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Simplified Heating and Cooling Energy Analysis Calculations for Residential Applications

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National Bureau of Standards
National Engineering Laboratory
Center for Building Technology
U.S. Department of Commerce
Washington, DC 20234

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[ ] Document describes a computer program; SF-185, FIPS Software Summary, is attached.

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In order to shorten the lengthy computational labor and cost common to most existing hourly simulation computer programs, a simplified energy calculation procedure was developed for the evaluation of energy conservation effectiveness of home retrofitting. The procedure utilizes monthly normal weather parameters such as temperature, humidity, wind data, and solar radiation, in lieu of the traditional degree-day procedure.

The thermal time constant was used to account for the effect of building thermal mass on seasonal heat transfer performance. In addition to standard retrofit procedures such as addition of thermal insulation, use of storm windows, and sealing of cracks, included in the procedure are the energy conservation effects due to the use of solar collectors, hot water tank insulation, and insulation around the heat distribution systems such as ducts and pipes.

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Simplified Heating and Cooling Energy Analysis
Calculation for Residential Applications

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Washington, D.C. 20234

ABSTRACT

In order to reduce the lengthy computational labor and costs common to most existing hourly simulation computer programs, a simplified energy calculation procedure suitable for a handheld calculator was developed for the evaluation of home retrofitting with respect to energy conservation. The procedure utilizes monthly normal weather parameters such as temperature, humidity, wind data, and solar radiation, in lieu of the traditional degree-day procedure.

The thermal time constant was used to account for the effect of building thermal mass on seasonal heat transfer performance. In addition to standard retrofit procedures such as addition of thermal insulation, use of storm windows, and sealing of cracks, this calculation includes energy conservation effect due to the use of solar collectors, hot water tank insulation, and insulation around the heat distribution systems such as ducts and pipes.

Also included are comparative annual heating and cooling requirements determined by the simplified procedure and that calculated by the DOE-2 computer program for a typical residence.

Keywords: Energy analysis calculation; energy retrofit; home audit; thermal time constant.

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* Guest worker from Ohbayashi-Gumi, Tokyo, Japan.

TABLE OF CONTENTS

1. INTRODUCTION

The purpose of this report is to describe detailed algorithm, data base and Fortran listing of a simplified home energy analysis procedure suitable for small computer or pocket calculator. This simplified procedure was originally developed for DOE to assist the state and local government energy officials who are making economic benefit analyses of various home improvement options, such as insulation, storm windows, hot water tank insulation, insulation around pipes and ducts, etc.

The procedure calculates the annual energy requirement calculations for heating and cooling of single-family residences in conjunction with the Department of Energy Project Home Energy Audit questionnaire and economic analysis. Since the Project Home Energy Audit Program mandated that the computation time, equivalent to the UNIVAC 1100 CPU (Central Processing Unit) time, is to be within 3 seconds, it precluded the comprehensive hourly simulation procedures such as used in BLAST, DOE-2, and NBSLD.

A scheme adopted in the DoE Home Energy Audit calculation procedure is to develop a simplified yet relatively comprehensive heating and cooling load calculation routine where most of the major building heat transfer elements are addressed in an approximate manner. The results of the calculation obtained by this simplified routine are then compared against those obtained from a DOE-2,[2/] the comprehensive hourly simulation computer program designated as the Standard Evaluation Technique for Building Energy Performance Standards, for a ranch house.

2. OVERALL ALGORITHMIC STRUCTURE

The flow chart for the simplified procedure is shown in Figure 1, and detailed algorithms, including Fortran listing, for each of the subroutines are given in the following sections.

The basic scheme of the calculation is to detemine monthly normal values of daytime and nighttime heat gains (heat loss will be considered a negative heat gain) separately for all of the major heat exchange components, and to integrate them into monthly normal daytime and nighttime heating and cooling requirements.

In Figure 1, all of the major heat gain (loss) through various elements of building envelope is denoted with symbols ending with D and N, indicating daytime heat gain and nighttime heat gain, respectively.

Although not described in detail in this report, a special subroutine, SOLDAT, was developed to generate daily total solar radiation data for the normal day for each of 12 months for any given orientation and tilt angle of the wall in a given locality, while a separate routine called SAT determines the normal daily average sol-air temperature to be applicable for the calculation of heat gain through walls, roofs, and doors. Detailed documentation for SOLDAT can be found in reference 2.

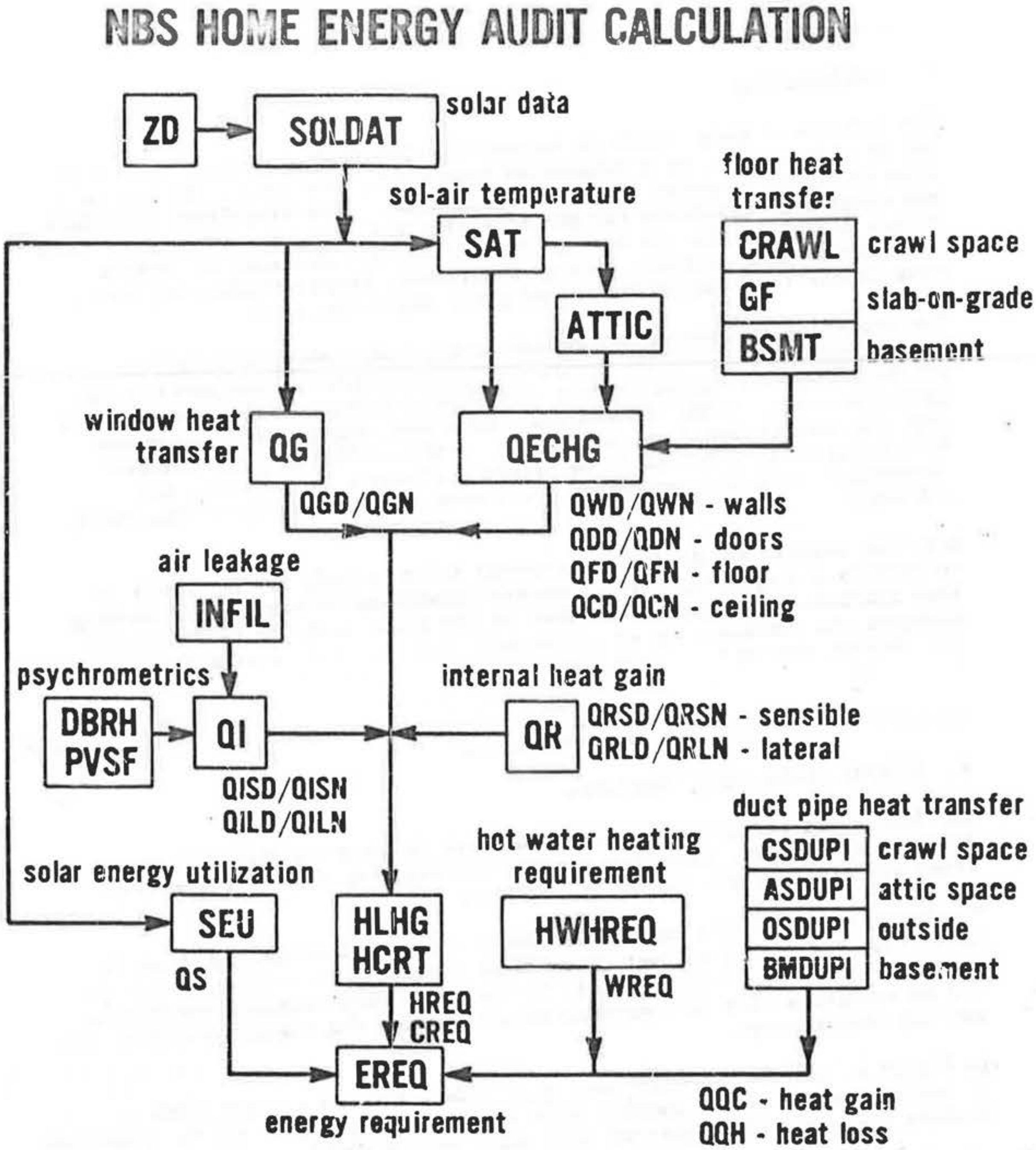

Figure 1. Flow chart of the Heating and Cooling Load Program

Where the roof has ventilated attic space, the program determines the attic space temperature based upon heat balance, which is in turn used to determine the heat gain through the ceiling.

The SOLDAT routine will also provide the solar radiation data for the solar collectors, which may be available in some of the energy conservation designs. The solar collector performance will be simulated by a simplified linear relationship between the collector efficiency and $\Delta T/I$, where ΔT represents the average temperature difference between the outdoor air and collector inlet fluid temperatures, while I represents the daily average of hourly solar insolation.

Heat gain from the floors is determined by the use of special algorithms to simulate the heat transfer process of basement, slab-on-grade, and crawl space under the floor, respectively.

In addition, there are several other subroutines in the calculation, such as INFIL to determine the air leakage rate, DBRH to determine the moist air properties, and subroutines to determine the energy loss from hot water tanks, ducts and pipes.

The major distinction of the present method from the existing degree-day or bin procedures is that the new method is based upon the monthly normal day data for each of the 12 months of the year. The monthly normal data needed are:

daytime average temperature
nighttime average temperature
total solar radiation upon horizontal surface
average relative humidity (morning and afternoon)
average wind speed
ground temperature

for the normal days of the month.

Fortunately, these data are available in the existing literature for most of the major Weather Bureau stations throughout the United States. The Liu and Jordan paper, entitled, "Availability of Solar Energy for Flat-Plate Solar Collectors," ASHRAE Symposium on Low Temperature Engineering Applications of Solar Energy, 1967, provides the average daytime temperature and the solar radiation data for more than 80 stations in the United States (see Appendix A). A U.S. Weather Bureau publication called "Comparative Climatic Data Through 1976"* provides the long-period (30 years or more) normals and extremes of monthly average temperature, precipitation, relative humidity, and wind data.

Ground temperature data, previously developed by Kusuda and Achenbach, shown in Appendix B, are also employed for the heat transfer calculation for slab-on-grade floor, basement walls and basement floor.

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* For sale by the National Climatic Center, Federal Bldg., Asheville, N.C., 28801 (Tel. 704-258-2850, X 683). $1.50 copy.

4.4. SOLAR ABSORPTIVITY, ABS

These data are used to determine the outside surface temperature of exterior walls as influenced by the solar radiation data. Typical values are:

for very dark surface	0.95
medium dark surface	0.7
light surface	0.4

4.5. SHADOW FACTORS, SHDW

This factor indicates how much of the exterior surface is shaded from direct sun by adjacent buildings, exterior shading devices, or by trees. Typical figures are:

if completely shaded	1.0
if partially shaded	0.5
if not shaded at all	0.

4.6. SHADING COEFFICIENT, SC

This factor relates to the internal shading devices used for the windows. Typical values for a single glaze window are:

for venetian blinds	0.5
roller shades	0.4
tinted films	0.3.

4.7. WALL ORIENTATION, WAZ

These data indicate the orientation of walls and windows, measured clockwise from the south. Thus, for example,

WAZ = 0 for south-facing wall/window/door
WAZ = 90 for west
WAZ = 180 for north
WAZ = 270 for east.

4.8. WALL TILT ANGLE, WTLT

These data are for the slant angle of the walls or windows. For most construction, the value is 90° for walls and windows and 0° for roofs. For solar collectors, the actual tilt angle will be used and will usually be an angle other than 0° or 90°.

5. SUBROUTINE ALGORITHMS

5.1. SOLDAT

Using the Liu/Jordan method [2/], this program generates 12 monthly values of total solar radiation over the roofs, floors, walls, windows, and solar collectors. The details of the calculation procedure are given in NBS Building Sciences Series 96 entitled "Hourly Solar Radiation Data for Vertical and Horizontal Surfaces on Average Days in the United States and Canada." This routine also includes the shadow effect of the roof overhang upon the direct radiation incident on a given vertical surface.

Input:
- XLAT = latitude, degree
- WAZ = wall azimuth angle, degrees from south
- WTLT = wall tilt angle, degree from horizontal surface
- ZKT = Liu/Jordan constants
- H = daily normal solar radiation over a horizontal surface Btu/ft^2 [1]
- RHO = ground reflectance
- TOWN = zip code
- OVHANG = roof overhang, ft
- WALLHT = wall height, ft

Output:
- XIDT = daily total solar radiation, Btu/hr ft^2
- XIDD = daily total diffuse sky radiation, Btu/hr ft^2
- HRDAY = daytime hours, hr
- HRNIT = nighttime hours, hr

5.2. SAT

Sol-air temperature routine

Input:
- WTLT = tilt angle, degrees from horizontal surface
- It = incident total solar insolation, Btu/day ft^2
- Id = incident sky radiation, Btu/day ft^2
- SHDW = shadow factor

  0 = no shadow
  0.5 = partial shadow
  1.0 = complete show

- AB = surface absorptivity
- FO = surface heat transfer coefficient, Btu/h ft^2 °F
  = 4 for J,J,A
  = 5 for M,A,M,S,O,N
  = 6 for D,J,F
- TOD = daytime temperature, °F
- TON = nighttime temperature, °F
- HRDAY = daytime hours, hr

Total radiation incident upon a surface

$$I = (It-Id) * (1-SHDW) + Id$$

Output: Sol-air temperature

Daytime $$SATD = TOD + \frac{AB*I}{HRDAY*FO} \quad \frac{10^{*/}}{FO} * \cos(WTLT)$$

$$\text{Nighttime} \quad SATN = TON - \overline{FO}^{\,10^{*/}} * \cos(WTLT)$$

5.3. INFIL

Infiltration calculation, cfm

Input: V = volume of the room, ft^3
ACHS = standard air change data, air change/hr
TO = outdoor temperature, °F = (TOD + TON)/2
TI = indoor temperture, °F = (TID + TIN)/2
WS = wind speed, mph

AC (air leakage rate) = (ACHS/0.695)* [0.15 + 0.013 * WS + 0.005 * ABS (TO-TI)]±/

Standard Air Leakage Data (ACHS)

In lieu of the crack method, hourly air-change values are to be provided because there are more experimentally measured data reported by the use of He and SF_6 tracer gas dilution technique. Recommended values are as follows:

Living space: 1.5 for leaky building
1.0 for standard building
0.5 for modern-type building

Attic space: mechanical ventilation 20 Ac/hr
natural ventilation 6 Ac/hr

Crawl space: 3 Ac/hr

Output: Air leakage rate

$$RINFIL = (V) * \frac{AC}{60} \quad , ft^3/m \text{ (cfm)}$$

---

*/ Assumed average sky heat loss: 10 Btu/hr, ft^2.

±/ Modified Achenbach/Coblenz equation.
"Field Measurements of Air Infiltration in Ten Electrically Heated Houses" ASHRAE Trans. 69, 1963, pp. 358-365.
DoE - 2 program uses, however, different equations such as
AC = 0.252 + 0.0218 * WS + 0.0084 * ABS (TO-TS)

5.4. ATTIC

Attic temperature calculation

Input:

AR = roof area, ft^2
TRD = daytime roof sol-air temperature, °F
TRN = nighttime roof sol-air temperature, °F
AC = ceiling area, ft^2
TAD = daytime room temperature, °F
TAN = nighttime room tepperture, °F
AW = end wall area, ft^2
TWD = daytime end wall sol-air temperature, °F (average of two end walls)
TWN = nighttime end wall sol-air temperature, °F
CFM = air flow, ft^3/min
UR, UC, UW = U-value for roof, ceiling and end walls, Btu/h ft^2 °F
TOD = daytime outdoor air temperature, °F
TON = nighttime outdoor air temperature, °F

Output: Attic temperature (daytime and nighttime)

$$ATTICD = \frac{UR*AR*TRD + UW*AW*TWD + UC*AC*TAD + 1.08*CFM*TOD}{UR*AR + UW*AW + UC*AC + 1.08*CFM}$$

$$ATTICN = \frac{UR*AR*TRN + UW*AW*TWN + UC*AC*TAN + 1.08*CFM*TON}{UR*AR + UW*AW + UC*AC + 1.08*CFM}$$

ATTICD = TID
ATTICN = TIN
if attic temperature is controlled

5.5. CRAWL

Crawl space temperature routine

Input: Daytime and nighttime crawl space temperatures

TOD = daytime outdoor temperature, °F
TON = nighttime outdoor temperature, °F
TG = ground temperature, °F
TAD = daytime room temperature, °F
TAN = nighttime room temperature, °F
TWD = daytime wall sol-air temperature, °F
TWN = nighttime wall sol-air temperature, °F
CFM = air flow rate, ft^3/min
UF = floor heat transfer coefficient, Btu/h ft^2 °F
UW = wall heat transfer coefficient,Btu/hr ft^2 °F
UG = ground surface heat transfer coefficient = 0.1, Btu/h ft^2 °F

AW = crawl space wall area, ft^2
AF = floor area, ft^2

Output:

$$CRAWLN = \frac{UF*TAD*AF + UW*TWD*AW + UG*(TG + TOD)*AF/2 + 1.08*CFM*TOD}{UF*AF + UW*AW + UG*AF + 1.08*CFM}$$

$$CRAWLN = \frac{UF*TAN*AF + UW*TWN*AW + UG*(TG + TON)*AF/2 + 1.08*CFM*TON}{UF*AF + UW*AW + UG*AF + 1.08*CFM}$$

5.6. GF

Ground floor heat transfer routine (slab-on-grade floor)

Input:

AF = floor area, ft^2
P = exposed perimeter length, ft
WT = wall thickness, ft
TAD = daytime room temperature, °F
TAN = nighttime room temperature, °F
TOD = daytime outdoor temperature, °F
TON = nighttime outdoor temperature, °F
R = Thermal resistance of hour layers, which is between the room air and the floor slab-ground interface,
ZK = Ground thermal conductivity Btu-in/h ft^2 °F

Calculation Procedure

The slab-on-grade heat transfer calculation presented herein is based upon an exact solution of Muncey and Spencer[37].

The Base Ground Thermal Resistance RS shown in Fig. 3 was precalculated for a square slab of 40 ft x 40 ft over a ground of thermal conductivity 12 Btu-in/h ft^2 °F.

In order to correct the value of RS for the specific slab under consideration, which would be different from the basic structure, the three correction factors α, β and FS are needed.

The Perimeter length correction factor

$$\alpha = P/160$$

The Conductivity correction factor

$$\beta = ZK/12$$

The slab shape correction factor FS can be determined from Fig. 4 by knowing $AF/\left(\frac{P}{4}\right)^2$

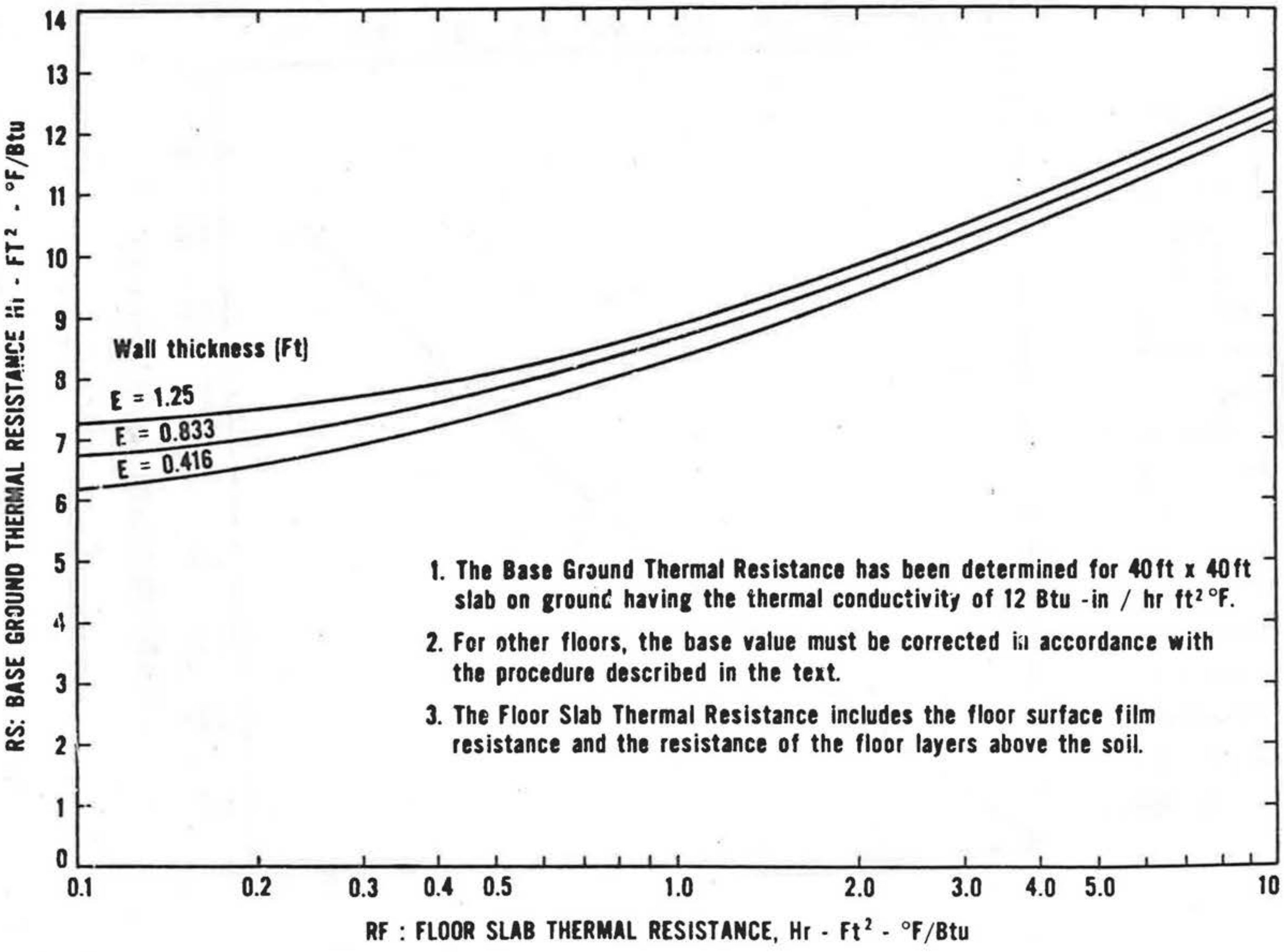


Figure 3. Thermal resistance of slab-on-grade floor.

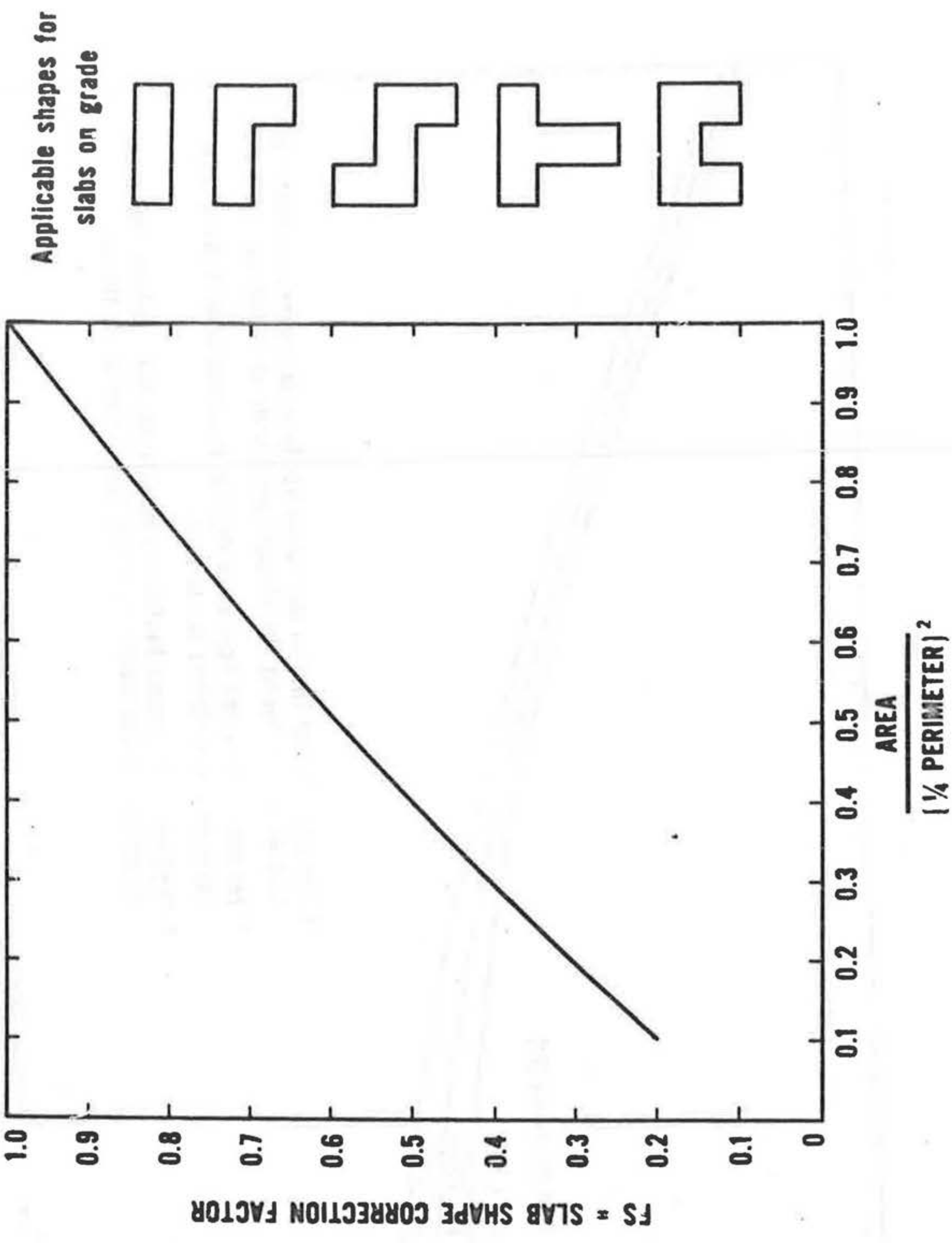


Figure 4. Shape correction factor for the slab-on-grade floor.

Calculation

$$RF = \frac{\beta}{(\alpha * UF)}: \text{ adjusted floor resistance}$$

$$E = \frac{WT}{\alpha} \quad \text{adjusted wall thickness}$$

Read from Figure 2 the value of RS corresponding to these RF and E data.

Ground Thermal Resistance:

$$RG = \frac{\alpha}{\beta} * RS * FS$$

Overall heat transfer coefficient of the slab-on-grade floor:

$$UF = \frac{1}{(RG + R)}$$

Heat loss through the slab-on-grade floor:

daytime: QFD = UF * AF * (TAD-TO)
nighttimes: QFN = UF * AF * (TAN-TO)

$$\text{where } TO = \frac{TOD+TON}{2}$$

5.7. QG

Window heat gain routine

Input:

AG = glass area, ft^2
SC = shading coefficient
UG = heat transfer coefficient, Btu/h ft^2 °F
TOD = daytime outdoor temperature, °F
TON = nighttime outdoor temperature, °F
TID = daytime indoor temperature, °F
TIN = nighttime indoor temperature, °F
SHDW = external shadow factor

0. = no shadow
0.5 = partial shadow
1.0 = complete shadow

It = total incident solar radiation, Btu/day ft^2
Id = diffuse sky radiation, Btu/day, ft^2
HRDAY = daytime hours, hr
HRNIT = nighttime hours, hr

Output: Daytime and nighttime window heat gain

I = (It-Id)*(1-SHDW) + Id

Daytime QGD = AG* [I*(SC)*0.87 + UG* (TOD-TID)* HRDY]
Nighttime QGN = AG* [UG*(TON-TIN)* HRNIT]

5.8. HLHG

Heat loss and heat gain calculations

Input:

QID = daytime infiltration heat gain, Btu/day
QIN = nighttime infiltration heat gain, Btu/day
QWD = daytime wall heat gain, Btu/day
QWN = nighttime wall heat gain, Btu/day
QDD = daytime door heat gain, Btu/day
QDN = nighttime door heat gain, Btu/day
QCD = daytime ceiling heat gain, Btu/day
QCN = nighttime ceiling heat gain, Btu/day
QGD = daytime window heat gain, Btu/day
QGN = nighttime window heat gain, Btu/day
QFD = daytime floor heat gain, Btu/day
QFN = nighttime floor heat gain, Btu/day
QRD = daytime internal heat gain, Btu/day
QRN = nighttime internal heat gain, Btu/day

The above values will be negative if they are heat loss.

THTC = thermal time constant, hr
SGD = daytime solar heat gain through windows, Btu/day
CFM = air leakage, cu ft/min
U_i (i = 1,2,..N) = overall heat transfer coefficient of each of the building envelope elements, Btu/h ft^2 °F
Ai(i=1,2,..N) = area of each of the building envelope elements, ft^2
N = total number of building envelope elements
IACNV = natural ventilation index: = 1 if open windows in summer when oudoor temp. < thermostat setting.
= 0 if never open windows.
PUH = pick-up time or pull-down time (see Appendix E)
HRDAY = daytime hours, hr
HRNIT = nighttime hours, hr

Output:

HLD = daytime sensible heating load, Btu/day
HLN = nighttime sensible heating load, Btu/day
CLD = daytime sensible cooling load, Btu/day
CLN = nighttime sensible cooling load, Btu/day

Calculation Procedure

This routine uses the building thermal time constant (THTC) concept, detail of which is given in the Appendix E.

Total envelope heat gain

daytime

$$QTD = QID + QWD + QDD + QGD + QFD + QRD + QCD$$

nighttime

$$QTN = QIN + QWN + QDN + QGN + QFN + QRN + QCN$$

If TID = TIN

HLD = QTD if OTD<0
HLN = QTN if QTN<0
CLD = QTD if QTD>0
CLN = QTN if QTN>0

otherwise the following calculations are necessary

Envelope heat transfer factor

$$ZK = \sum_{i=1}^{N} U_i A_i + 1.08 * CFM$$

also let

$$ZX = EXP \left(\frac{-PUH}{THTC} \right)$$

$$ZY = EXP \left(\frac{-12+PUH}{THTC} \right)$$

Cooling season calculations: (QTD>0 and QTN>0)

PULDWN: Evening pull-down cooling requirement necessary to lower the building temperature from TID of daytime to TIN of nighttime within a specified pickup period of PUH hours.

$$PULDWN = ZK * \left(TON - TID + \frac{(TID-TIN)}{1-ZX} \right) *PUH$$

DH = duration of morning warm-up hour during which the cooling is off

$$DH = THTC * \ln \left(\frac{ZQ-TIN+TOD+TD}{ZQ-TID+TOD} \right)$$

where $ZQ = \frac{SGD+QRD}{HRDAY*ZK}$

CON: total daytime cooling hour

$$CON = HRDAY - DH$$

daytime cooling load

$$QTD = QTD * CON/12$$

QTN: actual nighttime cooling requirement

$$CLN = \frac{QTN*(HRNIT-PUH)}{HRNIT} + PULDWN * PUH$$

If the natural cooling is used as

if IACNV=1, CLD=0 for TOD $\leq$ TID

CLN=0 for TON $\leq$ TIN

Heating season calculations: (QTD<0 and QTN<0)

PICKUP: early morning pick-up heating requirement necessary to raise the building temperatures from TIN to TID within PUH hours

$$PICKUP = ZK * \left((TIN - TOD) + \frac{(TID-TIN)}{1-ZX} \right) *PUH$$

DH: duration of evening cool-down hours during which the heating system is off

$$DH = THTC* \ln \left(\frac{TID+TD-TON-ZQ}{TIN-TON-ZQ} \right)$$

when $ZQ = \frac{QRN}{ZK*HRNIT}$

CON: total heating hours

$$CON = HRNIT-DH$$

daytime heating load

$$HCD = \frac{QTD*(HRNIT-PUH)}{HRNIT} - PICKUP * PUH$$

nighttime heating requirement

HLN = QTN*CON/HRNIT

5.9. HCRT: Heating and cooling requirement calculations

Input:

HLD = daytime sensible heating load, Btu/day
HCN = nighttime sensible heating load, Btu/day
CLD = daytime sensible cooling load, Btu/day
CLN = nighttime sensible cooling load, Btu/day
HL = daily sensible heat load = HLD + HLN
HG = daily sensible cooling load = CLD + CLN
RLGH = latent heat gain
AIRLOS = air leakage through ducts = $\frac{\text{AIR LOSS}}{\text{supply air}} \times 100\%$

Heating requirement: HREQ = HL * (1.0 + AIRLOS/100)

if cooling season, HREQ = 0

Cooling requirements: CREQ = (HG + LHG) * (1.0 + AIRLOS/100)

if open windows in summer when outdoor temp. < thermostat setting, LHG = 0

if heating season, CREQ = 0

5.10. EREQ: Energy requirement

Input:

HREQ = heating requirement
CREQ = cooling requirement
EH = heating efficiency
EC = cooling efficiency
WHREQ = hot water heating requirement
QS = energy from solar collector
QQC = heat gain through ducts and pipes
QQH = heat loss through ducts and pipes
ISYS = system index

1 = heating + no cooling
2 = no heating + cooling
3 = heating + cooling

Output:

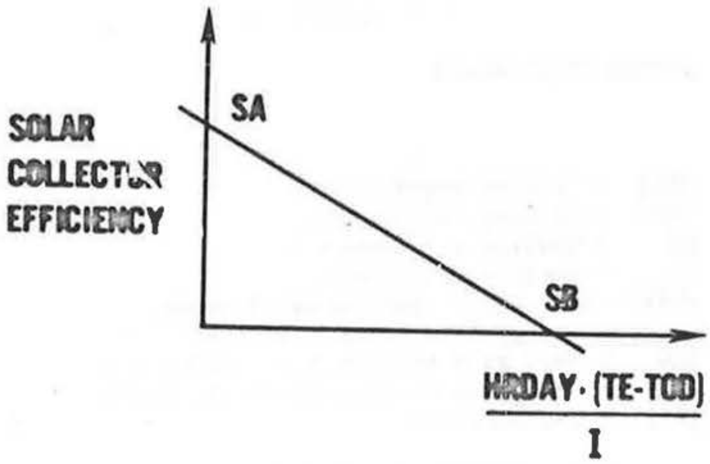
EREQ (Energy Requirement)

System Index	Heating Energy Requirement	Cooling Energy Requirement
ISYS = 1	(HREQ + WHREQ + QS + QQH)/EH	0
2	(WHREQ + QS + QQH)/EH	(CREQ + QQC)
3	(HREQ + WHREQ + QS + QQH)/EH	(CREQ + QQC)

5.11. SEU: Solar collector heat gain

Input:

SA, SB = Collector efficiency curve data



Typical solar collector performance.

	SA	SB
High Performance	0.8	1.2
(double glaze, selective surface)		
Medium Performance	0.75	1.0
(double glaze, common black)		
(single glaze, selective surface)		
Low Performance (single glaze, common black)	0.7	0.8

TE = inlet fluid temperature to the collector, °F
TOD = daytime outdoor temperature, °F
I = daily total solar radiation, Btu/day
SUF = solar heat utilization factor

0.8 for large storage tank system
0.5 for small storage tank system

AS = collector area, ft^2
HRDAY = daytime hours, hr

Solar heat utilized

$$QS = AS*SA*\left(1 - \frac{HRDAY*(TE-TOD)}{SB*I}\right)*SUF*I$$

5.12. QI: Infiltration heat gain

Input:

INFIL = infiltration rate, cfm
TOD = daytime outdoor temperature, °F
TON = nighttime outdoor temperature, °F
TID = daytime indoor temperature, °F
TIN = nighttime indoor temperature, °F
RH = room relative humidity, %
RHA = afternoon outdoor relative humidity, %
RHM = morning outdoor relative humidity, %
HRDAY = daytime hours
HRNIT = nighttime hours

Output:

Daytime sensible heat gain
QID = 1.08*INFIL* (TOD-TID)*HRDAY
Nighttime sensible heat gain
QIN = 1.08*INFIL*(TON-TIN)*HRNIT

Latent heat

Determine the humidity ratio of indoor and outdoor air from psychrometric chart or by calling the psychrometric routine described in (5.15).

Calculate indoor humidity ratio WIN and WID by nighttime Call DBRH (TIN, RH, WIN) and daytime Call DBRH (TID, RH, WID).

Determine the daytime and nighttime humidity ratios of outdoor air, WOD and WON by

```
Call DBRH (TOD, RHA, WOD)
Call DBRH (TON, RHM, WON)
```

Daytime latent heat gain:

QILD = 4.5*INFIL*(WOD-WID)*1061*HRDAY

Nighttime latent heat gain:

QILN = 4.5*INFIL*(WON-WIN)*1061*HRNIT

It is important to note that QID, QIN, QILD and QILN are all zero when the natural cooling is used to minimize or eliminate the need for mechanical cooling.

5.13. QECHG: Opaque envelope conduction heat gain (walls, doors, roofs and floors)

Input: For all the opaque envelope such as atticless roofs, walls and doors, the following input data should be provided:

SATD = daytime sol-air temperature, °F
SATN = nighttime sol-air temperature, °F
U = overall heat transfer coefficient, Btu/h ft^2 °F
A = area, ft^2
TID = daytime indoor temperature, °F
TIN = nighttime indoor temperature, °F
HRDAY = daytime hours, hr
HRNIT = nighttime hours, hr

For daytime heat gain, QD = U*A*(SATD-TID)*HRDAY Btu/day
For nighttime heat gain, QN = U*A*(SATN-TIN)*HRNIT Btu/day
For the attic ceiling and crawl space floor, the sol-air temperature should be replaced by the attic temperature and crawl-space temperature.

5.14. QR: Internal heat gain

Input:

NPD = number daytime occupants
NPN = number nighttime occupants
WTD = average daytime lighting power, w

WTN = average nighttime lighting power, w
WED = average daytime equipment power, w
WEN = average nighttime equipment power, w
HRDAY = daytime hours, hr
HRNIT = nighttime hours,

Sensible heat gain

It is assumed that 1/3 of the equipment heat is used for the evaporation of water vapor such as from cooking.

Daytime: QRSD = [NPD*240 + [WTD+(WED*0.66)]*3.413]*HRDAY
Nighttime: QRSN = [NPN*240 + [WTN+(WEN*0.66)]*3.413]*HRNIT

Latent heat gain

Daytime: QRLD = [NPD*160 + (WED*0.34)*3.413]*HRDAY
Nighttime: QRLN = [NPN*160 + (WEN*0.34)*3.413]*HRNIT

5.15. DBRH: Relative humidity routine (see Appendix C-27)

Input:

DB = dry-bulb temperature, °F
RH = relative humidity, %

Calculation algorithms for psychrometric routines are provided in reference [4].

Output:

W = humidity ratio, lb/lb

5.16. BSMT: Basement temperature and heat loss calculation

Input:

ZK = ground thermal conductivity Btu-in/hr ft^2 °F
UBW = basement wall heat conductance, Btu/hr ft^2 °F*/
UBF = basement floor heat conductance, Btu/hr ft^2 °F*/

UFLR1 = heat conductance of floor above the basement, Btu/hr ft^2°F
BWAEX = Area of the exposed section of the basement wall, ft^2
BWA = basement wall area, ft^2
BFA = basement floor area, ft^2
L = height of the basement wall which is ground covered, ft

*/ UBW and UBF are to be determined from the room air to the external surface of the wall/slab (soil interface).

TID = daytime temperature of the room above, °F
TIN = nighttime temperature of the room above, °F
TOD = daytime outdoor temperature, °F
TON = nighttime outdoor temperature, °F
TG = ground temperature, °F
HRDAY = daytime hours, hr
HRNIT = nighttime hours, hr

QBHG = basement heat gain from furnace, boiler, or other equipment, Btu/hr

Output:

BSMTD = daytime basement temperature, °F

BSMTN = nighttime basement temperature, °F

BQFD = daytime basement heat loss, Btu/day
BQFN = nighttime basement heat loss, Btu/day
TO = (TOD + TON)/2.0

There are no exact solutions, similar to those described in the slab-on-grade calculation, for the basement wall heat condition. An approximate value of UW may be obtained by the following equation.

$$UW = \frac{1}{\frac{1}{UFW} + \frac{1}{HO}} \qquad \text{for the exposed section.}$$

$$UW = \frac{2*ZK}{(\pi *L)} * \ln\left(1 + \frac{\pi * UFW * L}{2 * ZK}\right) \qquad \text{for the ground-covered section.}$$

The latter equation was derived from the assumption that the heat flow path between the basement wall and the ground surface is a quarter circle.

Basement flow heat transfer coefficient.

UF = The value should be determined by the same procedure used in the calculation of slab-on-grade floor heat transfer coefficient described in section 5.6.

$$BSMTD = \frac{QBHG+UW*BWA*TO+UF*BFA*TG+UFLR1*BFA*TID}{UW*BWA+UF*BFA+UFLR1*BFA}$$

$$BSMTN = \frac{QBHG+UW*BWA*TO+UF*BFA*TG+UFLR1*BFA*TIN}{UW*BWA+UF*BFA+UFLR1*BFA}$$

If basement is heated

BQFD = (-UW*(TID-TO)*BWA-UF*(TID-TG)*BFA)*HRDAY
BQFN = (-UW*(TIN-TO)*BWA-UF*(TIN-TG)*BFA)*HRNIT
BSMTD = TID, BSMTN = TIN

If basement is not heated BQFD & BQFN are calculated by using Subroutine QECHG (=7.13. Opaque envelope conduction heat gain calculations) and the basement temperatures, BSMTD and BSMTN above.

5.17. HWHREQ: hot water heating requirement

Input:
- TOUT = hot water outlet temperature °F
- TIN = hot water inlet temperature = ground temperature °F
- HWT = hot water usage, gallons/day
- A = total jacket area, ft^2
- BSMTD = daytime basement or indoor temperature, °F
- BSMTN = nighttime basement or indoor temperature, °F
- D1 = thickness of existing tank insulation, ft
- RAM1 = thermal conductivity of existing insulation, Btu/hr, ft, °F
- D2 = thickness of additional insulation, ft
- RAM2 = thermal conductivity of additional insulation, Btu/h, ft, °F
- HRDAY = daytime hour, hr
- HRNIT = nighttime hours, hr

Output: Heat loss through existing jacket insulation around the hot water tank

HLHWH1 = U1*A*((BSMTD-TOUT)*HRDAY) + (BSMTN-TOUT)*HRNIT)

where U1 = 1.0/(0.685 + D1/RAM1)

Heat loss through additional jacket insulation of hot water tank

HLHWH2 = U2*A*((BSMTD-TOUT)*HRDAY) + (BSMTN-TOUT)*HRNIT)

where U2 = 1.0/(0.685 + D1/RAM1 + D2/RAM2)

Energy saving by additional insulation over the hot water tank

SAVE = HLHWH2-HLHWH1

Hot water heating requirement, including jacket heat loss

WHREQ = 500.0/60.0*(TIN-TOUT)*HWT + HLHWH2

If WHREQ > 0, WHREQ = 0

Hot water heating requirement, excluding jacket heat loss

WHREQ2 = WHREQ - HLHWH2

5.18. CSDUPI: heat loss and gain through ducts and pipes in crawl space

Input: ADUCT = total surface area of duct in crawl space, ft^2
UDUCT = U value of duct, Btu/h ft^2 °F
APIPE = total surface area of pipe in crawl space, ft^2
UPIPE = U value of pipe, Btu/h ft^2 °F
TCSUPA = supply chilled air temperature, °F
TCSUPW = supply chilled water temperature, °F
THSUPA = supply hot air temperature, °F
THSUPW = supply hot water temperature, °F
CRAWLD = daytime crawl temperature, °F
CRAWLN = nighttime crawl temperature, °F
CFAC = factor for estimating operation time of cooling equipment
HFAC = factor for estimating operation time of heating equipment
HRDAY = daytime hours, hr
HRNIT = nighttime hours, hr

Output: Heat gain through ducts and pipes

QC = ADUCT*UDUCT*((CRAWLD - TCSUPA)*HRDAY + (CRAWLN - TCSUPA)*HRNIT) *CFAC + APIPE*UPIPE*((CRAWLD - TCSUPW)*HRDAY + (CRAWLN - TCSUPW)*HRNIT)*CFAC

Heat loss through ducts and pipes

QH = ADUCT*UDUCT*((CRAWLD - THSUPA)*HRDAY + (CRAWLN - THSUPA) *HRNIT) *HFAC + APIPE*UPIPE*((CRAWLD - THSUPW)*HRDAY + (CRAWLN - THSUPW)*HRNIT)*HFAC

If cooling season, QH = 0
If heating season, QC = 0

5.19. ASDUPI: heat loss and gain through ducts and pipes in attic space

Input: ADUCT = total surface area of duct in attic space, ft^2
UDUCT = U value of duct, Btu/h, ft^2, °F
APIPE = total surface area of pipe in attic space, ft^2
UPIPE = U value of pipe, Btu/h, ft^2, °F
TCSUPA = supply chilled air temperature, °F
TCSUPW = supply chilled water temperature, °F
THSUPA = supply hot air temperature, °F

THSUPW = supply hot water temperature, °F
ATD = attic daytime temperature, °F
ATN = attic nighttime temperature, °F
CFAC = factor for estimating operation time of cooling equipment
HFAC = factor for estimating operation time of heating equipment
HRDAY = daytime hours
HRNIT = nighttime hours

Output:

Heat gain through ducts and pipes

QC = ADUCT*UDUCT*((ATD - TCSUPA)*HRDAY + (ATN - TCSUPA)*HRNIT)*CFAC + APIPE*UPIPE*((ATD - TCSUPW)*HRDAY + (ATN - TCSUPW)*HRNIT)*CFAC

Heat loss through ducts and pipes

QH = ADUCT*UDUCT*((ATD - THSUPA)*HRDAY + (ATN - THSUPA)*HRNIT)*HFAC + APIPE*UPIPE*((ATD - THSUPW)*HRDAY + (ATN - THSUPW)*HRNIT)*HFAC

If cooling season, QH = 0
If heating season, QC = 0

5.20. BMDUPI: heat loss and gain through ducts and pipes in basement

Input:
ADUCT = total surface area of duct in basement, ft^2
UDUCT = U value of duct, Btu/h ft^2 °F
APIPE = total surface area of pipe in basement, ft^2
UPIPE = U value of pipe, Btu/h ft^2 °F
TCSUPA = supply chilled air temperature, °F
TCSUPW = supply chilled water temperature, °F
THSUPA = supply hot air temperature, °F
THSUPW = supply hot water temperature, °F
BSMTD = basement daytime temperature, °F
BSMTN = basement nighttime temperature, °F

CFAC = factor for estimating operation time of cooling equipment
HFAC = factor for estimating operation time of heating equipment
HRDAY = daytime hours, hr
HRNIT = nighttime hours, hr

Output:

Heat gain through ducts and pipes

QC = ADUCT*UDUCT*((BSMTD - TCSUPA)*HRDAY + (BSMTN - TCSUPA)*HRNIT)*CFAC + APIPE*UPIPE*((BSMTD - TCSUPW)*HRDAY + (BSMTN - TCSUPW)*HRNIT)*CFAC

Heat loss through ducts and pipes

QH = ADUCT*UDUCT*((BSMTD - THSUPA)*HRDAY + (BSMTN - THSUPA)
*HRNIT)*HFAC + APIPE*UPIPE*((BSMTD - THSUPW)*HRDAY +
(BSMTN - THSUPW)*HRNIT)*HFAC

If cooling season, QH = 0
If basement heated, QH = 0
If heating season, QC = 0

5.21. OSDUPI: heat loss and gain through outdoor ducts and pipes

Input: ADUCT = total surface area of outdoor duct, ft^2
ULUCT = U value of duct, Btu/h ft^2 °F
APIPE = total surface area of outdoor pipe, ft^2
UPIPE = U value of pipe, Btu/h ft^2 °F
TCSUPA = supply chilled air temperature, °F
TCSUPW = supply chilled water temperature, °F
THSUPA = supply hot air temperature, °F
THSUPW = supply hot water temperature, °F
TOD = daytime outdoor temperature, °F
TON = nighttime outdoor temperature, °F
CFAC = factor for estimating operation time of cooling equipment
HFAC = factor for estimating operation time of heating equipment
HRDAY = daytime hours, hr
HRNIT = nighttime hours, hr

Output:

Heat gain through ducts and pipes

QC = ADUCT*UDUCT*((TOD - TCSUPA)*HRDAY + (TON - TCSUPA)
*HRNIT)*CFAC + APIPE*UPIPE*((TOD - TCSUPW)*HRDAY +
(TON - TCSUPW)*HRNIT)*CFAC

Heat loss through ducts and pipes

QH = ADUCT*UDUCT*((TOD - THSUPA)*HRDAY + (TON - THSUPA)
*HRNIT)*HFAC + APIPE*UPIPE*((TOD - THSUPW)*HRDAY +
(TON - THSUPW)*HRNIT)*HFAC

If cooling season, QH = 0
If heating season, QC = 0

The routines described above are incorporated into a Fortran program, listing of which is given in Appendix C.

Appendix D presents a description of the data file and suggested default values to be used for the heating and cooling requirement calculations.

6. COMPARISON WITH DOE-2 RUNS

Figures 5 and 6 are comparisons of annual heating and cooling requirements obtained by the simplified procedure described herein with those obtained by DOE-2, a comprehensive hourly simulation program for building energy analysis, for ten cities and for a combination of several energy conservation options as shown in Table 1. The basic building data used for these comparative calculations are described in a recent report of the Lawrence Berkeley Laboratory[5/].

As can be seen, the total annual heating and cooling requirements obtained by the simplified procedure do not agree well with those determined by the DOE-2.

Since the DOE-2 uses TRY (Typical Reference Year) weather data, a set of monthly normal day data were generated from the DOE-2 program from the TRY weather data tape and used in the simplified calculation procedure. The infiltration routine was also modified to be consistent with the DOE-2 algorithm. Figures 7 and 8 show the improved relationships between the two calculations as the result of these two adjustments.

Table 1. Building Data for the Comparative Calculations with DOE-2

City	Base Case				Additions to Base Levels of Insulation, Glazing Options							
	Wall	Attic	Windows	Floor	1	2	3	4	5	6	7	8
Minneapolis	Alum Siding R-11	R-22	Double	Basement U=.000001	R-38 Attic	R-19 Wall	Triple Glaze	R-25 Wall				
Chicago	Alum Siding R-11	R-19	Double	Basement U=.000001	R-38 Attic	R-30 Attic	R-19 Wall	R-38 Attic	Triple Glaze	R-25 Wall		
Portland	Alum Siding R-11	R-19	Double	Crawl Space R-7 U=.04339	R-19 Wall	R-19 Floor	R-38 Attic	Triple Glaze	R-25 Wall			
Washington DC	Alum Siding R-11	R-19	Double	Basement U=.000001	R-30 Attic	R-19 Wall	R-38 Attic	Triple Glaze	R-25 Wall			
Atlanta	Alum Siding R-11	R-19	Single	Crawl Space R-7 U=.04339	Double Glaze	R-11 Floor	R-30 Attic	R-19 Wall	R-38 Attic	Triple Glaze	R-19 Floor	R-25 Wall
Fresno	Stucco R-11	R-19	Single	Slab-on-Grade U=.1202	Double Glaze	R-30 Attic	R-19 Wall	R-38 Attic	Triple Glaze			
Burbank	Stucco R-11	R-19	Single	Slab-on-Grade U=.1202	Double Glaze	R-30 Attic	R-19 Wall	R-38 Attic	Triple Glaze			
Phoenix	Alum Siding R-11	R-19	Single	Slab-on-Grade U=.1202	Double Glaze	R-30 Attic	R-19 Wall	R-38 Attic	Triple Glaze			
Houston	Alum Siding R-11	R-19	Single	Slab-on-Grade U=.1202	Double Glaze	R-30 Attic	R-19 Wall	R-38 Attic	Triple Glaze			
Ft. Worth	Alum Siding R-11	R-19	Single	Slab-on-Grade U=.1202	Double Glaze	R-30 Attic	R-19 Wall	R-38 Attic	Triple Glaze			

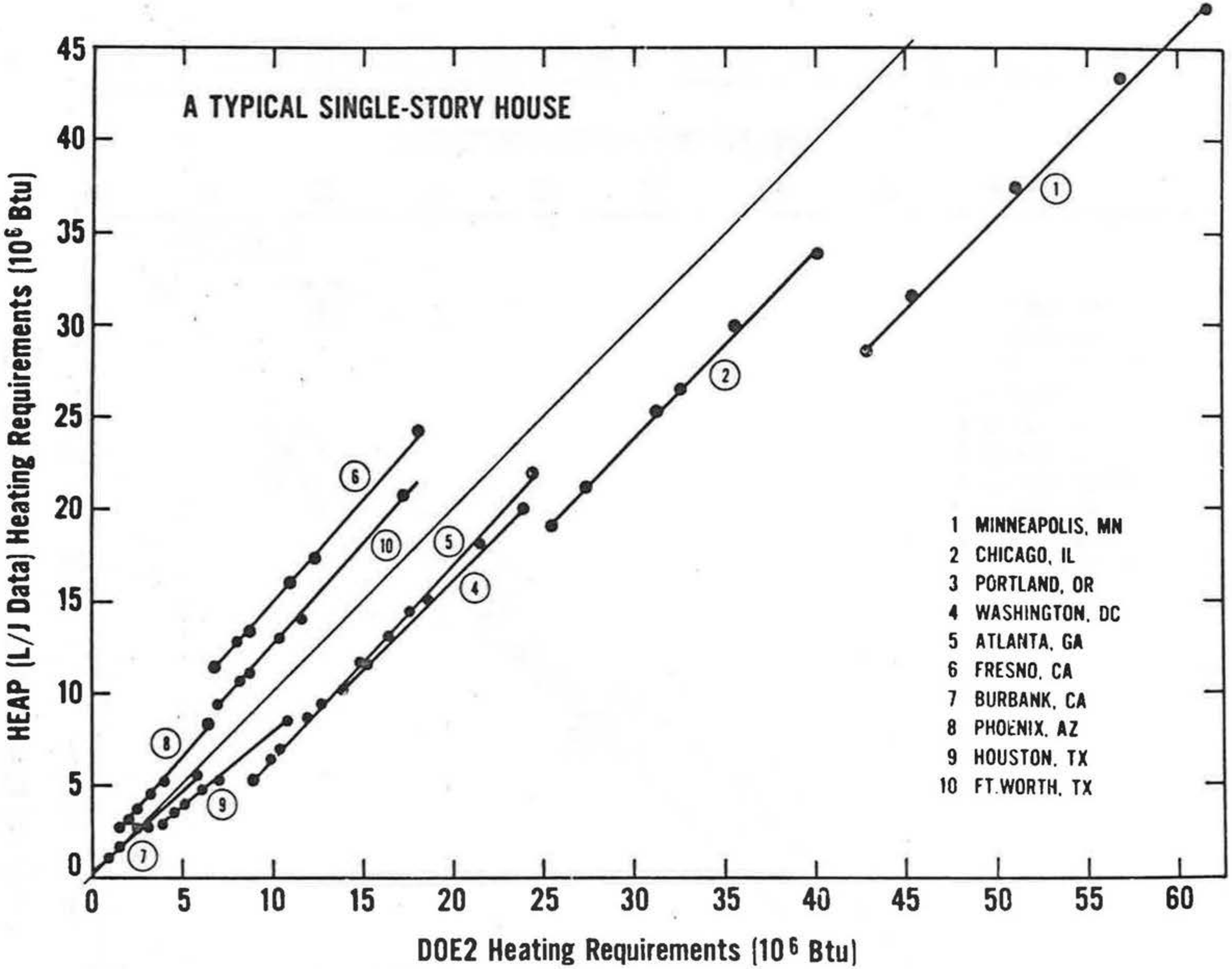


Figure 5. Comparison between the annual heating requirements of a typical residence determined by the simplfied procedure and by the DOE-2 program

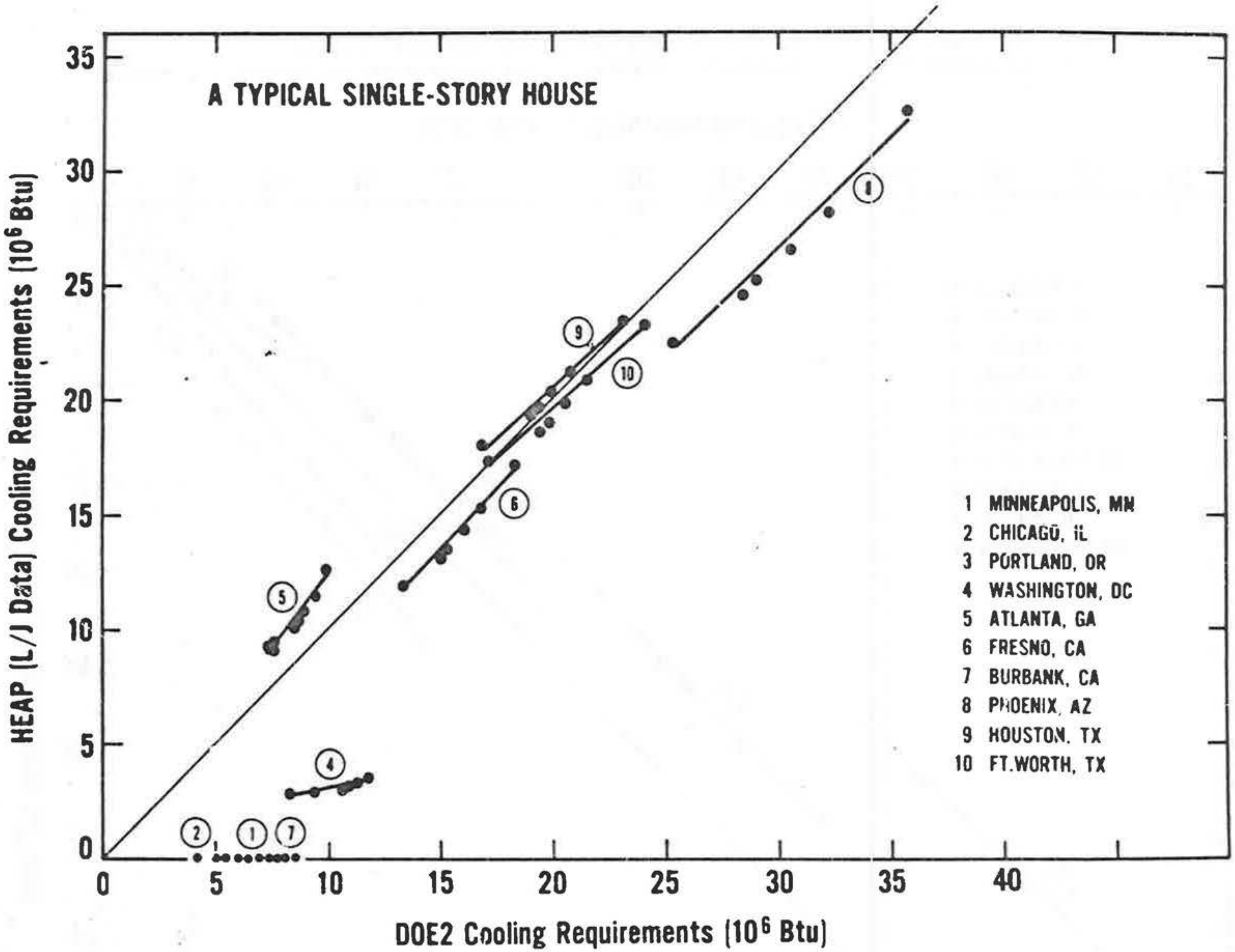


Figure 6. Comparison between the annual cooling requirements of a typical residence determined by the simplfied procedure and by the DOE-2 program

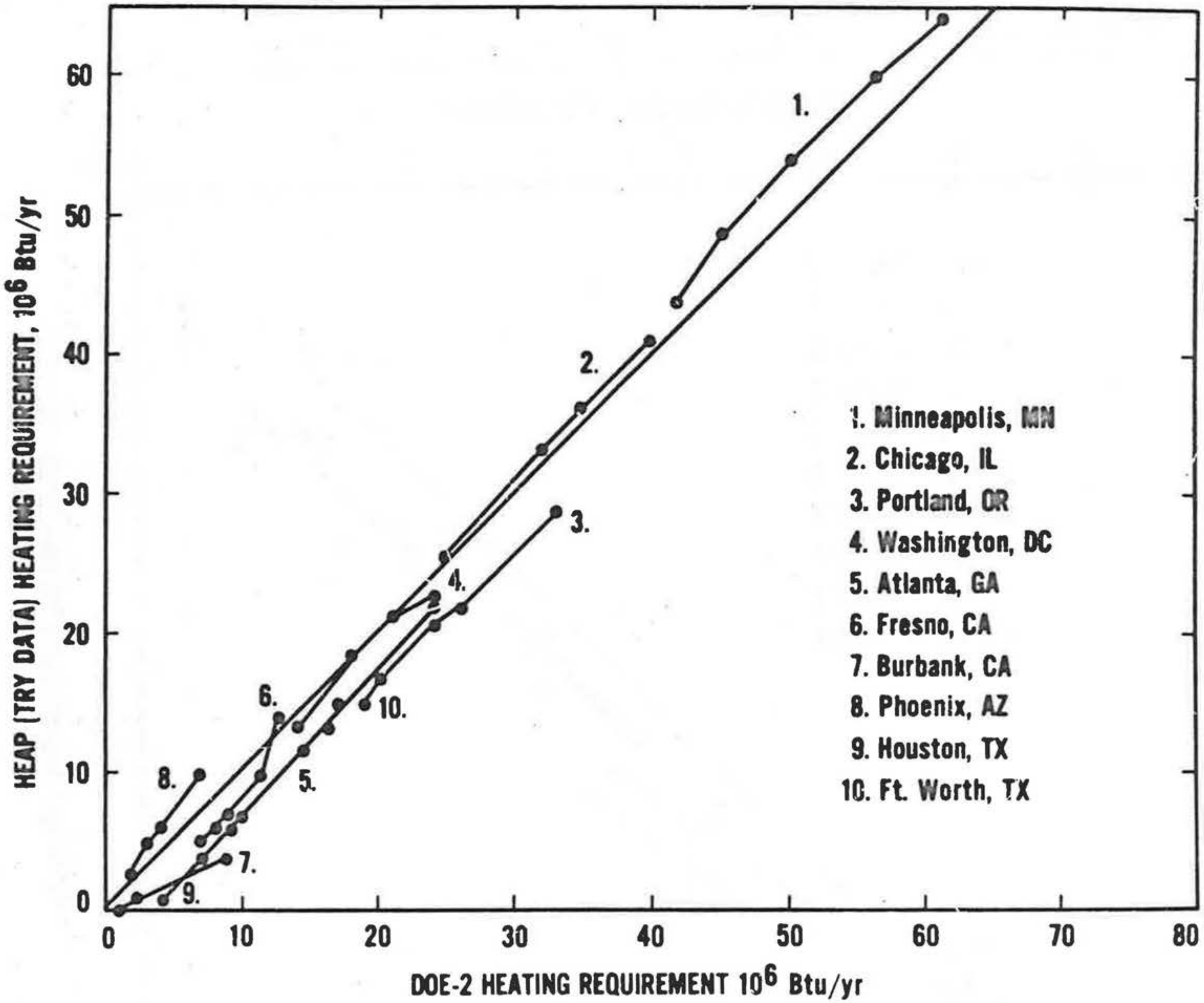


Figure 7. Improved comparison between the annual heating requirements of a typical residence determined by the simplified procedure and by the DOE-2 program

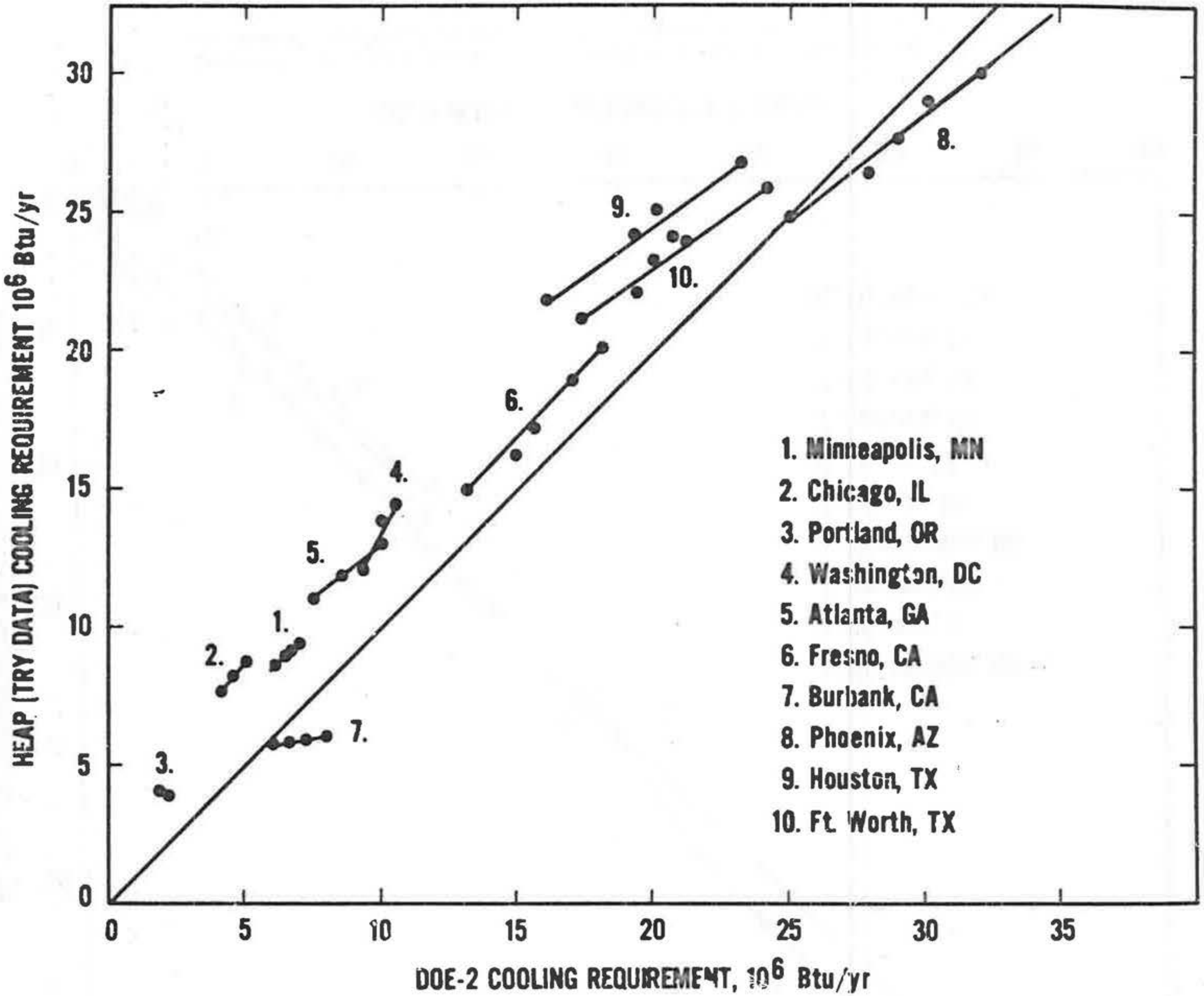


Figure 8. Improved comparison between the annual cooling requirements of a typical residence determined by the simplfied procedure and by the DOE-2 program

APPENDIX A. LIU-JORDAN SOLAR CALCULATION DATA

Radiation and Other Data for 80 Locations in the United States and Canada

($\bar{H}$ = Monthly average daily total radiation on a horizontal surface, Btu/day-ft^2; $\bar{K}_t$ = the fraction of the extraterrestrial radiation transmitted through the atmosphere; t_o = ambient temperature, deg F.)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Albuquerque, N. M.	$\bar{H}$	1150.9	1453.9	1925.4	2343.5	2560.9	2757.5	2561.2	2387.8	2120.3	1639.8	1274.2	1051.[illegible]
Lat. 35°03'N	$\bar{K}_t$	0.704	0.691	0.719	0.722	0.713	0.737	0.695	0.708	0.728	0.711	0.684	0.704
El. 5314 ft	t_o	37.3	43.3	50.1	59.6	69.4	79.1	82.8	80.6	73.6	62.1	47.8	39.4
Annette Is., Alaska	$\bar{H}$	236.2	428.4	883.4	1357.2	1634.7	1638.7	1632.1	1269.4	962	454.6	220.3	152
Lat. 55°02'N	$\bar{K}_t$	0.427	0.415	0.492	0.507	0.484	0.441	0.454	0.427	0.449	0.347	0.304	0.361
El. 110 ft	t_o	35.8	37.5	39.7	44.4	51.0	56.2	58.6	59.8	54.8	48.2	41.9	37.4
Apalachicola, Florida	$\bar{H}$	1107	1378.2	1654.2	2040.9	2268.6	2195.9	1978.6	1912.9	1703.3	1544.6	1243.2	982.3
Lat. 29°45'N	$\bar{K}_t$	0.577	0.584	0.576	0.612	0.630	0.594	0.542	0.558	0.559	0.608	0.574	0.543
El. 35 ft	t_o	57.3	59.0	62.9	69.5	76.4	81.8	83.1	83.1	80.6	73.2	63.7	58.55
Astoria, Oregon	$\bar{H}$	338.4	607	1008.5	1401.5	1838.7	1753.5	2007.7	1721	1322.5	780.4	413.6	295.2
Lat. 46°12'N	$\bar{K}_t$	0.330	0.397	0.454	0.471	0.524	0.466	0.551	0.538	0.526	0.435	0.336	0.332
El. 8 ft.	t_o	41.3	44.7	46.9	51.3	55.0	59.3	62.6	63.6	62.2	55.7	48.5	43.9
Atlanta, Georgia	$\bar{H}$	848	1080.1	1426.9	1807	2618.12	2002.6	2002.9	1898.1	1519.2	1290.8	997.8	751.6
Lat. 33°39'N	$\bar{K}_t$	0.493	0.496	0.522	0.551	0.561	0.564	0.545	0.559	0.515	0.543	0.510	0.474
El. 976 ft	t_o	47.2	49.6	55.9	65.0	73.2	80.9	82.4	81.6	77.4	66.5	54.8	47.7
Barrow, Alaska	$\bar{H}$	13.3	143.2	713.3	1491.5	1883	2055.3	1602.2	953.5	428.4	152.4	22.9	-
Lat. 71°20'N	$\bar{K}_t$	-	0.776	0.773	0.726	0.553	0.533	0.448	0.377	0.315	0.35	-	-
El. 22 ft	t_o	-13.2	-15.9	-12.7	2.1	20.5	35.4	41.6	40.0	31.7	18.6	2.6	-8.6
Bethel, Alaska	$\bar{H}$	142.4	404.8	1052.4	1662.3	1711.8	1698.1	1401.8	938.7	755	430.6	164.9	83
Lat. 60°47'N	$\bar{K}_t$	0.536	0.557	0.704	0.675	0.519	0.458	0.398	0.336	0.406	0.432	0.399	0.459
El. 125 ft	t_o	9.2	11.6	14.2	29.4	42.7	55.5	56.9	54.8	47.4	33.7	19.0	9.4
Bismarck, North Dakota	$\bar{H}$	587.4	934.3	1328.4	1668.2	2056.1	2173.8	2305.5	1929.1	1441.3	1018.1	600.4	464.2
Lat. 46°47'N	$\bar{K}_t$	0.594	0.628	0.605	0.565	0.588	0.579	0.634	0.606	0.581	0.584	0.510	0.547
El. 1660 ft	t_o	12.4	15.9	29.7	46.6	58.6	67.9	76.1	73.5	61.6	49.8	31.4	18.4
Blue Hill, Mass	$\bar{H}$	555.3	797	1143.9	1438	1776.4	1943.9	1881.5	1622.1	1314	941	592.2	482.3
Lat. 42°13'N	$\bar{K}_t$	0.445	0.458	0.477	0.464	0.501	0.516	0.513	0.495	0.492	0.472	0.406	0.436
El. 629 ft	t_o	28.3	28.3	36.9	46.9	58.5	67.2	72.3	70.6	64.2	54.1	43.3	31.5
Boise, Idaho	$\bar{H}$	518.8	884.9	1280.4	1814.4	2189.3	2376.7	2500.3	2149.4	1717.7	1128.4	678.6	456.8
Lat. 43°34'N	$\bar{K}_t$	0.446	0.533	0.548	0.594	0.619	0.631	0.684	0.660	0.656	0.588	0.494	0.442
El. 2844 ft	t_o	29.5	36.5	45.0	53.5	62.1	69.3	79.6	77.2	66.7	56.3	42.3	33.1

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Boston, Mass.	$\bar{H}$	505.5	738	1067.1	1355	1769	1864	1860.5	1570.1	1267.5	896.7	535.8	442.8
Lat. 42°22'N	$\bar{K}_t$	0.410	0.426	0.445	0.438	0.499	0.495	0.507	0.480	0.477	0.453	0.372	0.400
El. 29 ft	t_o	31.4	31.4	39.9	49.5	60.4	69.8	74.5	73.8	66.8	57.4	46.6	34.9
Brownsville, Texas	$\bar{H}$	1105.9	1262.7	1505.9	1714	2092.2	2288.5	2345	2124	1774.9	1536.5	1104.8	982.3
Lat. 25°55'N	$\bar{K}_t$	0.517	0.500	0.505	0.509	0.584	0.627	0.650	0.617	0.566	0.570	0.468	0.488
El. 20 ft	t_o	63.3	66.7	70.7	76.2	81.4	85.1	86.5	86.9	84.1	78.9	70.7	65.2
Caribou, Maine	$\bar{H}$	497	861.6	1360.1	1495.9	1779.7	1779.7	1898.1	1675.6	1254.6	793	415.5	398.9
Lat. 46°52'N	$\bar{K}_t$	0.504	0.579	0.619	0.507	0.509	0.473	0.522	0.527	0.506	0.455	0.352	0.470
El. 628 ft	t_o	11.5	12.8	24.4	37.3	51.8	61.6	67.2	65.0	56.2	44.7	31.3	16.8
Charleston, S.C.	$\bar{H}$	946.1	1152.8	1352.4	1918.8	2063.4	2113.3	1649.4	1933.6	1557.2	1332.1	1075.6	[illegible]
Lat. 32°54'N	$\bar{K}_t$	0.541	0.521	0.491	0.584	0.574	0.567	0.454	0.569	0.525	0.554	0.539	0.586
El. 46 ft	t_o	53.6	55.2	60.6	67.8	74.8	80.9	82.9	82.3	79.1	69.8	59.8	54.0
Cleveland, Ohio	$\bar{H}$	466.8	681.9	1207	1443.9	1928.4	2102.6	2094.4	1840.6	1410.3	997	526.6	427.3
Lat. 41°24'N	$\bar{K}_t$	0.361	0.383	0.497	0.464	0.543	0.559	0.571	0.559	0.524	0.491	0.351	0.371
El. 805 ft	t_o	30.8	30.9	39.4	50.2	62.4	72.7	77.0	75.1	68.5	57.4	44.0	32.8
Columbia, Mo	$\bar{H}$	651.3	941.3	1315.8	1631.3	1999.6	2129.1	2148.7	1953.1	1689.6	1202.6	839.5	590.4
Lat. 38°58'N	$\bar{K}_t$	0.458	0.492	0.520	0.514	0.559	0.566	0.585	0.588	0.606	0.562	0.510	0.457
El. 785 ft	t_o	32.5	36.5	45.9	57.7	66.7	75.9	81.1	79.4	71.9	61.4	46.1	35.8
Columbus, Ohio	$\bar{H}$	486.3	746.5	1112.5	1480.8	1839.1	(2111)	2041.3	1572.7	1189.3	919.5	479	430.2
Lat. 40°00'N	$\bar{K}_t$	0.356	0.401	0.447	0.470	0.515	(0.561)	0.555	0.475	0.433	0.441	0.302	0.351
El. 833 ft	t_o	32.1	33.7	42.7	53.5	64.4	74.2	78	75.9	70.1	58	44.5	34.0
Davis, Calif.	$\bar{H}$	599.2	945	1504	1959	2368.6	2619.2	2565.6	2287.8	1856.8	1288.5	795.6	550.5
Lat. 38°33'N	$\bar{K}_t$	0.416	0.490	0.591	0.617	0.662	0.697	0.697	0.687	0.664	0.598	0.477	0.421
El. 51 ft	t_o	47.6	52.1	56.8	63.1	69.6	75.7	81	79.4	76.7	67.8	57	48.7
Dodge City, Kan.	$\bar{H}$	953.1	1186.3	1565.7	1975.6	2126.5	2459.8	2400.7	2210.7	1841.7	1421	1065.3	873.8
Lat. 37°46'N	$\bar{K}_t$	0.639	0.598	0.606	0.618	0.594	0.655	0.652	0.663	0.654	0.650	0.625	0.652
El. 2592 ft	t_o	33.8	38.7	46.5	57.7	66.7	77.2	83.8	82.4	73.7	61.7	46.5	36.8
East Lansing, Michigan	$\bar{H}$	425.8	739.1	1086	1249.8	1732.8	1914	1884.5	1627.7	1303.3	891.5	473.1	379.7
Lat. 42°44'N	$\bar{K}_t$	0.35	0.431	0.456	0.406	0.489	0.508	0.514	0.498	0.493	0.456	0.333	0.349
El. 856 ft	t_o	26.0	26.4	35.7	48.4	59.8	70.3	74.5	72.4	65.0	53.5	40.0	29.0
East Wareham, Mass	$\bar{H}$	504.4	762.4	1132.1	1392.6	1704.8	1958.3	1873.8	1607.4	1363.8	996.7	636.2	521
Lat. 41°46'N	$\bar{K}_t$	0.398	0.431	0.469	0.449	0.480	0.520	0.511	0.489	0.508	0.496	0.431	0.461
El. 18 ft	t_o	32.2	31.6	39.0	48.3	58.9	67.5	74.1	72.8	65.9	56	46	34.8

Appendix A (Continued)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Edmonton, Alberta	$\bar{H}$	331.7	652.4	1165.3	1541.7	1900.4	1914.4	1964.9	1528	1113.3	704.4	413.6	245
Lat. 53°35'N	$\bar{K}_t$	0.529	0.585	0.624	0.564	0.558	0.514	0.549	0.506	0.506	0.504	0.510	0.492
El. 2219 ft	t_o	10.4	14	26.3	42.9	55.4	61.3	66.6	63.2	54.2	44.1	26.7	14.0
El Paso, Texas	$\bar{H}$	1247.6	1612.9	2048.7	2447.2	2673	2731	2391.1	2350.5	2077.5	1704.8	1324.7	1051.6
Lat. 31°48'N	$\bar{K}_t$	0.686	0.714	0.730	0.741	0.743	0.733	0.652	0.669	0.693	0.695	0.647	0.626
El. 3916 ft	t_o	47.1	53.1	58.7	67.3	75.7	84.2	84.9	83.4	78.5	69.0	56.0	48.5
Ely, Nevada	$\bar{H}$	871.6	1255	1749.8	2103.3	2322.1	2649	2417	2307.7	1935	1473	1078.6	814.8
Lat. 39°17'N	$\bar{K}_t$	0.618	0.660	0.692	0.664	0.649	0.704	0.656	0.695	0.696	0.691	0.658	0.64
El. 6262 ft	t_o	27.3	32.1	39.5	48.3	57.0	65.4	74.5	72.3	63.7	52.1	39.9	31.1
Fairbanks, Alaska	$\bar{H}$	66	283.4	860.5	1481.2	1806.2	1970.8	1702.9	1247.6	699.6	323.6	104.1	20.3
Lat. 64°49'N	$\bar{K}_t$	0.639	0.556	0.674	0.647	0.546	0.529	0.485	0.463	0.419	0.416	0.47	0.458
El. 436 ft	t_o	-7.0	0.3	13.0	32.2	50.5	62.4	63.8	58.3	47.1	29.6	5.5	-6.6
Fort Worth, Texas	$\bar{H}$	936.2	1198.5	1597.8	1829.1	2105.1	2437.6	2293.3	2216.6	1880.6	1476	1147.6	913.6
Lat. 32°50'N	$\bar{K}_t$	0.530	0.541	0.577	0.556	0.585	0.654	0.624	0.653	0.634	0.612	0.576	0.563
El. 544 ft	t_o	48.1	52.3	59.8	68.8	75.9	84.0	87.7	88.6	81.3	71.5	58.8	50.8
Fresno, Calif.	$\bar{H}$	712.9	1116.6	1652.8	2049.4	2409.2	2641.7	2512.2	2300.7	1897.8	1415.5	906.6	616.6
Lat. 36°46'N	$\bar{K}_t$	0.462	0.551	0.632	0.638	0.672	0.703	0.682	0.686	0.665	0.635	0.512	0.44
El. 331 ft	t_o	47.3	53.9	59.1	65.6	73.5	80.7	87.5	84.9	78.6	68.7	57.3	48.9
Gainesville, Fla.	$\bar{H}$	1036.9	1324.7	1635	1956.4	1934.7	1960.9	1895.6	1873.8	1615.1	1312.2	1169.7	919.5
Lat. 29°39'N	$\bar{K}_t$	0.535	0.56	0.568	0.587	0.538	0.531	0.519	0.547	0.529	0.515	0.537	0.508
El. 165 ft	t_o	62.1	63.1	67.5	72.8	79.4	83.4	83.8	84.1	82	75.7	67.2	62.4
Glasgow, Mont.	$\bar{H}$	572.7	965.7	1437.6	1741.3	2127.3	2261.6	2414.7	1984.5	1531	997	574.9	428.4
Lat. 48°13'N	$\bar{K}_t$	0.621	0.678	0.672	0.597	0.611	0.602	0.666	0.630	0.629	0.593	0.516	0.548
El. 2277 ft	t_o	13.3	17.3	31.1	47.8	59.3	67.3	76	73.2	61.2	49.2	31.0	18.6
Grand Junction, Colo	$\bar{H}$	848	1210.7	1622.9	2002.2	2300.3	2645.4	2517.7	2157.2	1957.5	1394.8	969.7	793.4
Lat. 39°07'N	$\bar{K}_t$	0.597	0.633	0.643	0.632	0.643	0.704	0.690	0.65	0.705	0.654	0.59	0.621
El. 4849 ft	t_o	26.9	35.0	44.6	55.8	66.3	75.7	82.5	79.6	71.4	58.3	42.0	31.4
Grand Lake, Colo.	$\bar{H}$	735	1135.4	1579.3	1876.7	1974.9	2369.7	2103.3	1708.5	1715.8	1212.2	775.6	660.5
Lat. 40°15'N	$\bar{K}_t$	0.541	0.615	0.637	0.597	0.553	0.63	0.572	0.516	0.626	0.583	0.494	0.542
El. 8389 ft	t_o	18.5	23.1	28.5	39.1	48.7	56.6	62.8	61.5	55.5	45.2	30.3	22.6
Great Falls, Mont	$\bar{H}$	524	869.4	1369.7	1621.4	1970.8	2179.3	2383	1986.3	1536.5	984.9	575.3	420.7
Lat. 47°29'N	$\bar{K}_t$	0.552	0.596	0.631	0.551	0.565	0.580	0.656	0.627	0.626	0.574	0.503	0.518
El. 3664 ft	t_o	25.4	27.6	35.6	47.7	57.5	64.3	73.8	71.3	60.6	51.4	38.0	29.1

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Greensboro, N.C.	$\bar{H}$	743.9	1031.7	1323.2	1755.3	1988.5	2111.4	2033.9	1810.3	1517.3	1202.6	908.1	690.8
Lat. 36°05'N	$\bar{K}_t$	0.469	0.499	0.499	0.543	0.554	0.563	0.552	0.538	0.527	0.531	0.501	0.479
El. 891 ft	t_o	42.0	44.2	51.7	60.8	69.9	78.0	80.2	78.9	73.9	62.7	51.5	43.2
Griffin, Georgia	$\bar{H}$	889.6	1135.8	1450.9	1923.6	2163.1	2176	2064.9	1961.2	1605.9	1352.4	1073.8	781.5
Lat. 33°15'N	$\bar{K}_t$	0.513	0.517	0.528	0.586	0.601	0.583	0.562	0.578	0.543	0.565	0.545	0.487
El. 980 ft	t_o	48.9	51.0	59.1	66.7	74.6	81.2	83.0	82.2	78.4	68	57.3	49.4
Hatteras, N.C.	$\bar{H}$	891.9	1184.1	1590.4	2128	2376.4	2438	2334.3	2085.6	1758.3	1337.6	1053.5	798.1
Lat. 35°13'N	$\bar{K}_t$	0.546	0.563	0.593	0.655	0.661	0.652	0.634	0.619	0.605	0.58	0.566	0.535
El. 7 ft.	t_o	49.9	49.5	54.7	61.5	69.9	77.2	80.0	79.8	76.7	67.9	59.1	51.3
Indianapolis, Ind	$\bar{H}$	526.2	797.4	1184.1	1481.2	1828	2042	2039.5	1832.1	1513.3	1094.4	662.4	491.1
Lat. 39°44'N	$\bar{K}_t$	0.380	0.424	0.472	0.47	0.511	0.543	0.554	0.552	0.549	0.520	0.413	0.391
El. 793 ft	t_o	31.3	33.9	43.0	54.1	64.9	74.8	79.6	77.4	70.6	59.3	44.2	33.4
Inyokern, Calif	$\bar{H}$	1148.7	1554.2	2136.9	2594.8	2925.4	3108.8	2908.8	2759.4	2409.2	1819.2	3170.1	1094.4
Lat. 35°39'N	$\bar{K}_t$	0.716	0.745	0.803	0.8	0.815	0.830	0.790	0.820	0.834	0.795	0.743	0.742
El. 2440 ft	t_o	47.3	53.9	59.1	65.6	73.5	80.7	87.5	84.9	78.6	68.7	57.3	48.9
Ithaca, N.Y.	$\bar{H}$	434.3	755	1074.9	1322.9	1779.3	2025.8	2031.3	1736.9	1320.3	918.4	466.4	370.8
Lat. 42°27'N	$\bar{K}_t$	0.351	0.435	0.45	0.428	0.502	0.538	0.554	0.530	0.497	0.465	0.324	0.337
El. 950 ft	t_o	27.2	26.5	36	48.4	59.6	68.9	73.9	71.9	64.2	53.6	41.5	29.6
Lake Charles, La	$\bar{H}$	899.2	1145.7	1487.4	1801.8	2080.4	2213.3	1968.6	1910.3	1678.2	1505.5	1122.1	875.3
Lat. 30°13'N	$\bar{K}_t$	0.473	0.492	0.521	0.542	0.578	0.597	0.538	0.558	0.553	0.597	0.524	0.494
El. 12 ft	t_o	55.3	58.7	63.5	70.9	77.4	83.4	84.8	85.0	81.5	73.8	62.6	56.9
Lander, Wyo	$\bar{H}$	786.3	1146.1	1638	1988.5	2114	2492.2	2438.4	2120.6	1712.9	1301.8	837.3	694.8
Lat. 42°48'N	$\bar{K}_t$	0.65	0.672	0.691	0.647	0.597	0.662	0.665	0.649	0.647	0.666	0.589	0.643
El. 5370 ft	t_o	20.2	26.3	34.7	45.5	56.0	65.4	74.6	72.5	61.4	48.3	3.4	23.8
Las Vegas, Nev	$\bar{H}$	1035.8	1438	1926.5	2322.8	2629.5	2799.2	2524	2342	2062	1602.6	1190	964.2
Lat. 36°05'N	$\bar{K}_t$	0.654	0.697	0.728	0.719	0.732	0.746	0.685	0.697	0.716	0.704	0.657	0.668
El. 2162 ft	t_o	47.5	53.9	60.3	69.5	78.3	88.2	95.0	92.9	35.4	71.7	57.8	50.2
Lemont, Illinois	$\bar{H}$	(590)	879	1255.7	1481.5	1866	2041.7	1990.8	1836.9	1469.4	1015.5	(639)	(531)
Lat. 41°40'N	$\bar{K}_t$	(0.464)	0.496	0.520	0.477	0.525	0.542	0.542	0.559	0.547	0.506	(0.433)	(0.467)
El. 595 ft	t_o	28.9	30.3	39.5	49.7	59.2	70.8	75.6	74.3	67.2	57.6	43.0	30.6
Lexington, Ky	$\bar{H}$	-	-	-	1834.7	2171.2	-	2246.5	2064.9	1775.8	1315.8	-	681.5
Lat. 38°02'N	$\bar{K}_t$	-	-	-	0.575	0.606	-	0.610	0.619	0.631	0.604	-	0.513
El. 979 ft	t_o	36.5	38.8	47.4	57.8	67.5	76.2	79.8	78.2	72.8	61.2	47.6	38.5

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Lincoln, Neb.	$\bar{H}$	712.5	955.7	1299.6	1587.8	1856.1	2040.6	2011.4	1902.6	1543.5	1215.8	773.4	643.2
Lat. 40°51'N	$\bar{K}_t$	0.542	0.528	0.532	0.507	0.522	0.542	0.547	0.577	0.568	0.596	0.508	0.545
El. 1189 ft	t_o	27.8	32.1	42.4	55.8	65.8	76.0	82.6	80.2	71.5	59.9	43.2	31.8
Little Rock, Ark	$\bar{H}$	704.4	974.2	1335.8	1669.4	1960.1	2091.5	2081.2	1938.7	1640.6	1282.6	913.6	701.1
Lat. 34°44'N	$\bar{K}_t$	0.424	0.458	0.496	0.513	0.545	0.559	0.566	0.574	0.561	0.552	0.484	0.463
El. 265 ft	t_o	44.6	48.5	56.0	65.8	73.1	76.7	85.1	84.6	78.3	67.9	54.7	46.7
Los Angeles, Calif. (WBAS).	$\bar{H}$	930.6	1284.1	1729.5	1948	2196.7	2272.3	2413.6	2155.3	1898.1	1372.7	1082.3	901.1
Lat. 33°56'N	$\bar{K}_t$	0.547	0.596	0.635	0.595	0.610	0.608	0.657	0.635	0.641	0.574	0.551	0.566
El. 99 ft	t_o	56.2	56.9	59.2	61.4	64.2	66.7	69.6	70.2	69.1	66.1	62.6	58.7
Los Angeles, Calif. (WBO).	$\bar{H}$	911.8	1223.6	1640.9	1866.8	2061.2	2259	2428.4	2198.9	1891.5	1362.3	1053.1	877.8
Lat. 34°03'N	$\bar{K}_t$	0.538	0.568	0.602	0.571	0.573	0.605	0.66	0.648	0.643	0.578	0.548	0.566
El. 99 ft	t_o	57.9	59.2	61.8	64.3	67.6	70.7	75.8	76.1	74.2	69.6	65.4	60.2
Madison, Wis	$\bar{H}$	564.6	812.2	1232.1	1455.3	1745.4	2031.7	2046.5	1740.2	1443.9	993	555.7	495.9
Lat. 43°08'N	$\bar{K}_t$	0.49	0.478	0.522	0.474	0.493	0.540	0.559	0.534	0.549	0.510	0.396	0.467
El. 866 ft	t_o	21.8	24.6	35.3	49.0	61.0	70.9	76.8	74.4	65.6	53.7	37.8	25.4
Matanuska, Alaska	$\bar{H}$	119.2	345	-	1327.6	1628.4	1727.6	1526.9	1169	737.3	373.8	142.[illegible]	58.4
Lat. 61°30'N	$\bar{K}_t$	0.513	0.503	-	0.545	0.494	0.466	0.434	0.419	0.401	0.390	0.372	0.364
El. 180 ft	t_o	13.9	21.0	27.4	38.6	50.3	57.6	60.1	58.1	50.2	37.7	22.9	13.9
Medford, Oregon H.	$\bar{H}$	435.4	804.4	1259.8	1807.4	2216.2	2440.5	2607.4	2261.8	1672.3	1043.5	[illegible]	346.5
Lat. 42°23'N	$\bar{K}_t$	0.353	0.464	0.527	0.584	0.625	0.648	0.710	0.689	0.628	0.526	0.384	0.313
El. 1329 ft	t_o	39.4	45.4	50.8	56.3	63.1	69.4	76.9	76.4	69.6	58.7	47.1	40.5
Miami, Florida	$\bar{H}$	1292.2	1554.6	1828.8	2020.6	2068.6	1991.5	1992.6	1890.8	1646.8	1436.5	1321	1183.4
Lat. 25°47'N	$\bar{K}_t$	0.604	0.616	0.612	0.600	0.578	0.545	0.552	0.549	0.525	0.534	0.559	0.588
El. 9 ft.	t_o	71.6	72.0	73.8	77.0	79.9	82.9	84.1	84.5	83.3	80.2	75.6	72.6
Midland, Texas	$\bar{H}$	1066.4	1345.7	1784.8	2036.1	2301.1	2317.7	2301.8	2193	1921.8	1470.8	1244.3	1023.2
Lat. 31°56'N	$\bar{K}_t$	0.587	0.596	0.638	0.617	0.639	0.622	0.628	0.643	0.642	0.600	0.609	0.611
El. 2854 ft	t_o	47.9	52.8	60.0	68.8	77.2	83.9	85.7	85.0	78.9	70.3	56.6	49.1
Nashville, Tenn	$\bar{H}$	589.7	907	1246.8	1662.3	1997	2149.4	2079.7	1862.7	1600.7	1223.6	823.2	614.4
Lat. 36°07'N	$\bar{K}_t$	0.373	0.440	0.472	0.514	0.556	0.573	0.565	0.554	0.556	0.540	0.454	0.426
El. 605 ft	t_o	42.6	45.1	52.9	63.0	71.4	80.1	83.2	81.9	76.6	65.4	52.3	44.3
New Port, R.I.	$\bar{H}$	565.7	856.4	1231.7	1484.8	1849	2019.2	1942.8	1687.1	1411.4	1035.4	656.1	527.7
Lat. 41°29'N	$\bar{K}_t$	0.438	0.482	0.507	0.477	0.520	0.536	0.529	0.513	0.524	0.512	0.44	0.460
El. 60 ft	t_o	29.5	32.0	39.6	48.2	58.6	67.0	73.2	72.3	65.7	56.2	46.5	34.4

Appendix A (Continued)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
New York, N. Y.	$\bar{H}$	539.5	790.8	1180.4	1426.2	1738.4	1994.1	1938.7	1605.9	1349.4	977.8	598.1	476
Lat. 40° 46'N	$\bar{K}_t$	0.406	0.435	0.480	0.455	0.488	0.53	0.528	0.486	0.500	0.475	0.397	0.403
El. 52 ft	t_o	35.0	34.9	43.1	52.3	63.3	72.2	76.0	75.3	69.5	59.3	48.3	37.7
Oak Ridge, Tenn	$\bar{H}$	604	895.9	1241.7	1689.6	1942.8	2066.4	1972.3	1795.6	1559.8	1194.8	796.3	610
Lat. 36° 01'N	$\bar{K}_t$	0.382	0.435	0.471	0.524	0.541	0.551	0.536	0.534	0.542	0.527	0.438	0.422
El. 905 ft	t_o	41.9	44.2	51.7	61.4	69.8	77.8	80.2	78.8	74.5	62.7	50.4	42.5
Oklahoma City, Oklahoma . .	$\bar{H}$	938	1192.6	1534.3	1849.4	2005.1	2355	2273.8	2211	1819.2	1409.6	1085.6	897.4
Lat. 35° 24'N	$\bar{K}_t$	0.580	0.571	0.576	0.570	0.558	0.629	0.618	0.565	0.628	0.614	0.588	0.608
El. 1304 ft	t_o	40.1	45.0	53.2	63.6	71.2	80.6	85.5	85.4	77.4	66.5	52.2	43.1
Ottawa, Ontario	$\bar{H}$	539.1	852.4	1250.5	1506.6	1857.2	2084.5	2045.4	1752.4	1326.6	826.9	458.7	408.5
Lat. 45° 20'N	$\bar{K}_t$	0.499	0.540	0.554	0.502	0.529	0.554	0.560	0.546	0.521	0.450	0.359	0.436
El. 339 ft	t_o	14.6	15.6	27.7	43.3	57.5	67.5	71.9	69.8	61.5	48.9	35	19.6
Phoenix, Ariz	$\bar{H}$	1126.6	1514.7	1967.1	2388.2	2709.6	2781.5	2450.5	2299.6	2131.3	1688.9	1290	1040.9
Lat. 33° 26'N	$\bar{K}_t$	0.65	0.691	0.716	0.728	0.753	0.745	0.667	0.677	0.722	0.708	0.657	0.652
El. 1112 ft	t_o	54.2	58.8	64.7	72.2	80.8	89.2	94.6	92.5	87.4	75.8	63.6	56.7
Portland, Maine	$\bar{H}$	565.7	874.5	1329.5	1528.4	1923.2	2017.3	2095.6	1799.2	1428.8	1035	591.5	507.7
Lat. 43° 39'N	$\bar{K}_t$	0.482	0.524	0.569	0.500	0.544	0.536	0.572	0.554	0.546	0.539	0.431	0.491
El. 63 ft	t_o	23.7	24.5	34.4	44.8	55.4	65.1	71.1	69.7	61.9	51.8	40.3	28.0
Rapid City, S.D.	$\bar{H}$	687.8	1032.5	1503.7	1807	2028	2193.7	2235.8	2019.9	1628	1179.3	783.1	590.4
Lat. 44° 09'N	$\bar{K}_t$	0.601	0.627	0.649	0.594	0.574	0.583	0.612	0.622	0.628	0.624	0.586	0.588
El. 3218 ft	t_o	24.7	27.4	34.7	48.2	58.3	67.3	76.3	75.0	64.7	52.0	38.7	29.2
Riverside, Calif	$\bar{H}$	999.6	1335	1750.5	1943.2	2282.3	2492.6	2443.5	2263.8	1955.3	1509.6	1169	979.7
Lat. 33° 57'N	$\bar{K}_t$	0.589	0.617	0.643	0.594	0.635	0.667	0.665	0.668	0.665	0.639	0.606	0.626
El. 1020 ft	t_o	55.3	57.0	60.6	65.0	69.4	74.0	81.0	81.0	78.5	71.0	63.1	57.2
St. Cloud, Minn	$\bar{H}$	632.8	976.7	1383	1598.1	1859.4	2003.3	2087.8	1828.4	1369.4	890.4	545.4	463.1
Lat. 45° 35'N	$\bar{K}_t$	0.595	0.629	0.614	0.534	0.530	0.533	0.573	0.570	0.539	0.490	0.435	0.504
El. 1034 ft	t_o	13.6	16.9	29.8	46.2	58.8	68.5	74.4	71.9	62.5	50.2	32.1	18.3
Salt Lake City, Utah	$\bar{H}$	622.1	986	1301.1	1813.3	-	-	-	-	1689.3	1250.3	-	552.8
Lat. 40° 46'N	$\bar{K}_t$	0.468	0.909	0.529	0.579	-	-	-	-	0.621	0.610	-	0.467
El. 4227 ft	t_o	29.4	36.2	44.4	53.9	63.1	71.7	81.3	79.0	68.7	57.0	42.5	34.0
San Antonio, Tex	$\bar{H}$	1045	1299.2	1560.1	1664.6	2024.7	814.8	2264.2	2185.2	1844.6	1487.4	1104.4	954.6
Lat. 29° 32'N	$\bar{K}_t$	0.541	0.550	0.542	0.500	0.563	0.220	0.647	0.637	0.603	0.584	0.507	0.528
El. 794 ft	t_o	53.7	58.4	65.0	72.2	79.2	85.0	87.4	87.8	82.6	74.7	63.3	56.5

Appendix A (Continued)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Santa Maria, Calif	$\bar{H}$	983.8	1296.3	1805.9	2067.9	2375.6	2599.6	2540.6	2293.3	1965.7	1586.4	1169	943.9
Lat. 34°54'N.	$\bar{K}_t$	0.595	0.613	0.671	0.636	0.661	0.695	0.690	0.678	0.674	0.676	0.624	0.627
El. 238 ft	t_o	54.1	55.3	57.6	59.5	61.2	63.5	65.3	65.7	65.9	64.1	60.6	56.1
Sault Ste. Marie, Michigan .	$\bar{H}$	488.6	843.9	1336.5	1559.4	1962.3	2064.2	2149.4	1767.9	1207	809.2	392.2	359.8
Lat. 46°28'N.	$\bar{K}_t$	0.490	0.560	0.606	0.526	0.560	0.549	0.590	0.564	0.481	0.457	0.323	0.408
El. 724 ft	t_o	16.3	16.2	25.6	39.5	52.1	61.6	67.3	66.0	57.9	46.8	33.4	21.9
Sayville, N.Y	$\bar{H}$	602.9	936.2	1259.[illegible]	1560.5	1857.2	2123.2	2040.9	1734.7	1446.8	1087.4	697.8	533.9
Lat. 40°30'N.	$\bar{K}_t$	0.453	0.511	0.510	0.498	0.522	0.564	0.555	0.525	0.530	0.527	0.450	0.447
El. 20 ft.	t_o	35	34.9	43.1	52.3	63.3	72.2	76.9	75.3	69.5	59.3	48.3	37.7
Schenectady, N.Y.	$\bar{H}$	488.2	753.5	1026.6	1272.3	1553.1	1687.8	1662.3	1494.8	1124.7	820.6	436.2	356.8
Lat. 42°50'N.	$\bar{K}_t$	0.406	0.441	0.433	0.413	0.438	0.448	0.454	0.458	0.426	0.420	0.309	0.331
El. 217 ft	t_o	24.7	24.6	34.9	48.3	61.7	70.8	76.9	73.7	64.6	53.1	40.1	28.0
Seattle, Wash	$\bar{H}$	282.6	520.6	992.2	1507	1881.5	1909.9	2110.7	1688.5	1211.8	702.2	386.3	239.5
Lat. 47°27'N.	$\bar{K}_t$	0.296	0.355	0.456	0.510	0.538	0.508	0.581	0.533	0.492	0.407	0.336	0.292
El. 386 ft	t_o	42.1	45.0	48.9	54.1	59.8	64.4	68.4	67.9	63.3	56.3	48.4	44.4
Seattle, Wash	$\bar{H}$	252	471.6	917.3	1375.6	1664.9	1724	1805.1	1617	1129.1	638	325.5	218.1
Lat. 47°36'N.	$\bar{K}_t$	0.266	0.324	0.423	0.468	0.477	0.459	0.498	0.511	0.459	0.372	0.284	0.269
El. 14 ft.	t_o	38.9	42.9	46.9	51.9	58.1	62.8	67.2	66.7	61.6	54.0	45.7	41.5
Seabrook, N.J	$\bar{H}$	591.9	854.2	1195.6	1518.8	1800.7	1964.6	1949.8	1715	1445.7	1071.9	721.8	522.5
Lat. 39°30'N.	$\bar{K}_t$	0.426	0.453	0.476	0.481	0.504	0.522	0.530	0.517	0.524	0.508	0.449	0.416
El. 100 ft	t_o	39.5	37.6	43.9	54.7	64.9	74.1	79.8	77.7	69.7	61.2	48.5	39.3
Spokane, Wash.	$\bar{H}$	446.1	837.6	1200	1864.6	2104.4	2226.5	2479.7	2076	1511	844.6	486.3	279
Lat. 47°40'N.	$\bar{K}_t$	0.478	0.579	0.556	0.602	0.603	0.593	0.684	0.656	0.616	0.494	0.428	0.345
El. 1968 ft	t_o	26.5	31.7	40.5	49.2	57.9	64.6	73.4	71.7	62.7	51.5	37.4	30.5
State College, Pa.	$\bar{H}$	501.8	749.1	1106.6	1399.2	1754.6	2027.6	1968.2	1690	1336.1	1017	580.1	443.9
Lat. 40°48'N.	$\bar{K}_t$	0.381	0.413	0.451	0.448	0.493	0.539	0.536	0.512	0.492	0.496	0.379	0.376
El. 1175 ft	t_o	31.3	31.4	39.8	51.3	63.4	71.8	75.8	73.4	66.1	55.6	43.2	32.6
Stillwater, Okla.	$\bar{H}$	763.8	1081.5	1463.8	1702.6	1879.3	2235.8	[illegible]4.3	2039.1	1724.3	1314	991.5	783
Lat. 36°09'N	$\bar{K}_t$	0.484	0.527	0.555	0.528	0.523	0.596	[illegible]	0.607	0.599	0.581	0.548	0.544
El. 910 ft	t_o	41.2	45.6	53.8	64.2	71.6	81.1	8[illegible].9	85.9	77.5	67.6	52.6	43.9
Tampa, Fla.	$\bar{H}$	1223.6	1461.2	1771.9	2016.2	2228	2146.5	1991.9	1845.4	1687.8	1493.3	1328.4	1119.5
Lat. 27°55'N.	$\bar{K}_t$	0.605	0.600	0.606	0.602	0.620	0.583	0.548	0.537	0.546	0.572	0.590	0.589
El. 11 ft.	t_o	64.2	65.7	68.8	74.3	79.4	83.0	84.0	84.4	8[illegible].9	77.2	69.6	65.[illegible]

Appendix A (Continued)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Toronto, Ontario	$\bar{H}$	451.3	674.5	1088.9	1388.2	1785.2	1941.7	1968.6	1622.5	1284.1	835	458.3	352.8
Lat. 43°41'N.	$\bar{K}_t$	0.388	0.406	0.467	0.455	0.506	0.516	0.539	0.500	0.493	0.438	0.336	0.346
El. 379 ft	t_o	26.5	26.0	34.2	46.3	58	68.4	73.8	71.8	64.3	52.6	40.9	30.2
Tucson, Arizona	$\bar{H}$	1171.9	1453.8	-	2434.7	-	2601.4	2292.2	2179.7	2122.5	1640.9	1322.1	1132.1
Lat. 32°07'N.	$\bar{K}_t$	0.648	0.646	-	0.738	-	0.698	0.625	0.640	0.710	0.672	0.650	0.679
El. 2556 ft	t_o	53.7	57.3	62.3	69.7	78.0	87.0	90.1	87.4	84.0	73.9	62.5	5[illegible].1
Upton, N.Y.	$\bar{H}$	583	872.7	1280.4	1609.9	1891.5	2159	2044.6	1789.6	1472.7	1102.6	686.7	551.3
Lat. 40°52'N.	$\bar{K}_t$	0.444	0.483	0.522	0.514	0.532	0.574	0.557	0.542	0.542	0.538	0.448	0.467
El. 75 ft.	t_o	35.0	34.9	43.1	52.3	63.3	72.2	76.9	75.3	69.5	59.3	48.3	37.7
Washington, D.C. (WBCO). .	$\bar{H}$	632.4	901.5	1255	1600.4	1846.8	2080.8	1929.9	1712.2	1446.1	1083.4	763.5	594.1
Lat. 38°51'N.	$\bar{K}_t$	0.445	0.470	0.496	0.504	0.516	0.553	0.524	0.516	0.520	0.506	0.464	0.460
El. 64 ft.	t_o	38.4	39.6	48.1	57.5	67.7	76.2	79.9	77.9	72.2	60.9	50.2	40.2
Winnipeg, Man.	$\bar{H}$	488.2	835.4	1354.2	1641.3	1904.4	1962	2123.6	1761.2	1190.4	767.5	444.6	345
Lat. 49°54'N.	$\bar{K}_t$	0.601	0.636	0.661	0.574	0.550	0.524	0.587	0.567	0.504	0.482	0.436	0.503
El. 786 ft	t_o	3.2	7.1	21.3	40.9	55.9	65.3	71.9	69.4	58.6	45.6	25.2	10.1

Appendix B

AVERAGE EARTH TEMPERATURE FOR UNDERGROUND HEAT DISTRIBUTION SYSTEM DESIGN

The following list presents the average earth temperature from 0 to 10 feet below the surface for the four seasons of the year and for the whole year for the indicated locals. The temperatures were computed on the basis of the method described in the 1965 ASHRAE technical paper entitled "Earth Temperature and Thermal Diffusivity at Selected Stations in the United States" by T. Kusuda and P. R. Achenbach (in ASHRAE Transactions, Volume 71, Part I, p. 61, 1965) using the monthly average air temperatures published by the U.S. Weather Bureau for the listed localities in the United States. Earth temperatures are expressed in fahrenheit degrees.

Location Month	Winter 12,1,2	Spring 3,4,5	Summer 6,7,8	Autumn 9,10,11	Annual
Alabama					
Anniston AP[a]	55.	58.	70.	67.	63.
Birmingham AP	54.	58.	71.	68.	63.
Mobile AP	61.	63.	74.	71.	67.
Mobile CO[b]	61.	64.	75.	72.	68.
Montgomery AP	58.	61.	73.	70.	65.
Montgomery CO	59.	62.	74.	71.	66.
Arizona					
Bisbee COOP[c]	55.	58.	70.	67.	62.
Flagstaff AP	35.	39.	54.	50.	45.
Ft Huachuca (proving ground)	55.	58.	71.	68.	63.
Phoenix AP	60.	64.	79.	75.	69.
Phoenix CO	61.	65.	80.	76.	70.
Prescott AP	46.	49.	65.	61.	55.
Tucson AP	59.	62.	76.	73.	68.
Winslow AP	45.	49.	65.	61.	55.
Yuma AP	65.	69.	84.	80.	75.
Arkansas					
Fort Smith AP	52.	56.	72.	68.	62.
Little Rock AP	53.	57.	72.	68.	62.
Texarkana AP	56.	60.	74.	71.	65.
California					
Bakersfield AP	56.	60.	74.	70.	65.
Beaumont CO	53.	56.	67.	64.	60.
Bishop AP	47.	51.	65.	61.	56.
Blue Canyon AP	43.	46.	58.	55.	50.
Burbank AP	58.	60.	68.	66.	63.
Eureka CO	50.	51.	54.	54.	52.
Fresno AP	54.	58.	72.	68.	63.
Los Angeles AP	58.	59.	64.	63.	61.
Los Angeles CO	60.	61.	68.	66.	64.

Location	Winter	Spring	Summer	Autumn	Annual
California					
Mount Shasta CO	41.	44.	57.	54.	49.
Oakland AP	53.	54.	60.	59.	56.
Red Bluff AP	54.	58.	72.	69.	63.
Sacramento AP	53.	56.	67.	64.	60.
Sacramento CO	54.	57.	68.	65.	61.
Sandberg CO	47.	50.	63.	60.	55.
San Diego AP	59.	60.	66.	65.	62.
San Francisco AP	53.	54.	59.	57.	56.
San Francisco CO	55.	55.	59.	58.	57.
San Jose COOP	55.	57.	64.	62.	59.
Santa Catalina AP	57.	58.	64.	62.	60.
Santa Maria AP	54.	55.	60.	59.	57.
Colorado					
Alamosa AP	30.	35.	52.	48.	41.
Colorado Springs AP	39.	43.	59.	55.	49.
Denver AP	39.	43.	60.	56.	50.
Denver CO	41.	45.	61.	58.	51.
Grand Junction AP	39.	44.	65.	60.	52.
Pueblo AP	41.	45.	62.	58.	51.
Connecticut					
Bridgeport AP	40.	44.	61.	57.	50.
Hartford AP	39.	43.	61.	57.	50.
Hartford AP (Brainer)	39.	43.	60.	56.	50.
New Haven AP	40.	44.	60.	56.	50.
Delaware					
Wilmington AP	44.	48.	64.	60.	54.
Washington, D.C.					
Washington AP	47.	51.	66.	63.	56.
Washington CO	47.	51.	66.	63.	57.
Silver Hill OBS[d]	46.	50.	65.	61.	55.
Florida					
Apalachicola CO	63.	65.	75.	73.	69.
Daytona Beach AP	65.	67.	75.	74.	70.
Fort Myers AP	70.	71.	78.	76.	74.
Jacksonville AP	63.	66.	75.	73.	69.
Jacksonville CO	64.	66.	76.	73.	70.
Key West AP	74.	75.	80.	79.	77.
Key West CO	75.	76.	81.	79.	78.
Lakeland CO	68.	69.	77.	75.	72.
Melbourne AP	68.	70.	77.	75.	72.
Miami AP	72.	74.	79.	78.	76.
Miami CO	72.	73.	78.	77.	75.
Miami Beach COOP	74.	75.	80.	78.	77.
Orlando AP	68.	70.	77.	75.	72.

Location	Winter	Spring	Summer	Autumn	Annual
Florida					
Pensacola CO	62.	64.	74.	72.	68.
Tallahassee AP	61.	64.	74.	72.	68.
Tampa AP	68.	69.	77.	75.	72.
West Palm Beach	71.	73.	79.	77.	75.
Georgia					
Albany AP	60.	63.	75.	72.	67.
Athens AP	54.	58.	71.	68.	63.
Atlanta AP	54.	57.	70.	67.	62.
Atlanta CO	54.	57.	70.	67.	62.
Augusta AP	56.	59.	72.	69.	64.
Columbus AP	56.	59.	72.	69.	64.
Macon AP	58.	61.	74.	71.	66.
Rome AP	53.	56.	70.	67.	61.
Savannah AP	60.	63.	74.	71.	67.
Thomasville CO	62.	64.	74.	72.	68.
Valdosta AP	61.	64.	74.	72.	68.
Idaho					
Boise AP	40.	44.	62.	58.	51.
Idaho Falls 46 W	30.	35.	55.	50.	42.
Idaho Falls 42 N W	28.	33.	54.	49.	41.
Lewiston AP	42.	46.	63.	59.	52.
Pocatello AP	35.	40.	59.	55.	47.
Salmon CO	32.	37.	56.	52.	44.
Illinois					
Cairo CO	49.	53.	70.	65.	60.
Chicago AP	38.	43.	62.	57.	50.
Joliet AP	37.	42.	61.	56.	49.
Moline AP	38.	43.	62.	58.	50.
Peoria AP	39.	44.	63.	58.	51.
Springfield AP	41.	45.	64.	60.	52.
Springfield CO	43.	47.	66.	62.	54.
Indiana					
Evansville AP	47.	51.	67.	63.	57.
Fort Wayne AP	39.	43.	61.	57.	50.
Indianapolis AP	41.	46.	64.	59.	52.
Indianapolis CO	43.	48.	65.	61.	54.
South Bend AP	38.	42.	61.	56.	49.
Terre Haute AP	42.	47.	65.	60.	53.
Iowa					
Burlington AP	39.	44.	64.	59.	51.
Charles City CO	33.	38.	60.	55.	46.
Davenport CO	39.	44.	64.	59.	51.
Des Moines AP	37.	42.	63.	58.	50.
Des Moines CO	38.	43.	64.	59.	51.

Location	Winter	Spring	Summer	Autumn	Annual
Iowa					
Dubuque AP	34.	39.	60.	55.	47.
Sioux City AP	35.	40.	62.	57.	49.
Waterloo AP	35.	40.	61.	56.	48.
Kansas					
Concordia CO	42.	47.	67.	62.	54.
Dodge City AP	43.	48.	67.	62.	55.
Goodland AP	38.	43.	62.	57.	50.
Topeka AP	43.	47.	66.	62.	55.
Topeka CO	44.	49.	68.	63.	56.
Wichita AP	45.	50.	68.	64.	57.
Kentucky					
Bowling Green AP	47.	51.	67.	63.	57.
Lexington AP	44.	48.	65.	61.	54.
Louisville AP	46.	50.	67.	63.	56.
Louisville CO	47.	51.	67.	64.	57.
Louisiana					
Baton Rouge AP	61.	63.	74.	72.	67.
Burrwood CO	65.	67.	77.	74.	71.
Lake Charles AP	61.	64.	75.	73.	68.
New Orleans AP	63.	65.	75.	73.	69.
New Orleans CO	64.	66.	77.	74.	70.
Shreveport AP	58.	61.	75.	72.	66.
Maine					
Caribou AP	24.	29.	50.	45.	37.
Eastport CO	33.	37.	51.	48.	42.
Portland AP	33.	38.	56.	51.	44.
Maryland					
Baltimore AP	45.	49.	65.	61.	55.
Baltimore CO	47.	51.	67.	63.	57.
Frederick AP	44.	48.	65.	61.	55.
Massachusetts					
Boston AP	41.	44.	61.	57.	51.
Nantucket AP	41.	44.	57.	54.	49.
Pittsfield AP	34.	38.	55.	51.	44.
Worcester AP	36.	40.	58.	54.	47.
Michigan					
Alpena CO	33.	37.	54.	50.	43.
Detroit Willow Run AP	38.	42.	60.	56.	49.
Detroit City AP	38.	43.	60.	56.	49.
Escanaba CO	30.	35.	53.	49.	42.
Flint AP	36.	40.	58.	54.	47.
Grand Rapids AP	36.	40.	58.	54.	47.

Location	Winter	Spring	Summer	Autumn	Annual
Michigan					
Grand Rapids CO	38.	42.	60.	56.	49.
East Lansing CO	36.	40.	58.	54.	47.
Marquette CO	31.	35.	53.	49.	42.
Muskecon AP	36.	40.	57.	53.	47.
Sault Ste Marie AP	28.	32.	51.	47.	39.
Minnesota					
Crookston COOP	25.	31.	55.	49.	40.
Duluth AP	25.	30.	52.	47.	38.
Duluth CO	26.	31.	52.	47.	39.
International Falls	22.	27.	51.	45.	36.
Minneapolis AP	32.	37.	60.	54.	46.
Rochester AP	31.	36.	58.	53.	44.
Saint Cloud AP	28.	33.	56.	51.	42.
Saint Paul AP	32.	37.	60.	54.	46.
Mississippi					
Jackson AP	57.	61.	73.	70.	65.
Meridian AP	57.	60.	72.	69.	64.
Vicksburg CO	58.	61.	74.	71.	66.
Missouri					
Columbia AP	43.	48.	66.	62.	55.
Kansas City AP	44.	49.	68.	64.	56.
Saint Joseph AP	42.	47.	67.	62.	54.
Saint Louis AP	45.	49.	67.	63.	56.
Saint Louis CO	46.	50.	68.	64.	57.
Springfield AP	45.	49.	66.	62.	56.
Montana					
Billings AP	35.	40.	59.	55.	47.
Butte AP	27.	31.	50.	45.	38.
Glasgow AP	27.	33.	56.	51.	42.
Glasgow CO	28.	34.	57.	52.	43.
Great Falls AP	34.	38.	56.	52.	45.
Harve CO	31.	36.	57.	52.	44.
Helena AP	31.	36.	55.	50.	43.
Helena CO	32.	36.	55.	50.	43.
Kalispell AP	32.	37.	54.	50.	43.
Miles City AP	32.	37.	59.	54.	45.
Missoula AP	33.	37.	56.	51.	44.
Nebraska					
Grand Island AP	38.	43.	64.	59.	51.
Lincoln AP	39.	44.	64.	60.	52.
Lincoln CO University	40.	45.	65.	61.	53.
Norfolk AP	35.	40.	62.	57.	48.
North Platte AP	37.	42.	62.	57.	49.
Omaha AP	39.	44.	65.	60.	52.

Location	Winter	Spring	Summer	Autumn	Annual
Nebraska					
Scottbluff AP	36.	41.	60.	56.	48.
Valentine CO	35.	40.	61.	56.	48.
Nevada					
Elko AP	34.	39.	57.	53.	46.
Ely AP	35.	39.	56.	52.	45.
Las Vegas AP	56.	60.	78.	74.	67.
Reno AP	40.	44.	58.	55.	49.
Tonopah	41.	45.	61.	57.	51.
Winnemucca AP	38.	42.	60.	56.	49.
New Hampshire					
Concord AP	33.	38.	56.	52.	45.
Mt Washington COOP	17.	21.	37.	33.	27.
New Jersey					
Atlantic City CO	45.	49.	63.	60.	54.
Newark AP	43.	47.	63.	59.	53.
Trenton CO	43.	47.	64.	60.	53.
New Mexico					
Albuquerque AP	46.	50.	67.	63.	57.
Clayton AP	43.	47.	63.	59.	53.
Raton AP	38.	42.	58.	54.	48.
Roswell AP	51.	54.	69.	66.	60.
New York					
Albany AP	36.	40.	59.	54.	47.
Albany CO	38.	43.	61.	56.	49.
Bear Mountain CO	38.	42.	59.	55.	48.
Binghampton AP	34.	38.	56.	52.	45.
Binghampton CO	38.	42.	59.	55.	48.
Buffalo AP	37.	41.	58.	54.	47.
New York AP (La Guardia)	44.	48.	64.	60.	54.
New York CO	44.	47.	63.	59.	53.
New York Central Park	44.	48.	64.	60.	54.
Oswego CO	36.	40.	58.	54.	47.
Rochester AP	37.	41.	58.	54.	47.
Schenectady COOP	35.	40.	59.	55.	47.
Syracuse AP	38.	42.	60.	56.	49.
North Carolina					
Asheville CO	48.	51.	64.	61.	56.
Charlotte AP	52.	55.	69.	66.	60.
Greensboro AP	49.	53.	67.	64.	58.
Hatteras CO	56.	59.	70.	68.	63.
Raleigh AP	51.	55.	69.	65.	60.
Raleigh CO	52.	56.	70.	66.	61.
Wilmington AP	56.	59.	71.	69.	64.
Winston Salem AP	50.	53.	67.	64.	58.

Location	Winter	Spring	Summer	Autumn	Annual
North Dakota					
Bismarck AP	27.	33.	56.	51.	42.
Devils Lake CO	24.	29.	54.	48.	39.
Fargo AP	26.	32.	56.	50.	41.
Minot AP	25.	31.	54.	49.	39.
Williston CO	27.	33.	56.	50.	41.
Ohio					
Akron-Canton AP	39.	43.	60.	56.	50.
Cincinnati AP	43.	47.	64.	60.	54.
Cincinnati CO	46.	50.	66.	63.	56.
Cincinnati ABBE OBS	45.	49.	65.	61.	55.
Cleveland AP	40.	44.	61.	57.	51.
Cleveland CO	41.	45.	62.	58.	51.
Columbus AP	41.	46.	62.	59.	52.
Columbus CO	43.	47.	64.	60.	53.
Dayton AP	42.	46.	63.	59.	52.
Sandusky CO	41.	45.	62.	58.	51.
Toledo AP	38.	43.	60.	56.	49.
Youngstown AP	39.	43.	60.	56.	50.
Oklahoma					
Oklahoma City AP	50.	54.	71.	67.	60.
Oklahoma City CO	50.	55.	71.	68.	61.
Tulsa AP	50.	54.	71.	67.	61.
Oregon					
Astoria AP	47.	48.	56.	54.	51.
Baker CO	36.	40.	56.	52.	46.
Burns CO	36.	40.	58.	54.	47.
Eugene AP	46.	48.	59.	57.	52.
Meacham AP	34.	38.	52.	49.	43.
Medford AP	46.	49.	62.	59.	54.
Pendelton AP	42.	46.	63.	59.	53.
Portland AP	46.	49.	60.	57.	53.
Portland CO	48.	50.	61.	59.	55.
Roseburg AP	47.	49.	60.	57.	53.
Roseburg CO	48.	51.	61.	59.	55.
Salem AP	46.	49.	60.	57.	53.
Sexton Summit	42.	44.	55.	52.	48.
Troutdale AP	45.	48.	59.	57.	52.
Pennsylvania					
Allentown AP	40.	44.	62.	58.	51.
Erie AP	38.	42.	58.	55.	48.
Erie CO	40.	44.	60.	56.	50.
Harrisburg AP	43.	47.	63.	59.	53.
Park Place CO	36.	40.	57.	53.	46.
Philadelphia AP	44.	48.	64.	61.	54.
Philadelphia CO	46.	50.	66.	62.	56.
Pittsburgh Allegheny	42.	46.	62.	58.	52.

Location	Winter	Spring	Summer	Autumn	Annual
Pennsylvania					
Pittsburgh GRTR PITT	40.	44.	61.	57.	51.
Pittsburgh CO	44.	48.	64.	60.	54.
Reading CO	43.	47.	64.	60.	54.
Scranton CO	40.	44.	61.	57.	50.
Wilkes Barre-Scranton	39.	43.	60.	56.	49.
Williamsport AP	40.	44.	61.	57.	51.
Rhode Island					
Block Island AP	41.	45.	59.	55.	50.
Providence AP	39.	43.	59.	56.	49.
Providence CO	41.	45.	62.	58.	51.
South Carolina					
Charleston AP	58.	61.	72.	70.	65.
Charleston CO	60.	62.	74.	71.	67.
Columbia AP	56.	59.	72.	69.	64.
Columbia CO	57.	60.	72.	69.	64.
Florence AP	55.	59.	72.	69.	64.
Greenville AP	53.	56.	69.	66.	61.
Spartanburg AP	53.	56.	70.	66.	61.
South Dakota					
Huron AP	31.	37.	60.	55.	46.
Rapid City AP	34.	39.	58.	54.	46.
Sioux Falls AP	32.	37.	60.	55.	46.
Tennessee					
Bristol AP	48.	51.	65.	62.	56.
Chattanooga AP	51.	55.	69.	65.	60.
Knoxville AP	50.	54.	68.	65.	59.
Memphis AP	52.	56.	71.	68.	62.
Memphis CO	53.	57.	72.	68.	62.
Nashville AP	51.	54.	69.	66.	60.
Oak Ridge CO	49.	52.	67.	64.	58.
Oak Ridge 8 S	49.	52.	67.	64.	58.
Texas					
Abilene AP	55.	58.	73.	70.	64.
Amarillo AP	47.	50.	67.	63.	57.
Austin AP	60.	63.	76.	73.	68.
Big Springs AP	56.	59.	74.	70.	65.
Brownsville AP	68.	70.	79.	77.	74.
Corpus Christi AP	65.	68.	78.	76.	72.
Dallas AP	57.	61.	76.	72.	66.
Del Rio AP	62.	65.	77.	75.	70.
El Paso AP	54.	58.	72.	69.	63.
Fort Worth AP (Amon Carter)	57.	60.	75.	72.	66.
Galveston AP	63.	66.	77.	74.	70.

Location	Winter	Spring	Summer	Autumn	Annual
Texas					
Galveston CO	63.	66.	77.	74.	70.
Houston AP	62.	65.	76.	73.	69.
Houston CO	63.	66.	77.	74.	70.
Laredo AP	67.	70.	81.	79.	74.
Lubbock AP	50.	54.	69.	65.	59.
Midland AP	55.	59.	73.	70.	64.
Palestine CO	58.	62.	74.	71.	66.
Port Arthur AP	61.	64.	75.	72.	68.
Port Arthur CO	63.	65.	76.	74.	69.
San Angelo AP	58.	61.	74.	71.	66.
San Antonio AP	61.	64.	77.	74.	69.
Victoria AP	64.	67.	78.	76.	71.
Waco AP	58.	62.	76.	73.	67.
Wichita Falls AP	53.	57.	73.	69.	63.
Utah					
Blanding CO	39.	43.	60.	56.	50.
Milford AP	37.	42.	61.	56.	49.
Salt Lake City AP	40.	44.	63.	59.	51.
Salt Lake City CO	41.	46.	65.	60.	53.
Vermont					
Burlington AP	32.	37.	57.	52.	44.
Virginia					
Cape Henry CO	51.	55.	68.	65.	60.
Lynchburg AP	48.	51.	66.	62.	57.
Norfolk AP	51.	54.	68.	64.	59.
Norfolk CO	52.	56.	69.	66.	61.
Richmond AP	48.	52.	67.	63.	58.
Richmond CO	50.	53.	68.	64.	59.
Roanoke AP	48.	51.	66.	62.	57.
Washington					
Ellensburg AP	37.	41.	59.	55.	48.
Kelso AP	45.	47.	57.	54.	51.
North Head L H RESVN	47.	49.	54.	53.	51.
Olympia AP	44.	46.	56.	54.	50.
Omak 2 mi N W	36.	40.	59.	55.	47.
Port Angeles AP	45.	46.	53.	52.	49.
Seattle AP (Boeing Field)	46.	48.	58.	56.	52.
Seattle CO	47.	50.	59.	57.	53.
Seattle-Tacoma AP	44.	47.	57.	55.	51.
Spokane AP	37.	41.	58.	54.	47.
Stampede Pass	32.	35.	48.	45.	40.
Tacoma CO	46.	48.	58.	55.	52.
Tattosh Island CO	46.	47.	52.	51.	49.
Walla Walla CO	44.	48.	65.	61.	54.
Yakima AP	40.	44.	61.	57.	50.

Location	Winter	Spring	Summer	Autumn	Annual
West Virginia					
Charleston AP	47.	50.	65.	61.	56.
Elkins AP	41.	45.	59.	56.	50.
Huntington CO	48.	52.	67.	63.	57.
Parkersburg CO	45.	49.	65.	61.	55.
Petersburg CO	44.	48.	63.	60.	54.
Wisconsin					
Green Bay AP	31.	36.	56.	51.	44.
La Crosse AP	32.	38.	60.	55.	46.
Madison AP	34.	39.	59.	54.	47.
Madison CO	34.	39.	60.	55.	47.
Milwaukee AP	35.	40.	58.	54.	47.
Milwaukee CO	36.	41.	59.	55.	48.
Wyoming					
Casper AP	34.	38.	57.	52.	45.
Cheyenne AP	35.	39.	55.	51.	45.
Lander AP	31.	35.	56.	51.	43.
Rock Springs AP	31.	35.	54.	50.	42.
Sheridan AP	33.	37.	56.	52.	44.
Hawaii					
Hilo AP	72.	72.	74.	74.	73.
Honolulu AP	74.	75.	77.	77.	76.
Honolulu CO	74.	74.	77.	76.	75.
Lihue AP	72.	73.	76.	75.	74.
Alaska					
Anchorage AP	25.	29.	46.	42.	35.
Annette AP	40.	42.	51.	49.	46.
Barrow AP	4.	7.	16.	14.	10.
Bethel AP	18.	23.	41.	37.	30.
Cold Bay AP	33.	35.	43.	41.	38.
Cordova AP	32.	35.	45.	43.	39.
Fairbanks AP	14.	19.	38.	34.	26.
Galena AP	13.	18.	37.	33.	25.
Gambell AP	15.	19.	34.	30.	24.
Juneau AP	34.	36.	47.	45.	41.
Juneau CO	36.	39.	49.	46.	42.
King Salmon AP	25.	28.	44.	40.	34.
Kotzebue AP	10.	14.	31.	27.	21.
McGrath AP	14.	18.	37.	33.	25.
Nome AP	16.	20.	37.	33.	26.
Northway AP	12.	16.	32.	29.	22.
Saint Paul Island AP	31.	32.	40.	38.	35.
Yakutat AP	33.	36.	45.	43.	39.
West Indies					
Ponce Santa Isabel AP	75.	76.	78.	78.	77.
San Juan AP	77.	77.	79.	79.	78.

Location	Winter	Spring	Summer	Autumn	Annual
West Indies					
San Juan CO	77.	77.	79.	79.	78.
Swan Island	80.	80.	82.	81.	81.
Virgin Islands					
St Croix, V.I. AP	78.	78.	81.	80.	79.
Pacific Islands					
Canton Island AP	83.	84.	84.	84.	84.
Koror	81.	81.	81.	81.	81.
Ponape Island AP	81.	81.	81.	81.	81.
Truk Moen Island	81.	81.	81.	81.	81.
Wake Island AP	79.	79.	81.	81.	80.
Yap	81.	81.	82.	82.	82.

[a]AP = Airport data.

[b]CO = City office data.

[c]COOP = Cooperative weather station.

[d]OBS = Observation station.

Appendix C

Fortran Listing of the Computer Program

(continued)

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QSQSQS*CONSP6(1).MAIN(23)
      C     THIS IS THE  HOME ENERGY AUDIT PROGRAM OF NBS
      C      CALCULATION PROCEDURES ARE BASED ON THE MONTHLY NORMAL WEATHER DATA AND ON THE
      C      VARIABLE DEGREE DAY METHODS.  DETAILS OF THE ALGORITHM ARE GIVEN IN
      C      NBSIR 80-1961 ENTITLED "SIMPLIFIED HEATING AND COOLING ENERGY CALCULATIONS
      C      FOR RESIDENTIAL APPLICATIONS" BY T. KUSUDA AND TOMONORI SAITOH.
      C
             DIMENSION B(350),R(50),HLHWH1(12),HLHWH2(12),SAVE(12)
            1,QQC(12),QQH(12),WHREQ(12),CDEG(16),HDEG(16),TOD(12),TON(12)
             DIMENSION TOWN(4)/' WASHI','NGTON ',' DC    ','       '/
             DIMENSION HOUSE(4)/' HASTI','NGS HO','USE   ','       '/
      C      HRDAY       DAYTIME HOURS
      C      HRNIT       NIGHTTIME HOURS
      C      CDEG        COOLING DEGREE DAYS FOR BASE 45 THROUGH 60 DEG F
      C      HDEG        HEATING DEGREE DAYS FOR BASE 45 THROUGH 60 DEG F
             COMMON/HR/HRDAY(12),HRNIT(12)
      C      DATA DEFINITIONS ARE IN THE SUBROUTINE HCLD
      C              B(I),I=1,337   : INPUT
      C              B(I),I=1,50    : OUTPUT
             DATA (B(I),I=1,153)/
            *  9600.0,0.5,38.4,39.6,48.1,57.5,67.7,76.2,79.9,                  1-9
            *77.9,72.2,60.9,50.2,40.2,35.6,37.3,45.1,56.4,                     10-18
            *66.2,74.6,78.7,77.1,70.6,59.8,48.,37.4,70.,70.,70.,70.,78.,78.,78. 19-33
            *,78.,78.,70.,70.,70.,65.,65.,65.,65.,78.,78.,78.,78.,78.,65.,65.,  34-49
            *65.,1.,-9999.,-9999.,9.9,                                          50-54
            *10.4,10.9,10.5, 9.2, 8.7, 8.1, 6.0, 8.2, 8.5,                     55-63
            * 9.2, 9.4,-9999.,-9999.,180.0,38.5,0.2,20234.,55.10,              64-72
            *0.80,1.13,0.0,270.0,0.0,0.0, 0.10,0.0,  0.0,                      73-81
            * 72.00,0.80,1.13,0.0, 90.0,0.0,0.0,0.1,0.0,                       82-90
            *90.0, .75,1.0,70.0,70.0,70.0,70.0,70.0,70.0,                      91-99
            *70.0,70.0,70.0,70.0,70.0,70.0,0.0, 0.0,1.0,                       100-108
            *10.0,0.0,0.9,-9999.,-9999.,-9999.,-9999.,-9999.,-9999.,           109-117
            *-9999.,-9999.,-9999.,-9999.,-9999.,-9999.,0.100,244.9,1.0,        118-126
            *10.,0.,.9,.1,240.,1.,10.,0.,.9,.1,248.,1.,10.,0.,.9,.1,240.,1.,   127-144
            *0.0,0.0,80.,60.,0.0,0.0,0.9,0.2,0.625/                            145-153
             DATA (B(I),I=154,314)/
            *1.0,1.0,-9999.,37.5, 3.0, 0.05, 0.4,-9999.,  0.1,                 154-162
            *75.0,6.0,9.0,1.0,1.0,140.0,60.0,62.0,64.0,                        163-171
            *66.0,67.0,68.0,67.0,66.0,65.0,64.0,62.0,61.0,                     172-180
            *0.0,0.0,0.0,0.0,0.0,1.79,3.0,116.4,260.4,                         181-189
            * 846.0,508.8,1200.0,1200.0,1.0,3.0,0.164,0.0,1.0,                 190-198
            *0.1,0.0,20.0,1.0,500.,500.,1.0,0.516,0.553,                       199-207
            *0.524,0.516,0.520,0.506,0.464,0.460,632.4,901.5,1255.0,           208-216
            *1600.4,1846.8,2080.8,1929.9,1712.2,1446.1,1083.4,763.5,594.1,     217-225
            *0.67,-9999.,-9999.,-9999.,-9999.,-9999.,2.1,-9999.,-9999.,        226-234
            *-9999.,-9999.,-9999.,-9999.,-9999.,   2.0,20.0,20.0,20.0,         235-243
            *20.0,20.0,60.0,60.0,60.0,60.0,20.0,20.0,20.0,                     244-252
            *20.0,20.0,20.0,20.0,20.0,60.0,60.0,60.0,60.0,                     253-261
            *20.0,20.0,20.0,69.0,67.0,68.0,68.0,72.0,75.0,                     262-270
            *75.0,79.0,80.0,79.0,73.0,71.0,54.0,52.0,49.0,                     271-279
            *47.0,51.0,52.0,52.0,54.0,55.0,51.0,52.0,57.0,                     280-288
            *-9999.,0.0,0.9,0.49,20.0,-9999.,0.0,0.0,0.0,                      289-297
            *0.0,-9999.,0.0,0.0,0.0,  0.0,-9999.,0.0,0.0,                      298-306
            Z0.46,0.0,1.0,40.0,0.08,0.025,0.0,0.0/                             307-314
             DATA (B(I),I=315,337)/
            162.0,41.0,140.0,176.0,                                            315-318
            2100.0,0.57,0.0,1.46,                                              319-322
            30.0,0.57,0.0,1.46,                                                323-326
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     4100.0,0.57,0.0,1.46,                                               327-330
     50.0,1.46,0.0,4.10,10.0,0.0,64000.0/                                331-337
      DATA CDEG/2251.,2084.,1927.,1773.,1626.,1483.,1346.,1210.,1078.,
     *953.,830.,718.,615.,520.,427.,344./,HDEG/827.,936.,1052.,1174.,
     *1298.,1430.,1568.,1714.,1861.,2018.,2185.,2359.,2537.,2722.,2911.,
     *3107./
      DO 100 I=1,4
      B(I+337)=TOWN(I)
  100 B(I+341)=HOUSE(I)
      CALL HCLD(B,R,HLHWH1,HLHWH2,SAVE,QQC,QQH,WHREQ,THT,TCT)
      TBTU=R(2)-R(1)
      WRITE (6,1000) (R(I),I=1,2)
      WRITE (6,1010) TBTU
C
C     VARIABLE DEGREE DAY METHOD CALCULATION
      CALL DEGDAY(R,CDEG,HDEG,THT,TCT)
      SUM1=0.0
      SUM2=0.0
      SUM3=0.0
      SUM4=0.0
      SUM5=0.0
      SUM6=0.0
      SUM7=0.0
      DO 200 I=1,12
      SUM1=SUM1+HLHWH1(I)
      SUM2=SUM2+HLHWH2(I)
      SUM3=SUM3+SAVE(I)
      SUM4=SUM4+WHREQ(I)
      SUM5=SUM5+QQC(I)
      SUM6=SUM6+QQH(I)
      SUM7=SUM4-SUM2
  200 CONTINUE
      WRITE(6,1001) SUM1
 1001 FORMAT(/1H ,'ANNUAL HEAT LOSS THROUGH NON-ADDITIONAL JACKET INSULA
     1TION OF HOT WATER TANK : ',G10.4)
      WRITE(6,1002) SUM2
 1002 FORMAT(1H ,'ANNUAL HEAT LOSS THROUGH ADDITIONAL JACKET INSULATION
     1OF HOT WATER TANK : ',G10.4)
      WRITE(6,1003) SUM3
 1003 FORMAT(1H ,'ANNUAL ENERGY SAVING BY ADDITIONAL INSULATION OF HOT W
     1ATER TANK : ',G10.4)
      WRITE(6,1004) SUM4
 1004 FORMAT(1H ,'ANNUAL HOT WATER REQUIREMENT,INCLUDING JACKET HEAT LOS
     1S : ',G10.4)
      WRITE(6,1005) SUM7
 1005 FORMAT(1H ,'ANNUAL HOT WATER REQUIREMENT,EXCLUDING JACKET HEAT LOS
     1S : ',G10.4)
      WRITE(6,1006) SUM5
 1006 FORMAT(1H ,'ANNUAL HEAT GAIN THROUGH DUCTS & PIPES FOR SPACE COOLI
     1NG : ',G10.4)
      WRITE(6,1007) SUM6
 1007 FORMAT(1H ,'ANNUAL HEAT LOSS THROUGH DUCTS & PIPES FOR SPACE HEATI
     1NG : ',G10.4)
 1000 FORMAT(1H ,40X,'SHBTU = ',F15.0,5X,'SCBTU = ',F15.0)
 1010 FORMAT (7H  TBTU=,F15.0)
      STOP
      END
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QSQSQS*CONSP6(1).HCLD(5)

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      SUBROUTINE HCLD (B, R,HLHWH1,HLHWH2,SAVE,QQC,QQH,WHREQ,SUM1,SUM2)
C
C     ***********          ***********          ************
C
C     HEAP HEATING/COOLING LOAD DETERMINATION ROUTINE
C
C
C     ***********          ***********          ************
C
      COMMON/HR/HRDAY(12),HRNIT(12)
      DIMENSION    TOD(12),     TON(12),     TID(12),     TIN(12),RINFIL(12),
     1        RH(2,12),   QISD(12),  QISN(12),QILD(12),   QILN(12),
     2  XIDT(12),   XIDD(12),   QCD1(12),   QCN1(12),   QCD2(12),   QCN2(12),
     3  QCD3(12),   QCN3(12),   QCD4(12),   QCN4(12),    QCD(12),    QCN(12),
     4    QS(12),   SATD(12),   SATN(12),    CD1(12),    CN1(12),    CD2(12),
     5   CN2(12),    CD3(12),    CN3(12),    CD4(12),    CN4(12),    QDD(12),
     6   QDN(12),    QCD(12),    QCN(12),     FO(12),   TWD1(12),   TWN1(12),
     7   ATD(12),    ATN(12),    QFD(12),    QFN(12),CRAWLD(12),CRAWLN(12),
     8    QRD(12),    QRN(12),TOT(12),B(350),R(50),
     9   QID(12),    QIN(12),    QTD(12),    QTN(12),     HG(12),     HL(12),
     A  RLHG(12),   HREQ(12),   CREQ(12),
     B       QWD(12),    QWN(12),      ZT(12),
     C    TE(12),     TG(12),      H(12), BSMTD(12), BSMTN(12), TOWN(4)
     D ,TWD2(12),   TWN2(12),    TWD(12),    TWN(12)
      DIMENSION DAYS(12)/31.,28.,31.,30.,31.,30.,31.,31.,30.,31.,30.,31.
     */
      DIMENSION    XIDTS(12), XIDDS(12), XIDTW(12), XIDDW(12), XIDTN(12),
     1 XIDDN(12). .IDTE(12), XIDDE(12),       AA(32),   BQFD(12),   BQFN(12),
     2 ATQCD(12), ATQCN(12), WHREQ(12),   QDD1(12),   QDN1(12),   QDD2(12),
     3   QDN2(12),   QDD3(12),   QDN3(12),   QDD4(12),   QDN4(12), XT901(12),
     4 XD901(12), XT902(12), XD902(12), XT903(12), XD903(12), XT904(12),
     5 XD904(12),     RHM(12),     RHA(12),      XX(12),      WS(12),HLHWH1(12),
     6HLHWH2(12),   SAVE(12),     QC1(12),     QC2(12),     QC3(12),     QC4(12),
     7    SCD(12),     QH1(12),     QH2(12),     QH3(12),     QH4(12),     QQC(12),
     8    QQH(12),   CFAC(12),   HFAC(12),   SCD1(12),   SCD2(12),   SCD3(12),
     9  SCD4(12),      ZK(12)
      DATA AA/3HTID,3HTIN,3HTOD,3HTON,5HXIDTS,5HXIDDS,5HXIDTW,5HXIDDW,
     1 5HXIDTN,5HXIDDN,5HXIDTE,5HXIDDE,3HQID,3HQIN,3HQWD,3HQWN,3HQDD,
     2 3HQDN,3HQCD,3HQCN,3HQGD,3HQGN,3HQFD,3HQFN,3HQRD,3HQRN,3HQTD,3HQTN
     3 ,5HHRDAY,5HHRNIT,3HSCD,2HZK/
      DATA FO/6.,6.,5.,5.,5.,4.,4.,4.,5.,5.,5.,6./
      V      = B(1)      @           (INFIL)   VOLUME OF THE ROOM, FT3   L*W*H
      ACHS   = B(2)      @           (INFIL)   STD AIR CHANGE DATA, AC/HR
      DO 10 I=1,12
      TOD(I) = B(I+2)    @                     DAYTIME OUTDOOR TEMPERATURE  TO
      TOT(I) = B(I+14)
      TON(I) = 2.*TOT(I)-TOD(I)
      TID(I) = B(I+26)   @                     DAYTIME INDOOR TEMP         RMDBS/W
   10 TIN(I) = B(I+38)   @                     NIGHTTIME INDOOR TEMP       RMDBS/W
      IACNV=B(51)
      DO 20 I=1,12
   20 WS(I)  = B(I+53)   @           (INFIL)   WIND SPEED, MPH
      ORT1   = B(68)     @                     ORIENTATION (0S,90W,180N,270E) AZW
      XLAT   = B(69)     @                                                    LAT
      RHO    = B(70)     @           (SOLDAT)
      ZIP    = B(71)     @           (SOLDAT)  NOT USED---ALPHANUMERIC TITLE
      AG1    = B(72)     @           (QG)      GLASS AREA                  A
      SC1    = B(73)     @           (QG)      SHADING COEFFICIENT         SHADE
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C 3

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      UG1    = B(74)    @          (QC)       HEAT TRANSFER COEFFICIENT U
      SHDW1  = B(75)    @          (QC)       EXTERNAL SHADOW FACTOR     SHDW
      ORT2   = B(76)
      AC2    = B(77)
      SC2    = B(78)
      UC2    = B(79)
      SHDW2  = B(80)
      ORT3   = B(81)
      AC3    = B(82)
      SC3    = B(83)
      UC3    = B(84)
      SHDW3  = B(85)
      ORT4   = B(86)
      AC4    = B(87)
      SC4    = B(88)
      UC4    = B(89)
      SHDW4  = B(90)
      WTLT1  = B(91)    @          (SOLDAT)   TILT ANGLE 0-90 DEG FROM HOR.SURF.
      SA     = B(92)    @          (QS)       SOLAR COLLECTOR EFFICIENCY FACTORS
      SB     = B(93)    @          (QS)       SOLAR COLLECTOR EFFICIENCY FACTORS
      DO 30 I=1,12
   30 TE(I)  = B(I+93)  @          (SEU,QS)   INLET FLUID TEMP. TO THE COLLECTOR
      SUF    = B(106)   @          (SEU)      SOLAR HEAT UTILIZATION FACTOR
      AS     = B(107)   @          (SEU)      COLLECTOR AREA, FT2
      WALL11 = B(108)   @ ROOF OVERHANG OVER WALL
      WALL12 = B(109)   @ HEIGHT OF WALL 1
      WALL13 = B(110)   @ SHDW     (QC,SAT)   EXTERNAL SHADOW FACTOR (0.0 - 1.0)
      WALL14 = B(111)   @ AB       (SAT)      SURFACE ABSORPTIVITY        ABSP
      WALL15 = B(124)   @ U        (QECHC)    OVERALL HEAT TRANSFER COEFFICIENT
      WALL16 = B(125)   @ A        (QECHC)    AREA
      WALL21 = B(126)   @ ROOF OVERHANG OVER WALL 2
      WALL22 = B(127)   @ HEIGHT OF WALL 2
      WALL23 = B(128)   @ SHDW
      WALL24 = B(129)   @ AB
      WALL25 = B(130)   @ U
      WALL26 = B(131)   @ A
      WALL31 = B(132)   @ ROOF OVERHANG OVER WALL 3
      WALL32 = B(133)   @ HEIGHT OF WALL 3
      WALL33 = B(134)   @ SHDW
      WALL34 = B(135)   @ AB
      WALL35 = B(136)   @ U
      WALL36 = B(137)   @ A
      WALL41 = B(138)   @ ROOF OVERHANG OVER WALL 4
      WALL42 = B(139)   @ HEIGHT OF WALL 4
      WALL43 = B(140)   @ SHDW
      WALL44 = B(141)   @ AB
      WALL45 = B(142)   @ U
      WALL46 = B(143)   @ A
      SOGFRC  = B(144)
      CRWFRC  = B(145)
      BSMFRC  = B(146)
      TIC    = B(147)
      TIH    = B(148)
      ROOF1  = B(150)   @ SHDW     (SAT)      ATTICLESS
      ROOF2  = B(151)   @ AB       (SAT)      ATTICLESS
      ROOF3  = B(152)   @ U / UR   (QECHC/ATTIC)      ATTICLESS/WITH ATTIC
      AEWH = B(153)
      ISOLHW = B(154)
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      ISOLSH = B(155)
      ROOF4 = B(149)
      AW   = B(157)
      ACAT=B(158)
      UCEIL  = B(159)   @ UC / U    (ATTIC/QECHG)     U-VALUE CLG / HTC UCELNG
      AEW5   = B(160)   @ UW / A    (ATTIC/QECHG)     U-VALUE WALL/AREA UENDW/A
      UFLR1  = B(163)     @ U          (GF)      FLOOR HEAT TRANSFER COEFF. (HTC)
      HWT  = B(163)
      NSTART = B(164)
      NLAST = B(165)
      INDEXD = B(166)
      INDEXC = B(167)
      ZL = B(168)  @ EXPOSED PERIMETER LENGTH OF THE FLOOR
      DO 50 I=1,12
   50 TC(I)  = B(I+168) @           (CRAWL,CF)    GROUND TEMP, SEASONAL  TCS/TCW
      ACCS=B(181)
      UFLR2  = B(182)   @ UF / U    (CRAWL/QECHG)     FLOOR HTC/OVERALL HTC    U
      UCLW   = B(183)   @ UW / U    (CRAWL/QECHG)     WALL  HTC/OVERALL HTC    U
      HCL = B(184)
      AWCL   = B(185)   @ AW / A    (CRAWL/QECHG)     CRAWL SPACE WALL AREA    A
      NPD    = B(186)   @           (QR)     NO. DAYTIME OCCUPANTS      QOCUP
      NPN    = B(187)   @           (QR)     NO. NIGHTTIME OCCUPNATS    QOCUP
      WTD    = B(188)   @           (QR)     AVG.DAYTIME LIGHTING       QLITX
      WTN    = B(189)   @           (QR)     AVG. NIGHTTIME LIGHTING    QLITX
      WED    = B(190)   @           (QR)     AVG. DAYTIME EQUIPMENT     QEQUX
      WEN    = B(191)   @           (QR)     AVG. NIGHTTIME EQUIPMENT   QEQUX
      FLOORA = B(192)   @ AF        (QR)     FLOOR AREA
      ATFLR = B(193)
      UBW    = B(194)
      ISYS   = B(195)   @           (EREQ)   SYSTEM INDEX
      UFW    = B(196)
      BWA    = B(197)   @           (BSMT)   BASEMENT WALL AREA
      UBF    = B(198)
      UFF    = B(199)
      QBHG   = B(200)   @           (BSMT)   HEAT GAIN FROM FURNACE, BOILER,ETC
      THTC = B(201)
      ZKS = B(202)     @          (GF)     GROUND THERMAL CONDUCTIVITY
      DX  = B(203)     @          (GF)     SIDE HOUSE DISTANCE
      DY  = B(204)     @          (GF)     FRONT HOUSE DISTANCE
      E   = B(205)     @          (GF)     WALL THICKNESS
      DO 60 I=1,12
   60 H(I)= B(I+213)   @          (SOLDAT)  DAILY TOTAL HORIZONTAL RADIATION
      EH = B(226)
      EC = B(232)
      PUH=B(240)       @       PICK UP HOURS
      DO 80 I=1,12
      RH(1,I) = B(I + 240)
      RH(2, I) = B(I + 252)
   80 CONTINUE
      RHM(1) = B(265)
      RHM(2) = B(266)
      RHM(3) = B(267)
      RHM(4) = B(268)
      RHM(5) = B(269)
      RHM(6) = B(270)
      RHM(7) = B(271)
      RHM(8) = B(272)
      RHM(9) = B(273)
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RHM(10) = B(274)
RHM(11) = B(275)
RHM(12) = B(276)
RHA(1) = B(277)
RHA(2) = B(278)
RHA(3) = B(279)
RHA(4) = B(280)
RHA(5) = B(281)
RHA(6) = B(282)
RHA(7) = B(283)
RHA(8) = B(284)
RHA(9) = B(285)
RHA(10) = B(286)
RHA(11) = B(287)
RHA(12) = B(288)
DOOR13=B(290)
DOOR14=B(291)
DOOR15=B(292)
DOOR16=B(293)
DOOR23=B(295)
DOOR24=B(296)
DOOR25=B(297)
DOOR26=B(298)
DOOR33=B(300)
DOOR34=B(301)
DOOR35=B(302)
DOOR36=B(303)
DOOR43=B(305)
DOOR44=B(306)
DOOR45=B(307)
DOOR46=B(308)
TOUT = 140.0
ICHECK=B(309)
AJAC=B(310)
D1   =B(311)
RAM1=B(312)
D2   =B(313)
RAM2=B(314)
TCSUPA= B(315)
TCSUPW= B(316)
THSUPA= B(317)
THSUPW= B(318)
ADUCT1= B(319)
UDUCT1= B(320)
APIPE1= B(321)
UPIPE1= B(322)
ADUCT2= B(323)
UDUCT2= B(324)
APIPE2= B(325)
UPIPE2= B(326)
ADUCT3= B(327)
UDUCT3= B(328)
APIPE3= B(329)
UPIPE3= B(330)
ADUCT4= B(331)
UDUCT4= B(332)
APIPE4= B(333)
UPIPE4= B(334)
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      AIRLOS= P(335)
      CAPCL= B(336)
      CAPHT= B(337)
      DO 70 I=1,12
      IF(TIN(I).GT.TID(I)) TIN(I)=TID(I)
   70 CONTINUE
      IF(ICHECK.NE.1) GO TO 9901
      WRITE(6,75)(B(I),I=338,345)
   75 FORMAT(1H1,50X,'CITY NAME : '4A6/51X,'HOUSE NAME: '4A6//56X,'INPUT DATA LISTING'/)
     * DATA LISTING'/)
      WRITE(6,90)(I,B(I),I=1,337)
   90 FORMAT(10(I4,F9.3))
 9901 CONTINUE
C
C01 ** WINDOW HEAT GAIN **    WINDOW NO. 1 TO 4  -- START FROM NORTH WINDOW AND
C                                                 MOVE TO EAST, SOUTH, AND WEST
      DO 304 I =1,12
      QGD1(I)=0.0
      QGN1(I)=0.0
      QGD2(I)=0.0
      QGN2(I)=0.0
      QGD3(I)=0.0
      QGN3(I)=0.0
      QGD4(I)=0.0
      QGN4(I)=0.0
      SGD1(I)=0.0
      SGD2(I)=0.0
      SGD3(I)=0.0
      SGD4(I)=0.0
  304 CONTINUE
      TILT=90.0
      CALL SOLDAT(ZT,H,ORT1,TILT,WALL11,WALL12,XLAT,RHO,TOWN,XT901,XD901
     *)
      IF(AG1.EQ.0.0) GO TO 305
      CALL QG    (AG1, SC1, UG1, TOD, TON, TID, TIN, SHDW1, XT901,XD901,
     1           QGD1, QGN1,SGD1)
  305 DO 300 I=1,12
      XIDTN(I)=XT901(I)
      XIDDN(I)=XD901(I)
  300 CONTINUE
C     IF(ICHECK.EQ.1) WRITE(6,8002)
C8002 FORMAT(1H ,'WINDOW HEAT GAIN ROUTINE NO1. COMPLETED')
      CALL SOLDAT(ZT,H,ORT2,TILT,WALL21,WALL22,XLAT,RHO,TOWN,XT902,XD902
     *)
      IF(AG2.EQ.0.0) GO TO 306
      CALL QG    (AG2, SC2, UG2, TOD, TON, TID, TIN, SHDW2, XT902,XD902,
     1           QGD2, QGN2, SGD2)
  306 DO 301 I=1,12
      XIDTE(I)=XT902(I)
      XIDDE(I)=XD902(I)
  301 CONTINUE
C     IF(ICHECK.EQ.1) WRITE(6,8003)
C8003 FORMAT(1H ,'WINDOW HEAT GAIN ROUTINE NO2. COMPLETED')
      CALL SOLDAT(ZT,H,ORT3,TILT,WALL31,WALL32,XLAT,RHO,TOWN,XT903,XD903
     *)
      IF(AG3.EQ.0.0) GO TO 307
      CALL QG    (AG3, SC3, UG3, TOD, TON, TID, TIN, SHDW3, XT903,XD903,
     1           QGD3, QGN3, SGD3)
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  307 DO 302 I=1,12
      XIDTS(I)=XT903(I)
      XIDDS(I)=XD903(I)
  302 CONTINUE
C     IF(ICHECK.EQ.1) WRITE(6,8004)
C8004 FORMAT(1H ,'WINDOW HEAT GAIN ROUTINE NO3. COMPLETED')
      CALL SOLDAT(ZT,H,ORT4,TILT,WALL41,WALL42,XLAT,RHO,TOWN,XT904,XD904
     *)
      IF(AG4.EQ.0.0) GO TO 308
      CALL QG    (AG4, SC4, UG4, TOD, TON, TID, TIN, SHDW4, XT904,XD904,
     1             QGD4, QGN4, SGD4)
  308 DO 303 I=1,12
      SGD(I)=SGD1(I)+SGD2(I)+SGD3(I)+SGD4(I)
      XIDTW(I)=XT904(I)
      XIDDW(I)=XD904(I)
  303 CONTINUE
      IF(ICHECK.EQ.1) WRITE(6,8005)
 8005 FORMAT(1H ,'WINDOW HEAT GAIN ROUTINE  COMPLETED')
      DO 102 I = 1, 12
      QGD(I)=QGD1(I)+QGD2(I)+QGD3(I)+QGD4(I)
      QGN(I)=QGN1(I)+QGN2(I)+QGN3(I)+QGN4(I)
  102 CONTINUE
C
C02 ** SOLAR ENERGY UTILIZATION **
      CALL SOLDAT(ZT,H,0.0,WTLT1,0.,   10.,   XLAT,RHO,TOWN,XIDT,XIDD)
      CALL SEU(SA,SB,TE,TOD,XIDT,SUF,AS,QS,ISOLHW, ISOLSH)
      DO 103 I=1,12
  103 QS(I)=QS(I)*DAYS(I)
      IF(ICHECK.EQ.1) WRITE(6,8006)
 8006 FORMAT(1H ,'SOLAR ENERGY UTILIZATION ROUTINE COMPLETED')
C
C03 ** INFILTRATION HEAT GAIN **
      CALL INFIL (V, ACHS, TOD, TON, TID, TIN, WS, RINFIL,
     1            NSTART,NLAST,IACNV)
      CALL QI    (RINFIL, TOD, TON,  TID, TIN, RH, QISD, QISN, QILD,
     1             QILN,RHM,RHA)
C
      IF(ICHECK.EQ.1) WRITE(6,8001)
 8001 FORMAT(1H ,'INFILTRATION HEAT GAIN ROUTINE COMPLETED')
C
C04 ** WALL HEAT GAIN **    WALL NO. 1 TO 4
      DO 401 I=1,12
      GD1(I)=0.0
      GN1(I)=0.0
      GD2(I)=0.0
      GN2(I)=0.0
      GD3(I)=0.0
      GN3(I)=0.0
      GD4(I)=0.0
      GN4(I)=0.0
  401 CONTINUE
      IF(WALL16.EQ.0.0) GO TO 402
      CALL SAT(XT901,XD901,WALL13,WALL14,FO,90.0,TOD,TON,SATD,SATN)
      CALL QECHG(SATD,SATN,WALL15,WALL16,TID,TIN,GD1,GN1)
  402 IF(WALL26.EQ.0.0) GO TO 403
      CALL SAT(XT902,XD902,WALL23,WALL24,FO,90.0,TOD,TON,SATD,SATN)
      CALL QECHG(SATD,SATN,WALL25,WALL26,TID,TIN,GD2,GN2)
  403 IF(WALL36.EQ.0.0) GO TO 404
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      CALL SAT(XT903,XD903,WALL33,WALL34,FO,90.0,TOD,TON,SATD,SATN)
      CALL QECHG(SATD,SATN,WALL35,WALL36,TID,TIN,GD3,GN3)
  404 IF(WALL46.EQ.0.0) GO TO 405
      CALL SAT(XT904,XD904,WALL43,WALL44,FO,90.0,TOD,TON,SATD,SATN)
      CALL QECHG(SATD,SATN,WALL45,WALL46,TID,TIN,GD4,GN4)
  405 DO 104 I=1,12
      QWD(I)=GD1(I)+GD2(I)+GD3(I)+GD4(I)
      QWN(I)=GN1(I)+GN2(I)+GN3(I)+GN4(I)
  104 CONTINUE
      IF(ICHECK.EQ.1) WRITE(6,8007)
 8007 FORMAT(1H ,'WALL HEAT GAIN ROUTINE COMPLETED')
C
C05 ** DOOR HEAT GAIN **
      DO 500 I=1,12
      QDD1(I)=0.0
      QDN1(I)=0.0
      QDD2(I)=0.0
      QDN2(I)=0.0
      QDD3(I)=0.0
      QDN3(I)=0.0
      QDD4(I)=0.0
      QDN4(I)=0.0
  500 CONTINUE
      IF(DOOR16.EQ.0.0) GO TO 501
      CALL SAT(XT901,XD901,DOOR13,DOOR14,FO,90.0,TOD,TON,SATD,SATN)
      CALL QECHG(SATD,SATN,DOOR15,DOOR16,TID,TIN,QDD1,QDN1)
  501 IF(DOOR26.EQ.0.0) GO TO 502
      CALL SAT(XT902,XD902,DOOR23,DOOR24,FO,90.0,TOD,TON,SATD,SATN)
      CALL QECHG(SATD,SATN,DOOR25,DOOR26,TID,TIN,QDD2,QDN2)
  502 IF(DOOR36.EQ.0.0) GO TO 503
      CALL SAT(XT903,XD903,DOOR33,DOOR34,FO,90.0,TOD,TON,SATD,SATN)
      CALL QECHG(SATD,SATN,DOOR35,DOOR36,TID,TIN,QDD3,QDN3)
  503 IF(DOOR46.EQ.0.0) GO TO 504
      CALL SAT(XT904,XD904,DOOR43,DOOR44,FO,90.0,TOD,TON,SATD,SATN)
      CALL QECHG(SATD,SATN,DOOR45,DOOR46,TID,TIN,QDD4,QDN4)
  504 CONTINUE
      DO 505 I =1,12
      QDD(I)=QDD1(I)+QDD2(I)+QDD3(I)+QDD4(I)
      QDN(I)=QDN1(I)+QDN2(I)+QDN3(I)+QDN4(I)
  505 CONTINUE
      IF(ICHECK.EQ.1) WRITE(6,8008)
 8008 FORMAT(1H ,'DOOR HEAT GAIN ROUTINE COMPLETED')
C
C06 ** CEILING HEAT GAIN **
C
      DO 16 I=1,12
      XX(I) = 0.0
      QCD(I)=0.0
      QCN(I)=0.0
   16 CONTINUE
C       ATTICLESS ROOFS
      TILT=0.0
      CALL SOLDAT(ZT,H,0.0,TILT,0.,10.,XLAT,RHO,TOWN,XIDT,XIDD)
      CALL SAT(XIDT,XIDD,ROOF1,ROOF2,FO,0.0,TOD,TON,SATD,SATN)
      IF(ROOF4.EQ.0.0) GO TO 6
      CALL QECHG(SATD,SATN,ROOF3,ROOF4,TID,TIN,QCD,QCN)
      IF(ICHECK.EQ.1) WRITE(6,8009)
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    6 IF(ATFLR.EQ.0.0) GO TO 66
C       ATTIC ROOFS
      DO 600 I=1,12
      ATD(I)=TID(I)
      ATN(I)=TIN(I)
  600 CONTINUE
      CALL SAT(XX,XX,0.0,0.0,FO,90.0,TOD,TON,TWD1,TWN1)
      CALL SAT(XX,XX,0.0,0.0,FO,90.0,TOD,TON,TWD2,TWN2)
      DO 666 I = 1, 12
      TWD(I) = (TWD1(I) + TWD2(I))/ 2.0
      TWN(I) = (TWN1(I) + TWN2(I))/ 2.0
  666 CONTINUE
      IF(INDEXD.EQ.0) GO TO 9902
      CFM=ACAT*ATFLR*AEWH/60.0
      CALL ATTIC(ATFLR,SATD,SATN,ATFLR,TID,TIN,AW,TWD,TWN,CFM,ROOF3,
     *           UCEIL,AEW5,TOD,TON,ATD,ATN)
C 601 IF(ICHECK.NE.1) GO TO 9902
C     WRITE(6,9001)(ATD(K),ATN(K),TWD(K),TWN(K),SATD(K),SATN(K),K=1,12)
C9001 FORMAT(1H ,6(F9.3))
 9902 CONTINUE
      CALL QECHC(ATD,ATN,UCEIL,ATFLR,TID,TIN,ATQCD,ATQCN)
      GO TO 6666
   66 DO 166 I=1,12
      ATQCD(I)=0.0
      ATQCN(I)=0.0
  166 CONTINUE
 6666 DO 106 I=1,12
      QCD(I)=QCD(I)+ATQCD(I)
      QCN(I)=QCN(I)+ATQCN(I)
  106 CONTINUE
      IF(ICHECK.EQ.1) WRITE(6,8010)
 8010 FORMAT(1H ,'CEILING HEAT GAIN ROUTINE COMPLETED')
C
C07 ** FLOOR HEAT GAIN **
C
C       SLAB ON GRADE
      AF=FLOORA*SOGFRC
      DO 177 I=1,12
      QFD(I)=0.0
      QFN(I)=0.0
  177 CONTINUE
      IF(AF.EQ.0.0) GO TO 7
      CALL GF(AF,ZL,DX,DY,ZKS,E,TOD,TON,UFF,TID,TIN,QFD,QFN)
      IF(ICHECK.EQ.1) WRITE(6,8011)
 8011 FORMAT(1H ,'SLAB ON GRADE ROUTINE COMPLETED')
C       CRAWL SPACE
    7 DO 701 I=1,12
      GD1(I)=0.0
      GN1(I)=0.0
      GD2(I)=0.0
      GN2(I)=0.0
  701 CONTINUE
      AFCL=FLOORA*CRWFRC
      IF(AFCL.EQ.0.0) GO TO 702
      CALL SAT(XX,XX,0.0,0.0,FO,90.0,TOD,TON,SATD,SATN)
      CFMM=ACCS*FLOORA*CRWFRC*HCL/60.0
      CALL CRAWL(TOD,TON,TG,TID,TIN,SATD,SATN,CFMM,UFLR2,UCLW,1.0,AFCL,
     *           AWCL,CRAWLD,CRAWLN)
```

```
      CALL QECHC(CRAWLD,CRAWLN,UFLR2,AFCL.TID,TIN,GD1,GN1)
  702 DO 107 I=1,12
      QFD(I)=GD1(I)+GD2(I)+QFD(I)
      QFN(I)=GN1(I)+GN2(I)+QFN(I)
  107 CONTINUE
      IF(ICHECK.EQ.1) WRITE(6,8012)
 8012 FORMAT(1H ,'CRAWL SPACE ROUTINE COMPLETED')
      BFA=FLOORA*BSMFRC
      DO 703 I=1,12
      BQFD(I)=0.0
      BQFN(I)=0.0
  703 CONTINUE
      IF(BFA.EQ.0.0) GO TO 764
C     BASEMENT
      CALL BSMT (UFW,BWA,BFA,UFLR1,UFF,QBHG,TID,TIN,TG,TOD,TON,
     1           UBW,UBF,BSMTD,BSMTN,BQFD,BQFN)
      IF(ICHECK.EQ.1) WRITE(6,9999) (BSMTD(I),I=1,12)
 9999 FORMAT(/1H ,12G10.4)
      IF(ICHECK.EQ.1) WRITE(6,9999) (BSMTN(I),I=1,12)
      IF(INDEXC.NE.0)CALL QECHG(BSMTD,BSMTN,UFLR1,BFA,TID,TIN,
     1                          BQFD,BQFN)
      IF(ICHECK.EQ.1) WRITE(6,9999) (BQFD(I),I=1,12)
      IF(ICHECK.EQ.1) WRITE(6,9999) (BQFN(I),I=1,12)
      IF(ICHECK.EQ.1) WRITE(6,8013)
 8013 FORMAT(1H ,'BASEMENT ROUTINE COMPLETED')
  704 DO 1777 I=1,12
      QFD(I)=QFD(I)+BQFD(I)
      QFN(I)=QFN(I)+BQFN(I)
 1777 CONTINUE
      IF(ICHECK.EQ.1) WRITE(6,8014)
 8014 FORMAT(1H ,'FLOOR HEAT GAIN ROUTINE COMPLETED')
C
C08 ** INTERNAL HEAT GAIN **
      DO 109 I=1,12
      CALL QR(NPD,NPN,WTD,WTN,WED,WEN,QRSD,QRSN,QRLD,QRLN,HRDAY(I),HRNIT(I))
     *(I))
 8015 FORMAT(1H ,'INTERNAL HEAT GAIN ROUTINE COMPLETED')
C
      QRD(I)=QRSD
      QRN(I)=QRSN
      QID(I)=QISD(I)
      QIN(I)=QISN(I)
  109 CONTINUE
      CALL ZKDN(RINFIL,B,ZK)
      IF(ICHECK.EQ.1) WRITE(6,8015)
C
C09 ** HEAT LOSS AND HEAT GAIN **
      IF(ICHECK.NE.1) GO TO 9900
      WRITE(6,9005)
 9005 FORMAT(1H1,60X,'ANNUAL SUMMARY')
      WRITE(6,9006)
 9006 FORMAT(1H ,60X,14(1H-))
      WRITE(6,9007)
 9007 FORMAT(/1H ,10X,'J',9X,'F',9X,'M',9X,'A',9X,'M',9X,'J',9X,
     1 'J',9X,'A',9X,'S',9X,'O',9X,'N',9X,'D'/)
      WRITE(6,9003) AA(1),(TID(I),I=1,12)
 9003 FORMAT(1H ,A5,12G10.4)
      WRITE(6,9003) AA(2),(TIN(I),I=1,12)
```

```
      WRITE(6,9003) AA(3),(TOD(I),I=1,12)
      WRITE(6,9003) AA(4),(TON(I),I=1,12)
      WRITE(6,9003) AA(29),HRDAY,AA(30),HRNIT
      WRITE(6,9003) AA(5),(XIDTS(I),I=1,12)
      WRITE(6,9003) AA(6),(XIDDS(I),I=1,12)
      WRITE(6,9003) AA(7),(XIDTW(I),I=1,12)
      WRITE(6,9003) AA(8),(XIDDW(I),I=1,12)
      WRITE(6,9003) AA(9),(XIDTN(I),I=1,12)
      WRITE(6,9003) AA(10),(XIDDN(I),I=1,12)
      WRITE(6,9003)AA(11),(XIDTE(I),I=1,12)
      WRITE(6,9003)AA(12),(XIDDE(I),I=1,12)
      WRITE(6,9003)AA(13),(QID(I),I=1,12)
      WRITE(6,9003)AA(14),(QIN(I),I=1,12)
      WRITE(6,9003)AA(15),(QWD(I),I=1,12)
      WRITE(6,9003)AA(16),(QWN(I),I=1,12)
      WRITE(6,9003)AA(17),(QDD(I),I=1,12)
      WRITE(6,9003)AA(18),(QDN(I),I=1,12)
      WRITE(6,9003)AA(19),(QCD(I),I=1,12)
      WRITE(6,9003)AA(20),(QCN(I),I=1,12)
      WRITE(6,9003)AA(21),(QGD(I),I=1,12)
      WRITE(6,9003)AA(22),(QGN(I),I=1,12)
      WRITE(6,9003)AA(23),(QFD(I),I=1,12)
      WRITE(6,9003)AA(24),(QFN(I),I=1,12)
      WRITE(6,9003)AA(25),(QRD(I),I=1,12)
      WRITE(6,9003)AA(26),(QRN(I),I=1,12)
      WRITE(6,9003)AA(31),SGD,AA(32),ZK
 9004 FORMAT(/1H ,A5,12G10.4)
 9900 CONTINUE
C
C
      CALL HLHG(QID,QIN,QWD,QWN,QDD,QDN,QCD,QCN,QFD,QFN,THTC,PUH,QRD,QRN
     * ,QTD,QTN,HG,HL,QCD,QCN,NSTART,NLAST,TIN,TON,TID,TOD,IACNV,SGD,
     * ICHECK,TIC,TIH,ZK)
      IF(ICHECK.NE.1) GO TO 9010
      WRITE(6,9004)AA(27),(QTD(I),I=1,12)
      WRITE(6,9004)AA(28),(QTN(I),I=1,12)
 9002 FORMAT(1X,14E9.4)
 9010 CONTINUE
      IF (ICHECK.EQ.1) WRITE(6,8016)
 8016 FORMAT(1H ,'HEAT LOSS 8 HEAT GAIN ROUTINE COMPLETED')
C
C10 ** HEATING AND COOLING REQUIREMENT **
      DO 110 I=1,12
      RLHG(I)=0.0
      IF(QRLD.GT.0.0) RLHG(I)=RLHG(I)+QRLD
      IF(QRLN.GT.0.0) RLHG(I)=RLHG(I)+QRLN
      IF(I.GE.NSTART.AND.I.LE.NLAST.AND.TOD(I).LT.TID(I).AND.
     1   QRLD.GT.0.0.AND.IACNV.EQ.1) RLHG(I)=RLHG(I)-QRLD
      IF(I.GE.NSTART.AND.I.LE.NLAST.AND.TON(I).LT.TIN(I).AND.
     1   QRLN.GT.0.0.AND.IACNV.EQ.1) RLHG(I)=RLHG(I)-QRLN
      IF(QILD(I).GT.0.0) RLHG(I)=RLHG(I)+QILD(I)
      IF(QILN(I).GT.0.0) RLHG(I)=RLHG(I)+QILN(I)
      IF(I.GE.NSTART.AND.I.LE.NLAST.AND.TOD(I).LT.TID(I).AND.
     1   QILD(I).GT.0.0.AND.IACNV.EQ.1) RLHG(I)=RLHG(I)-QILD(I)
      IF(I.GE.NSTART.AND.I.LE.NLAST.AND.TON(I).LT.TIN(I).AND.
     1   QILN(I).GT.0.0.AND.IACNV.EQ.1) RLHG(I)=RLHG(I)-QILN(I)
  110 CONTINUE
      IF(ICHECK.EQ.1) WRITE(6,9011) (RLHG(I),I=1,12)
```

C 13

```
 9011 FORMAT(/1H ,'RLHG',12G10.4)
C
      CALL HCRT(HL,HG,RLHG,HREQ,CREQ,AIRLOS)
      DO 200 I = 1, 12
      HREQ(I) = HREQ(I) * DAYS(I)
      CREQ(I) = CREQ(I) * DAYS(I)
  200 CONTINUE
      DO 202 I = NSTART,NLAST
      HREQ(I) = 0.0
  202 CONTINUE
      DO 203 I=1,12
      IF(I.LT.NSTART.OR.I.GT.NLAST) CREQ(I)=0.0
  203 CONTINUE
      DO 207 I=1,12
      QC1(I)=0.0
      QC2(I)=0.0
      QC3(I)=0.0
      QH1(I)=0.0
      QH2(I)=0.0
      QH3(I)=0.0
      CFAC(I)=0.0
      HFAC(I)=0.0
      IF(CAPCL.EQ.0.0) GO TO 208
      CFAC(I)=CREQ(I)/CAPCL/24.0/DAYS(I)
  208 IF(CAPHT.EQ.0.0) GO TO 207
      HFAC(I)=-HREQ(I)/CAPHT/24.0/DAYS(I)
  207 CONTINUE
      IF(CRWFRC.EQ.0.0) GO TO 705
      CALL CSDUPI(ADUCT1,UDUCT1 APIPE1,UPIPE1,TCSUPA,TCSUPW,THSUPA,
     1            THSUPW,CRAWLD,CRAWLN,NSTART,NLAST,QC1,QH1,
     2            CFAC,HFAC)
  705 IF(ICHECK.EQ.1) WRITE(6,9995)
 9995 FORMAT(1H ,'CSDUPI  COMPLETED')
      IF(ATFLR.EQ.0.0) GO TO 706
      CALL ASDUPI(ADUCT2,UDUCT2,APIPE2,UPIPE2,TCSUPA,TCSUPW,THSUPA,
     1            THSUPW,ATD,ATN,NSTART,NLAST,QC2,QH2,CFAC,HFAC)
  706 IF(ICHECK.EQ.1) WRITE(6,9998)
 9998 FORMAT(1H ,'ASDUPI  COMPLETED')
      IF(BSMFRC.EQ.0.0) GO TO 707
      CALL BMDUPI(ADUCT3,UDUCT3,APIPE3,UPIPE3,TCSUPA,TCSUPW,THSUPA,
     1            THSUPW,BSMTD,BSMTN,NSTART,NLAST,INDEXC,QC3,QH3,
     2            CFAC,HFAC)
  707 IF(ICHECK.EQ.1) WRITE(6,9997)
 9997 FORMAT(1H ,'BMDUPI  COMPLETED')
      CALL OSDUPI(ADUCT4,UDUCT4,APIPE4,UPIPE4,TCSUPA,TCSUPW,THSUPA,
     1            THSUPW,TOD,TON,NSTART,NLAST,QC4,QH4,CFAC,HFAC)
      IF(ICHECK.EQ.1) WRITE(6,9996)
 9996 FORMAT(1H ,'OSDUPI  COMPLETED')
      DO 206 I=1,12
      QQC(I)=(QC1(I)+QC2(I)+QC3(I)+QC4(I))*DAYS(I)
      QQH(I)=(QH1(I)+QH2(I)+QH3(I)+QH4(I))*DAYS(I)
  206 CONTINUE
      DO 205 I=1,12
      IF(BSMFRC.EQ.0.0) BSMTD(I)=TID(I)
      IF(BSMFRC.EQ.0.0) BSMTN(I)=TIN(I)
  205 CONTINUE
      CALL HWHREQ(TOUT, TC, HWT,AJAC,BSMTD,BSMTN,D1,RAM1,D2,RAM2,HLHWH1,
     1            HLHWH2,SAVE,WHREQ)
```

```
      DO 204 I=1,12
      WHREQ(I)=WHREQ(I)*DAYS(I)
      HLHWH1(I)=HLHWH1(I)*DAYS(I)
      HLHWH2(I)=HLHWH2(I)*DAYS(I)
      SAVE(I)=SAVE(I)*DAYS(I)
  204 CONTINUE
C
      IF(ICHECK.EQ.1) WRITE(6,8017)
 8017 FORMAT(1H ,'HEATING & COOLING REQUIREMENT ROUTINE COMPLETED')
C11 ** ENERGY REQUIREMENT **
      CALL EREQ(HREQ,CREQ,EH,EC,ISYS,R(1),R(2),WHREQ,QS,QQC,QQH)
      IF(ICHECK.EQ.1) WRITE(6,8018)
 8018 FORMAT(1H ,'ENERGY REQUIREMENT ROUTINE COMPLETED')
C
C   ** OUTPUT **
      IF(ICHECK.NE.1) GO TO 9903
      WRITE(6,9005)
      WRITE(6,9006)
      WRITE(6,9007)
      WRITE(6,9008)(HREQ(I),I=1,12)
 9008 FORMAT(1H ,'HREQ ',12G10.4)
      WRITE(6,9009)(CREQ(I),I=1,12)
 9009 FORMAT(1H ,'CREQ ',12G10.4)
 9903 CONTINUE
      IF(ICHECK.NE.1) GO TO 9904
      SUM1 = 0.0
      SUM2 = 0.0
      DO 201 I = 1, 12
      SUM1 = SUM1 + HREQ(I)
      SUM2 = SUM2 + CREQ(I)
      R(I+2) =HREQ(I)
      R(I+14)=CREQ(I)
      R(I+26)=TOD(I)
      R(I+38)=TON(I)
  201 CONTINUE
C
      IF(ICHECK.NE.1) GO TO 9904
      WRITE(6,1002)THTC,SUM1,SUM2
 1002 FORMAT(/1H ,F7.2,60X,6H THT=,G15.7,6H TCT=,G15.7)
      WRITE(6,1001) ISYS, (R(I),I=1,2)
 1001 FORMAT(/1H ,I2,40X,'SHBTU = ',G10.4,'  SCBTU = ',G10.4)
 9904 CONTINUE
C
      RETURN
      END
```

QQQ3*CONSP6(1).SOLDAT(22)

```
      SUBROUTINE SOLDAT(ZKT,H,WAZ,WTLT,OVHANG,WALLHT,XLAT,RHO,TOWN,XIDT,
     *XIDD)
C     THIS SUBROUTINE CALCULATES MONTHLY AVERAGE SOLAR HEAT RADIATION
C     INCIDENT UPON A GIVEN SURFACE WITH THE OVERHANG.
C     ZKT...LIU/JORDAN FACTOR - DAILY TOTAL RADIATION ON A HORIZONTAL SURFACE /
C           THE SAME IN OUTER SPACE
C     H.....DAILY TOTAL RADIATION ON A HORIZONTAL SURFACE
C     TO....DAILY AVERAGE TEMPERATURE
C     XLAT..LATITUDE OF THE LOCATION
C     RHO...REFLECTIVITY OF THE GROUND AROUND THE WINDOW
C     WAZ...SURFACE AZIMUTH ANGLE, DEGREES FROM SOUTH   ( 0S, 90W, 180N, -90E )
C     WTLT..SURFACE TILT ANGLE    (90 DEG VERTICAL, 0 DEG HORIZONTAL)
C     XIDT..TOTAL RADIATION INCIDENT UPON A GIVEN SURFACE, BTU/HR,FT**2
C     XIDD..DIFFUSE RADIATION INCIDENT UPON A GIVEN SURFACE, BTU/HR,FT**2
C     OVHANG..OVERHANG OVER A WALL, FT
C     WALLHT..WALL HEIGHT, FT
C
      COMMON/HR/HRDAY(12),HRNIT(12)
      DIMENSION LDAY(12)/31,28,31,30,31,30,31,31,30,31,30,31/
      DIMENSION XDEC(12)/-19.51,-10.28,.20,11.56,20.14,23.27,20.26,12.03
     *,.37,-10.47,-19.58,-23.27/
      DIMENSION R(12)/1.03,1.0207,1.0057,.9875,.9727,.967,.9692,.9785,
     *.9945,1.0133,1.0267,1.0327/
      REAL US(12)/1.13,1.13,1.13,1.13,1.06,1.06,1.06,1.06,1.06,1.13,1.13
     *,1.13/,H(12),ZKT(12)
      REAL TOWN(4),ZIT(24),DLITE(12)
      REAL RST/442.1/,PI/3.1415927/,LAT
      DIMENSION B(12)/.142,.144,.156,.18,.196,.205,.207,.201,.177,.16,.149,.142/
     *49,.142/
      REAL DNI(24),ASI(24),RSI(24),XIDT(12),XIDD(12)
      PIOV2=PI/2.
      XLAX=AINT(XLAT)
      LAT=(XLAX+(XLAT-XLAX)/0.6)*PI/180.
      LAX=INT(XLAT)
      MINUTE=(XLAT-XLAX)*100
      WTLTX=WTLT*PI/180.
      WAZX=WAZ*PI/180.
      DO 1 N=1,12
      RD=AINT(XDEC(N))
      DEC=(RD+(XDEC(N)-RD)/0.6)*PI/180.
      COSWS=-TAN(LAT)*TAN(DEC)
      IF(COSWS.GT.1..OR.COSWS.LT.-1.) RETURN
      WS=ACOS(COSWS)
      TWS=WS*12/PI
      SUNRIZ=12.-ABS(TWS)
      SUNSET=12.+ABS(TWS)
      HRDAY(N)=SUNSET-SUNRIZ
      HRNIT(N)=24.-HRDAY(N)
      COSLD=COS(LAT)*COS(DEC)
      SINLD=SIN(LAT)*SIN(DEC)
      S=0.
      DO 500 L=1,39
      WW=WS*L/40.
      CZE=COSLD*COS(WW)+SINLD
      PAR=-B(N)/CZE
      APA=ABS(PAR)
      IF(APA.GT.80.) GO TO 501
```

```
      ANS=EXP(PAR)*CZE
      GO TO 502
  501 ANS=0.
  502 S=ANS+S
  500 CONTINUE
      ANSO=EXP(-B(N)/(COSLD+SINLD))*(COSLD+SINLD)/2.
      AI=WS/ 40.*(ANSO+S)
      HO=24./PI*R(N)*RST*(COSLD*SIN(WS)+WS*SINLD)
      THH=H(N)
      ZKT(N)=H(N)/HO
      ZKD=ZD(ZKT(N))
      DHH=HO*(ZKT(N)-ZKD)                 @ DAILY TOTAL DIRECT ON HORIZONTAL
      RHH=HO*ZKD                          @ DAILY TOTAL DIFFUSE ON HORIZONTAL
      A=DHH/(24./PI*AI)
      FAC=A/ZKT(N)
      DO 2 I=1,24
      DNI(I)=0.
      ASI(I)=0.
      RSI(I)=0.
    2 ZIT(I)=0.
      BLITE(N)=2.*ABS(TWS)
      DO 3 I=1,24
      TIME=I-1.
      WT=ABS(12.-TIME)
      W=WT*PI/12.
      IF(TIME-SUNRIZ) 3,3,4
    4 IF(TIME-SUNSET) 5,3,3
    5 COSZ=SINLD+COSLD*COS(W)
      COSW=COS(DEC)*SIN(W)
      COSS=SQRT(1.-COSW*COSW-COSZ*COSZ)
      V=TAN(DEC)/TAN(LAT)
      TEST=COS(W)-V
      IF(TEST) 9,9,8
    9 COSS=-COSS
    8 ALT=ASIN(COSZ)
      AZM=ASIN(COSW/COS(ALT))
      IF(COSS) 23,24,24
   23 AZM=PI-AZM
   24 IF(AZM.GT.PI) AZM=2.*PI-AZM
      IF(TIME.LT.12.) AZM=-AZM
      AZMP=AZM*180./PI
      PAR2=-B(N)/COSZ
      AP2=ABS(PAR2)
      IF(AP2.GT.80.) GO TO 3
      DNI(I)=A*EXP(PAR2)
      IF(DNI(I).LE.0.) DNI(I)=0.
      DHI=DNI(I)*COSZ
      IF(DHI.LE.0.) DHI=0.
      RR=PI/24.*(COS(W)-COS(WS))/(SIN(WS)-WS*COS(WS))
      IF(RR.LT.0.) RR=0.
      RHI=RHH*RR
      IF(WTLT.GT.0.) GO TO 25
      COSTH=COSZ
      GO TO 26
   25 CONTINUE
      SAZM=AZM-WAZX
      SAZMP=SAZM*180./PI
      ALTP=ALT*180./PI
```

```
      IF(WTLT.GE.90.) GO TO 50
      ALPHA=COS(WTLTX)
      BETA=SIN(WAZX)*SIN(WTLTX)
      GAMMA=COS(WAZX)*SIN(WTLTX)
      COSTH=ALPHA*COSZ+BETA*COSW+GAMMA*COSS
      GO TO 26
   50 COSTH=COS(SAZM)*COS(ALT)
   26 CONTINUE
      SUNLIT=0.
      IF(COSTH.LE.0.) GO TO 27
      TEST=COS(SAZM)
      COSALT=COS(ALT)
      IF(COSALT.EQ.0.) GO TO 27
      IF(TEST.NE.0.) TANPRO=TAN(ALT)/TEST
C     WRITE(6,789) N,I,SAZM,ALT,TEST,COSALT,PROFIL
  789 FORMAT(/'  N   I       SAZM        ALT       TEST    COSALT   PROFIL'/
     *2I3,5F10.3)
      IF(TEST.EQ.0.) GO TO 27
      SUNLIT=(WALLHT-OVHANG*TANPRO)/WALLHT
      IF(SUNLIT.LE.0.) SUNLIT=0.
      IF(SUNLIT.GE.1.) SUNLIT=1.
   27 CONTINUE
      IF(COSTH.LE.0.) COSTH=0.
      THP=ACOS(COSTH)*180./PI
      ASI(I)=DNI(I)*COSTH*SUNLIT           @ DIRECT RADIATION
      IF(ASI(I).LE.0.) ASI(I)=0.
      RSI(I)=(RHI+(RHI+DHI)*RHO)/2.        @ DIFFUSE RADIATION
      IF(WTLT.LE.0.) RSI(I)=RHI
      ZIT(I)=ASI(I)+RSI(I)                 @ TOTAL RADIATION
   10 CONTINUE
    3 CONTINUE
      SUMN=0.
      SUMD=0.
      SUMR=0.
      SUM=0.
      DO 14 I=1,24
      SUMN=SUMN+DNI(I)
      SUMD=SUMD+ASI(I)
      SUMR=SUMR+RSI(I)
   14 SUM=SUM+ZIT(I)
      XIDT(N)=SUMD+SUMR
      XIDD(N)=SUMR
   12 CONTINUE
    1 CONTINUE
      RETURN
      END
```

```
QSQSQS*CONSP6(1).ZD(1)
            FUNCTION ZD(ZT)
      C     PART OF SOLDAT ROUTINE
            DIMENSION ZKT(6)/.3,.4,.5,.6,.7,.75/
            DIMENSION ZKD(6)/.179,.183,.188,.174,.149,.125/
            IF(ZT-0.3) 1,1,2
          1 ZD=.179
            GO TO 10
          2 IF(ZT-0.75) 3,3,4
          4 ZD=.125
            GO TO 10
          3 DO 20 J=2,6
            T1=ZT-ZKT(J-1)
            T2=ZT-ZKT(J)
            TEST=T1*T2
            IF(TEST) 5,6,20
          5 Y1=ZKD(J-1)
            Y2=ZKD(J)
            ZD=Y1+(Y2-Y1)*(ZT-ZKT(J-1))/(ZKT(J)-ZKT(J-1))
            GO TO 20
          6 IF(T1) 8,9,8
          9 ZD=ZKD(J-1)
            GO TO 20
          8 ZD=ZKD(J)
         20 CONTINUE
         10 RETURN
            END
```

```
Q$Q$Q$*CONSP6(1).F(1)
      FUNCTION F(DB,R,INDHTD)
C     SLAB-ON-GRADE PERIMETER HEAT LOSS 1972 ASHRAE HANDBOOK
C     INDHTD =0 UNHEATED, =1 HEATED
      REAL TABLE(2,3,9),LINE(3)
      DATA (TABLE(1,1,N),N=1,9)/34.,32.,30.,28.,27.,25.,24.,22.,21./
      DATA (TABLE(1,2,N),N=1,9)/51.,48.,45.,43.,40.,38.,36.,33.,31./
      DATA (TABLE(1,3,N),N=1,9)/67.,64.,60.,57.,54.,51.,48.,44.,42./
      DATA (TABLE(2,1,N),N=1,9)/46.,44.,41.,39.,37.,35.,32.,30.,25./
      DATA (TABLE(2,2,N),N=1,9)/69.,66.,61.,59.,55.,52.,48.,45.,38./
      DATA (TABLE(2,3,N),N=1,9)/92.,88.,82.,78.,74.,70.,64.,60.,50./
      REAL RVALUE(3)/5.0,3.75,2.50/
      DBT=DB-1
      N=(DBT+40.)/5.
      IF(N.LT.1) N=1
      IF(N.GT.9) N=9
      I=INDHTD+1
      DO 1 L=1,3
1     LINE(L)=TABLE(I,L,N)
      IF(I.EQ.2) RVALUE(2)=3.33
      DO 2 L=1,3
      IF(R.GT.RVALUE(L)) GO TO 3
2     CONTINUE
      F=LINE(3)
      RETURN
3     IF(L-2) 4,5,5
4     F=LINE(1)
      RETURN
5     F=LINE(L)-(R-RVALUE(L))/(RVALUE(L-1)-RVALUE(L))*(LINE(L)-LINE(L-
     *1))
      RETURN
      END
```

```
Q8Q8Q8*CONST( ).SAT(1)
      SUBROUTINE SAT(XIDT,XIDD,SHDW,AB,FO,WTLT,TOD,TON,SATD,SATN)
C
C     THIS IS SOL-AIR TEMPERATURE ROUTINE
C
C     *** INPUT ***
C
C         WTLT   : TILT ANGLE
C         XIDT   : DAILY TOTAL RADIATION
C         XIDD   : DAILY DIFFUSE RADIATION
C         SHDW   : SHADOW FACTOR
C         AB     : SURFACE ABSORPTIVITY
C         FO     : SURFACE HEAT TRANSFER COEFFICIENT
C         TOD    : DAYTIME TEMPERATURE
C         TON    : NIGHTTIME TEMPERATURE
C
C     *** OUTPUT ***
C
C         SATD   : DAYTIME SOL-AIR TEMPERATURE
C         SATN   : NIGHTTIME SOL-AIR TEMPERATURE
C
      COMMON/HR/HRDAY(12),HRNIT(12)
      DIMENSION XIDT(12),XIDD(12),FO(12),TOD(12),TON(12),SATD(12),
     + SATN(12)
C
      XWTLT=WTLT/180.0*3.14159
      DO 10 J=1,12
      R=(XIDT(J)-XIDD(J))*(1.0-SHDW)+XIDD(J)
      SATD(J)=TOD(J)+AB*R/HRDAY(J)/FO(J)-10.0/FO(J)*COS(XWTLT)
      SATN(J)=TON(J)-10.0/FO(J)*COS(XWTLT)
   10 CONTINUE
      RETURN
      END
```

C 20

Q0Q0Q0*CONSP6(1).ATTIC(1)

```
      SUBROUTINE ATTIC(AR,TRD,TRN,AC,TAD,TAN,AW,TWD,TWN,CFM,UR,UC,UW,TOD
     *,TON,ATD,ATN)
C     THIS IS ATTIC TEMPERATURE CALCULATION ROUTINE
C
C     *** INPUT ***
C
C         AR     : ROOF AREA
C         TRD    : DAYTIME SOL-AIR TEMPERATURE
C         TRN    : NIGHTTIME SOL-AIR TEMPERATURE
C         AC     : CEILING AREA
C         TAD    : DAYTIME ROOM TEMPERATURE
C         TAN    : NIGHTTIME ROOM TEMPERATURE
C         AW     : END WALL AREA
C         TWD    : DAYTIME END WALL SOL-AIR TEMPERATURE
C         TWN    : NIGHTTIME END WALL SOL-AIR TEMPERATURE
C         CFM    : AIR FLOW
C         UR     : U-VALUE FOR ROOF
C         UC     : U-VALUE FOR CEILING
C         UW     : U-VALUE FOR WALLS
C         TOD    : DAYTIME OUTDOOR TEMPERATURE
C         TON    : NIGHTTIME OUTDOOR TEMPERATURE
C
C     *** OUTPUT ***
C
C         ATD    : DAYTIME ATTIC TEMPERATURE
C         ATN    : NIGHTTIME ATTIC TEMPERATURE
      DIMENSION TRD(12),TRN(12),TOD(12),TON(12),ATD(12),
     *          ATN(12),TWD(12),TWN(12),TAD(12),TAN(12)
      DO 10 I=1,12
      ATD(I)=(UR*AR*TRD(I)+UW*AW*TWD(I)+UC*AC*TAD(I)+1.08*CFM*TOD(I))/
     /(UR*AR+UW*AW+UC*AC+1.08*CFM)
      ATN(I)=(UR*AR*TRN(I)+UW*AW*TWN(I)+UC*AC*TAN(I)+1.08*CFM*TON(I))/
     /(UR*AR+UW*AW+UC*AC+1.08*CFM)
   10 CONTINUE
      RETURN
      END
```

```
Q$Q$Q$*CONSP6(1).CRAWL(1)
      SUBROUTINE CRAWL(TOD,TON,TC,TAD,TAN,TWMD,TWMN,CFM,UF,UW,UG,AF,AW,
     *CRAWLD,CRAWLN)
C     THIS IS CRAWL SPACE TEMPERATURE CALCULATION ROUTINE
C
C     *** INPUT ***
C         TWMD   : DAYTIME WALL SOL-AIR TEMPERATURE
C         TOD    : DAYTIME OUTDOOR TEMPERATURE
C         TON    : NIGHTTIME OUTDOOR TEMPERATURE
C         TG     : GROUND TEMPERATURE
C         TAD    : DAYTIME ROOM TEMPERATURE
C         TAN    : NIGHTTIME ROOM TEMPERATURE
C         CFM    : AIR FLOW RATE
C         UF     : FLOOR HEAT TRANSFER COEFFICIENT
C         UW     : WALL HEAT TRANSFER COEFFICIENT
C         UG     : GROUND SURFACE HEAT TRANSFER COEFFICIENT = 1.0
C         AF     : FLOOR AREA
C         AW     : WALL AREA
C         TWMN   : NIGHTTIME WALL SOL-AIR TEMPERATURE
C     *** OUTPUT ***
C         CRAWLD : DAYTIME CRAWL SPACE TEMPERATURE
C         CRAWLN : NIGHTTIME CRAWL SPACE TEMPERATURE
      DIMENSION TOD(12),TON(12),TG(12),TAD(12),TAN(12),TWMD(12),TWMN(12)
     *          ,CRAWLD(12),CRAWLN(12)
C
      DO 10 I=1,12
      CRAWLD(I)=(UF*TAD(I)*AF+UW*TWMD(I)*AW+UG*(TG(I)+TAD(I))/2.0*AF+
     *1.08*CFM*TOD(I))/(UF*AF+UW*AW+UG*AF+1.08*CFM)
      CRAWLN(I)=(UF*TAN(I)*AF+UW*TWMN(I)*AW+UG*(TG(I)+TAN(I))/2.0*AF+
     *1.08*CFM*TON(I))/(UF*AF+UW*AW+UG*AF+1.08*CFM)
   10 CONTINUE
      RETURN
      END
```

```
Q$Q$Q$*CONSP6(1).GF(14)
         SUBROUTINE GF (AF.P.DX,DY,ZKS,E,TOD,TON,USLAB,TAD,TAN,CFD,CFN)
C
C        THIS IS GROUND FLOOR HEAT TRANSFER ROUTINE
C
C         ** INPUT ***
C
C           TOD    : DAYTIME OUTDOOR TEMPERATURE
C           TON    : NIGHTTIME OUTDOOR TEMPERATURE
C           TG     : GROUND TEMPERATURE
C           AF     : FLOOR AREA
C           P      : EXPOSED PERIMETER LENGTH
C           USLAB  : SLAB THERMAL CONDUCTANCE
C                    INCLUDING THE SURFACE HEAT TRANSFER COEFFICIENT
C           TAD    : DAYTIME ROOM TEMPERATURE
C           TAN    : NIGHTTIME ROOM TEMPERATURE
C           XL     : LENGTH OF SLAB, FT
C           YL     : WIDTH OF SLAB, FT
C           DX     : SLAB SPACING ALONG XL, FT
C           DY     : SLAB SPACING ALONG YL, FT
C           ZKS    : GROUND THERMAL CONDUCTIVITY, BTU/FT/HR/F
C           UF     : SLAB THERMAL CONDUCTANCE
C           E      : WALL THICKNESS, FT
C        *** OUTPUT ***
C
C           GFD    : DAYTIME GROUND FLOOR HEAT TRANSFER
C           GFN    : NIGHTTIME GROUND FLOOR HEAT TRANSFER
         COMMON/HR/HRDAY(12),HRNIT(12)
         DIMENSION TOD(12),TON(12),TAD(12) TAN(12),GFD(12),GFN(12)
         R=1./USLAB
         XL=(0.5*P+SQRT(0.25*P*P-4.*AF))/2.
         YL=AF/XL
         XD=AINT(DX/XL)
         YD=AINT(DY/YL)
         CALL SLABR(XL,YL,XD,YD,E,ZKS,R,UF)
         U=1./(1./UF+R)
         DO 10 I=1,12
C
         TAM=(TAD(I)*HRDAY(I)+TAN(I)*HRNIT(I))/24.
         GFD(I)=(U*AF*(TAM-TAD(I) ))*HRDAY(I)
         GFN(I)=(U*AF*(TAM-TAN(I) ))*HRNIT(I)
C
      10 CONTINUE
         RETURN
         END
```

```
Q$Q$Q$*CONSP6(1).SLABR(17)
              SUBROUTINE SLABR(XL,YL,XD,YD,E,ZKS,RRR,UW)
        C     THIS ROUTINE WAS DEVELOPED BY DR. R.W.R. MUNCEY TO CALCULATE HEAT LOSS
        C     FROM SLAB ON GRADE
        CALCULATES P11/P12 AT STEADY STATE
        C  INPUT DATA
        C     XL         LENCTH OF SLAB IN X DIRECTION
        C     YL         LENCTH OF SLAB IN Y DIRECTION
        C     XD,YD      SLAB SPACINC IN X AND Y DIRECTIONS
        C     E          EDGE DISTANCE CORRESPONDINC TO UNIT TEMPERATURE CHANCE
        C                AT THE TANGENT SLOPE AT 'TEMPERATURE' OF 0.5
        C     ZKS        GROUND THERMAL CONDUCTIVITY
        C     R          SURFACE THERMAL RESISTANCE
              REAL LAMBDA
              COMMON /SLAB/ PISQ,ALPHSQ,BETASQ,LAMBDA,R,COM,FSQ,CSQ
              DIMENSION COM(8),SX(2500),SY(2500)
              DATA PI/3.14159265/
              ALPHA=XL*0.5
              BETA=YL*0.5
              F=XD
              C=YD
              LAMBDA=ZKS
              R=RRR
              PISQ=PI*PI
              WRITE(6,10)
              WRITE(6,70)
           10 FORMAT       (//20X,'CALCULATION OF U VALUE FOR GROUND WITH FILM R
             RESISTANCE ABOVE'  )
           70 FORMAT(/69X,'CALC. FROM TEMPERATURE INPUT',2X,'(',4X
             1'CALC. FROM HEAT FLOW INPUT' /
             23X,'WIDTH LENGTH  AREA  PERIM  F  C   EDGE DIST.    LAMBDA  FILM R
             3',   2(6X,'U    R=1/U-FILM R  L=LAMBDA',2H*R) /)
        C  CONSTANTS
             ML=F*ALPHA/E     @ NL=C*BETA/E
             NL=C*BETA/E
        C99   WRITE(6,140) ALPHA,BETA,F,C,ML,NL,E,LAMBDA,R
              IF(ML.NE.NL.OR.IFIX(F).NE.IFIX(C)) CO TO 74
           72 DO 73 J=1,ML
              XS=PI*FLOAT(J)/F
        C999  WRITE(6,140) XS
              S=SIN(XS)/J         @ SX(J)=SY(J)=S*S
              SY(J)=S*S
              SX(J)=SY(J)
           73 CONTINUE
              CO TO 78
           74 DO 75 J=1,ML
              XS=PI*FLOAT(J)/F
              S=SIN(XS)/J        @ SX(J)=S*S
              SX(J)=S*S
           75 CONTINUE
              DO 76 J=1,NL
              XS=PI*FLOAT(J)/C
              S=SIN(XS)/J    @ SY(J)=S*S
              SY(J)=S*S
           76 CONTINUE
           78 CONTINUE
              FSQ=F*F        @ CSQ=C*C
              CSQ=C*C
```

C 24

```
      CM1=2*F/(G*LAMBDA*PISQ)          @ CM2=2*F*LAMBDA/(G*PISQ)
      CM2=2*F*LAMBDA/(G*PISQ)
      CN1=2*G/(F*LAMBDA*PISQ)          @ CN2=2*G*LAMBDA/(F*PISQ)
      CN2=2*G*LAMBDA/(F*PISQ)
      CMN1=4*F*G/(LAMBDA*PISQ*PISQ)    @ CMN2=4*F*G*LAMBDA/(PISQ*PISQ)
      CMN2=4*F*G*LAMBDA/(PISQ*PISQ)
      ALPHSQ=ALPHA*ALPHA      @ BETASQ=BETA*BETA
      BETASQ=BETA*BETA
      SMT=0.
      SMW=0.
      SNT=0.
      SNW=0.
      SMNT=0.
      SMNW=0.
      DO 110 M=1,ML
      CALL GAMMAR(M,0,EF,GH)
      SMT=SMT+EF*SX(M)             @ SMW=SMW+GH*SX(M)
      SMW=SMW+GH*SX(M)
  110 CONTINUE
      DO 130 N=1,NL
      CALL GAMMAR(0,N,EF,GH)
      SNT=SNT+EF*SY(N)
      SNW=SNW+GH*SY(N)
      DO 120 M=1,ML
      CALL GAMMAR(M,N,EF,GH)
      SMNT=SMNT+EF*SX(M)*SY(N)          @ SMNW=SMNW+GH*SX(M)*SY(N)
      SMNW=SMNW+GH*SX(M)*SY(N)
  120 CONTINUE
  130 CONTINUE
C  P11/P12 = - HEAT FLOW
      UW=((F*G-1)/(F*G))*(SMW*CM2+SNW*CN2+SMNW*CMN2)
      RESW=1/UW -R             @ DW=RESW*LAMBDA
      DW=RESW*LAMBDA
C  AV. TEMPERATURE OVER SLAB
      TM=((F*G-1)/(F*G))*(SMT*CM1+SNT*CN1+SMNT*CMN1)
C  P11/P12 = -1/TM
      UT=(((F*G-1)/(F*G))**2)/TM
      REST=1/UT - R             @ DT=REST*LAMBDA
      DT=REST*LAMBDA
      ALPHA2=2*ALPHA
      BETA2=2*BETA
      ALPHAB=4*ALPHA*BETA
      ABETA=4*ALPHA+4*BETA
      IF=IFIX(F)
      IG=IFIX(G)
      WRITE(6,140) ALPHA2,BETA2,ALPHAB,ABETA,IF,IG
     1,E,LAMBDA,R,UW,RESW,DW,UT,REST,DT
  140 FORMAT(F6.1,3F7.1,2I4,F8.2,F12.3,F9.2,2(2F9.3,F14.3,2X))
  145 CONTINUE
      RETURN
      END
```

```
QSQ8Q3*CONSP6(1).GAMMAR(4)
              SUBROUTINE GAMMAR(M,N,EF,GH)
              REAL LAMBDA
      C  THIS IS A SUBROUTINE USED IN SLABR
      C  CALCULATES EF = (1+GAMMA*LAMBDA*R)/GAMMA
      C  CALCULATES GH = GAMMA/(1+GAMMA*LAMBDA*R)
      C  FOR STEADY STATE WITH FILM RESISTANCE R
              COMMON /SLAB/ PISQ,ALPHSQ,BETASQ,LAMBDA,R,COM,FSQ,GSQ
              REAL COM(8)
              IF(M.NE.0) GO TO 20
           10 AM=0.
              GO TO 50
           20 AM=PISQ*M*M/(FSQ*ALPHSQ)
           30 IF(N.NE.0) GO TO 50
           40 AN=0.
              GO TO 60
           50 AN=PISQ*N*N/(GSQ*BETASQ)
           60 A=AM+AN
              SGAM=SQRT(A)
              EF=(1.+R*LAMBDA*SGAM)/SGAM
              GH=1./EF
              RETURN
              END
END PRT

@PRT,S CONSP6.BSMT,.QECHG,.QG,.INFIL,.QI,.DBRH,.PVSF,.QR,.HLHG,.THTCX,.HCRT,.SEU
```

C 26

```
Q$Q$Q$*CONSP6(1).BSMT(5)
      SUBROUTINE BSMT (UFW,BWA,BFA,UFLR1,UFF,QBHG,TID,TIN,TG,TOD,TON,
     1                 UBW,UBF,BSMTD,BSMTN,BQFD,BQFN)
C
C     THIS IS BASEMENT TEMPERATURE CALCULATION
C
C     *** INPUT ***
C
C         BWA    = BASEMENT WALL AREA , FT**2
C         BFA    = BASEMENT FLOOR AREA , FT**2
C         UFLR1  = FLOOR HEAT TRANSFER COEFFICIENT , BT/FT**2.F
C         UFF    = FLOOR-GROUND HEAT TRANSFER COEFFICIENT, =0.1
C         UFW    = WALL-GROUND HEAT TRANSFER COEFFICIENT, =0.164
C         QBHG   = BASEMENT HEAT GAIN FROM FURNACE, BOILER, OR OTHER
C                  EQUIPMENT, BTU/HR
C         TID    = DAYTIME TEMPERATURE OF THE ROOM ABOVE THE BASEMENT ,F
C         TIN    = NIGHTTIME TEMPERATURE OF THE ROOM ABOVE THE BASEMENT
C
C
C
C     *** OUTPUT ***
C
C         BSMTD  = DAYTIME BASEMENT TEMPERATURE
C         BSMTN  = NIGHTTIME BASEMENT TEMPERATURE
C         BQFD
C         BQFN
C
      COMMON/HR/HRDAY(12),HRNIT(12)
      DIMENSION TID(12), TIN(12), BSMTD(12), BSMTN(12)
      DIMENSION TG(12), TOD(12), TON(12), BQFD(12), BQFN(12)
C
      UW=UFW
      IF(UBW.EQ.0.0) GO TO 20
      UW=1.0/(1.0/UFW+1.0/UBW)
   20 UF=UFF
      IF(UBF.EQ.0.0) GO TO 30
      UF=1.0/(1.0/UFF+1.0/UBF)
   30 CONTINUE
      DO 10 I = 1, 12
      TO=(TOD(I)*HRDAY(I)+TON(I)*HRNIT(I))/24.
      BSMTD(I)=(UW*TO*BWA+UF*TG(I)*BFA+UFLR1*TID(I)*BFA+QBHG)
     1        /(UW*BWA+UF*BFA+UFLR1*BFA)
      BSMTN(I)=(UW*TO*BWA+UF*TG(I)*BFA+UFLR1*TIN(I)*BFA+QBHG)
     1        /(UW*BWA+UF*BFA+UFLR1*BFA)
      BQFD(I)=(-UW*(TID(I)-TO)*BWA-UF*(TID(I)-TG(I))*BFA)*HRDAY(I)
      BQFN(I)=(-UW*(TIN(I)-TO)*BWA-UF*(TIN(I)-TG(I))*BFA)*HRNIT(I)
   10 CONTINUE
      RETURN
      END
```

```
Q8Q8Q8*CONSP6(1).QECHG(3)
            SUBROUTINE QECHG (SATD, SATN, U, A, TID, TIN, GD,GN)
      C
      C     THIS IS OPAQUE ENVELOPE CONDUCTION HEAT GAIN CALCULATIONS
      C
      C     *** INPUT ***
      C
      C         SATD   : DAYTIME SOL-AIR (OR ATTIC OR CRAWL SPACE) TEMPERATURE
      C         SATN   : NIGHTTIME SOL-AIR(OR ATTIC OR CRAWL SPACE)TEMPERATURE
      C         U      : OVERALL HEAT TRANSFER COEFFICIENT
      C         A      : AREA
      C         TID    : DAYTIME INDOOR TEMPERATURE
      C         TIN    : NIGHTTIME INDOOR TEMPERATURE
      C
      C     *** OUTPUT ***
      C
      C         GD     : DAYTIME HEAT GAIN
      C         GN     : NIGHTTIME HEAT GAIN
      C
            COMMON/HR/HRDAY(12),HRNIT(12)
            DIMENSION SATD(12), SATN(12), TID(12), TIN(12), GD(12), GN(12)
      C
            DO 10 I=1,12
            GD(I)=U*A*(SATD(I)-TID(I)) * HRDAY(I)
            GN(I)=U*A*(SATN(I)-TIN(I)) * HRNIT(I)
         10 CONTINUE
            RETURN
            END
```

```
Q8Q$Q8*CONSP6(1).QG(9)
      SUBROUTINE QG (AG, SC, UG, TOD, TON, TID, TIN, SHDW, XIDT, XIDD,
     1               QGD, QGN, SGD)
C     THIS IS WINDOW HEAT GAIN ROUTINE
C
C     *** INPUT ***
C
C         AG     : GLASS AREA
C         SC     : SHADING COEFFICIENT
C         UG     : HEAT TRANSFER COEFFICIENT
C         TOD    : DAYTIME OUTDOOR TEMPERATURE
C         TON    : NIGHTTIME OUTDOOR TEMPERATURE
C         TID    : DAYTIME INDOOR TEMPERATURE
C         TIN    : NIGHTTIME INDOOR TEMPERATURE
C         SHDW   : EXTERNAL SHADOW FACTOR
C                    0.0 = NO SHADOW
C                    0.5 = PARTIAL SHADOW
C                    1.0 = COMPLETE SHADOW
C         XIDT   : DAILY TOTAL RADIATION
C         XIDD   : DAILY DIFFUSE RADIATION
C
C     *** OUTPUT ***
C
C         QGD    : DAYTIME WINDOW HEAT GAIN
C         QGN    : NIGHTTIME WINDOW HEAT GAIN
C
       COMMON/HR/HRDAY(12),HRNIT(12)
      DIMENSION TOD(12), TON(12), TID(12), TIN(12), XIDT(12), XIDD(12),
     1          QGD(12), QGN(12), SGD(12)
      REAL I
      DO 10 J = 1, 12
      I = (XIDT(J) - XIDD(J)) * (1.0 - SHDW) + XIDD(J)
      SGD(J)=AG*I*SC
      QGD(J) = AG * (I * SC * 0.87 + UG * (TOD(J) - TID(J)) * HRDAY(J))
      QGN(J) = AG * (UG * (TON(J) - TIN(J)) * HRNIT(J))
   10 CONTINUE
      RETURN
      END
```

```
Q8Q8Q8*CONSP6(1).INFIL(10)
              SUBROUTINE INFIL (V, ACHS, TOD, TON, TID, TIN, WS,
             1                  RINFIL, K, L,IACNV)
        C     THIS IS INFILTRATION CALCULATION ROUTINE
        C
        C     *** INPUT ***
        C
        C         V      = VOLUME OF THE ROOM
        C         ACHS   = STANDARD AIR CHANGE DATA
        C         TOD    = DAYTIME OUTDOOR TEMPERATURE
        C         TON    = NIGHTTIME OUTDOOR TEMPERATURE
        C         TID    = DAYTIME INDOOR TEMPERATURE
        C         TIN    = NIGHTTIME INDOOR TEMPERATURE
        C         WS     = WIND SPEED
        C
        C     *** OUTPUT ***
        C
        C         RINFIL = INFILTRATION RATE
        C
              DIMENSION TOD(12), TON(12), TID(12), TIN(12), RINFIL(12)
              DIMENSION WS(12)
        C
              DO 10 I = 1,12
              TO = ( TOD( I) + TON( I)) / 2.0
              TI = ( TID( I) + TIN( I)) / 2.0
              AC = ACHS / 0.695 * (0.15 + 0.013 *WS(I)+0.005 * ABS(TO - TI))
              RINFIL( I) = V * AC / 60.0
           10 CONTINUE
              RETURN
              END
```

```
QSQSQS*CONSP6(1).QI(10)
      SUBROUTINE QI (INFILT,TOD, TON,     TID, TIN, RH, QID, QIN, QILD,
     1              QILN, RHM, RHA)
C
C     THIS IS INFILTRATION HEAT GAIN CALCULATION ROUTINE
C
C     *** INPUT ***
C
C         INFIL  = INFILTRATION RATE CFM
C         TOD    = DAYTIME OUTDOOR TEMPERATURE
C         TON    = NIGHTTIME OUTDOOR TEMPERATURE
C         TID    = DAYTIME INDOOR TEMPERATURE
C         TIN    = NIGHTTIME INDOOR TEMPERATURE
C         RH     = ROOM RELATIVE HUMIDITY
C         RHM    = MORNING OUTDOOR RELATIVE HUMIDITY
C          RHA    = AFTERNOON OUTDOOR RELATIVE HUMIDITY
C
C     *** OUTPUT ***
C
C         QID    = DAYTIME SENSIBLE HEAT GAIN
C         QIN    = NIGHTTIME SENSIBLE HEAT GAIN
C         QILD   = DAYTIME LATENT HEAT GAIN
C         QILN   = NIGHTTIME LATENT HEAT GAIN
C
      COMMON/HR/HRDAY(12),HRNIT(12)
      DIMENSION TOD(12), TON(12),  TID(12), TIN(12), RH(2, 12),
     1          QID(12), QIN(12), QILD(12), QILN(12), WID(12), WIN(12),
     2          WOD(12), WON(12),RHM(12),RHA(12)
      REAL INFILT(12)
      DO 10 I = 1,12
      QID(I) = 1.08 * INFILT(I)* (TOD(I) - TID(I)) * HRDAY(I)
      QIN(I) = 1.08 * INFILT(I)* (TON(I) - TIN(I)) * HRNIT(I)
   10 CONTINUE
C
      DO 20 I = 1, 12
      CALL DBRH (TID(I), RH(1, I), WID(I))
      CALL DBRH (TIN(I), RH(2, I), WIN(I))
      CALL DBRH (TOD(I),RHA(I),WOD(I))
      CALL DBRH (TON(I),RHM(I),WON(I))
      QILD(I) = 4.5 * INFILT(I)* (WOD(I) - WID(I)) * 1061.0 * HRDAY(I)
      QILN(I) = 4.5 * INFILT(I)* (WON(I) - WIN(I)) * 1061.0 * HRNIT(I)
   20 CONTINUE
      RETURN
      END
```

```
QSQSQS*CONSP6(1).DBRH(2)
      SUBROUTINE DBRH (DB,RH,W)
C
C     *****************************************************************
C
C     PSYCHROMETRIC ROUTINE TO DETERMINE HUMIDITY RATIO, GIVEN DB AND RH
      PVS=PVSF(DB)
      PV=RH*PVS/100.
      W=0.622*PV/(29.92-PV)
      RETURN
C
      END
```

```
Q0Q0Q0*CONSP6(1).PVSF(2)
              FUNCTION PVSF (X)
      C       SATURATION VAPOR PRESSURE, INCHES OF MERCURY
      C       ******************************************************************
      C
              DIMENSION A(6) /-7.90298,5.02808,-1.3816E-7,11.344,
             2 8.1328E-3,-3.49149/ ,B(4) /-9.09718,-3.56654,0.876793,0.0060273/
             3,P(4)
              T=(X+459.688)/1.8
              IF (T.LT.273.16) GO TO 10
              Z=373.16/T
              P(1)=A(1)*(Z-1)
              P(2)=A(2)*LOG10(Z)
              Z1=A(4)*(1-1/Z)
              P(3)=A(3)*(10**Z1-1)
              Z1=A(6)*(Z-1)
              P(4)=A(5)*(10**Z1-1)
              GO TO 20
      C
      10      Z=273.16/T
              P(1)=B(1)*(Z-1)
              P(2)=B(2)*LOG10(Z)
              P(3)=B(3)*(1-1/Z)
              P(4)=LOG10(B(4))
      20      SUM=0
              DO 30 I=1,4
      30      SUM=SUM+P(I)
              PVSF=29.921*10**SUM
              RETURN
      C
              END
```

C 33

```
Q8Q8Q8*CONSP6(1).QR(7)
      SUBROUTINE QR(NPD,NPN,WTD,WTN,WED,WEN,QRSD,QRSN,QRLD,QRLN,HD,HN)

C     THIS IS INTERNAL HEAT GAIN ROUTINE
C
C     *** INPUT ***
C
C         NPD    : NUMBER OF DAYTIME OCCUPANTS
C         NPN    : NUMBER OF NIGHTTIME OCCUPANTS
C         WTD    : AVERAGE DAYTIME LIGHTING POWER W
C         WTN    : AVERAGE NIGHTTIME LIGHTING POWER W
C         WED    : AVERAGE DAYTIME EQUIPMENT POWER W
C         WEN    : AVERAGE NIGHTTIME EQUIPMENT POWER W
C         HD     : DAYTIME HOURS
C         HN     : NIGHTTIME HOURS
C
C     *** OUTPUT ***
C
C         QRSD   : DAYTIME SENSIBLE HEAT GAIN
C         QRSN   : NIGHTTIME SENSIBLE HEAT GAIN
C         QRLD   : DAYTIME LATENT HEAT GAIN
C         QRLN   : NIGHTTIME LATENT HEAT GAIN
C
      RNPD=NPD
      RNPN=NPN
      QRSD=(RNPD*240.0+(WTD+(WED*0.66))*3.413)*HD
      QRSN=(RNPN*240.0+(WTN+(WEN*0.66))*3.413)*HN
C
      QRLD=(RNPD*160.0+WED*0.34*3.413)*HD
      QRLN=(RNPN*160.0+WEN*0.34*3.413)*HN
      RETURN
      END
```

Q8Q8Q8*CONSP6(1).HLHC(57)

```
      SUBROUTINE HLHC(QID,QIN,QWD,QWN,QDD,QDN,QCD,QCN,QFD,QFN,THTC,PUH,
     *QRD,QRN,QTD,QTN,HG,HL,QCD,QCN,K,L,TIN,TON,TID,TOD,IACNV,SGD,ICHECK
     *,TIC,TIH,ZK)
C     THIS IS HEAT LOSS AND HEAT GAIN CALCULATIONS
C
C     *** INPUT ***
C         QCD    : DAYTIME CEILING HEAT GAIN
C         QID    : DAYTIME INFILTRATION HEAT GAIN
C         QIN    : NIGHTTIME INFILTRATION HEAT GAIN
C         QWD    : DAYTIME WALL HEAT GAIN
C         QWN    : NIGHTTIME WALL HEAT GAIN
C         QDD    : DAYTIME DOOR HEAT GAIN
C         QDN    : NIGHTTIME DOOR HEAT GAIN
C         QGD    : DAYTIME WINDOW HEAT GAIN
C         QGN    : NIGHTTIME WINDOW HEAT GAIN
C         QFD    : DAYTIME FLOOR HEAT GAIN
C         QFN    : NIGHTTIME FLOOR HEAT GAIN
C         QRD    : DAYTIME INTERNAL HEAT GAIN
C         QRN    : NIGHTTIME INTERNAL HEAT GAIN
C         THTC   : THERMAL TIME CONSTANT
C         QCN    : NIGHTTIME CEILING HEAT GAIN
C         SGD    : DAYTIME SOLAR HEAT GAIN
C         PUH    : PICK UP HOURS
C         IACNV  : NATURAL VENTILATION INDEX
C                  = 0 IF WINDOW ALWAYS CLOSED
C                  = 1 IF WINDOW OPENS WHEN OUTDOOR TEMPERATURE IS LESS THAN THE
C                      THERMOSTAT SET POINT IN SUMMER
C         TIC    : COOLING THERMOSTAT SETTING -- NOT USED
C         TIH    : HEATING THERMOSTAT SETTING -- NOT USED
C         ZK     : OVERALL HEAT TRANSFER FACTOR
C         K      : FIRST COOLING MONTH
C         L      : LAST COOLING MONTH
C
C     *** OUTPUT ***
C         QTD    : DAYTIME HEAT LOSS AND HEAT GAIN
C         QTN    : NIGHTTIME HEAT LOSS AND HEAT GAIN
C         HL     : DAILY HEAT LOSS
C         HG     : DAILY HEAT GAIN
C
      COMMON/HR/HRDAY(12),HRNIT(12)
      DIMENSION QID(12), QIN(12), QWD(12), QWN(12), QDD(12), QDN(12),
     *          QGD(12), QGN(12), QFD(12), QFN(12), QRD(12), QRN(12),
     *          QTD(12), QTN(12), HG (12), HL (12), QCD(12), QCN(12),
     *          TIN(12), TON(12), TID(12), TOD(12), SGD(12), AA (10),
     *          BB(10,12),ZK(12)
      DATA AA/2HZK,4HDHCD,4HDHWU,3HPUH,6HPULDWN,6HPICKUP,3HCLD,3HCLN,
     *        3HHLD,3HHLN/
      DO 10 I=1,12
     HLD=0.
     CLD=0.
     HLN=0.
     CLN=0.
      PICKUP=0.
      PULDWN=0.
      DHCD=0.
      DHWU=0.
      QTD(I)=QID(I)+QWD(I)+QDD(I)+QGD(I)+QFD(I)+QRD(I)+QCD(I)
```

```
      QTN(I)=QIN(I)+QWN(I)+QDN(I)+QCN(I)+QFN(I)+QRN(I)+QCN(I)
      IF(TID(I).NE.TIN(I)) GO TO 11
      IF(QTD(I).GT.0.) CLD=QTD(I)
      IF(QTN(I).GT.0.) CLN=QTN(I)
      IF(QTD(I).LT.0.) HLD=QTD(I)
      IF(QTN(I).LT.0.) HLN=QTN(I)
      GO TO 9
   11 IF(QTD(I).GE.0.AND.QTN(I).GE.0.AND.TID(I).GE.TIN(I)) IX=1
      IF(QTD(I).GE.0.AND.QTN(I).GE.0.AND.TID(I).LT.TIN(I)) IX=2
      IF(QTD(I).GE.0.AND.QTN(I).LE.0.AND.TID(I).GE.TIN(I)) IX=3
      IF(QTD(I).GE.0.AND.QTN(I).LT.0.AND.TID(I).LT.TIN(I)) IX=4
      IF(QTD(I).LE.0.AND.QTN(I).LE.0.AND.TID(I).GE.TIN(I)) IX=5
      IF(QTD(I).LE.0.AND.QTN(I).LE.0.AND.TID(I).LT.TIN(I)) IX=6
      IF(QTD(I).LT.0.AND.QTN(I).GE.0.AND.TID(I).GE.TIN(I)) IX=7
      IF(QTD(I).LT.0.AND.QTN(I).GE.0.AND.TID(I).LT.TIN(I)) IX=8
      GO TO (1,2,3,4,5,6,7,8), IX
    1 DT=TIN(I)-TID(I)
      CALL THTCX(TON(I),TID(I),DT,PULDWN,ZK(I),PUH,THTC,2)
      DT=TID(I)-TIN(I)
      Q=(QRD(I)+SGD(I))/HRDAY(I)
      CALL THTCX(TOD(I),TIN(I),DT,Q,ZK(I),DHWU,THTC,1)
      IF(DHWU.GE.HRDAY(I)) DHWU=HRDAY(I)
      CLD=QTD(I)*(1.-DHWU/HRDAY(I))
      CLN=PULDWN*PUH+QTN(I)*(1.-PUH/HRNIT(I))
      GO TO 9
    2 DT=TIN(I)-TID(I)
      Q=QRN(I)/HRNIT(I)
      CALL THTCX(TON(I),TID(I),DT,Q,ZK(I),DHWU,THTC,1)
      IF(DHWU.GE.HRNIT(I)) DHWU=HRNIT(I)
      DT=TID(I)-TIN(I)
      CALL THTCX(TOD(I),TIN(I),DT,PULDWN,ZK(I),PUH,THTC,2)
      CLD=QTD(I)*(1.-PUH/HRDAY(I))+PULDWN*PUH
      CLN=QTN(I)*(1.-DHWU/HRNIT(I))
      GO TO 9
    3 DT=TIN(I)-TID(I)
      Q=QRN(I)/HRNIT(I)
      CALL THTCX(TON(I),TID(I),DT,Q,ZK(I),DHCD,THTC,1)
      IF(DHCD.LT.HRNIT(I)) DHCD=HRNIT(I)
      DT=TID(I)-TIN(I)
      Q=(QRD(I)+SGD(I))/HRDAY(I)
      CALL THTCX(TOD(I),TIN(I),DT,Q,ZK(I),DHWU,THTC,1)
      IF(DHWU.GE.HRDAY(I)) DHWU=HRDAY(I)
      HLN=QTN(I)*(1.-DHCD/HRNIT(I))
      CLD=QTD(I)*(1.-DHWU/HRDAY(I))
      GO TO 9
    4 DT=TIN(I)-TID(I)
      CALL THTCX(TON(I),TID(I),DT,PICKUP,ZK(I),PUH,THTC,2)
      DT=TID(I)-TIN(I)
      CALL THTCX(TOD(I),TIN(I),DT,PULDWN,ZK(I),PUH,THTC,2)
      CLD=QTD(I)*(1.-PUH/HRDAY(I))+PICKUP*PUH
      HLN=QTN(I)*(1.-PUH/HRNIT(I))+PULDWN*PUH
      GO TO 9
    5 DT=TID(I)-TIN(I)
      CALL THTCX(TOD(I),TIN(I),DT,PICKUP,ZK(I),PUH,THTC,2)
      Q=QRN(I)/HRNIT(I)
      DT=TIN(I)-TID(I)
      CALL THTCX(TON(I),TID(I),DT,Q,ZK(I),DHCD,THTC,1)
      IF(DHCD.GE.HRNIT(I)) DHCD=HRNIT(I)
```

```
      HLN=QTN(I)*(1.-DHCD/HRNIT(I))
      HLD=QTD(I)*(1.-PUH/HRDAY(I))+PICKUP*PUH
      GO TO 9
    6 DT=TIN(I)-TID(I)
      CALL THTCX(TON(I),TID(I),DT,PICKUP,ZK(I),PUH,THTC,2)
      Q=(QRD(I)+SGD(I))/HRDAY(I)
      DT=TID(I)-TIN(I)
      CALL THTCX(TOD(I),TIN(I),DT,Q,ZK(I),DHCD,THTC,1)
      IF(DHCD.GE.HRDAY(I)) DHCD=HRDAY(I)
      HLD=QTD(I)*(1.-DHCD/HRDAY(I))
      HLN=PICKUP*PUH+QTN(I)*(1.-PUH/HRNIT(I))
      GO TO 9
    7 DT=TIN(I)-TID(I)
      CALL THTCX(TON(I),TID(I),DT,PULDWN,ZK(I),PUH,THTC,2)
      DT=TID(I)-TIN(I)
      CALL THTCX(TOD(I),TIN(I),DT,PICKUP,ZK(I),PUH,THTC,2)
      HLD=PICKUP*PUH+QTD(I)*(1.-PUH/HRDAY(I))
      CLN=PULDWN*PUH+QTN(I)*(1.-PUH/HRNIT(I))
      GO TO 9
    8 DT=TID(I)-TIN(I)
      Q=(QRD(I)+SGD(I))/HRDAY(I)
      CALL THTCX(TOD(I),TIN(I),DT,Q,ZK(I),DHCD,THTC,1)
      IF(DHCD.GE.HRDAY(I)) DHCD=HRDAY(I)
      DT=TIN(I)-TID(I)
      Q=QRN(I)/HRNIT(I)
      CALL THTCX(TON(I),TID(I),DT,Q,ZK(I),DHWU,THTC,1)
      IF(DHWU.GE.HRNIT(I)) DHWU=HRNIT(I)
      HLD=QTD(I)*(1.-DHCD/HRDAY(I))
      CLN=QTN(I)*(1.-DHWU/HRNIT(I))
    9 HG(I)=CLD+CLN
      HL(I)=HLD+HLN
      BB(1,I)=ZK(I)
      BB(2,I)=DHCD
      BB(3,I)=DHWU
      BB(4,I)=PUH
      BB(5,I)=PULDWN
      BB(6,I)=PICKUP
      BB(7,I)=CLD
      BB(8,I)=CLN
      BB(9,I)=HLD
      BB(10,I)=HLN
   10 CONTINUE
      DO 20 J=1,10
      IF(ICHECK.EQ.1) WRITE(6,2000) AA(J),(BB(J,KK),KK=1,12)
 2000 FORMAT(1H ,A6,12G10.4)
   20 CONTINUE
      RETURN
      END
```

QSQSQS*CONSP6(1).THTCX(5)

```
      SUBROUTINE THTCX(TO,TI,DT,Q,ZK,DH,THTC,IX)
C     TO   OUTSIDE TEMPERATURE
C     TI   INITIAL INDOOR TEMPERATURE, F
C     DT   TEMPERATURE RISE AFTER DH HOURS
C     Q         INTERNAL HEAT GAIN, BTU/DAY
C     ZK        HEAT LOSS FACTOR, BTU/(HR)(F)
C     DH        TIME DURATION, HR
C     THTC      THERMAL TIME CONSTANT
C     IX        CALCULATION INDEX
C     IX = 1     CALCULATE DH
C     IX = 2     CALCULATE ZQ
C     IX = 3     CALCULATE DT
C     WRITE(6,5) TO,TI,DT,Q,ZK,DH,THTC,IX
C   5 FORMAT(' TO='F12.6,' TI='F12.6,' DT='F12.6,' Q='F12.6,
C    *       ' ZK='F12.6,' DH='F12.6,' THTC='F12.6,' IX='I2)
      IF(IX.EQ.1) GO TO 1
      Z1=EXP(-DH/THTC)
      Z2=1.-Z1
    1 GO TO (2,3,4), IX
    2 Z3=TO-TI+Q/ZK
      Z4=TO-(TI+DT)+Q/ZK
      Z6=Z3/Z4
      IF(Z6) 5,5,6
    5 DH=24.
      RETURN
C     WRITE(6,6) Z3,Z4,Z6
C   6 FORMAT(' Z3='F12.6,' Z4='F12.6,' Z6='F12.6)
    6 Z5=ALOG(Z3/Z4)
      DH=THTC*Z5
      IF(DH.LE.0.) DH=24.
      RETURN
    3 Z6=TI-TO
      Z7=Z6+DT/Z2
      Q=-ZK*Z7
      RETURN
    4 Z3=TO-TI+Q/ZK
      DT=Z3*Z2
      RETURN
      END
```

```
Q3Q8Q8*CONSP6(1).HCRT(7)
      SUBROUTINE HCRT (HL, HG, LHG,  HREQ, CREQ, AIRLOS)
C
C     THIS IS HEATING AND COOLING REQUIREMENT ROUTINE
C
C     *** INPUT ***
C
C         HL     : SENSIBLE HEAT LOSS
C         HG     : SENSIBLE HEAT GAIN
C         LHG    : LATENT HEAT GAIN
C         AIRLOS : AIR LEAKAGE THROUGH DUCTS, PERCENT OF DELIVERED AIR
C
C
C     *** OUTPUT ***
C
C         HREQ   : HEATING REQUIREMENT
C         CREQ   : COOLING REQUIREMETT
C
      DIMENSION HL(12), HG(12), LHG(12),  HREQ(12), CREQ(12)
      REAL LHG
      DO 10 I = 1,12
      HREQ(I) = (HL(I)+LHG(I)) * (1.0 + AIRLOS/100.0)
      IF(HREQ(I).GE.0.) HREQ(I)=0.
      CREQ(I) = (HG(I) + LHG(I))*(1.0 + AIRLOS/100.0)
   10 CONTINUE
      RETURN
      END
```

```
QSQSQS*CONSP6(1).SEU(10)
      SUBROUTINE SEU(SA,SB,TE,TOD,I,SUF,AS,QS,ISOLHW,ISOLSH)
C
C     THIS IS SOLAR ENERGY UTILIZATION
C
C     *** INPUT ***
C
C         SA     : COLLECTOR NORMAL EFFICIENCY CURVE DATA A
C         SB     : COLLECTOR NORMAL EFFICIENCY CURVE DATA B
C         TE     : INLET FLUID TEMPERATURE
C         TOD    : DAYTIME OUTDOOR TEMPERATURE
C         I      : DAILY TOTAL SOLAR RADIATION
C         SUF    : SOLAR HEAT UTILIZATION FACTOR
C         AS     : COLLECTOR AREA
C         ISOLHW : SOLAR HOT WATER INDEX, 0 FOR NO, 1 FOR YES
C         ISOLSH : SOLAR SPACE HEATING INDEX, 0 FOR NO, 1 FOR YES
C
C     *** OUTPUT ***
C
C         QS     : SOLAR HEAT UTILIZED
C
      COMMON/HR/HRDAY(12),HRNIT(12)
      DIMENSION TE(12),TOD(12),I(12),QS(12)
      REAL I
C
      DO 10 J=1,12
      QS(J)=0.0
      IF(ISOLHW.EQ.0.AND.ISOLSH.EQ.0) GO TO 10
      QS(J)=AS*SA*(1.0-HRDAY(J)*(TE(J)-TOD(J))/SB/I(J))*SUF*I(J)
      IF((TE(J)-TOD(J))/I(J).GT.SB) QS(J) = 0.0
      IF((TE(J)-TOD(J))/I(J).LT.0.) QS(J) = AS*SA*SUF*I(J)
   10 CONTINUE
      RETURN
      END
END PRT

@PRT,S CONSP6.EREQ,.HWHREQ,.CSDUPI,.ASDUPI,.BMDUPI,.QSDUTI,.ZKDN,.PSY2,.WBF
```

```
QSQSQS*CONSP6(1).EREQ(14)
              SUBROUTINE EREQ(HREQ,CREQ,EH,EC,ISYS,SHBTU,SCBTU,WHREQ,QS,QQC,QQH)
        C
        C     THIS IS ENERGY REQUIREMENT CALCULATION ROUTINE
        C
        C     *** INPUT ***
        C
        C         HREQ    : HEATING REQUIREMENT
        C         CREQ    : COOLING REQUIREMENT
        C         EH      : HEATING EFFICIENCY
        C         EC      : COOLING EFFICIENCY
        C         WHREQ   : HOT WATER HEATING REQUIREMENT
        C         QS      : ENERGY FROM SOLAR COLLECTOR
        C         QQC     : HEAT GAIN THROUGH DUCTS 8 PIPES
        C         QQH     : HEAT LOSS THROUGH DUCTS 8 PIPES
        C         ISYS    : SYSTEM INDEX
        C                     1 =  HEATING + NO COOLING
        C                     2 = NO HEATING + COOLING
        C                     3 =  HEATING + COOLING
        C
        C     *** OUTPUT ***
        C
        C          SHBTU : HEATING ENERGY REQUIREMENT AFTER USING ENERGY FROM SOLAR
        C                  COLLECTOR, INCLUDING HOT WATER ENERGY REQUIREMENT
        C          SCBTU : SPACE COOLING ENERGY REQUIREMENT
        C
              DIMENSION HREQ(12),CREQ(12),WHREQ(12),QS(12),QQC(12),QQH(12)
        C
              GO TO (100,101,102), ISYS
        C
          100 SCBTU=0.0
              SHBTU=0.0
              DO 200 I=1,12
              X=(HREQ(I)+WHREQ(I)+QS(I)+QQH(I))/EH
              IF(X.GT.0.0) X=0.0
              SHBTU=SHBTU+X
          200 CONTINUE
              GO TO 999
        C
          101 SHBTU=0.0
              SCBTU=0.0
              DO 201 I=1,12
              Y=(WHREQ(I)+QS(I))/EH
              IF(Y.GT.0.0) Y=0.0
              SHBTU=SHBTU+Y
              SCBTU=SCBTU+(CREQ(I)+QQC(I))/EC
          201 CONTINUE
              GO TO 999
        C
          102 SHBTU=0.0
              SCBTU=0.0
              DO 202 I=1,12
              Z=(HREQ(I)+WHREQ(I)+QS(I)+QQH(I))/EH
              IF(Z.GT.0.0) Z=0.0
              SHBTU=SHBTU+Z
              SCBTU=SCBTU+(CREQ(I)+QQC(I))/EC
          202 CONTINUE
        C
```

```
  999 RETURN
      END
```

Q8Q8Q8*CONSP6(1).HWHREQ(12)

```
      SUBROUTINE HWHREQ(TOUT,TIN,HWT,A,BSMTD,BSMTN,D1,RAM1,D2,RAM2,
     1                  HLHWH1,HLHWH2,SAVE,WHREQ)
C
C     THIS IS HOT WATER HEATING REQUIREMENT ROUTINE
C     *** INPUT ***
C
C         TOUT   : HOT WATER OUTLET TEMPERATURE
C         TIN    : HOT WATER INLET TEMPERATURE = GROUND TEMPERATURE
C         HWT    : HOT WATER USAGE  75. GALLON/DAY
C         A       : TOTAL JACKET AREA
C         BSMTD   : DAYTIME BASEMENT TEMPERATURE
C         BSMTN   : NIGHTTIME BASEMENT TEMPERATURE
C         D1      : THICKNESS OF ALREADY INSTALLED INSULATION
C         RAM1    : THERMAL CONDUCTIVITY OF ALREADY INSTALLED INSULATION
C         D2      : THICKNESS OF ADDITIONAL INSULATION
C         RAM2    : THERMAL CONDUCTIVITY OF ADDITIONAL INSULATION
C
C     *** OUTPUT ***
C
C         HLHWH1  : HEAT LOSS THROUGH NON-ADDITIONAL JACKET
C         HLHWH2  : HEAT LOSS THROUGH     ADDITIONAL JACKET
C         SAVE    : ENERGY SAVING BY ADDITIONAL INSULATION
C         WHREQ  : HOT WATER HEATING REQUIREMENT
C
      COMMON/HR/HRDAY(12),HRNIT(12)
      DIMENSION TIN(12),WHREQ(12),BSMTD(12),BSMTN(12),HLHWH1(12),
     1          HLHWH2(12),SAVE(12)
C
      UX=0.685
      IF(RAM1.EQ.0.0) GO TO 10
      UX=0.685+D1/RAM1
   10 U1=1.0/UX
C
      UY=0.685
      IF(RAM1.NE.0.0.AND.RAM2.NE.0.0) UY=0.685+D1/RAM1+D2/RAM2
      IF(RAM1.NE.0.0.AND.RAM2.EQ.0.0) UY=0.685+D1/RAM1
      IF(RAM1.EQ.0.0.AND.RAM2.NE.0.0) UY=0.685+D2/RAM2
      U2=1.0/UY
C
      DO 20 I=1,12
      QD1=U1*A*(BSMTD(I)-TOUT)*HRDAY(I)
      QN1=U1*A*(BSMTN(I)-TOUT)*HRNIT(I)
      QD2=U2*A*(BSMTD(I)-TOUT)*HRDAY(I)
      QN2=U2*A*(BSMTN(I)-TOUT)*HRNIT(I)
      HLHWH1(I)=QD1+QN1
      HLHWH2(I)=QD2+QN2
      SAVE(I)=HLHWH2(I)-HLHWH1(I)
      WHREQ(I)=590.0/60.0*(TIN(I) - TOUT) * HWT+HLHWH2(I)
      IF(WHREQ(I).GT.0.0) WHREQ(I)=0.0
   20 CONTINUE
      RETURN
      END
```

```
Q$Q$Q$*CONSP5(1).CSDUPI(5)
      SUBROUTINE CSDUPI(ADUCT,UDUCT,APIPE,UPIPE,TCSUPA,TCSUPW,THSUPA,
     1                  THSUPW,CRAWLD,CRAWLN,NSTART,NLAST,QC,QH,
     2                  CFAC,HFAC)
C     THIS IS HEAT LOSS & GAIN THROUGH DUCTS & PIPES IN CRAWL SPACE
C
C     *** INPUT ***
C         ADUCT  = TOTAL SURFACE AREA OF DUCT IN CRAWL SPACE
C         UDUCT  = U VALUE OF DUCT
C         APIPE  = TOTAL SURFACE AREA OF PIPE IN CRAWL SPACE
C         UPIPE  = U VALUE OF PIPE
C         TCSUPA = SUPPLY CHILLED AIR TEMPERATURE
C         TCSUPW = SUPPLY CHILLED WATER TEMPERATURE
C         THSUPA = SUPPLY HOT AIR TEMPERATURE
C         THSUPW = SUPPLY HOT WATER TEMPERATURE
C         CRAWLD = DAYTIME CRAWL TEMPERATURE
C         CRAWLN = NIGHTTIME CRAWL TEMPERATURE
C
C     *** OUTPUT ***
C
C         QC     = HEAT GAIN THROUGH DUCTS & PIPES
C         QH     = HEAT LOSS THROUGH DUCTS & PIPES
C
      COMMON/HR/HRDAY(12),HRNIT(12)
      DIMENSION CRAWLD(12), CRAWLN(12), QC(12), QH(12),
     1          CFAC(12), HFAC(12)
C
      DO 10 I=1,12
      DUCTCD=ADUCT*UDUCT*(CRAWLD(I)-TCSUPA)*HRDAY(I)*CFAC(I)
      DUCTCN=ADUCT*UDUCT*(CRAWLN(I)-TCSUPA)*HRNIT(I)*CFAC(I)
      PIPECD=APIPE*UPIPE*(CRAWLD(I)-TCSUPW)*HRDAY(I)*CFAC(I)
      PIPECN=APIPE*UPIPE*(CRAWLN(I)-TCSUPW)*HRNIT(I)*CFAC(I)
      QC(I)=DUCTCD+DUCTCN+PIPECD+PIPECN
      IF(I.LT.NSTART.OR.I.GT.NLAST) QC(I)=0.0
      DUCTCD=ADUCT*UDUCT*(CRAWLD(I)-THSUPA)*HRDAY(I)*HFAC(I)
      DUCTCN=ADUCT*UDUCT*(CRAWLN(I)-THSUPA)*HRNIT(I)*HFAC(I)
      PIPECD=APIPE*UPIPE*(CRAWLD(I)-THSUPW)*HRDAY(I)*HFAC(I)
      PIPECN=APIPE*UPIPE*(CRAWLN(I)-THSUPW)*HRNIT(I)*HFAC(I)
      QH(I)=DUCTCD+DUCTCN+PIPECD+PIPECN
      IF(I.GE.NSTART.AND.I.LE.NLAST) QH(I)=0.0
   10 CONTINUE
      RETURN
      END
```

```
Q8Q8Q3*CONSP6(1).ASDUPI(4)
      SUBROUTINE ASDUPI(ADUCT,UDUCT,APIPE,UPIPE,TCSUPA,TCSUPW,THSUPA,
     1                  THSUPW,ATD,ATN,NSTART,NLAST,QC,QH,CFAC,HFAC)
C     THIS IS HEAT LOSS 8 GAIN THROUGH DUCTS 8 PIPES IN ATTIC SPACE
C
C     *** INPUT ***
C         ADUCT  : TOTAL SURFACE AREA OF DUCT IN ATTIC SPACE
C         UDUCT  : U VALUE OF DUCT
C         APIPE  : TOTAL SURFACE AREA OF PIPE IN ATTIC SPACE
C         UPIPE  : U VALUE OF PIPE
C         TCSUPA : SUPPLY CHILLED AIR TEMPERATURE
C         TCSUPW : SUPPLY CHILLED WATER TEMPERATURE
C         THSUPA : SUPPLY HOT TEMPERATURE
C         THSUPW : SUPPLY HOT WATER TEMPERATURE
C         ATD    : ATTIC DAYTIME TEMPERATURE
C         ATN    : ATTIC NIGHTTIME TEMPERATURE
C
C     *** OUTPUT ***
C
C         QC     : HEAT GAIN THROUGH DUCTS 8 PIPES
C         QH     : HEAT LOSS THROUGH DUCTS 8 PIPES
C
      COMMON/HR/HRDAY(12),HRNIT(12)
      DIMENSION ATD(12), ATN(12), QC(12), QH(12),CFAC(12),HFAC(12)
C
      DO 10 I=1,12
      DUCTAD=ADUCT*UDUCT*(ATD(I)-TCSUPA)*HRDAY(I)*CFAC(I)
      DUCTAN=ADUCT*UDUCT*(ATN(I)-TCSUPA)*HRNIT(I)*CFAC(I)
      PIPEAD=APIPE*UPIPE*(ATD(I)-TCSUPW)*HRDAY(I)*CFAC(I)
      PIPEAN=APIPE*UPIPE*(ATN(I)-TCSUPW)*HRNIT(I)*CFAC(I)
      QC(I)=DUCTAD+DUCTAN+PIPEAD+PIPEAN
      IF(I.LT.NSTART.OR.I.GT.NLAST) QC(I)=0.0
      DUCTAD=ADUCT*UDUCT*(ATD(I)-THSUPA)*HRDAY(I)*HFAC(I)
      DUCTAN=ADUCT*UDUCT*(ATN(I)-THSUPA)*HRNIT(I)*HFAC(I)
      PIPEAD=APIPE*UPIPE*(ATD(I)-THSUPW)*HRDAY(I)*HFAC(I)
      PIPEAN=APIPE*UPIPE*(ATN(I)-THSUPW)*HRNIT(I)*HFAC(I)
      QH(I)=DUCTAD+DUCTAN+PIPEAD+PIPEAN
      IF(I.GE.NSTART.AND.I.LE.NLAST) QH(I)=0.0
   10 CONTINUE
      RETURN
      END
```

```
QSQSQS*CONSP6(1).BMDUPI(8)
      SUBROUTINE BMDUPI(ADUCT,UDUCT,APIPE,UPIPE,TCSUPA,TCSUPW,THSUPA,
     1                  THSUPW,BSMTD,BSMTN,NSTART,NLAST,INDEXC,QC,QH,
     2                  CFAC,HFAC)
C
C     THIS IS HEAT LOSS & GAIN THROUGH DUCTS & PIPES IN BASEMENT
C
C     *** INPUT ***
C
C         ADUCT  : TOTAL SURFACE AREA OF DUCT IN BASEMENT
C         UDUCT  : U VALUE OF DUCT
C         APIPE  : TOTAL SURFACE AREA OF PIPE IN BASEMENT
C         UPIPE  : U VALUE OF PIPE
C         TCSUPA : SUPPLY CHILLED AIR TEMPERATURE
C         TCSUPW : SUPPLY CHILLED WATER TEMPERATURE
C         THSUPA : SUPPLY HOT AIR TEMPERATURE
C         THSUPW : SUPPLY HOT WATER TEMPERATURE
C         BSMTD  : BASEMENT DAYTIME TEMPERATURE
C         BSMTN  : BASEMENT NIGHTTIME TEMPERATURE
C         INDEXC : =0 IF BASEMENT HEATED; =1 IF UNHEATED
C
C     *** OUTPUT ***
C
C         QC     : HEAT GAIN THROUGH DUCTS & PIPES
C         QH     : HEAT LOSS THROUGH DUCTS & PIPES
C
      COMMON/HR/HRDAY(12),HRNIT(12)
      DIMENSION BSMTD(12), BSMTN(12), QC(12), QH(12),
     1          CFAC(12), HFAC(12)
      DO 10 I=1,12
      DUCTBD=ADUCT*UDUCT*(BSMTD(I)-TCSUPA)*HRDAY(I)*CFAC(I)
      DUCTBN=ADUCT*UDUCT*(BSMTN(I)-TCSUPA)*HRNIT(I)*CFAC(I)
      PIPEBD=APIPE*UPIPE*(BSMTD(I)-TCSUPW)*HRDAY(I)*CFAC(I)
      PIPEBN=APIPE*UPIPE*(BSMTN(I)-TCSUPW)*HRNIT(I)*CFAC(I)
      QC(I)=DUCTBD+DUCTBN+PIPEBD+PIPEBN
      IF(I.LT.NSTART.OR.I.GT.NLAST) QC(I)=0.0
      DUCTBD=ADUCT*UDUCT*(BSMTD(I)-THSUPA)*HRDAY(I)*HFAC(I)
      DUCTBN=ADUCT*UDUCT*(BSMTN(I)-THSUPA)*HRNIT(I)*HFAC(I)
      PIPEBD=APIPE*UPIPE*(BSMTD(I)-THSUPW)*HRDAY(I)*HFAC(I)
      PIPEBN=APIPE*UPIPE*(BSMTN(I)-THSUPW)*HRNIT(I)*HFAC(I)
      QH(I)=DUCTBD+DUCTBN+PIPEBD+PIPEBN
      IF(I.GE.NSTART.AND.I.LE.NLAST) QH(I)=0.0
      IF(INDEXC.EQ.0) QH(I)=0.0
   10 CONTINUE
      RETURN
      END
```

```
Q@Q@Q@*CONSP6(1).OSDUPI(4)
                 SUBROUTINE OSDUPI(ADUCT,UDUCT,APIPE,UPIPE,TCSUPA,TCSUPW,THSUPA,
                1                 THSUPW,TOD,TON,NSTART,NLAST,QC,QH,CFAC,HFAC)
      C
      C          THIS IS HEAT LOSS & GAIN THROUGH DUCTS & PIPES IN OUTSIDE
      C
      C          *** INPUT ***
      C
      C               ADUCT  : TOTAL SURFACE AREA OF DUCT IN OUTSIDE
      C               UDUCT  : U VALUE OF DUCT
      C               APIPE  : TOTAL SURFACE AREA OF PIPE IN OUTSIDE
      C               UPIPE  : U VALUE OF PIPE
      C               TCSUPA : SUPPLY CHILLED AIR TEMPERATURE
      C               TCSUPW : SUPPLY CHILLED WATER TEMPERATURE
      C               THSUPA : SUPPLY HOT AIR TEMPERATURE
      C               THSUPW : SUPPLY HOT WATER TEMPERATURE
      C               TOD    : DAYTIME OUTSIDE TEMPERATURE
      C               TON    : NIGHTTIME OUTSIDE TEMPERATURE
      C
      C         *** OUTPUT ***
      C
      C               QC     : HEAT GAIN THROUGH DUCTS & PIPES
      C               QH     : HEAT LOSS THROUGH DUCTS & PIPES
      C
                 COMMON/HR/HRDAY(12),HRNIT(12)
                 DIMENSION TOD(12), TON(12), QC(12), QH(12),CFAC(12),HFAC(12)
      C
                 DO 10 I=1,12
                 DUCTOD=ADUCT*UDUCT*(TOD(I)-TCSUPA)*HRDAY(I)*CFAC(I)
                 DUCTON=ADUCT*UDUCT*(TON(I)-TCSUPA)*HRNIT(I)*CFAC(I)
                 PIPEOD=APIPE*UDUCT*(TOD(I)-TCSUPW)*HRDAY(I)*CFAC(I)
                 PIPEON=APIPE*UDUCT*(TON(I)-TCSUPW)*HRNIT(I)*CFAC(I)
                 QC(I)=DUCTOD+DUCTON+PIPEOD+PIPEON
                 IF (I.LT.NSTART.OR.I.GT.NLAST) QC(I)=0.0
                 DUCTOD=ADUCT*UDUCT*(TOD(I)-THSUPA)*HRDAY(I)*HFAC(I)
                 DUCTON=ADUCT*UDUCT*(TON(I)-THSUPA)*HRNIT(I)*HFAC(I)
                 PIPEOD=APIPE*UPIPE*(TOD(I)-THSUPW)*HRDAY(I)*HFAC(I)
                 PIPEON=APIPE*UPIPE*(TON(I)-THSUPW)*HRNIT(I)*HFAC(I)
                 QH(I)=DUCTOD+DUCTON+PIPEOD+PIPEON
                 IF (I.GE.NSTART.AND.I.LE.NLAST) QH(I)=0.0
              10 CONTINUE
                 RETURN
                 END
```

```
Q$Q$Q$*CONSP6(1).ZKDN(4)
      SUBROUTINE ZKDN(RINFIL,B,ZK)
C     THIS ROUTINE DETERMINES THE OVERALL ENVELOPE HEAT TRANSFER FACTOR
C     A SUBROUTINE OF HLBG ROUTINE
      REAL RINFIL(12),B(350)
      REAL ZK(12)
      SUMZK=B(72)*B(74)+B(77)*B(79)+B(82)*B(84)+B(87)*B(89)+B(124)*B(125
     *)+B(130)*B(151)+B(136)*B(137)+B(142)*B(143)+B(292)*B(293)+B(297)*B
     *(298)+B(302)*B(303)+B(307)*B(308)+B(152)*B(192)
      DO 1 I=1,12
      ZZ=SUMZK+RINFIL(I)*1.08
    1 ZK(I)=ZZ
      RETURN
      END
```

C 48

```
Q0Q0Q0*CONSP6(1).PSY2(1)
      SUBROUTINE PSY2 (DB,DP,PB,WB,PV,W,H,V,RH)
C
C     ****************************************************************
C
C    THIS SUBROUTINE CALCULATES THE FOLLOWINGS WHEN DRY-BULB TEMPERATURE
C    (DB),DEW-POINT TEMPERATURE(DP),AND BAROMETRIC PRESSURE(PB) ARE GIVEN
C    WB   WET-BULB TEMPERATURE
C    W    HUMIDITY RATIO
C     H   ENTHALPY
C     V   VOLUME
C    PV   VAPOR PRESSURE
C    RH   RELATIVE HUMIDITY
      IF (DP-DB) 20,10,10
   10 DP=DB
   20 PV=PVSF(DP)
      PVS=PVSF(DB)
      RH=PV/PVS
      W=0.622*PV/(PB-PV)
      V=0.754*(DB+459.7)*(1+7000*W/4360)/PB
      H=0.24*DB+(1061+0.444*DB)*W
      IF (H) 30,30,40
   30 WB=DP
      RETURN
C
   40 WB=WBF(H,PB)
      RETURN
C
      END
```

```
Q8Q8Q8*CONSP6(1).WBF(1)
              FUNCTION WBF (H,PB)
      C
      C       ****************************************************************
      C
      C  THIS PROGRAM APPROXIMATES THE WET-BULB TEMPERATURE WHEN
      C   ENTHALPY IS GIVEN
              IF (H) 30,30,10
       10     Y=LOG(H)
              IF (H.GT.11.758) GO TO 20
              WBF=0.6041+3.4841*Y+1.3601*Y*Y+0.97307*Y*Y*Y
              GO TO 100
      C
       20     WBF=30.9185-39.68200*Y+20.5841*Y*Y-1.758*Y*Y*Y
              GO TO 100
      C
       30     WB1=150.
              PV1=PVSF(WB1)
              W1=0.622*PV1/(PB-PV1)
              X1=0.24*WB1+(1061+0.444*WB1)*W1
              Y1=H-X1
       40     WB2=WB1-1
              PV2=PVSF(WB2)
              W2=0.622*PV2/(PB-PV2)
              X2=0.24*WB2+(1061+0.444*WB2)*W2
              Y2=H-X2
              IF (Y1*Y2) 90,60,50
       50     WB1=WB2
              Y1=Y2
              GO TO 40
      C
       60     IF (Y1) 80,70,80
       70     WBF=WB1
              GO TO 100
      C
       80     WBF=WB2
              GO TO 100
      C
       90     Z=ABS(Y1/Y2)
              WBF=(WB2*Z+WB1)/(1+Z)
      100     RETURN
      C
              END
END PRT

@PRT,S CONSP6.DEGDAY,.LINT,.MAX,.MIN
```

```
QSQSQS*CONSP6(1).DECDAY(5)
            SUBROUTINE DEGDAY(R,CDEG,HDEG,THT,TCT)
C           THIS ROUTINE DETERMINES ANNUAL HEATING AND COOLING REQUIREMENTS
C           BY THE VARIABLE DEGREE DAY METHOD
C           HREQ        MONTHLY HEATING REQUIREMENT (NEGATIVE)
C           CREQ        MONTHLY COOLING REQUIREMENT (POSITIVE)
C           TOD         MONTHLY NORMAL DAYTIME TEMPERATURE
C           TON         MONTHLY NORMAL NIGHTTIME TEMPERATURE
C           CDEG        COOLING DEGREE DAY AT DIFFERENT BASE TEMPERATURE
C           HDEG        HEATING DEGREE DAY AT DIFFERENT BASE TEMPERATURE
C           THT         ANNUAL HEATING REQUIREMENT
C           TCT         ANNUAL COOLING REQUIREMENT
            DIMENSION HREQ(12),CREQ(12),TOD(12),TON(12),TO(12),CDEG(16),HDEG(16)
           16),R(50),DAYS(12)/31.,28.,31.,30.,31.,30.,31.,31.,30.,31.,30.,31./
            WRITE(6,5)
            DO 1 I=1,12
            HREQ(I)=R(I+2)/DAYS(I)
            CREQ(I)=R(I+14)/DAYS(I)
            TOD(I)=R(I+26)
            TON(I)=R(I+38)
          1 TO(I)=(TOD(I)+TON(I))/2.
            CALL MAX(CREQ,QC2,IMAX,12)
            CALL MIN(CREQ,QC1,IMIN,12)
            TC1=TO(IMIN)
            TC2=TO(IMAX)
            TBC=(TC1*QC2-TC2*QC1)/(QC2-QC1)
            WRITE(6,2) TC1,TC2,QC1,QC2,TBC
            CALL MAX(HREQ,QH1,IMAX,12)
            CALL MIN(HREQ,QH2,IMIN,12)
          2 FORMAT(' TC1='F15.1,6X,' TC2='F15.1,6X,' QC1='F15.1,6X,' QC2='F15.
           *1,6X,' TBC='F15.1/)
            TH1=TO(IMAX)
            TH2=TO(IMIN)
            TBH=(TH1*QH2-TH2*QH1)/(QH2-QH1)
            WRITE(6,3) TH1,TH2,QH1,QH2,TBH
          3 FORMAT(' TH1='F15.1,6X,' TH2='F15.1,6X,' QH1='F15.1,6X,' QH2='F15.
           *1,6X,' TBH='F15.1/)
            CALL LINT(60.,CDEG,TBC,CDD,16)
            CALL LINT(45.,HDEG,TBH,HDD,16)
            TCT=QC2/(TC2-TBC)*CDD
            THT=QH2/(TBH-TH2)*HDD
            WRITE(6,4) CDD,HDD,THT,TCT
          4 FORMAT(' CDD='F15.1,6X,' HDD='F15.1,6X,' THT='F13.1,6X,' TCT='
           *F13.1/)
          5 FORMAT(//18X,'THE ANNUAL HEATING AND COOLING REQUIREMENT ANALYSIS
           *CALCULATED BY THE VARIABLE DEGREE-DAY METHOD'/51X,'TBC: BALANCE PO
           *INT FOR COOLING'/51X,'TBH: BALANCE POINT FOR HEATING'/)
            RETURN
            END
```

```
Q8Q8Q8*CONSP6(1).LINT(3)
          SUBROUTINE LINT(X,Y,XX,YY,N)
C         THIS ROUTINE DOES THE LINEAR INTERPOLATION BETWEEN TWO CONSECUTIVE POINTS.
          DIMENSION Y(N)
          X1=X
          XN=X+(N-1)
          IF(XX.GE.X1.AND.XX.LE.XN) GO TO 6
          IF(XX.GT.XN) GO TO 7
          Z=(X1-XX)/(X1+1.-XX)
          YY=(Z*Y(2)-Y(1))/(Z-1.)                          ● ALSO WORKS FOR EXTRAPOLATION
          GO TO 5
        7 Z=(XX-XN)/(XX-XN+1.)
          YY=(Y(N)-Y(N-1)*Z)/(1.-Z)
          GO TO 5
        6 DO 4 I=1,N
          X1=X+(I-1)
          X2=X+I
          IF(XX.NE.X1) GO TO 1
          YY=Y(I)
          GO TO 5
        1 IF(XX.NE.X2) GO TO 2
          YY=Y(I+1)
          GO TO 5
        2 IF(XX.LT.X1.OR.XX.GT.X2) GO TO 4
          Z1=(XX-X1)/(X2-X1)
          Z2=Y(I+1)-Y(I)
          YY=Y(I)+Z1*Z2
          GO TO 5
        4 CONTINUE
        5 RETURN
          END
```

```
QSQSQS*CONSP6(1).MAX(1)
      SUBROUTINE MAX(A,AMAX,IMAX,N)
      DIMENSION A(N)
C  INITIALIZE AMAX TO FIRST NON-ZERO VALUE AND IMAX TO ITS SUBSCRIPT
      DO 3 M=1,N
      IF(A(M).NE.0.) GO TO 2
    3 CONTINUE
    2 AMAX=A(M)
      IMAX=M
      DO 1 I=M,N
      IF(A(I).EQ.0.) GO TO 1
      IF(A(I).LE.AMAX) GO TO 1
      AMAX=A(I)
      IMAX=I
    1 CONTINUE
      RETURN
      END
```

```
QSQSQS*CONSP6(1).MIN(1)
              SUBROUTINE MIN(A,AMIN,IMIN,N)
              DIMENSION A(N)
        C  INITIALIZE AMIN TO FIRST NON-ZERO VALUE AND IMIN TO ITS SUBSCRIPT
              DO 3 M=1,N
              IF(A(M).NE.0.) GO TO 2
            3 CONTINUE
            2 AMIN=A(M)
              IMIN=M
              DO 1 I=M,N
              IF(A(I).EQ.0.) GO TO 1
              IF(A(I).GE.AMIN) GO TO 1
              AMIN=A(I)
              IMIN=I
            1 CONTINUE
              RETURN
              END
 END PRT

@PACK,P CONSP6.
END PREP. QSQSQS*CONSP6(1) 39 REL 39 ENTRY PT(S) NO DUP(S)
END PACK. TEXT=25,TOC=2,SYM=40,REL=39

@MAP,IN
MAP 30R1 S74T11 06/02/80 19:00:26

END MAP.  ERRORS: 0  TIME: 10.556  STORAGE: 17792/5/036777/073777

@XQT
```

C 54

CITY NAME : WASHINGTON DC
HOUSE NAME: HASTINGS HOUSE

INPUT DATA LISTING

1	9600.000	2	.500	3	38.400	4	39.600	5	48.100	6	57.500	7	67.700	8	76.200	9	79.900	10	77.900
11	72.200	12	60.900	13	50.200	14	40.200	15	35.600	16	37.300	17	45.100	18	56.400	19	66.200	20	74.600
21	78.700	22	77.100	23	70.600	24	59.800	25	48.000	26	37.400	27	70.000	28	70.000	29	70.000	30	70.000
31	78.000	32	78.000	33	78.000	34	78.000	35	78.000	36	70.000	37	70.000	38	70.000	39	65.000	40	65.000
41	65.000	42	65.000	43	78.000	44	78.000	45	78.000	46	78.000	47	78.000	48	65.000	49	65.000	50	65.000
51	1.000	52	-9999.000	53	-9999.000	54	9.900	55	10.400	56	10.900	57	10.500	58	9.200	59	8.700	60	8.100
61	6.000	62	8.200	63	8.500	64	9.200	65	9.400	66	-9999.000	67	-9999.000	68	180.000	69	38.500	70	.200
71	20234.000	72	55.100	73	.800	74	1.130	75	.000	76	270.000	77	.000	78	.000	79	.100	80	.000
81	.000	82	72.000	83	.800	84	1.130	85	.000	86	90.000	87	.000	88	.000	89	.100	90	.000
91	90.000	92	.750	93	1.000	94	70.000	95	70.000	96	70.000	97	70.000	98	70.000	99	70.000	100	70.000
101	70.000	102	70.000	103	70.000	104	70.000	105	70.000	106	.000	107	.000	108	1.000	109	10.000	110	.000
111	.900	112	-9999.000	113	-9999.000	114	-9999.000	115	-9999.000	116	-9999.000	117	-9999.000	118	-9999.000	119	-9999.000	120	-9999.000
121	-9999.000	122	-9999.000	123	-9999.000	124	.100	125	244.900	126	1.000	127	10.000	128	.000	129	.900	130	.100
131	240.000	132	1.000	133	10.000	134	.000	135	.900	136	.100	137	248.000	138	1.000	139	10.000	140	.000
141	.900	142	.100	143	240.000	144	1.000	145	.000	146	.000	147	80.000	148	60.000	149	.000	150	.000
151	.900	152	.200	153	.625	154	1.000	155	1.000	156	-9999.000	157	37.500	158	3.000	159	.050	160	.400
161	-9999.000	162	.100	163	75.000	164	6.000	165	9.000	166	1.000	167	1.000	168	140.000	169	60.600	170	62.000
171	64.000	172	66.000	173	67.000	174	68.000	175	67.000	176	66.000	177	65.000	178	64.000	179	62.000	180	61.000
181	.000	182	.000	183	.000	184	.000	185	.000	186	1.790	187	3.000	188	116.400	189	260.400	190	846.000
191	508.800	192	1200.000	193	1200.000	194	1.000	195	3.000	196	.164	197	.000	198	1.000	199	.100	200	.000
201	20.000	202	1.000	203	500.000	204	500.000	205	1.000	206	.516	207	.553	208	.524	209	.516	210	.520
211	.506	212	.464	213	.460	214	632.400	215	901.500	216	1255.000	217	1600.400	218	1846.800	219	2080.800	220	1929.900
221	1712.200	222	1446.100	223	1083.400	224	763.500	225	594.100	226	.670	227	-9999.000	228	-9999.000	229	-9999.000	230	-9999.000
231	-9999.000	232	2.100	233	-9999.000	234	-9999.000	235	-9999.000	236	-9999.000	237	-9999.000	238	-9999.000	239	-9999.000	240	2.000
241	20.000	242	20.000	243	20.000	244	20.000	245	20.000	246	60.000	247	60.000	248	60.000	249	60.000	250	20.000
251	20.000	252	20.000	253	20.000	254	20.000	255	20.000	256	20.000	257	20.000	258	60.900	259	60.000	260	60.000
261	60.000	262	20.000	263	20.000	264	20.000	265	69.000	266	67.000	267	68.000	268	68.000	269	72.000	270	75.000
271	75.000	272	79.000	273	80.000	274	79.000	275	73.000	276	71.000	277	54.000	278	52.000	279	49.000	280	47.000
281	51.000	282	52.000	283	52.000	284	54.000	285	55.000	286	51.000	287	52.000	288	57.000	289	-9999.000	290	.000
291	.900	292	.490	293	20.000	294	-9999.000	295	.000	296	.000	297	.000	298	.000	299	-9999.000	300	.000
301	.000	302	.000	303	.000	304	-9999.000	305	.000	306	.000	307	.460	308	.000	309	1.000	310	40.000
311	.080	312	.025	313	.000	314	.000	315	62.000	316	41.000	317	140.000	318	176.000	319	100.000	320	.570
321	.000	322	1.460	323	.000	324	.570	325	.000	326	1.460	327	100.000	328	.570	329	.000	330	1.460
331	.000	332	1.460	333	.000	334	4.100	335	10.000	336	.000	337	64000.000						

WINDOW HEAT GAIN ROUTINE COMPLETED
SOLAR ENERGY UTILIZATION ROUTINE COMPLETED
INFILTRATION HEAT GAIN ROUTINE COMPLETED
WALL HEAT GAIN ROUTINE COMPLETED
DOOR HEAT GAIN ROUTINE COMPLETED
CEILING HEAT GAIN ROUTINE COMPLETED

CALCULATION OF U VALUE FOR GROUND WITH FILM RESISTANCE ABOVE

WIDTH	LENGTH	AREA	PERIM	F	G	EDGE DIST.	LAMBDA	FILM R	CALC. FROM TEMPERATURE INPUT (U	R=1/U-FILM R	L=LAMBDA*R	CALC. FROM HEAT FLOW INPUT U	R=1/U-FILM R	L=LAMBDA*
40.0	30.0	1200.0	140.0	12	16	1.00	1.000	10.00	.047	11.146	11.146	.040	14.713	14.713

SLAB ON GRADE ROUTINE COMPLETED
CRAWL SPACE ROUTINE COMPLETED
FLOOR HEAT GAIN ROUTINE COMPLETED
INTERNAL HEAT GAIN ROUTINE COMPLETED

ANNUAL SUMMARY

	J	F	M	A	M	J	J	A	S	O	N	D
TID	70.00	70.00	70.00	70.00	78.00	78.00	78.00	78.00	78.00	70.00	70.00	70.00
TIN	65.00	65.00	65.00	65.00	78.00	78.00	78.00	78.00	78.00	65.00	65.00	65.00
TOD	38.40	39.60	48.10	57.50	67.70	76.20	79.90	77.90	72.20	60.90	50.20	40.20
TON	32.80	35.09	42.10	55.30	64.70	73.00	77.50	76.30	69.00	58.70	45.80	34.60
HRDAY	9.747	10.86	12.04	13.31	14.30	14.72	14.33	13.32	12.07	10.82	9.733	9.275
HRNIT	14.25	13.14	11.96	10.69	9.699	9.275	9.673	10.68	11.93	13.18	14.27	14.72
XIDTS	852.0	900.1	897.6	780.1	686.9	672.2	698.8	822.2	1042.	1150.	1107.	948.7
XIDDS	200.4	280.7	372.7	466.2	522.9	547.6	525.1	469.2	384.3	293.6	213.7	179.1
XIDTW	386.5	533.1	706.3	868.4	958.2	1053.	991.1	913.7	799.9	630.8	466.2	372.1
XIDDW	200.4	280.7	372.7	466.2	522.9	547.6	525.1	469.2	384.3	293.6	213.7	179.1
XIDTN	200.4	280.7	372.7	479.3	578.3	642.3	584.7	482.5	384.3	293.6	213.7	179.1
XIDDN	200.4	280.7	372.7	466.2	522.9	547.6	525.1	469.2	384.3	293.6	213.7	179.1
XIDTE	386.5	533.1	706.3	868.4	958.2	1053.	991.1	913.7	799.9	630.8	466.2	372.1
XIDDE	200.4	280.7	372.7	466.2	522.9	547.6	525.1	469.2	384.3	293.6	213.7	179.1
QID	-.1678+05	-.1790+05	-.1323+05	-7072.	-6017.	-922.9	875.8	-38.50	-2554.	-3661.	-8794.	-.1452+05
QIN	-.2500+05	-.2138+05	-.1375+05	-4410.	-5269.	-1615.	-155.6	-524.8	-3920.	-3085.	-.1250+05	-.2352+03
QWD	-.2328+05	-.2390+05	-.1389+05	-3083.	-436.6	.1609+05	.2047+05	.1698+05	6447.	2294.	-8836.	-.2002+05
QWN	-.4465+05	-.3835+05	-.2666+05	-.1009+05	-.1255+05	-4512.	-470.6	-1767.	-.1043+05	-8976.	-.2665+05	-.4355+05
QDD	-2724.	-2823.	-1926.	-784.5	-423.4	1157.	1556.	1051.	-8.002	7.5	-1512.	-2445.
QDN	-4498.	-3863.	-2685.	-1017.	-1264.	-454.5	-47.40	-177.9	-1053.	.3.5	-2685.	-4387.
QCD	-.1218+05	-.1172+05	-4984.	2303.	4958.	.1615+05	.1749+05	.1420+05	6067.	2109.	-4830.	-.1079+05
QCN	-.2385+05	-.2055+05	-.1463+05	-6040.	-7219.	-3252.	-1221.	-1937.	-6323.	-5207.	-.1482+05	-.2332+05
QGD	6141.	8458.	.2141+05	.3359+05	.3544+05	.5451+05	.6135+05	.5951+05	.5689+05	.5473+05	.3600+05	.1471+05
QGN	-.6591+05	-.5662+05	-.3935+05	-.1490+05	-.1853+05	-6661.	-694.6	-2608.	-.1543+05	-.1192+05	-.3934+05	-.6429+05
QFD	-1115.	-1145.	-1156.	-1142.	-.5255-03	-.5410-03	.0000	-.4894-03	-.4433-03	-1145.	-1115.	-1096.
QFN	1115.	1145.	1156.	1142.	-.3564-03	-.3408-03	.0000	-.3924-03	-.4385-03	1145.	1115.	1096.
QRD	.2479+05	.2762+05	.3061+05	.3384+05	.3637+05	.3744+05	.3643+05	.3387+05	.3068+05	.2753+05	.2475+05	.2359+05
QRN	.3926+05	.3620+05	.3296+05	.2946+05	.2672+05	.2555+05	.2665+05	.2942+05	.3288+05	.3630+05	.3930+05	.4057+05
SCD	.5791+05	.6422+05	.6813+05	.6606+05	.6506+05	.6703+05	.6682+05	.6863+05	.7695+05	.7917+05	.7319+05	.6254+05
ZK	545.2	544.9	540.9	533.2	531.6	525.5	522.9	519.6	527.2	527.9	536.3	543.3
ZK	545.2	544.9	540.9	533.2	531.6	525.5	522.9	519.6	527.2	527.9	536.3	543.3
DHCD	3.381	3.654	11.96	14.87	.0000	.0000	.0000	.0000	.0000	.0000	14.27	3.603
DHWU	.0000	.0000	12.04	13.31	.0000	.0000	.0000	.0000	.0000	8.404	9.733	.0000
PUH	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000
PULDWN	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.2177+05	.0000	.0000
PICKUP	-.4315+05	-.4247+05	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	-.4202+05
CLD	.0000	.0000	.0000	.0000	.6989+05	.1244+06	.1382+06	.1256+06	.9753+05	.1820+05	.0000	.0000
CLN	.0000	.0000	.0000	.0000	.0000	9058.	.2406+05	.2236+05	.0000	.5061+05	.0000	.0000
HLD	-.1642+05	-.1421+05	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	-6475.
HLN	-.1925+06	-.1726+06	.0000	2284.	-.1811+05	.0000	.0000	.0000	-4295.	.0000	.0000	-.1855+06
QTD	-.2515+05	-.2142+05	.1683+05	.5764+05	.6989+05	.1244+06	.1382+06	.1256+06	.9753+05	.8141+05	.3566+05	-.1059+05
QTN	-.1235+06	-.1034+06	-.6296+05	-5854.	-.1811+05	9058.	.2406+05	.2236+05	-4295.	8338.	-.5558+05	-.1174+06

HEAT LOSS & HEAT GAIN ROUTINE COMPLETED

RLHG	.2665+05	.2714+05	.3059+05	.3779+05	.4413+05	-.1221-03	.1059+05	-.1221-03	-.1221-03	.4343+05	.3423+05	.2762+05

CSDUPI COMPLETED
ASDUPI COMPLETED
BMDUPI COMPLETED
OSDUPI COMPLETED
HEATING & COOLING REQUIREMENT ROUTINE COMPLETED
ENERGY REQUIREMENT ROUTINE COMPLETED

ANNUAL SUMMARY

	J	F	M	A	M	J	J	A	S	O	N	D
HREQ	-.6215+07	-.4919+07	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	-.5604+07
CREQ	.0000	.0000	.0000	.0000	.0000	.4405+07	.5893+07	.5045+07	.3218+07	.0000	.0000	.0000

29.00 THT= -.1673822+08 TCT= .1856165+08

3 SHBTU = -.5993+08 SCBTU = .8839+07
SHBTU = -59929121. SCBTU = 8838883.

TBTU= 68768004.

THE ANNUAL HEATING AND COOLING REQUIREMENT ANALYSIS CALCULATED BY THE VARIABLE DEGREE-DAY METHOD
TBC: BALANCE POINT FOR COOLING
TBH: BALANCE POINT FOR HEATING

TC1=	70.6	TC2=	78.7	QC1=	107282.7	QC2=	190112.0	TBC=	60.1
TH1=	37.3	TH2=	35.6	QH1=	-175663.6	QH2=	-200496.4	TBH=	49.3
CDD=	2232.9	HDD=	1341.0	THT=	-19588311.0	TCT=	22832792.0		

ANNUAL HEAT LOSS THROUGH NON-ADDITIONAL JACKET INSULATION OF HOT WATER TANK : -.6155+07
ANNUAL HEAT LOSS THROUGH ADDITIONAL JACKET INSULATION OF HOT WATER TANK : -.6155+07
ANNUAL ENERGY SAVING BY ADDITIONAL INSULATION OF HOT WATER TANK : .0000
ANNUAL HOT WATER REQUIREMENT, INCLUDING JACKET HEAT LOSS : -.2341+08
ANNUAL HOT WATER REQUIREMENT, EXCLUDING JACKET HEAT LOSS : -.1726+08
ANNUAL HEAT GAIN THROUGH DUCTS & PIPES FOR SPACE COOLING : .0000
ANNUAL HEAT LOSS THROUGH DUCTS & PIPES FOR SPACE HEATING : .0000

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APPENDIX D

ELEMENTS OF DATA STATEMENT IN MAIN PROGRAM

Number*	Variable	Type	Comments	Units	Meaning
B(1)	V	F		ft^3	Volume (L*W*H) of Heated Living Area
B(2)	ACRM	F	Tight = .5 Average = 1.0 Leaky = 1.5 Very Leaky = 2.0	AC/hr	Standard Air Leakage Data
B(3-14)	TOD(X)	F(12)		deg F	Daytime Outdoor Temperature (Month)
B(15-26)	TOT(X)	F(12)		deg F	Daily Temperature (Month)
B(27-38)	TID(X)	F(12)		deg F	Daytime Indoor Temperature (Month)
B(39-50)	TIN(X)	F(12)		deg F	Nighttime Indoor Temperature (Month)
B(51)	IACNV	I	0-Never open windows 1-Open windows in summer when temp. < thermostat setting Default = 0		
B(52)	X1	F	Unused		
B(53)	X2	F	Unused		
B(54-65)	WS(X)	F(12)		mph	Wind Speed
B(66)	X3	F	Unused		
B(67)	X4	F	Unused		
B(68)	ORT1	F	0.0 - 359.0	deg	Orientation from south of window/wall/door No. 1
B(69)	XLAT	F		deg	Latitude (North)

* Number shows position of element at data statement in main program.

Number	Variable	Type	Comments	Units	Meaning
B(70)	RHO	F	0.2 = Dark 0.4 = Medium 0.6 = Light	---	Ground Surface Reflectance
B(71)	ZIP	I			Zip Code
B(72)	AG1	F		ft^2	Window 1 Area
B(73)	SC1	F	Default = 0.55 if Shades Else 0	---	Window 1 Shading Coefficient
B(74)	UG1	F	1.13 = Single Glaze 0.55 = Double Glaze Default = 1.13	Btuh*	Window 1 U Value
B(75)	SHADW1	F	1.0 = All Shadow 0.5 = Part Shadow 0.0 = No Shadow Default = 0.0	---	Window 1 Shadow
B(76)	ORT2	F	0.0 - 359.0	deg	Orientation from South of Window/ Wall/Door No. 2
B(77)	AG2	F		ft^2	Window 2 Area
B(78)	SC2	F	Default = 0.55 if Shades Else 0	---	Window 2 shading coefficient
B(79)	UG2	F	1.13 = Single Glaze 0.55 = Double Glaze Default = 1.13	Btuh	Window 2 U value
B(80)	SHADW2	F	1.0 = All Shadow 0.5 = Part Shadow 0.0 = No Shadow Default = 0.0	---	Window 2 Shadow
B(81)	ORT3	F	0.0 - 359.0	deg	Orientation from South of Window/ Wall/Door No. 3
B(82)	AG3	F		ft^2	Window 3 Area
B(83)	SC3	F	Default = 0.55 If Shades Else 0	---	Window 3 Shading Coefficient
B(84)	UGE	F	1.13 = Single Glaze 0.55 = Double Glaze Default = 1.13	Btuh	Window 3 U Value

* Btuh = Btu/hr ft^2 F
all the U values hereafter will be expressed in this unit

Number	Variable	Type	Comments	Units	Meaning
B(85)	SHADW3	F	1.0 = All Shadow 0.5 = Part Shadow 0.0 = No Shadow Default = 0.0	----	Window 3 Shadow
B(86)	ORT4	F	0.0 - 359.0	deg	Orientation from South of Window/ Wall/Door No. 4
B(87)	AG4	F	0.0 - 359.0	ft^2	Window 4 Area
B(88)	SC4	F	Default = 0.55 If Shades Else 0	---	Window 4 Shading Coefficient
B(89)	UG4	F	1.13 = Single Glaze 0.55 = Double Glaze Default = 1.13	Btuh	Window 4 U Value
B(90)	SHDW4	F	1.0 = All Shadow 0.5 = Part Shadow 0.0 = No Shadow Default = 0.0	---	Window 4 Shadow
B(91)	WTILT1	F	Default = 50.0	deg from horiz	Solar Collector Tilt Angle
B(92)	SA	F	High Performance = 0.8 Medium Performance = 0.75 Low Performance = 0.7 Default = 0.7	---	Solar Collector Efficiency (Y Axis) (Absorption Factor From Glass)
B(93)	SB	F	High Performance = 1.2 Medium Performance = 1.0 Low Performance = 0.8 Default = 0.8	---	Solar Collector Efficiency (X Axis) (Water Temp - Outdoor Temp)/Solar Radiation
B(94-105)	TE(X)	F(12)	Default = 70.0	deg F	Inlet Fluid Temperature to Solar Collector (Month)
B(106)	SUF	F	Default = 1.0	---	Sollar Collector Utilization
B(107)	AS	F	Default = 0.0	ft^2	Solar Collector Area = 0 to Signal No Sollar Collector
B(108)	X5	F	Default = 1.0	ft	Roof overhang projection over wall 1
B(109)	X6	F	Default = 10.0	ft	Height of wall 1
B(110)	WALL13	F	Much = 1.0 Part = 0.5 None = 0.0 Default = 0.0	---	Wall 1 Shadow Factor

Number	Variable	Type	Comments	Units	Meaning
B(11)	WALL14	F	Dark = 0.95 Medium = 0.7 Light = 0.4 Default = 0.4	---	Wall 1 Surface Absorptivity
B(112-123)	X7	F(12)	Unused		
B(124)	WALL15	F	Wood Insulated = 0.07 Wood Uninsulated=0.23 Masonry Insulated=0.13 Masonry Uninsulated=0.29	Btuh	Wall 1 U Value U of Mobile Home = U of Wood Insulated Home
B(125)	WALL16	F		ft^2	Wall 1 Area Excludes Windows and Doors 0 if Attached Includes Above-Ground Basement Wall Area
B(126)	X8	F	Default = 1.0	ft	Roof overhang projection over wall 2
B(127)	X9	F	Default = 10.0	ft	Height of wall 2
B(128)	WALL 23	F	Much = 1.0 Part = 0.5 None = 0.0 Default = 0.0	---	Wall 2 Shadow Factor
B(129)	WALL 24	F	Dark = 0.95 Medium = 0.7 Light = 0.4 Default = 0.4	---	Wall 2 Surface Absorptivity
B(130)	WALL 25	F	Wood Insulated=0.07 Wood Uninsulated=0.23 Masonry Insulated=0.13 Masonry Uninsulated=0.29	Btuh	Wall 2 U Value U of Mobile Home = U of Wood Insulated Home
B(131)	WALL 26	F		ft^2	Wall 2 Area Excludes Windows and Doors 0 if attached Includes Above-Ground Basement Wall Area
B(132)	X10	F	Default = 1.0	ft	Roof overhang projection over wall 3
B(133)	X11	F	Default = 10.0	ft	Height of wall 3

Number	Variable	Type	Comments	Units	Meaning
B(134)	WALL 33	F	Much = 1.0 Part = 0.5 None = 0.0 Default = 0.0	---	Wall 3 Shadow Factor
B(135)	WALL 34	F	Dark = 0.95 Medium = 0.7 Light = 0.4 Default = 0.4	---	Wall 3 Surface Absorptivity
B(136)	WALL 35	F	Wood Insulated=0.07 Wood Uninsulated=0.23 Masonry Insulated=0.13 Masonry Uninsulated=0.29	Btuh	Wall 3 U Value U of Mobile Home = U of Wood Insulated Home
B(137)	WALL 36	F		ft^2	Wall 3 Area Excludes Windows and Doors 0 if Attached Includes Above-Ground Basement Wall Area
B(138)	X12	F	Default = 1.0	ft	Roof overhang projection over wall 4
B(139)	X13	F	Default = 10.0	ft	Height of wall 4
B(140)	WALL 43	F	Much = 1.0 Part = 0.5 None = 0.0 Default = 0.0	---	Wall 4 Shadow Factor
B(141)	WALL 44	F	Dark = 0.95 Medium = 0.7 Light = 0.4 Default = 0.4	---	Wall 4 Surface Absorptivity
B(142)	WALL 45	F	Wood Insulated=0.07 Wood uninsulated=0.23 Masonry Insulated=0.13 Masonry Uninsulated=0.29	Btuh	Wall 4 U Value U of Mobile Home = U of Wood Insulated Home
B(144)	SOGFRC	F	0.0-1.0 (SUM B (144-146) = 1)	---	Fraction of Floor Which is SOG

Number	Variable	Type	Comments	Units	Meaning
B(145)	CRWFRC	F	0.0-1.0 (SUM B(144-146) = 1)	---	Fraction of Floor Which is Crawl Space
B(146)	BSMFRC	F	0.0-1.0 (SUM B(144-146) = 1)	---	Fraction of Floor Which is Basement
B(147-148)	X14	F(2)	Unused		
B(149)	ROOF4 (ANATT)	F	Default = 0.0	ft^2	Non-Attic Roof Area (AFLOOR - ATFLR)
B(150)	ROOF1	F	Default = 0.0 1.0 = All Shadow 0.5 = Part Shadow 0.0 = No Shadow	---	Roof Shadow Factor
B(151)	ROOF2	F	Default = 0.9 Dark = 0.95 Medium = 0.7 Light = 0.4	---	Roof Absorptivity
B(152)	ROOF3	F	Default = 0.2 0.55 With Vented or No Attic 0.2 With Unvented Attic	Btuh	Roof U Value
B(153)	AEWH	F	Default = 4.0	ft	Attic End Wall Height
B(154)	SOLHW	I	0 = Not Used for Hot Water 1 = Is Used	---	Use of Solar Collector for Hot Water Heating
B(155)	SOLSH	I	0 = Not Used for Hot Heating 1 = Is Used	---	Use of Solar Collector For Space Heating
B(156)	X23	I	Unused		
B(157)	AW	F		ft^2	Attic End Wall Area
B(158)	ACAT	F	20.0 = Attic Fan 6.0 = Soffit Vent and Ridge Vent 3.0 = Cable Vent 0.0 = No vent Default = 3.0	AC/hr	Air Change per Hour
B(159)	UCEIL	F	Default = 0.1	Btuh	Ceiling U Value - Only When There is an Attic

Number	Variable	Type	Comments	Units	Meaning
B(160)	AEW5	F	Default = 0.25 Same as Wall U B(124)	Btuh	Attic End Wall U Value
B(161)	X15	F	Unused		
B(162)	UFLRI	F	Default = 0.30	Btuh	Floor U Value (Floor Above Basement)
B(163)	HWT	F	Default = 75.0	gal/day	Hot Water Usage
B(164)	NSTART	I	1-12	---	First Month of Cooling
B(165)	NLAST	I	1-12	---	Last Month of Cooling Season
B(166)	INDEXES	I	0-Attic is Temp Controlled 1-Attic Not Temp Controlled = 1 If There is an Attic Else 0	---	Attic Temperature Control Index
B(167)	INDEXC	I	0 = Basement Heated 1 = Basement Unheated	---	Basement Temperature Control Index
B(168)	ZL	F		ft	Exposed Perimeter Length of SOG
B(169-180)	TG(X)	F(12)		deg F	Ground Temperature (Month)
B(181)	ACCS	F	0.0 = Unvented 3.0 = Vented	AC/hr	Crawl Space Air Change/Hour
B(182)	UFLR2	F	Default = 0.30	Btuh	Crawl Space Floor U Value (Floor Above Crawl Space)
B(183)	UCLW	F	Default = 0.25	Btuh	Crawl Space Wall U Value
B(184)	HCL	F		ft	Crawl Space Height
B(185)	AWCL	F		ft^2	Crawl Space Wall Area
B(186)	NPD	I	Default = 3	---	Daytime Occupancy
B(187)	NPN	I	Default = 3	---	Nightime Occupancy
B(188)	WTD	F	Default = 0.097 * ft^2	watt	Average Daytime Lighting
B(189)	WTN	F	Default = 0.217 * ft^2	watt	Average Nighttime Lighting

Number	Variable	Type	Comments	Units	Meaning
B(190)	WED	F	Default = 0.705 * ft^2	watt	Average Daytime Electric Equipment For Gas Appliance, Use Electric Equivalent Value
B(191)	WEN	F	Default = 0.424 * ft^2	watt	Average Nighttime Electric Equipment For Gas Appliance, Use Electric Equivalent Value
B(192)	FLOORA	F	Default = 1200.0	ft^2	Floor Area (Flat Projection of House)
B(193)	ATFLR	F	Default = 1200.0	ft^2	Area of Attic Floor
B(194)	UBW	F	Default = 1.0	Btuh	Basement Wall Heat Conductance
B(195)	ISYS	I	1 = Heat, No Cool 2 = Cool, No Heat 3 = Heat + Cool	---	System Index
B(196)	UFW	F	Default = 0.164	Btuh	Ground Heat Conductance for Wall
B(197)	BWA	F		ft^2	Basement Wall Area
B(198)	UBF	F	Default = 1.0	Btuh	Basement Floor Heat Conductance
B(199)	UFF	F	Default = 0.1	Btuh	Ground Heat Conductance for Floor
B(200)	QBHG	F	Default = 0.0	Btuh	Basement Heat Gain From Furnace and Other Equipment
B(201)	THTC	F	Table on page E-2 Default = 15.0	hr	Thermal Time Constant
B(202)	ZKS	F	Default = 1.0	Btuh-ft	Ground Thermal Conductivity
B(203)	DX	F	Default = 500	ft	Side Distance from Adjacent House
B(204)	DY	F	Default = 500	ft	Front to Back Distance from Adjacent House
B(205)	E	F	Default = 0.5	ft	Wall Thickness
B(206-213)			unused		
B(214-225)	H(X)	F(12)		Btu/day/ft^2	Total Horizontal Solar Insolation (Month)
B(226)	EH	F	Value = F(Fuel EFF, Mod Factor)	---	Heating Efficiency
B(227-231)	X(16)	F(5)	Unused		

Number	Variable	Type	Comments	Units	Meaning
B(232)	EC	F	Value = F(Fuel EFF, Mod Factor)	---	Cooling Efficiency
B(233-239)	X(17)	F(7)	Unused		
B(240)	X(18)	F	Unused		
B(241-252)	RH(1,X)	F(2,12)	Default Summer = 50.0 WIN = 20.0 If No Humidifier WIN = 35.0 if + Humidifier	pct*	Indoor Daytime Rel Humid (Month)
B(253-264)	RH(2,X)		Same	pct	Indoor Nighttime Rel Humid (Month)
B(265-276)	RHM (X)	F(12)		pct	Outdoor Morning Rel Humid (Month)
B(277-288)	RHA (X)	F(12)		pct	Outdoor Afternoon Rel Humid (Month)
B(289)	X(19)	F	Unused		
B(290)	DOOR13	F	Same as Wall Shadow	---	Door 1 Shadow
B(291)	DOOR14	F	Same as Wall Absorptivity	---	Door 1 Absorptivity
B(292)	DOOR15	F	Default = 0.5	Btuh	Door 1 U Value
B(294)	X20	F	Unused		
B(295)	DOOR23	F	Same as Wall Shadow	---	Door 2 Shadow
B(296)	DOOR24	F	Same as Wall Absorptivity	---	Door 2 Absorptivity
B(297)	DOOR25	F	Default = 0.5	Btuh	Door 2 U Value
B(298)	DOOR26	F		ft^2	Door 2 Area Excludes Sliding Glass Doors
B(299)	X21	F	Unused		
B(300)	DOOR33	F	Same as Wall Shadow	---	Door 3 Shadow
B(301)	DOOR34	F	Same as Wall Absorptivity	---	Door 3 Absorptivity
B(302)	DOOR35	F	Default = 0.5	Btuh	Door 3 U Value
B(303)	DOOR36	F		ft^2	Door 3 Area Excludes Sliding Glass Doors

* pct = percent

Number	Variable	Type	Comments	Units	Meaning
B(304)	X22	F	Unused		
B(305)	DOOR43	F	Same as Wall Shadow	---	Door 4 Shadow
B(306)	DOOR44	F	Same as Wall Absorptivity	---	Door 4 Absorptivity
B(307)	DOOR45	F	Default = 0.5	Btuh	Door 4 U Value
B(308)	DOOR46	F		ft^2	Door 4 Area Excludes Sliding Glass Doors
B(309)	ICHECK	F	Default = 0.0	---	= 1 To Get Debug Output From Thermodynamic Model
B(310)	AJAC	F	Default = 40	ft^2	Total Jacket Area
B(311)	D1	F	Default = 0.08	ft	Thickness of Existing Insulation
B(312)	RAM1	F	Default = 0.025	Btuh-ft	Thermal Conductivity of the Above
B(313)	D2	F		ft	Thickness of Additional Insulation
B(314)	RAM2	F	Default = 0.025	Btuh-ft	Thermal Conductivity of the Above
B(315)	TCSUPA	F	Default = 62	deg F	Supply Cold Air Temp.
B(316)	TCSUPW	F	Default = 41.0	deg F	Supply Chilled Water Temp.
B(317)	THSUPA	F	Default = 95.0	deg F	Supply Hot Air Temp.
B(318)	THSUPW	F	Default = 113.0 for Heat Pump Default = 176.0 for Boiler	deg F deg F	Supply Hot Water Temp.
B(319)	ADUCT1	F	Default = 100	ft^2	Surface Area of Duct in the Crawl Space
B(320)	UDUCT1	F	Default = 1.46 If Not Insulated 0.15 If Insulated	Btuh	U Value of Duct in the Crawl Space

Number	Variable	Type	Comments	Units	Meaning
B(321)	APIPE1	F	Default = 1.5	ft^2	Surface Area of Pipe in Crawl Space
B(322)	UPIPE1	F	Default = 1.46 If Not Insulated 0.15 If Insulated	Btuh	U Value of Pipe in Crawl Space
B(323)	ADUCT2	F		ft^2	Surface Area of Duct in Attic
B(324)	UDUCT2	F		Btuh	U Value of Duct in Attic
				ft^2	Surface Area of Pipe in Attic
B(326)	UPIPE2	F		Btuh,	U Value of Duct in Attic
B(327)	ADUCT3	F		ft^2	Surface Area of Duct in Basement
B(328)	UDUCT3	F	Same as the Crawl Space	Btuh	U Value of Duct in Basement
B(329)	APIPE3	F		ft^2	Surface Arer of Pipe in Basement
B(330)	UPIPE3	F		Btuh	U Value of Pipe in Basement
B(331)	ADUCT4	F		ft^2	Surface Area of Outdoor Duct
B(332)	UDUCT4	F		Btuh	U Value of Duct Outdoors
B(333)	APIPE4	F		ft^2	Surface Area of Outdoor Pipe
B(334)	UPIPE4	F		Btuh	U Value of Pipe Outdoors
B(335)	AIRLOS	F	Percentage To Total Air Flow Rate; Default = 10.0	pct	Air Leakage Through Duct
B(336)	CAPCL	F	Default = 24000	Btu/h	Capacity of Cooling Equipment
B(337)	CAPHT	F	Default = 64000	Btu/h	Capacity of Heating Equipment
R(1)	SHBTU	F		Btu/yr	Annual Heating Energy Requirement After Using Energy From Solar Collector
R(2)	SCBTU	F		Btu/yr	Annual Space Cooling Energy Requirement

APPENDIX E

Thermal Time Constant and Its Application

The thermal time constant of a building is a parameter to indicate the speed of indoor temperature response to a sudden change of building heating and cooling operation. The heavier the thermal mass of a building, the slower its response, compared to a lighter building, to cool down or heat up when the building heating system is turned off and on, respectively. The thermal time constant is defined as a ratio between the equivalent thermal mass of the building and the building overall heat transfer factor. Whereas the overall heat transfer factor may be approximated by the heat transfer coefficients, U value, multiplied by the areas, A, of all the elements, such as walls, doors, windows, roof and floors, and the air leakage rate multiplied by the specific heat of air, the equivalent building thermal mass is rather difficult to ascertain. The building mass is distributed in a complex manner, with respect to its size and shape, position in the insulated structure, and floor interface with the earth.

Although difficult to calculate, the overall building thermal time constant can readily be determined by a simple cool-down test during a heating season based upon the following mathematical relationship.

When the heating system and all the heat sources in a house are suddenly shut off during a steady cold night (outdoor temperature of To), its temperature would decay from the initial setpoint of T_1 according to the following equation:

$$MC* \frac{dT}{dH} = -K* (T-To) \qquad \text{E-(1)}$$

where

MC = overall thermal mass, Btu/°F
K = overall heat transfer factor, Btu/hr, °F
H = hour

The thermal time constant, THTC, is defined as

$$THTC = \frac{MC}{K}, \text{ in the unit of hour}$$

The differential equation E-(1) becomes then

$$\frac{dT}{T-To} = -\frac{dH}{THTC}, \qquad \text{E-(2)}$$

which has a following solution:

$$THTC = \frac{H}{\ln\left(\frac{T_i - T_o}{T - T_o}\right)} \qquad E\text{-}(3)$$

Thus by measuring a logarithmic decay of the building temperature, from initial value of T_1 to T during a time span of H hours, one can readily calculate the value of the thermal time constant.

According to Nash's data[7/], typical THTC for residences are:

	Light Weight	Medium Weight	Heavy Weight
One-story house	10	15	20
Two-story house	30	35	40

When a building heat transfer process is simulated by a simple thermal capacity model, its temperature change may similarly be represented by the following first order differential equation

$$MC^* \frac{dT}{dH} = - K^* (T-To) + SPHG \qquad E\text{-}(4)$$

T = building temperature, °F
To = outdoor temperature, °F
MC = building thermal capacity, Btu/°F
K = overall heat transfer factor, Btu/hr °F
SPHG = total space heat gain due to internal heat, heating systems, solar heat gain through windows, and occupancy, Btu/hr
H = elapsed time, hour.

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T = building temperature, °F
To = outdoor temperature, °F
MC = building thermal capacity, Btu/°F
K = overall heat transfer factor, Btu/hr °F
SPHG = total space heat gain due to internal heat, heating systems, solar heat gain through windows, and occupancy, Btu/hr
H = elapsed time, hour.

General solution to the above equation is

$$\frac{Q-T_1 + To}{Q-T + To} = e^{\frac{H}{THTC}} \qquad E-(5)$$

where

$$Q = \frac{SPHG}{K} = \text{heat source constant, °F}$$

$$THTC = \frac{MC}{K} = \text{thermal time constant, hr}$$

$$T_1 = \text{value of T when H = 0, °F.}$$

Equation E-(5) permits, for example, the determination of the duration, DH, for which the house temperature reaches from the daytime set point TID to the nighttime set point TIN, which is usually lower.

Since Q is very small during that period, referring to Figure E-(1),

$$DH = THTC*\ell n \left[\frac{TID-TON}{TIN-TON}\right] \qquad E-(6)$$

Likewise equation E-(5) may be used to determine the early morning pick-up heating load (or the early evening pull-down cooling load), MPUL, by specifying the required temperature recovery time or pick-up time, PUH, (or pull down time, PHD) as follows

$$\frac{\frac{MPUL}{K} - TIN + TOD}{\frac{MPUL}{K} - TID + TOD} = e^{\frac{PUH}{THTC}} \qquad E-(7)$$

By rearranging the term, MPUL can be determined by

$$MPUL = K* \left[(TIN-TOD) + \frac{TID-TIN}{1-e^{-PUH/THTC}}\right] \qquad E-(8)$$

Another example of the use of THTC is to approximate the benefit of excess solar heat gain during a sunny winter day to offset the heat loss during the night.

The procedure used is first to determine the indoor temperature rise TR, due to the excess heat gain, above the daytime indoor temperature setpoint TID by the following equation

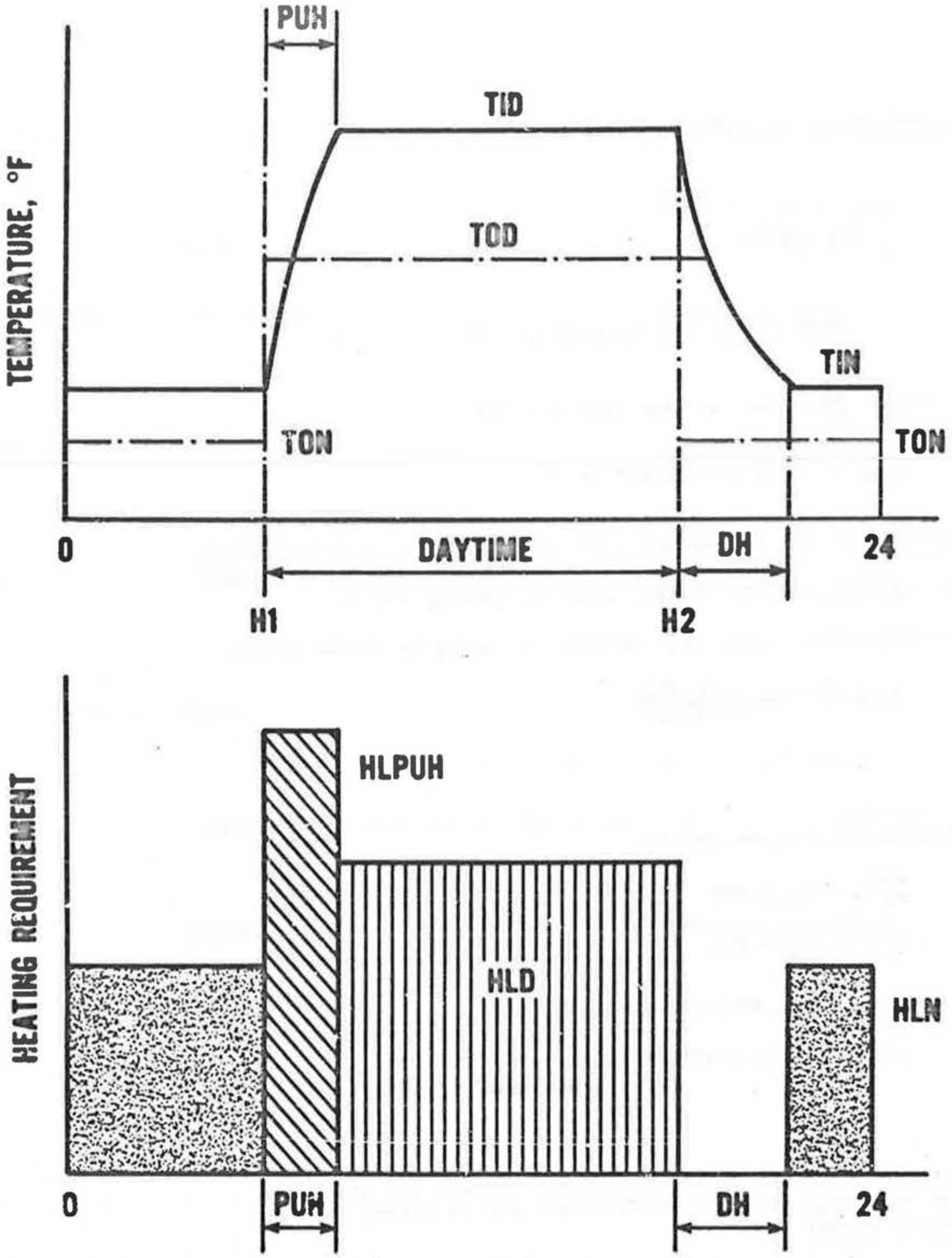

Figure E-1. Temperature and heating requirement profile during the nighttime thermostat setback.

$$TR = \frac{QTD}{K*12} * [1-e^{\frac{-(H_2-H_1)}{THTC}}] \qquad E-(9)$$

where QTD is the excess daytime heat gain during hour from H_1 to H_2, which is the balance of heat gain above what is required to cancel the envelope heat loss.

The equation E-(6) will now be used to determine the "off" period of the heating system except that TID in equation (6) is now replaced by the new starting temperature TID + TR.

A similar concept may be used to determine the effect of night heat loss during the cooling season to offset the daytime cooling requirement as follows:

The temperature drop of the room air from the set point of TIN during the cool night due to the excess heat loss QTN is

$$TD = \frac{QTN}{K*12} * (1-e^{-\frac{HN}{THTC}}) \qquad E-(10)$$

where HN is the nighttime hours

The period when the air-conditioning system could be off due to this night cooling is then

$$DH = THTC* \ell n \left(\frac{\frac{QTD}{K*12} - TIN + TD + TOD}{\frac{QTD}{K*12} - TID + TOD} \right) \qquad E-(11)$$

provided that (TIN-TD) < TID.

Figure E-2 depicts indoor temperatures, cooling and heating periods, and other notations such as DH, PDH, PUH and TD in cooling season. Figure E-2(a) shows indoor temperatures and cooling period in a day when QTD $\geq$ 0 and QTN $\geq$ 0. The daytime indoor temperature rises from TIN to TID during early morning pickup hours, DH, while the cooling system is turned off. After this period, the temperature is maintained at TID during daytime, followed by a pull down to TID at the beginning of nighttime for a period of PHD hours. The cooling system is, therefore, assumed to be running all day except for the period of DH.

Figure E-2(b) shows the case of QTD $\geq$ 0 and QTN $\geq$ 0. In this case, the nighttime indoor temperature decreases from TIN to TIN-TD according to the nighttime heat losses, while the cooling system is turned on during a period of PDH. Because of the night heat loss the indoor temperature is lower than TIN by TD at the beginning of daytime. During an early morning period of DH, the temperature naturally rises to TID because of the daytime heat gains. Consequently, the cooling system continues to operate throughout the day except periods DH and PDH.

There is a limitation on input of daytime and nighttime indoor temperatures, TID and TIN, in that TID is always equal to or higher than TIN. The reason of this limitation is to avoid algorithmic complexities.

Figures E-2(c) and (d) depict indoor temperatures profile during the heating period.

Figure E-2(c) shows indoor temperatures and heating period in a day when QTD > 0 and QTN $\leq$ 0. The daytime indoor temperature goes up to TID + TD at the end of daytime because the cooling system is not running in spite of QTD > 0 during the daytime. The nighttime indoor temperature goes down from TID + TR to TIN during a period of PH because QTN $\leq$ 0 and the heating system is turned off. After the temperature reached to TIN, the heating system is turned on.

Figure E-2(d) shows indoor temperatures and heating period in a day when QTD $\leq$ 0 and QTN $\leq$ 0. The nighttime indoor temperature decreases to TIN from TID because of night setback. during a period of DH, the heating system is turned off. PUH is pick-up time, during which the indoor temperature goes up to TID from TIN because of the heating system.

If there is a case of QTD $\leq$ 0 and QTN $\geq$ 0, it is neglected, meaning that the heating and cooling requirements should be equal to zero because the case should seldom occur in the cooling season.

The heating and cooling requirement are both set equal to zero during the heating season when the daytime and nighttime heat balance, QTD and QTN, are both positive. Likewise QTD and QTN are both set equal to zero during the cooling season if QTD and QTN are both negative.

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