PREDICTING SEASONAL HEATING ENERGY CONSUMPTION FOR OKLAHOMA RESIDENCES

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PREFACE

The major purpose of this study was to evaluate the accuracy of currently used heating degee day methodologies in predicting residential heating energy or fuel consumption. This investigation of degree day procedures was intended to locate sources of error in current practices and yield mechanisms for improvement of degree day methodologies.

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INTRODUCTION

Scope of Investigation

During the 1970's, homeowners across America were exposed to a large number of energy awareness programs. These programs were designed to encourage homeowners to reduce their energy consumption. They encouraged energy conservation measures such as insulation, storm windows, and weather-stripping. These programs, together with increasing energy costs, have stimulated many homeowners to add energy conservation measures to their homes. However, during the late 1970's, homeowners began to be more interested in economics of energy conservation measures. They became interested in dollar as well as energy savings.

To analyze the energy saving potential of energy conservation measures for a particular residential structure, seasonal energy use must be estimated. Several simplified approaches have been used to estimate or predict residential energy consumption. Many of these approaches utilize the heating degree day concept to predict energy consumption during the heating season.

Heating degree days have traditionally been calculated using an 18.3° C base temperature. Use of a base temperature of 18.3° C, assumes that at outdoor temperatures below 18.3° C the structure must have an external supply of heat energy. Thus, 18.3° C represents the balance point of the structure. Factors which affect balance point temperature of a structure are internal heat gains, structural thermal characteristics, solar gains, and thermostat setting. With improved thermal characteristics and lower thermostat settings, balance point temperatures are being lowered. Thus, use of heating degree days calculated from a 18.3° C base temperature may lead to considerable error in prediction of residential heating energy consumption.

In addition to prediction errors due to seasonal heating degree day base temperature, other potential errors exist primarily in the area of heat load calculations. The heat load parameter used in degree day methodology has traditionally been overestimated. Using heat loads larger than necessary causes over prediction of seasonal energy consumption.

This research will investigate impact of heat load calculations and degree day base temperature on prediction of seasonal energy or fuel consumption in Oklahoma residential structures.

Objectives of Study

1. Develop computerized analyses to use basic residential construction and thermal characteristic data to predict seasonal heating energy consumption using degree day procedures.

2. Use collected energy and construction data from Oklahoma homes to evaluate prediction accuracy of the standard degree day equation.

3. Analyze prediction accuracy of modified degree day equations such as American Gas Association, National Electric Manufacturers Association, and American Society of Heating, Refrigeration, and Air-Conditioning Engineers.

4. Present improved procedures for predicting seasonal heating energy use in Oklahoma homes.

CHAPTER II

REVIEW OF LITERATURE

Concept of the Degree Day

Use of the degree day for predicting heating energy consumption in residential buildings was originated over 40 years ago. A basic assumption used in formation of degree days was that the amount of energy consumed in a structure is primarily dependent upon the difference between inside and outside temperature. Strock and Hotchkiss (1) state that the degree day is a measure of energy consumption based on combined knowledge of time and temperature. The knowledge of time and temperature is related by the degree day. By definition, a degree day is the product of one day and the degree difference in temperature between a reference temperature and the average daily outside air temperature.

The reference or base temperature was originally developed by two general methods (1). One approach was an analytical method in which inside temperature profiles were assumed and average temperatures calculated. After assuming and analyzing several profiles, early investigators selected 65° F to be a mean reference temperature. This method was highly criticized for not being a conclusive and reliable means of determining base temperature. The second approach for establishment of a reference temperature was based on field data. Data were collected on fuel consumption and outside temperature. A linear relationship between mean outdoor temperature and fuel consumption was found to exist. From the relationship, it was found that zero fuel consumption occurred at a mean outdoor temperature of 65° F. Thus, 65° F was selected and used as a base temperature for calculation of degree days. With a base temperature of 65° F, an equation for calculating degree days was developed.

$$DD = 65 - T_0, \ DD \geq 0 \tag{1}$$

where

DD = Heating degree days, ° F - days.

T_0 = Average outside daily temperature, ° F.

65 = Reference temperature, ° F.

To obtain annual heating degree days, daily degree days are summed over a period of one year. Studies have revealed annual heating degree days based on an appropriate base temperature can account for as much as 90 percent of the variance of calculated heating requirements (2).

Predicting Heating Energy Consumption

Annual degree days have been combined with parameters of structural heat load and heating unit efficiencies to obtain an expression for energy consumption.

$$EC = \frac{24 \times DD \times Q}{TD \times N} \qquad (2)$$

where

EC = Seasonal energy consumption, BTU's.
DD = Seasonal Heating Degree Days, ° F - days.
Q = Design heat load, BTU/HR.
TD = Design temperature difference, ° F.
N = Furnace efficiency, dec.
24 = Constant, hrs/day.

Often, the equation is rewritten to obtain fuel quantities consumed rather than energy quantities.

$$FC = \frac{24 \times DD \times Q}{TD \times N \times H_V} \qquad (3)$$

where

FC = Seasonal fuel consumption, units of fuel.
DD = Seasonal heating degree days, ° F - days.
Q = Design heat load, BTU/HR.
TD = Design temperature difference, ° F.

N = Furnace efficiency, dec.

H_V = Heating value of fuel, BTU's/unit.

24 = Constant, hrs/day.

Use of equations 2 and 3 has led to considerable errors in prediction of heating energy consumption in residential structures. Because of this, several variations of the basic equations have been made.

The National Electrical Manufacturers Association (NEMA) uses equation 4 to predict electrical energy consumption in residential structures heated with electric resistance furnaces (3).

$$EE = \frac{HL * DD * C}{TD} \qquad (4)$$

where

EE = Seasonal electrical energy consumption, kWhr.

HL = Design heat load, kW.

DD = Seasonal heating degree days, ° F - days.

TD = Design temperature difference, ° F.

C = Constant, hrs/day.

The constant, C, was used to account for variations in energy consumption. These variations were assumed to be due to inaccuracies in load calculations, degree days, and various differences in occupant life style. Based on experience with thousands of electrically heated residential structures, NEMA recommends use of 18.5 for a value of C.

A modified degree day approach is also recommended by the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) (4). The general equation for predicting energy consumption is given in equation 5.

$$E = \frac{(24 * DD * Q)}{(TD * N * H_V)} * C_D * C_F \qquad (5)$$

where

E = Seasonal energy or fuel consumption, units.

DD = Seasonal heating degree days, ° F - days.

Q = Design heat load, BTU/HR.

TD = Design temperature difference, ° F.

N = Rated fuel load furnace efficiency, dec.

H_V = Heating value of fuel, BTU/Unit.

C_D = Correction factor

C_F = Correction factor

24 = Constant, hrs/day.

Correction factors C_D and C_F are used to modify prediction results of the basic degree day equation. Factor C_D is a degree day correction factor, while C_F is a factor which takes into account decreased efficiencies of fuel-fired equipment with oversizing. Values of C_D and C_F are contained in Tables I and II.

TABLE I

HEAT LOSS VS. DEGREE DAYS INTERIM FACTOR C_D

Outdoor Design Temp., ° F	-20	-10	0	+10	+20
Factor C_D	0.57	0.64	0.71	0.79	0.89

TABLE II

PART-LOAD CORRECTION FACTOR FOR FUEL-FIRED EQUIPMENT

Percent Oversizing	0	20	40	60	80
Factor C_F	1.36	1.56	1.79	2.04	2.32

The American Gas Association (AGA) recommends use of equation 6 as an acceptable degree day approach (5).

$$E = \frac{24 * DD * Q}{TD * N_s * H_v} * 0.77 \qquad (6)$$

where

E = Seasonal energy of fuel consumption, units.

DD = Seasonal heating degree days, ° F - days.

Q = Design heat load, BTU/HR.

TD = Design temperature difference, ° F.

N_s = Seasonal furnace efficiency, dec.

H_v = Heating value of fuel, BTU/Unit.

.77 = Correction factor

24 = Constant, hrs/day.

AGA states the multiplier of 0.77 was added because calculated heat losses for a particular structure are most likely higher than actual heat losses. It is interesting to note that the product of 0.77 and 24 is 18.5 which makes the AGA equation very similar to that proposed by NEMA (3).

It should be emphasized that degree day procedures represent simplified calculation approaches. More detailed models, using hourly weather data, have been developed by numerous groups. Blancett et al. (6) report on three residential energy prediction models using hourly weather data. The Electrical Power Research Institute (EPRI) has sponsored numerous residential energy use simulation studies (7, 8). These types of models can be very accurate in simulating and predicting energy use. However, they are limited in use because of the requirement of hourly weather data.

Degree Day Base Temperature

Several studies have been initiated to determine validity of the 65° F base temperature. Base temperature is the temperature at which no external application of heat to the structure is needed. Often, it is referred to as balance temperature. Balance temperature is a function of structural heat loss rate, internal heat gains, solar heat gains, and interior thermostat setting. In an effort to improve energy consumption prediction accuracy, many investigators have looked to the degree day base temperature as a source of error.

Nall and Arens (9) investigated the influence of degree day base temperature on energy prediction accuracy at 60 locations across the United States. A computer model was used to simulate performance of a 1,200 square feet, single-story ranch house at each of these locations. Results of the study verified the theory that heating consumption is a function of heating degree days. However, results also revealed traditional 65° F base temperature to be inadequate in reflecting heating balance point temperature of occupied residential structures. A base temperature of 53° F was found to be more appropriate. Nall and Arens noted that base temperatures or balance temperatures were difficult to determine due to variations in solar gains, internal heat grains, and occupant living habits.

Burch and Hunt (10) tested a 2054 square feet residential structure before and after energy conservation retrofitting. Before retrofitting, the structure had no wall or floor insulation, three and one half inches fiber glass ceiling insulation, single pane windows, and good caulking and weatherstripping. Retrofitting included addition of three and one half inches of insulation to floors and wall, six inches additional insulation to ceiling area, and addition of storm windows. Results of the study found base temperature before retrofitting to be 63.5° F and 59.0° F after retrofitting. This finding supports the common opinion that base temperature should decrease as structural thermal characteristics improve.

Mayer and Benjamini (11) found 65° F to be an adequate value for structures with high heat losses but was inadequate for structures with low heat losses. Again, in this study, balance temperature or base temperature was assumed to be a function of interior temperature, solar heat gain, and internal heat gain. Tests were conducted on 50 structures in which balance temperature was treated as a variable. This was a conglomerate study of 50 homes and resulted in an overall base temperature of 62.3° F. Studies on single or individual structures revealed base temperature to be 62.1° F.

Harris et al. (12) proposed a single alternative equation for estimation of seasonal energy consumption for residential heating. The equation is given as follows:

$$F = \frac{h\ D_s\ 24}{E_s\ C}\ [1 - K_d\ (65 - t + DT_O)] \qquad (7)$$

where

F = Seasonal energy or fuel consumption, units.

h = Heat loss rate of structure, BTU/hr ° F.

D_s = Seasonal heating degree days (65° F base), ° F - days.

E_s = Seasonal utilization efficiency, dec.

C = Heating value of fuel, BTU/Unit.

K_d = Degree day correction factor, dec.

DT_O = Indoor-outdoor temperature difference, ° F.

Parameter, K_d, is a base temperature sensitivity coefficient developed from data of degree days calculated at different base temperatures for 46 cities in the United States. Parameter, DT_O, is the indoor-outdoor temperature difference at zero heating energy requirement. Thus, the primary modification of this approach is a variable base temperature. The modified equation was tested on 170 structures in six cities. Mean error of prediction was found to be 3.4% with a standard deviation of 31.0%. This was a significant improvement over results obtained from conventional degree day techniques.

In a study by Fischer (13), data from 54 instrumented homes and three townhouse apartments were evaluated to determine adequacy of the degree day technique for estimating energy consumption in residences. A total prediction error of less than 7 percent was found in the study. Base temperature was varied from structure to structure. Overall average base temperature was 64.4° F.

Heat Loads

Along with base temperature, another potential source of error in degree day predictions is in calculation of heat loads. Strock and Hotchkiss (1) noted in their initial studies of degree day techniques that heat loss calculations were often too generous. Over predicted heat loads directly impact energy consumption predictions. AGA modified the standard degree day equation because of consistently high heat loss calculations (5). The proposed AGA multiplier is used to reduce design loads to actual loads. Harris et al. (12) attributed significant error to heat loss calculations. Harris suggested average heat loss rates would yield better results.

Two of the most common methods of calculating design heat loss are Manual J method developed by National Environmental Systems Contractors Association and methods presented by American Society of Heating, Refrigeration, and Air-Conditioning Engineers (14, 15). Common consensus is that the Manual J method overestimates design heat loads for residential structures. Improved methods of calculating design heat loads are presented in ASHRAE GRP 158 Heating and Cooling Load Calculation Manual (16). This manual was published in 1979 and presents latest ASHRAE techniques for calculation of design heat losses.

For the most part, heat load calculations are based primarily on conduction principles. Heat loads due to losses through ceilings, walls, windows, etc. are primarily a function of heat transfer coefficients, temperature difference, and area. Primary exceptions to this are infiltration and concrete slab floor heat losses.

Infiltration is perhaps the most highly variable and hardest to predict heat loss associated with a residential structure. Infiltration is air leakage through cracks and openings around windows and doors and through walls and floors. The quantity of infiltration or quantity of air flow into and out of a residential structure is dependent upon inside-outside pressure difference. Pressure differences are largely due to wind forces, temperature differences, and internal pressurization by the air distribution system (17). ASHRAE Handbook of Fundamentals outlines two basic techniques for calculation of heat loss due to infiltration (15). One method is the crack length method. This method is based on the amount of crack around windows and doors. An assumption is made that one-half of the total crack allows inflow of air while the remaining crack is used for exhausting of air. Both sensible and latent heat loss due to infiltration can be calculated by the crack length method. The crack length method is generally considered to be the most accurate method when window and pressure characteristics can be properly evaluated (17).

The second method commonly used is the air change method. The air change method is based on a judgment regarding structural infiltration characteristics. Based on structural characteristics, an estimated number of air changes per hour is selected from which heat loss is calculated. ASHRAE states that measured infiltration rates have been found to range from 0.45 to greater than 1.5 air changes per hour in winter conditions (15).

A significant quantity of research has been done to evaluate infiltration in residential buildings. Behnfleth et al. (18) measured infiltration in two residences at the University of Illinois and found infiltration in research home number one to range from 0.17 to 0.43 air changes per hour and 0.26 to 0.64 in research home number two. A conclusion was drawn that measured infiltration quantities were in good agreement with those found using ASHRAE crack length and air change methods. Tamura (19) also conducted tests in the measurement of air infiltration and found results supportive of those reported by ASHRAE. While many research findings support ASHRAE methods, others have suggested ASHRAE design calculations yield air change rates higher than actual. Hill and Kusuda (20) found this to be evident in their study of air infiltration. Peterson (21) recommends use of the air change method and reports measured air change rates from 0.37 to 0.86 air changes per hour in residential structures. Tamura (22) states that ASHRAE crack length and air change methods are adequate for design load calculations but not for hourly energy analysis calculations.

Research in heat loss from concrete slab floors was primarily conducted during the late 1940's and early 1950's. Dill et al. (23) derived three heat loss factors:

1. Factor F_1: Factor F_1 represented heat loss in BTU per hour per linear foot of exposed edge divided by the number of degree-days in a particular month.
2. Factor F_2: Factor F_2 represented heat loss in BTU per hour per linear foot of exposed edge divided by the average temperature differences between inside air and outside air.

3. Factor F_3: Factor F_3 represented heat loss in BTU per hour per linear foot of exposed edge divided by difference in inside air temperature and the ground temperature measured one foot below surface.

Of the factors, F_3 was found to yield the best estimate of slab floor heat loss. However, it was somewhat impractical to use since ground temperature data was not readily available. Because of this, Factor F_2 was suggested as the best factor to be used for general purposes of estimating floor heat loss.

Bareither et al. (24) studied heat losses from concrete slab floors of various configurations. Isotherm patterns, drawn for each floor type indicated floor heat loss at a distance of three feet from the exposed edge of the floor was essentially straight downward and the magnitude was practically constant. Because of this, two equations were proposed for estimating design heat loss through concrete slab floors laid on the ground. One equation describes losses through perimeter sections of the slab while the other estimates losses through the interior floor section.

ASHRAE utilizes results obtained from the above studies to define recommended procedures for calculating heat losses through slab floors (15). The proposed procedures identify two types of floors. Type one floor is an unheated concrete slab floor on grade. Type two is a concrete slab floor which contains heating pipes or hot air distribution ducts. In both cases, heat loss was found to be more nearly proportional to perimeter length than to floor area. Therefore, a floor heat loss factor, F_2, was developed. This factor represents heat loss in BTU per hour per linear foot of exposed edge per degree Fahrenheit temperature difference between inside and outside temperature. Factor F_2 is amplified in the ASHRAE procedure to account for interior floor loss to the ground. Recommended values of F_2 are proposed for general design purposes.

CHAPTER III

DATA COLLECTION AND PROCEDURES

Data Collection

To adequately evaluate prediction accuracy of degree day techniques, detailed energy consumption and structural data were required for a large number of Oklahoma houses. Data were collected on a total of 207 houses in Oklahoma. All houses were single story structures with no basements. Of the 207 houses, 105 were heated with natural gas furnaces, 87 with electric resistance furnaces,and 15 with electric air source heat pumps. Data were collected with the help and cooperation of several utility companies within the state. Arkansas-Oklahoma Gas, Lone Star Gas, Oklahoma Gas and Electric, and Oklahoma Natural Gas companies were instrumental in collection and gathering of data related to residential structures heated with natural gas (25, 26, 27, 28). Public Service Company of Oklahoma and State Rural Electric Cooperatives provided data for houses heated with electric resistance furnaces and heat pumps (29, 30).

Energy consumption data were obtained from billing records of companies supplying the heating fuel or energy. Energy consumption data were obtained for calendar year 1978 for many of the houses and for heating season 1978-1979 for the remainder. For each house, seasonal heating degree days were calculated for the season over which energy consumption data were recorded. Degree day information was obtained for the various locations from Climatological Data for Oklahoma published by National Oceanic and Atmospheric Administration (31). These degree days are reported using a 18.3° C base temperature.

Heating season energy consumption data provided by utility companies were monthly data which included base usage. Therefore, it was necessary to evaluate each home independently to determine base loads. Base loads represent relatively constant energy or fuel use by items such as appliances, lights and water heating. Base usage is difficult to determine. One method used by many utility companies and recommended in the Residential Conservation Service Model Audit consists of plotting monthly energy or fuel consumption as a function of monthly degree days (32). The plot is linear in nature with the slope of the line representing fuel or energy usage per degree day. From the plot, base load can be estimated by extrapolation of the line to zero degree days. For this research, base loads determined by this technique appeared to be questionable in accuracy. Texas Energy Management Training Manual recommends estimation of heating season base load by examining energy consumption during non-heating season months (33). For purposes of this research, both techniques were employed. However, results obtained from the latter method were primarily used.

Structural data were obtained for each residence through an onsite inspection by utility company employees. Structural data and thermal characteristic data were required in sufficient detail to enable calculation of heat loads. A summary of the type of structural and thermal data collected is contained in Table III. Specific energy consumption, structural, and thermal data are contained in Appendix A.

Load Calculations

For purposes of this research, heat loads were calculated by two methods. The first method is one commonly used by engineers in heating, ventilating and air conditioning fields. This method is described in detail in the ASHRAE GRP 158 Heating and Cooling Load Calculation Manual (16). The design heating load of each structure was calculated by this methodology using an outdoor design temperature of -10.6° C and an indoor design temperature of 22.2° C. Original programming of this methodology was done by Oklahoma Gas and Electric Company (34). Modifications to the program were necessary to adapt input-output data routines. While modifications were necessary, no change in calculation methodology was made.

TABLE III

REQUIRED STRUCTURAL AND THERMAL DATA FOR CALCULATION OF HEAT LOADS

Floor Area

Floor Type

Type of Duct System

Duct Location

Duct Insulation

Door Type

Door Area

Window Area

Window Location

Window Type

Perimeter Length

Wall Area

Wall Construction Type

Infiltration Characteristics

Heating System Type

Ceiling Insulation

Floor Insulation

Wall Insulation

In addition to the ASHRAE heat load program, a revised calculation procedure was developed. Investigation of the standard degree day equation (equation No. 3) reveals a parameter of design heat load in the numerator and design temperature difference in the denominator. Division of heat load by temperature difference yields a heat loss rate in watts per degree Celsius. A majority of the design heat load is due to conduction and is calculated according to the basic conduction equation as described in equation 8.

$$q = 1/R * A * (T_i - T_O) \qquad (8)$$

where

q = Heat loss rate, W.

R = Thermal resistance, ° C-m^2/W.

A = Area, m^2.

T_i = Inside design temperature, ° C.

T_O = Outside design temperature, ° C.

Dividing conduction heat loss by design temperature difference yields a heat loss rate equal to the quantity of area divided by thermal resistance (A/R). Therefore, in this step, design temperature difference actually becomes an irrelevant term. However, this is not exactly true for heat loss calculations in areas such as floors and infiltration. These heat loss calculations are normally not based on conventional conduction principles. Because of these principles, the revised load calculation procedure was developed. The procedure consisted of a computer program called Computerized Residential Heating Analysis (CRHA) (35). The primary difference between ASHRAE heat loads and heat loads calculated by CRHA is that the intent of CRHA is to calculate average heat loss rates while ASHRAE programs calculate design loads. Again, it should be pointed out that heat loads calculated by the conduction equation actually become heat loss rates when used in the degree day methodology. Therefore, primary emphasis in the CRHA procedure was to revise calculations of infiltration and floor heat losses to reflect average heat loss rates rather than design loads.

All research houses in the data set contained suspended frame floors over unconditioned crawl space, concrete slab constructed on grade, or a combination of the two. Floor heat loss calculations are vastly different for the different floor types.

For suspended frame floors, normal procedure is to use the basic conduction equation as shown in equation 8. However, for suspended floors over an unconditioned crawl space, use of outside design temperature leads to overestimation of heat losses. This is because the stem wall of the crawl space does provide some resistance to heat flow which in turn causes an increase in crawl space temperature. For an unvented crawl space, an energy balance can be used to determine the unvented crawl space temperature under design conditions. However, few houses in Oklahoma have a completely unvented crawl space. In reality, actual temperature of the crawl space at design conditions is somewhere between the vented and unvented condition. The program assumes a crawl space air infiltration rate of 1/8 air change per hour. Thus, a crawl space temperature is first calculated using an energy balance of heat flow through the floor and stem wall assuming an unvented crawl space. The unvented crawl space temperature is then corrected for the 1/8 air change per hour to obtain the temperature for the vented crawl space. The procedure takes into account the added resistance of the stem wall.

Heat loss from concrete slab floors was calculated based on procedures set forth by Bareither et al. (24). Equation 9 was used to express slab floor heat loss.

$$QHF = [F \times PL \times (T_i - T_O) + 3.94 \times (FA - 0.91 \times PL)] \qquad (9)$$

where

QHF = Heat loss rate in concrete slab floor, W.

F = Heat loss factor, W/° C-m.

PL = Perimeter length, m.

T_i = Temperature inside, ° C.

T_O = Temperature outside, ° C.

FA = Floor area, m^2.

3.94 = Heat loss constant, W/m^2.

0.91 = Constant, m.

The first component of the equation represents heat losses through the perimeter edge. Factor F is a perimeter edge heat loss factor which has a value of 0.477 for slabs with perimeter insulation and 0.839 for slabs with no perimeter insulation (24). The second component describes heat loss through the floor interior. This includes floor area inside of a 0.91 m boundary around the perimeter (24). Heat loss through this region of the floor is assumed constant with a value of 3.94 W/m^2.

Air infiltration heat losses were evaluated by classifying each structure as to its quality in the areas of caulking, weatherstripping, etc. Each house was classified as tight, medium, or loose. Basically, the ASHRAE crack length method was used to calculate infiltration heat loss (15). Crack length is normally determined by measurement of crack length around windows and doors. An additional assumption is made in crack length methodology that only one-half of the total crack should be used for calculation purposes. This assumes outdoor air enters through windward cracks and exits through leeward cracks. In the CRHA program, one-half of total crack length was estimated by multiplying total window area in square meters by 2.46. Through a study a several example homes, this approximation was found to be reasonably accurate. The approximation was validated by Public Service Company of Oklahoma in an independent analysis (29).

Air infiltration rates corresponding to various structural classifications are contained in Table IV. Values of air inflow rates are given in cubic meters of air per hour per meter of crack. Equation 10 is used to calculate heat loss due to infiltration around doors and windows (15).

$$q_i = 0.386 \times CL \times Q_i \times (T_i - T_O) \qquad (10)$$

where

q_i = Infiltration heat loss around windows and doors, W.

CL = Crack length, m.

Q_i = Air infiltration rate, m^3/hr-m.

T_i = Inside design temperature, ° C.

T_O = Outside design temperature, ° C.

0.386 = Constant, W/° C-m^3.

A component of air infiltration is also attributed to wall area. Research results from Simplex Industries were used to derive equation 11 (36).

$$q_{iw} = [0.4906 * WA * (T_i - T_O)]/2.0 \qquad (11)$$

where

q_{iw} = Heat loss rate from infiltration in walls, W.

WA = Wall area, m^2.

TABLE IV

AIR INFILTRATION RATES

Classification	Air Flow Rate (m^3/hr-m)
Good	1.3
Average	2.6
Poor	5.2

Source: American Society of Heating, Refrigeration and Air-Conditioning Engineers (15).

T_i = Inside design temperature, ° C.

T_O = Outside design temperature, ° C.

0.4906 = Heat loss factor, W/° C-m^2.

Heat losses in air distribution ducts were calculated as a percentage of the overall structural heat loss. Percentage values are contained in Table V.

Degree Day Applications

After heat loads and seasonal heating degree days were determined for each research house, initial evaluations of seasonal heating energy predictions were made. Prediction accuracy of the standard degree day equation (equation no. 3), NEMA modified equation (equation no. 4), ASHRAE modified degree day equation (equation no. 5), and AGA modified equation (equation no. 6) was determined using both ASHRAE and CRHA heating loads. Each house was evaluated with each equation. Seasonal energy consumption predictions from each equation or methodology was then compared to actual energy or fuel consumption to determine accuracy of prediction.

After determining accuracy or inaccuracy of the various degree day methodologies, methods of improvement in prediction accuracy were investigated. In this investigation, attention was again given to the original degree day equation (equation no. 3). Basic parameters included in the equation which affect seasonal prediction are degree days, heat load,

TABLE V

DUCT HEAT LOSS FACTORS

No Insulation	20%
2.54 cm Insulation	15%
5.08 cm Insulation	10%

Source: National Environmental Systems Contractors Association (14).

design temperature difference, furnace efficiency, and heating fuel value. Potential errors in overall prediction could be attributed to any one of these parameters. In order to narrow the possibilities for error, an investigation was initiated using 55 of the 87 research houses heated with electric resistance furnaces. Using homes heated with electric resistances furnances allowed use of a constant value for furnace efficiency of 100 percent. Along with furnace efficiency, design temperature difference and heating value of fuel could also be treated as constants. By a process of elimination, only parameters of design heat load and seasonal heating degree days were left to make contribution to error and variance of prediction. Because design heat load or heat loss rate was calculated using the two methodologies previously described, primary attention was given to seasonal heating degree days. As was noted in the literature review, much speculation as to primary source of error in degree day methodologies has been attributed to seasonal heating degree days.

Using the base data set of 55 houses heated with electric resistance furnaces and standard degree day methodology given in equation 3, seasonal heating degree days were varied to determine overall impact on prediction accuracy. Degree days were varied by changing the base or reference temperature. Seasonal heating degree days were calculated using base temperatures ranging from 12.8° C to 18.3° C. A method of converting seasonal heating degree days from one base to another was developed by Harris et al. (12). However, this methodology was a general derivation based on nationwide data. A more site specific investigation was done for Oklahoma. Locations of Idabel, Goodwell, and Oklahoma City were picked in the State of Oklahoma for analysis. These locations represent the broad range of climates found in Oklahoma. Idabel represents the extreme warmest area in Oklahoma, while Goodwell represents the coldest. Oklahoma City serves as an average. A methodology was developed to change total seasonal heating degree days from one base temperature to another.

From the analysis of the 55 houses, the degree day base temperature which yielded the best results was determined for each heat load methodology. After selecting appropriate base temperature, the test was repeated using the remaining 32 research houses heated with electric resistance heat. This procedure was used to verify results obtained from the first step in the analysis.

Final step in the analysis was to evaluate prediction accuracy of the standard degree day methodology using new degree day base temperatures on research houses heated with natural gas furnaces and electric air source heat pumps. At this point in the study, conclusions were drawn on the effectiveness of reducing degree day base temperature on predicting seasonal energy or fuel consumption for residential structures.

CHAPTER IV

ANALYSIS OF DATA AND RESULTS

Comparison of Load Calculation Routines

Both ASHRAE and CRHA routines were used to calculate structural heating loads for each house in the research data set. Even though the CRHA routine is based on principles of heat loss rate rather than design heat loads, loads were calculated at design conditions to enable a comparison of the two procedures. Design conditions are based on -10.6° C outside air temperature and 22.2° C inside air temperature. Table VI contains a summary of average loads of the entire 207 research home data base.

Design heat loads calculated from ASHRAE procedures are consistently higher than those calculated by CRHA procedures. Based on average values from the entire data set CRHA procedures yield design heat loads approximately 32 percent lower than ASHRAE. A further breakdown of load calculations for each procedure is shown in Table VII. In Table VII, load calculations for each basic structural heat loss item are shown. Calculation differences for windows, doors, walls, and ceilings are small. The differences are due

TABLE VI

AVERAGE DESIGN LOADS FOR 207 RESEARCH HOUSES

Method	Mean (W)	Minimum (W)	Maximum (W)	Standard Deviation (W)
ASHRAE	16345	6892	41052	5569
CRHA	11058	5408	23387	3186

TABLE VII

AVERAGE COMPONENT DESIGN LOADS FOR 207 RESEARCH HOUSES

Component	Method	Mean (W)	Standard Deviation (W)
Windows	ASHRAE	2181	1221
	CRHA	2462	1283
Doors	ASHRAE	310	134
	CRHA	309	135
Walls	ASHRAE	2010	805
	CRHA	1875	1137
Ceilings	ASHRAE	1827	1024
	CRHA	1530	840
Floors	ASHRAE	5477	3548
	CRHA	2055	797
Infiltration	ASHRAE	3306	1085
	CRHA	1953	640
Ducts	ASHRAE	1233	946
	CRHA	874	731
Total	ASHRAE	16345	5569
	CRHA	11059	3186

primarily to differences in internal assumptions of thermal resistance. For example, in the walls, ASHRAE corrects wall R-value for 20 percent wood framing while CRHA does not.

Major differences in overall calculation of loads occur primarily in floors and infiltration. As stated in the Chapter III of this thesis, infiltration calculations in the CRHA procedures were designed to represent average heat loss rates and, therefore, average or reduced loads. The same is true for calculation of floor heat loss. Of the 207 research houses, 96 had suspended frame floor construction and 111 had concrete slab frame construction. A comparison of floor heat loads by both procedures subject to floor type is contained in Table VIII. From information contained in Table VIII, a major difference in floor heat loss calculations occurs in calculation of loads for frame floors. In the ASHRAE methodology, heat loads for suspended frame floor are calculated by conduction principles at inside and outside design air temperatures. This together with the thermal resistance of the floor yields a heat load at design conditions. The primary difference in CRHA procedures is that a combined R-value of the floor and stem wall is used. Heat losses from a suspended frame floor follow patterns shown in Figure 1. Heat energy moves from the conditioned space through the frame floor into the crawl space area. From the crawl space, heat energy flows through the stem wall and into the ground. In most cases, heat lost to the ground is neglected.

TABLE VIII

COMPARISON OF FLOOR HEAT LOAD CALCULATION

Floor Type	Method	Mean (W)
Frame	ASHRAE	7980
	CRHA	1882
Slab	ASHRAE	3314
	CRHA	2210

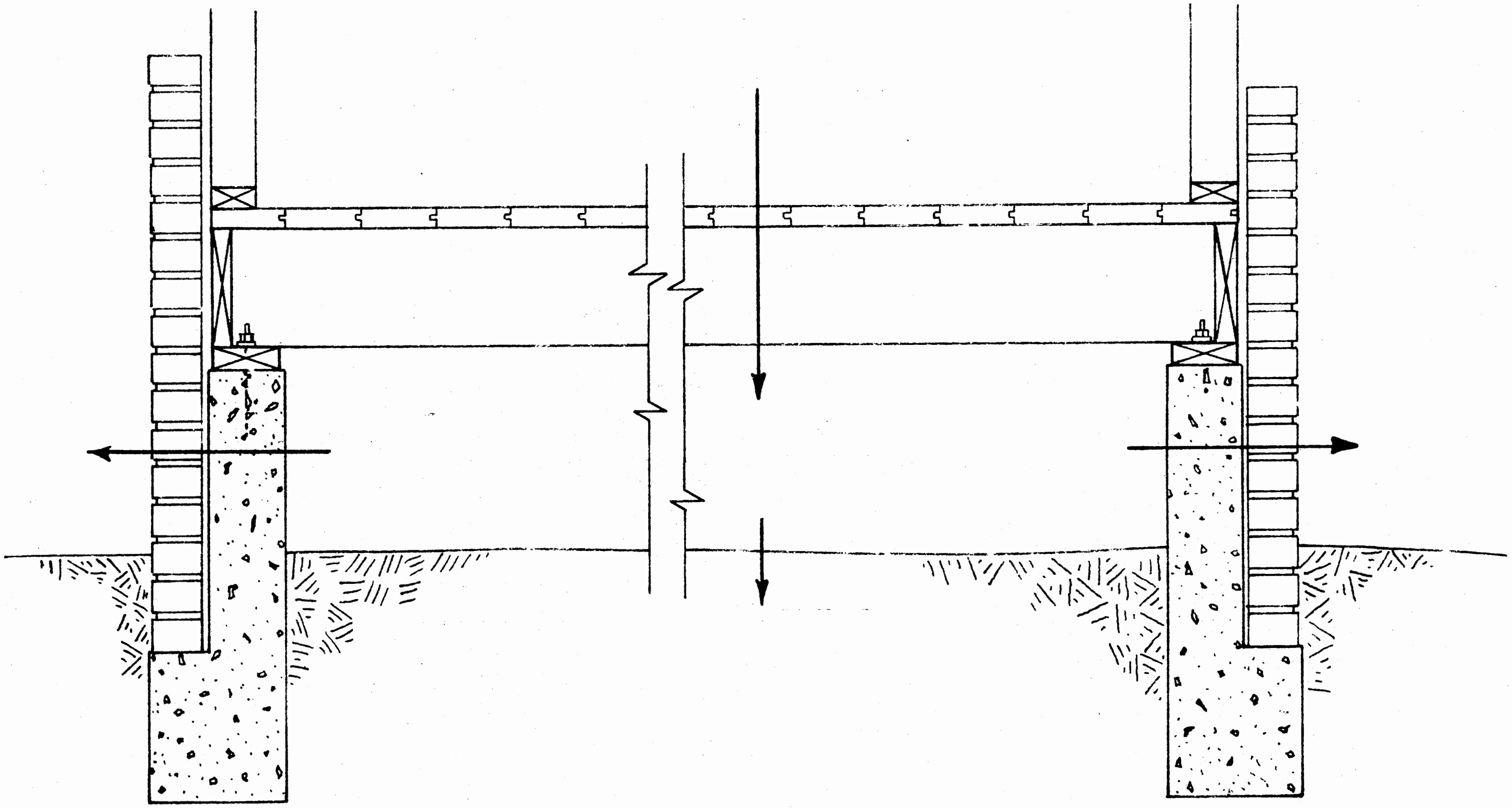

Figure 1. Schematic of Frame Floor Heat Losses

Even though crawl spaces are vented, common practice is to close vents during winter seasons. Even if they are not closed, the stem wall still provides some resistance to heat flow. This resistance is noticed primarily in the fact that crawl space temperatures are higher than outside temperature. An energy balance on the floor section can be made as was discussed in Chapter III. This procedure accounts for the added resistance of the stem walls and provides the primary difference in the two calculation routines. It should be noted that stem wall resistance is particularly significant when the frame floor has low thermal resistance or R-value. However, as frame floor thermal resistance increases, thermal resistance of the stem wall becomes less significant. Figure 2 contains a frequency distribution of frame floor R-values for the 96 houses with suspended frame floors in the research data set. Most of the houses had no added insulation in the frame floor. Therefore, stem wall resistance was significant and contributed greatly to the differences in calculations.

Differences in slab floor calculations are primarily in assumptions concerning heat loss factors. ASHRAE methodology utilizes equation 12 to estimate design heat load for concrete slab floors with no embedded supply ducts and equation 13 for slabs with embedded air distribution ducts.

$$q_f = 76.9 - 1.0 \times RV \qquad (12)$$

$$q_f = 48.1 - 0.7 * RV \qquad (13)$$

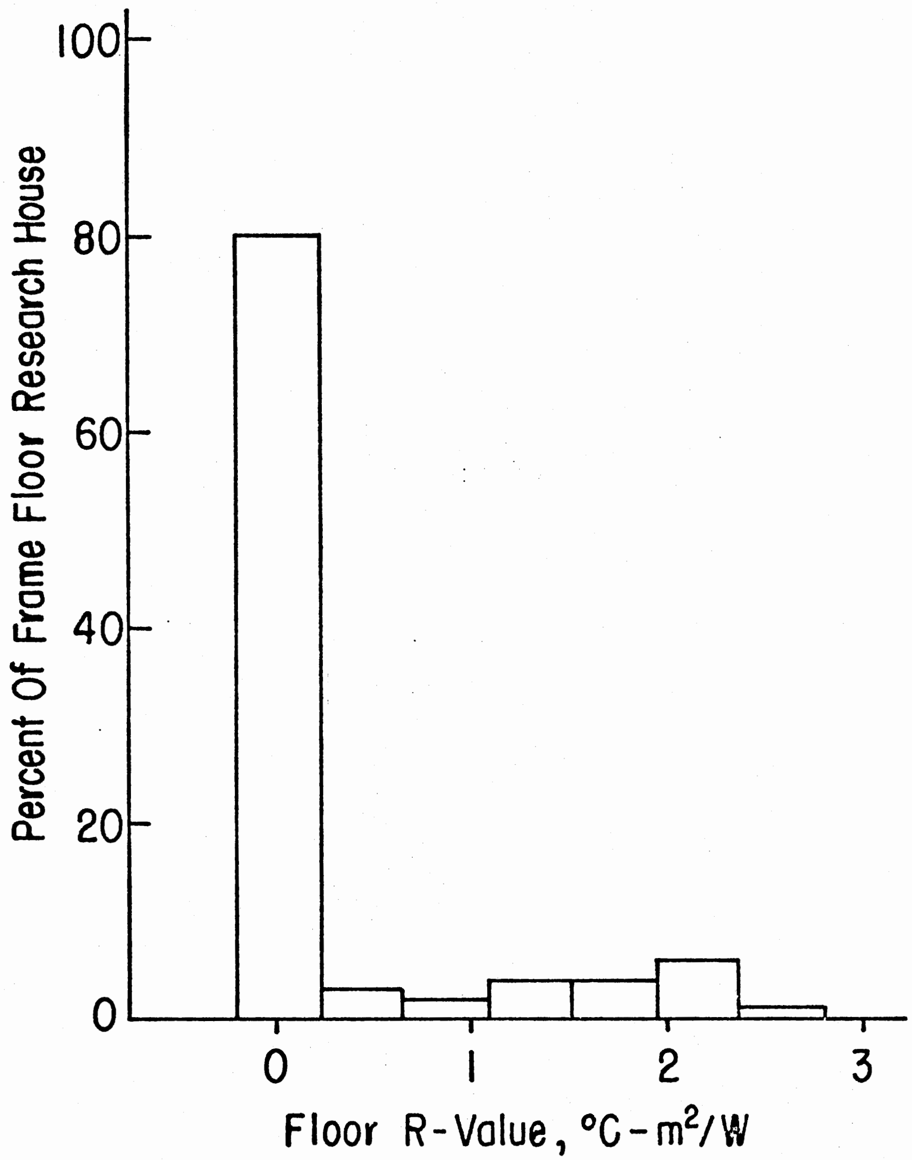

Figure 2. Distribution of Frame Floor R-Values

where

q_f = Floor heat load, W/m.
RV = R-value of stem wall insulation, ° $C\text{-}m^2/W$.
76.9 = Constant, W/m.
48.1 = Constant, W/m.
1.0 = Coefficient, $W^2/° C\text{-}m^3$.
0.7 = Coefficient, $W^2/° C\text{-}m^3$.

ASHRAE procedures and methodology base all slab floor losses on perimeter heat loss factors. These factors are amplified to account for losses to the ground.

As was stated in Chapter III, CHRA procedures were derived from research results obtained from Bareither et al. (24). These procedures establish a separate heat loss for perimeter and ground. Basic heat flow patterns for concrete slab floors are shown in Figure 3. Heat loss in the outer 0.91 m of perimeter edge is primarily a function of edge construction and inside-outside temperature difference. Heat loss in the inner floor area is a function primarily of ground temperature.

Differences in infiltration calculations occur in basic assumptions and methodologies. Both procedures categorize houses according to infiltration characteristics. Houses are categorized as tight, medium, or loose. ASHRAE procedures are based primarily on the air change method. ASHRAE air infiltration rates used for design conditions in Oklahoma are contained in Table IX. Much of the literature

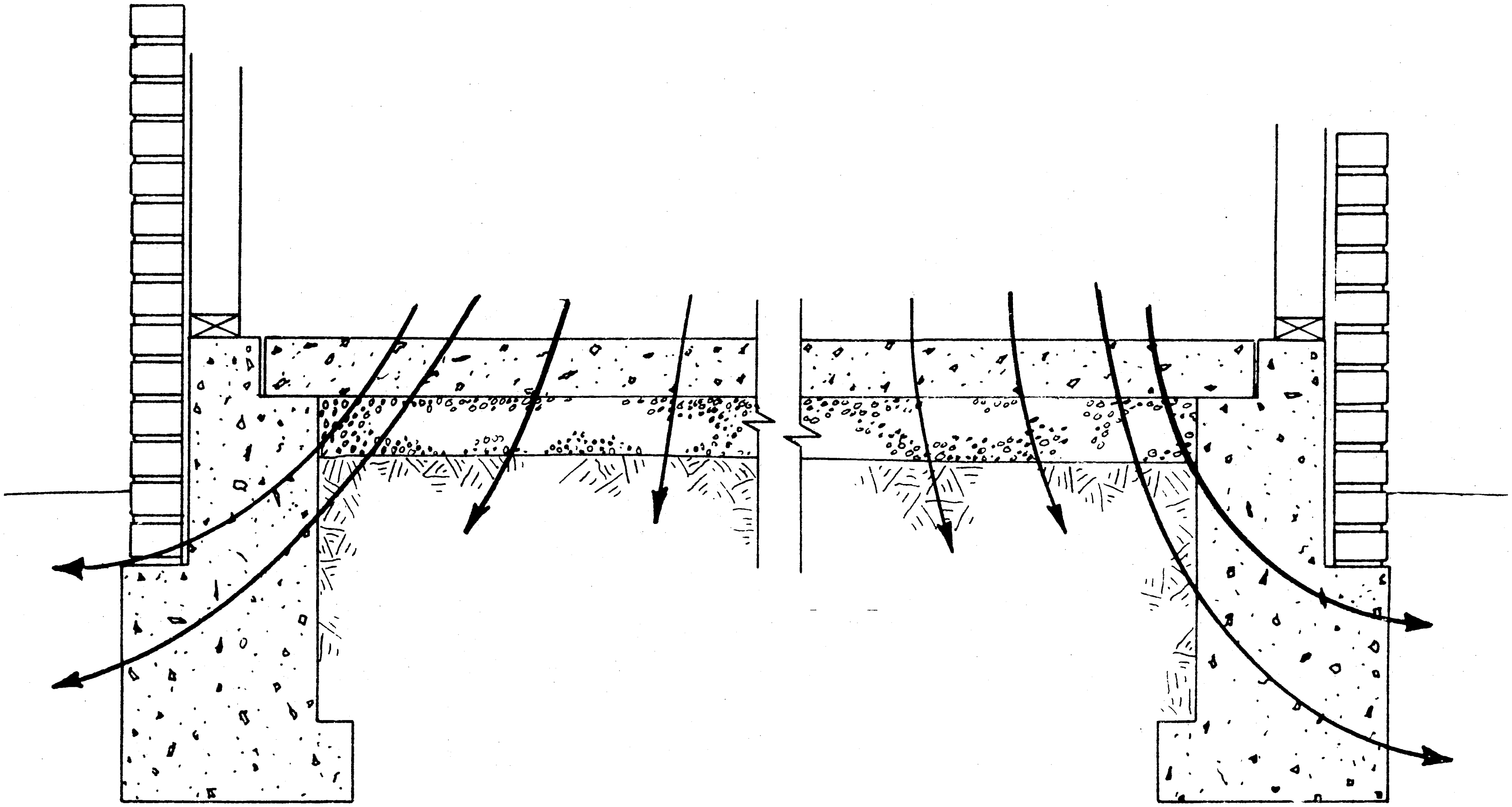

Figure 3. Heat Flow Patterns For Concrete Slab-on-Grade Floors

TABLE IX

ASHRAE AIR INFILTRATION RATES AT DESIGN CONDITIONS

Category	Infiltration Rate (Air changes/Hr)
Tight	0.67
Medium	0.97
Loose	1.27

review contained in Chapter II stated that design infiltration rates of 0.3-0.8 were common. Values used in Table IX are much greater than this.

CRHA infiltration calculation procedures are based on principles outlined in Chapter III and reflect loads based on average conditions. The purpose of comparing heat load calculation procedures in this research is not necessarily to prove one procedure correct over another. Rather, the purpose is to critically review current simplified calculation procedures in connection with degree day methodologies. However, from this comparison, it appears significant work is needed in calculating heat loads with simplified procedures. Some of this work is already being conducted. Fischer (13) in his study compared the ASHRAE methodology contained in ASHRAE GRP 158 Heating and Cooling Load Calculation Manual to data collected on actual homes heated with electric resistance furnaces (16). Actual loads were calculated from hourly data of energy consumption and inside-outside temperature difference. Findings from the study revealed ASHRAE calculated loads to be approximately 50 percent higher than those actually measured.

Analysis of Existing Degree Day Methodologies

One of the primary purposes of this study was to evaluate prediction accuracy of currently employed degree day methodologies. This was accomplished by comparing estimated energy or fuel consumption to actual consumption for each research house in the base data set. For each house, percent error in prediction was calculated according to equation 14.

$$PER = \frac{FP - FUA}{FUA} * 100 \qquad (14)$$

where

PER = Percent error in prediction.

FP = Predicted energy or fuel consumption, units.

FUA = Actual energy or fuel consumption, units.

Analysis of various degree day methodologies was initially done using only houses heated with natural gas and electricity. Houses heated with heat pumps will be discussed in a later section.

The first methodology analyzed was standard degree day methodology shown in equation 3. The equation utilizes basic parameters of heat load and degree days with no assumed correction factors for either parameter. Results of the analysis are contained in Table X. Rated full load furnace efficiency of 75 percent was used for natural gas furnaces and 100 percent for electric resistance furnaces.

TABLE X

RESULTS OF ENERGY CONSUMPTION PREDICTION USING STANDARD DEGREE DAY METHODOLOGY

Load Calculation Procedure	Furnace Type	Mean Error (Percent)	Standard Deviation (Percent)
ASHRAE	Electric	64.3	50.0
CRHA	Electric	16.6	28.9
ASHRAE	Natural Gas	61.6	40.4
CRHA	Natural Gas	7.5	30.4

*Mean error is the average percent error in prediction of energy consumption as calculated by equation 14.

From results shown in Table X, it can be seen that both calculation procedures yield unsatisfactory results with the standard degree day equation. Clearly, ASHRAE procedures greatly over predict energy and fuel consumption. This is the primary reason why many attempts have been made to correct or modify standard degree day methodology.

One of the first attempts to modify standard degree day methodology was made by NEMA (3). Equation 4 represents NEMA's proposed modification with the value C equal to 18.5. NEMA methodology originally was only developed for predicting electrical energy consumption. Therefore, analysis of NEMA methodology was done using only the electrically heated portion of the base data set. Results of the analysis are contained in Table XI. Again, furnace efficiency is taken by NEMA to be 100 percent.

Modifications by NEMA were found to significantly improve prediction accuracy for both load calculation routines. Not only was mean percent error reduced, standard deviation was also lowered.

ASHRAE Modified Degree Day Methodology was shown in equation 5. Correction factors C_D and C_F were added to modify and improve overall accuracy. From Table I, at design condition, C_D is 0.82. C_F was taken from Table II for a 20 percent oversized furnace. The value of C_F is 1.56. Factor C_F only applied to fuel-fired furnaces and therefore is taken to be 1.0 for electric furnaces. Results

TABLE XI

RESULTS OF ENERGY CONSUMPTION PREDICTION USING NEMA METHODOLOGY

Load Calculation Procedure	Furnace Type	Mean Error (Percent)	Standard Deviation (Percent)
ASHRAE	Electric	26.6	38.5
CRHA	Electric	-10.1	22.3

using ASHRAE Modified Degree Day Methodology are contained in Table XII. Natural Gas furnace efficiency of 75 percent and electric furnace efficiency of 100 percent is used in the ASHRAE methodology.

Modifications to standard degree day procedures made by ASHRAE show no improvement. Prediction error is greater with the modified procedure than that obtained from standard procedures. Because of this, the American Gas Association proposed revisions to the ASHRAE method (5).

AGA proposed equation 6 to be used for more accurate prediction of residential energy and fuel consumption. The AGA methodology suggests a seasonal furnace efficiency of 67.5 percent be used for natural gas furnaces and a seasonal furnace efficiency of 97.5 percent be used for electric resistance furnaces. Results of using AGA methodology are contained in Table XIII.

Results using AGA methodology were found to be significantly improved over standard degree day methodology and ASHRAE Modified Degree Day Methodology. Results from AGA are similar to those found by NEMA. This was expected in that the major differences between the two methods is in assumptions of furnace efficiency.

Tables XIV and XV contain summaries of the various degree day methodologies for both ASHRAE and CRHA load calculations. From the summaries, NEMA and AGA methodologies appear to provide best prediction accuracy.

TABLE XII

RESULTS OF ENERGY CONSUMPTION PREDICTION USING ASHRAE MODIFIED DEGREE DAY METHODOLOGY

Load Calculation Procedure	Furnace Type	Mean Error (Percent)	Standard Deviation (Percent)
ASHRAE	Electric	34.7	40.1
CRHA	Electric	-4.4	23.7
ASHRAE	Natural Gas	106.7	51.6
CRHA	Natural Gas	37.6	38.9

TABLE XIII

RESULTS OF ENERGY CONSUMPTION PREDICTION USING AGA MODIFIED DEGREE DAY METHODOLOGY

Load Calculation Procedure	Furnace Type	Mean Error (Percent)	Standard Deviation (Percent)
ASHRAE	Electric	29.7	39.4
CRHA	Electric	-7.9	22.8
ASHRAE	Natural Gas	38.2	34.5
CRHA	Natural Gas	-8.0	26.0

TABLE XIV

SUMMARY OF DEGREE DAY PREDICTION METHODS USING ASHRAE HEATING LOAD

Degree Day Methodology	Furnace Type	Mean Error (Percent)	Standard Deviation (Percent)
Standard Method	Electric	64.3	50.0
	Natural Gas	61.6	40.4
NEMA Modification	Electric	26.6	38.5
ASHRAE Modification	Electric	34.7	40.1
	Natural Gas	106.7	51.6
AGA Modification	Electric	29.7	39.4
	Natural Gas	38.2	34.5

TABLE XV

SUMMARY OF DEGREE DAY PREDICTION METHODS USING CRHA HEATING LOAD

Degree Day Methodology	Furnace Type	Mean Error (Percent)	Standard Deviation (Percent)
Standard Method	Electric	16.6	28.9
	Natural Gas	7.5	30.4
NEMA Modification	Electric	-10.1	22.3
ASHRAE Modification	Electric	-4.4	23.7
	Natural Gas	37.6	38.9
AGA Modification	Electric	-7.9	22.8
	Natural Gas	-8.0	26.0

Development of New Constants

One approach to improve prediction accuracy of degree day methodology was to utilize the basic degree day equation and apply an overall correction factor. This is basically the technique of improvement that all modified degree day procedures have used. Two correction factors were developed. A factor, GFact, was developed to be used for natural gas heated homes. EFact is the electric resistance correction factor. Equations 15 and 16 illustrate use of the factors.

$$FUG = 0.071 \times Q \times DD \times GFact \qquad (15)$$

$$FUE = 0.732 \times Q \times DD \times EFact \qquad (16)$$

where

FUG = Seasonal fuel consumption, m^3.
FUE = Seasonal energy consumption, kWhr.
Q = Heat loss rate, kW.
DD = Seasonal heating degree days (18.3° C base), ° C-days.
GFact = Natural gas correction factor.
EFact = Electric resistance correction factor.
.071 = Constant, hrs/° C-days.
.732 = Constant, hrs/° C-days.

Notice that furnace efficiencies have been incorporated into the factors of GFact and EFact. Furnace efficiencies are variable and are relatively hard to determine without extensive on-site investigation. Because of this, furnace efficiencies were incorporated into the basic constants for ease in utilizing equations 15 and 16.

Optimum values of GFact and EFact were determined by equating the right hand side of equations 15 and 16 to actual energy or fuel consumption of the research houses. This was done using both ASHRAE load calculation procedures and CRHA procedures. Results are shown in Tables XVI and XVII.

It should be emphasized that GFact and EFact are merely constants which serve to improve prediction accuracy. They were developed from the base data itself. Therefore, before constants such as these are applied for use in Oklahoma houses, more data are needed to validate their accuracy.

Influence of Base Temperature on Heating Degree Days

In order to determine effect of degree day base temperature on prediction accuracy, it was necessary to vary base temperature and note corresponding changes in overall prediction accuracy. In this process, it was also necessary to determine change in magnitude of seasonal heating degree days as a function of change in base temperature from the

TABLE XVI

CONSTANT CORRECTION FACTOR USED TO IMPROVE DEGREE DAY ACCURACY FOR NATURAL GAS FURNACES

Load Calculation Methodology	GFact	Mean Error (Percent)	Standard Deviation (Percent)
ASHRAE	0.83	0.6	25.1
CRHA	1.25	0.8	28.5

TABLE XVII

CONSTANT CORRECTION FACTOR USED TO IMPROVE DEGREE DAY ACCURACY FOR ELECTRIC RESISTANCE FURNACES

Load Calculation Methodology	EFact	Mean Error (Percent)	Standard Deviation (Percent)
ASHRAE	0.61	0.2	30.5
CRHA	0.86	0.3	24.7

standard 18.3° C base. Three locations within the State of Oklahoma were used to determine this change. The locations were Goodwell, Oklahoma City, and Idabel. Long term average degree days for each location are shown in Table XVIII. The locations of Goodwell and Idabel represent extremes in Oklahoma climate. As can be seen from the tabulation of degree days, Goodwell represents colder regions of Oklahoma in the Oklahoma panhandle. Idabel represents warmer regions of southeastern Oklahoma and Oklahoma City represents average Oklahoma conditions.

Daily average temperature data were compiled for calendar years 1974 and 1978 for both Goodwell and Idabel. From daily average temperatures, seasonal heating degree days were calculated for base temperatures from 15.6° C to 18.3° C. From this data, reduction in seasonal heating degree days from seasonal heating degree days calculated with a 18.3° C base were plotted as a function of base temperature. These graphs are shown in figures 4 and 5.

Daily average temperatures were also developed for Oklahoma City for calendar year 1978 and for a 34 year period of record. Daily average temperatures for the 34 year period were obtained from an Oklahoma City weather tape compiled by the National Oceanic and Atmospheric Administration (31). Seasonal heating degree days at various base temperatures were calculated. Reduction in seasonal heating

TABLE XVIII

LONG TERM AVERAGE DEGREE DAYS

Location	Degree Days (18.3° C base)
Goodwell	2400
Oklahoma City	2052
Idabel	1519

degree days from the 18.3° C standard as a function of base temperature is expressed in Figure 6 for the Oklahoma City location.

Each of the three figures reveal reduction in heating degree day base temperature can be approximated by a linear function of base temperature. The figures also reveal only a relatively small variation due to data taken in different years. Figure 7 contains a comparison of the three locations. Assuming that Goodwell and Idabel represent extremes in Oklahoma climate, all locations in Oklahoma would be expected to fall in the range illustrated by Figure 7.

Using average degree day data for each location shown in Table XVIII, an average percent reduction in seasonal heating degree days per degree day change in base temperature can be calculated. The slope of the line for each location represents the reduction in seasonal heating degree days per degree Celsius change in base temperature. By dividing the slope by long term average seasonal heating degree days (18.3° C base), a degree day correction factor can be derived. This correction factor represents the reduction in seasonal heating degree days per degree Celsius change in base temperature as a function of seasonal heating degree days calculated at 18.3° C base. Correction factors for each location are shown in Table XIX.

As an example of the use of the degree day correction factor, suppose long term average seasonal heating degree days are desired for Oklahoma City for a 16.3° C base tem-

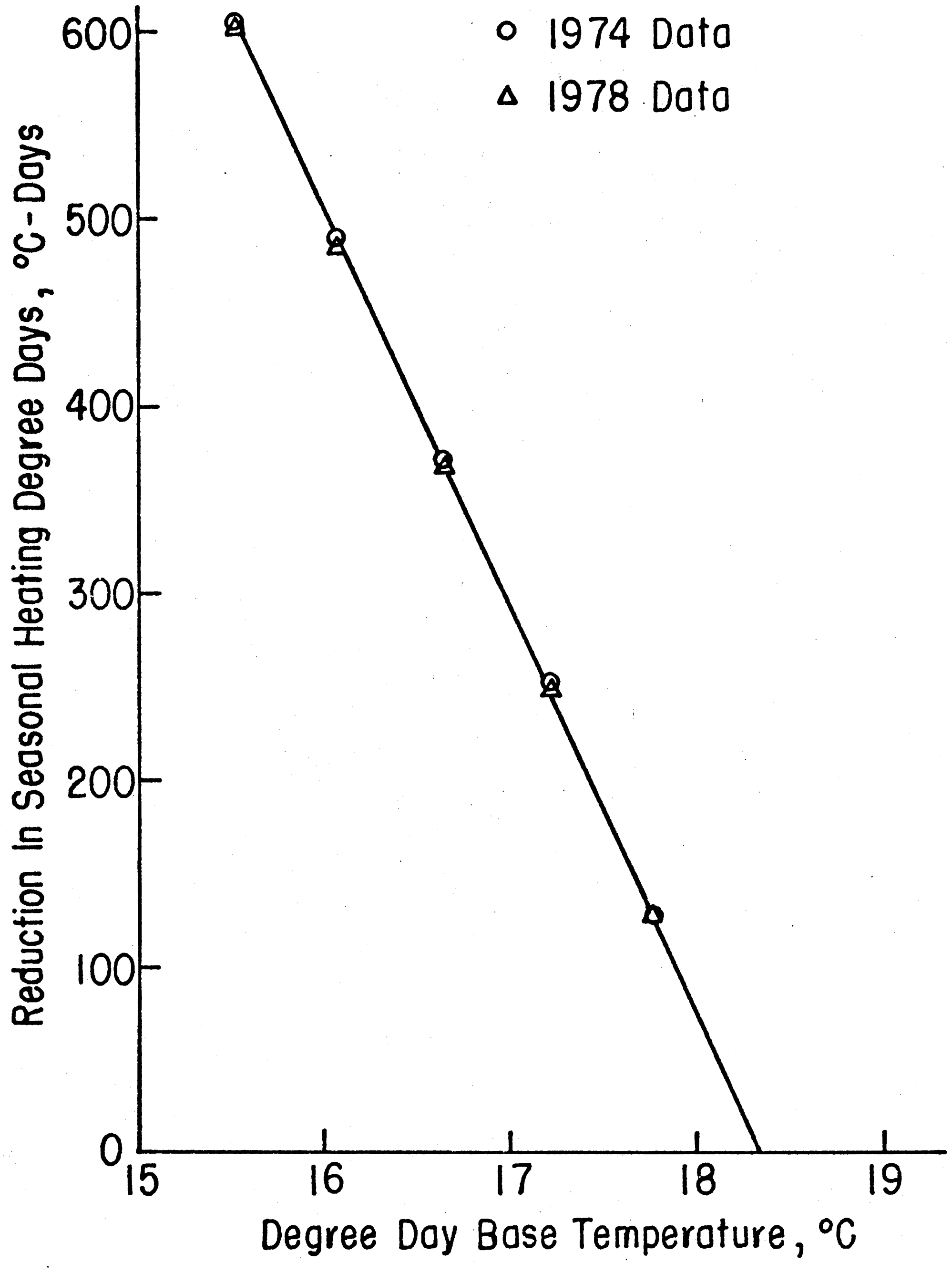

Figure 4. Reduction in Seasonal Heating Degree Days as a Function of Base Temperature--Goodwell, Oklahoma

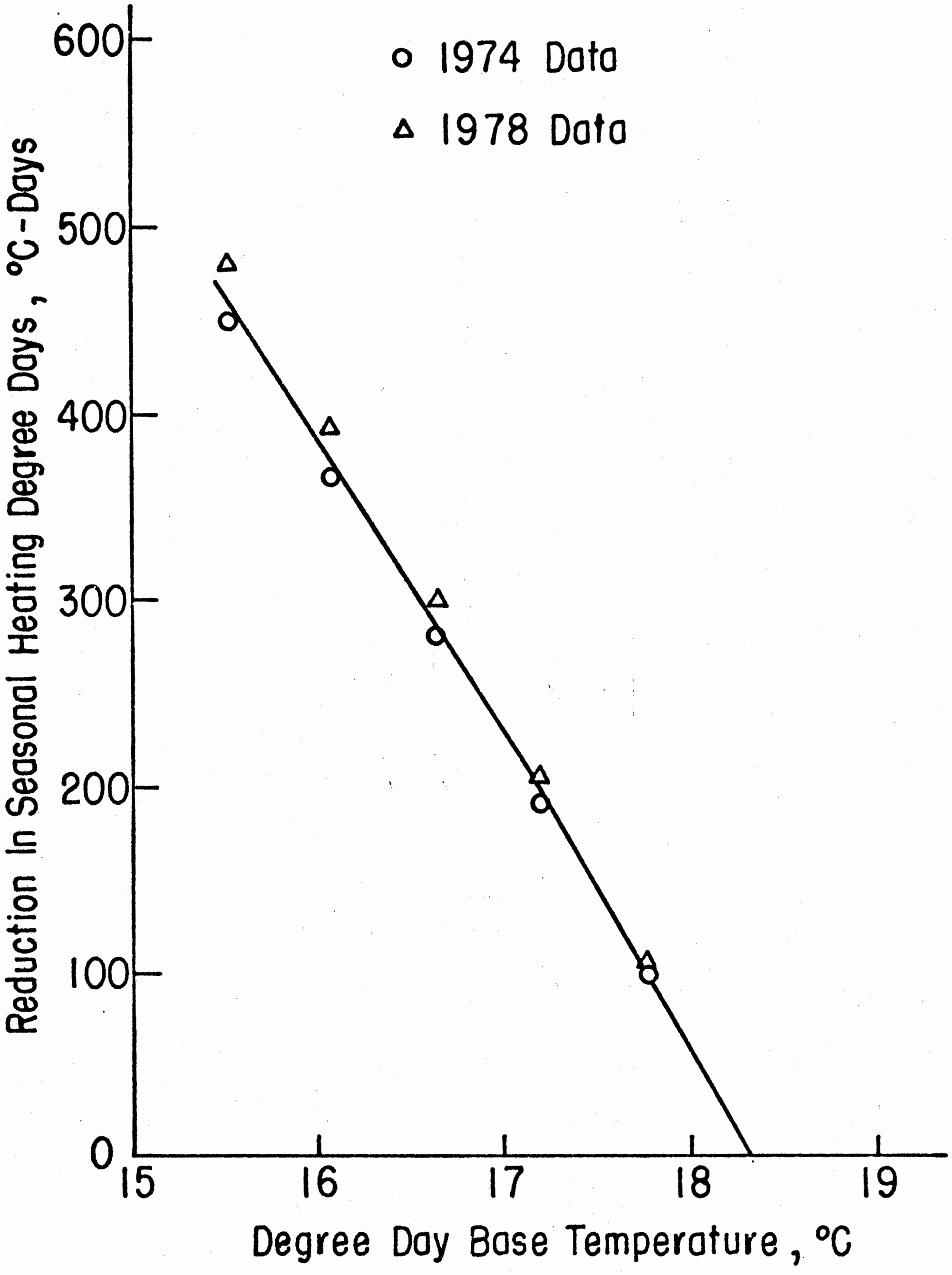

Figure 5. Reduction in Seasonal Heating Degree Days as a Function of Base Temperature--Idabel, Oklahoma

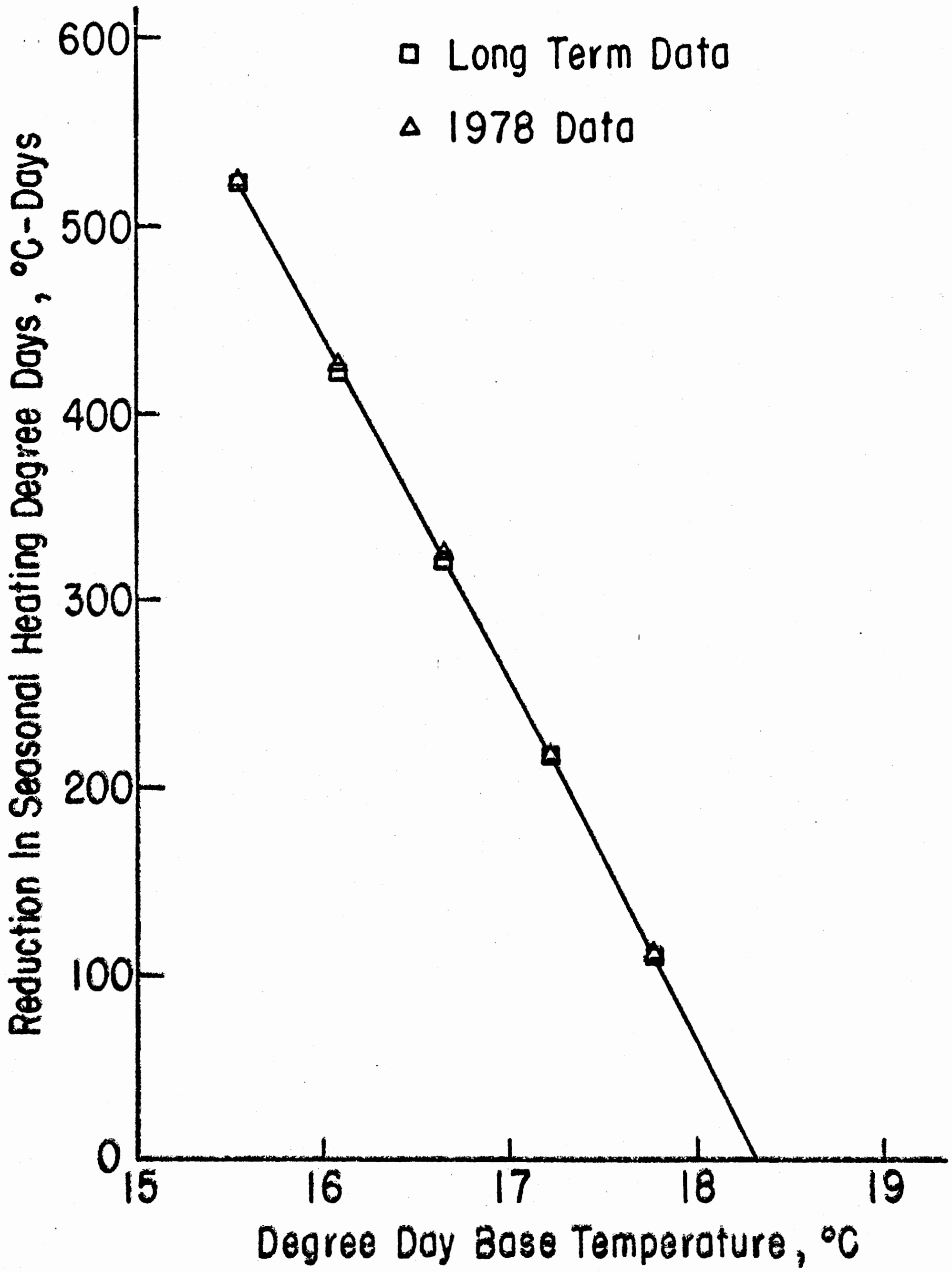

Figure 6. Reduction in Seasonal Heating Degree Days as a Function of Base Temperature--Oklahoma City, Oklahoma

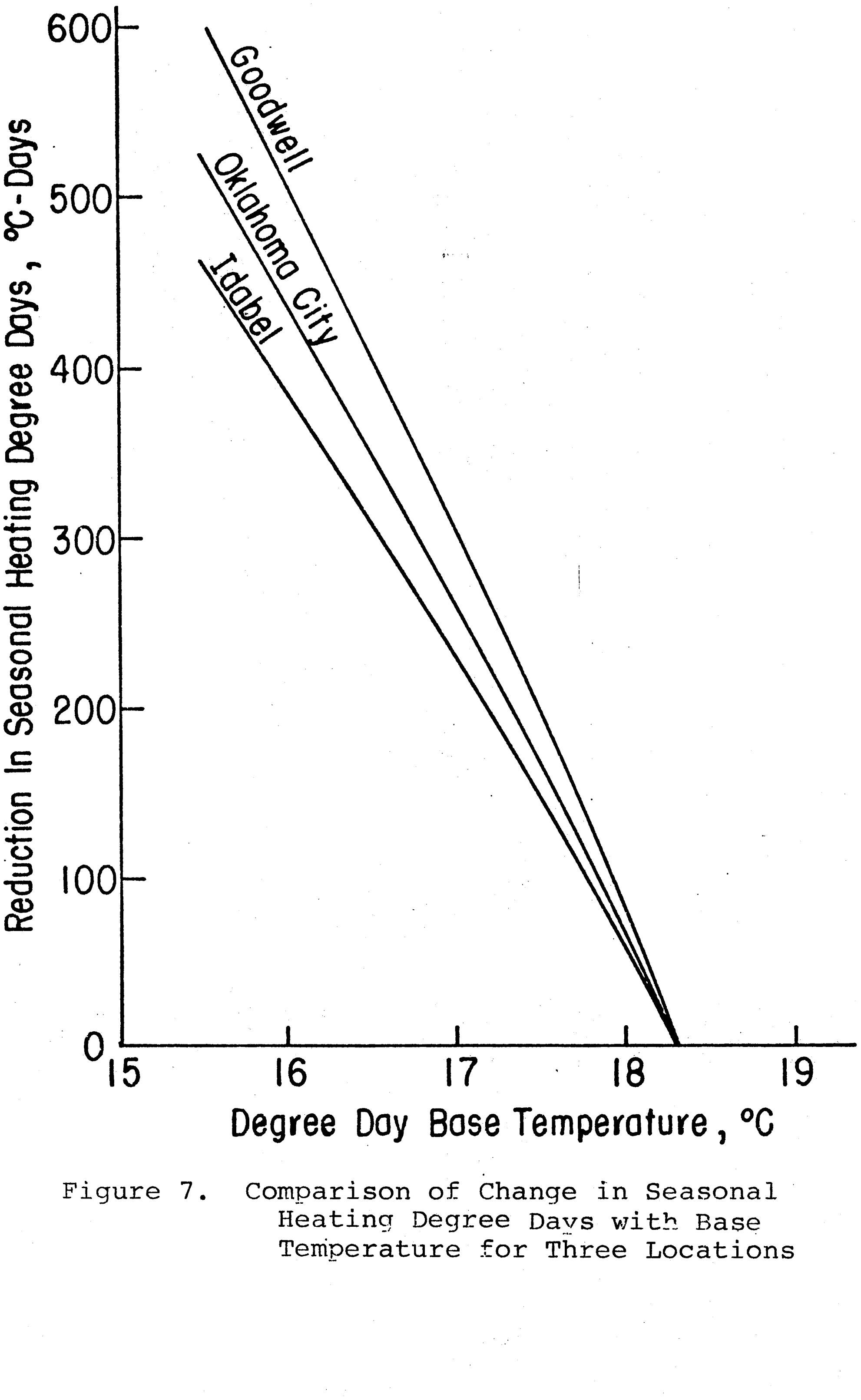

Figure 7. Comparison of Change in Seasonal Heating Degree Days with Base Temperature for Three Locations

TABLE XIX

DEGREE DAY BASE CORRECTION FACTORS

Location	Average Degree Days (° C-days)	Correction Factor
Goodwell	2400	0.090
Oklahoma City	2052	0.091
Idabel	1519	0.110

perature. From Table XIX, the correction factor per ° C change in base temperature is 0.091. For a two degree change in base temperature, total reduction will be 0.182 times the long term average degree days (18.3° C base) for Oklahoma City. For this procedure, total reduction is 373 degree days. Therefore, long term average degree days for Oklahoma City at a base temperature of 16.3° C are 1678.

Harris et al. (12) developed a degree day correction factor, K_d. This was done by calculating seasonal degree days at various base temperatures for 46 cities across the United States. For each city, the average percent change in total number of degree days per season per degree Farenheit change in base temperature was determined. These values were then plotted against the total number of degree days per season at a base temperature of 65° F. The results are shown in Figure 8. For the range of degree days (65° F base) found in Oklahoma, the Harris correction factor, ranges from approximately 0.50 to 0.63. This is equivalent to values of 0.09 to 0.113 in terms of degree Celsius, and thus, is in very good agreement with results obtained in this study. The equation developed by Harris to predict K_d is shown in equation 17.

$$K_d = 6.398/D_s^{0.577} \tag{17}$$

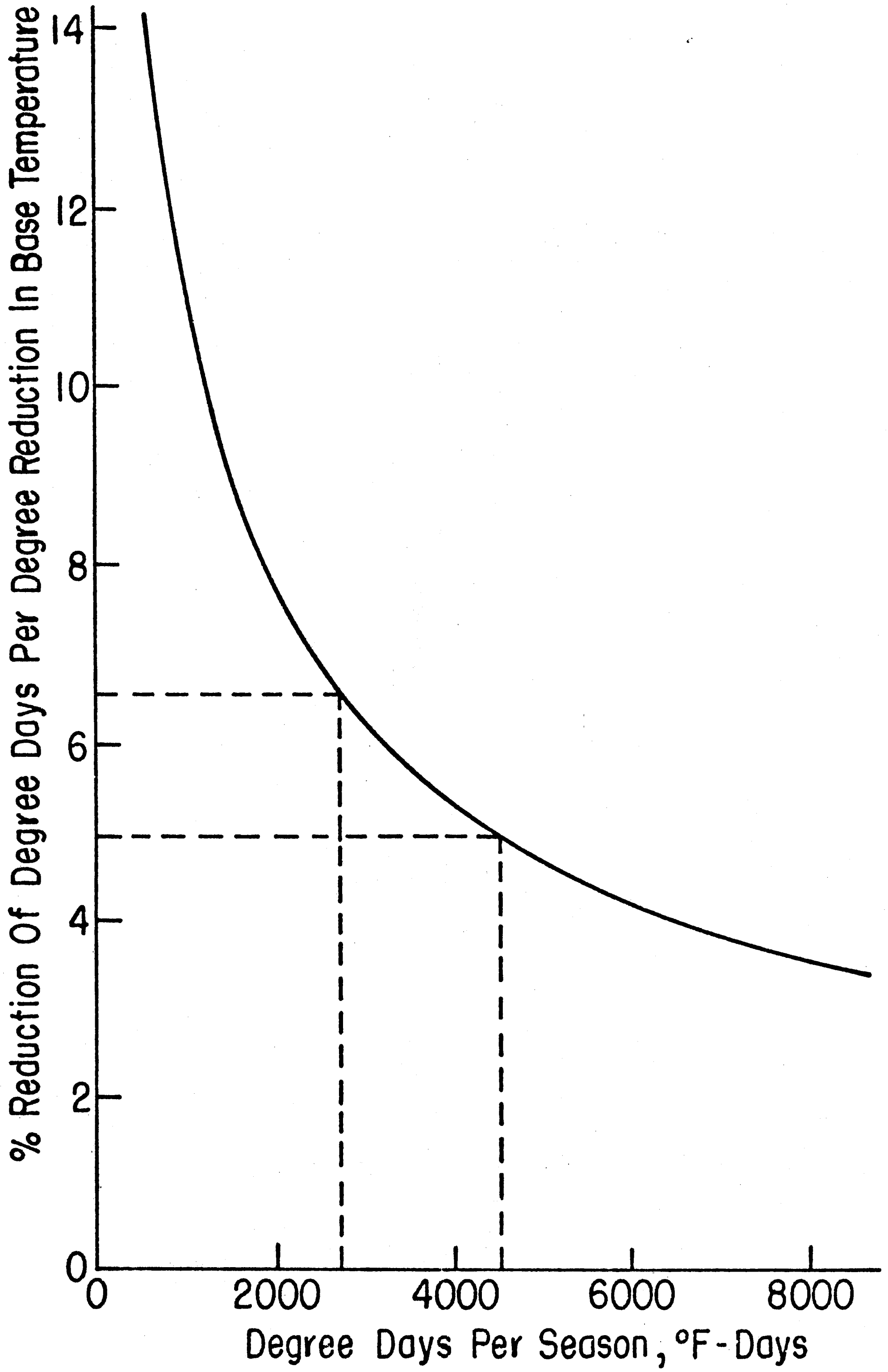

Figure 8. Relationship of K_d and Seasonal Degree Days

where

K_d = Degree day correction factor (° F base)

D_s = Seasonal heating degree days (65° F base)

Equation 17a is an identical relationship using heating degree days with 18.3° C base temperature. The value K_d given in equation 17a is a correction factor based on change in base temperature per degree Celsius.

$$K_d = 8.19/(DD)^{.577} \qquad (17a)$$

Because of the good agreement between the study by Harris (13) and the study completed in this research, equation 17a was used to correct seasonal heating degree days for various base temperatures.

Reducing Degree Day Base Temperature

An additional approach to improve degree day methods of predicting seasonal energy or fuel use in residential structures was centered around the parameter of seasonal heating degree days. From the review of literature, it was found that degree days were formulated on a base or reference temperature of 18.3° C in excess of 40 years ago. Much speculation has been given to the need for reducing base temperature. Houses constructed during the past 20 years have typically been constructed with higher thermal standards than those of the 1930's and 40's. Therefore, using the base data collected for this study, an analysis was made on the effects of reducing seasonal heating degree days by reducing base or reference temperature. To determine these effects, the standard degree day equation (equation 3) was utilized with no correction factors applied. The data set of 87 houses heated with electric resistance furnaces was divided into two base data sets. One data set contained 55 houses and the other contained 32. Initial analysis was made using the 55 house data set. Electric resistance houses were chosen for the initial phase of this study because of their relatively constant furnace efficiency. Furnace efficiencies for electric resistance furnaces are commonly taken to be in a range from 95 to 100 percent. For this phase of the study, electric resistance furnace efficiency was taken to 100 percent. Therefore, the only variable parameters in the basic equation were heat load and seasonal heating degree days. Values for heat loads were calculated with both ASHRAE procedures and CRHA procedures. Fixing heat load calculations by these procedures, seasonal heating degree days were reduced by reducing base temperature. For CRHA load calculation procedures, base temperature was varied from 15.6° C to 17.7° C. Base temperature was varied from 12.7° C to 17.7° C for ASHRAE load calculation procedures. Results of this step in the analysis are contained in Tables XX and XXI.

TABLE XX

PREDICTION ACCURACY AS A FUNCTION OF BASE TEMPERATURE FOR CRHA LOAD CALCULATION PROCEDURES

Base Temperature (° C)	Mean Error (Percent)	Standard Deviation (Percent)
17.7	8.1	29.8
17.2	2.2	28.3
16.7	-3.6	26.7
16.1	-9.4	25.1
15.5	-15.3	23.5

TABLE XXI

PREDICTION ACCURACY AS A FUNCTION OF BASE TEMPERATURE FOR ASHRAE LOAD CALCULATION PROCEDURES

Base Temperature (° C)	Mean Error (Percent)	Standard Deviation (Percent)
17.7	52.9	50.8
17.2	44.6	48.1
16.7	36.4	45.5
16.1	28.1	42.8
15.5	19.9	40.2
14.9	11.7	37.6
14.4	3.4	34.9
13.8	-4.8	32.3
13.3	-13.1	29.7
12.7	-21.3	27.1

From this analysis, a base temperature of approximately 16.9° C appears to yield best results when heating loads are calculated with CRHA procedures. A base temperature of 14.2° C seems to be more appropriate for ASHRAE load procedures.

Seasonal heating degree days calculated at base temperatures of 16.9° C and 14.2° C were used to analyze the data set with the remaining 32 houses heated with electric resistance furnaces. Prediction results using these base temperatures are contained in Table XXII. Mean errors and standard deviations reported in Table XXII are within reasonable limits for degree day applications. These values support the base temperature results obtained on the original data set of 55 houses.

The final step in this phase of the overall study was to evaluate prediction accuracy using fixed degree day base temperatures of 16.9° C for CRHA load procedures and 14.2° C for ASHRAE load procedures on research houses heated with natural gas furnaces. A rated full load furnace efficiency of 75 percent was used in the basic degree day equation. Results are shown in Table XXIII.

Again, results of using reduced values of base temperature appear to be satisfactory even on houses heated with natural gas furnaces. Even though the mean error reveals overall prediction to be low, prediction accuracy still falls within a tolerable band of plus or minus 10 percent.

TABLE XXII

PREDICTION ACCURACY USING MODIFIED BASE TEMPERATURE ON 32 ELECTRICALLY HEATED HOUSES

Load Calculation Methodology	Base Temperature (° C)	Mean Error (Percent)	Standard Deviation (Percent)
ASHRAE	14.2	2.9	26.7
CRHA	16.9	5.4	20.5

TABLE XXIII

PREDICTION ACCURACY USING MODIFIED BASE TEMPERATURE ON RESEARCH HOUSES HEATED WITH NATURAL GAS

Load Calculation Methodology	Base Temperature (° C)	Mean Error (Percent)	Standard Deviation (Percent)
ASHRAE	14.2	-3.8	24.2
CRHA	16.9	-7.0	26.3

Heat Pumps and Degree Day Methodology

Of the 207 research houses, 15 were heated with electric air source heat pumps. Prediction of seasonal energy consumption for a house heated with an electric air source heat pump on a simplified basis is normally done by first predicting energy consumption for the same house assuming it is heated with an electric resistance furnace. Knowing energy consumption of an electric resistance furnace, a seasonal efficiency can be applied for the heat pump to obtain seasonal energy consumption. As has been stated earlier, electric resistance furnaces have relatively constant efficiencies near 100 percent. Seasonal efficiency of a heat pump is expressed as a seasonal performance factor. Seasonal performance factor (SPF) is a ratio of energy output over the heating season to energy input to the heat pump. A common average value of SPF for Oklahoma is 2.0. This says that over the entire heating season a heat pump outputs two times as much energy as it consumes. This is because the heat pump moves energy rather than converts energy. Electric resistance furnaces and natural gas furnaces convert an energy or fuel source to usable heat. The heat pump extracts heat from one source and moves it to another location. Air source heat pumps extract heat from outdoor air and move this heat to the interior of the home as usable heat. Therefore, if the energy consumption of a house heated with an electric resistance furnace is known, energy consumption of the same house using a heat pump can be calculated by dividing electric resistance energy consumption by the seasonal performance factor. In this study, an SPF of 2.0 was used. Prediction results obtained from the various degree day methodologies are contained in Table XXIV.

With all methodologies, prediction accuracy of seasonal energy consumption of air source heat pumps is low. In some cases mean error is acceptable, but standard deviation is high. Similar results are obtained when using degree day methodology based on constant reduced base temperature. These results are shown in Table XXV.

There are at least two primary reasons for the poor prediction accuracy of energy consumption in houses heated with heat pumps. One has to do with the particular year in which base research data for this study was taken. The winter seasons of both 1978 and 1979 were extremely cold. In extremely cold conditions, heat pump capacity is reduced while structural demand for heat increases. During these times, supplemental heat in the form of electric resistance strip heaters is employed. As already stated, SPF of resistance heat is 1.0. Therefore, in cold conditions and severe winter seasons, SPF may drop well below 2.0. This can result in a major source of error.

The second reason for error in prediction of heat pump energy consumption is the base assumption of average values of SPF. Seasonal efficiencies vary from one application to

TABLE XXIV

PREDICTION ACCURACY OF DEGREE DAY METHODOLOGIES FOR AIR SOURCE HEAT PUMPS

Degree Day Methodology	Heat Load Methodology	Mean Error (Percent)	Standard Deviation (Percent)
Standard	ASHRAE	10.0	42.0
	CRHA	-21.8	52.8
ASHRAE Modified	ASHRAE	-9.8	43.3
	CRHA	-35.9	34.4
AGA Modified	ASHRAE	-13.2	41.7
	CRHA	-38.3	33.2
NEMA Modified	ASHRAE	-15.2	40.7
	CRHA	-39.7	32.4

TABLE XXV

PREDICTION ACCURACY USING CONSTANT DEGREE DAY BASE TEMPERATURE FOR AIR SOURCE HEAT PUMPS

Load Calculation Procedure	Base Temperature (° C)	Mean Error (Percent)	Standard Deviation (Percent)
ASHRAE	14.2	-33.4	31.4
CRHA	16.9	-32.1	36.3

another. Assuming constant efficiencies for all houses can lead to significant error. Additional research is needed in the area of seasonal efficiencies for heat pumps.

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

Energy consumption, thermal, and structural characteristic data were collected for 207 houses in the State of Oklahoma. The data were used to evaluate simplified degree day techniques for predicting seasonal heating energy or fuel consumption in residential structures. Various degree day methodologies investigated in the study were the standard degree day method, National Electrical Manufacturers Association modified method, American Society of Heating, Refrigeration, and Air-Conditioning Engineers modified method, and the American Gas Association modified degree day procedure. All methods were found to have considerable error of prediction. An investigation into the reason for errors in prediction yielded two major sources. One source of error was found in calculation of heating loads. For the study, heating loads were calculated by two methods. Commonly used and accepted ASHRAE procedures served as one method while an additional procedure was developed which concentrated on average heat loss rates rather than design loads. From the analysis of both procedures, ASHRAE procedures appear to over predict design heat loss values. Major errors of over prediction within ASHRAE procedures appear to be in floor and infiltration heat loss calculations. The study was not intended to promote the revised load calculation technique over ASHRAE procedures. However, results appear to be more satisfactory with the revised load calculation procedures.

The second major source of error in simplified degree day methodologies was found to be in degree day base temperature. An investigation was made into the effect of varying base temperature on prediction accuracy of standard degree day methods. Lowering base temperature achieved good results in improving overall prediction accuracy. Using CRHA load calculation procedures, an optimum base temperature of 16.9° C was derived. Using ASHRAE procedures, a base temperature of 14.2° C was found to yield best results. This finding supports earlier conclusions that ASHRAE load calculation procedures overestimate design loads and therefore result in over prediction of seasonal energy or fuel consumption. A base temperature of 14.2° C appears to be an extremely low base. To illustrate this, Oklahoma City, Oklahoma has an average seasonal heating degree days (° C -days) value of 2052 when calculated using 18.3° C as a base temperature. At a 16.9° C base temperature, average seasonal heating degrees are 1765. At a base temperature of 14.2° C, the value is 1025. The latter value appears to be extremely low.

Even though 16.9° C appears to be a reasonable base temperature, it should not be taken as a strict value for common use. As derived in this study, errors in calculations of heat load are incorporated into the derivation of base temperature. Therefore, if significant errors were made in the load calculations, base temperatures reported by this study will also be in error.

While the study did not yield a conclusive determination of degree day base temperature, it was valuable in noting errors in currently used degree day procedures. It was also valuable in determining sources of error, need for improvement, and need for future research. In addition, by using analysis results from the study, improved predictions of seasonal heating energy or fuel consumption can be made on Oklahoma homes.

Conclusions

1. Calculation of heat loss rate with ASHRAE procedures yielded excessively high values. Errors in calculation procedure were found to be primarily in floors and infiltration.

2. Currently used modified degree day methodologies do not satisfactorily predict residential seasonal heating energy or fuel consumption in Oklahoma.

3. Use of revised load calculation procedures developed in this study and a degree day base temperature of 16.9° C yields improved results in prediction of seasonal heating energy or fuel consumption in Oklahoma houses.

Suggestions for Future Work

From this study, it can be clearly seen that work is needed in the calculation of structural heating loads. Current load calculation procedures need to be re-evaluated for accuracy. One method of evaluating actual structural heating loads is by collecting hourly energy consumption and temperature data for residential structures heated with electric resistance furnaces. Because resistance furnaces have efficiencies of 100 percent, hourly energy consumption can be correlated with inside-outside temperature differences. By obtaining energy consumption or energy demand as a function of temperature difference, heating demand or load can be estimated at design conditions. This type of data will aid in determining accuracy of present simplified load calculation techniques.

Further investigations need to be made in the areas of design heat loss in concrete slab-on-grade floors and infiltration. Even though significant research has been conducted in these areas, research specifically oriented to determination of design loads in each of these components is needed. Further investigation is also needed in the area of degree day base temperature. Studies relating base temperature or balance temperature to internal heat gains of a structure are needed. Further work is needed in studies such as the one reported in this thesis to develop more insight into appropriate degree day base temperatures.

Research in seasonal efficiencies of air source heat pumps is also needed. Seasonal efficiencies of residential heat pumps vary with heat pump design, structural thermal characteristics, sizing, and geographical location. Studies need to be conducted to determine more reliable techniques of estimating seasonal performance.

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APPENDIXES

APPENDIX A

COLLECTED AND COMPUTED DATA FOR RESEARCH HOUSES

COLLECTED AND COMPUTED DATA FOR RESEARCH HOUSES

Research data for the 207 houses used in this study are contained in Table XXVI. Definition of the variable list is as follows:

1. DD - Seasonal heating degree days, ° C-days.
2. QCHRA - Design heat load calculated by CRHA methodology, W.
3. QASHRAE - Design heat load calculated by ASHRAE methodology, W.
4. FUA - Actual seasonal energy consumption. If FUH = 1, FUA = m^3. If FUH = 3 or 4, FUA = kWhr.
5. TLA - Total living area, m^2.
6. RC - Ceiling thermal resistance, ° C-m^2/W.
7. FAF - Frame floor area, m^2.
8. FAS - Slab floor area, m^2.
9. RF - Frame floor thermal resistance, ° C-m^2/W.
10. DA - Exterior door area without storm doors, m^2.
11. DAS - Exterior door area with storm doors, m^2.
12. GAS - Single glass area facing South, m^2.
13. GAN - Single glass area facing North, m^2.
14. GAE - Single glass area facing East, m^2.

15. GAW - Single glass area facing West. m^2.
16. GASD - Double glass area facing South, m^2.
17. GAND - Double glass area facing North, m^2.
18. GAED - Double glass area facing East, m^2.
19. GAWD - Double glass area facing West, m^2.
20. PL - Perimeter length, m.
21. WA - Net exterior wall area, m^2.
22. RW - Exterior wall thermal resistance, ° C-m^2/W.
23. RCOL - Roof color; 1 = Dark, 2 = Light.
24. FTYP - Floor type; 1 = Suspended frame, 2 = Concrete slab, 3 = Combination.
25. SLABI - Concrete slab insulation; 1 = Yes, 2 = No.
26. DUCTL - Supply duct location; 1 = No duct system, 2 = Concrete slab, 3 = Attic space, 4 = Suspended frame floor, 5 = Conditioned space.
27. DUCTI - Duct insulation; 1 = No insulation, 2 = 2.54 cm duct insulation, 3 = 5.08 cm duct insulation.
28. WC - Wall construction type; 1 = Brick veneer, 2 = Frame, 3 = Masonry.
29. IC - Infiltration condition; 1 = Tight, 2 = Medium, 3 = Loose.
30. OCC - Number of occupants.
31. FUH - Type of heating system; 1 = Natural gas, 2 = L.P. gas, 3 = Electric resistance, 4 = Electric heat pump.

TABLE XXVI

RESEARCH DATA

VARIABLE \ OBS	1	2	3	4	5	6	7	8	9	10
DD	2391	2523	2342	2359	2500	2607	2500	2607	2607	2423
QCHRA	7619	8195	12537	11211	8993	13230	7553	9808	11499	11374
QASHRAE	9316	10135	16827	14120	11889	17354	9190	11179	14756	23872
FUA	17433.0	15561.0	23590.0	13708.0	19382.0	19289.0	13314.0	14376.0	14902.0	18376.0
TLA	161.6	159.8	220.5	158.3	167.2	236.3	130.1	139.4	204.4	204.4
RC	2.7	2.7	4.0	2.6	4.7	2.7	5.0	2.7	6.1	3.6
FAF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	204.4
FAS	161.6	159.3	220.5	158.3	167.2	236.3	130.1	139.4	204.4	0.0
RF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DA	0.0	1.9	6.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DAS	1.9	0.0	0.0	3.9	5.2	5.2	5.2	3.7	5.3	3.7
GAS	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
GAN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GAE	0.0	0.0	0.0	6.1	0.0	0.0	0.0	0.0	0.0	0.0
GAW	0.0	0.0	0.0	7.3	0.0	0.0	0.0	0.0	0.0	0.0
GASD	5.0	4.4	9.0	0.0	4.7	4.8	3.3	5.4	2.9	3.2
GAND	5.6	0.9	10.2	0.0	0.0	6.0	0.0	8.6	0.9	4.2
GAED	1.5	4.9	0.0	0.0	4.2	5.4	11.5	0.0	11.2	8.9
GAWD	3.2	8.9	0.0	0.0	5.2	2.4	7.4	1.0	11.0	9.5
PL	46.0	45.7	76.8	57.9	73.8	75.6	47.5	50.0	70.7	65.2
WA	97.9	98.8	162.4	112.6	161.6	161.8	90.1	104.2	143.0	131.4
RW	2.2	2.2	1.2	2.2	1.9	1.6	2.6	1.6	2.6	1.2
RCOL	1	2	1	1	1	1	1	2	1	2
FTYP	2	2	2	2	2	2	2	2	2	1
SLABI	1	1	1	2	1	2	1	2	2	1
DUCTL	2	2	2	2	3	2	3	2	2	1
DUCTI	1	1	1	3	3	1	3	1	3	1
WC	1	1	1	1	1	1	1	1	1	1
IC	1	1	2	1	1	1	1	1	1	1
OCC	4	3	2	4	2	6	1	4	4	2
FUH	3	3	3	3	3	3	3	3	3	3

TABLE XXVI (Continued)

VARIABLE \ OBS	11	12	13	14	15	16	17	18	19	20
DD	2523	2607	2423	2607	2607	2523	2188	2346	2391	2523
QCHRA	10929	8891	9264	9801	9885	11331	9494	6800	8408	8835
QASHRAE	31127	10762	12984	12828	12279	17038	12729	9376	10293	21790
FUA	18055.0	13146.0	23908.0	17660.0	20343.0	13971.0	13857.0	8880.0	17642.0	14148.0
TLA	225.7	130.1	176.5	125.4	148.6	213.7	212.6	102.6	104.5	148.6
RC	6.1	2.7	2.7	4.7	2.7	4.1	3.0	3.0	3.3	2.2
FAF	225.7	130.1	0.0	0.0	0.0	213.7	0.0	0.0	0.0	148.6
FAS	0.0	0.0	176.5	125.4	148.6	0.0	212.6	102.6	104.5	0.0
RF	0.0	2.7	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0
DA	0.0	0.0	0.0	4.2	0.0	0.0	0.0	1.7	0.0	0.0
DAS	5.2	1.9	7.2	0.0	3.5	7.4	5.1	1.9	3.4	6.9
GAS	0.0	0.0	0.0	3.1	0.0	0.0	0.0	0.0	0.0	0.0
GAN	0.0	0.0	0.0	6.8	0.0	0.0	0.0	0.0	0.0	0.0
GAE	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0
GAW	0.0	0.0	0.0	3.1	0.0	0.0	0.0	0.0	0.0	0.0
GASD	8.2	6.0	7.6	0.0	6.9	0.0	1.8	1.3	7.9	2.0
GAND	6.2	5.5	2.6	0.0	9.5	1.2	0.0	0.0	8.3	0.0
GAED	9.3	3.2	1.1	0.0	2.1	22.2	4.9	5.7	0.0	6.7
GAWD	5.0	1.6	1.5	0.0	0.8	3.0	7.8	1.8	0.0	7.4
PL	52.4	89.0	61.0	46.3	54.6	72.5	68.0	43.3	51.8	56.1
WA	96.0	200.0	129.5	89.0	111.6	144.9	147.3	91.8	107.9	114.9
RW	1.6	2.6	2.6	1.6	1.6	1.6	3.1	2.3	1.6	4.1
RCOL	2	2	1	1	1	2	2	2	1	1
FTYP	1	1	2	2	2	1	2	2	2	1
SLABI	1	1	2	2	2	1	1	2	2	1
DUCTL	4	4	3	3	2	3	2	2	2	4
DUCTI	3	3	3	3	3	3	3	1	1	3
WC	1	1	2	1	2	1	3	1	1	1
IC	1	1	1	2	1	1	1	2	1	1
OCC	2	2	3	4	4	2	2	2	3	2
FUH	3	3	3	3	3	3	3	3	3	3

TABLE XXVI (Continued)

VARIABLE \ OBS	21	22	23	24	25	26	27	28	29	30
DD	2523	2423	2423	2423	2391	2198	2391	2227	2526	2526
QCHRA	10597	9540	7316	13161	11203	7811	12742	8350	10978	11448
QASHRAE	28714	12566	10682	16779	16060	10483	16087	11558	14012	13192
FUA	20293.0	19530.0	16673.0	26831.0	14031.0	10821.0	18735.0	19545.0	19592.0	15661.0
TLA	204.4	174.2	93.6	185.9	97.5	130.1	199.7	189.5	173.9	169.6
RC	2.7	2.7	3.7	6.2	4.7	4.4	2.6	7.0	3.2	2.5
FAF	204.4	0.0	93.6	0.0	97.5	0.0	0.0	0.0	0.0	0.0
FAS	0.0	174.2	0.0	185.8	0.0	130.1	199.7	189.5	173.9	169.6
RF	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DA	0.0	0.0	1.9	0.0	5.2	0.0	3.6	3.9	0.0	0.0
DAS	3.5	5.3	1.9	5.7	0.0	3.9	0.0	1.7	5.0	3.4
GAS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0
GAN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GAE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GAW	0.0	0.0	0.0	0.0	0.0	0.0	3.7	0.0	0.0	0.0
GASD	0.0	5.5	3.6	8.5	7.3	7.5	1.8	3.6	11.6	3.6
GAND	2.5	6.4	4.2	6.6	7.7	4.8	0.0	4.1	0.0	19.1
GAED	8.0	0.0	3.5	6.2	2.6	2.4	10.7	3.6	0.0	4.2
GAWD	8.5	2.0	3.9	1.4	0.0	0.0	6.7	6.6	4.8	0.0
PL	70.1	66.4	50.3	73.2	40.4	54.9	70.1	72.5	63.1	59.7
WA	149.8	143.3	93.2	151.4	76.9	116.2	145.8	154.7	132.8	131.2
RW	4.1	1.6	2.7	1.3	0.0	2.2	2.2	4.6	1.2	1.9
RCOL	1	2	1	2	2	2	2	1	2	2
FTYP	1	2	1	2	1	2	2	2	2	2
SLABI	1	1	1	2	1	1	2	1	2	1
DUCTL	4	3	3	3	3	3	2	3	2	2
DUCTI	3	3	3	2	2	3	1	3	1	1
WC	1	1	2	2	1	1	1	1	1	1
IC	1	1	2	2	2	2	1	1	1	1
OCC	5	4	3	3	2	3	4	2	4	4
FUH	3	3	3	3	3	3	3	3	3	3

TABLE XXVI (Continued)

VARIABLE \ OBS	31	32	33	34	35	36	37	38	39	40
DD	2526	2526	2398	2526	2500	2391	2366	2366	1976	1976
QCHPA	3786	12174	9262	9537	7518	9096	9192	6934	8488	7366
QASHPAE	10674	15683	11559	12356	10674	20531	10786	9017	18265	8657
FUA	19031.0	17560.0	10700.0	16020.0	9321.0	23089.0	16306.0	8961.0	17426.0	8966.0
TLA	119.3	199.0	154.9	182.6	151.4	162.0	118.4	120.4	128.4	104.6
RC	3.2	3.2	3.2	3.2	1.7	2.2	3.0	3.7	4.7	2.6
FAF	0.0	139.0	0.0	0.0	151.4	162.0	0.0	0.0	128.4	0.0
FAS	119.3	60.0	154.9	182.6	0.0	0.0	118.4	120.4	0.0	104.6
RF	0.0	1.8	0.0	0.0	1.7	0.0	0.0	0.0	0.0	0.0
DA	0.0	0.0	0.0	0.0	0.0	3.8	0.0	0.0	0.0	1.9
DAS	3.4	5.3	3.4	3.4	0.2	0.0	3.7	1.9	1.9	1.9
GAS	0.7	0.0	0.0	0.0	0.3	0.0	0.0	0.0	4.5	0.0
GAN	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	3.7
GAE	9.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.3	0.0
GAW	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0
GASD	0.0	6.8	10.1	2.3	2.4	4.0	0.0	0.0	0.0	0.9
GAND	0.0	2.1	5.9	1.0	0.3	3.8	0.0	0.0	0.0	3.1
GAED	0.0	10.0	3.4	0.0	4.9	2.3	6.7	6.1	0.0	3.8
GAWD	0.0	10.0	0.0	12.7	5.2	2.2	11.0	5.9	0.3	2.2
PL	52.1	69.2	62.8	68.6	49.4	57.3	49.4	45.3	18.9	43.3
WA	93.2	141.5	130.8	148.9	104.8	124.2	155.9	97.4	104.8	92.5
RW	1.9	1.9	1.9	1.9	1.6	2.6	3.0	3.0	2.1	2.2
RCOL	2	2	2	2	2	2	1	2	2	2
FTYP	2	3	2	2	1	1	2	2	1	2
SLABI	1	2	1	1	1	1	2	2	1	1
DUCTL	2	4	3	2	1	3	2	2	3	3
DUCTI	1	2	3	1	1	3	1	1	3	2
WC	1	1	1	1	2	2	3	3	2	1
IC	1	1	1	1	1	1	1	1	2	1
OCC	6	6	4	4	2	5	2	2	2	4
FUH	3	3	3	3	3	3	3	3	3	3

TABLE XXVI (Continued)

VARIABLE \ OBS	41	42	43	44	45	46	47	48	49	50
DD	2523	2423	2556	2523	2500	1972	2182	2227	2526	2216
QCHRA	9600	8779	11039	12113	23255	11660	15978	5409	11351	10209
QASHRAE	11716	10638	13348	25028	29840	17650	17655	6982	14192	17590
FUA	15544.0	14886.0	11389.0	18024.0	40880.0	9011.0	22641.0	9225.0	10250.0	13894.0
TLA	167.2	125.4	137.1	204.4	371.6	213.7	210.4	91.0	232.7	192.8
RC	2.7	2.2	2.7	7.7	6.1	3.0	3.0	2.6	5.4	2.7
FAF	0.0	0.0	0.0	204.4	0.0	213.7	0.0	0.0	0.0	0.0
FAS	167.2	125.4	137.1	0.0	371.6	0.0	210.4	91.0	232.7	192.8
RF	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0
DA	0.0	0.0	0.0	0.0	0.0	0.0	3.7	1.7	0.0	3.5
DAS	5.2	5.7	3.7	5.0	24.2	5.4	0.0	2.0	7.2	3.5
GAS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	0.0	0.0
GAN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	0.0	0.0
GAE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GAW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GASD	0.0	6.9	1.8	8.4	8.3	8.0	30.0	0.0	9.9	3.6
GAND	1.2	10.3	0.0	10.0	15.9	2.0	10.0	0.0	16.2	10.8
GAED	9.9	1.1	5.4	9.4	14.2	8.0	2.0	0.0	0.0	1.8
GAWD	10.5	0.0	6.6	5.6	8.2	7.0	8.0	0.0	5.5	3.6
PL	56.1	54.9	50.6	54.3	118.9	58.5	57.9	40.8	72.8	75.6
WA	111.5	111.1	106.8	96.2	291.2	114.0	91.2	91.2	141.1	158.9
RW	1.6	1.6	1.6	2.0	3.5	1.9	1.9	2.6	3.1	2.2
RCOL	1	2	2	2	2	2	1	2	1	1
FTYP	2	2	2	1	2	1	2	2	2	2
SLABI	1	1	2	1	2	1	1	2	1	1
DUCTL	2	3	2	4	2	4	3	1	2	3
DUCTI	1	3	3	3	1	3	3	1	1	3
WC	1	2	1	3	3	2	2	3	2	1
IC	1	1	3	1	2	2	2	1	1	2
OCC	2	3	3	4	5	2	3	3	5	4
FUH	4	4	4	4	4	4	4	4	4	4

TABLE XXVI (Continued)

VARIABLE \ OBS	51	52	53	54	55	56	57	58	59	60
DD	2216	2216	2216	2216	2216	2214	2214	1921	2214	1780
QCHRA	12002	9123	10211	8966	9651	17712	9471	10042	8827	9436
QASHRAE	15137	12872	20052	14955	13083	28190	15076	12618	16434	17204
FUA	4469.0	9866.0	12946.0	13002.0	9731.0	3086.6	1670.7	1812.3	1953.9	1642.4
TLA	155.4	177.0	163.0	200.6	131.5	176.5	114.5	114.9	125.4	119.6
RC	4.7	6.4	4.7	3.9	1.3	3.9	6.2	2.2	3.7	5.4
FAF	0.0	0.0	112.9	200.6	0.0	176.5	114.5	0.0	125.4	119.6
FAS	155.4	177.0	50.2	0.0	131.5	0.0	0.0	114.9	0.0	0.0
RF	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0
DA	1.6	0.0	3.4	0.0	0.0	5.9	0.0	0.0	0.0	0.0
DAS	2.0	3.9	2.0	3.9	5.1	0.0	5.0	1.9	5.0	5.9
GAS	0.0	0.0	0.0	0.0	0.0	3.7	0.0	3.3	0.0	5.6
GAN	7.9	0.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0	3.6
GAE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.0	5.3
GAW	4.6	0.0	0.0	0.0	0.0	2.1	0.0	0.8	0.0	0.0
GASD	0.0	0.9	9.8	2.7	2.3	0.0	6.0	0.0	4.4	0.0
GAND	2.7	1.8	3.0	4.5	4.2	9.6	1.8	0.0	1.8	0.0
GAED	1.8	5.3	0.0	4.5	2.1	8.8	3.0	0.0	3.2	0.0
GAWD	2.7	7.8	2.9	6.1	0.0	0.0	3.6	0.0	4.4	0.0
PL	61.0	52.9	43.9	63.1	54.7	48.8	55.8	46.0	54.3	52.1
WA	125.9	110.4	127.1	133.7	120.4	119.8	136.0	100.3	132.3	104.0
RW	2.2	2.2	1.6	2.2	2.0	0.0	2.2	1.3	2.2	2.1
RCOL	1	2	1	2	1	2	2	2	2	2
FTYP	2	2	3	1	2	1	1	2	1	1
SLABI	2	2	2	1	2	1	1	2	1	1
DUCTL	2	2	3	4	2	4	3	3	3	4
DUCTI	1	1	2	3	3	3	3	2	3	3
WC	1	1	1	1	3	2	2	1	2	1
IC	2	2	2	1	2	2	1	2	1	1
OCC	2	4	2	4	2	4	3	4	5	4
FUH	4	1	4	4	4	1	1	1	1	1

TABLE XXVI (Continued)

VARIABLE \ OBS	61	62	63	64	65	66	67	68	69	70
DD	1780	1780	2118	2118	2146	1921	1921	2062	2062	1823
QCHRA	10495	8571	15047	15345	12911	9032	12185	10414	19244	6757
QASHRAE	11617	12283	22704	21292	21863	11027	14669	13769	25945	8397
FUA	1387.5	3511.3	2067.1	2746.7	3114.9	1500.8	1387.5	3143.2	1784.0	1217.6
TLA	131.9	195.1	111.5	92.9	144.9	110.0	154.6	185.8	139.4	78.0
RC	3.9	4.4	0.0	0.0	2.6	2.2	2.2	4.4	2.2	2.2
FAF	0.0	0.0	111.5	92.9	144.9	0.0	0.0	0.0	139.4	78.0
FAS	131.9	195.1	0.0	0.0	0.0	110.0	154.6	185.8	0.0	0.0
RF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1
DA	0.0	0.0	3.9	3.9	0.0	0.0	0.0	3.6	3.6	3.3
DAS	4.0	3.9	0.0	0.0	2.0	5.9	2.0	1.9	0.0	0.0
GAS	8.9	0.0	1.7	1.7	5.2	4.9	4.3	0.0	6.3	2.2
GAN	6.1	0.0	1.7	0.8	1.9	2.1	8.5	0.0	8.9	2.2
GAE	3.9	0.0	1.7	1.7	6.2	1.7	2.1	0.0	4.5	0.6
GAW	2.2	0.0	0.8	0.8	4.5	0.8	1.4	0.0	7.1	1.7
GASD	0.0	1.8	0.0	0.0	0.0	0.0	0.0	8.1	0.0	0.0
GAND	0.0	4.2	0.0	0.0	0.0	0.0	0.0	7.3	0.0	0.0
GAED	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4	0.0	0.0
GAWD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PL	16.7	53.6	42.7	39.6	59.4	43.9	51.2	67.1	43.9	45.1
WA	109.3	125.2	94.3	87.7	125.3	91.6	106.6	132.2	80.8	100.0
RW	2.2	1.3	0.0	0.0	1.3	1.3	1.3	2.2	0.0	2.1
RCOL	2	1	2	2	2	2	1	2	2	2
FTYP	2	2	1	1	1	2	2	2	1	1
SLABI	1	2	1	1	1	2	2	2	1	1
DUCTL	3	3	1	4	3	3	3	2	4	4
DUCTI	3	2	3	2	2	2	2	3	2	2
WC	1	2	2	2	1	1	1	1	2	2
IC	1	1	2	2	1	1	1	1	2	2
OCC	3	3	1	5	5	3	4	2	4	3
FUH	1	1	1	1	1	1	1	1	1	1

TABLE XXVI (Continued)

VARIABLE \ OBS	71	72	73	74	75	76	77	78	79	80
DD	1823	2062	2116	2116	2116	2034	2034	2218	2391	2198
QCHRA	7605	11895	12974	11445	11967	9792	9659	12605	10908	8278
QASHRAE	15903	19290	24447	13077	19184	13152	13018	27991	14385	13619
FUA	1982.2	2576.8	2123.8	2067.1	2718.4	1755.7	1387.5	2095.5	2208.7	2010.5
TLA	120.4	134.7	134.7	139.4	125.4	154.6	154.6	209.0	185.8	84.5
RC	2.2	2.6	0.0	2.2	1.5	2.6	2.6	6.8	2.6	1.5
FAF	120.4	134.7	134.7	0.0	125.4	0.0	0.0	209.0	0.0	84.5
FAS	0.0	0.0	0.0	139.4	0.0	154.6	154.6	0.0	185.8	0.0
RF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DA	2.0	0.0	0.0	0.0	0.0	3.9	0.0	0.0	3.3	3.8
DAS	2.0	3.9	3.9	5.9	5.9	0.0	3.9	4.9	2.0	0.0
GAS	0.0	0.0	0.0	1.1	0.0	2.8	5.6	2.8	0.0	2.1
GAN	0.0	0.0	0.0	0.0	0.0	5.6	2.8	0.0	0.0	3.8
GAE	0.0	0.0	0.0	2.0	0.0	1.7	0.8	6.3	0.0	2.1
GAW	0.0	0.0	0.0	3.9	0.0	0.8	1.7	2.4	0.6	0.0
GASD	3.0	5.2	1.9	0.0	5.5	0.0	0.0	0.0	0.8	0.0
GAND	3.9	3.2	1.7	0.0	5.8	0.0	0.0	3.6	0.6	0.0
GAED	3.0	6.5	0.8	0.0	5.0	0.0	0.0	0.0	7.4	0.0
GAWD	1.5	6.5	3.3	0.0	7.6	0.0	0.0	0.0	5.5	0.0
PL	21.9	36.6	15.2	51.2	45.7	51.2	51.2	73.5	66.4	38.4
WA	39.0	69.3	31.1	110.1	81.6	110.1	110.1	149.4	142.9	81.8
RW	0.0	0.0	0.0	0.7	1.6	2.2	2.2	2.2	2.2	2.2
RCOL	2	2	2	2	2	2	1	1	2	2
FTYP	1	1	1	2	1	2	2	1	2	1
SLABI	1	1	1	2	1	1	1	1	2	1
DUCTL	3	3	3	3	3	3	3	4	2	3
DUCTI	3	2	2	2	2	2	2	2	1	2
WC	2	2	2	3	2	1	1	1	1	2
IC	1	1	1	1	2	2	2	2	1	2
OCC	4	2	2	2	5	3	5	2	4	3
FUH	1	1	1	1	1	1	1	1	1	1

TABLE XXVI (Continued)

VARIABLE \ OBS	81	82	83	84	85	86	87	88	89	90
DD	2391	2116	2391	2391	2391	2391	2391	2391	2526	2391
QCHRA	9389	11602	9837	8459	8409	13161	17349	9254	12162	7637
QASHRAE	11637	14314	17862	10690	12868	17089	20190	11461	23206	9844
FUA	2152.1	1500.8	2095.5	2831.7	1784.0	3341.4	3596.3	1755.7	2945.0	1614.1
TLA	134.7	89.2	92.9	139.4	83.6	181.2	116.1	148.6	169.7	125.4
RC	2.6	0.0	1.0	2.2	1.1	1.1	1.1	3.0	1.5	2.2
FAF	0.0	0.0	92.9	0.0	83.6	55.7	116.1	0.0	169.7	0.0
FAS	134.7	89.2	0.0	139.4	0.0	62.2	0.0	148.6	0.0	125.4
RF	0.0	0.0	0.0	0.0	0.0	3.1	0.0	0.0	0.0	0.0
DA	1.7	3.9	2.0	0.0	0.0	0.0	4.5	3.5	2.0	0.0
DAS	2.0	0.0	2.0	4.1	2.0	6.9	0.0	0.0	2.0	3.9
GAS	0.0	3.3	3.9	0.0	0.0	0.0	7.8	0.0	0.0	0.0
GAN	3.1	3.3	4.1	0.0	0.0	0.0	6.1	3.3	0.0	0.0
GAE	0.0	0.0	1.5	0.0	0.0	0.0	2.2	0.7	0.0	0.0
GAW	0.0	0.0	0.0	0.0	0.0	0.0	1.3	8.9	0.0	0.0
GASD	6.2	0.0	0.0	3.4	3.2	8.1	0.0	0.0	0.9	1.5
GAND	5.5	0.0	0.0	2.4	1.8	7.8	0.0	0.0	0.0	4.1
GAED	2.7	0.0	0.0	4.6	4.1	1.8	0.0	0.0	9.8	1.1
GAWD	0.7	0.0	0.0	3.0	2.4	0.9	0.0	0.0	9.2	3.6
PL	51.8	39.0	40.2	42.1	47.5	50.0	19.5	51.2	66.1	57.9
WA	105.6	88.4	65.0	90.1	118.5	97.7	30.1	111.9	139.0	127.7
RW	2.2	2.2	0.0	1.2	0.7	0.5	0.0	1.9	2.2	1.9
RCOL	1	2	2	1	1	2	2	1	2	2
FTYP	2	2	1	2	1	3	1	2	1	2
SLABI	2	2	1	2	1	2	1	1	1	1
DUCTL	2	3	1	2	1	4	4	2	3	2
DUCTI	1	2	1	2	1	2	2	3	2	1
WC	1	1	1	2	1	2	2	1	1	1
IC	1	2	2	1	1	2	2	1	1	1
OCC	2	3	1	3	1	2	2	3	4	2
FUH	1	1	1	1	1	1	1	1	1	1

TABLE XXVI (Continued)

VARIABLE \ OBS	91	92	93	94	95	96	97	98	99	100
DD	2346	2183	2034	2311	2311	2311	2311	2311	1910	2127
QCHRA	14541	10545	9792	17907	14074	7719	16120	15265	8450	9879
QASHRAE	17065	15330	13152	23858	17035	14594	25974	22495	17867	17487
FUA	2322.0	1812.3	1897.2	2435.3	2038.8	1614.1	4219.2	2463.6	1784.0	1897.2
TLA	165.1	148.6	154.6	146.0	192.1	98.7	163.5	131.1	140.5	109.3
RC	2.2	2.2	2.6	1.9	1.9	3.3	3.3	2.1	3.3	1.5
FAF	0.0	148.6	0.0	146.0	0.0	98.7	163.5	131.1	140.5	109.3
FAS	165.1	0.0	154.6	0.0	192.1	0.0	0.0	0.0	0.0	0.0
RF	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DA	0.0	1.8	3.9	0.0	0.0	3.7	3.7	3.7	0.0	0.0
DAS	2.5	3.5	0.0	5.2	3.7	0.0	0.0	0.0	3.7	3.7
GAS	11.0	0.0	2.8	0.0	0.0	2.4	2.2	9.4	0.0	2.2
GAN	6.5	0.5	5.6	0.0	0.0	4.6	2.2	6.7	0.0	0.0
GAE	2.0	0.0	1.7	0.0	0.0	0.0	2.2	5.4	0.0	4.7
GAW	3.3	0.0	0.8	0.0	0.0	1.5	4.5	2.4	0.0	2.8
GASD	0.0	7.9	0.0	25.1	16.4	0.0	0.0	0.0	3.3	0.0
GAND	0.0	5.8	0.0	11.0	17.8	0.0	0.0	0.0	7.9	0.0
GAED	0.0	4.6	0.0	2.8	2.3	0.0	0.0	0.0	2.4	0.0
GAWD	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0
PL	59.5	56.7	51.2	58.2	68.0	39.6	53.0	48.8	52.4	42.7
WA	122.1	114.9	110.1	96.7	128.3	84.4	114.8	91.3	108.7	90.6
RW	1.1	1.9	2.2	0.0	1.9	2.3	0.0	1.9	2.3	1.2
RCOL	1	2	2	2	2	1	2	2	2	2
FTYP	2	1	2	1	2	1	1	1	1	1
SLABI	2	1	1	1	2	1	1	1	1	1
DUCTL	2	4	3	4	3	4	4	4	4	4
DUCTI	1	2	2	2	3	2	2	2	3	2
WC	1	1	1	2	1	1	2	2	1	1
IC	1	2	2	1	1	2	2	2	1	2
OCC	3	3	3	3	2	5	4	4	2	3
FUH	1	1	1	1	1	1	1	1	1	1

TABLE XXVI (Continued)

VARIABLE \ OBS	101	102	103	104	105	106	107	108	109	110
DD	2536	2536	2062	2146	2146	2377	2377	2377	2450	2243
QCHRA	12817	12212	10233	9889	11866	23388	13888	13615	17457	7657
QASHRAE	19899	22574	15807	20164	23715	33390	16192	27771	21951	9627
FUA	3114.9	3539.6	1727.3	3199.8	4332.5	4927.2	2520.2	2576.8	2973.3	1614.1
TLA	122.3	151.9	105.9	139.4	162.6	185.8	130.1	213.9	113.7	107.1
RC	3.3	2.0	1.6	2.3	2.3	2.5	1.9	2.6	5.3	2.3
FAF	122.3	151.9	105.9	139.4	162.6	185.8	130.1	213.9	113.7	0.0
FAS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	107.1
RF	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0
DA	3.7	0.4	0.0	0.0	0.0	3.5	3.5	0.0	5.6	0.0
DAS	0.0	0.0	3.7	3.7	3.7	0.0	0.0	3.5	0.0	5.2
GAS	6.2	1.5	0.0	1.5	1.1	9.8	7.2	0.0	6.1	0.0
GAN	3.6	5.4	0.0	0.0	0.0	11.6	6.6	0.0	1.4	0.0
GAE	7.0	0.7	0.0	5.6	4.5	2.9	4.9	0.0	7.6	0.0
GAW	0.0	3.0	0.6	2.2	6.1	0.0	3.4	0.0	9.6	0.0
GASD	0.0	0.0	7.5	0.0	0.0	0.0	0.0	7.4	0.0	3.2
GAND	0.0	0.0	6.5	0.0	0.0	0.0	0.0	7.5	0.0	0.0
GAED	0.0	0.0	3.8	0.0	0.0	0.0	0.0	3.9	0.0	7.8
GAWD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.9	0.0	4.2
PL	49.4	53.6	48.2	48.8	57.9	72.8	52.9	67.1	46.3	46.9
WA	99.9	116.5	96.7	105.9	125.8	149.7	103.3	138.0	82.7	95.1
RW	1.2	1.2	1.2	1.9	1.9	0.0	1.2	1.2	0.0	3.3
RCOL	2	2	2	2	2	2	1	2	2	2
FTYP	1	1	1	1	1	1	1	1	1	2
SLABI	1	1	1	1	1	1	1	1	1	2
DUCTL	4	4	4	4	4	4	4	4	4	2
DUCTI	2	2	2	2	2	2	2	2	2	2
WC	2	2	2	1	1	1	1	1	2	1
IC	2	2	1	2	2	2	2	1	2	1
OCC	3	2	2	4	2	4	4	3	2	1
FUH	1	1	1	1	1	1	1	1	1	1

TABLE XXVI (Continued)

VARIABLE \ OBS	111	112	113	114	115	116	117	118	119	120
DD	2377	1982	1982	2377	2536	2377	1694	2377	2176	2377
QCHRA	16591	18993	13432	9779	7598	10534	16186	8383	18206	12116
QASHRAE	25004	27030	15730	19142	14896	15296	17390	16222	23624	23157
FUA	3086.6	2860.0	2237.0	3199.8	2378.6	2746.7	2548.5	2350.3	1642.4	2973.3
TLA	143.3	153.3	101.3	133.7	102.2	88.2	141.7	106.6	116.8	148.6
RC	1.9	3.9	3.3	5.3	3.9	3.3	1.9	2.6	3.9	2.0
FAF	143.3	153.3	101.3	133.7	102.2	88.2	0.0	106.6	116.8	148.6
FAS	0.0	0.0	0.0	0.0	0.0	0.0	141.7	0.0	0.0	0.0
RF	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DA	0.0	5.8	0.0	3.7	5.6	0.0	0.0	0.0	0.0	0.0
DAS	3.5	0.0	5.2	0.0	0.0	3.5	5.2	3.5	3.7	5.2
GAS	6.7	6.5	0.6	4.1	0.4	3.2	9.4	2.0	3.0	4.8
GAN	5.9	3.1	2.8	6.2	1.7	4.5	2.6	2.5	0.0	5.6
GAE	2.2	9.8	7.0	1.6	2.5	2.8	4.3	3.1	27.6	3.7
GAW	0.8	3.7	4.2	0.0	2.5	1.9	3.4	1.6	10.2	0.8
GASD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GAND	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GAED	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GAWD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PL	51.2	67.4	48.2	52.1	41.1	38.1	54.9	39.9	50.0	49.7
WA	105.7	135.4	97.7	111.1	87.7	77.1	108.9	84.3	77.4	100.6
RW	0.0	0.0	0.0	2.6	1.9	0.0	0.0	1.2	1.9	1.2
RCOL	2	2	2	2	2	2	2	1	2	2
FTYP	1	1	1	1	1	1	2	1	1	1
SLABI	1	1	1	1	1	1	2	1	1	1
DUCTL	4	4	3	4	4	3	2	4	3	3
DUCTI	2	3	3	2	2	3	1	3	3	3
WC	1	1	2	1	1	1	1	1	1	1
IC	2	1	2	2	2	1	1	2	2	2
OCC	3	2	3	4	6	2	2	4	3	3
FUH	1	1	1	1	1	1	1	1	1	1

TABLE XXVI (Continued)

VARIABLE \ OBS	121	122	123	124	125	126	127	128	129	130
DD	1982	2536	2377	2377	2176	2127	2377	2243	2183	2377
QCHRA	9149	13941	9500	14046	10788	13012	11390	10749	14756	10255
QASHRAE	19552	24337	16744	23199	18899	21733	14364	12762	23714	20798
FUA	2123.8	4587.4	2463.6	2860.0	1642.4	3539.6	3341.4	1784.0	2916.7	3143.2
TLA	153.3	175.4	120.8	138.5	116.1	160.3	174.6	120.5	140.8	163.9
RC	3.1	2.0	2.6	2.3	2.0	3.3	2.6	1.3	1.2	3.9
FAF	153.3	175.4	120.8	138.5	116.1	110.4	0.0	0.0	140.8	163.9
FAS	0.0	0.0	0.0	0.0	0.0	50.0	174.6	120.5	0.0	0.0
RF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.7	0.0
DAS	3.5	1.9	3.7	3.1	3.5	3.7	5.9	1.9	0.0	5.2
GAS	0.0	0.0	0.0	7.8	3.3	5.6	0.0	0.0	4.7	0.0
GAN	0.0	0.0	0.0	5.5	2.5	5.9	0.0	3.7	7.7	0.0
GAE	0.0	0.0	0.0	1.7	1.5	4.6	0.0	5.2	1.8	0.0
GAW	0.0	0.0	0.0	4.9	6.9	3.4	0.0	0.0	0.8	0.0
GASD	2.8	4.8	3.0	0.0	0.0	0.0	7.2	6.5	0.0	5.5
GAND	0.0	10.3	4.6	0.0	0.0	0.0	6.9	1.2	0.0	7.0
GAED	7.0	14.1	3.2	0.0	0.0	0.0	3.6	0.0	0.0	2.0
GAWD	7.0	3.7	7.4	0.0	0.0	0.0	0.5	0.0	0.0	0.6
PL	54.9	69.5	50.3	59.4	44.5	58.8	62.5	48.8	56.7	67.4
WA	114.6	137.0	101.6	121.6	91.7	120.4	129.5	101.1	119.1	145.0
RW	1.9	1.9	1.2	1.2	1.2	2.3	1.2	1.9	1.2	1.9
RCOL	2	2	2	2	2	1	2	2	2	1
FTYP	1	1	1	1	1	3	2	2	1	1
SLABI	1	1	1	1	1	2	2	1	1	1
DUCTL	4	4	4	4	4	4	2	3	3	4
DUCTI	3	2	2	3	3	3	1	2	2	2
WC	1	1	1	1	1	1	1	1	2	1
IC	1	1	1	2	2	2	1	2	2	1
OCC	2	4	3	2	2	4	2	5	4	1
FUH	1	1	1	1	1	1	1	1	1	1

TABLE XXVI (Continued)

VARIABLE \ OBS	131	132	133	134	135	136	137	138	139	140
DD	2377	2377	1982	2536	2764	1694	2127	2377	2377	2243
QCHRA	13809	11748	13609	13297	7905	17381	7989	7485	14781	7288
QASHRAE	19232	14914	20952	16523	10485	24658	15364	15119	26232	14974
FUA	1925.6	2491.9	2067.1	1982.2	2067.1	2576.8	1585.8	2775.1	4559.0	1953.9
TLA	104.0	142.5	141.3	161.2	139.8	137.6	120.4	118.6	171.4	105.5
RC	1.9	4.9	5.3	4.1	5.3	3.3	6.7	3.7	3.3	3.3
FAF	104.0	0.0	141.3	0.0	0.0	137.6	120.4	118.6	171.4	105.5
FAS	0.0	142.6	0.0	161.2	139.8	0.0	0.0	0.0	0.0	0.0
RF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DA	5.4	1.7	0.0	3.7	0.0	3.5	0.0	0.0	3.7	0.0
DAS	0.0	3.7	5.6	0.0	1.9	0.0	3.7	3.7	0.0	3.7
GAS	4.4	3.2	0.0	8.4	0.0	7.8	0.0	0.0	3.7	0.0
GAN	0.0	1.9	0.0	10.8	0.0	0.8	0.0	0.0	3.3	0.0
GAE	8.6	7.1	0.0	0.0	0.0	6.8	0.0	0.0	6.9	3.6
GAW	8.6	2.4	0.0	0.0	0.0	4.8	0.0	0.0	6.0	0.0
GASD	0.0	0.0	5.6	0.0	2.4	0.0	3.6	3.8	0.0	0.9
GAND	0.0	0.0	5.6	0.0	0.0	0.0	0.0	5.0	0.0	0.0
GAED	0.0	0.0	2.4	0.0	5.7	0.0	3.9	2.9	0.0	0.0
GAWD	0.0	0.0	0.0	0.0	5.1	0.0	6.8	2.4	0.0	1.3
PL	54.6	61.0	58.5	61.0	53.9	52.4	54.9	43.3	65.2	41.5
WA	106.4	128.8	124.5	125.8	117.2	104.0	116.8	88.7	135.4	91.7
RW	2.3	1.9	0.0	2.6	2.3	0.0	1.9	1.9	1.9	1.2
RCOL	2	2	1	1	2	2	2	2	2	2
FTYP	1	2	1	2	2	1	1	1	1	1
SLABI	1	2	1	2	2	1	1	1	1	1
DUCTL	4	3	4	3	2	4	4	4	4	4
DUCTI	2	2	2	2	1	2	2	2	2	2
WC	1	1	1	1	2	1	1	1	1	1
IC	2	2	1	2	1	2	1	1	2	2
OCC	4	4	2	4	2	4	2	2	2	4
FUH	1	1	1	1	1	1	1	1	1	1

TABLE XXVI (Continued)

VARIABLE \ OBS	141	142	143	144	145	146	147	148	149	150
DD	2377	2377	2377	2377	2377	2377	2377	2377	2377	2243
QCHRA	11467	12263	10921	16299	9354	9036	10164	14629	11807	12509
QASHRAE	19774	15119	20712	21024	12182	11970	12601	24216	14340	15728
FUA	2463.6	1727.3	2605.2	2378.6	2038.8	1642.4	1699.0	3511.3	3029.9	2746.7
TLA	135.6	123.2	140.1	107.3	125.0	160.7	144.0	167.2	148.6	211.2
RC	2.1	2.3	3.3	2.6	2.9	4.7	2.2	2.2	3.0	6.5
FAF	135.6	0.0	140.1	107.3	0.0	0.0	0.0	151.6	0.0	0.0
FAS	0.0	123.2	0.0	0.0	125.0	160.7	144.0	15.6	148.6	211.2
RF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DA	0.0	0.0	3.7	3.5	1.7	1.9	1.7	1.7	1.7	1.7
DAS	3.5	5.6	0.0	0.0	2.0	4.1	2.0	3.5	1.9	5.2
GAS	0.0	5.2	6.0	6.3	3.4	0.0	0.0	7.2	3.2	2.2
GAN	0.0	2.1	2.0	4.6	7.8	0.0	0.0	6.9	4.6	1.7
GAE	0.0	2.0	2.5	4.8	0.6	0.0	3.4	3.1	2.3	7.2
GAW	0.0	2.5	2.0	1.4	0.6	0.0	0.0	2.2	7.3	9.5
GASD	6.2	0.0	0.0	0.0	0.0	5.6	2.1	0.0	0.0	0.0
GAND	5.8	0.0	0.0	0.0	0.0	4.8	0.7	0.0	0.0	0.0
GAED	6.0	0.0	0.0	0.0	0.0	1.6	2.4	0.0	0.0	0.0
GAWD	1.7	0.0	0.0	0.0	0.0	0.9	5.4	0.0	0.0	0.0
PL	46.9	60.4	53.0	53.3	54.3	57.6	52.4	60.0	54.9	78.9
WA	92.6	129.8	113.1	109.2	116.3	127.9	110.7	121.9	104.4	165.0
RW	1.2	1.1	1.9	0.0	2.3	1.9	1.3	1.3	1.9	2.8
RCOL	2	2	2	2	1	2	2	2	2	2
FTYP	1	2	1	1	2	2	2	3	2	2
SLABI	1	2	1	1	1	2	2	2	1	1
DUCTL	4	3	4	4	3	2	3	4	3	2
DUCTI	2	2	2	2	3	2	2	2	2	2
WC	2	1	1	1	2	1	1	1	1	1
IC	2	2	2	2	2	1	1	1	2	1
OCC	5	2	2	2	3	4	2	2	4	2
FUH	1	1	1	1	1	1	1	1	1	1

TABLE XXVI (Continued)

VARIABLE \ OBS	151	152	153	154	155	156	157	158	159	160
DD	2377	2412	2216	2216	2216	2216	2216	2388	2333	2388
QCHRA	10587	5851	7801	5779	9756	17633	10242	8327	8739	8060
QASHRAE	12793	8772	10094	7506	13050	22279	14008	10815	13507	10899
FUA	2803.4	11148.0	10405.0	10859.0	13795.0	27507.0	12007.0	12145.0	11223.0	12470.0
TLA	130.1	109.8	101.1	83.6	135.3	263.8	84.4	115.9	132.3	127.6
RC	1.7	5.4	4.7	1.7	2.7	6.1	1.2	1.8	2.6	1.7
FAF	0.0	109.8	0.0	0.0	0.0	0.0	84.4	0.0	132.3	0.0
FAS	130.1	0.0	101.1	83.6	135.3	263.8	0.0	115.9	0.0	127.6
RF	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0
DA	1.7	0.0	1.6	3.5	0.0	1.6	0.0	2.0	0.0	2.0
DAS	2.0	3.9	2.0	0.0	3.5	2.2	3.9	3.9	3.9	2.0
GAS	6.1	0.0	2.5	0.0	0.0	2.8	0.0	1.7	0.0	0.0
GAN	1.3	0.0	0.8	0.0	0.0	19.8	0.0	0.0	0.0	0.0
GAE	1.7	0.0	2.3	0.0	0.0	8.0	0.0	2.9	0.0	0.0
GAW	5.5	0.0	6.5	0.0	0.0	2.2	0.0	5.3	0.0	0.0
GASD	0.0	4.7	0.0	2.7	4.5	0.0	5.2	0.0	4.0	1.8
GAND	0.0	4.2	0.0	1.8	0.0	0.0	3.8	0.0	3.4	0.0
GAED	0.0	2.4	0.0	5.4	6.9	0.0	4.5	0.0	1.8	3.3
GAWD	0.0	0.0	0.0	1.8	5.0	0.0	2.2	0.0	3.0	5.7
PL	44.8	43.9	34.4	41.8	60.0	79.2	39.0	45.1	53.6	52.7
WA	91.0	93.0	68.2	45.6	127.6	156.6	76.6	94.3	114.6	114.6
RW	2.3	2.2	2.2	2.2	2.2	2.2	0.0	2.2	1.3	2.2
RCOL	2	2	2	2	2	2	2	2	2	2
FTYP	2	1	2	2	2	2	1	2	1	2
SLABI	2	1	2	2	1	2	1	1	1	1
DUCTL	3	4	3	1	3	3	1	2	3	2
DUCTI	2	3	3	1	3	3	1	3	3	3
WC	1	1	1	1	1	1	2	1	2	1
IC	1	2	2	2	2	1	2	2	2	2
OCC	4	3	2	4	4	5	1	2	2	3
FUH	1	3	3	3	3	3	3	3	3	3

TABLE XXVI (Continued)

VARIABLE \ OBS	161	162	163	164	165	166	167	168	169	170
DD	2412	2388	2388	2216	2216	2216	1982	1910	1910	1910
QCHRA	7872	10198	8101	10024	8166	8574	11332	6952	17710	13989
QASHRAE	10530	12380	10123	13355	10724	10760	18309	13143	20489	24582
FUA	5086.0	14406.0	9720.0	16469.0	15136.0	12211.0	1812.3	1161.0	1840.6	3143.2
TLA	113.0	135.3	102.6	144.0	66.5	99.1	127.0	111.5	109.9	168.1
RC	2.8	1.8	2.7	2.7	2.7	2.7	5.3	4.4	1.1	1.2
FAF	0.0	0.0	0.0	0.0	66.5	0.0	127.0	111.5	109.9	168.1
FAS	113.0	135.3	102.6	144.0	0.0	99.1	0.0	0.0	0.0	0.0
RF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DA	0.0	2.0	0.0	1.6	0.0	3.9	0.0	0.0	3.2	3.3
DAS	3.9	2.0	3.9	2.0	3.9	0.0	5.6	3.3	0.0	1.9
GAS	0.0	0.0	0.0	0.0	0.0	2.5	0.0	0.0	12.0	3.7
GAN	3.9	0.0	0.0	0.0	0.0	2.5	0.0	0.0	0.0	6.7
GAE	0.0	3.9	3.3	0.0	0.0	4.6	0.0	0.0	4.8	0.0
GAW	0.0	0.0	3.9	0.0	0.0	0.8	0.0	0.0	7.4	0.0
GASD	4.0	0.0	0.0	0.0	5.0	0.0	2.4	3.7	0.0	7.4
GAND	0.9	0.0	0.0	0.9	2.5	0.0	1.4	3.6	0.0	0.0
GAED	0.0	7.9	3.6	11.6	5.0	0.0	6.1	3.6	0.0	0.0
GAWD	1.2	8.4	2.7	4.7	2.5	0.0	2.0	5.1	0.0	0.0
PL	43.6	54.9	46.3	54.3	32.6	40.8	47.5	45.1	29.9	64.9
WA	92.8	110.8	96.0	112.8	61.7	85.3	99.3	91.8	45.4	158.9
RW	2.2	2.2	2.2	1.6	0.0	2.2	0.0	1.9	0.0	1.8
RCOL	2	2	2	1	2	2	2	2	2	2
FTYP	2	2	2	2	1	2	1	1	1	1
SLABI	2	1	1	2	1	2	1	1	1	1
DUCTL	3	2	3	3	1	3	3	1	1	1
DUCTI	2	3	3	3	1	2	3	1	1	1
WC	1	1	1	1	2	1	2	2	2	2
IC	2	2	2	2	2	2	1	1	3	2
OCC	1	4	2	4	2	3	2	2	3	3
FUH	3	3	3	3	3	3	1	1	1	1

TABLE XXVI (Continued)

VARIABLE \ OBS	171	172	173	174	175	176	177	178	179	180
DD	1910	1910	1910	1910	1910	2266	2286	2286	2286	2286
QCHRA	21276	22920	11268	15004	8467	11870	7519	13530	9871	12675
QASHRAE	36286	41052	18910	16588	15327	14468	10308	16733	17577	16417
FUA	4474.1	4870.5	1642.4	1925.6	1387.5	11637.0	15302.0	20795.0	12200.0	20218.0
TLA	232.6	268.9	131.1	131.5	118.7	132.3	123.5	183.9	117.1	167.2
RC	0.9	2.7	1.7	2.2	1.8	3.7	1.7	1.3	4.0	1.5
FAF	190.3	268.9	131.1	131.5	118.7	0.0	0.0	0.0	117.1	0.0
FAS	42.5	0.0	0.0	0.0	0.0	132.3	123.5	183.9	0.0	167.2
RF	0.0	0.0	0.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0
DA	1.7	3.2	0.0	1.7	1.7	1.9	0.0	0.0	0.0	0.0
DAS	5.3	1.9	3.5	3.4	3.3	1.9	5.2	7.8	3.7	7.8
GAS	8.3	4.7	0.0	4.1	5.6	0.0	0.0	0.0	3.3	0.0
GAN	1.5	5.2	0.0	6.9	0.0	1.6	0.0	3.3	2.9	0.0
GAE	5.2	9.0	0.0	8.4	0.7	8.2	0.0	0.0	4.2	0.0
GAW	0.0	15.2	4.9	0.0	0.0	3.2	0.0	0.0	3.6	0.0
GASD	2.2	0.0	3.6	0.0	0.0	0.0	2.6	12.0	0.0	2.4
GAND	2.6	0.0	0.0	0.0	6.0	0.0	3.7	7.9	0.0	5.2
GAED	0.0	0.0	7.7	0.0	1.5	0.0	0.9	0.0	0.0	7.2
GAWD	3.0	0.0	3.6	0.0	0.9	0.0	2.4	0.0	0.0	3.7
PL	69.8	86.3	48.8	48.2	49.1	50.6	48.8	62.2	43.9	62.8
WA	140.9	171.1	96.6	93.0	85.6	106.7	104.8	122.0	89.4	128.1
RW	0.7	2.7	1.7	0.0	2.2	2.2	2.2	1.2	2.6	1.6
RCOL	2	2	1	2	2	1	1	1	2	2
FTYP	3	1	1	1	1	2	2	2	1	2
SLABI	2	1	1	1	1	2	1	1	1	2
DUCTL	3	3	3	3	1	3	2	2	3	2
DUCTI	2	3	2	2	1	3	1	1	3	1
WC	1	3	2	2	2	1	1	1	3	1
IC	2	2	1	2	1	3	2	2	2	2
OCC	3	2	2	2	2	2	3	2	5	2
FUH	1	1	1	1	1	3	3	3	3	3

TABLE XXVI (Continued)

VARIABLE \ OBS	181	182	183	184	185	186	187	188	189	190
DD	2286	2286	2282	2097	2296	2286	2423	2286	2473	2286
QCHRA	9629	9517	8027	12379	10336	10196	13695	7891	12977	11761
QASHRAE	12597	13330	10358	15599	18330	13073	19934	16116	23115	16185
FUA	16121.0	13509.0	13448.0	20540.0	15251.0	15411.0	19945.0	9755.0	19440.0	16331.0
TLA	130.1	153.3	102.8	168.1	136.6	141.2	200.1	131.5	167.2	193.5
RC	1.3	5.2	1.7	2.6	2.0	3.1	2.6	3.4	1.7	1.5
FAF	0.0	0.0	0.0	0.0	136.6	0.0	200.1	131.5	167.2	0.0
FAS	130.1	153.3	102.8	168.1	0.0	141.2	0.0	0.0	0.0	193.5
RF	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0
DA	0.0	1.6	0.0	5.6	2.0	2.0	0.0	3.9	3.5	0.0
DAS	3.9	3.4	3.5	0.0	2.0	2.0	6.5	0.0	1.7	3.9
GAS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.8	0.0
GAN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GAE	0.0	0.0	0.0	0.0	3.3	0.0	0.0	0.0	0.0	0.0
GAW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GASD	0.0	2.5	3.8	0.9	6.9	3.0	2.0	0.9	3.4	7.4
GAND	2.4	2.0	5.1	13.4	5.3	1.2	1.2	3.7	9.2	6.6
GAED	2.4	3.7	2.2	7.0	0.0	7.0	3.8	5.3	2.2	2.0
GAWD	8.1	4.3	0.0	2.4	3.1	7.3	5.1	1.2	0.0	0.0
PL	63.7	63.1	41.5	64.0	48.2	56.7	69.5	46.3	67.1	56.7
WA	139.4	137.2	87.3	128.5	95.4	117.1	151.7	98.8	137.8	119.5
RW	1.9	2.1	1.2	2.2	2.6	2.1	1.6	2.5	2.2	2.2
RCOL	1	2	2	1	2	2	2	2	2	2
FTYP	2	2	2	2	1	2	1	1	1	2
SLABI	1	2	2	2	1	2	1	1	1	2
DUCTL	2	2	2	2	4	2	4	3	1	2
DUCTI	1	1	1	1	3	1	1	3	1	1
WC	1	1	1	1	2	1	2	3	2	1
IC	2	2	2	2	2	2	3	2	2	2
OCC	3	2	3	3	2	4	2	2	2	4
FUH	3	3	3	3	3	3	3	3	3	3

TABLE XXVI (Continued)

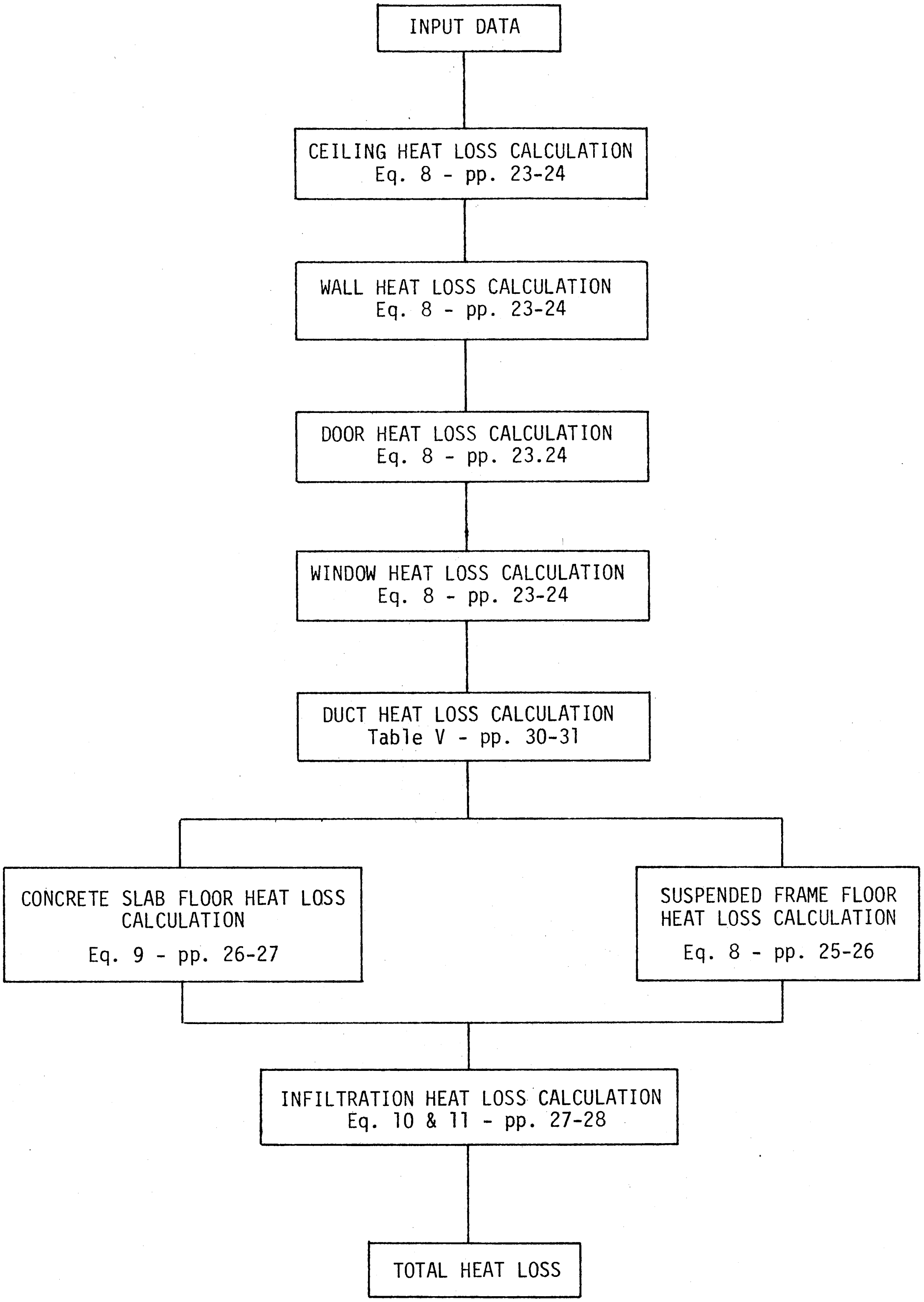
VARIABLE \ OBS	191	192	193	194	195	196	197	198	199	200
DD	2473	2286	2311	1960	2064	2097	2473	2357	2434	2473
QCHRA	12126	6780	10809	9801	9410	9595	9490	12490	13531	10731
QASHRAE	14794	13924	13217	12327	11238	12933	12187	16872	16718	14100
FUA	16621.0	8448.0	24937.0	10213.0	10233.0	17225.0	14946.0	14304.0	16802.0	16611.0
TLA	149.3	109.6	129.5	116.1	98.1	155.7	148.6	204.4	195.1	162.6
RC	1.5	6.1	2.7	3.1	1.5	3.9	2.2	3.5	4.4	4.4
FAF	0.0	109.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	162.6
FAS	149.3	0.0	129.5	116.1	98.1	155.7	148.6	204.4	195.1	0.0
RF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1
DA	1.9	2.0	5.0	0.0	0.0	3.7	1.8	3.7	7.1	1.9
DAS	1.8	2.0	1.7	3.5	2.0	1.9	5.4	5.6	0.0	3.5
GAS	0.0	0.0	0.0	1.7	1.7	0.0	0.0	0.0	0.0	0.0
GAN	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0
GAE	0.0	0.0	0.0	3.9	6.3	0.0	0.0	0.0	0.0	0.0
GAW	0.0	0.0	0.0	6.1	5.6	0.0	0.0	3.7	0.0	0.0
GASD	4.6	3.0	0.0	0.0	0.0	3.0	2.2	5.1	3.0	13.0
GAND	4.7	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	9.0
GAED	6.9	3.8	13.0	0.0	0.0	5.2	7.3	8.8	8.5	4.3
GAWD	1.4	5.3	4.4	0.0	0.0	7.7	8.0	3.6	7.9	1.4
PL	58.5	47.5	55.2	48.2	34.1	52.4	55.2	78.0	69.5	64.3
WA	122.7	100.3	108.9	99.6	67.7	107.5	111.1	161.0	144.0	125.7
RW	0.5	2.1	1.6	2.2	2.2	2.2	2.2	2.2	2.2	2.2
RCOL	1	2	1	2	2	2	2	1	1	2
FTYP	2	1	2	2	2	2	2	2	2	1
SLABI	1	1	2	1	2	2	1	1	1	1
DUCTL	2	4	2	3	3	3	2	3	3	3
DUCTI	1	3	1	2	2	2	1	3	3	3
WC	1	1	1	1	1	1	1	1	1	1
IC	2	1	2	2	2	2	2	2	3	2
OCC	4	3	3	2	4	2	4	4	2	2
FUH	3	3	3	3	3	3	3	3	3	3

TABLE XXVI (Continued)

VARIABLE \ OBS	201	202	203	204	205	206	207
DD	2286	2286	2393	1960	2473	2423	2286
QCHRA	7854	8835	11041	8695	10015	8479	13794
QASHRAE	9699	11325	19590	11058	12662	11213	17943
FUA	8830.0	10066.0	22944.0	8093.0	12538.0	11110.0	21640.0
TLA	122.9	125.4	229.5	118.0	142.0	119.1	176.5
RC	3.6	1.7	3.7	4.9	4.9	3.7	1.0
FAF	122.9	0.0	229.5	0.0	0.0	0.0	0.0
FAS	0.0	125.4	0.0	118.0	142.0	119.1	176.5
RF	2.2	0.0	1.2	0.0	0.0	0.0	0.0
DA	2.6	0.0	0.0	0.0	2.0	2.0	2.0
DAS	3.6	3.5	7.0	3.5	3.9	2.0	2.0
GAS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GAN	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GAE	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GAW	0.0	0.0	0.0	0.0	0.0	3.9	0.0
GASD	7.2	8.0	4.0	4.8	2.4	0.9	0.9
GAND	7.2	4.6	0.0	7.0	0.0	0.0	0.0
GAED	4.9	2.4	7.0	2.4	6.3	4.0	8.2
GAWD	1.4	1.2	7.0	0.0	7.0	3.2	10.2
PL	54.3	50.3	74.4	51.8	58.5	50.6	62.5
WA	106.8	104.0	157.7	126.3	122.3	105.8	130.5
RW	2.3	2.1	2.2	2.2	2.2	2.7	1.6
RCOL	2	2	2	2	1	2	1
FTYP	1	2	1	2	2	2	2
SLABI	1	2	1	1	2	2	2
DUCTL	1	3	4	3	3	3	2
DUCTI	1	3	3	2	1	2	1
WC	1	2	1	1	1	2	1
IC	2	1	2	2	2	2	2
OCC	2	2	3	4	5	4	4
FUH	3	3	3	3	3	3	3

APPENDIX B

FLOW CHART OF CRHA HEAT LOAD CALCULATION PROCEDURES


INPUT DATA
CEILING HEAT LOSS CALCULATION Eq. 8 - pp. 23-24
WALL HEAT LOSS CALCULATION Eq. 8 - pp. 23-24
DOOR HEAT LOSS CALCULATION Eq. 8 - pp. 23.24
WINDOW HEAT LOSS CALCULATION Eq. 8 - pp. 23-24
DUCT HEAT LOSS CALCULATION Table V - pp. 30-31
CONCRETE SLAB FLOOR HEAT LOSS CALCULATION Eq. 9 - pp. 26-27
SUSPENDED FRAME FLOOR HEAT LOSS CALCULATION Eq. 8 - pp. 25-26
INFILTRATION HEAT LOSS CALCULATION Eq. 10 & 11 - pp. 27-28
TOTAL HEAT LOSS

APPENDIX C

LISTING OF CRHA COMPUTER PROGRAM

LISTING OF CRHA COMPUTER PROGRAM

The following computer program contains calculation methodology for the CRHA load calculation program. In addition, the program also contains cooling load calculation data, energy consumption calculations, and fuel or energy prediction verification statements. The program is written in Fortran IV Language for an IBM 370/168 computing system. All equations, constants, and data contained in the computer program are in the English system of units.

```
C                                 A U D I T
C                   ENERGY AUDIT FOR SINGLE STORY HOMES
C                     TEST VERSION FOR VERIFICATION
C
C       PROGRAM METHODOLOGY BY KEN JONES AND SAM HARP OF THE AGRICULTURAL
C       ENIGINEERING DEPARTMENT AT OKLAHOMA STATE UNIVERSITY.  PROGRAM
C       CODING AND MODIFICATION BY LARRY SCHULTZ.
C
        COMMON /CHECK/QHT,CHT,QCT,CCCCLT,QHTR,QCTR,EFACT,FACT2,TDIFFH
        COMMON /USAGE/KJAN,KFEB,KMAR,KAPR,KMAY,KJUN,KJUL,KAUG,KSEP,KOCT,
       + KNOV,KDEC,KBASE,HJAN,HFEB,HMAR,HAPR,HMAY,HJUN,HJUL,HAUG,HSEP,
       + HOCT,HNOV,HDEC,HBASE,IHFLAG,ICFLAG,IDDFLG
        COMMON /CODATA/NAME,ADD1,ADD2,RNAME,RADD1,RADD2,COUNTY,FA,
       - RCCL,RC,FTYP,FASF,FACS,RSF,SLABI,DUCTL,DUCTI,DA,RD,DAS,RDS,
       - GAS,GAN,GAE,GAW,GASD,GAND,GAED,GAWD,GAST,GANT,
       - GAET,GAWT,RL,WA,WC,RW,IC,FUH,CCCL,PNG,PLF,PEH,PEC,CCC,
       - SEF,DD,COOLHP,IDDTYP,IRD,ICOOLH
        DIMENSION NAME(20),ADD1(20),ADD2(20),IPAGE4(20,50),ILOGO(32,36)
        DIMENSION INFIL(3)
        DIMENSION RNAME(10),RADD1(10),RADD2(10)
        DIMENSION INSTR(10)
        REAL IC
        DOUBLE PRECISION COUNTY
        DATA CNG,CLP,CELEC/1000000.0,92000.0,3413.0/
        DATA INFIL/3HMIN,3HAVG,3HMAX/
        DATA E,R/0.10,0.06/
        DATA WETDRS,WETDRN,WETDRW,WETDRE/35.0,27.0,60.0,60.0/
        DATA WETDTS,WETDTN,WETDTW,WETDTE/22.0,16.0,37.0,37.0/
        DATA WETDDS,WETDDN,WETDDW,WETDDE/27.0,19.0,49.0,49.0/
        DATA TOH,TIH,TOC,TIC/13.0,72.0,99.0,76.0/
        DATA ETDB,ETDM,ETDRD,ETDRL/27.6,20.3,48.0,40.0/
        DATA COEF0,COEF1,COEF2/16.78,-1.39E-02,6.90E-06/
C
C       ** SET TEMPERATURE DIFFERENCES
C
        TDIFFH = TIH - TOH
        TDIFFC = TOC - TIC
C
C       ** CALL SUBROUTINE INDATA TO INPUT STRUCTURAL DATA
C
 1040   CALL INDATA(ISTOP)
        IF (ISTOP .EQ. 1) GO TO 2260
C
C       ** CONVERT IC (INFILTRATION COND.) TO INTEGER FOR OUTPUT PURPOSES
C
        IIC = INT(IC)
        IFTYP = INT(FTYP)
        IDUCTL  = INT(DUCTL)
        IFUH = INT(FUH)
C
C       ** CALCULATE PRESENT HEATING LOAD
C
        QHA=FA*TDIFFH/RC
        QHW=WA*TDIFFH/RW
        QHDN=DA*TDIFFH/RD
        QHDS=DAS*TDIFFH/RDS
        QHD=QHDN+QHDS
```

```
      QHG1=(GAS+GAN+GAE+GAW)*TDIFFH/0.55
      QHG2=(GASD+GAND+GAED+GAWD)*TDIFFH/1.7
      QHG3=(GAST+GANT+GAET+GAWT)*TDIFFH/2.86
      QHG=QHG1+QHG2+QHG3
      IF (DUCTL .EQ. 1.0) DX=6.0
      IF (DUCTL .EQ. 2.0) DX=2.0
      IF (DUCTL .EQ. 3.0) DX=4.0
      IF (DUCTL .EQ. 4.0) DX=2.0
      IF (FTYP .EQ. 3.0) GO TO 1115
      QHFCS = 0.0
      QHFS = 0.0
      IF (FTYP .EQ. 1) GO TO 1110
      IF (SLABI .EQ. 1) F=0.276
      IF (SLABI .EQ. 2) F=0.495
      QHF=(F*PL*TDIFFH)+(1.25*(FA-(3.0*PL)))
      IF (DUCTL .EQ. 2.0) QHF=QHF*1.6
      GO TO 1120
1110  IF (WC .EQ. 1) USW=0.33
      IF (WC .GE. 2) USW=0.58
      UF=1.0/RSF
      RCF=(USW*PL*1.5)/(UF*FA)
      TCS=(TOH*RCF+TIH-DX)/(RCF+1.0)
      TCS=(0.875*TCS)+(0.125*TOH)
      QHF=UF*FA*((TIH-DX)-TCS)
      GO TO 1120
 1115 IF (SLABI.EQ.1) F = 0.276
      IF (SLABI.EQ.2) F = 0.465
      PLR = PL * (FACS/FA)
      QHFCS = (F*PLR*TDIFFH)+(1.25*(FACS-(3.0*PLR)))
      IF (DUCTL .EQ. 2.0) QHFCS = QHFCS * 1.6
      IF (WC.EQ.1) USW = 0.33
      IF (WC.GE.2) USW = 0.58
      UF = 1.0/RSF
      PLF = PL*(FASF/FA)
      RCF = (USW*PLF*1.5)/(UF*FASF)
      TCS = (TOH*RCF+TIH-DX)/(RCF+1.0)
      TCS = (0.875*TCS)+(0.125*TOH)
      QHFS = UF*FASF*((TIH-DX)-TCS)
      QHF = QHFCS+QHFS
1120  GTA=GAS+GAN+GAE+GAW+GASD+GAND+GAED+GAWD
     + +GAST +GANT +GAET +GAWT
      IF (IC .EQ. 1) Q=14.0
      IF (IC .EQ. 2) Q=28.0
      IF (IC .EQ. 3) Q=77.0
      QIHS=((GTA*0.75)*Q*0.24*TDIFFH)/11.5
      QIHL=(0.0864*WA*TDIFFH)/2.0
      QHI=QIHS+QIHL
      QHT=QHA+QHW+QHD+QHG+QHF+QHI
      UFACT = QHA/(TDIFFH*FA) + QHW/(TDIFFH*FA) + QHD/(TDIFFH*FA) +
     + QHG/(TDIFFH*FA) + QHF/(TDIFFH*FA) + QHI/(TDIFFH*FA)
      IF (DUCTI .EQ. 1.0) DL=0.20
      IF (DUCTI .EQ. 2.0) DL=0.15
      IF (DUCTI .EQ. 3.0) DL=0.10
      IF (DUCTL .LT. 3.0) DL=0.0
      QHDT=QHT*DL
      QHL = QHT
      QHT=QHT+QHDT
      QH = QHT-QHI
```

```
C
C     CALCULATE PARASITIC LOAD FOR GAS HEATING
C
      FANT = (24.0*DD/(TDIFFH*1.5))
      IF (DUCTL .EQ. 1.0 .OR. FUH .GT. 2.0) GO TO 9234
      IF (CCOL .NE. 1.0) GO TO 9182
      IF (QHT .LE. 24000.0) FURN = 0.187*FANT
      IF (QHT .GT. 24000.0 .AND. QHT .LE. 30000.0) FURN = 0.294*FANT
      IF (QHT .GT. 30000.0) FURN = 0.373*FANT
      GO TO 1328
9182  IF (QHT .LE. 24000.0) FURN = 0.149*FANT
      IF (QHT .GT. 24000.0 .AND. QHT .LE. 30000.0) FURN = 0.187*FANT
      IF (QHT .GT. 30000.0) FURN = 0.294*FANT
      GO TO 1328
9234  FURN = 0.0
1328  CHM = FURN*PEC
      CHMP = CHM*QHTR/QHT
C
C     ** SET CORRECTION FACTORS TO APPROPRIATE VALUES FOR FUEL TYPE USED
C
C     GHI = 292.5*OCC+2.35*((FA+WA)/3.0)+1950.0
      GFACT1 = 1.18
      GFACT2 = 1.33
      GFACT3 = 1.94
      EFACT1 = 1.00
      EFACT2 = 1.02
      EFACT3 = 1.05
      EFACT = 1.00
      B = QHT/TDIFFH
      C = (CHL)  /TDIFFH
C     DELT = COEF2*B*B + COEF1*B + COEF0
C     DELT = AMAX1(2.0,DELT)
C     DELT = AMIN1(11.0,DELT)
C2    DELT = 4000.0/B
C     DELT = 5075.0/C
C     BDD = 72.0 - DELT
C     BDD = AMIN1(65.0,BDD)
C     BDDC = 65.0 - BDD
C     DELTDD = 256.00 * BDDC
C     DDCOR = DD - DELTDD
C   ** BDDC=0 FOR 65 F BASE TEMPERATURE
C   ** BDDC IS DEGREES REDUCTION IN BASE TEMPERATURE
C     DK = 6.398/(DD**0.577)
C     FACT2 = 1.0 - (DK*BDDC)
C     DDCOR = DD*FACT2
      FACT2 = 1.0000
      IF (FUH .EQ. 1) CONST1 = GFACT1*FACT2/CNG
      IF (FUH .EQ. 2) CONST1 = GFACT1*FACT2/CLP
      IF (FUH .EQ. 3) CONST1 = EFACT1*FACT2/CELEC
      IF (FUH .EQ. 4) CONST1 = EFACT1*FACT2/CELEC/SPF
      IF (FUH .EQ. 1) CONST2 = GFACT2*FACT2/CNG
      IF (FUH .EQ. 2) CONST2 = GFACT2*FACT2/CLP
      IF (FUH .EQ. 3) CONST2 = EFACT2*FACT2/CELEC
      IF (FUH .EQ. 4) CONST2 = EFACT2*FACT2/CELEC/SPF
      IF (FUH .EQ. 1) CONST3 = GFACT3*FACT2/CNG
      IF (FUH .EQ. 2) CONST3 = GFACT3*FACT2/CLP
      IF (FUH .EQ. 3) CONST3 = EFACT3*FACT2/CELEC
      IF (FUH .EQ. 4) CONST3 = EFACT3*FACT2/CELEC/SPF
```

```
C
C     ** CALCULATE FUEL USE
C
      FU1 =(24.*DDCOR*QHT)/(TDIFFH)*CONST1
      FU2 =(24.*DDCOR*QHT)/(TDIFFH)*CONST2
      FU3 =(24.*DDCOR*QHT)/(TDIFFH)*CONST3
      FUA=(24.*DDCOR*QHA )/(TDIFFH)*CONST
      FUW=(24.*DDCOR*QHW )/(TDIFFH)*CONST
      FUG=(24.*DDCOR*QHG )/(TDIFFH)*CONST
      FUG1=(24.*DDCOR*QHG1)/(TDIFFH)*CONST
      FUG2=(24.*DDCOR*QHG2)/(TDIFFH)*CONST
      FUG3=(24.*DDCOR*QHG3)/(TDIFFH)*CONST
      FUD=(24.*DDCOR*QHD )/(TDIFFH)*CONST
      FUD1=(24.*DDCOR*QHDN)/(TDIFFH)*CONST
      FUD2=(24.*DDCOR*QHDS)/(TDIFFH)*CONST
      FUF=(24.*DDCOR*QHF )/(TDIFFH)*CONST
      FUF1=(24.*DDCOR*QHFS)/(TDIFFH)*CONST
      FUF2=(24.*DDCOR*QHFCS)/(TDIFFH)*CONST
      FUI=(24.*DDCOR*QHI )/(TDIFFH)*CONST
      FUDT=(24.*DDCOR*QHDT)/(TDIFFH)*CONST
C
C     ** CALL BASE FOR VERIFICATION OF RESULTS
C
      CALL BASE(BBASE,HTOT)
C
C     PRINT & PUNCH RESULTS
C
      IFUH = INT(FUH)
      WRITE (6,222) FUH,HTOT,QHT,QHL,QH,IC,FA,WA,GTA,OCC,BBASE,PL,RC,RW,
     + FTYP,DD
222   FORMAT (//,(' ',8F10.2))
      WRITE (7,333) FUH,HTOT,QHT,QHL,QH,IC,FA,WA,GTA,OCC,BBASE,PL,RC,RW,
     + FTYP,DD
333   FORMAT (8F10.2)
      GO TO 1040
C
C     ** END OF DATA -- TIME TO QUIT
C
2260  WRITE (6,2270)
2270  FORMAT (1H ,'******  PROGRAM ENDING - END OF DATA ******')
      STOP
      END
```

```
      SUBROUTINE INDATA(ISTOP)
C
C
C     INDATA -- PROGRAMMED BY JEFF FARRIS -- MODIFIED BY LARRY SCHULTZ
C
C     THIS SUBROUTINE RETRIEVES DATA FOR THE AUDIT PROGRAM,
C     CHECKS FOR ERRORS AND IF CORRECT PASSES DATA BACK TO CALLING
C     PROGRAM, ELSE IT PRINTS ERROR AND CONTINUES.
C
      IMPLICIT REAL (K)
      DIMENSION INSTR(10), NAME(20), ADD1(20), ADD2(20), RNAME(10),
     -          RADD1(10), RADD2(10)
      COMMON /CODATA/NAME,ADD1,ADD2,RNAME,RADD1,RADD2,COUNTY,FA,
     - RCCL,RC,FTYP,FASF,FACS,RSF,SLABI,DUCTL,DUCTI,DA,RD,DAS,RDS,
     - GAS,GAN,GAE,GAW,GASD,GAND,GAED,GAWD,GAST,GANT,
     - GAET,GAWT,RL,WA,WC,RW,IC,FUH,COOL,PNG,PLP,PEH,PEC,CCC,
     - SPF,DD,COOLHR,IDDTYP,ICD,ICOOLH
      COMMON /CHECK/QHT,CHT,QCT,CCCCLT,QHTR,QCTR,EFACT,FACT2,TDIFFH
      COMMON /USAGE/KJAN,KFEB,KMAR,KAPR,KMAY,KJUN,KJUL,KAUG,KSEP,KOCT,
     + KNOV,KDEC,KBASE,HJAN,HFEB,HMAR,HAPR,HMAY,HJUN,HJUL,HAUG,HSEP,
     + HOCT,HNOV,HDEC,HBASE,IHFLAG,ICFLAG,IDDFLG
      REAL IC
      DOUBLE PRECISION COUNTY
      DATA STAR, ASTER, END/'STAR', '****', 'END '/
      ISTOP = 0
C
C     BEGIN INPUT OF SYMBOL AND ALPHA FIELDS
C
 1040 READ (5,1050) SYMBOL
 1050 FORMAT (1A4)
      IF (SYMBOL .EQ. STAR .OR. SYMBOL .EQ. ASTER) GO TO 1060
      IF (SYMBOL .EQ. END) GO TO 2260
      IRC = 1
      GO TO 2200
 1060 READ (5,1070) NAME
      READ (5,1070) ADD1
      READ (5,1070) ADD2
 1070 FORMAT (20A4)
      READ (5,1080) RNAME
      READ (5,1080) RADD1
      READ (5,1080) RADD2
 1080 FORMAT (10A4)
      READ (5,1090) COUNTY
 1090 FORMAT (1A8)
C
C     BEGIN INPUT OF NUMERIC DATA, ONE VALUE PER CARD
C
  200 READ (5,1100) INSTR
      CALL TRANS(INSTR,IRC,FA)
      GO TO (210,2200,2200,2200), IRC
  210 READ (5,1100) INSTR
      CALL TRANS(INSTR,IRC,RCCL)
      GO TO (220,2200,2200,2200), IRC
  220 READ (5,1100) INSTR
      CALL TRANS(INSTR,IRC,RC)
      IF (RC .EQ. 0.0) RC = 1.0
      GO TO (230,2200,2200,2200), IRC
  230 READ (5,1100) INSTR
```

```
      SUBROUTINE INDATA(ISTOP)
C
C
C     INDATA -- PROGRAMMED BY JEFF FARRIS -- MODIFIED BY LARRY SCHULTZ
C
C     THIS SUBROUTINE RETRIEVES DATA FOR THE AUDIT PROGRAM,
C     CHECKS FOR ERRORS AND IF CORRECT PASSES DATA BACK TO CALLING
C     PROGRAM, ELSE IT PRINTS ERROR AND CONTINUES.
C
      IMPLICIT REAL (K)
      DIMENSION INSTR(10), NAME(20), ADD1(20), ADD2(20), RNAME(10),
     -          RADD1(10), RADD2(10)
      COMMON /CODATA/NAME,ADD1,ADD2,RNAME,RADD1,RADD2,COUNTY,FA,
     - RCOL,RC,FTYP,FASF,FACS,RSF,SLABI,DUCTL,DUCTI,DA,RD,DAS,RDS,
     - GAS,GAN,GAE,GAW,GASD,GAND,GAED,GAWD,GAST,GANT,
     - GAET,GAWT,RL,WA,WC,RW,IC,FUH,COOL,RNG,RLP,REH,REC,CCC,
     - SRF,DD,COOLHR,IDDTYP,ICD,ICOOLH
      COMMON /CHECK/QHT,CHT,QCT,CCOOLT,QHTR,QCTR,EFACT,FACT2,TDIFFH
      COMMON /USAGE/KJAN,KFEB,KMAR,KAPR,KMAY,KJUN,KJUL,KAUG,KSEP,KOCT,
     + KNOV,KDEC,KBASE,HJAN,HFEB,HMAR,HAPR,HMAY,HJUN,HJUL,HAUG,HSEP,
     + HOCT,HNOV,HDEC,HBASE,IHFLAG,ICFLAG,IDDFLG
      REAL IC
      DOUBLE PRECISION COUNTY
      DATA STAR, ASTER, END/'STAR', '****', 'END '/
      ISTOP = 0
C
C     BEGIN INPUT OF SYMBOL AND ALPHA FIELDS
C
 1040 READ (5,1050) SYMBOL
 1050 FORMAT (1A4)
      IF (SYMBOL .EQ. STAR .OR. SYMBOL .EQ. ASTER) GO TO 1060
      IF (SYMBOL .EQ. END) GO TO 2260
      IRC = 1
      GO TO 2200
 1060 READ (5,1070) NAME
      READ (5,1070) ADD1
      READ (5,1070) ADD2
 1070 FORMAT (20A4)
      READ (5,1080) RNAME
      READ (5,1080) RADD1
      READ (5,1080) RADD2
 1080 FORMAT (10A4)
      READ (5,1090) COUNTY
 1090 FORMAT (1A8)
C
C     BEGIN INPUT OF NUMERIC DATA, ONE VALUE PER CARD
C
  200 READ (5,1100) INSTR
      CALL TRANS(INSTR,IRC,FA)
      GO TO (210,2200,2200,2200), IRC
  210 READ (5,1100) INSTR
      CALL TRANS(INSTR,IRC,RCOL)
      GO TO (220,2200,2200,2200), IRC
  220 READ (5,1100) INSTR
      CALL TRANS(INSTR,IRC,RC)
      IF (RC .EQ. 0.0) RC = 1.0
      GO TO (230,2200,2200,2200), IRC
  230 READ (5,1100) INSTR
```

```
      SUBROUTINE INDATA(ISTOP)
C
C
C     INDATA -- PROGRAMMED BY JEFF FARRIS -- MODIFIED BY LARRY SCHULTZ
C
C     THIS SUBROUTINE RETRIEVES DATA FOR THE AUDIT PROGRAM,
C     CHECKS FOR ERRORS AND IF CORRECT PASSES DATA BACK TO CALLING
C     PROGRAM, ELSE IT PRINTS ERROR AND CONTINUES.
C
      IMPLICIT REAL (K)
      DIMENSION INSTR(10), NAME(20), ADD1(20), ADD2(20), RNAME(10),
     -          RADD1(10), RADD2(10)
      COMMON /CODATA/NAME,ADD1,ADD2,RNAME,RADD1,RADD2,COUNTY,FA,
     - RCOL,RC,FTYP,FASF,FACS,RSF,SLABI,DUCTL,DUCTI,DA,RD,DAS,RDS,
     - GAS,GAN,GAE,GAW,GASD,GAND,GAED,GAWD,GAST,GANT,
     - GAET,GAWT,PL,WA,WC,RW,IC,FUH,COOL,PNG,PLP,PEH,PEC,CCC,
     - SPF,DD,COOLHR,IDDTYP,ICD,ICOOLH
      COMMON /CHECK/QHT,CHT,QCT,CCOOLT,QHTR,QCTR,EFACT,FACT2,TDIFFH
      COMMON /USAGE/KJAN,KFEB,KMAR,KAPR,KMAY,KJUN,KJUL,KAUG,KSEP,KOCT,
     + KNOV,KDEC,KBASE,HJAN,HFEB,HMAR,HAPR,HMAY,HJUN,HJUL,HAUG,HSEP,
     + HOCT,HNOV,HDEC,HBASE,IHFLAG,ICFLAG,IDDFLG
      REAL IC
      DOUBLE PRECISION COUNTY
      DATA STAR, ASTER, END/'STAR', '****', 'END '/
      ISTOP = 0
C
C     BEGIN INPUT OF SYMBOL AND ALPHA FIELDS
C
 1040 READ (5,1050) SYMBOL
 1050 FORMAT (1A4)
      IF (SYMBOL .EQ. STAR .OR. SYMBOL .EQ. ASTER) GO TO 1060
      IF (SYMBOL .EQ. END) GO TO 2260
      IRC = 1
      GO TO 2200
 1060 READ (5,1070) NAME
      READ (5,1070) ADD1
      READ (5,1070) ADD2
 1070 FORMAT (20A4)
      READ (5,1080) RNAME
      READ (5,1080) RADD1
      READ (5,1080) RADD2
 1080 FORMAT (10A4)
      READ (5,1090) COUNTY
 1090 FORMAT (1A8)
C
C     BEGIN INPUT OF NUMERIC DATA, ONE VALUE PER CARD
C
  200 READ (5,1100) INSTR
      CALL TRANS(INSTR,IRC,FA)
      GO TO (210,2200,2200,2200), IRC
  210 READ (5,1100) INSTR
      CALL TRANS(INSTR,IRC,RCOL)
      GO TO (220,2200,2200,2200), IRC
  220 READ (5,1100) INSTR
      CALL TRANS(INSTR,IRC,RC)
      IF (RC .EQ. 0.0) RC = 1.0
      GO TO (230,2200,2200,2200), IRC
  230 READ (5,1100) INSTR
```

```
      READ (5,99) KJUL,KAUG,KSEP,KOCT,KNOV,KDEC
      READ (5,99) KBASE
C
C     ** READ HEATING FUEL USE
      READ (5,99) HJAN,HFEB,HMAR,HAPR,HMAY,HJUN
      READ (5,99) HJUL,HAUG,HSEP,HOCT,HNOV,HDEC
      READ (5,99) HBASE
99    FORMAT (7F10.5)
C
C     CALL LOOKUP FOR DATA VALUES DEGREE DAYS (DD) AND
C     COOLING HOURS (COOLHR)
C
      IF (IDDFLG .EQ. 0)
     + CALL TABLE1 (COUNTY,DD,COOLHR,IPC,IDDTYP)
      IF (IDDFLG .EQ. 1)
     + CALL TABLE2 (COUNTY,DD,COOLHR,IPC,IDDTYP)
      IF (IPC .EQ. 2) GO TO 2200
C
C     CORRECT COOLING HOURS
C
      COOLHR = COOLHR * 0.82
C
C     CONVERT DD AND COOLHR TO INTEGERS FOR OUTPUT PURPOSES
C
      IDD = INT(DD)
      ICOOLH = INT(COOLHR)
C
C     CALCULATE SEASONAL PERFORMANCE FACTOR (SPF)
C
      SPF = 2.572 - 0.000143 * DD
      RETURN
 2200 CONTINUE
C
C     THIS BLOCK OF CODE ATTEMPTS TO RECOVER PROGRAM
C     EXECUTION WHEN AN ERROR OCCURS IN THE INPUT DATA
C
      IERROR = IERROR + 1
      WRITE (25,2278) INSTP, IERROR
 2278 FORMAT (10A1,F10.2,I5)
      WRITE (25,2274) NAME, ADD1, ADD2, COUNTY
 2274 FORMAT (1H0,'NAME    = ',20A4,/,' ADD1    = ',20A4,/,
     -           ' ADD2    = ',20A4,/,' COUNTY = ',20A4,//)
      IF (IPC .EQ. 3) GO TO 1060
      IF (IPC .EQ. 4) GO TO 2250
 2240 READ (5,2250) SYMBOL
 2250 FORMAT (1A4)
      IF (SYMBOL .EQ. ASTER) GO TO 1060
      IF (SYMBOL .EQ. END) GO TO 2260
      GO TO 2240
 2260 WRITE (6,2270)
 2270 FORMAT (1H ,'******  PROGRAM ENDING - END OF DATA ******')
C
C     OUTPUT ERROR SUMMARY AND CONTENTS OF ERROR FILE
C
      WRITE (6,2271) IERROR
 2271 FORMAT (1H1,'SUMMARY OF ERRORS FOR THIS RUN',/,
     -          1H0,'NUMBER OF ERRORS   =   ',I2)
      ISTOP = 1
```

```
      SUBROUTINE TRANS(ITEXT, IRC, RNUM)
C
C     TRANS - PROGRAMMED BY JEFF FARRIS -- MODIFIED BY LARRY SCHULTZ
C
C     THIS IS A SUBROUTINE WHICH TRANSLATES NUMBERS READ IN
C     CHARACTER FORM INTO THEIR CORRECT REAL VALUE EQUIVALENT.
C     THE NUMBERS MAY BE EITHER INTEGER OR REAL REPRESENTATIONS
C     ON INPUT.
C
C     VARIABLE LIST
C       ITEXT - 10 ELEMENT VECTOR CONTAINING CHARACTER STRING
C       RNUM  - REAL NUMBER EQUIVALENT RETURNED TO DRIVER
C       IRC   - INTEGER RETURN CODE
C               IRC = 0 FOR A NORMAL RETURN
C               IRC = 1 FOR AN ERROR CONDITION
C
C     SUBPROGRAM LIST
C       RCHAR - FUNCTION SUBPROGRAM WHICH GIVES REAL VALUE
C               FOR CORRESPONDING CHARACTER REPRESENTATION.
C               ONLY ONE PARAMETER IS PASSED, THE CHARACTER TO
C               BE TRANSLATED.
C
      DIMENSION ITEXT(10)
      DATA IZERO, NINE, IDECPT, IBLANK /'0', '9', '.', ' '/
C
C     ASSUME NORMAL RETURN WILL OCCUR
C
      IRC = 0
C
C     INITIALIZE RNUM SO IT CAN BE USED TO ACCUMULATE A LATER TOTAL
C
      RNUM = 0
C
C     CHECK CHARACTER STRING FOR INVALID CHARACTER
C
      DO 10 I=1, 10
        IF (ITEXT(I) .EQ. IBLANK) GO TO 10
        IF (ITEXT(I) .GE. IZERO .AND. ITEXT(I) .LE. NINE) GO TO 10
        IF (ITEXT(I) .EQ. IDECPT) GO TO 10
C
C       IF ABOVE CONDITION FAILS - INVALID CHARACTER
C       SET APPROPRIATE RETURN CODE AND RETURN
C
        IRC = 1
        RETURN
   10 CONTINUE
C
C     SET DECIMAL POSITION (IDECPS) TO 0, ASSUMING INTEGER NUMBER
C
      IDECPS = 0
C
C     LOCATE DECIMAL POSITION (IF ANY) AND SET IDECPS
C
      DO 20 I=1, 10
        IF (ITEXT(I) .NE. IDECPT) GO TO 20
        IDECPS = I
        GO TO 30
   20 CONTINUE
```

```
   30 CONTINUE
C
C      SET FLAG TO HELP LOCATE BEGIN AND END OF CHARACTER STRING
C      FLAG = 0 BEFORE FIRST CHARACTER FOUND
C      FLAG = 1 AFTER FIRST CHARACTER FOUND
C      FLAG = 2 AFTER FIRST BLANK AFTER LAST CHARACTER FOUND
C
C      INITIALIZE IFLAG TO 0 TO START LOOP
C
       IFLAG = 0
       DO 50 I=1, 10
         IF (ITEXT(I) .EQ. IBLANK) GO TO 40
         IF (IFLAG .NE. 0) GO TO 50
         IBEG = I
         IFLAG = 1
         GO TO 50
   40    IF (IFLAG .EQ. 0 .OR. IFLAG .EQ. 2) GO TO 50
         IEND = I - 1
         IFLAG = 2
   50 CONTINUE
C
C      CHECK FOR INTEGER VALUE, IF SO GO TO INTEGER SECTION (100)
C
       IF (IDECPS .EQ. 0) GO TO 100
C
C      CHECK TO SEE IF CHARACTER STRING BEGINS WITH DECIMAL POINT
C      IF SO PROCESS ONLY DECIMAL PART OF NUMBER
C
       IF (IDECPS .EQ. IBEG) GO TO 70
C
C      PROCESS INTEGER PART OF REAL NUMBER
C
       IHOLD = IDECPS - 1
       DO 60 I=IBEG, IHOLD
         RNUM = RNUM + RCHAR(ITEXT(I)) * 10.0 ** (IDECPS - I - 1)
   60 CONTINUE
   70 CONTINUE
C
C      CHECK TO SEE IF CHARACTER STRING ENDS WITH DECIMAL POINT
C      IF SO END PROCESSING OF REAL NUMBER
C
       IF (IDECPS .EQ. IEND) GO TO 90
C
C      PROCESS DECIMAL PART OF REAL NUMBER
C
       IHOLD = IDECPS + 1
       DO 80 I=IHOLD, IEND
         RNUM = RNUM + RCHAR(ITEXT(I)) * 10.0 ** (IDECPS - I)
   80 CONTINUE
       GOTO 90
C
C      SECTION OF CODE FOR PROCESSING OF INTEGER (IDECPS = 0)
C
  100 CONTINUE
       IF (IBEG .EQ. 0) GO TO 120
       DO 110 I=IBEG, IEND
         RNUM = RNUM + RCHAR(ITEXT(I)) * 10.0 ** (IEND - I)
  110 CONTINUE
```

```
C
C     SECTION OF CODE TO ROUND NUMBER
C     TO DESIRED NUMBER OF SIG. FIGURES.
C
   90 CONTINUE
      IF (IDECPS .EQ. 0) GO TO 120
      ISIGFG = IEND - IDECPS
      IPLACE = 10**ISIGFG
      ROUND = 5.0/(FLOAT(IPLACE)*10.0)
      IRNUM = INT((RNUM+ROUND)*IPLACE)
      RNUM = FLOAT(IRNUM)/FLOAT(IPLACE)
C
C     PROCESSING COMPLETED, RETURN RESULTS
C
  120 RETURN
      END
```

```
      FUNCTION RCHAR(IN)
C
C     RCHAR -- PROGRAMMED BY JEFF FARRIS
C
C     THIS SUBPROGRAM CHANGES THE CHARACTER FORM OF A NUMBER
C     INTO ITS CORRECT INTEGER VALUE.
C     EXAMPLE:
C       '9' = 9
C       '0' = 0
C
      DIMENSION ITAB(10)
      DATA ITAB /'0', '1', '2', '3', '4', '5', '6',
     -           '7', '8', '9'/
C
C     LOOKUP CHARACTER IN TABLE (ITAB) AND BY POSITION
C     IN TABLE ASSIGN APPROPRIATE INTEGER VALUE.
C
      DO 10 I=1, 10
        IF (IN .NE. ITAB(I)) GO TO 10
        RCHAR = FLOAT (I - 1)
        RETURN
   10 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE BASE(BBASE,HTOT)
C     BASE -- 26 NOV 79 VERSION -- LARRY SCHULTZ
C
C     AUDIT VALIDATION ROUTINE.  FOR USE WITH ANY TYPE OF FUEL.
C
      IMPLICIT REAL (K)
      DIMENSION INSTR(10), NAME(20), ADD1(20), ADD2(20), RNAME(10),
     -          RADD1(10), RADD2(10)
      COMMON /CHECK/QHT,CHT,QCT,CCCCLT,QHTR,QCTR,EFACT,FACT2,TDIFFH
      COMMON /CODATA/NAME,ADD1,ADD2,RNAME,RADD1,RADD2,COUNTY,FA,
     - FCOL,RC,FTYP,FASF,FACS,RSF,SLABI,DUCTL,DUCTI,DA,RD,DAS,RDS,
     - GAS,GAN,GAE,GAW,GASD,GAND,GAED,GAWD,GAST,GANT,
     - GAET,GAWT,PL,WA,WC,PW,IC,FUH,CCOL,PNG,PLP,PEH,PEC,CCC,
     - SPF,DD,CCOLHR,IDDTYP,ICO,ICCOLH
      COMMON /USAGE/KJAN,KFEB,KMAR,KAPR,KMAY,KJUN,KJUL,KAUG,KSEP,KOCT,
     + KNOV,KDEC,KBASE,HJAN,HFEB,HMAR,HAPR,HMAY,HJUN,HJUL,HAUG,HSEP,
     + HOCT,HNOV,HDEC,HBASE,IHFLAG,ICFLAG,IDDFLG
       DOUBLE PRECISION COUNTY
C
C     ** DEFINE PERCENT ERROR FUNCTION
      ERR(EST,ACT) = (EST-ACT)/ACT*100.0
C
C     ** MAIN CALCULATIONS
      IF (FUH .GT. 2) GO TO 1111
      HTOT = (HJAN+HFEB+HMAR+HAPR+HOCT+HNOV+HDEC) - (HBASE*7.0)
      CTOT = (KMAY+KJUN+KJUL+KAUG+KSEP) - (KBASE * 5.0)
      GO TO 2222
1111  TOTK = KJAN+KFEB+KMAR+KAPR+KMAY+KJUN+KJUL+KAUG+KSEP+KOCT+KNOV+KDEC
      HTOT = (KJAN+KFEB+KMAR+KAPR+KOCT+KNOV+KDEC) - (KBASE * 7.0)
      HCTOT = TOTK - (KBASE * 12.0)
      CTOT = HCTOT - HTOT
      IF (HTOT .LE. 0.0) HTOT=1.0
      SPE= (24.0*DD*QHT*EFACT*FACT2)/(TDIFFH*3413.0*HTOT)
      IF (FUH .EQ. 1) CFACT = (HTOT*TDIFFH*1000000.0)/(24.0*DD*QHT)
      IF (FUH .EQ. 2) CFACT = (HTOT*TDIFFH*92000.0)/(24.0*DD*QHT)
      IF (FUH .EQ. 3) CFACT = (HTOT*TDIFFH*3413.0)/(24.0*DD*QHT)
      IF (FUH .GT. 4) CFACT = (HTOT*TDIFFH*3413.0*SPF)/(24.0*DD*QHT)
      PCT = ERR(SPF,SPE)
2222  IF (FUH .EQ. 1) PRICE = PNG
      IF (FUH .EQ. 2) PRICE = PLP
      IF (FUH .GT. 2) PRICE = PEH
      HCOST = HTOT * PRICE
      CCOST = CTOT * PEC
      HLPFT = QHT/FA
      HLPFTR= QHTR/FA
      CLPFT = QCT/FA
      CLPFTR= QCTR/FA
C
C     ** CALCULATE PERCENTAGE DIFFERENCES
      PCTDH = 0.0
      PCTDC = 0.0
      IF (HCOST .NE. 0.0) PCTDH = ERR(CHT,HCOST)
      IF (CCOST .NE. 0.0) PCTDC = ERR(CHT,CCOST)
      IF (FUH .LE. 2) BBASE = HBASE
      IF (FUH .GT. 2) BBASE = KBASE
      RETURN
      END
```

```
      SUBROUTINE TABLE1(COUNTY, DD, COOLHR, IRC, IDDTYP)
C
C     THIS IS A BLOCK OF CODE TO LOOK UP VARIABLES DD AND COOLHR
C     BY INPUTING THE COUNTY NAME.  PROVIDES ACTUAL DEGREE DAYS.
C
      DIMENSION CLIST(77), T(77,2)
      DOUBLE PRECISION COUNTY, CLIST
      IDDTYP = 2
      DATA CLIST( 1)/'ADAIR'       /,T( 1, 1),T( 1, 2)/1575.0,4145.0/,
     -     CLIST( 2)/'ALFALFA'     /,T( 2, 1),T( 2, 2)/1325.0,4796.0/,
     -     CLIST( 3)/'ATOKA'       /,T( 3, 1),T( 3, 2)/1765.0,3793.0/,
     -     CLIST( 4)/'BEAVER'      /,T( 4, 1),T( 4, 2)/1225.0,5162.0/
      DATA CLIST( 5)/'BECKHAM'     /,T( 5, 1),T( 5, 2)/1420.0,4246.0/,
     -     CLIST( 6)/'BLAINE'      /,T( 6, 1),T( 6, 2)/1450.0,4373.0/,
     -     CLIST( 7)/'BRYAN'       /,T( 7, 1),T( 7, 2)/1780.0,3535.0/,
     -     CLIST( 8)/'CADDO'       /,T( 8, 1),T( 8, 2)/1520.0,4122.0/
      DATA CLIST( 9)/'CANADIAN'    /,T( 9, 1),T( 9, 2)/1500.0,4353.0/,
     -     CLIST(10)/'CARTER'      /,T(10, 1),T(10, 2)/1740.0,3200.0/,
     -     CLIST(11)/'CHEROKEE'    /,T(11, 1),T(11, 2)/1580.0,5151.0/,
     -     CLIST(12)/'CHOCTAW'     /,T(12, 1),T(12, 2)/1780.0,3354.0/
      DATA CLIST(13)/'CIMARRON'    /,T(13, 1),T(13, 2)/ 950.0,5313.0/,
     -     CLIST(14)/'CLEVELAN'   /,T(14, 1),T(14, 2)/1610.0,4139.0/,
     -     CLIST(15)/'COAL'        /,T(15, 1),T(15, 2)/1755.0,3809.0/,
     -     CLIST(16)/'COMANCHE'    /,T(16, 1),T(16, 2)/1580.0,4008.0/
      DATA CLIST(17)/'COTTON'      /,T(17, 1),T(17, 2)/1625.0,3528.0/,
     -     CLIST(18)/'CRAIG'       /,T(18, 1),T(18, 2)/1480.0,4381.0/,
     -     CLIST(19)/'CREEK'       /,T(19, 1),T(19, 2)/1570.0,3938.0/,
     -     CLIST(20)/'CUSTER'      /,T(20, 1),T(20, 2)/1400.0,4107.0/
      DATA CLIST(21)/'DELAWARE'    /,T(21, 1),T(21, 2)/1520.0,4318.0/,
     -     CLIST(22)/'DEWEY'       /,T(22, 1),T(22, 2)/1400.0,4473.0/,
     -     CLIST(23)/'ELLIS'       /,T(23, 1),T(23, 2)/1300.0,5010.0/,
     -     CLIST(24)/'GARFIELD'    /,T(24, 1),T(24, 2)/1450.0,4469.0/
      DATA CLIST(25)/'GARVIN'      /,T(25, 1),T(25, 2)/1650.0,3737.0/,
     -     CLIST(26)/'GRADY'       /,T(26, 1),T(26, 2)/1590.0,3715.0/,
     -     CLIST(27)/'GRANT'       /,T(27, 1),T(27, 2)/1375.0,4555.0/,
     -     CLIST(28)/'GREER'       /,T(28, 1),T(28, 2)/1480.0,3736.0/
      DATA CLIST(29)/'HARMON'      /,T(29, 1),T(29, 2)/1490.0,3693.0/,
     -     CLIST(30)/'HARPER'      /,T(30, 1),T(30, 2)/1260.0,4569.0/,
     -     CLIST(31)/'HASKELL'     /,T(31, 1),T(31, 2)/1675.0,3914.0/,
     -     CLIST(32)/'HUGHES'      /,T(32, 1),T(32, 2)/1725.0,3992.0/
      DATA CLIST(33)/'JACKSON'     /,T(33, 1),T(33, 2)/1550.0,3605.0/,
     -     CLIST(34)/'JEFFERSO'   /,T(34, 1),T(34, 2)/1680.0,3499.0/,
     -     CLIST(35)/'JOHNSTON'    /,T(35, 1),T(35, 2)/1760.0,3420.0/,
     -     CLIST(36)/'KAY'         /,T(36, 1),T(36, 2)/1425.0,4880.0/
      DATA CLIST(37)/'KINGFISH'  /,T(37, 1),T(37, 2)/1475.0,4439.0/,
     -     CLIST(38)/'KIOWA'       /,T(38, 1),T(38, 2)/1510.0,4269.0/,
     -     CLIST(39)/'LATIMER'     /,T(39, 1),T(39, 2)/1740.0,3592.0/,
     -     CLIST(40)/'LEFLORE'     /,T(40, 1),T(40, 2)/1700.0,3605.0/
      DATA CLIST(41)/'LINCOLN'     /,T(41, 1),T(41, 2)/1550.0,4462.0/,
     -     CLIST(42)/'LOGAN'       /,T(42, 1),T(42, 2)/1500.0,4139.0/,
     -     CLIST(43)/'LOVE'        /,T(43, 1),T(43, 2)/1750.0,3471.0/,
     -     CLIST(44)/'MAJOR'       /,T(44, 1),T(44, 2)/1375.0,4298.0/
      DATA CLIST(45)/'MARSHALL'    /,T(45, 1),T(45, 2)/1780.0,3418.0/,
     -     CLIST(46)/'MAYES'       /,T(46, 1),T(46, 2)/1540.0,4362.0/,
     -     CLIST(47)/'MCCLAIN'     /,T(47, 1),T(47, 2)/1625.0,4084.0/,
     -     CLIST(48)/'MCCURTAI'   /,T(48, 1),T(48, 2)/1700.0,3661.0/
      DATA CLIST(49)/'MCINTOSH'    /,T(49, 1),T(49, 2)/1675.0,3691.0/,
     -     CLIST(50)/'MURRAY'      /,T(50, 1),T(50, 2)/1740.0,3691.0/,
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     -       CLIST(51)/'MUSKOGEE'     /,T(51, 1),T(51, 2)/1630.0,4010.0/,
     -       CLIST(52)/'NOBLE'        /,T(52, 1),T(52, 2)/1470.0,4316.0/
      DATA CLIST(53)/'NOWATA'         /,T(53, 1),T(53, 2)/1475.0,4307.0/,
     -       CLIST(54)/'OKFUSKEE'     /,T(54, 1),T(54, 2)/1625.0,3775.0/,
     -       CLIST(55)/'OKLAHOMA'     /,T(55, 1),T(55, 2)/1550.0,4223.0/
      DATA CLIST(56)/'OKMULGEE'       /,T(56, 1),T(56, 2)/1630.0,3984.0/,
     -       CLIST(57)/'OSAGE'        /,T(57, 1),T(57, 2)/1475.0,4350.0/,
     -       CLIST(58)/'OTTAWA'       /,T(58, 1),T(58, 2)/1450.0,4909.0/,
     -       CLIST(59)/'PAWNEE'       /,T(59, 1),T(59, 2)/1500.0,4258.0/
      DATA CLIST(60)/'PAYNE'          /,T(60, 1),T(60, 2)/1510.0,4546.0/,
     -       CLIST(61)/'PITTSBUR'     /,T(61, 1),T(61, 2)/1730.0,4079.0/,
     -       CLIST(62)/'PONTOTOC'     /,T(62, 1),T(62, 2)/1740.0,3696.0/,
     -       CLIST(63)/'POTTAWAT'     /,T(63, 1),T(63, 2)/1630.0,3823.0/
      DATA CLIST(64)/'PUSHMATA'       /,T(64, 1),T(64, 2)/1760.0,3759.0/,
     -       CLIST(65)/'ROGER MI'     /,T(65, 1),T(65, 2)/1375.0,4648.0/,
     -       CLIST(66)/'ROGERS'       /,T(66, 1),T(66, 2)/1530.0,4452.0/,
     -       CLIST(67)/'SEMINOLE'     /,T(67, 1),T(67, 2)/1680.0,3728.0/
      DATA CLIST(68)/'SEQUOYAH'       /,T(68, 1),T(68, 2)/1650.0,3663.0/,
     -       CLIST(69)/'STEPHENS'     /,T(69, 1),T(69, 2)/1650.0,3928.0/,
     -       CLIST(70)/'TEXAS'        /,T(70, 1),T(70, 2)/1125.0,5162.0/,
     -       CLIST(71)/'TILLMAN'      /,T(71, 1),T(71, 2)/1570.0,3933.0/
      DATA CLIST(72)/'TULSA'          /,T(72, 1),T(72, 2)/1550.0,4114.0/,
     -       CLIST(73)/'WAGONER'      /,T(73, 1),T(73, 2)/1570.0,4160.0/,
     -       CLIST(74)/'WASHINGT'     /,T(74, 1),T(74, 2)/1500.0,4242.0/,
     -       CLIST(75)/'WASHITA'      /,T(75, 1),T(75, 2)/1475.0,4206.0/
      DATA CLIST(76)/'WOODS'          /,T(76, 1),T(76, 2)/1300.0,4550.0/,
     -       CLIST(77)/'WOODWARD'     /,T(77, 1),T(77, 2)/1320.0,4896.0/
C
C     INITIALIZE RETURN CODE (IRC) TO 1
C     IF ERROR OCCURS IN COUNTY NAME RETURN CODE (IRC) IS SET TO 2
C
      IRC = 1
      DO 8500 I=1, 77
        IF (CLIST(I) .EQ. COUNTY) GO TO 8600
 8500 CONTINUE
      IRC = 2
      GO TO 8700
 8600 COOLHR = T(I,1)
      DD = T(I,2)
 8700 RETURN
      END
```

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      SUBROUTINE TABLE2(COUNTY, DD, COOLHR, IRC, IDDTYP)
C
C     THIS IS A BLOCK OF CODE TO LOOK UP VARIABLES DD AND COOLHR
C     BY INPUTING THE COUNTY NAME.  PROVIDES DEGREE DAYS FOR
C     '78 - '79 HEATING SEASON.
C
      DIMENSION CLIST(77), T(77,2)
      DOUBLE PRECISION COUNTY, CLIST
      IDDTYP = 2
      DATA CLIST( 1)/'ADAIR'     /,T( 1, 1),T( 1, 2)/1575.0,4023.0/,
     -     CLIST( 2)/'ALFALFA'   /,T( 2, 1),T( 2, 2)/1325.0,4587.0/,
     -     CLIST( 3)/'ATOKA'     /,T( 3, 1),T( 3, 2)/1785.0,3597.0/,
     -     CLIST( 4)/'BEAVER'    /,T( 4, 1),T( 4, 2)/1225.0,5222.0/
      DATA CLIST( 5)/'BECKHAM'   /,T( 5, 1),T( 5, 2)/1420.0,4298.0/,
     -     CLIST( 6)/'BLAINE'    /,T( 6, 1),T( 6, 2)/1450.0,4461.0/,
     -     CLIST( 7)/'BRYAN'     /,T( 7, 1),T( 7, 2)/1780.0,3712.0/,
     -     CLIST( 8)/'CADDO'     /,T( 8, 1),T( 8, 2)/1520.0,4156.0/
      DATA CLIST( 9)/'CANADIAN'  /,T( 9, 1),T( 9, 2)/1500.0,4410.0/,
     -     CLIST(10)/'CARTER'    /,T(10, 1),T(10, 2)/1740.0,3049.0/,
     -     CLIST(11)/'CHEROKEE'  /,T(11, 1),T(11, 2)/1580.0,4124.0/,
     -     CLIST(12)/'CHOCTAW'   /,T(12, 1),T(12, 2)/1780.0,3204.0/
      DATA CLIST(13)/'CIMARRON'  /,T(13, 1),T(13, 2)/ 950.0,5226.0/,
     -     CLIST(14)/'CLEVELAN' /,T(14, 1),T(14, 2)/1610.0,4033.0/,
     -     CLIST(15)/'COAL'      /,T(15, 1),T(15, 2)/1755.0,3597.0/,
     -     CLIST(16)/'COMANCHE'  /,T(16, 1),T(16, 2)/1580.0,3989.0/
      DATA CLIST(17)/'COTTON'    /,T(17, 1),T(17, 2)/1625.0,3532.0/,
     -     CLIST(18)/'CRAIG'     /,T(18, 1),T(18, 2)/1480.0,4536.0/,
     -     CLIST(19)/'CREEK'     /,T(19, 1),T(19, 2)/1570.0,3829.0/,
     -     CLIST(20)/'CUSTER'    /,T(20, 1),T(20, 2)/1400.0,4272.0/
      DATA CLIST(21)/'DELAWARE'  /,T(21, 1),T(21, 2)/1520.0,4296.0/,
     -     CLIST(22)/'DEWEY'     /,T(22, 1),T(22, 2)/1400.0,4549.0/,
     -     CLIST(23)/'ELLIS'     /,T(23, 1),T(23, 2)/1300.0,5077.0/,
     -     CLIST(24)/'GARFIELD'  /,T(24, 1),T(24, 2)/1450.0,4565.0/
      DATA CLIST(25)/'GARVIN'    /,T(25, 1),T(25, 2)/1650.0,3962.0/,
     -     CLIST(26)/'GRADY'     /,T(26, 1),T(26, 2)/1590.0,3750.0/,
     -     CLIST(27)/'GRANT'     /,T(27, 1),T(27, 2)/1375.0,4671.0/,
     -     CLIST(28)/'GREER'     /,T(28, 1),T(28, 2)/1490.0,3875.0/
      DATA CLIST(29)/'HARMON'    /,T(29, 1),T(29, 2)/1490.0,3808.0/,
     -     CLIST(30)/'HARPER'    /,T(30, 1),T(30, 2)/1260.0,4617.0/,
     -     CLIST(31)/'HASKELL'   /,T(31, 1),T(31, 2)/1675.0,3549.0/,
     -     CLIST(32)/'HUGHES'    /,T(32, 1),T(32, 2)/1725.0,3736.0/
      DATA CLIST(33)/'JACKSON'   /,T(33, 1),T(33, 2)/1550.0,4183.0/,
     -     CLIST(34)/'JEFFERSO' /,T(34, 1),T(34, 2)/1680.0,3281.0/,
     -     CLIST(35)/'JOHNSTON'  /,T(35, 1),T(35, 2)/1760.0,3416.0/,
     -     CLIST(36)/'KAY'       /,T(36, 1),T(36, 2)/1425.0,5160.0/
      DATA CLIST(37)/'KINGFISH'/,T(37, 1),T(37, 2)/1475.0,4558.0/,
     -     CLIST(38)/'KIOWA'     /,T(38, 1),T(38, 2)/1510.0,4341.0/,
     -     CLIST(39)/'LATIMER'   /,T(39, 1),T(39, 2)/1740.0,3835.0/,
     -     CLIST(40)/'LEFLORE'   /,T(40, 1),T(40, 2)/1700.0,3438.0/
      DATA CLIST(41)/'LINCOLN'   /,T(41, 1),T(41, 2)/1550.0,4006.0/,
     -     CLIST(42)/'LOGAN'     /,T(42, 1),T(42, 2)/1500.0,3929.0/,
     -     CLIST(43)/'LOVE'      /,T(43, 1),T(43, 2)/1750.0,3314.0/,
     -     CLIST(44)/'MAJOR'     /,T(44, 1),T(44, 2)/1375.0,4865.0/
      DATA CLIST(45)/'MARSHALL'  /,T(45, 1),T(45, 2)/1780.0,3257.0/,
     -     CLIST(46)/'MAYES'     /,T(46, 1),T(46, 2)/1540.0,4614.0/,
     -     CLIST(47)/'MCCLAIN'   /,T(47, 1),T(47, 2)/1625.0,3813.0/,
     -     CLIST(48)/'MCCURTAI' /,T(48, 1),T(48, 2)/1700.0,3457.0/
      DATA CLIST(49)/'MCINTOSH'  /,T(49, 1),T(49, 2)/1675.0,4015.0/,
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     -      CLIST(50)/'MURRAY'      /,T(50, 1),T(50, 2)/1740.0,3517.0/,
     -      CLIST(51)/'MUSKOGEE'    /,T(51, 1),T(51, 2)/1630.0,4160.0/,
     -      CLIST(52)/'NOBLE'       /,T(52, 1),T(52, 2)/1470.0,4223.0/
      DATA  CLIST(53)/'NOWATA'      /,T(53, 1),T(53, 2)/1475.0,4516.0/,
     -      CLIST(54)/'OKFUSKEE'    /,T(54, 1),T(54, 2)/1625.0,3880.0/,
     -      CLIST(55)/'OKLAHOMA'    /,T(55, 1),T(55, 2)/1550.0,4279.0/
      DATA  CLIST(56)/'OKMULGEE'    /,T(56, 1),T(56, 2)/1630.0,3896.0/,
     -      CLIST(57)/'OSAGE'       /,T(57, 1),T(57, 2)/1475.0,4507.0/,
     -      CLIST(58)/'OTTAWA'      /,T(58, 1),T(58, 2)/1450.0,4891.0/,
     -      CLIST(59)/'PAWNEE'      /,T(59, 1),T(59, 2)/1500.0,4190.0/
      DATA  CLIST(60)/'PAYNE'       /,T(60, 1),T(60, 2)/1510.0,4605.0/,
     -      CLIST(61)/'PITTSBUR'    /,T(61, 1),T(61, 2)/1730.0,3899.0/,
     -      CLIST(62)/'PONTOTOC'    /,T(62, 1),T(62, 2)/1740.0,3569.0/,
     -      CLIST(63)/'POTTAWAT'    /,T(63, 1),T(63, 2)/1630.0,3916.0/
      DATA  CLIST(64)/'PUSHMATA'    /,T(64, 1),T(64, 2)/1760.0,3626.0/,
     -      CLIST(65)/'ROGER MI'    /,T(65, 1),T(65, 2)/1375.0,4965.0/,
     -      CLIST(66)/'ROGERS'      /,T(66, 1),T(66, 2)/1530.0,4719.0/,
     -      CLIST(67)/'SEMINOLE'    /,T(67, 1),T(67, 2)/1690.0,3557.0/
      DATA  CLIST(68)/'SEQUOYAH'    /,T(68, 1),T(68, 2)/1650.0,3568.0/,
     -      CLIST(69)/'STEPHENS'    /,T(69, 1),T(69, 2)/1650.0,3715.0/,
     -      CLIST(70)/'TEXAS'       /,T(70, 1),T(70, 2)/1125.0,5354.0/,
     -      CLIST(71)/'TILLMAN'     /,T(71, 1),T(71, 2)/1570.0,3986.0/
      DATA  CLIST(72)/'TULSA'       /,T(72, 1),T(72, 2)/1550.0,4228.0/,
     -      CLIST(73)/'WAGONER'     /,T(73, 1),T(73, 2)/1570.0,4223.0/,
     -      CLIST(74)/'WASHINGT'    /,T(74, 1),T(74, 2)/1500.0,4323.0/,
     -      CLIST(75)/'WASHITA'     /,T(75, 1),T(75, 2)/1475.0,4200.0/
      DATA  CLIST(76)/'WOODS'       /,T(76, 1),T(76, 2)/1300.0,4644.0/,
     -      CLIST(77)/'WOODWARD'    /,T(77, 1),T(77, 2)/1320.0,4976.0/
C
C     INITIALIZE RETURN CODE (IRC) TO 1
C     IF ERROR OCCURS IN COUNTY NAME RETURN CODE (IRC) IS SET TO 2
C
      IRC = 1
      DO 8500 I=1, 77
        IF (CLIST(I) .EQ. COUNTY) GO TO 8600
 8500 CONTINUE
      IRC = 2
      GO TO 8700
 8600 COOLHR = T(I,1)
      DD = T(I,2)
 8700 RETURN
      END
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VITA

Lyndell Ken Jones

Candidate for the Degree of

Doctor of Philosophy

Thesis: PREDICTING SEASONAL HEATING ENERGY CONSUMPTION FOR OKLAHOMA RESIDENCES

Major Field: Agricultural Engineering

Biographical:

Personal Data: Born in Sentinel, Oklahoma, April 10, 1951, the son of Kenneth E. and Frieda F. Jones; married Susan Cox in 1971; daughter, Jennifer Ann, born September 10, 1973; son, Mitchell Ken, born May 26, 1977.

Education: Graduated from Cordell High School, Cordell, Oklahoma in May, 1969. Attended Cameron State Agricultural College in 1969 and 1970; received a Bachelor of Science degree in Agricultural Engineering from Oklahoma State University in May, 1973; received a Master of Science degree in Agricultural Engineering from Oklahoma State University in July, 1974; completed requirements for Doctor of Philosophy degree at Oklahoma State University in December, 1981.

Professional Experience: Graduate Research Assistant at Oklahoma State University, May, 1973 to July, 1974; Civil Engineer, U.S. Army Corp of Engineers, Tulsa, Oklahoma, July, 1974 to July, 1975; Agricultural Engineer, U.S.D.A. Soil Conservation Service, Duncan, Oklahoma, July, 1975 to October, 1975; Area Engineer, U.S.D.A. Soil Conservation Service, Perry, Oklahoma, October, 1975 to January, 1978; Assistant Professor of Agricultural Engineering and Extension Energy Specialist, Oklahoma State University, January, 1978 to present.

Professional Organizations: Associate Member of the American Society of Agricultural Engineers.