	= 447.4 Btu/Hr/F
TOTAL Heat loss	= 808.81 Btu/Hr/F
Ventilation	= 55.3% of the total heat loss.

Minimun ventilating fans often remove much more heat from livestock buildings than producers realize. For the building as initally designed, an increase in the minimum ventilation rate from 15 CFM to 20 CFM would increase the fuel cost for heating only by $27.88 during an average month of January.

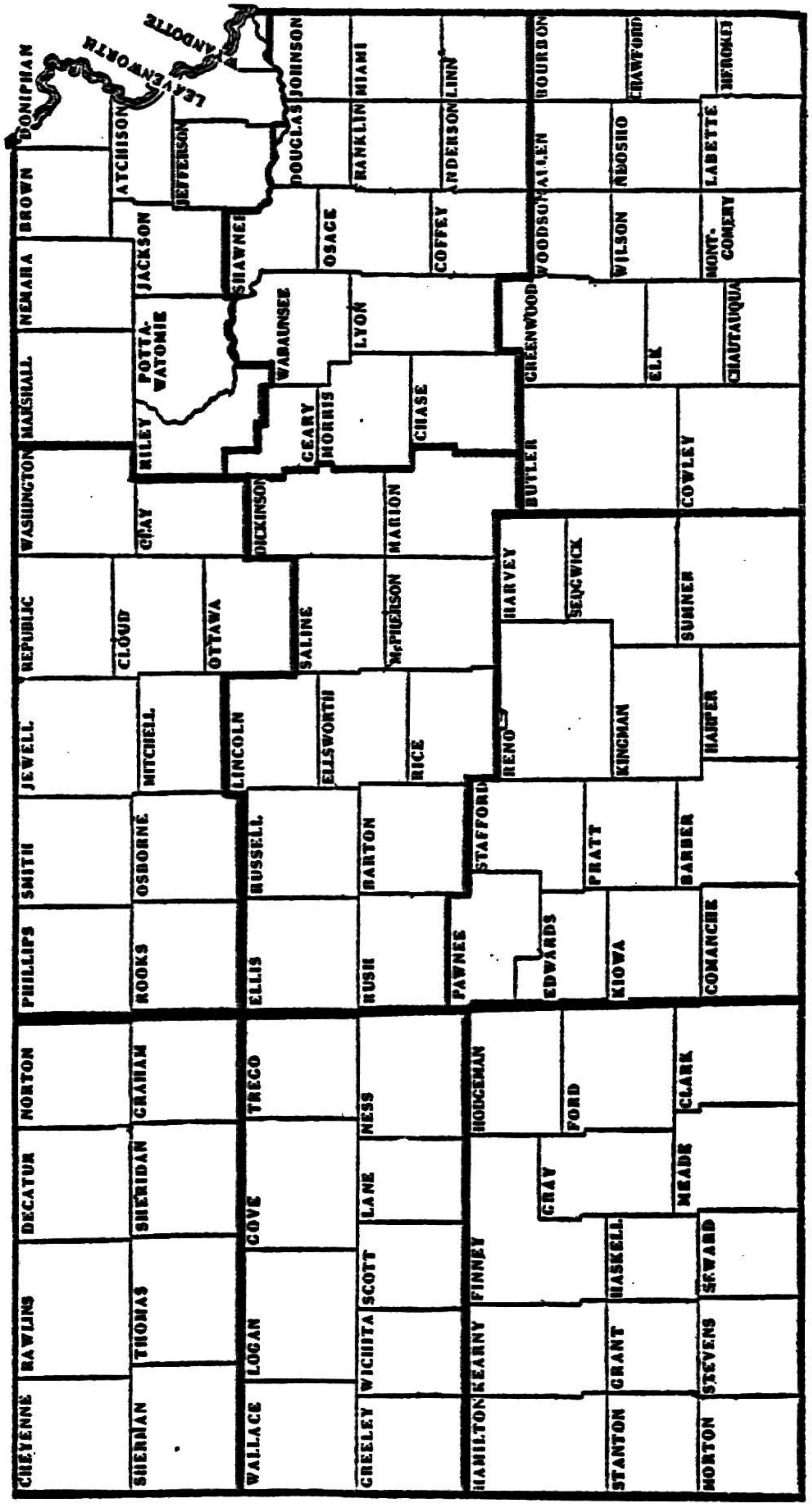
When selecting equipment for this 90 ft x 30 ft farrowing house for 29 sows, to operate at 72 (F) in NC Kansas, consider equipment which will meet the following minimum requirements:

Minimun ventilation fan	==>	435 CFM	Continuous operation
Maximum ventilation fan	==>	5365 CFM	Hot weather operation
Furnace output	==>	131489 Btu/Hr	Set at 72 (F)

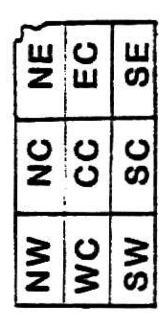
CAUTION!!

At the current levels of insulation, condensation is likely to occur;
on the doors,
on the ceiling,
on the walls,
on the foundation,
This condensation can be reduced by increasing the amount of insulation used.

APPENDIX D : WEATHER MAP AND DATA



Climatalogical Regions of Kansas



Weather Data

Area		Jan	Feb	Mar	Arp	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
NW	Max.	38.9	44.6	50.5	63.3	73.0	84.3	90.6	88.6	79.4	68.4	51.3	42.8
Colby	Min.	12.8	17.6	23.2	35.5	46.3	56.5	62.5	59.9	50.1	37.4	24.6	16.6
NC	Max.	39.1	46.1	54.3	68.0	75.5	88.3	94.1	92.2	82.9	72.0	54.4	43.8
Phillipsburg	Min.	14.2	19.7	27.2	39.4	50.4	60.8	66.1	63.9	53.6	41.4	27.7	18.9
NE	Max.	44.8	51.1	58.4	70.0	78.9	89.7	94.8	92.1	84.1	73.5	56.4	48.0
Holton	Min.	13.5	18.8	25.5	37.1	47.8	58.2	63.6	61.3	51.7	37.9	24.5	16.8
WC	Max.	43.6	49.2	55.4	67.0	76.0	87.2	92.7	89.9	81.8	71.1	54.4	46.4
Tribune	Min.	14.2	18.9	24.3	35.1	45.6	55.8	61.6	59.5	50.1	37.8	24.9	17.6
CC	Max.	40.3	46.6	55.9	69.0	78.1	88.5	94.0	92.7	82.8	72.3	55.5	45.1
Ellsworth	Min.	15.5	20.4	29.0	41.3	52.2	62.4	67.7	65.6	55.9	43.9	30.0	20.5
EC	Max.	39.2	45.4	55.3	68.4	77.5	85.8	91.2	90.0	82.1	71.6	56.0	44.4
Ottawa	Min.	18.4	24.0	32.5	44.8	54.5	63.8	68.1	65.9	57.5	46.4	34.0	24.6
SW	Max.	41.7	47.5	54.1	66.8	75.9	87.1	92.3	89.8	81.1	70.1	54.5	45.8
Syracuse	Min.	14.4	19.3	26.3	38.3	49.4	59.5	64.7	62.7	53.3	40.1	26.6	18.4
SC	Max.	44.9	51.3	60.0	72.0	80.4	90.2	95.4	94.3	85.1	75.0	58.6	49.0
Medicine Lodge	Min.	19.3	24.1	31.8	43.9	53.7	63.2	67.6	66.0	57.5	45.1	32.1	23.3
SE	Max.	42.9	49.3	58.5	70.7	78.2	86.4	92.2	91.6	83.4	73.2	58.2	47.7
Independence	Min.	21.2	26.3	34.4	46.4	55.8	64.4	69.0	67.1	59.1	47.5	34.9	26.1

Temperatures are "Average Daily Maximum and Minimum (^{o}F)" 1951-1980.

APPENDIX E : DESCRIPTION OF THE PROGRAM

DESCRIPTION OF THE PROGRAM

2 - 8	Variable declarations.
9- 64	data statements for all the arrays.
65- 78	introduction to the program to be written to the user.
90- 75	subroutine calls from the main body of the program.
90- 91	'stop' and 'end' of the main.
91	subroutine 'rfact' parameters.
94	variable declaration.
95- 160	output of the check sheet of materials and assigned R-values.
161-162	'return' and 'end' of subroutine 'rfact'.
167-169	subroutine 'ask' parameters.
170-178	variable declaration.
179-185	inputing the owners name etc. and outputting that information to the output files.
186-191	inputing the length of the structure.
192-197	inputing the width of the structure.
198-208	inputing the capacity (number of sows) of the structure.
209-219	inputing the interior temperature (^{O}F).
220-238	inputing the location within the state . This information will be used to obtain the proper outside temperatures for each month of the year.
239-254	inputing the fuel used as a heat source.
255-264	inputing the value (or price/unit) of the fuel used.
265-268	converts the price/unit of fuel to the cost/million BTU.
269-278	inputing the number of outside doors.
279-289	presenting for the user the menu of doors.
290-294	inputing if the doors are all of the same type.
295-	checking for a valid input.

296-307 inputing the type of door used from the menu list.

308-317 inputing the R-value of the door(s) if not of the types offered in the menu.

308-320 assigning the R-value value to the door(s).

321-331 inputing the number of doors of type 1 on the menu.

332 checks that the door count has not exceeded the total number of doors.

333 assigning the R-value of the total doors.

334-343 inputing the number of doors of type 2 on the menu.

344 adds the R-values to present door to the door totals.

345 checks that the door count has not exceeded the total number of doors.

346-355 inputing the number of doors of type 3 on the menu.

356 adds the R-values to present door to the door totals.

357 checks that the door count has not exceeded the total number of doors.

358-367 inputing the number of doors of type 4 on the menu.

368 adds the R-values to present door to the door totals.

369 checks that the door count has not exceeded the total number of doors.

370-379 inputing the number of doors of type 5 on the menu.

380 adds the R-values to present door to the door totals.

381 checks that the door count has not exceeded the total number of doors.

382-391 inputing the number of doors of type 6 on the menu.

392-400 inputs the R-value of the door, as it is not in the menu.

401 adds the R-values to present door to the door totals.

403 checks that the door count has not exceeded the total number of doors.

404-408 writes the message that the door count has exceeded the total number of doors.

409 calculates the sum of the R-values to the average R-value.

$$\text{R-value}_{door} = \frac{\text{R-values}_{doors}}{\text{number of doors}}$$

412-415 prints the error message if "are all doors of the same type" received an invalid input.

416 calculates the total area of the doors.

$$\text{area}_{doors} = 20 \text{ ft}^2 \text{ x number of doors}$$

417 calculates the exposure factor for the doors.

$$\text{exposure factor}_{doors} = \frac{\text{area}_{doors}}{\text{R-value}_{door(s)}}$$

418-427 inputs the number of windows to the outside. If there are no windows, the remainder of the questions about windows are omitted.

428-431 assigns a very small value to the R-value of the windows, if there are no windows. This is to prevent dividing by '0'. It also steps around the remainder of the questions about windows.

432-439 presents the menu of windows.

440-442 inputing if all the windows are of the same type.

443 checks that the input is valid.

444-453 inputing the type of window(s) used from the menu list.

454-463 inputing the R-value for the window(s), if the type is not in the menu provided.

465 assigns the R-value of the window(s) if the windows were all of the same type

466-535 inputing the number of each type of window listed in the menu. The R-value of the windows are summed. The window count is checked that it does not exceed the total number of windows.

536-541 prints the error message that the window count has exceeded the total number of windows.

545-546 prints the error message if "are all window(s) of the same type" received an invalid input.

548-568 if the number of windows is greater than '0', the average width and length (ft) is input.

569 calculates the area of the windows.

$$area_{windows} = \text{no. windows} \times length_{window}\ (ft) \times width_{window}\ (ft)$$

570 calculates the exposure factor for the windows.

$$\text{exposure factor}_{window} = \frac{area_{window}}{R\text{-}value_{window}}$$

571-580 outputs some check values to an output file.

581-581 'return' and 'stop' for the subroutine 'ask'.

586-588 subroutine 'wall' parameters.

589-593 variable declaration.

594 initialize inch ==> '0'.

595-600 inputing if all the walls are of the same type.

601-605 verifies that a correct answer was given.

606-614 presents the menu of exterior siding.

615-626 inputing the type of exterior siding used.

627-628 assigns the R-value for the exterior siding (if included in the menu).

630-641 inputing the R-value for the exterior siding (if not included in the menu).

642-652 inputing the average height of the frame wall (ft).

653 calculates the total area of the frame wall.

$$area_{wall} = (2 \times length \times width) - area_{doors} - area_{windows}$$

655-662 presents the menu for the rigid insulation used between the siding and the studs.

663-667 inputing if there is rigid insulation between the siding and the studs.

668-673 verifying if a proper input was given.

674-684 inputing the type of rigid insulation used in the wall.

685-695 inputing the R-value of the the rigid insulation if not included in the menu.

691 assigns a very small value to the R-value of the rigid insulation layer.

697-704 inputs the thickness of the rigid insulation layer (in).

706 assigns the R-value of the rigid insulation to '0.0' if no insulation is used.

708-716 presents the menu for wall insulation.

717-726 inputing the type of wall insulation used.

727-736 inputing the R-value of the wall insulation used (not included in the menu.

738-747 inputing the thickness of the wall insulation (in).

748 assigns the R-value to the wall insulation.

750-758 presents the menu of interior wall siding.

759-768 inputing the type of interior wall siding, from the menu.

769-772 assigns the proper R-value to tin when used for interior siding.

773-782 inputing the R-value of the interior siding when not included in the menu.

785 assigns the R-value to the interior siding.

791-800 inputing the number of walls that are similar.

801-808 inputing the length (combined) of this type of wall(s).

809-814 inputing the average height of this type wall.

815-821 inputing the number of doors in this type wall(s).

822-828 inputing the number of windows in this type wall.

829-843 inputing the average height (ft) and width (ft) of the windows in this type wall(s).

845 calculate the area of this type wall.

$$area_{wall\ sec} = length\ ft \times height\ (ft) - (nc.\ doors \times 20\ (ft)^2) - (no.\ window \times height_{window}(ft) \times width_{window}(ft))$$

846 calculate the R-value for this type wall.

$$R_{wall} = R_{ext} + R_{layer} + R_{insul} + R_{int} + .68 + .17$$

847 calculate the total area of the walls.

$$total\ area_{wall} = area_{wall} + total\ area_{wall}$$

848 calculate the average exposure for the walls.

$$ef_{wall} = ef_{wall} + \frac{area_{wall\ section}}{R\text{-}value_{wall\ section}}$$

849-853 outputs check values to the output file.

855-864 inputing the remaining number of wall which are similar.

865-871 print that the forth wall is to be considered.

874 calculates the R-value of the walls (all similar).

$$R\text{-}value_{wall} = R_{ext} + R_{layer} + R_{insul} + R_{int} + .68 + .17$$

875 calculates the exposure factor for the walls (all similar).

$$exposure\ factor_{wall} = \frac{area_{walls}}{R\text{-}value_{walls}}$$

877-879 outputs total area and the exposure factor of the walls.

884-885 prints message that the foundation is now to be considered.

886-892 inputing the average height of the foundation.

893 calculates the area of the foundation.

$$area_{foun} = height_{foun} \times (2 \times length + 2 \times width - 2.5 \times no.\ doors)$$

894 calculates the new values for the area of the walls.

$$\text{total area}_{wall} = \text{total area}_{wall} - (\ 2.5 \times \text{no. doors} \times \text{height}_{foun}\ )$$

895-904 presents the menu for foundations.

905-913 inputing the foundation material from the menu.

914-923 inputing the thickness of the foundation if made of concrete.

924 calculate the R-value of the of the foundation if of concrete.

$$R_{foundation} = (\ R/in. \times \text{thickness}\ ) + .68 + .17$$

926 assigns the R-value of the foundation other than concrete.

928-934 presents the menu of foundation insulation materials.

935-939 inputing if the foundation has any insulation covering.

940-949 inputing the type of insulation used on the exterior of the foundation.

950-955 inputing the thickness of foundation insulation material.

956 calculate the R-value for the exterior foundation insulation plus the foundation.

$$R_{foundation} = R/in\ \text{material} \times \text{thickness} + R_{foundation}$$

957-964 inputing the R-value of foundation insulation if other than what is in the menu.

963 calculates the new value for the R-value of the foundation.

$$R_{foundation} = R_{foundation} + R_{foundation\ insulation}$$

966-972 inputing if there is a covering over the exterior foundation insulation.

971 calculates the new value for the foundation R-value.

$$R_{foundation} = R_{foundation} + .25$$

973 calculates the exposure factor for the foundation.

$$\text{exposure factor}_{foundation} = \frac{\text{area}_{foundation}}{R_{foundation}}$$

974-977 inputing if the foundation below grade is insulated.

979-981 assigns the proper R-values for the perimeter.

983 calculates the exposure factor of the perimeter.

$$\text{exposure factor}_{perimeter} = \frac{2 \times \text{length} + 2 \times \text{width}}{R_{perimeter}}$$

987-995 presents the menu of ceiling materials.

996-1006 inputing the type of material used on the ceiling from the menu.

1007-1009 assigns the R-value for tin to the ceiling.

1011-1019 inputing the R-value for the ceiling covering.

1020 assigns the R-value for ceiling.

1023 assigns the R-value for the ceiling.

1025 calculates the area of the ceiling.

$$\text{area}_{ceiling} = \text{length} \times \text{width}$$

1026-1037 presents the ceiling insulation materials.

1038-1046 inputing the type of ceiling insulation used from the menu.

1047-1056 inputing the R-value of the ceiling insulation if not included in the menu.

1059-1063 inputing the thickness of the ceiling insulation is included in the menu.

1065 calculates the total R-value for the ceiling.

$$R_{ceiling} = R_{ceiling} + R_{ceiling\ insulation} + .68$$

1066 calculates the exposure factor for the ceiling.

$$\text{exposure factor}_{ceiling} = \frac{\text{area}_{ceiling}}{R_{ceiling}}$$

1067-1082 outputs values to the output files.

1080 calculates total exposure factor for the building.

$$ef = ef_{door} + ef_{window} + ef_{wall} + ef_{foun} + ef_{peri} + ef_{ceil}$$

1083-1087 inputting if the minimum ventilating rate is to be set at a level other than 15 CFM/sow

1088-1098 inputting the new minimum ventilating rate.

1099-1100 'return' and 'stop' for the subroutine 'wall'.

1108-1111 subroutine 'output' parameters.

1112-1119 variable declaration.

1121 assigns the value to 'a'.

1122 calculates heat generated by the animals (sows).

$$BTU_{sow} = 600 \text{ BTU/hr} \times \text{number}_{sows}$$

1124-1128 formating heading for 'MONTHLY AVERAGE VALUES'.

1129 assigning total cost/mo ==> 0.0 .

1130-1156 looping which calculates and outputs a month's value for the table.

1135-1136 calculates transmission heat losses.

$$\text{BTU losses}_{/hr} = \text{exposure factor} \times \Delta t$$

1138 calculates ventilation rate.

$$\text{vent rate} = \frac{V}{C_p \cdot 60 \text{ min/hr} \cdot \Delta t}(q_s - (ef_{bldg} \cdot \Delta t$$

1141 calculates the ventilation rate (when outside temp approaches or exceedes the desired inside temperature.

$$\text{vent rate} = \frac{V}{C_p \cdot 60 \text{ min}_{/hr} \cdot 2}(q_s - (ef_{bldg} \cdot \Delta t))$$

1143-1144 assigns the maximum and minimum level to ventilation rates.

$$\text{maximum ventilation rate} = \text{sows} \cdot 200 \text{ cfm}$$

$$\text{maximum ventilation rate} = \text{sows} \cdot \text{min rate cfm}$$

1146 calculates the heat loss in ventilation air.

$$q_v = \frac{\text{cfm} \cdot C_p \cdot 60 \text{ min}_{/hr} \cdot \Delta t}{V}$$

1147 calculate the supplemental heat requirement.

$$\text{supplemental heat} = q_b - q_s + q_v$$

1148 assigns the minimum values to supplemental heat.

1151 calculates the monthly fuel cost.

$$\text{fuel cost} = \frac{\text{supp heat}_{/hr} \cdot 24\ \text{hr}_{/day} \cdot \text{days}_{/mo} \cdot \$_{\text{million btu}}}{1{,}000{,}000\ \text{btu}}$$

1152 calculates the total fuel cost (year).

$$\text{total fuel cost} = \text{total fuel cost} + \text{monthly fuel cost}$$

1153-1155 outputs month, temperature, transmission losses, supplemental heat, ventilation rate, ventilation rate per sow and cost/mo.

1157-1158 outputs total yearly fuel cost.

1159-1161 outputs heading for the ventilation guide.

1163 calculates the Δt for each exterior temperature.

$$\Delta t = \text{inside } ({}^{o}F) - \text{outside } ({}^{o}F)$$

1164 calculates the transmission loss of the building for each of the Δt.

$$\text{transmission loss} = ef_b \times \Delta t$$

1167 calculates ventilation rate.

$$\text{vent rate} = \frac{V}{C_p \cdot 60\ \text{min/hr} \cdot \Delta t}(q_s - (ef_{bldg} \cdot \Delta t))$$

1169 calculates the ventilation rate (when outside temp approaches or exceedes the desired inside temperature.

$$\text{vent rate} = \frac{V}{C_p \cdot 60\ \text{min}_{/hr} \cdot 2}(q_s - (ef_{bldg} \cdot \Delta t))$$

1171-1172 assigns the maximum and minimum level to ventilation rates.

maximum ventilation rate = sows $\cdot$ 200 cfm

maximum ventilation rate = sows $\cdot$ 15 cfm

1173 calculates the heat loss in ventilation air.

$$q_v = \frac{cfm \cdot C_p \cdot 60\ min/_{hr} \cdot \Delta t}{V}$$

1174 calculate the supplemental heat requirement.

$$\text{supplemental heat} = q_b - q_s + q_v$$

1176-1177 outputs the temperature (^oF), supplemental heat required, ventilation rate and ventilation rate$/_{sow}$.

1184-1189 assigns values to the recommended R-values.

1190-1195 calculates the exposure factor for each building component.

$$\text{exposure factor} = \frac{\text{area}}{\text{R-value}}$$

1196 calculate the total exposure factor of the building.

$$\text{total exposure factor} = ef_{door} + ef_{windows} + \cdots$$

1197-1198 assigns a minimum level to the exposure factor of the windows.

1199-1216 outputs length, width, sows, transmission losses and inside temperature.

calculates and outputs exposure factor for each building components and it's percentage of the total transmission losses.

eg. $$\text{percent of transmission losses} = \frac{ef_{door} \times 100}{ef_b}$$

1217 calculates the exposure factor of the ventilation air.

$$ef_{vent\ air} = \frac{sows \cdot 15\ cfm \cdot C_p \cdot 60\ min/_{hr}}{V}$$

1218 calculates the total of exposure factor of the building and the exposure factor of the ventilation air.

$$\text{total exposure factor} = ef_b + ef_v$$

1219-1223 calculates and outputs the exposure factor of the ventilation air, total equivalent exposure factor for the building, and the percentage to heat loss in the ventilation air.

1224-1228 calculates the R-value for each of the building components.

$$R = \frac{A}{\text{exposure factor}}$$

1229-1244 outputs location, total fuel cost, price of the fuel, type of fuel used, R-value of the desired building component and the R-value of the current building components.

1246-1259 assigns current and modified exposure factors to an array.

1260-1277 calculates the fuel savings by each building component.

1278 calculates the Δt for January.

1279 assigns the constant value to "zzzz".

1280-1306 calculates and outputs transmission heat loss, new exposure factor of the building components (door etc.), percent of the transmission losses by each building component, btu saved and the dollars saved by each building component.

eg. $\text{percent building loss} = \frac{ef_{component} \times 100}{ef_{building}}$

eg $\text{dollars saved} = cost_{/BTU\ hr} \cdot \text{BTU saved}$

1307 calculates the equivalent total exposure factor.

$$\text{total } ef_{building} = ef_{vent\ air} + ef_{building}$$

1308-1312 calculates and outputs exposure factor for ventilation air, total exposure factor $_{building}$, percent ventilation of the total heat loss of the building.

$$\text{percent } q_v = \frac{ef_v \cdot 100}{ef_{total\ building}}$$

1313-1319 calculate and output the additional cost for 5 cfm ventilation air.

$$\$_{/5\ cfm} = \frac{cost_{/btu} \cdot sows \cdot 5_{cfm} \cdot 60\ min_{/hr} \cdot C_p}{V}$$

1320-1331 calculates and outputs building length, building width, sows, inside temperature (^oF), location, minimum ventilation rate, maximum ventilation rate, furnace output requirement (btu/hr).

winter fan = sows · minimum ventilating rate summer fan (cfm) = sows x (200 - minimum ventilating rate)

furnace = $ef_{total\ building} \times (\,^{o}F_{inside} - (-10)) - q_s / sow)$

1332-1338 calculates each internal surface temperature of each building component, if the temperature is 7 ^{o}F or more below the building temperature, the corresponding value is assigned to 1

$$\Delta t = \frac{.68 \cdot \text{inside temperature}}{R_t}$$

1338 checks if any of the building components have a condensation problem

1339-1358 outputs the "CAUTION" about condensation and which surfaces of the building condensation might be expected to occur

1360-1361 "return" and "end" of the "output"subroutine.

6213 subroutine "cycle" parameters.

1363-1364 variable declaration

1365 assigns pi ==> π

1366-1374 calculates the hourly Δ t to approximate the diurnal temperature variations.

1367 calculates the daily temperature variations.

$$\text{variation} = \frac{\text{avg. daily Max.} - \text{avg. daily Min.}}{2}$$

1368 calculates the monthly mean temperature.

$$\text{mean} = \frac{\text{avg. daily Max.} + \text{avg.daily Min.}}{2}$$

1369 assigns mean to the array.

1370-1371 calculates the hourly temperature diurnal variations. The Sine function is the model used to approximate the temperature curve.

$$\Delta t = \text{inside} - ((\sin(\frac{\pi \times \theta}{12}) \times \text{var}) + \text{mean})$$

1374-1375 "return" and "end" of subroutine "cycle".

1383 subroutine "conver" parameters.

1384-1387 variable declaration

1388 assigns the digits to the array.

1390 "blank" is invalid.

1393-1399 finds the numeric value of the "whole" portion of the input.

1401 when an invalid character is found, -1 is returned.

1405-1416 finds the "decimal" value of the input.

1417 assigns the value of total ==>digit.

1418-1419 "return" and "end" of the subroutine 'conver'.

APPENDIX F : COMPUTER PROGRAM

```
integer i
character *1 reply
real door(5),window(4),insul(9),peri(11),ext(5),roof(3),wall(5),minv,
        length, width,min(12,9),max(12,9),inside,deltaT(12,24),out(12)
character *33 energy(4)
character *10 month(12)
character *2 local(9)
integer days(12),fuel
data door/2.17,3.92,3.23,5.26,2.13/
data window/.91,2.0,1.72,2.56/
data insul/3.5,2.5,2.2,2.22,3.13,4.0,3.57,4.0,6.25/
data peri/.08,1.1,1.28,2.0,2.27,5.03,5.82,4.0,3.57,4.0,6.25/
data ext/.81,.79,0.0000001,0.61,1.82/
data wall/.22,.47,.63,2.08,.79/
data max/
NW Kansas
38.9,44.6,50.5,63.3,73.0,84.3,90.6,88.6,79.4,68.4,51.3,42.8,
NC Kansas
39.1,46.1,54.3,68.0,75.5,88.3,94.1,92.2,82.9,72.0,54.4,43.8,
NE Kansas
44.8,51.1,58.4,70.0,78.9,89.7,94.8,92.1,84.1,73.5,56.4,48.0,
&       35.7,42.4,52.8,67.4,76.9,85.4,90.3,88.6,80.5,70.0,53.4,41.5,
WC Kansas
43.6,49.2,55.4,67.0,76.0,87.2,92.7,89.9,81.8,71.1,54.4,46.4,
CC Kansas
40.3,46.6,55.9,69.0,78.1,88.5,94.0,92.7,82.8,72.3,55.5,45.1,
&       38.8,44.8,52.7,66.1,75.2,86.2,92.2,90.8,81.2,70.9,54.0,43.6,
EC Kansas
39.2,45.4,55.3,68.4,77.5,85.8,91.2,90.0,82.1,71.6,56.0,44.4,
SW Kansas
41.7,47.5,54.1,66.8,75.9,87.1,92.3,89.8,81.1,70.1,54.5,45.8,
SC Kansas
44.9,51.3,60.0,72.0,80.4,90.2,95.4,94.3,85.1,75.0,58.6,49.0,
SE Kansas
42.9,49.3,58.5,70.7,78.2,86.4,92.2,91.6,83.4,73.2,58.2,47.7/
data min/
NW Kansas
12.8,17.6,23.2,35.5,46.3,56.5,62.5,59.9,50.1,37.4,24.6,16.6,
NC Kansas
14.2,19.7,27.2,39.4,50.4,60.8,66.1,63.9,53.6,41.4,27.7,18.9,
NE Kansas
13.5,18.8,25.5,37.1,47.8,58.2,63.6,61.3,51.7,37.9,24.5,16.8,
&       13.9,19.7,28.9,41.7,52.1,61.6,66.2,64.0,55.1,43.4,30.5,20.3,
WC Kansas
14.2,18.9,24.3,35.1,45.6,55.8,61.6,59.5,50.1,37.8,24.9,17.6,
```

```
46=c        CC Kansas
47=&        15.5,20.4,29.0,41.3,52.2,62.4,67.7,65.6,55.9,43.9,30.0,20.5,
48=c        &       13.0,17.8,25.9,39.1,49.9,60.3,65.8,63.5,53.7,40.6,26.8,17.8,
49=c        EC Kansas
50=&        18.4,24.0,32.5,44.8,54.5,63.8,68.1,65.9,57.5,46.4,34.0,24.6,
51=c        SW Kansas
52=&        14.4,19.3,26.3,38.3,49.4,59.5,64.7,62.7,53.3,40.1,26.6,18.4,
53=c        SC Kansas
54=&        19.3,24.1,31.8,43.9,53.7,63.2,67.6,66.0,57.5,45.1,32.1,23.3,
55=c        SE Kansas
56=&        21.2,26.3,34.4,46.4,55.8,64.4,69.0,67.1,59.1,47.5,34.9,26.1/
57=         data local /'NW','NC','NE','WC',' C','EC','SW','SC','SE'/
58=         data month/'January','February','March','April','May',
59=&        'June','July','August','September','October','November','December'/
60=         data days/31,28,31,30,31,30,31,31,30,31,30,31/
61=         data energy/'Electricity per KWH.',
62=&                 'Natural Gas per 1000 cubic ft.',
63=&                 'Liquified petrolum per gallon.',
64=&                 'Fuel oil per gallon.'/
65=         write(6,100)
66=100      format(
67=&        '                    FARROWING HOUSE HEAT LOSS',////
68=&        'This program is designed to assist in the design and construction',/
69=&        'of farrowing houses in Kansas.  The program knows the R-value',/
70=&        'of most common building materials (you may enter the R-value',/
71=&        'if the material is not included).',//
72=&        '     Read the questions as presented on the screen,  most',/
73=&        'invalid answers will cause the same question to be represented',/
74=&        'on the screen.',///////
75=&        '              (press <return> or <enter> to continue)',/
76=&        '                    press <ctr> and <c> to stop')
77=         read (5,101) reply
78=101      format(a1)
79=c              call Rfact( door,window,insul,peri,ext,roof,wall)
80=         call ask(door,window,insul,peri,ext,roof,wall,
81=&              length,width,Adoors,Awindo,ndoors,Expdor,Expwin,
82=&              sows,inside,cost,local,fuel,energy,price,loc)
83=         call walls (insul,peri,ext,roof,wall,
84=&              length,width,Adoors,Awindo,ndoors,Expdor,Expwin,
85=&              expfac,expwal,expfon,expper, expcel, tawall, afound,minv)
86=         call cycle (loc,deltat,min,max,inside,out)
87=         call output (expfac, expdor, expwin, expwal,
88=&               expfon, expper, expcel, adoors, awindo, tawall, afound,
89=&              length,width,loc,out,cost,
90=&              sows,inside,fuel,price,energy,month,local,days,deltaT,minv)
91=         stop
92=         end
```

```
      subroutine Rfact( door,window,insul,peri,ext,roof,wall)
      real door(5),window(4),insul(9),peri(11),ext(5),roof(3),wall(5)
      write(7,10)
10    format('        MATERIAL                                  Resistance R',/
&     '_______________________________________________________________',/)
      write (7,15)door(1),door(2),door(3),door(4),door(5)
15    format(/'Exterior Doors',/,
&     '     Solid Core wood            1 3/4 in        ',f4.2,/,
&     '     + Wood Storm                               ',f4.2,/,
&     '     + Metal Storm                              ',f4.2,/,
&     '     Metal, urethane core       1 3/4''         ',f4.2,/
&     '     Metal, polystyrene core    1 3/4''         ',f4.2)
      write(7,20)window(1),window(2),window(3),window(4)
20    format(/'Windows (surface condtions included)',/,
&     '    Single glass                                        ',f4.2/,
&     '    + storm                                     ',f4.2/,
&     '    Twin glazed                                 ',f4.2/,
&     '    Triple glazed                               ',f4.2),
      write(7,30)insul(1),insul(2),insul(3),insul(4),insul(5),insul(6),
&     insul(7),insul(8),insul(9)
30    format(/'Insulation'/,'Blanket or Batt'/,
&     '    Glass wool, mineral wool or fiber glass     ',f4.2,'/in'/,
&     'Loose fill'/,
&     '    Glass or Mineral wool                       ',f4.2,'/in'/,
&     '    Vermiculite                                 ',f4.2,'/in'/,
&     '    Shavings or sawdust                         ',f4.2,'/in'/,
&     '    Milled paper or wood pulp                   ',f4.2,'/in'/,
&     'Rigid',/,
&     '    Expanded Polystyrene'/,
&     '       Extruded                                 ',f4.2,'/in'/,
&     '       Molded (bead board)                      ',f4.2,'/in'/,
&     '    Fiber glass                                 ',f4.2,'/in'/,
&     'Exp. Polyurethane (aged), 1.5#/cu ft            ',f4.2,'/in'/)
      write (7,35)peri(1),peri(2),peri(3),peri(4),peri(5),peri(6),
&     peri(7),peri(8),peri(9),peri(10),peri(11)
35    format(/'Foundations'/,
&     'Concrete, solid                                         ',f4.2,'/in'/,
&     'Concrete blocks'/,
&     '    Sand and Gravel            8 in            ',f4.2/,
&     '                              12 in            ',f4.2/,
&     '    Lightweight                8 in            ',f4.2/,
&     '                              12 in            ',f4.2/,
&     '    Lightweight                8 in            ',f4.2/,
&     '    + Vermiculite in cores    12 in            ',f4.2/,
&     'Rigid foundation insulations'/,
```

```
&        '   Expanded polystyrene                                      ',f4.2,'/in'/,
&        '   Molded, (bead board)                                      ',f4.2,'/in'/,
&        '   Glass fiber                                ',f4.2,'/in'/,
&        '   Exp. Polyurethane (aged) 1.5#/ cu ft                      ',f4.2,'/in'/)
         write(7,40)ext(1),ext(2),ext(3),ext(4),ext(5)
40       format(/'Siding'/,
&        '   Wood, 8 in beveled                         ',f4.2/,
&        '   Wood, 8 in drop                            ',f4.2/,
&        '   Metal, farm building (unbacked)            ',f4.2/,
&        '   Metal, residential (hollow backed)         ',f4.2/,
&        '   Metal, residential (insulation backed)     ',f4.2/)
         write(7,45)roof(1),roof(2),roof(3)
45       format('Roofing'/,
&        '   Metal, farm building                                      ',f4.2/,
&        '   Asphalt shingles                           ',f4.2/,
&        '   Roll felt                                  ',f4.2/)
         write(7,50)wall(1),wall(2),wall(3),wall(4),wall(5)
50       format(/'Wall Materials'/,
&        '   Plaster or Gypsum board                    ',f4.2,'/in'/,
&        '   Plywood  3/8 in                            ',f4.2/,
&        '            1/2 in                            ',f4.2/,
&        '   Fiber board sheathing  25/32 in            ',f4.2/,
&        '   Particle board, med. density                              ',f4.2,'in'/)
         return
         end
```

```
c       ****************************************************************
c       This is the first of the question and answer part.
c
c       ****************************************************************
        subroutine ask(door,window,insul,peri,ext,roof,wall,
&               length,width,Adoors,Awindo,ndoors,Expdor,Expwin,
&               sows,inside,cost,local,fuel,energy,price,loc)
        character *1 reply, char(10)
        character *33 energy(4)
        character *2 local(9)
        character *70 info
        character *1 answ,all,belowI,layer
        integer door1,door2,door3,door4,door5,fuel,
&               windo1,windo2,windo3,windo4,windo5, tydoor,twindo,
        real door(5),window(4),peri(11),wall(5),insul(9),ext(5),roof(3),
&               digit,inside
        write(6,5)
5       format('Enter the owner''s name and address',/)
        read(5,6) info
6       format (a70)
        write(7,7)info
7       format('1 ',a70)
        write(8,7) info
103     write(6,10)
10      format('What is the length of the building?            (ft.)',/)
                        read(5,1111)char
                        call conver(digit,char)
                        length = digit
        if((length .le.0).or.(length .gt.999)) go to 103
120     write(6,20)
20      format('What is the width of the building?             (ft.)',/)
                        read(5,1111)char
                        call conver(digit,char)
                        width = digit
        if((width .le.0).or.(width .gt.999)) go to 120
2999    write(6,3000)
3000    format(//'What will be the capacity of the farrowing house?',/
&               'Enter the number of sows.')
                read (5,1111) char
                call conver(digit,char)
                sows = digit
                if (digit .lt. 0) then
                        write(6,1113)
1113                    format(//'  Enter only digits'//)
                        goto 2999
```

```
208=                endif
209=9005      write(6,3005)
210=3005      format(//'What temperature will you attempt to maintain'
211=&         ' inside the building?',/'Enter temperature (F)')
212=                read (5,1111) char
213=                call conver(digit,char)
214=                inside = digit
215=                if (digit .lt. 0) then
216=                        write(6,1114)
217=1114                    format(//'  Enter only digits or decimals'//)
218=                        goto 3005
219=                endif
220=9336      write(6,3360)
221=3360      format (//'Which section of Kansas is the building located?'/,
222=&               '       1.   NW Kansas',/
223=&               '       2.   NC Kansas',/
224=&               '       3.   NE Kansas',/
225=&               '       4.   WC Kansas',/
226=&               '       5.   C  Kansas',/
227=&               '       6.   EC Kansas',/
228=&               '       7.   SW Kansas',/
229=&               '       8.   SC Kansas',/
230=&               '       9.   SE Kansas')
231=          read (5,1111) char
232=                call conver(digit,char)
233=                loc = digit
234=                if ((digit .le. 0).or.(digit .gt.9)) then
235=                        write(6,1116)
236=1116                    format(/'Enter a digit (1 thru 9)')
237=                        goto 9336
238=                endif
239=9335      write (6,3350)
240=3350            format(//'Which fuel are you using for heating?',/
241=&         '       1.  Electricity',/
242=&         '       2.  Natural Gas',/
243=&         '       3.  Propane or butane',/
244=&         '       4.  Fuel oil',/
245=&         'Enter 1, 2, 3, or 4')
246=          read (5,1111) char
247=1111      format(10a1)
248=                call conver(digit,char)
249=                fuel = digit
250=                if ((digit .le. 0).or.(digit .gt.4)) then
251=                        write(6,1121)
252=1121                    format(/'Enter a digit (1 thru 4)')
```

```
                          goto 9335
                  endif
9356      write(6,3356) energy(fuel)
3356      format (/,'Enter the price of ',a33,/'  ($.60 = .60)')
                  read(5,1111)char
                  call conver(digit,char)
                  price = digit
                  if (digit .lt.0)then
                          write(6,9357)
9357                      format(//'  Enter no letters only digits or decimals'////)
                          goto 9356
                  endif
          if(fuel .eq. 1)   cost = price * 293
          if(fuel .eq. 2)   cost = price * 1.583
          if(fuel .eq. 3)   cost = price * 16.54
          if(fuel .eq. 4)   cost = price * 11.15
9030      write(6,30)
30        format('How many normal man doors open to the outside?',/)
          read(5,1111)char
          call conver(digit,char)
          ndoors = digit
          if (digit .le. 0) then
                  write(6,1112)
1112              format(/'Enter digits ( 0 thru 9 )')
                  goto 9030
          endif
          write(6,1007)
1007      format(/////)
101       write(6,40)door(1),door(2),door(3),door(4),door(5)
40        format(
&         /'Exterior Doors',/,
&         '1    Solid Core wood           1 3/4 in        ',f4.2,/,
&         '2    + Wood Storm                              ',f4.2,/,
&         '3    + Metal Storm                             ',f4.2,/,
&         '4    Metal, urethane core      1 3/4''         ',f4.2,/,
&         '5    Metal, polystyrene core   1 3/4''         ',f4.2,/,
&         '6    Other')
          write(6,44)
44        format(//'Are the doors all made of the same materials?',
&                 //'   y or n')
          read(5,45)reply
45        format(a1)
          if ((reply .eq. 'n').or.(reply .eq.'y')) then
                  if (reply .eq. 'y' )then
9050                      write(6,50)
```

```
298=50                  format(//'Which type of door is used?',
299=&                   /,'    Enter 1 thru 6 ')
300=                    read(5,1111)char
301=                    call conver(digit,char)
302=                    tydoor = digit
303=                    if ((digit .le. 0).or.(digit .gt.6))then
304=                    write(6,40)door(1),door(2),door(3),door(4),door(5)
305=                            write(6,1112)
306=                            goto 9050
307=                    endif
308=                    if (tydoor .eq. 6)then
309=9060                        write(6,60)
310=60                          format(/'Enter the R-factor for the door(s)')
311=                    read(5,1111)char
312=                    call conver(digit,char)
313=                    Rdoor = digit
314=                    if (digit .le. 0) then
315=                            write(6,1114)
316=                            goto 9060
317=                    endif
318=                    else
319=                            Rdoor = door(tydoor)
320=                    endif
321=            else
322=9070                write(6,70)
323=70                  format(/'How many doors are of type 1')
324=                    read(5,1111)char
325=                    call conver(digit,char)
326=                    door1 = digit
327=                    if (digit .lt. 0) then
328=                    write(6,40)door(1),door(2),door(3),door(4),door(5)
329=                            write(6,1112)
330=                            goto 9070
331=                    endif
332=                 if (ndoors .le. door1)goto 9115
333=                    Rdoor = Rdoor+ (door1*door(1))
334=9072                write(6,72)
335=72                  format(/'How many doors are of type 2')
336=                    read(5,1111)char
337=                    call conver(digit,char)
338=                    door2 = digit
339=                    if (digit .lt. 0) then
340=                    write(6,40)door(1),door(2),door(3),door(4),door(5)
341=                            write(6,1112)
342=                            goto 9072
```

```
           endif
           Rdoor = Rdoor+ (door2*door(2))
          if (ndoors.le.door1+door2)goto 9115
9073       write(6,73)
73         format(/'How many doors are of type 3')
           read(5,1111)char
           call conver(digit,char)
           door3 = digit
           if (digit .lt. 0) then
           write(6,40)door(1),door(2),door(3),door(4),door(5)
                   write(6,1112)
                   goto 9073
           endif
           Rdoor = Rdoor+ (door3*door(3))
          if (ndoors.le.door1+door2+door3)goto 9115
9074       write(6,74)
74         format(/'How many doors are of type 4')
           read(5,1111)char
           call conver(digit,char)
           door4 = digit
           if (digit .lt. 0) then
           write(6,40)door(1),door(2),door(3),door(4),door(5)
                   write(6,1112)
                   goto 9074
           endif
           Rdoor = Rdoor+ (door4*door(4))
          if (ndoors.le.door1+door2+door3+door4)goto 9115
9075       write(6,75)
75         format(/'How many doors are of type 5')
           read(5,1111)char
           call conver(digit,char)
           door5 = digit
           if (digit .lt. 0) then
           write(6,40)door(1),door(2),door(3),door(4),door(5)
                   write(6,1112)
                   goto 9075
           endif
           Rdoor = Rdoor+ (door5*door(5))
          if(ndoors.le.door1+door2+door3+door4+door5)goto 9115
9076       write(6,76)
76         format(/'How many doors are of type 6')
           read(5,1111)char
           call conver(digit,char)
           door6 = digit
           if (digit .lt. 0) then
```

```
                        write(6,40)door(1),door(2),door(3),door(4),door(5)
                                write(6,1112)
                                goto 9076
                        endif
                        if (door6 .gt.0) then
960                             write(6,60)
                                read(5,1111)char
                                call conver(digit,char)
                                Rdoor6 = digit
                                if (digit .le. 0) then
                                        write(6,1114)
                                        goto 960
                                endif
                                Rdoor = Rdoor+ (door6*Rdoor6)
                        endif
9115                 if (ndoors.ne.door1+door2+door3+door4+door5+door6)then
                        write(6,115)ndoors,(door1+door2+door3+door4+door5+door6)
115                     format(//'Lets try that again,  you said there were',
&                       i2,' doors.',/,'You only told of ',i2,' .')
                        goto 101
                     endif
999             Rdoor = Rdoor / ndoors
                endif
        else
                write(6,1115)
1115            format (/'     y or n')
                goto 101
        endif
        Adoors = 20*ndoors
        Expdor = Adoors/Rdoor
9105    write(6,105)
105     format('How many windows to the outside are there?',
&       /'      Enter 0 (zero) if none.')
                read(5,1111)char
                call conver(digit,char)
                nwindo = digit
                if (digit .lt. 0) then
                        write(6,1112)
                        goto 9105
                endif
        if (nwindo.eq.0)then
                Rwindo = .000001
                goto 200
        endif
102     write(6,110)window(1),window(2),window(3),window(4)
```

```
433=110      format(/////
434=&        'Windows (surface condtions included)',/,
435=&        '1   Single glass                              ',f4.2/,
436=&        '2   + storm                                   ',f4.2/,
437=&        '3   Twin glazed                                   ',f4.2/,
438=&        '4   Triple glazed                             ',f4.2/,
439=&        '5   Other',
440=&        ///'Are the windows all of the same type?'/,'   y or n')
441=         read(5,145)reply
442=145      format(a1)
443=         if((reply .eq. 'y') .or.(reply .eq. 'n')) then
444=                 if (reply .eq. 'y' )then
445=                         write(6,150)
446=150                      format(//'Which type of window is used?')
447=                         read(5,1111)char
448=                         call conver(digit,char)
449=                         twindo = digit
450=                         if ((digit .le. 0).or.(digit .gt. 5)) then
451=                                 write(6,1112)
452=                                 goto 102
453=                         endif
454=                         if (twindo .eq. 5)then
455=9160                             write(6,160)
456=160                              format(//'Enter the R-factor for the window')
457=                                 read(5,1111)char
458=                                 call conver(digit,char)
459=                                 Rwindo = digit
460=                                 if (digit .le. 0) then
461=                                         write(6,1114)
462=                                         goto 9160
463=                                 endif
464=                         else
465=                                 Rwindo = window(twindo)
466=                         endif
467=                 else
468=9170                     write(6,170)
469=170                      format(//'How many windows are of type 1')
470=                         read(5,1111)char
471=                         call conver(digit,char)
472=                         windo1 = digit
473=                         if (digit .lt. 0) then
474=                                 write(6,110)window(1),window(2),window(3),window(4)
475=                                 write(6,1112)
476=                                 goto 9170
477=                         endif
```

```
        Rwindo = Rwindo+ (windo1*window(1))
     if (nwindo.le.windo1) goto998
9172    write(6,172)
172     format(/'How many windows are of type 2')
        read(5,1111)char
        call conver(digit,char)
        windo2 = digit
        if (digit .lt. 0) then
                write(6,110)window(1),window(2),window(3),window(4)
                write(6,1112)
                goto 9172
        endif
        Rwindo = Rwindo+ (windo2*window(2))
      if (nwindo.le.windo1+windo2)goto 998
9173    write(6,173)
173     format(/'How many windows are of type 3')
        read(5,1111)char
        call conver(digit,char)
        windo3 = digit
        if (digit .lt. 0) then
                write(6,110)window(1),window(2),window(3),window(4)
                write(6,1112)
                goto 9173
        endif
        Rwindo = Rwindo+ (windo3*window(3))
      if (nwindo.le.windo1+windo2+windo3)goto 998
9174    write(6,174)
174     format(/'How many windows are of type 4')
        read(5,1111)char
        call conver(digit,char)
        windo4 = digit
        if (digit .lt. 0) then
                write(6,110)window(1),window(2),window(3),window(4)
                write(6,1112)
                goto 9174
        endif
        Rwindo = Rwindo+ (windo4*window(4))
      if (nwindo.le.windo1+windo2+windo3+windo4)goto 998
9175    write(6,175)
175     format(/'How many windows are of type 5')
        read(5,1111)char
        call conver(digit,char)
        windo5 = digit
        if (digit .lt. 0) then
                write(6,110)window(1),window(2),window(3),window(4)
```

```
                        write(6,1112)
                        goto 9175
                endif
                if (windo5 .gt. 0) then
                        write(6,160)
                        read (5,1111) char
                        call conver(digit,char)
                        if (digit .lt. 0 ) then
                                write(6,1112)
                                goto 9175
                        endif
                endif
                Rwindo = Rwindo+ (windo5*digit)
998          if (nwindo.ne.windo1+windo2+windo3+windo4+windo5)then
                write(6,176)nwindo,(windo1+windo2+windo3+windo4+windo5)
176             format(///'Lets try that again, you said there were ',
&               i2,' windows,'/', you now show there are ',i2,' .')
                goto 102
             endif
        Rwindo = Rwindo / nwindo
        endif
else
        write(6,1115)
        goto 102
endif
if (nwindo .gt. 0)then
9190 write(6,190)
190 format(//'To estimate the area of the windows,',//
& 'What is the average width of each window?  (ft)')
        read(5,1111)char
        call conver(digit,char)
        wide = digit
        if (digit .lt. 0) then
                write(6,1112)
                goto 9190
        endif
9191 write(6,191)
191 format(//'What is the average length of each window?  (ft.)')
        read(5,1111)char
        call conver(digit,char)
        lth = digit
        if (digit .lt. 0) then
                write(6,1112)
                goto 9191
        endif
```

```
        endif
200     Awindo = nwindo * lth * wide
        Expwin = Awindo/Rwindo
        write(8,201) length, width, ndoors, Adoors,
&        Rdoor,nwindo,Awindo,Rwindo
201     format(f6.2,'   = building length'/
&       f6.2,'  = building width',/
&       i4,'    = number of doors',/
&       f6.2,'  = sq. ft of doors',/
&       f6.2,'  = average R-factor of doors',/
&       i4,'    = number of windows',/
&       f6.2,'  = sq. ft. of windows',/
&       f6.2,'  = average R-factor of windows',)
        return
        end
```

```
583=c      ************************************************************
584=c      this should start wall
585=c      ************************************************************
586=       subroutine walls(insul,peri,ext,roof,wall,
587=&              length,width,Adoors,Awindo,ndoors,Expdor,Expwin,
588=&              expfac,expwal,expfon,expper, expcel, tawall, Afound,minv)
589=       character *1 reply, char(10)
590=       character *1 answ,all,belowI,layer
591=               integer
592=&              tywall, tyins, Tsand, tfound, outfou,troof, tylay,tyceil
593=       real peri(11),wall(5),insul(9),ext(5),roof(3), digit,minv
594=       inch = 0
595=       write(6,41)
596=41      format(//'Are all the walls of the same type?',
597=&       /'and have approx. the same amount of wall height exposed?'/
598=&       '    y or n')
599=       read(5,47)all
600=47      format(a1)
601=       if (('y' .eq. all) .or. ('n' .eq. all)) then
602=       else
603=               write(6,1115)
604=               goto 325
605=       endif
606=       if (all .eq. 'y') then
607=500            write(6,140)ext(1),ext(2),ext(3),ext(4),ext(5)
608=140     format(//'Siding'/
609=&       '1.    Wood, 8 in beveled                               ',f4.2/,
610=&       '2.    Wood, 8 in drop                          ',f4.2/,
611=&       '3.    Metal, farm building (unbacked)          ',f4.2/,
612=&       '4.    Metal, residential (hollow backed)               ',f4.2/,
613=&       '5.    Metal, residential (insulation backed)   ',f4.2/,
614=&       '6.    Other')
615=                       write(6,310)
616=310                    format(//'Which type of siding was used on the outside?',/
617=&                      '    Enter 1 thru 6')
618=                       read(5,1111)char
619=1111                   format(10a1)
620=                       call conver(digit,char)
621=                       tywall = digit
622=                       if ((digit .le. 0).or.(digit.gt.6)) then
623=                       write(6,1112)
624=1112                   format(/'Enter a digit ( 0 thru 9 )')
625=                       goto 500
626=               endif
627=               if (tywall .le.5) then
```

```
                        Rext= wall(tywall)
                else
9320                    write(6,320)
320                     format(//'Enter the R-factor for the siding used.')
                        read(5,1111)char
                        call conver(digit,char)
                        Rext = digit
                        if (digit .le. 0) then
                                write(6,1114)
1114                    format(/'Enter digits ( 0 thru 9 ',
&                       ' with or without a decimal(.)')
                                goto 9320
                        endif
                endif
                if (all .eq. 'y') then
9315                    write(6,315)
315                     format(//'What is the average height of the frame wall?        (ft.)',/
&                               '    Enter Ft.  (6.5 ft = 6.5)')
                        read(5,1111)char
                        call conver(digit,char)
                        height = digit
                if (digit .le. 0) then
                        write(6,1112)
                        goto 9315
                endif
                TAwall = 2*(length+width)*height- Adoors-Awindo
                endif
9331        write(6,331)insul(6),insul(7),insul(8),insul(9)
331         format(//'Rigid',/,
&           '    Expanded Polystyrene'/,
&           ' 1.    Extruded                                              ',f4.2,'/in'/,
&           ' 2.    Molded, (bead board)                          ',f4.2,'/in'/,
&           ' 3.   Fiber glass                                    ',f4.2,'/in'/,
&           ' 4.   Exp. Polyurethane (aged), 1.5#/cu ft           ',f4.2,'/in'/,
&           ' 5.   Other ')
            write (6,325)
325         format(//'Is there a layer of rigid insulation used between'/
&           ' the sidings and the studs?      y or n')
            read(5,326)layer
326         format(a1)
            if ((layer .eq.'y') .or.(layer .eq.'n'))then
            else
                write(6,1115)
1115            format (/'    y or n')
                goto 9331
```

```
          endif
                  if(layer.eq.'y')then
9335                      write(6,335)
335                       format(//'Which type of material was used?')
                          read(5,1111)char
                          call conver(digit,char)
                          tylay = digit+5
                          if((digit .le. 0).or.(digit.gt.6)) then
                          write(6,331)insul(6),insul(7),insul(8),insul(9)
                                  write(6,1112)
                                  goto 9335
                          endif
                          if (tylay .ge.10)then
9345                              write (6,345)
345                               format(//'Enter the R-factor for the layer.')
                                  read(5,1111)char
                                  call conver(digit,char)
                                  Rlay = digit
                                  if (digit .eq.0) Rlay = .00000001
                                  if (digit .lt. 0) then
                                          write(6,1114)
                                          goto 9345
                                  endif
                          endif
                          if ((tylay .ge.6).and.(tylay.le.9))then
                          write(6,346)
346                       format(//'What the thickness of the layer?  ( inches )')
                          read(5,1111)char
                          call conver(digit,char)
                          inch = digit
                          Rlay = inch *  insul(tylay)
                          endif
                  else
                          Rlay = 0.0
                  endif
9330      write(6,330)insul(1),insul(2),insul(3),insul(4),insul(5)
330       format(///'Insulation'/,'Blanket or Batt'/,
&         ' 1.   Glass wool, mineral wool or fiber glass  ',f4.2,'/in'/,
&         'Loose fill'/,
&         ' 2.   Glass or Mineral wool                    ',f4.2,'/in'/,
&         ' 3.   Vermiculite                              ',f4.2,'/in'/,
&         ' 4.   Shavings or sawdust                      ',f4.2,'/in'/,
&         ' 5.   Milled paper or wood pulp                         ',f4.2,'/in'/
&         ' 6.   Other')
          write(6,350)
```

```
350     format(/'What type insulation was used in the wall?',/
&              '   Enter 1 thru 6')
               read(5,1111)char
               call conver(digit,char)
               tyins = digit
               if ((digit .le. 0).or.(digit .gt. 6)) then
                      write(6,1112)
                      goto 9330
               endif
        if (tyins .ge.6)then
9351           write(6,351)
351            format('What if the R-factor of the wall insulation?')
               read(5,1111)char
               call conver(digit,char)
               Rinsu = digit
               if (digit .le. 0) then
                      write(6,1114)
                      goto 9351
               endif
        else
9360           write(6,360)
360            format(/'How many inches of insulation were used?              (in.)')
               read(5,1111)char
               call conver(digit,char)
               inch = digit
               if(digit.le.0) then
                      write(6,330)insul(1),insul(2),insul(3),insul(4),insul(5)
                      write(6,1112)
                      goto 9360
               endif
               Rinsu = insul(tyins)*inch
         endif
9370    write(6,370)wall(1),wall(2),wall(3),wall(4),wall(5),ext(3)
370     format(//'Wall Materials'/,
&       '1.   Plaster or Gypsum board                ',f4.2,'/in'/,
&       '2.   Plywood  3/8 in                        ',f4.2/,
&       '3.            1/2 in                        ',f4.2/,
&       '4.   Fiber board sheathing  25/32 in        ',f4.2/,
&       '5.   Particle board, med. density           ',f4.2,'/in'/,
&       '6.   Metal, farm building (unbacked)        ',f4.2/,
&       '7.   Other')
        write(6,371)
371     format(//'Which type of material was used on the interior wall?',/
&              '     Enter 1 thru 7')
               read(5,1111)char
```

```
                    call conver(digit,char)
                    tywall = digit
                    if (digit .lt. 0) then
                            write(6,1112)
                            goto 9370
                    endif
            if (tywall .ge.6) then
                    If (tywall .eq.6) then
                            Rint = ext(3)
                    else
9375                        write(6,375)
375                         format(//'Enter the R-factor for the interior wall'
&                           ' material used.')
                            read(5,1111)char
                            call conver(digit,char)
                            Rint = digit
                            if (digit .le. 0) then
                                    write(6,1114)
                                    goto 9375
                            endif
                    endif
            else
                    Rint = wall(tywall)
            endif
c           ##########################################################
c           This should be the false side of are all wall alike
c           ##########################################################
            else
                            write(6,405)
405                         format(//'Tell me about the first wall(s).')
                            write(6,400)
400                         format(//'How many walls are alike?')
                            read(5,1111)char
                            call conver(digit,char)
                            Twall = digit
                            Lwall =  Twall
                            goto 500
            endif
            if (Lwall.gt.0) then
1200                write(6,420)
420                 format(//'What is the combined length(s) of this type'
&                   ' of wall section?              (ft.)')
                            read(5,1111)char
                            call conver(digit,char)
                            leng = digit
```

```
          if((leng .lt.0).or.(leng .gt.999)) go to 1200
9421      write(6,421)
421       format(//'What is the average height of this type section.      (ft.)')
                  read(5,1111)char
                  call conver(digit,char)
                  height = digit
          if((height .lt.0).or.(height .gt.999)) go to 9421
9422      write(6,422)
422       format(//'How many doors are in this type wall?',//
&         'Enter 0 (zero) for none')
                  read(5,1111)char
                  call conver(digit,char)
                  ndoor = digit
          if((ndoor .lt.0).or.(ndoor .gt.999)) go to 9422
9423      write(6,423)
423       format(//'How many windows are on this type wall?',
&         //'Enter 0 (zero) for none.')
                  read(5,1111)char
                  call conver(digit,char)
                  numwin = digit
          if((numwin .lt.0).or.(numwin .gt. 999))goto 9423
          if (numwin .ge.1)then
                  write(6,424)
424               format(//'What is the average height of the window(s).  (ft.)'/,
&                 '           (60 inches ==> 5.0)')
                  read(5,1111)char
                  call conver(digit,char)
                  windoH = digit
          if((windoH .lt.0).or.(windoH .gt. 999))goto 9423
                  write(6,425)
425               format(//'What is the average width of the window(s)?   (ft.)'/,
&                 '    Enter ft  (30 inches ==> 2.5)')
                  read(5,1111)char
                  call conver(digit,char)
                  windoW = digit
          if((windoW .lt.0).or.(windoW .gt. 999))goto 9423
          endif
          Awall = (leng*height)-(ndoor*20)-(numwin*windoH*windoW)
          Rwall = Rext + Rlay + Rinsu + Rint + .68 + .17
          TAwall = TAwall + Awall
          Expwal = Expwal + Awall/Rwall
     write(8,416) Twall, Awall, Rwall, numwin, ndoor, (Awall/Rwall)
416  format(/,'      ',i2,' walls',/,'         ',f6.1,' sq ft of wall area',/
&    '       ',f6.2,' btuhr/sqft/F',/'       ',i2,' windows',/
&    '       ',i2,' doors',/'         ',f6.2,' Exposure factor of the wall')
```

```
        endif

        if((Lwall.lt.3).and.(Lwall.ge.1))then
                write(6,410)
410             format(//'Now for the next wall(s),',//
&               'how many walls are of the next type?')
                        read(5,1111)char
                        call conver(digit,char)
                        Twall = digit
                Lwall = Lwall + Twall
                goto 500
        endif
        if (Lwall .eq.3)then
                write(6,415)
415             format(//'Now for the 4th wall !!!')
                Lwall = 1+ Lwall
                Twall = 1
                goto 500
        endif
        If (all.eq.'y') then

                Rwall = Rext + Rlay + Rinsu + Rint + .68 + .17
                Expwal = TAwall /Rwall
        endif
        write(8,417) TAwall,Expwal
417     format('          ',f6.2,' total area of the walls',/
&       '       ',f6.2,' Exposure factor for all the walls')
        if (Lwall.eq.4) goto 1000
c       ************************************************************
c       This is the front of foundations.
c       ************************************************************
1000    write(6,480)
480     format(///'Now to discuss the foundation.'///)
9482    write(6,482)
482     format(//'What is the average height of foundation',
&                 ' above soil level?'/           '(ft.)')
                        read(5,1111)char
                        call conver(digit,char)
                        Hfound = digit
                if((Hfound .lt.0).or.(Hfound .gt.999)) go to 9482
        Afound = Hfound * (2*length + 2*width-(2.5*ndoors))
        TAwall = TAwall - 2.5*ndoors*Hfound
        write (6,485)peri(1),peri(2),peri(3),peri(4),peri(5),peri(6),peri(7)
485     format(//'Foundations'/,
&       '1.  Concrete, solid                                ',f4.2,'/in'/,
```

```
898=&      'Concrete blocks'/,
899=&      '2. Sand and Gravel               8 in          ',f4.2/,
900=&      '3.                              12 in          ',f4.2/,
901=&      '4. Lightweight                   8 in          ',f4.2/,
902=&      '5.                              12 in          ',f4.2/,
903=&      '6. + Vermiculite in cores        8 in          ',f4.2/,
904=&      '7. + Vermiculite in cores       12 in          ',f4.2)
905=9486   write(6,486)
906=486    format(/'Which type of material is in the foundation?')
907=              read(5,1111)char
908=              call conver(digit,char)
909=              Tfound = digit
910=              if ((digit .le. 0).or.(digit .gt. 7)) then
911=                     write(6,1112)
912=                     goto 9486
913=              endif
914=       if (Tfound .eq.1) then
915=9487          write(6,487)
916=487           format(/'How thick is the concrete foundation?          (in.)')
917=              read(5,1111)char
918=              call conver(digit,char)
919=              thickF = digit
920=              if ((digit .le. 0).or.(digit .gt. 999)) then
921=                            write(6,1112)
922=                            goto 9487
923=              endif
924=              Rfound = peri(1)*thickF + .68 + .17
925=       else
926=              Rfound = peri(Tfound) + .68 + .17
927=       endif
928=       write (6,493) peri(8),peri(9),peri(10),peri(11)
929=493    format(//'Rigid foundation insulations'/,
930=&      '1. Expanded polystyrene                                ',f4.2,'/in'/,
931=&      '2. Molded, (bead board) Polystyrene            ',f4.2,'/in'/,
932=&      '3. Glass fiber                                 ',f4.2,'/in'/,
933=&      '4. Exp. Polyurethane (aged) 1.5#/ cu ft                ',f4.2,'/in'/,
934=&      '5. Other')
935=       write(6,489)
936=489    format(//'Is there any rigid insulation material on the outside',
937=&      ' of the foundation?   ',/,'     y or n')
938=       read(5,490)answ
939=490    format(a1)
940=       if (answ.eq. 'y') then
941=9491          write (6,491)
942=491           format(//'Which type insulation is used of the outside'
```

```
&               ' of the foundation?')
                        read(5,1111)char
                        call conver(digit,char)
                        outfou = digit
                if((digit .le.0).or.(digit .gt.5)) go to 9491
                outfou = outfou + 7
                if (digit .le.4 ) then
9492                    write(6,492)
492             format(//'How many inches if the material is used?                (in.)')
                        read(5,1111)char
                        call conver(digit,char)
                        inch = digit
                if((digit .le.0).or.(digit .gt.999)) go to 9492
                Rfound = peri(outfou)*inch+ Rfound
                else
                        write(6,503)
503                     format(/'     What is the R-value of the exterior',
&               'foundation insulation?')
                        read (5,1111) char
                        call conver(digit,char)
                        Rfound = Rfound + digit
                endif
9688            write(6,688)
688             format(/'     Is this insulation covered with '
&                       'Asbestos cement board, plastic',/
&                       'or a simmular material?       y or n')
                read(5,490)answ
                if ((answ .ne. 'y').and.(answ .ne. 'n')) goto 9688
                if (answ .eq. 'y') Rfound = Rfound + .25
        endif
        Expfon = Afound/Rfound
        write(6,501)
501     format(///'Is the foundation below grade insulated?')
        read (5,502)belowI
502     format(a1)
        if (belowI .eq. 'y') then
                Rperi = 2.22
        else
                Rperi = 1.23
        endif
        Expper = ((2*length)+(2*width))/Rperi
c       *****************************************************************
c       figure the ceiling
c       *****************************************************************
9870    write(6,870)wall(1),wall(2),wall(3),wall(4),wall(5),ext(3)
```

```
988=870      format(//'Ceiling Materials'/,
989=&        '1.   Plaster or Gypsum board                    ',f4.2,'/in'/,
990=&        '2.   Plywood  3/8 in                            ',f4.2/,
991=&        '3.            1/2 in                            ',f4.2/,
992=&        '4.   Fiber board sheathing  25/32 in            ',f4.2/,
993=&        '5.   Particle board, med. density               ',f4.2,'in'/,
994=&        '6.   Metal, farm building (unbacked)            ',f4.2/,
995=&        '7.   Other')
996=         write (6,535)
997=535      format(/'What type of material is on the ceiling?',/
998=&                '  Enter 1 thru 7')
999=                 inch = 0
1000=                read(5,1111)char
1001=                call conver(digit,char)
1002=                tyceil = digit
1003=                if ((digit .le. 0).or.(digit .gt. 7)) then
1004=                        write(6,1112)
1005=                        goto 9870
1006=                endif
1007=        if (tyceil .ge.6) then
1008=                if (tyceil .eq.6) then
1009=                        Rceil = ext(3) + .68
1010=                else
1011=9875                    write(6,875)
1012=875                     format(/'Enter the R-factor for the interior of the ceiling')
1013=                        read(5,1111)char
1014=                        call conver(digit,char)
1015=                        Rceil = digit
1016=                        if (digit .le. 0) then
1017=                                write(6,1114)
1018=                                goto 9875
1019=                        endif
1020=                        Rceil = Rceil + .68
1021=                endif
1022=        else
1023=                Rceil = wall(tyceil) + .68
1024=        endif
1025=        Aceil = length * width
1026=        write(8,997) Aceil,Rceil
1027=997     format(/'         ',f6.2,'area if the ceiling',/
1028=&       '       ',f6.2,'Rfactor of ceiling')
1029=9830    write(6,830)insul(1),insul(2),insul(3),insul(4),insul(5)
1030=830     format(///'Insulation'/,'Blanket or Batt'/,
1031=&       ' 1.   Glass wool, mineral wool or fiber glass  ',f4.2,'/in'/,
1032=&       'Loose fill'/,
```

```
&       ' 2.   Glass or Mineral wool                    ',f4.2,'/in'/,
&       ' 3.   Vermiculite                              ',f4.2,'/in'/,
&       ' 4.   Shavings or sawdust                      ',f4.2,'/in'/,
&       ' 5.   Milled paper or wood pulp                          ',f4.2,'/in'/
&       ' 6.   Other')
        write(6,850)
850     format(//'What type insulation was used in the ceiling?')
                read(5,1111)char
                call conver(digit,char)
                tyins = digit
                if ((digit .le. 0).or.(digit .gt. 6)) then
                        write(6,1112)
                        goto 9830
                endif
        if (tyins .ge.6)then
9851            write(6,851)
851             format('What is the R-factor of the ceiling insulation?')
                        read(5,1111)char
                        call conver(digit,char)
                        Roeins = digit
                        if (digit .le. 0) then
                                write(6,1114)
                                goto 9851
                        endif
        else
9860            write(6,860)
860             format(//'How many inches of insulation were used?              (in.)')
                        read(5,1111)char
                        call conver(digit,char)
                        inch = digit
                if((digit .le.0).or.(digit .gt.999)) go to 9860
        endif
                Roeins = Roeil + Roeins + (inch * insul(tyins))+ .68
                Expoel = Aceil/Roeins
        write(8,998) Roeins, Roeil, inch, tyins, insul(tyins)
998     format(f6.2,'R of ceiling insul',/
&       '     ',        f6.2,'R of ceiling cover',/
&       '     ',        i2,'inches of insulation',/
&       '     ',        i2,'type of insulation',/
&       '     ',        f6.2,'R of insulation')
        Write (8,707) Expdor, Expwin, Expwal,Expfon, Expper, Expcel
707     format(/'        ',f8.2,' Exposure factor for the doors',/
&       '       ',f8.2,' Exposure factor for the windows',/
&       '       ',f8.2,' Exposure factor for the walls',/
&       '       ',f8.2,' Exposure factor for the foundation',/
```

```
&       '       ',f8.2,' Exposure factor for the perimeter',/
&       '       ',f8.2,' Exposure factor for the ceiling')
        expfac = Expdor + Expwin + Expwal + Expfon + Expper + Expcel
        write(8,708)expfac
708     format('        ',f8.1, ' The total Exposure factor for the building')
1301    write(6,1300)
1300    format(///'Would you like to set the minimum Winter ventilating ',
&       'rate?  ',//'The current value is 15 CFM/min/sow.'//,'  Y or N')
        read(5,1201) reply
1201    format(a1)
        if ((reply .eq. 'y') .or. (reply .eq.'n')) then
                if (reply .eq. 'n') minv = 15
                if (reply .eq. 'y') then
                        write(6,1202)
1202                    format(//'Enter the minimum ventilating rate you desire.').
                        read (5,1111) char
                        call conver (digit,char)
                        if (digit .lt. 0) goto 1301
                        minv = digit
                endif
        endif
        return
        end

c       ************************************************
c       end of wall
c       ************************************************
```

```
c       * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
c       this subroutine should make the printout
c       * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
        subroutine output (expfac, expdor, expwin, expwal,
&                expfon, expper, expcel, adoors, awindo, tawall, afound,
&               length, width,loc,out,cost,
&               sows,inside,fuel,price,energy,month,local,days,deltaT,minv)
        character *33 energy(4)
        character *10 month(12)
        character *1 a
        character *2 local(9)
        integer days(12), fuel , h
        real out(12), expfac, supp, Vrate,btusow, inside, digit,ef(20),minv,
&               cost, price, fcost, tcost,saves(10), tsup(10),
&               delta, trans, tsupp, tvrate, heat, deltaT(12,24), hheat
                delta= inside - out(1) + .0000001
        a = '_'
        btusow = 600 * sows
        write(7,4442)(a,i=1,73),(a,i=1,73)
4442    format(//,'                              MONTHLY AVERAGE VALUES',//,5x,73a1,/,
&               5x,'    Month      Temp    Bldg Loss   Supp Heat'
&       '     Ventilation        Cost',/
&          6x,'             deg F        Btu/Hr       Btu/Hr '
&       '     CFM     CFM/sow     $/Mo.',/,5x,73a1)
        tcost = 0.0
        do 3003 i = 1,12
        trans = 0.0
        tvrate = 0.0
        tsupp = 0.0
        do 1000 h = 1,24
                btuout = expfac *  deltaT(i,h)
                if ( btuout .le. 0 ) btuout = 0
                trans=btuout/24+trans
                if (2 .lt. deltaT(i,h))  then
                        Vrate = 14/(.24 *60)/deltaT(i,h) * (btusow - (expfac * deltaT(i,h)))
                else
                        Vrate =  14/(.24 * 60 * 2) * (btusow - (expfac * deltaT(i,h)))
                endif
                if (Vrate .gt. sows * 200) Vrate = sows * 200
                if (Vrate .le. sows * minv) Vrate = sows * minv
                tvrate = Vrate/24 + tvrate
                qvent = minv * sows * .24 / 14 * deltaT(i,h) * 60
                supp = btuout - btusow + qvent
                if (supp.le.0) supp = 0.00
                tsupp = supp/24 + tsupp
```

```
1150=1000     continue
1151=                 fcost = (tsupp * 24 *  days(i)) / 1000000 * cost
1152=                 tcost = fcost + tcost
1153=                 write(7,3010)month(i), out(i), trans,
1154=&                tsupp, tvrate, (tvrate/ sows), fcost
1155=3010             format(' ',a15,3x,i5,3x,f10.2,3x,f8.2,3x,f8.2,f8.2,2x,'$',f7.2)
1156=3003     continue
1157=         write(7,3355)(a,i=1,73),tcost
1158=3355     format(5x,73a1,/40x,'Projected total fuel cost = $',f8.2)
1159=         write(7,4443)
1160=4443     format(//'                       TEMPERATURE & VENTILATION GUIDE',//
1161=&            '                       Temp    Supp Heat       CFM   CFM/sow')
1162=         do 3004 new=0 , 100,5
1163=                 delta= inside - new +.00000001
1164=                 btuout = expfac *  delta
1165=                 if ( btuout .le. 0 ) btuout = 0
1166=                 if (inside .gt.new - 2) then
1167=                         Vrate = 14/(.24 *60)/delta* (btusow - (expfac * delta))
1168=                 else
1169=                         Vrate =  14/(.24 * 60 * 2) * (btusow - (expfac * delta))
1170=                 endif
1171=                 if (Vrate .gt. sows * 200) Vrate = sows * 200
1172=                 if (Vrate .le. sows * minv) Vrate = sows * minv
1173=                 qvent = vrate * .24 / 14 * 60 * delta
1174=                 supp = btuout - btusow + qvent
1175=                 if (supp.le.0) supp = 0.00
1176=         write(7,4444) new,supp,Vrate, Vrate/sows
1177=4444     format('                        ',i5,f12.2,f12.2,f10.2)
1178=3004     continue
1179=c        * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
1180=c
1181=c        These are the modified values for the building insulation.
1182=c
1183=c        * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
1184=         zdoor = 6.0
1185=         zwin = 3.0
1186=         zwall = 20.
1187=         zceil = 30.
1188=         zfound = 8.
1189=         zper = 2.22
1190=         ex2dor = adoors/zdoor
1191=         ex2win = awindo/zwin
1192=         ex2wal = tawall/zwall
1193=         ex2cel = length*width/zceil
1194=         ex2fon = afound / zfound
1195=         ex2per = (2 * (length + width))/zper
```

```
         ex2fac = ex2dor + ex2win + ex2wal + ex2cel + ex2fon + ex2per
         if (expwin .eq.0) expwin = .0000001
         if (ex2win .eq. 0) ex2win = .0000001
         write(7,2000) length, width, sows, (expfac*(inside - out(1))),
&         inside,
&               expdor, (expdor/expfac*100), expwin, (expwin/expfac*100),
&               expwal, (expwal/expfac*100), expcel, (expcel/expfac*100),
&               expfon, (expfon/expfac*100), expper, (expper/expfac*100),
&               expfac
2000     format('1',/
&        '      This ',i3,' X ',i3,' farrowing house with ',i3,' sows',/
&        '  has an average January heat loss of ',f4.1,' Btu/Hr at the',/
&        '  desired temperature of ',f5.1,' degrees (F).',//
&        '      The heat loss from each building component is:',//
&        '      doors           = ',f6.1,' Btu/Hr/F    or  ',f4.1,' % of total',/
&        '      windows         = ',f6.1,' Btu/Hr/F    or  ',f4.1,' % of total',/
&        '      walls           = ',f6.1,' Btu/Hr/F    or  ',f4.1,' % of total',/
&        '      ceiling         = ',f6.1,' Btu/Hr/F    or  ',f4.1,' % of total',/
&        '      foundations     = ',f6.1,' Btu/Hr/F    or  ',f4.1,' % of total',/
&        '      perimeters      = ',f6.1,' Btu/Hr/F    or  ',f4.1,' % of total',//
&        '      TOTAL           = ',f6.1,' Btu/Hr/F')
         expven = sows * minv * .24 * 60 / 14
         texpfc = expfac + expven
         write (7,3700) expven, texpfc, (expven/texpfc* 100)
3700     format (/,
&        '      Ventilation     = ',f6.1,' Btu/Hr/F',/
&        'TOTAL Heat loss       = ',f6.1,' Btu/Hr/F',/
&        '      Ventilation     = ',f5.1,'% of the total heat loss.'///)
         rdoor = adoors/expdor
         rwindo = awindo/expwin
         rwall = tawall/expwal
         rceil = length*width/expcel
         rfound = afound/expfon
         write(7,2001) local(loc), tcost, price, energy(fuel),
&                zdoor, rdoor,
&               zwin, rwindo, zwall, rwall,
&               zceil, rceil, zfound,
&               rfound, zper, (2*(length+width)/expper)
2001     format(
&        '      Located in ',a2,' Kansas, this building would have a heating cost',/
&        '  of $',f5.2,' /year, using a fuel price of $',f5.2,' for ',a33,//
&        '      If all areas were insulated at the recommended rate of:',//
&        '                                                current R-Value',/
&        '              ',f4.1,'  R-value for all doors              ',f4.1,/
&        '              ',f4.1,'  R-value for all windows            ',f4.1,/
```

```
&       '               ',f4.1,'  R-value for all walls              ',f4.1,/
&       '               ',f4.1,'  R-value for all ceilings           ',f4.1,/
&       '               ',f4.1,'  R-value for all foundations        ',f4.1,/
&       '               ',f5.2,' R-value for all perimeters          ',f5.2,//   )

        ef(1)=expdor
        ef(2)=expwin
        ef(3)=expwal
        ef(4)=expcel
        ef(5)=expfon
        ef(6)=expper
        ef(7)=expfac
        ef(11)=ex2dor
        ef(12)=ex2win
        ef(13)=ex2wal
        ef(14)=ex2cel
        ef(15)=ex2fon
        ef(16)=ex2per
        ef(17)=ex2fac
        do 33 j=1,7
                sheat = 0.0
                tsup(j)=0.0
                x =     expfac - ef(j) + ef(j + 10)
                do 34 i=1,12
                heat = 0.0
                        do 1500 h=1,24
                                qvent = minv * sows * 60 * .24 / 14 * deltaT(i,h)
                                hheat = (x * deltaT(i,h) + qvent - btusow)
                                if (hheat.le.0) hheat = 0.0
                                heat = hheat + heat
1500                    continue
                sheat = heat*days(i)+sheat
c               write(7,*)'heat',heat,'sheat',sheat
c               tsup(j) = tsup(j) + sheat
34              continue
        saves(j) = tcost - sheat / 1000000 * cost
33      continue
                delta= inside - out(1) + .0000001
                zzzz=delta* 24 /1000000*31* cost
        write(7,2002)(ex2fac*delta),
&               ex2dor, (ex2dor/ex2fac*100),
&               (expdor-ex2dor),(zzzz*(expdor-ex2dor)), saves(1),
&               ex2win, (ex2win/ex2fac*100),
&               (expwin-ex2win),(zzzz*(expwin-ex2win)), saves(2),
&               ex2wal, (ex2wal/ex2fac*100),
```

```
&       (expwal-ex2wal),(zzzz*(expwal-ex2wal)), saves(3),
&       ex2cel, (ex2cel/ex2fac*100),
&       (expcel-ex2cel),(zzzz*(expcel-ex2cel)), saves(4),
&       ex2fon, (ex2fon/ex2fac*100),
&       (expfon-ex2fon),(zzzz*(expfon-ex2fon)), saves(5),
&       ex2per, (ex2per/ex2fac*100),
&       (expper-ex2per),(zzzz*(expper-ex2per)), saves(6),
&       ex2fac,(expfac-ex2fac),(zzzz*(expfac-ex2fac), saves(7))
2002  format(
&     '       The new values would lead to a average January heat loss of',/
&     ,' ',f6.1,' Btu/Hr at the desired temperature.',//
&     '                Modified heat loss values',/
&     '                                %      Btu/hr/F   $                    Annual',/
&     '                Btu/Hr/F    Bldg Loss    Saved    Saved                Savings',/
&     'doors       = ',f6.2,'             ',f4.1,'  ',f5.1,'     ',f6.2,'            $',f7.2,/
&     'windows     = ',f6.2,'             ',f4.1,'  ',f5.1,'     ',f6.2,'            $',f7.2,/
&     'walls       = ',f6.2,'             ',f4.1,'  ',f5.1,'     ',f6.2,'            $',f7.2,/
&     'ceiling     = ',f6.2,'             ',f4.1,'  ',f5.1,'     ',f6.2,'            $',f7.2,/
&     'foundations = ',f6.2,'             ',f4.1,'  ',f5.1,'     ',f6.2,'            $',f7.2,/
&     'perimeter   = ',f6.2,'             ',f4.1,'  ',f5.1,'     ',f6.2,'            $',f7.2,//
&     'TOTAL       = ',f6.2,' Btu/Hr/F           ',f5.1,' ',f6.2,'           $',f7.2)
      texpf2 = expven + ex2fac
      write (7,3701) expven, texpf2, (expven/texpf2* 100)
3701  format (/,
&     '       Ventilation     = ',f6.1,' Btu/Hr/F',/
&     'TOTAL Heat loss        = ',f6.2,' Btu/Hr/F',/
&     '       Ventilation     = ',f5.1,'% of the total heat loss.'//)
      write(7,3800)(zzzz*sows*5*60*.24/14)
3800  format (/
&     '     Minimun ventilating fans often remove much more heat from',/
&     'livestock buildings than producers realize.  For the building',/
&     'as initally designed, an increase in the minimum ventilation',/
&     'rate from 15 CFM to 20 CFM would increase the fuel cost for',/
&     'heating only by $',f4.2,' during an average month of January.'//)
      write(7,3801)length,width,sows,inside,local(loc),(sows*minv),
&     (sows*(200-minv)),
&     (texpfc * (inside-(-10))-(btusow)),
&     inside
3801  format(/
&     '     When selecting equipment for this ',i1,' ft x ',i1,' ft',/
&     'farrowing house for ',i1,' sows, to operate at ',i1,' (F) in',/
&     a2,' Kansas, consider equipment which will meet the following',/
&     'minimum requirements:',//
&     '       Minimun ventilation fan ==> ',i6,' CFM      Continuous operation',/
&     '       Maximum ventilation fan ==> ',i6,' CFM      Hot weather operation',/
```

```
&       '       Furnace output          ==> ',i6,' Btu/Hr   Set at ',i1,' (F)')
        if (rfound .eq. 0) rfound = 1000
        if (rwindo .eq. 0) rwindo = 1000
        if((.68/rdoor*inside).ge. 7) rd = 1
        if ((.61/rceil*inside).ge.7) rc = 1
        if ((.68/rwall*inside).ge.7) rw = 1
        if ((.68/rfound*inside).ge.7) rf = 1
        if ((.68/rwindo*inside).ge.7) rwo = 1
        if((rd.eq.1).or.(rc.eq.1).or.(rw.eq.1).or.(rf.eq.1).or.(rwo.eq.1))then
                write(7,7777)
7777            format(////,'     CAUTION!!',//,
&       ' At the current levels of insulation, condensation ',
&       ' is likely to occur;')
                if(rd.eq.1) write(7,7778)
7778            format('    on the doors,')
                if (rc.eq.1) write(7,7779)
7779            format('    on the ceiling,')
                if (rw.eq.1) write(7,7780)
7780            format('    on the walls,')
                if(rf.eq.1) write(7,7781)
7781            format('    on the foundation,')
                if (rwo.eq.1) write(7,7782)
7782            format('    on the windows,')
        if((rd.eq.1).or.(rc.eq.1).or.(rw.eq.1).or.(rf.eq.1).or.(rwo.eq.1))then
        write(7,7783)
7783            format(' This condensation can be reduced by',
&               ' increasing the amount of insulation used.')
                endif
        endif
        return
        end
```

```
      subroutine cycle(loc,deltat,min,max,inside,out)
      integer h, loc,
      real    deltat(12,24), max(12,9), min(12,9), inside, out(12)
      pi = 3.1415927
      do 20 m=1,12
            var =(max(m,loc)-min(m,loc))/2
            avg = (max(m,loc)+min(m,loc))/2
            Out(m)=avg
            do 30 h=1,24
                  deltat(m,h)= inside-((sin(pi*h/12)*var)+avg)
30          continue
20    continue
      return
      end

      end
```

COMPUTERIZED HEAT LOSS EVALUATION
of
FARROWING HOUSES

by

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Abstract

Accurate and concise heat loss analysis is available through a computer program to help swine producers. The economic benefit of insulating a new structure or increasing the insulation level of each of the building parts (ceiling, walls, windows etc.) is calculated by the program. Ventilation is evaluated to assist the swine producer in understanding proper ventilation rates.

The declining energy supply and the generally increasing cost of energy have made it essential that producers emphasize the reduction of heat losses in livestock buildings.

Through computer analysis, insulation and ventilation levels are evaluated for farrowing houses.

Energy cost is most intensive in the farrowing to weaning portion of swine production. Kansas Extension publication MF-263 points out that utility costs make up 7 percent (%) of the variable cost in the farrowing operation or 5.6 percent (%) of the total cost of raising feeder pigs (up to 40#).

Heat loss calculations tend to be very time consuming; however, through a set of questions and answers, building heat loss for farrowing houses may be evaluated using a computer to handle the time consuming calculations. All questions are written in terms producers can understand. The program requires little or no computer experience to operate.