LBL-6840 Revised
UC-95c

Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

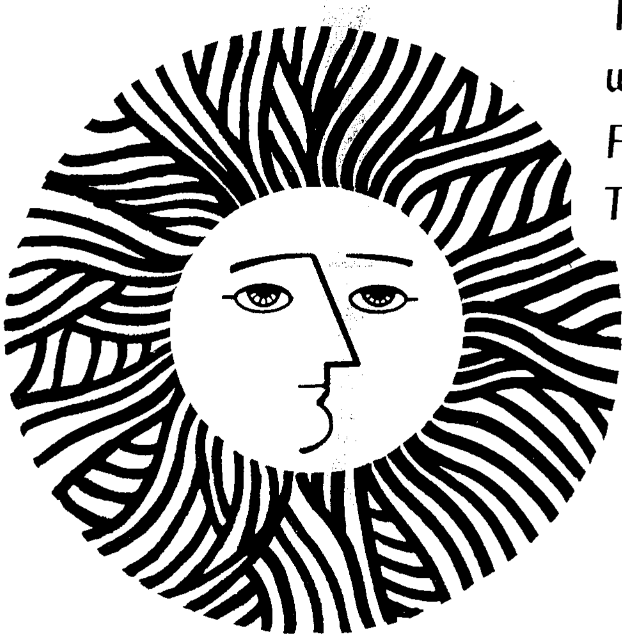
ENERGY & ENVIRONMENT DIVISION

TWOZONE
Users Manual

2nd Edition Revised

October 1981

Ashok J. Gadgil, Gay Gibson, and Arthur H. Rosenfeld



Prepared for the U.S. Department of Energy under Contract W-7405-ENG-48

LBL-6840 Revised
BEV 78-2

TWOZONE
Users Manual

2nd Edition

*Ashok J. Gadgil, Gay Gibson,
and Arthur H. Rosenfeld*

October 1981

Energy and Environment Division
Lawrence Berkeley Laboratory
Berkeley, California 94720

This work was supported by the U.S. Department of Energy under Contract W-7405-ENG-48

Note to the second edition of the TWOZONE USERS MANUAL.

In the past five years since TWOZONE was first unveiled, it has been used by many throughout the building and construction industry and at many academic institutions (both in the US and abroad) for modeling energy flow in residential and light commercial buildings. Several hundred requests for this manual have been received by us during this time.

During this time many advances have taken place in the field of energy conservation in buildings and this second edition of the TWOZONE USERS MANUAL, reflects an attempt to keep the program current with the other programs at the same time retaining the remarkable simplicity and user-accessibility of the TWOZONE code. In fact the user-accessibility and simplicity of the TWOZONE program, and the ease with which it can be modified by the innovative user for testing new features and control strategies, retains its great attractiveness even today in the face of large, sophisticated, and relatively complex programs such as DOE-2 and BLAST.

The Cal-ERDA program has been updated to become DOE-2, and changes have been introduced accordingly. In addition, there is additional information on the NOAA TRY weather tapes, the variable listings, and the filename listings. A few bugs, - some in the text of the MANUAL and some in the TWOZONE program, have been set right.

We hope that TWOZONE will continue to be as useful as it has been in the past.

Ashok Gadgil
Lawrence Berkeley Laboratory
October, 1981

CONTENTS

1. INTRODUCTION

TWOZONE was written in the summer of 1975 to analyze the heating and cooling loads of single family residences for the purpose of investigating the effect on energy consumption of various changes in building design, construction and management.[2,7]

The program eveluates the annual energy demand taking into account 1) various amounts, types and locations of glass areas in a house, 2) different wall and roof constructions, 3) various amounts and locations of insulation, 4) scheduled thermostat settings, 5) other changes in the building envelope. The model differentiates between the thermal behavior of the north and south zones of a house (Hence the name TWOZONE).

This manual describes the most recent version of TWOZONE (version BLUEL) implemented in November 1977. (A revised version, 1980, removed some of the program bugs). This version includes many new features (e.g., ventilation strategies, evaporative cooler, improved air conditioner algorithm, ability to read Cal-ERDA weather tapes, user-specified tilting of the roof, an economics subroutine, etc.)

Without the many requests from current and potential users of TWOZONE, this manual would never have been finished. We thank them for their persistance. We also gratefully acknowledge the help given by Steve Gates and Dave Waltz in writing sections on the Evaporative Cooler and the Economics Subroutine, and of course by Professor Leonard Wall through valuable discussions and descriptions of his contributions to the program.

2. PROGRAM DESCRIPTION

A prime motivation for the development of the TWOZONE model was to determine how to maximize usable solar energy collected by windows. The program computes the thermal performance of a building on an hourly basis and takes into account the following:

1) The heating and cooling loads on a house, given the hourly weather data.

2) The hourly internal loads (i.e. heat generated by appliances, lights, and people).

3) Strategies for loads management. These include daytime-nighttime thermostat schedules, a schedule for use of shades, curtains or reflecting tint on windows, strategies for cooling the house with air-conditioner, evaporative-cooler or venting (open windows) depending on outside and inside air temperatures and humidity.

The model house is a two-zone space, connected thermally by convective air flow. This two-zone feature was included because we were particularly interested in capturing solar heat through large south windows. Many standard plans for houses naturally divide the house into two prominent zones due to a central load-bearing wall and the stair location* The external shading on the house is currently modelled as if the house has a backyard and is in a row of similar houses facing a street. When AZW(1)=0.0 in the INPUT deck (see page 10), the street runs East-West. Then the house is shaded by similar houses on the east and west sides with an approximately 30 degree angle of obstruction. The south side of the house faces the street and is unshaded. The north side is assumed

---

*The TWOZONE model incorporates 5% interior shading at the windows; a 7 hr. weighted time delay for contribution to the heating and cooling loads from sunlight incident through the glazing; wood framing corrections for thermal response of walls and ceilings; internal heat load schedule (people, lights, appliances); and floor losses.

to face the backyard (i.e., not shaded by another house) and a tree which provides some shade. When ASW(1) is not zero, this whole configuration (including the street and the tree, and so on) rotates in a clockwise sense that many degrees.*

Heat losses are due to 1) air infiltration through cracks around construction joints, windows and doorways, and microscopic cracks in the house sheathing itself (¼ airchange/hr at 0 windspeed increasing to 3/4 ach at windspeed of 10 mph), 2) conduction/radiation through roof, walls, windows, and floors. The heat sources are the furnace, solar heat gain (through fenestration** walls, and roof) and internal heat loads (people, lights, appliances).

The temperature of each zone, T_x (x=south or north) is computed according to the rate of change of temperature, as follows:

$$\frac{c}{2}\ \frac{dTx}{dT} = (\text{Heat Flow})_x$$

$(\text{Heat Flow})_x$ = rate of solar heat gain to 'x' zone through fenestration
+ rate of net heat gain to 'x' zone walls and roof (solair)
+ heat transfer, by convection, from the other zone
- infiltration losses
+ internal heat load/2

C = The effective thermal capacity of entire house. (Typically C (effective) is 3200 Btu/^{o}F for a 1400 sq. ft. house. A moderately insulated house has a temperature relaxation time of about 4 hours[7].)

Using these rates of change, the next hour's temperatures are calculated. Depending on the average temperature, the house switches into one of the modes described below.

---

*Wall and Window shadowing done carefully. Data for 38x38 ft house with 3 ft overhang 10 ft up on E and W sides, and 13 ft up on N and S sides. 13 ft houses 20 ft away on N and S sides and 40 ft away on W side. 10x25 ft tree on W side 20 ft away. 3 ft hight windows 4 ft off ground and greater than 4 ft from corners. Wall to interior begins 2 ft off ground.

**fenestration- window complex; includes number of panes, types of glass, interior and exterior shading.

1) Should the average house temperature (TTB) rise above the set maximum, (THI), cooling of the house is accomplished in one of two ways;
   a. during months when A.C. (evaporative-cooler) is available, and the outside temperature is greater than or equal to THI, A.C. (evaporative-cooler) switches on. Depending on the time of the day, temperatures and humidity, different strategies for using A.C. or evaporative-cooler are available (see Appendix I).
   b. during the rest of the year, or when the outside temperature is cooler than T, windows are opened to vent the house. The program can also simulate houses with forced A.C. (i.e., with fixed closed windows).
2) If T lies between TLOW (the thermostat setting for heating) and THI, the house temperature "floats."
3) If T is below TLOW, the furnace is "on" until the house temperature reaches the thermostat setting.

The program calculates the hourly heat load and energy consumption required for heating and cooling. The hourly weather data (see Appendix III) consists of the following: outside dry bulb air temperature, outside wet bulb air temperature, cloud amount, cloud type, wind speed, dewpoint, humidity ratio, enthalpy, density and atmospheric pressure for the given location. The standard ASHRAE[3] algorithms are used to calculate solar radiation from observed cloud cover, and the solar heat gains through fenestration. The delayed thermal responses of walls and roof are calculated using the conduction transfer functions of Mitalas and Arsenault[4] (see Appendix II). At the end of the run, the program can make economic comparison (along ERDA guidelines) with a 'base case', using economic and other base case data supplied by the user.

In summary, the input to the program consists of the following: a weather file with hourly values, building description schedule for internal loads, thermostat settings, fenestration description, calculated transfer function coefficients that characterize wall and roof thermal behavior (see Appendix II) and economic data (optional). Source of these last five input groups is the INPUT DECK.

The typical output consists of 1) hourly furnace and AC load for first four days of each month, 2) a printer plot of hourly energy use (optional), 3) the hourly heating and hourly cooling load distributions averaged over each month (optional), 4) summary output for entire run period, including apportioned heat gains (losses) and apportioned heating and cooling loads from windows, walls, roof, floor and infiltration.

3. ADVANTAGES AND LIMITATIONS

There are several public-domain programs available for residential building heating and cooling analysis (e.g. Cal-ERDA, BLAST, NECAP and NBSLD). In comparison to these programs, the following strengths and limitations of TWOZONE arise from the fact that it is a simplified loads, systems and plant simulation while retaining (and sometimes introducing) many sophisticated algorithms for residential building energy simulation.

1) TWOZONE is easy to understand and can be easily modified by the user.
2) There is good agreement between TWOZONE results and available field data from Utility surveys.[7] There is reasonable agreement with the detailed radiation exchange calculations of NBSLD (NBSFAST).[2]

3) TWOZONE is inexpensive to run ($3.00 on LBL's CDC computer for one year run period, at deferred priority) and doesn't require a large memory (125,000 octal on LBL systems).

4) TWOZONE simulates a building's loads and systems-plant complex hour by hour. This unique feature makes TWOZONE attractive for testing new algorithms modelling nonstandard innovations. (To our knowledge all other public domain programs first calculate the loads for the full run-period and then use perturbation techniques to account for changes in loads due to system-plant complex).

5) The program has attractive and simple input/output.

These stengths are obtained at the expense of accepting the following limitations:

1) As is stands the program cannot simulate non-standard building shapes without extensive modifications.

2) The program uses weighting factors to handle radiation exchange (unlike the almost exact handling of radiation balance equations by some of the public-domain programs like BLAST).

3) ASHRAE does not recommend one element of our theory (assigning a lumped capacitance to the house).

4) TWOZONE does not have a user-oriented, powerful input-language such as used by Cal-ERDA or BLAST.

5) TWOZONE does not handle HVAC of large buildings or apartments with separate thermostats for each unit.

6) The model assumes a constant furnance efficiency of 60%. (In reality the furnace efficiency may vary from say 50% in warm weather to 80% at full load.) Simulation of the furnance is a task for the near future.

7) Estimates indicate that the results of TWOZONE may be within 20% of actual energy use for residential houses of conventional design.

8) The results predicted by TWOZONE have not been field verified by an independent-testing group for their accuracy.

The TWOZONE program has demonstrated its reliability as an educational tool and a research model. It was one of the tools used by California Energy Resource Conservation and Development Commission to formulate the current California residential building codes. The user must keep in mind that the results of a single run may not agree exactly with the performance of an actual house. However, the strength of TWOZONE is in its ability to determine the relative energy efficiency of various strategies in building design, construction and management.

4. INPUT DECK

The input data required for this program include: time period of test run, location of building, building design, dimensions and construction materials, thermostat schedule, and hours of building occupancy.

This section presents a detailed explanation of each variable, its position in the INPUT DECK, format, source and units. There are 6 groups of cards (37 cards total.) All 37 cards must be present or else the program will abort.

The INPUT DECK is echoed just before processing of the input data occurs, (see sample OUTPUT). This makes it convenient to check for card punch errors.

4.1 General Building Description, Time and Location.

(cards 1-6),columns 71-80 reserved for comments.

o Card 1, format (4(3X,I2), 5X, 2(3X,I2), 10x, 13(I1, 1X))

Columns (4-5) KDAY = day of month simulation run begins

(9-10) MO = month of year " " "

(14-15) KDAYND = day of month simulation run ends

(19-20) MOEND = month of year " " "
program can run for 365 days

(29-30) ACSTART = starting month of air-conditioner (AC) operation.

(34-35) ACEND = ending month of AC operation.

(36-45) Blank

The following columns should have 1/0 to activate/skip options.

Inbetween columns are always blank.

(46) IFLAG1 = puts degree-hour and degree-day data on tapes for use by a plotting program.

(48) IFLAG4 = punches card with load apportioning data for use by a bar graph program (APPLEPLOTS).

(50) IFLAG5 = gives table and graph of house temperature, outside temperature, heating and cooling loads in Btuh for each hour of the first 4 days of each month.

IFLAG3 = gives table and graph daily.

IFLAG2 = gives graph only, daily

(52) IFLAG6 = fives hourly heating and hourly cooling load distributions averaged over each month.

Instead of 1/0, the following three columns should have integer/0:

(56) IFLAG8 controls evaporative cooler operation.

IFLAG8 = 0 suppresses the evaporative cooler
= 1 cooler is operated on the basis of house temperature.
= 2 cooler is operated on the basis of both house temperature + relative humidity
= 3 like 2, but also specifies a minimum air temperature from the evaporative cooler
= 4 determines the size of a thermostat-controlled evaporative-cooler needed to cool the house.
= 5 determines the size of a thermostat-and-humidistat controlled evaporative cooler needed by the house.

See Appendix I for more detail.

(58) IFLAG9 controls air conditioner operation

IFLAG9 = 0 suppresses air condintioning
= 1 allows air conditioner
= 2 sizes the air conditioner

See Appendix I for more detail.

(60) IFLAG10 governs nighttime cooling options between the hours of BED and BRKFST (midnight to 8 a.m.)

IFLAG10 = 0 suppresses venting (i.e., windows cannot be opened
= 1 vents the house to TAMCOL (see next card, columns 51-60) at night.
= 2 resets cooling thermostat back to TAMCOL at night.
= 3 runs evaporative cooling only at night, air conditioning during the day. At night the thermostat is set to TAMCOL.

See Appendix I for more detail and allowable combinations of

IFLAG8, IFLAG9, IFLAG10.

(62) IFLAG11 = 1 will produce economic analysis.

See the description of Subroutine ECON for more detail.

o Card 2, format (8F10.4)

Columns (1-10) THI = maximum temperature allowed (^{o}F). If A.C. is available and outside temperature is warmer than house temperature, A.C. switches on, otherwise house vents (i.e., windows "open"). (T-HI)

(11-20) TDAYMN = lowest temperature allowed during the day, (^{o}F), heater thermostat setting). Furnace switches on if house temperature drops below this setting (T-DAY-MN)

(21-30)TNIGHT = nighttime heater thermostat setting (midnight-8am), (^{o}F) (T-NIGHT)

(31-40)THOLDY = daytime heater thermostat setting during holiday periods, (^{o}F) (i.e., Sat, Sun, and all Federal holidays). (T-HOLDY)

(41-50)THOLNT = nighttime heater thermostat setting (midnight-8am) during holiday periods, (^{o}F). (T-HOL-NT)

(51-60)TAMCOL = temperature to which the house will be vented or cooled at night during the cooling season if IFLAG10 allows it (leave blank if IFLAG10=0) Should be greater than TLOWAC (T-AM-COL)

(61-70)TLOWAC = temperature to which the heater thermostat is set during the cooling season. Never greater than TNIGHT. (T-LOW-AC)

o Card 3, format (8F10.4)

Columns (1-10)PCTGLS = percent of south wall that is glass

(11-20)PCTGLW = " " west " " " "

(21-30)PCTGLN = " " north " " " "

(31-40)PCTGLE = " " east " " " "

(41-50)SHDCF = "shading coefficient" of glass, i.e., fraction of incident solar heat transmitted. Perfectly clean 1/8" window glass has coefficient = 1 by definition. Typically shading coefficient of .95 is used for 1/8" regular glass, without drapes. Drapes, blinds, and tinted glass also affect the shading coefficient. See ASHRAE Handbook (3) for details.(SHD-CF)

(51-60)GLTYP = currently use 1. Eventually will call specific properties of glass such as reflection, transmission and absorbtion coefficients from a library (to be installed). (GL-TYP)

(61-70)GLAZE = Defines number of layers of glass in windows: 1 for single pane, 2 for double pane.

o Card 4, format (8F10.4)

Columns (1-10)UDAY = U-value (conductance) of window glass during day, Btuh/sq.ft.-^{o}F. Use 0.6 for double-paned windows, 1.1 for single paned (Btuh/sq.ft.-^{o}F.)

(11-20)UNIGHT = U-value of window glass at night. Dependent on window construction, glass tint, shades, and curtains.

(21-30)UFLOOR = U-value of floor, typically .05 to .3 (see reference 3 for specific data), (Btuh/sq.ft.-^{o}F)

(31-40)CC = effective lumped heat capacity of house, (Btu/^{o}F). We suggest values in the neighborhood of 3000 Btu/^{o}F for a typical house of 1200 square feet floor area.

o Card 5, format (8F10.4)

Columns (1-10)WALLAR(1) = south face, total area sq. ft.

(11-20)WALLAR(2) = west

(21-30)WALLAR(3) = north " " " " "

(31-40)WALLAR(4) = east

(41-50)WALLAR(5) = area of southern portion of roof, sq. ft.

(51-60)WALLAR(6) = area of northern portion of roof, sq. ft.

(61-70)ARFLOR = total area of the foundation, sq. ft.

o Card 6, format (8F10.4)

Columns (1-10) S(1) = Latitude of house location

(11-20) S(2) = Longitude of house location

(21-30) S(3) = Time Zone of house location, with Greenwich = 1.

Eastern Standard = 5.
Central = 6.
Rocky Mountain = 7.
Western = 8.

(31-40)AZW(1) = Azimuth of southernmost wall, degrees clockwise from south.

(41-50)AZW(5) = Azimuth of southernmost roof section, degrees from south.

(51-60)RFTILT5= tilt of southernmost roof section, angle between the outward normal of the roof and the vertical axis, degrees. (RF-TILT-5)

(61-70)RFTILT6= tilt of northernmost roof section. (RF-TILT-6)

4.2. Cooling Input

(cards 7-9)

- Card 7, format (8F10.4) (leave blank if not applicable, see pp 88-90)

Columns	(1-10) ACAPAC =	maximum cooling capacity of air-conditioner, Btuh
	(11-20) FANVOL =	air flow rate through air conditioner, cfm
	(21-30) TCOIL =	minimum temperature of cooling coil (typically 50°F), °F (T-COIL)

- Card 8, format (8F10.4) (leave blank if not applicable, see pp 88-90)

Columns	(1-10) ECVOL(1) =	lowest fan speed of the evaporative cooler, cfm (EC-VOL)
	(11-20) EWATT(1) =	electrical consumption of fan motor at lowest speed, watts (E-WATT)
	(21-30) ECVOL(2) =	next highest speed, cfm
	(31-40) EWATT(2) =	next highest wattage, watts
	(41-50) ECVOL(3) =	etc.
	(51-60) EWATT(3) =	etc.
	(61-70) ECVOL(4) =	etc.
	(71-80) EWATT(4) =	etc.
		enter data from the lowest to highest setting, leave extra settings blank (i.e. for a two-speed cooler, leave (41-80) blank).

- Card 9, format (8F10.4) (leave blank if not applicable, see pp 88-90)

Columns	(1-10) TOFFEC =	temperature the evaporative cooler shuts off at. (usually a few degrees below THI) (T-OFF-EC)
	(11-20) EFFECT =	effective wetbulb depression attainable with the evaporative cooler (usually 0.8). See ASHRAE (3) for more detail.
	(21-30) RHSET =	maximum % relative humidity desired in house, with evaporative cooling. RHSET corresponds to the humidistat setting. (RH-SET)
	(31-40) RHSENS =	sensitivity of humidistat, %. Humidity is controlled to RHSET $\pm$ RHSENS. (5.0 is good) (RH-SENS)

(41-50)TECMIN = minimum temperature of the air entering the house from the evaporative cooler (used only when IFLAG=3). (T-EC-MIN)

4.3. Comment Section

o Cards 10-14 Columns 1-80, format (8A10)

This set of 5 comment cards can be used to describe the input variables. Each of these cards will be directly echoed above the graph in OUTPUT. (See sample OUTPUT.) All 5 cards must be included in the INPUT DECK, even if they are blank.

4.4. Transfer Functions for walls and roof

o Cards 15-30

These 16 cards provide thermal properties of the walls and roof which are needed to evaluate conduction heat transfer from a room to the outdoors. This heat transfer is computed using the conduction transfer functions (B,C,D coefficients, see App. II for explanation) and the eight-hour history of heat flux through each surface. Frame walls typically consist of two "components": 20-25% studs, 80-75% air space or insulation. The program assumes parallel heat flow paths through these two components. Frame roofs typically also consist of two components: 10% studs, 90% air space or insulation. The B,C,D coefficients depend on the type and amount of building materials used in the construction (i.e. insulation, air-gaps, dry wall, stucco, etc.). A preprogram is available to generate the BCD coefficients appropriate to a given construction (see Appendix II). A set of 4 cards is used for each of the two components of the wall and roof, (i.e. 4 x 4 = 16 cards total). These are entered in the INPUT DECK as follows;

Walls: Air space or insulation component

- o Card 15, format (A10, F10.1)

Column (1-10) Names of component (e.g. "air space," or "insulation R - x")

(11-20) component fraction of whole wall, typically 0.75

- o Card 16, format (8F10.7)

"B" coefficients B_1, B_2,...B_N (maximum is 8) beginning with the B coefficient of the current hour and working back one hour at a time

- o Card 17, format (8F10.7)

"C" coefficients C_1,C_2,...C_N (maximum is 8)

- o Card 18, format (8F10.7)

"D" coefficients D_1,D_2,...D_N (maximum is 8)

Stud component

- o Card 19, format (A10, F10.2)

Column (1-10) comment space, names component (i.e. "stud")

(11-20) component fraction of wall, typically 0.25

- o Cards 20-22, format (8F10.7)

Format same as Cards 16-18.

Roof: Air space or insulation component

- o Card 23, format (A10, F10.2)

Column (1-10) comment space, names component (i.e. "air space" or "insulation R = x")

(11-20) component fraction of roof, typically 0.9

- o Cards 24-26, format (8F10.7)

Format same as Cards 16-18.

Stud Component

o Card 27, format (A10, F10.2)

Column (1-10) comment space, names component (i.e., stud).

(11-20) component fraction of roof, typically 0.1

o Cards 28-30, format (8G10.7)

Format same as cards 13-15.

4.5 Internal Heat Loads

o Cards 31-33

The hourly internal heat load is the cumulative heat released into the house during the hour by inhabitants and their activities, including use of appliances (TV, vacuum, cooking, fraction of heating water which does not go down the drain, etc.) The amount of heat generated can be significant, and varies considerably hour by hour. Data we use is scaled from the estimates used by the National Bureau of Standards (NBS)[8]. See page 22 for the values that we use.

o Card 31, format (8x, 8F9.2)

Column (1-8) comment phrase e.g., HR 01-08 means lam to 8 am.

(9-80) internal loads for each of these 8 hours (Btuh).

o Card 32, format (8x, 8F9.2)

Column (1-8) e.g. HR 9-16 means 9am to 4pm.

(9-80) internal loads for each hour (Btuh).

o Card 33, format (8x, 8F9.2)

Column (1-8) e.g. HR 17-24 means 5pm to midnight.

(9-80) internal loads for each hour (Btuh).

<u>4.6</u> Economic Data. The following three cards may be left blank if no economic analysis is desired (IFLAG11=0).

o CARD 34, format (8F10.4)

Columns (1-10) BLF, years. The lifetime of the base configuration. (B-LF)

(11-20) REMLF, years. The remaining years of useful life of existing equipment. (REM-LF)

(21-30) ALTF, years. The lifetime of the alternative equipment or strategy. (ALT-F)

(31-40) BRC, $. The Replacement Cost of Baseline equipment. (Note: includes the cost of removal of old equipment, less the scrap value.) (B-R-C)

(41-50) AREPCO, $. The replacemt cost of equipment for the replacement case. (A-REP-CO)

(51-60) CGAS, ¢/therm. The current cost of natural gas. (C-GAS)

(61-70) COIL, ¢/gal. The current cost of fuel oil. (C-OIL)

(71-80) CELECT, ¢/kwh. The current cost of electricity. (C-ELECT)

o CARD 35, format (8F10.4)

Columns (1-10) BGAS, therms. Base case gas use. (B-GAS)

(11-20) BOIL, gal. Base case oil use. (B-OIL)

(21-30) BELECT, kwh. Base case electricity use. (B-ELECT)

(31-40) GNF, % per year (i.e. 7.0 for seven per cent) The general inflation rate during the time of the study.

(41-50) DNF(1), % per year (as above) The differential rate of price inflation for natural gas; that is, the amount above the general rate of inflation.

(51-60) DNF(2), % per year (as above) ... for fuel oil

(61-70) DNF(3), % per year (as above) ... for electricity

(71-80) DSCR, % per year (as above) The discount rate, the annual rate at which a future sum of money is discounted to its present value. (DSC-R) o CARD 36, format (6F10.4, 4(I2, 1X), I4)

(1-10) DMAINT, $. The annual maintenance differential (addition or reduction of annual maintenance costs)

(11-20) FTYPE, fuel type: 1 = natural gas, 2 = fuel oil, 3 = electricity

(21-30) FEF, %, furnace efficiency (F-EF)

(31-40) EER, BTU/watt, energy efficiency ratio

(41-50) COMPP, watts, power to drive compressor of the air-conditioner

(51-60) FANP, watts, air-conditioner fan power

(61-62) KDAYB, the day of the month on which the base run starts.

(64-65) MOB, the month (01-12) of the year on which the base run starts.

(67-68) KDYNDB, the day of the month on which the base run ends.

(70-71) MOENDB, the month (01-12) of the year on which the base run ends.

(73-76) IYRB, the year of the base run

o Cards 37, 38, 39, 40 are headline cards for printerplots (2 for each plot).

o Card 41, format (F10.4) constant in Ohio State Infiltration Routine. (suggested value, 3.19)

o Card 42 "END" in columns 1-3. Without this END card, program assumes INPUT DECK error, and aborts.

5. OUTPUT

Typically, output from a run of TWOZONE consists of the following:

1. Summary of input data;
2. Sample hourly response of TWOZONE house (optional, see INPUT DECK).
   A. Hourly data for the first four days of each month.
   B. Hourly printer plots of above data.
3. Loads curve (optional, see INPUT DECK);
4. Summary of loads for the entire run;
5. Economic Analysis;
6. Short summary of INPUT.

5.1 Echo of INPUT DATA card images, and summary of input.

The INPUT DECK is first echoed exactly as it was read in. A summary of the INPUT variables is then printed out along with a table of the transfer function coefficients and the resulting U-values for the walls and roofs, (see sample OUTPUT). *

5.2 Response of TWO-ZONE house

A. Detailed hourly data is given for the first four days of each month of the run, (see sample OUTPUT).

The table headings are:

MONTH

DAY

ZST - hour of the day

QDX(KBTUH) - rate of heat gain (loss) in KBTUH for each hour

QTOTAL(THERMS) - cumulative heat energy provided by furnance

ACTOTAL(THERMS) - cumulative cooling energy provided by AC

ECTOTAL(KWH) - cumulative cooling energy required by evaporative cooler.

TOUT - temperature outside (^{o}F)

TBAR - average temperature in house (^{o}F)

TSOUTH - temperature in S zone of twozone house (^{o}F)

TNORTH - temperature in N zone of twozone house (^{o}F)

SHG(s) south, SHG(w) west, SHG(n) north, SHG(e) east } solar heat transmitted through the fenestration on each of the 4 house faces, BTUH/sq.ft. (independent of window area)

* These U-values are a very useful overall check of the response factor coefficients.

In addition, symbols are printed by the DAY column to indicate which system in the house was operating that hour.

$ = heater on

+ = house venting

* = air conditioner or evaporative cooler on

** = air conditioner or evaporative cooler on but overloaded

If no symbol is printed, the house temperature is floating.

B. Data for the first four days of each month of the test period is plotted on a graph if IFLAG5 = 1 in the INPUT DECK. The comment cards 7-11 entered in the INPUT DECK appear at the top of the graph, (see sample OUTPUT).

X axis = ZST, (4 days x 24 hours/day = 96 hours)

Y axis = a) left scale = QDFURN, BTUH (heat output of furnace each hour)
b) right scale = temp ^{o}F. This scale is not printed. It ranges from -15^{o}F to 105^{o}F in increments of 15^{o}F marked by asterisks.

Symbolic variables used in the graph:

F = furnace heat rate, Btuh ("." fill in area under curve)

C = AC rate, Btuh. Note: won't appear during months when AC not operational (see INPUT DECK)

E = evaporative cooler electrical consumption, Btuh.

T = drybulb temperature outside, ^{o}F

.... = thermostat setting; T_{HI}, TDAYMN or TNIGHT, ^{o}F

---- = house temperature, ^{o}F

5.3 Load Curves

If IFLAG6 = 1 in INPUT DECK, twenty-four hour load curves averaged for each month will be generated, (see sample OUTPUT).

ZST = hour of the day, (0-23)

FURNACE - LD (BTUH) = furnace load

AC - LOAD (BTUH) = air-conditioner load

EC - LOAD (KWH) = electrical consumption of evaporative cooler.

Total heat delivered by furnace, extracted by the air conditioner, and KWH used by the evaporative cooler, for the whole month are printed on the bottom line. Response of TWOZONE house and the Load curves are repeated for each month, or portion thereof, for the entire length of the run period.

5.4 Summary for the entire run (See sample OUTPUT)

1. Total heat (therms) delivered to the house.

2. Net gains (or losses), (BTUH) during furnace operation apportioned into windows, walls, roof, floor, infiltration and internal loads. (Negative values indicate losses from building.)

3. Apportioning of furnace load (BTUH) to windows, walls, roof, floor and infiltration.

4. Hours and amount of useful solar heat gain through windows.

5. Solar heat gain (BTUH) through windows of S, W, N and E sides respectively.

6. The inefficiency of the house, K, is defined to be the total heat per sq. ft. delivered over the test period/degree days in that period. The program prints both $K_{effective}$ (calculated from the Q total computed above) and K_{theory} (calculated using the U-values of the building envelope).

7. Heating season comfort chart, temperature vs. hour of day.

8. The same information as above is given separately for air conditioning and evaporative cooling. In addition, there is a chart of temperature vs. relative humidity for the hours during which cooling was used.

9. Sizing charts for air conditioning and evaporative cooling.

10. The comfort chart for the full period of the run is printed.

Sections of output are printed only if they contain non-zero data. For example, if the evaporative cooler did not operate, then no evaporative cooler information is printed.

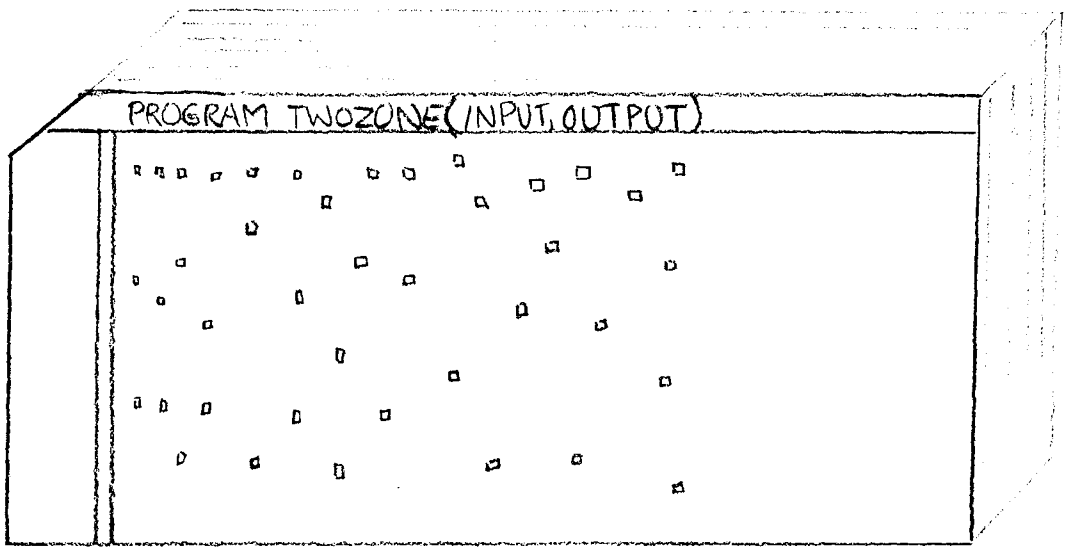
5.5 Economic Analysis

If IFLAG11 is set different from 0 in the input deck, economic analysis of the run is printed (see sample OUTPUT).

First the physical and economic data used in the analysis are printed. Using these, life cycle cost comparisons and other useful economic parameters (such as: Btu's saved per discounted dollar etc.) are calculated according to DOE guidelines and printed.

5.6 Short Summary of Input

The comment section from the INPUT deck is repeated, followed by a compact summary of INPUT for the given run.



6. SAMPLE OUTPUT

(Sample OUTPUT) 6.1 Echo and summary of input data. See Section 5.1 (page 18)

```
                     ********************
                     *                  *
                     *    INPUT DECK    *
                     *                  *
                     ********************

*  01   01   31   12        05   10                 1 1   0 2 0 1           *
*78.        68.        60.        68.        60.        65.        60.      *
*20.        6.         43.        16.        .95        1.0        1.0      *
*1.1        1.1        .2         3200.                                     *
*290.33     558.       105.       558.       267.       289.       546.     *
*38.5       121.5      8.         0.         0.         15.7       0.       *
*36000.     1200.      55.                                                  *
*1000.      300.                                                            *
*74.        .8         65.        5.         0.                             *
*TWO STORY TOWNHOUSE                                                        *
*SACRAMENTO WEATHER,CTZ12                                                   *
*BOTH EVAPORATIVE COOLING AND AIR CONDITIONING                              *
*R11 WALLS                                                                  *
*R19 ROOF.                                                                  *
*  AIR..    .75                                                             *
*.004174    .023916   .008476   .000140                                     *
*.846316    -1.027112 .217890   -.000388                                    *
*0.         -.601748  .089462   -.000072                                    *
*  WOOD..   .25                                                             *
*.000021    .002979   .012264   .006913   .000629   .000007                 *
*.935650    -1.621661 .847695   -.144553  .005712   -.000024                *
*0.0        -1.320345 .526143   -.069438  .002061   -.000004                *
*  AIR..    .9                                                              *
*.000000    .000207   .001821   .002189   .000517   .000023                 *
*.856748    -1.824663 1.283060  -.336043  .026170   -.000514  .000001       *
*0.0        -1.538468 .796573   -.160300  .010963   -.000192                *
*  WOOD..   .1                                                              *
*.000000    .000001   .000076   .000473   .000626   .000226   .000023   .000001  *
*.935650    -2.618735 2.748220  -1.346704 .313911   -.032215  .001317   -.000017 *
*0.0        -2.385993 2.117456  -.873193  .171218   -.014921  .000518   -.000005 *
*HR 1-8     1844.    1844.    1844.    1344.    1844.    1844.    1844.    1844.  *
*HR 9-16    3174.    1294.    1294.    1294.    1294.    1294.    1294.    1294.  *
*HR17-24    1294.    1544.    6514.    6514.    4804.    4804.    4804.    3584.  *
*30.        15.        20.        600.       500.       23.        44.       4.   *
*0.         0.         0.         6.0        6.5        4.0        6.0       10.0 *
*50.        1.0        60.        8.         1000.      350.       01 01 31 12 1958 *
*END                                                                        *
```

(Sample OUTPUT) 6.1 (Continued).

```
THE FOLLOWING VALUES WERE READ

AC STARTS IN MONTH  5  AC ENDS IN MONTH 10

HIGHEST ALLOWED TEMP IS 78. LOWEST ALLOWED TEMPS ARE 68. DURING THE DAY AND 60. AT NIGHT

ON HOLIDAYS THE THERMOSTAT SETTINGS ARE       68. FOR DAY  AND     60.  FOR NIGHT.

IF SUMMERTIME VENTING IS ALLOWED (FLAG10),THE LOWEST ALLOWED HOUSE TEMP IS  60.0 AND THE VENTDOWN TEMP IS  65.0

THE HEAT CAPACITY OF THE HOUSE IS =  3200.  (BTU/F)

PERCENTAGE OF WALL WHICH IS GLASS IS   SOUTH 20.0 WEST  6.0 NORTH 43.0 EAST 16.0

U-VALUES FOR GLASS ARE   DAY  1.1 NIGHT  1.1

WALL AREAS ARE S,W,N,E,ROOF HALVES,FLOOR  290.   558.   105.   558.   267.   289.   546.

UFLOOR IS   .2

LAT,LONG,TIME ZONE ARE   39.  122.    8.

 SHADING COEFF.=        .950  GLASS TYPE     1.       GLAZE     1.

WALL AND ROOF AZIMUTHS ARE,SWNE56,   0.    90.   180.   270.     0.   180.

ROOFTILTS FROM HORIZONTAL ARE,  16.     0.

BTUS AIR CONDITIONING=    36000.0,CFM=     1200.0 TCOIL= 55.0

 1 SPEED COOLER FAN VOLUMES AND ELECTRICAL REQTS ARE 1000. CFM AND  300. WATTS
                                                        0. CFM AND    0. WATTS
                                                        0. CFM AND    0. WATTS
                                                        0. CFM AND    0. WATTS

THE EVAP COOLER TURNS ON AT 78.0 AND OFF AT 74.0 DEGREES F.
EFFECTIVE WETBULB DEPRESSION= .80
RELATIVE HUMIDITY SET POINT= 65.0 WITH  5.0 DEGREES SENSITIVITY EITHER DIRECTION
MINIMUM TEMPERATURE OF AIR LEAVING THE COOLER=  0.0
```

(Sample OUTPUT) 6.1 (Continued).

```
WALL 1 PART 1  AIR..    FR  .750        BN  .004     .024    .008      .000    0.000    0.000   0.000   0.000
CN    .846  -1.027    .218   -.000   0.000  0.000   0.000   0.000  DN  0.000   -.502    .089   -.000  0.000   0.000    0.000   0.

WALL 1 PART 2  WOOD..   FR  .250        BN  .000     .003    .012      .007     .001     .000   0.000   0.000
CN    .936  -1.622    .848   -.145    .006  -.000   0.000   0.000  DN  0.000  -1.320    .526   -.069   .002   -.000    0.000   0.

WALL 2 PART 1  AIR..    FR  .750        BN  .004     .024    .008      .000    0.000    0.000   0.000   0.000
CN    .846  -1.027    .218   -.000   0.000  0.000   0.000   0.000  DN  0.000   -.502    .089   -.000  0.000   0.000    0.000   0.

WALL 2 PART 2  WOOD..   FR  .250        BN  .000     .003    .012      .007     .001     .000   0.000   0.000
CN    .936  -1.622    .848   -.145    .006  -.000   0.000   0.000  DN  0.000  -1.320    .526   -.069   .002   -.000    0.000   0.

WALL 3 PART 1  AIR..    FR  .750        BN  .004     .024    .008      .000    0.000    0.000   0.000   0.000
CN    .846  -1.027    .218   -.000   0.000  0.000   0.000   0.000  DN  0.000   -.502    .089   -.000  0.000   0.000    0.000   0.

WALL 3 PART 2  WOOD..   FR  .250        BN  .000     .003    .012      .007     .001     .000   0.000   0.000
CN    .936  -1.622    .848   -.145    .006  -.000   0.000   0.000  DN  0.000  -1.320    .526   -.069   .002   -.000    0.000   0.

WALL 4 PART 1  AIR..    FR  .750        BN  .004     .024    .008      .000    0.000    0.000   0.000   0.000
CN    .846  -1.027    .218   -.000   0.000  0.000   0.000   0.000  DN  0.000   -.502    .089   -.000  0.000   0.000    0.000   0.

WALL 4 PART 2  WOOD..   FR  .250        BN  .000     .003    .012      .007     .001     .000   0.000   0.000
CN    .936  -1.622    .848   -.145    .006  -.000   0.000   0.000  DN  0.000  -1.320    .526   -.069   .002   -.000    0.000   0.

WALL 5 PART 1  AIR..    FR  .900        BN  0.000    .000    .002      .002     .001     .000   0.000   0.000
CN    .857  -1.825   1.283   -.336    .026  -.001    .000   0.000  DN  0.000  -1.538    .797   -.161   .011   -.000    0.000   0.

WALL 5 PART 2  WOOD..   FR  .100        BN  0.000    .000    .000      .000     .001     .000    .000    .000
CN    .936  -2.619   2.748  -1.347    .314  -.032    .001   -.000  DN  0.000  -2.386   2.117   -.873   .171   -.015     .001   -.

WALL 6 PART 1  AIR..    FR  .900        BN  0.000    .000    .002      .002     .001     .000   0.000   0.000
CN    .857  -1.825   1.283   -.336    .026  -.001    .000   0.000  DN  0.000  -1.538    .797   -.161   .011   -.000    0.000   0.

WALL 6 PART 2  WOOD..   FR  .100        BN  0.000    .000    .000      .000     .001     .000    .000    .000
CN    .936  -2.619   2.748  -1.347    .314  -.032    .001   -.000  DN  0.000  -2.385   2.117   -.873   .171   -.015     .001   -.


AS COMPUTED FROM THE BCD COEFF.S .....
 THE CORRECT U-VALUES ARE   SOUTH  .10 WEST  .10 NORTH  .10 EAST  .10 ROOF5  .05 ROOF6  .05
```

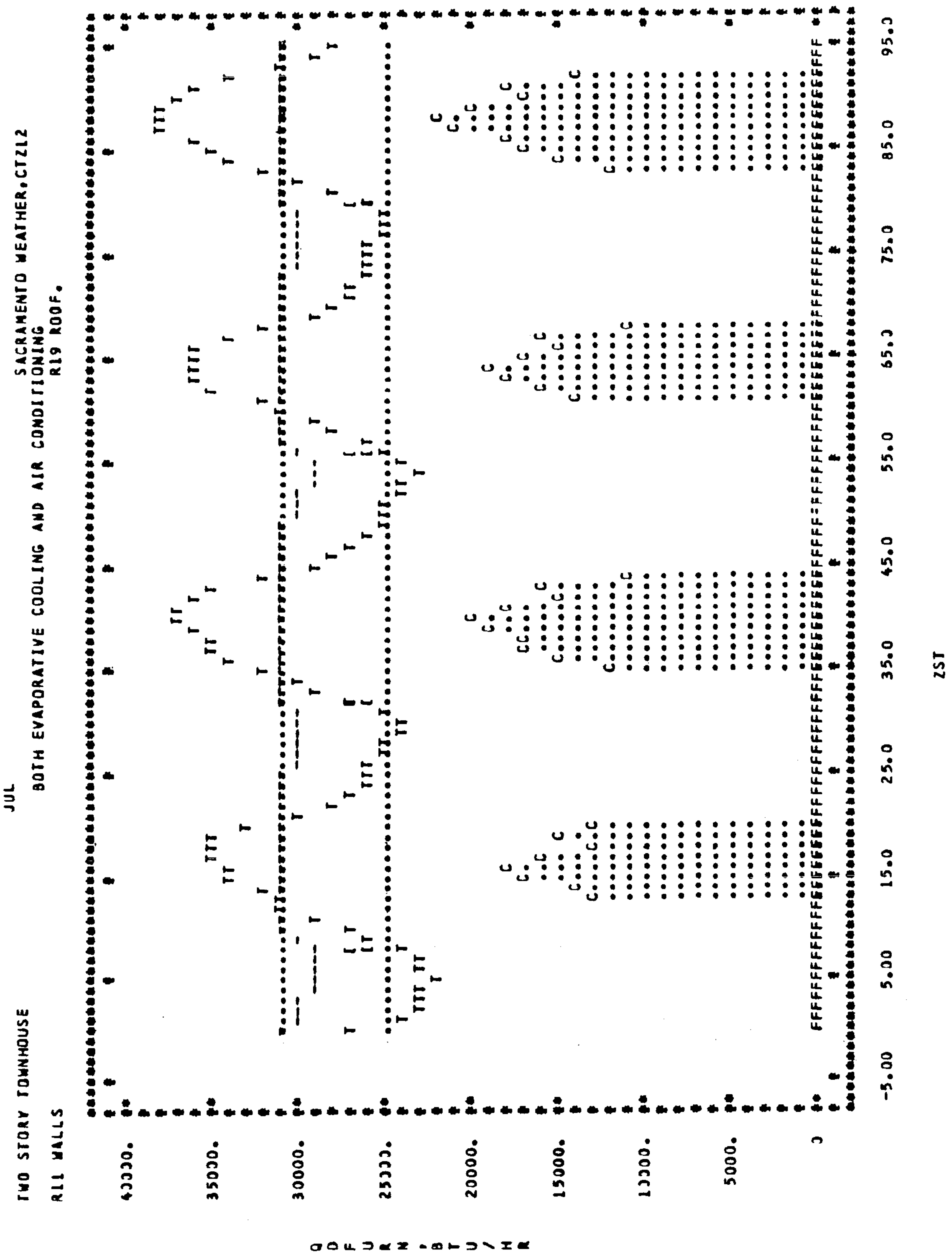
MONTH		DAY	ZST	QDX KBTUH	QTOTAL THERMS	ACTOTAL THERMS	ECTOTAL KWH	TOUT	TBAR	TSOUTH	TNORTH	SHG(S)	SHG(W)	SHG(N)	SHG(E)
												--------BTU/(SQ.FT*HR).--------			
JUL		1	0.0	-4.447	43.546	30.71	0.00	56.0	76.1	75.9	75.2	0.0	0.0	0.0	0.0
			1.0	-3.497	43.546	30.71	0.00	55.0	75.1	74.0	75.3	0.0	0.0	0.0	0.0
			2.0	-4.335	43.546	30.71	0.00	53.0	73.8	73.5	74.1	0.0	0.0	0.0	0.0
			3.0	-3.655	43.546	30.71	0.00	53.0	72.7	72.4	73.0	0.0	0.0	0.0	0.0
			4.0	-4.014	43.546	30.71	0.00	52.0	71.5	71.2	71.9	.0	.0	.0	.2
			5.0	-1.874	43.546	30.71	0.00	53.0	71.0	70.7	71.4	4.8	4.8	4.8	6.7
			6.0	-.501	43.546	30.71	0.00	54.0	70.9	70.5	71.3	12.2	12.2	17.1	13.6
			7.0	8.627	43.546	30.71	0.00	58.0	73.4	73.0	73.8	20.4	20.4	24.4	94.6
			8.0	6.430	43.546	30.71	0.00	63.0	75.2	74.8	75.5	28.7	26.9	29.7	79.4
			9.0	6.453	43.546	30.71	0.00	67.0	77.1	77.0	77.3	41.5	31.7	31.9	69.4
	+		10.0	5.572	43.546	30.71	0.00	71.0	78.0	78.0	78.0	57.5	35.2	35.2	39.7
	+		11.0	9.305	43.546	30.71	0.00	77.0	78.0	78.0	78.0	66.5	35.2	35.2	38.5
	*		12.0	12.293	43.546	30.84	0.00	79.0	78.0	78.0	78.0	72.3	36.4	36.4	38.8
	*		13.0	13.721	43.546	30.99	0.00	82.0	78.0	78.0	78.0	57.1	57.5	36.0	36.0
	*		14.0	16.603	43.546	31.16	0.00	87.0	78.0	78.0	78.0	54.8	109.5	34.8	34.8
	*		15.0	17.712	43.546	31.33	0.00	88.0	78.0	78.0	78.0	39.4	156.3	31.2	31.2
	*		16.0	15.533	43.546	31.49	0.00	91.0	78.0	78.0	78.0	28.1	108.0	26.2	26.2
	*		17.0	13.165	43.546	31.62	0.00	91.0	78.0	78.0	78.0	19.6	57.7	32.0	19.6
	*		18.0	14.553	43.546	31.78	0.00	90.0	78.1	78.0	78.0	10.5	22.8	19.4	10.5
	*		19.0	11.411	43.546	31.90	0.00	85.0	78.0	78.0	78.0	3.9	12.8	10.3	3.9
	+		20.0	5.542	43.546	31.90	0.00	76.0	78.0	78.0	78.0	.5	6.4	.5	.5
	+		21.0	2.919	43.546	31.90	0.00	70.0	78.0	78.0	78.0	0.0	0.0	0.0	0.0
	+		22.0	1.267	43.546	31.90	0.00	66.0	78.0	78.0	78.0	0.0	0.0	0.0	0.0
			23.0	-1.279	43.546	31.90	0.00	63.0	77.6	77.5	77.7	0.0	0.0	0.0	0.0
JUL		2	0.0	-2.478	43.546	31.90	0.00	63.0	76.9	76.3	77.0	0.0	0.0	0.0	0.0
			1.0	-2.139	43.546	31.90	0.00	62.0	76.3	76.1	75.5	0.0	0.0	0.0	0.0
			2.0	-3.186	43.546	31.90	0.00	59.0	75.4	75.1	75.6	0.0	0.0	0.0	0.0
			3.0	-2.441	43.546	31.90	0.00	59.0	74.7	74.4	74.9	0.0	0.0	0.0	0.0
			4.0	-2.740	43.546	31.90	0.00	58.0	73.9	73.5	74.1	.0	.0	.0	.1
			5.0	-1.082	43.546	31.90	0.00	58.0	73.5	73.2	73.3	4.8	4.8	4.8	7.4
			6.0	1.058	43.546	31.90	0.00	61.0	73.8	73.5	74.2	12.2	12.2	19.4	14.1
			7.0	9.789	43.546	31.90	0.00	66.0	76.7	76.3	77.1	20.4	20.4	26.1	95.0
	+		8.0	7.902	43.546	31.90	0.00	72.0	78.0	78.0	78.0	28.7	26.9	30.9	79.4
	+		9.0	8.965	43.546	31.90	0.00	75.0	78.0	78.0	78.0	41.7	31.7	32.0	69.4
	*		10.0	11.236	43.546	32.02	0.00	80.0	78.0	78.0	78.0	57.5	35.2	35.2	39.4
	*		11.0	14.581	43.546	32.17	0.00	86.0	78.0	78.0	78.0	71.0	37.3	37.3	40.4
	*		12.0	16.429	43.546	32.34	0.00	89.0	78.0	78.0	78.0	75.6	37.9	37.9	40.1
	*		13.0	17.269	43.546	32.51	0.00	91.0	78.0	78.0	78.0	69.5	51.1	37.1	37.1
	*		14.0	19.294	43.546	32.71	0.00	94.0	78.0	78.0	78.0	55.0	104.1	34.8	34.8
	*		15.0	20.276	43.546	32.91	0.00	95.0	78.0	78.0	78.0	39.5	152.4	31.2	31.2
	*		16.0	18.176	43.546	33.10	0.00	96.0	78.0	78.0	78.0	28.1	107.9	30.8	26.2
	*		17.0	14.807	43.546	33.25	0.00	94.0	78.0	78.0	78.0	19.6	57.3	31.1	19.6
	*		18.0	15.410	43.546	33.41	0.00	90.0	78.0	78.0	78.0	10.5	22.5	18.7	10.5
	*		19.0	10.443	43.546	33.52	0.00	81.0	78.0	78.0	78.0	3.9	12.5	8.1	3.9
	+		20.0	4.545	43.546	33.52	0.00	73.0	78.0	78.0	78.0	.5	6.3	.5	.5
	+		21.0	2.057	43.546	33.52	0.00	68.0	78.0	78.0	78.0	0.0	0.0	0.0	0.0
	+		22.0	.577	43.546	33.52	0.00	65.0	78.0	78.0	78.0	0.0	0.0	0.0	0.0
			23.0	-1.403	43.546	33.52	0.00	63.0	77.6	77.5	77.7	0.0	0.0	0.0	0.0
JUL		3	0.0	-3.483	43.546	33.52	0.00	61.0	75.6	76.4	75.7	0.0	0.0	0.0	0.0

(Sample OUTPUT) 6.2A. Hourly data for the first four days of July. Refer to Section 5.2A (pg. 18) for explanations.

(Sample OUTPUT) 6.2A (Continued).

		1.0	-2.531	43.546	33.52	0.00	60.0	75.9	75.7	76.0	0.0	0.0	0.0	0.0
		2.0	-3.084	43.546	33.52	0.00	59.0	75.0	74.7	75.2	0.0	0.0	0.0	0.0
		3.0	-3.040	43.546	33.52	0.00	57.0	74.1	73.3	74.3	0.0	0.0	0.0	0.0
		4.0	-3.250	43.546	33.52	0.00	56.0	73.1	72.8	73.4	.0	.0	.0	.1
		5.0	-1.862	43.546	33.52	0.00	55.0	72.6	72.3	72.9	4.7	4.7	4.7	8.4
		6.0	-.159	43.546	33.52	0.00	56.0	72.5	72.2	72.9	12.1	12.1	19.1	14.8
		7.0	8.703	43.546	33.52	0.00	60.0	75.1	74.7	75.5	20.4	20.4	25.8	95.5
		8.0	6.397	43.546	33.52	0.00	64.0	76.9	76.5	77.3	28.7	26.8	30.7	79.4
	+	9.0	6.199	43.546	33.52	0.00	68.0	78.0	78.0	73.0	41.7	31.7	31.9	69.3
	+	10.0	5.778	43.546	33.52	0.00	72.0	78.0	78.0	78.0	57.8	35.2	35.2	38.8
	+	11.0	11.630	43.546	33.52	0.00	78.0	78.0	78.0	73.0	71.2	37.2	37.2	40.0
	*	12.0	13.652	43.546	33.67	0.00	82.0	78.0	78.0	73.0	75.9	37.9	37.9	39.9
	*	13.0	15.874	43.546	33.83	0.00	90.0	78.0	78.0	73.0	69.8	44.8	37.1	37.1
	*	14.0	17.992	43.546	34.01	0.00	92.0	78.0	78.0	78.0	55.3	99.6	34.8	34.8
	*	15.0	18.710	43.546	34.20	0.00	92.0	73.0	78.0	73.0	39.7	149.1	31.2	31.2
	*	16.0	16.859	43.546	34.37	0.00	94.0	78.0	73.0	73.0	29.2	107.9	30.7	26.2
	*	17.0	14.310	43.546	34.52	0.00	94.0	78.0	78.0	73.0	19.6	56.3	35.0	19.6
	*	18.0	14.569	43.546	34.68	0.00	88.0	78.0	78.0	73.0	10.5	21.7	21.5	10.5
	*	19.0	10.028	43.546	34.79	0.00	80.0	78.0	78.0	73.0	3.9	12.0	10.2	3.9
	+	20.0	4.514	43.546	34.79	0.00	73.0	78.0	78.0	73.0	.5	6.3	.5	.5
	+	21.0	2.369	43.546	34.79	0.00	69.0	78.0	78.0	73.0	0.0	0.0	0.0	0.0
	+	22.0	.970	43.546	34.79	0.00	66.0	78.0	78.0	73.0	0.0	0.0	0.0	0.0
		23.0	-.901	43.546	34.79	0.00	65.0	77.7	77.7	77.8	0.0	0.0	0.0	0.0
JUL	4	0.0	-2.409	43.546	34.79	0.00	64.0	77.0	76.9	77.2	0.0	0.0	0.0	0.0
		1.0	-1.935	43.546	34.79	0.00	64.0	75.5	76.3	75.6	0.0	0.0	0.0	0.0
		2.0	-2.418	43.546	34.79	0.00	62.0	75.8	75.6	75.0	0.0	0.0	0.0	0.0
		3.0	-1.965	43.546	34.79	0.00	62.0	75.2	75.0	75.4	0.0	0.0	0.0	0.0
		4.0	-2.448	43.546	34.79	0.00	60.0	74.5	74.2	74.8	.0	.0	.0	.1
		5.0	-.721	43.546	34.79	0.00	60.0	74.3	74.0	74.5	4.7	4.7	4.7	9.7
		6.0	.444	43.546	34.79	0.00	60.0	74.4	74.1	74.8	12.1	12.1	18.8	15.6
		7.0	9.378	43.546	34.79	0.00	64.0	77.1	76.3	77.5	20.3	20.3	25.5	96.1
	+	8.0	6.806	43.546	34.79	0.00	68.0	78.0	78.0	78.0	28.7	26.8	30.5	79.3
	+	9.0	9.257	43.546	34.79	0.00	74.0	78.0	78.0	73.0	41.8	31.7	31.8	69.3
	*	10.0	11.250	43.546	34.91	0.00	81.0	78.0	78.0	73.0	57.9	35.1	35.1	38.0
	*	11.0	14.284	43.546	35.06	0.00	86.0	78.0	78.0	73.0	71.5	37.2	37.2	39.5
	*	12.0	16.788	43.546	35.23	0.00	91.0	78.0	78.0	79.0	76.2	37.9	37.9	39.5
	*	13.0	17.255	43.546	35.41	0.00	93.0	73.0	78.0	73.0	70.1	39.4	37.1	37.2
	*	14.0	20.020	43.546	35.61	0.00	98.0	78.0	78.0	78.0	55.5	95.6	34.8	34.8
	*	15.0	21.203	43.546	35.83	0.00	99.0	73.0	78.0	73.0	39.8	146.3	31.2	31.2
	*	15.0	19.146	43.546	36.03	0.00	99.0	78.0	78.0	78.0	23.2	107.9	30.6	26.2
	*	17.0	16.200	43.546	36.20	0.00	97.0	78.0	78.0	73.0	19.6	56.3	34.8	19.6
	*	18.0	16.212	43.546	36.37	0.00	92.0	78.0	78.0	73.0	10.5	20.2	21.4	10.5
	*	19.0	12.472	43.546	36.51	0.00	87.0	78.0	73.0	73.0	3.9	10.9	10.1	3.9
	+	20.0	6.374	43.546	36.51	0.00	78.0	78.0	78.0	79.0	.5	5.5	.5	.5
	+	21.0	3.966	43.546	36.51	0.00	73.0	78.0	78.0	73.0	0.0	0.0	0.0	0.0
	+	22.0	2.186	43.546	36.51	0.00	69.0	78.0	78.0	73.0	0.0	0.0	0.0	0.0
	+	23.0	.074	43.546	36.51	0.00	67.0	78.0	78.0	78.0	0.0	0.0	0.0	0.0

(Sample OUTPUT) 6.2B. Hourly printer plot of data in Section 6.2A. Refer to Section 5.2B (pg. 19) for explanations.



LOAD DISTRIBUTION BY THE HOUR...(FOR AN AVERAGED DAY OF THIS MONTH)

MONTH OF	ZST	FURNACE-LD (BTUH)	MONTH OF	ZST	AC-LOAD (BTUH)	EC-LOAD (KWH)
JUL	1.0	0.	JUL	1.0	0.	0.000
	2.0	0.		2.0	0.	0.000
	3.0	0.		3.0	0.	0.000
	4.0	0.		4.0	0.	0.000
	5.0	0.		5.0	0.	0.000
	6.0	0.		6.0	0.	0.000
	7.0	0.		7.0	0.	0.000
	8.0	0.		8.0	0.	0.000
	9.0	0.		9.0	0.	0.000
	10.0	0.		10.0	1905.	0.000
	11.0	0.		11.0	3832.	0.000
	12.0	0.		12.0	8895.	0.000
	13.0	0.		13.0	13673.	0.000
	14.0	0.		14.0	16551.	0.000
	15.0	0.		15.0	17570.	0.000
	16.0	0.		16.0	17584.	0.000
	17.0	0.		17.0	16731.	0.000
	18.0	0.		18.0	14314.	0.000
	19.0	0.		19.0	14667.	0.000
	20.0	0.		20.0	6863.	0.000
	21.0	0.		21.0	799.	0.000
	22.0	0.		22.0	0.	0.000
	23.0	0.		23.0	0.	0.000
	24.0	0.		24.0	0.	0.000

TOTAL HEAT DELIVERED THIS MONTH = 0.00 THERMS

TOTAL AIR CONDITIONING THIS MONTH = 41.35 THERMS
TOTAL EVAPORATIVE COOLING THIS MONTH= 0.0 KWH

(Sample OUTPUT) 6.3. Load curves for the month of July. Refer to Section 5.3 (pg. 19) for details.

(Sample OUTPUT) 6.4, Sections 1 through 7. See Section 5.4 (pg. 20) for explanations.

SUMMARY OF RUN

****FURNACE OPERATION****

TOTAL HEAT DELIVERED TO HOUSE= 71.6 THERMS (ROUGHLY TWO-THIRDS OF FUEL CONSUMED)

NET GAINS (LOSSES) DURING FURNACE OPERATION (BTU)		APPORTIONING OF FURNACE LOAD (BTU)	
WINDOWS S=	-989296.		
W=	-1088113.		
N=	-1522235.	WINDOWS=	-4929476.
E=	-2476314.		
WALLS=	-1840613.	WALLS=	-1085338.
CEILING=	-412315.	CEILING=	-183514.
FLOOR=	75796.	FLOOR=	54952.
INFILTRATION=	-1408452.	INFILTRATION=	-1020397.
INTERNAL LOADS=	2497769.		

HOURS OF NET WINDOW GAIN (HEATING SEASON)= 1384
USEFUL SOLAR HEAT GAIN (ALL YEAR)= 13054333. BTU
DIRECTIONAL SOLAR HEAT GAIN SUMS (BTU) PER SQUARE FOOT OF GLASS
SOUTH= 251346. WEST= 141739. NORTH= 73518. EAST= 142684.

THE EFFECTIVE K VALUE OF THE HOUSE= 2.842 BTU/DDAY/SQ FT
THE THEORETICAL K VALUE IS 25.034 BTU/DDAY/SQ FT
2853.2 DEGREE DAYS 3332.0 X 24 DEGREE HOURS FOR PERIOD

HEATING SEASON COMFORT CHART
TEMPERATURE VS. HOUR OF DAY

HOUR	TEMP= 56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	
1	0	0	1	0	1	88	25	33	18	12	3	0	0	0	0	0	0	0	
2	0	0	1	0	47	57	30	24	14	7	1	0	0	0	0	0	0	0	
3	0	0	1	26	59	34	30	19	9	3	0	0	0	0	0	0	0	0	
4	0	0	9	53	48	32	23	12	3	1	0	0	0	0	0	0	0	0	
5	0	0	38	52	33	27	20	8	2	1	0	0	0	0	0	0	0	0	
6	0	0	63	49	26	25	10	7	1	0	0	0	0	0	0	0	0	0	
7	0	0	86	36	20	23	8	5	3	0	0	0	0	0	0	0	0	0	
8	0	0	28	8	6	7	119	7	3	3	0	0	0	0	0	0	0	0	
9	0	0	0	0	0	0	161	6	8	2	2	2	0	0	0	0	0	0	
10	0	0	0	0	0	0	125	32	8	8	3	4	0	0	0	0	0	0	
11	0	0	0	0	0	0	92	55	18	11	6	9	0	0	0	0	0	0	
12	0	0	0	0	0	0	65	49	27	15	8	17	0	0	0	0	0	0	
13	0	0	0	0	0	0	44	52	25	23	13	21	3	0	0	0	0	0	
14	0	0	0	0	0	0	33	44	31	22	16	28	5	2	0	0	0	0	
15	0	0	0	0	0	0	29	39	29	25	14	34	3	5	3	0	0	0	
16	0	0	0	0	0	0	31	35	30	20	18	37	2	4	2	2	0	0	
17	0	0	0	0	0	0	37	34	31	19	16	35	0	2	5	1	0	0	
18	0	0	0	0	0	0	55	23	30	18	17	30	2	4	2	0	0	0	
19	0	0	0	0	0	0	47	28	31	18	15	39	2	0	0	0	0	0	
20	0	0	0	0	0	0	54	25	30	22	19	31	0	0	0	0	0	0	
21	0	0	0	0	0	0	50	29	29	19	24	20	0	0	0	0	0	0	
22	0	0	0	0	0	0	71	31	27	21	20	11	0	0	0	0	0	0	
23	0	0	0	0	0	0	83	29	21	23	20	5	0	0	0	0	0	0	
24	0	0	0	0	0	0	98	28	25	15	15	0	0	0	0	0	0	0	
TOTAL	0	0	227	224	240	293	1341	654	453	308	231	324	17	17	12	3	0	0	4344

(Sample OUTPUT) 6.4 Section 8. This gives the same information as Sections 1 through 6 above, for hours of air conditioner operation, together with a chart of temperature vs. relative humidity indoors during air conditioner operation.

********COOLING OPERATION********

++AIR CONDITIONER++

TOTAL AIR CONDITIONER LOAD= 117.6 THERMS, OF WHICH 2.9 THERMS IS LATENT
TOTAL SENSIBLE BUILDING LOAD FOR COOLING= 114.9 THERMS

TO CALCULATE KWH OF ELECTRICTY CONSUMED, MULTIPLY THE AIR CONDITIONER LOAD BY 100 AND DIVIDE BY THE ENERGY EFFICIENCY RATIO (EER). THE EER VARIES WITH THE AC UNIT USED. A TYPICAL VALUE IS ABOUT 6 (1976)

NET SENSIBLE GAINS (LOSSES) DURING AIR CONDITIONER OPERATION (BTU)		APPORTIONING OF TOTAL AIR CONDITIONER LOAD (BTU)	
S=	2925602.		
W=	1820693.		
WINDOWS N=	1256947.	WINDOWS=	8487749.
E=	2592454.		
WALLS=	650766.	WALLS=	679166.
CEILING=	366316.	CEILING=	359945.
FLOOR=	-132888.		
INFILTRATION=	438698.	INFILTRATION=	559101.
INTERNAL LOADS=	1533629.	INTERNAL LOADS=	1674819.

NOTE APPORTIONING IS DONE ONLY WHEN THE HOURLY SUM OF THE ABOVE TERMS IS POSITIVE.

NUMBER OF HOURS DURING WHICH THE AIR CONDITIONER TURNED ON AT LEAST ONCE= 753
THE AIR CONDITIONER RAN A TOTAL OF 418.9 HOURS, DURING WHICH THE COMPRESSOR RAN 326.7 HOURS

49.1 COOLING DEGREE DAYS, 375.0 X 24 COOLING DEGREE HOURS (BASE TEMPERATURE = 78F)

+AIR CONDITIONING HOURS+
TEMPERATURE VS. RELATIVE HUMIDITY

TEMP	RH= 0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	TOTAL
60.	0	0	0	0	0	0	0	0	0	0	0
62.	0	0	0	0	0	0	0	0	0	0	0
64.	0	0	0	0	0	0	0	0	0	0	0
66.	0	0	0	0	0	0	0	0	0	0	0
68.	0	0	0	0	0	0	0	0	0	0	0
70.	0	0	0	0	0	0	0	0	0	0	0
72.	0	0	0	0	0	0	0	0	0	0	0
74.	0	0	0	0	0	0	0	0	0	0	0
76.	0	0	0	0	0	0	0	0	0	0	0
78.	0	0	4	7	742	0	0	0	0	0	753
80.	0	0	0	0	0	0	0	0	0	0	0
82.	0	0	0	0	0	0	0	0	0	0	0
84.	0	0	0	0	0	0	0	0	0	0	0
86.	0	0	0	0	0	0	0	0	0	0	0
88.	0	0	0	0	0	0	0	0	0	0	0
90.	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	0	4	7	742	0	0	0	0	0	753

AVERAGE TEMPERATURE AND RELATIVE HUMIDITY DURING OPERATION ARE= 78.0 DEG F., AND 42.58 PERCENT
MAXIMUM TEMPERATURE AND CORRESPONDING RELATIVE HUMIDITY ARE= 78.0 DEG F., AND 49.76 PERCENT
MAXIMUM RELATIVE HUMIDITY AND CORRESPONDING TEMPERATURE ARE= 49.76 PERCENT, AND 78.0 DEG F.

(Sample OUTPUT) 6.4, Section 8 (continued) This gives the same information as Sections 1 through 6 above, for hours of evaporative cooler operation, together with a chart of temperature vs. relative humidity indoors during evaporative cooler operation.

++EVAPORATIVE COOLER++

```
TOTAL ENERGY USED IN EVAPORATIVE COOLING=   61.4 KWH
TOTAL WATER USED IN COOLER=  402.0 GALLONS
NET TOTAL BUILDING LOAD FOR COOLING=  2147185. BTU
EFFECTIVE ENERGY EFFICIENCY RATIO= 34.98 BTU/WATT
```

NET GAINS (LOSSES) DURING EVAPORATIVE COOLER OPERATION (BTU)		APPORTIONING OF EVAPORATIVE COOLER LOAD (KWH)	
WINDOWS S=	543993.		
W=	288245.		
N=	187235.	WINDOWS=	38.
E=	384904.		
WALLS=	101784.	WALLS=	3.
CEILING=	73069.	CEILING=	2.
FLOOR=	-45527.		
INFILTRATION=	NONE	INFILTRATION=	NONE
INTERNAL LOADS=	565769.	INTERNAL LOADS=	18.

NOTE APPORTIONING IS DONE ONLY WHEN THE HOURLY SUM OF THE ABOVE TERMS IS POSITIVE.

+EVAPORATIVE COOLING HOURS+
TEMPERATURE VS. RELATIVE HUMIDITY

TEMP RH=	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	TOTAL
60.	0	0	0	0	0	0	0	0	0	0	0
62.	0	0	0	0	0	0	0	0	0	0	0
64.	0	0	0	0	0	0	0	0	0	0	0
66.	0	0	0	0	0	0	0	0	0	0	0
68.	0	0	0	0	0	0	0	0	0	0	0
70.	0	0	0	0	0	0	0	0	0	0	0
72.	0	0	0	0	0	0	0	0	0	0	0
74.	0	0	0	0	2	6	0	0	0	0	8
76.	0	0	0	1	30	46	6	0	0	0	83
78.	0	0	0	4	37	63	24	0	0	0	128
80.	0	0	0	0	0	0	0	0	0	0	0
82.	0	0	0	0	0	0	0	0	0	0	0
84.	0	0	0	0	0	0	0	0	0	0	0
86.	0	0	0	0	0	0	0	0	0	0	0
88.	0	0	0	0	0	0	0	0	0	0	0
90.	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	0	0	5	69	115	30	0	0	0	219

```
AVERAGE TEMPERATURE AND RELATIVE HUMIDITY DURING OPERATION ARE= 77.0 DEG F., AND 53.07 PERCENT
MAXIMUM TEMPERATURE AND CORRESPONDING RELATIVE HUMIDITY ARE= 78.0 DEG F., AND 60.24 PERCENT
MAXIMUM RELATIVE HUMIDITY AND CORRESPONDING TEMPERATURE ARE= 65.70 PERCENT, AND 77.7 DEG F.
NUMBER OF HOURS AT SPEED 1= 219, SPEED 2=    0,SPEED 3=    0, SPEED 4=    0 TOTAL HOURS= 219

     49.1 COOLING DEGREE DAYS,     375.0 X 24 COOLING DEGREE HOURS (BASE TEMPERATURE = 78F)
```

COOLING SEASON COMFORT CHART
TEMPERATURE VS. HOUR OF DAY

HOUR	TEMP=	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	
1		0	0	0	0	0	127	27	13	8	3	5	1	0	0	0	0	0	0	
2		0	0	0	0	0	157	10	9	2	3	3	0	0	0	0	0	0	0	
3		0	0	0	0	0	167	7	4	1	3	1	1	0	0	0	0	0	0	
4		0	0	0	0	0	171	5	3	1	3	1	0	0	0	0	0	0	0	
5		0	0	0	0	0	175	3	1	4	1	0	0	0	0	0	0	0	0	
6		0	0	0	0	0	178	1	2	3	0	0	0	0	0	0	0	0	0	
7		0	0	0	0	45	104	28	1	2	4	0	0	0	0	0	0	0	0	
8		0	0	0	0	6	56	81	32	3	4	2	0	0	0	0	0	0	0	
9		0	0	0	0	1	10	28	62	54	20	6	3	0	0	0	0	0	0	
10		0	0	0	0	0	3	12	29	37	61	29	13	0	0	0	0	0	0	
11		0	0	0	0	0	0	3	11	20	36	44	70	0	0	0	0	0	0	
12		0	0	0	0	0	0	0	5	13	19	23	122	2	0	0	0	0	0	
13		0	0	0	0	0	0	0	1	3	14	18	148	0	0	0	0	0	0	
14		0	0	0	0	0	0	0	1	2	4	17	160	0	0	0	0	0	0	
15		0	0	0	0	0	0	0	1	0	3	12	167	1	0	0	0	0	0	
16		0	0	0	0	0	0	0	0	1	2	14	167	0	0	0	0	0	0	
17		0	0	0	0	0	0	0	1	0	4	17	161	1	0	0	0	0	0	
18		0	0	0	0	0	0	0	1	0	6	17	160	0	0	0	0	0	0	
19		0	0	0	0	0	0	0	0	1	1	10	169	3	0	0	0	0	0	
20		0	0	0	0	0	0	0	0	1	1	11	171	0	0	0	0	0	0	
21		0	0	0	0	0	0	0	0	1	1	20	162	0	0	0	0	0	0	
22		0	0	0	0	0	0	0	0	1	2	35	146	0	0	0	0	0	0	
23		0	0	0	0	0	0	0	1	0	4	49	130	0	0	0	0	0	0	
24		0	0	0	0	0	44	38	39	35	15	10	3	0	0	0	0	0	0	
TOTAL		0	0	0	0	52	1192	243	217	193	214	344	1954	7	0	0	0	0	0	4416

(Sample OUTPUT) 6.4, Section 8 (Continued). Cooling season comfort chart.

(Sample OUTPUT) 6.4, Section 9. Sizing chart for air conditioner.

+AC SIZING+

LOAD	HOURS
6000.	63
12000.	398
18000.	487
24000.	47
30000.	0
36000.	0
42000.	0
48000.	0
54000.	0
60000.	0
66000.	0
72000.	0
78000.	0
84000.	0
90000.	0
96000.	0
102000.	0
108000.	0
114000.	0
120000.	0
TOTAL	995

MAXIMUM AND MINIMUM LOADS EXPERIENCED ARE 25673. AND 4906. BTU/HR

ALL SEASON COMFORT CHART
TEMPERATURE VS. HOUR OF DAY

HOUR	TEMP= 56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	
1	0	0	1	0	1	215	52	47	25	15	8	1	0	0	0	0	0	0	
2	0	0	1	0	47	214	41	33	15	10	4	0	0	0	0	0	0	0	
3	0	0	1	26	59	201	38	23	9	6	1	1	0	0	0	0	0	0	
4	0	0	9	53	48	204	28	14	4	4	1	0	0	0	0	0	0	0	
5	0	0	38	52	33	203	23	8	6	2	0	0	0	0	0	0	0	0	
6	0	0	63	49	26	204	11	8	4	0	0	0	0	0	0	0	0	0	
7	0	0	86	36	65	128	35	6	5	4	0	0	0	0	0	0	0	0	
8	0	0	28	8	12	64	200	38	6	7	2	0	0	0	0	0	0	0	
9	0	0	0	0	1	10	190	67	62	22	8	5	0	0	0	0	0	0	
10	0	0	0	0	0	3	138	62	44	69	32	17	0	0	0	0	0	0	
11	0	0	0	0	0	0	85	66	39	46	50	79	0	0	0	0	0	0	
12	0	0	0	0	0	0	65	54	40	34	32	138	2	0	0	0	0	0	
13	0	0	0	0	0	0	44	53	28	37	31	170	2	0	0	0	0	0	
14	0	0	0	0	0	0	33	45	33	26	33	188	5	2	0	0	0	0	
15	0	0	0	0	0	0	29	40	29	28	26	201	4	5	3	0	0	0	
16	0	0	0	0	0	0	31	35	31	22	32	204	2	4	2	2	0	0	
17	0	0	0	0	0	0	37	35	31	23	33	197	1	2	5	1	0	0	
18	0	0	0	0	0	0	55	24	30	24	34	190	2	4	2	0	0	0	
19	0	0	0	0	0	0	47	28	32	19	26	208	5	0	0	0	0	0	
20	0	0	0	0	0	0	54	25	31	23	30	202	0	0	0	0	0	0	
21	0	0	0	0	0	0	60	29	30	20	44	182	0	0	0	0	0	0	
22	0	0	0	0	0	0	71	31	28	23	55	157	0	0	0	0	0	0	
23	0	0	0	0	0	0	83	30	21	27	69	135	0	0	0	0	0	0	
24	0	0	0	0	0	44	136	67	60	30	25	3	0	0	0	0	0	0	
TOTAL	0	0	227	224	292	1490	1586	868	643	521	576	2278	23	17	12	3	0	0	8760

(Sample OUTPUT) 6.4, Section 10. All-season comfort chart.

```
*************************************
*                                   *
*        ECONOMIC ANALYSIS-         *
*                                   *
*      (IN CONSTANT DOLLARS)        *
*                                   *
*************************************
```

```
EQUIPMENT PARAMETERS                          THE LENGTH OF THIS RUN IS *** DAYS.
--------------------

FURNACE EFFICIENCY-   60.                FUEL USE- GAS-   119.40 THERMS, FUEL OIL-   0.00 GAL, ELECTRICITY-   398. KWH

EER (IF GIVEN)-      35.                 FUEL COST-  GAS- $   27.46 , FUEL OIL- $    0.00 , ELECTRICITY- $   15.90
OR-
AC COMPRESSOR POWER-1000. WATTS          TOTAL ENERGY USE- 13296.46 KBTU

AC FAN POWER-        350. WATTS          TOTAL COST-      $   43.36

EC WATTAGES-  1)--  300.,  2-    0.      COOLING SYSTEM ENERGY REQUIREMENT- 1356.84 KBTU

              3)-   0.,  4)-    0.       COOLING SYSTEM FUEL COST-  $   15.90

FURNACE FUEL- NATURAL GAS.               HEATING SYSTEM ENERGY REQUIREMENT-11939.62 KBTU

INITIAL FUEL PRICES-                     HEATING SYSTEM FUEL COST-  $   27.46
--------------------

   NAT GAS-    23.0 CENTS/TH
   FUEL OIL-   44.0 CENTS/GAL
   ELEC-        4.0 CENTS/KWH


BASE CASE ENERGY USE AND COST
-----------------------------

FUEL USE-   GAS-   1000.0 THERMS,  FUEL OIL-      0.GAL,  ELECTRICITY-   2500.0 KWH

FUEL COST-  GAS-   $  230.00  ,  FUEL OIL- $    0.00    ELECTRICITY- $  100.00

TOTAL ENERGY USE-   108532.50 KBTU

TOTAL ENERGY COST- $ 330.00
```

(Sample OUTPUT) 6.5. Economic analysis, pg. 1. Printout of the physical and economic data used in the economic analysis.

```
**********************************
*                                *
*   LIFE CYCLE COST COMPARISONS  *
*                                *
**********************************

ECONOMIC PARAMETERS-
--------------------

YEARS UNTIL MAJOR REPLACEMENT IN BASE CASE-  15.0YRS.

LIFETIME OF REPLACEMENT 30.0 YRS.

COST OF REPLACEMENT-  $   600.00

LIFETIME OF CONSERVATION OPTION-  20.0 YRS.

COST OF OPTION-   $  500.00

CHANGE IN ANNUAL MAINTENANCE FROM BASE CASE-  $   50.00

GENERAL RATE OF PRICE INFLATION-                  6. PER CENT

DIFFERENTIAL PRICE INFLATION (NATURAL GAS)-       7. PER CENT

DIFFERENTIAL PRICE INFLATION (FUEL OIL)-          4. PER CENT

DIFFERENTIAL PRICE INFLATION (ELECTRICITY)-       6. PER CENT

DISCOUNT RATE-                                    0. PER CENT


**********************************************************************************
*                                                                                *
*     BTUS SAVED EACH YEAR-    .552E+08                                          *
*                                                                                *
*     BTUS SAVED PER DISCOUNTED INVESTMENT DOLLAR-    .896E+04                   *
*                                                                                *
*     PV OF INCREMENTAL CAPITAL COST,LESS PV SAVINGS IN OPERATIONS-  -.150E+05   *
*                                                                                *
*     SAVINGS/INVESTMENT RATIO-     .363E+02                                     *
*                                                                                *
*     DISCOUNTED PAYBACK PERIOD (INCLUDES THE TIME VALUE OF MONEY)-    .2E+01YRS *
*                                                                                *
**********************************************************************************
```

(Sample OUTPUT) 6.5. Economic analysis, pg. 2. The life cycle cost comparisons and other economic parameters calculated by the program. (See the description of the subroutine ECON, pg. 77.)

(Sample OUTPUT) 6.5 (Continued). Economic data are printed like this if the base-case fuel uses are set equal to zero in the input deck. (See the description of subroutine ECON, pg.77.)

```
                         ***************************
                         *  THIS IS A BASE CASE.  *
                         ***************************

                   THE LENGTH OF THIS RUN IS *** DAYS.

FURNACE EFFICIENCY-   60.             FUEL USE- GAS-   119.40 THERMS, FUEL OIL-   0.00 GAL, ELECTRICITY-  1887. KWH

EER (IF GIVEN)-        8.             FUEL COST-  GAS- $   27.46 , FUEL OIL- $    0.00 , ELECTRICITY- $   75.49
OR-
AC COMPRESSOR POWER-1000. WATTS       TOTAL ENERGY USE- 18381.02 KBTU

AC FAN POWER-        350. WATTS       TOTAL COST-      $  102.95

EC WATTAGES-  1)--  300.,  2-    0.   COOLING SYSTEM ENERGY REQUIREMENT- 6441.40 KBTU

             3)-   0.,  4)-    0.     COOLING SYSTEM FUEL COST-  $   75.49

FURNACE FUEL- NATURAL GAS.            HEATING SYSTEM ENERGY REQUIREMENT-11939.62 KBTU

INITIAL FUEL PRICES-                  HEATING SYSTEM FUEL COST-  $   27.45
--------------------

   NAT GAS-   23.0 CENTS/TH
   FUEL OIL-  44.0 CENTS/GAL
   ELEC-       4.0 CENTS/KWH
```

```
TWO STORY TOWNHOUSE

 SACRAMENTO WEATHER,CTZ12

 BOTH EVAPORATIVE COOLING AND AIR CONDITIONING

 R11 WALLS

 R19 ROOF.

SUMMARY OF INPUT *  JAN 1 TO DEC31,1958.  ACSTART= 5  ACEND=10  THI=78.  TDAY=68.  TNITE=60.  THOLDY=68.  THOLNT=60.  CC=3200.
  FOR THIS RUN   *  WALLARS= 290.,558.,105.,558.  ROOFAR= 556.  FLRAR= 546.  PCTGL= 20.0, 6.0,43.0,16.0  UDAY=1.1  UNIGHT=1.1
                 *  UWALL= .098  WALL-STUDSFRAC= .25  UROOF= .049  ROOF-STUDSFRAC= .10  UFLOOR= .20  .   INTERNAL LOADS .
                 *  LAT=39.  LONG=122.  TZONE=8.

****************************************  TWOZONE--VERSION *BLUEL* IMPLEMENTED NOV 5, 1977.  ****************************************
```

(Sample OUTPUT) 6.6. Short summary of INPUT.

7. DICTIONARY OF VARIABLES FOR THE MAIN PROGRAM TWOZONE

'A'

A	=	natural convection component of infiltration, insures that at windspeed = 0, airchange is 1/4 of house volume per hour and at windspeed = 10 mph, airchange is 3/4 of house volume per hour.
AA	=	heat gains to the house, Btuh
ACAPAC	=	air conditioner capacity, Btuh
ACDD	=	cooling degree-day sum (temporary for ACDGDY)
ACDH	=	cooling degree-hour sum (temporary for ACDGHR)
ACEND	=	month in which cooling ends (user supplied data)
ACSIZE	=	storage array for air conditioner sizing
ACSTART	=	month in which cooling starts (user supplied data)
ACTOTAL	=	total air conditioner load
AG(1)	=	glass on south face of house--SqFt
AG(2)	=	" " west " " " "
AG(3)	=	" " north " " " "
AG(4)	=	" " east " " " "
ALAT	=	latent infiltration constant
ALOAD(NHR)	=	cumulative hourly air conditioning load, for month, KBTU, used to generate load curve
ARFLOR	=	floor area, SqFt., (user supplied data)
ARGLAS	=	Total glass area of walls of space house, SQFT
	=	AG(1)+AG(2)+AG(3)+AG(4)
AZW	=	wall azimuth (user supplied data)

'B'

B	= constant for component of infiltration due to wind speed
BB	= infiltration-induced heat load + steady-state convective losses at glass + floor losses + wall losses, BTUH/^{O}F
BBCC	= BB/CC = "BB" divided by the house specific heat, in HR^{-1}. BBCC is the time constant used in the argument of the exponential function describing the floating of house mean temperature toward AA/BB
BED	= the value of ZST at which the house occupants retire for the night
BLAT	= latent infiltration constant for windspeed dependence
BN(L,I,K)	= transfer function coefficient for the particular type construction used in walls or roof; see also CN & DN (user supplied data)
BRKFST	= the value of ZST at which house occupants awaken to begin a day
B1	= effective 'K' value of house, Btu/(DGDAY-Sq.Ft.)

'C'

CC	= heat capacity of house, Btu/°F, (user supplied data)
CEE	= the difference between the house temperature one hour ago and the average house equilibrium temperature, °F. "CEE" is effectively $T_O - T$
CHRTIME	= characteristic time for the house to approach equilibrium temperature.
CLCPORT	= heat gain or loss through ceiling due to cooling operation, Btuh
CLCTOT	= net gain (loss) through roof during air conditioner operation, Btuh
CLD	= air conditioning load on the house. Can be sensible, or sensible and latent load, depending on branch, BTU
CLDMIN	= minimum cooling load
CLDOTQ	= heat gain or loss through roof, Btuh
CLECPT	= ceiling apportioning for evaporative cooling
CLECT	= total ceiling cooling load for evaporative cooling
CLPORT	= portion of furnace load due to ceiling losses, Btuh
CLTOT	= net heat gain (loss) to house through roof, Btuh
CN(L,I,K)	= transfer function coefficient for the construction type used in walls and roof, (user supplied data)

'D'

DD	= counts deg-hrs/day
DENSITY	= density of air lb/ft^3
DGDAY	= cumulative degree-days for heating, 65^{o}F base
DGDAYO	= degree-day value one hour ago
DGHR	= cumulative degree-hours for heating, 65^{o}F base
DGHRO	= degree-hour value one hour ago
DN(L,I,K)	= transfer function coefficient for the particular construction type used in walls or roof (user supplied data)
DRYBLB	= outside drybulb air temperature, ^{o}F
DTIME	= fraction of hour for air conditioner load calculation

'E'

ECBTU	= ECLD converted from watts to Btus
ECLD	= hourly evaporative cooler electrical consumption
ECTOTAL	= total evaporative cooler electrical consumption
ECVOL	= array of evaporative cooler speeds (user supplied data)
EER	= Energy Efficiency Ratio
EFFECT	= fraction of distance from DRYBULB to WETBULB evap cooler can accomplish (user supplied data)
EFT	= storage array for EFFECT in evap cooler sizing
EFTAVE	= average of EFFECT during evap cooler sizing
EFTMAX	= maximum EFFECT during evap cooler sizing
EFTMIN	= minimum EFFECT during evap cooler sizing
EFTT	= total hours at a given EFFECT during evap cooler sizing
EFTVMN	= EFFECT at minimum volume during evap cooler sizing
EFTVMX	= EFFECT at maximum volume during evap cooler sizing
ELOAD	= like ECTOTAL, but monthly
EWATT	= array of evaporative cooler electrical ratings (watts) (user supplied data)

'F'

F = the difference between north and south heat inputs or losses for the following components: solar heat gain at windows + total heat transfer rate at walls less steady state conductance-area products at walls and windows. Used to calculate air-convection.

FANVOL = CFM of air conditioner fan (user supplied data)

FLCPRT = heat loss through floor due to air conditioner operation, Btuh

FLCTOT = net heat gain (loss) through floor during air conditioner operation, Btuh

FLECT = total floor cooling load in evap cooling

FLLOSS = heat transfer rate through the floor, Btuh

FLOAD(NHR) = heat cumulative furnace load for month, to generate load curve, KBTU

FLOWAR = effective area at doors through which air flows, assuming that buoyancy currents exhibit unidirectional flow through top and bottom 2 feet of doorway only

FLPORT = portion of furnace load due to floor losses, Btuh

FLTOT = net heat gain (loss) to house through floor, Btuh

FRAC = a scaling factor based on THI or TLOW.
FRAC = (TTB - THI)/(TTB - TTBOLD) for cooling and
FRAC = (TLOW - TTB)/(TTBOLD-TTB) for heating

FR(I,L) = fraction of wall 'I' which is constructed of component 'L'.

FZCC = the equilibrium temperature which north and south halves approach; FZCC is the difference in steady state "UA" values plus T times the steady state losses divided by the house specific heat. Used to calculate air-convection.

'G'

GLAZE	= glazing code; 1 for single glazing, 2 for double glazing (user supplied data)
GLTYP	= glass type code, (reflection, transmission and absorption coefficients), (user supplied data)
GRDTEMP	= outside ground temperature, ^{o}F, taken as a monthly average
GTB(1)	= zonal standard time, decimal hours
GTB(2)	= total heat transfer rate to house KBTUH
GTB(3)	= total furnace power consumption, therms
GTB(4)	= sensible and latent cooling load, therms
GTB(5)	= energy consumed by the evaporative cooler, Btu
GTB(6)	= drybulb temperature, ^{o}F
GTB(7)	= average house temperature, ^{o}F
GTB(8)	= temperature of south half of house, ^{o}F
GTB(9)	= temperature of north half of house, ^{o}F

GTB(N) used for hourly response output

'H'

H = the energy content of moist air at TTB with a $0^{O}F$ reference for water vapor, in Btu/lbm of dry air

HCOIL = minimum exit enthalpy from air conditioner

HEAT = hourly furnace power consumption, Btu

HGRM(I,K) = heat gain to room per unit wall area, Btuh/SqFt, where I = 1-5 is the wall locator subscript, and K = 1-8 is the backward time step index for calculation of temperatures and heat transfer rates using transfer function method

HGRMF(L,I,K) = fraction of heat gain to room per unit wall area from L^{th} component, where L = 1 means air and L = 2 means studs

HH = convective heat transfer rate per unit wall area, Btuh/SqFt, used to initialize heat transfer calculations

HIN = enthalpy of the air drawn into the cooling unit, Btu/lbm

HLATNT(NHR) = hourly latent cooling load generated in the house, Btuh

HNIGHT = cumulative power consumption of the furnace between midnight and 0800 HRS

HOL = 1 means a holiday
HOL = 0 otherwise

HOLLMO(MO) = 12-member array containing the abbreviations for the months of the year for purposes of output headings

HOLLMO(MSTORE) = beginning month of the program run

HSTEP = value used to increment TIME1 in float branch. Present "HSTEP" of 0.05 requires 20 executions of float logic before exit

H2OEC = total water used in evap cooler (lb)

H2ORMT = total water removed from room in air conditioning

'I'

IAMCOL	=	flag for nighttime cooldown
ICOOL	=	flag for cooling season comfort chart
IFLAG	=	1; air-conditioning is available
IFLAG1	=	1; stores degree-day and degree-hour data on external magnetic tapes. (user supplied data).
IFLAG2	=	1; prevents venting or air-conditioning when TTB > THI. Usually left as IFLAG 2 = 0. (user supplied data).
IFLAG3	=	1; permits venting if DRYBLB < THI
IFLAG4	=	1; data for load apportioning bar graph punched on cards (see Appendix 4), (user supplied data)
IFLAG5	=	1; graph of data for first four days of each month printed with output (user supplied data)
IFLAG6	=	1; load curves for "average day" of each month printed with output (user supplied data)
IFLAG7	=	not currently used
IFLAG8	=	evaporative cooling flag
IFLAG9	=	air conditioning flag
IFLAG10	=	nightime cooling flag
IFLAG11	=	economics package flag
IFLGEC	=	tells main program evap. cooler is running (lets temperature drop)
IHEAT	=	flag or heating season comfort chart
IMPOS	=	impossible evap cooling for a given house temperature
IMPOSS	=	impossible evap cooler sizing for a given house temperature
INFCPOR	=	portion of heat gain or loss due to infiltration due to cooling operation, Btuh
INFCTOT	=	net gain(loss) due to infiltration during air conditioner operation, Btuh
INFIL	=	when multiplied by temperature difference (i.e. DRYBULB-TTB) gives heat load induced by infiltration INFIL=A + B*WDATA(7) Btuh/^{o}F

'I' - continued

INFILOS = heat gain or loss due to infiltration, Btuh
INFILOS = INFIL * (DRYBLB-TTB)

INFPORT = portion of furnace load due to infiltration, Btuh

INFTOT = net gain (loss) to house due to infiltration, Btuh

INLCPOR = portion of heat gain (loss) due to internal loads due to cooling operation, Btuh

INLCTOT = net gain (loss) to house due to internal loads during A.C. operation, Btuh

INLECPT = internal loads evap cooling apportioning

INLECT = total internal loads during evap cooling

INLOAD = same as INTLD (NHR), hourly internal loads, Btuh

INLTOT = net heat gain to house due to internal loads, Btuh

INTLOAD(NHR) = internal heat load (TV, washing machine, etc.) as function of hour of day, Btuh

IRHAC = relative humidity storage array for AC operation

IRHACT = same with totals over temperatures

IRHEC = relative humidity storage array for evap. cooler operation

IRHECT = same with totals over temperatures

ISPEED = number of speeds the evap. cooler has (4 is maximum)

ISTEPS = number of steps per hour in AC calculation

ITAC = temperature storage array in AC operation

ITEC = temperature storage array in evap. cooler operation

ITEMPC = temperature storage array for cooling comfort chart

ITEMPH = temperature storage array for heatinc comfort chart

ITEMPT = sum of above two

ITHRSC = output storage array

ITHRSH = output storage array

ITHRST = output storage array

'I' - continued

ITHRST	=	output storage array
ITOT	=	output storage array
ITOTC	=	output storage array
ITOTH	=	output storage array
IWARN	=	counter for 100 per cent relative humidity in house
IYR	=	the year of the program run or source year of the weather data

'J'

J1 = an integer counter for use in calculating K_{eff} of house

'K'

K = the time subscript used for computing heat transfer rates. Eight steps back in time are taken.

KDAY = the current value of the day of the month.

KDAYND = the value of KDAY at which the program is to end (user supplied data)

KFLAG = power consumption flag. Results in an hourly response notation for the following operating conditions and output variables:

BLANK; blank space--house temperature is floating, no power being consumed,
KLAXON; $--furnace is on,
KAIRON; *--air conditioner or evaporative cooler is on,
KOVRLD; **--air conditioner or evaporative cooler unable to handle cooling load.
KVENT; +--house is venting

KSTORE = current day of month as far as program operation is concerned

'L'

L	=	wall component numbering subscript, L=1 means air and L=2 means stud component
LEGEND(36)	=	an array used to echo input comment cards to the end of the output format. These cards may contain any information the user desires concerning weather, house construction, etc. (user supplied data)
LOADAC	=	summation of sensible building load during AC
LOADEC	=	summation of sensible building load during evap. cooling
LOSS	=	total heat transfer rate to house less solar heat gain through windows but including internal loads, Btuh

'M'

MMO	=	integer check to determine whether a month is odd or even
MO	=	the value of the current month of the year, 1-12
MOEND	=	the month at which the program is to end, (user supplied data)
MSTORE	=	current value of month as far as a program operation is concerned

'N'

NDAY = ending Julian day of program

NHR = an integer index used throughout the main program; NHR = 1 + INT(ZST)

NHRAC = number of hours during which the AC turned on

NHREC = number of hours during which evap. cooling is on

NHRVOL = number of hours at each evap cooler speed

NIGHT = the time from bed to breakfast, considered off-hours

NO = solar power arriving through fenestration into north zone of house

NSUN = an integer counter used to indicate the total number of hours of net heat gain through windows. Only used Oct-Apr

NUMBER = a 12-member array containing the number of days in each month 'o'

'P'

P	=	(steady state losses at walls and glass)* (initial float branch entry temperature less house equilbrium temperature)
PCC	=	'P' divided by the house specific heat
PCTGLS	=	percentage of south face of house which is glass
PCTGLW	=	" " west " " "
PCTGLN	=	" " north " " "
PCTGLE	=	" " east " " "
PCTGL(1)	=	percentage of south face of house which is glass
PCTGL(2)	=	" " west " " "
PCTGL(3)	=	" " north " " "
PCTGL(4)	=	" " east " " "
PV	=	vapor pressure of water

'Q'

QDACC	= an intermediate derivation of the heat gain to the house due to buoyancy currents divided by the house specific heat
QDBOUA	= an intermediate step, the enthalpy flux per unit temperature change with a 3-hour relaxation time
QDBOUB	= energy transfer due to buoyancy because of the temperature difference--this is the total heat
QDBUOY	= total free convective heat transfer between zones due to buoyancy currents
QDDIFF	= difference between south and north heat transfer rates, Btuh
QDFURN	= power level of furnace, Btuh
QDNTOT	= hourly heat gain (loss) to house through north wall and windows, Btuh
QDO	= cumulative furnace power consumption one hour ago, Btu
QDSTOT	= hourly heat gain (loss) to house through south wall and windows, Btuh
QDWALL(1)	= algebraic heat flow/surface density into house via south face, Btuh/SqFt
QDWALL(2)	= " " " " west " "
QDWALL(3)	= " " " " north " "
QDWALL(4)	= " " " " east " "
QDX	= algebraic rate of change of heat energy content of house, Btuh (Q Dot eXternal)
QLATNT	= total latent cooling load of the house, Btuh
QLATN2	= the internal latent cooling load
QLINFT	= total latent infiltration (Btu) for hour
QLOSS	= total solar heat transfer rate to house through the glass, plus algebraic heat transfer rate through the walls, plus convective h.t. rate at glass, plus h.t. rate through the roof, plus heat lost through the floor, plus infiltration heat transfer rate, Btuh. Note that internal loads are not included in QLOSS term.

'Q' (continued)

QLTOT = cumulative total of latent cooling loads, Btu

QNIGHT = the hourly furnace energy consumption between midnight and 0800 HRS

QNO = the cumulative power consumption of the furnace one hour ago, used only for hours midnight to 0800

QQ = apportionment factor for furnace load. "QQ" is normally defined as -(QLOSS + INTLD)/-QLOSS for the case of a net window heat loss. When the house gains heat through the windows, QQ = -(QLOSS + INTLD)/(-WLOSS + WLOSS + WGAIN).

QSACT = total hours sensible load in AC

QTOTAL = cumulative heat energy consumed by furnace, Btu

'R'

REPHR	= stores heat losses of a representative night hour, used to apportion furnace load at thermostat set-forward time
RFTILT5	= tilt from horizontal of south roof portion (user supplied data)
RFTILT6	= tilt from horizontal of north roof potion (user supplied data)
RH	= relative humidity, decimal fraction
RHAVAC	= used in AC to find average relative humidity
RHAVEC	= used in evap. cooler branch to find average relative humidity
RHMAC1	= relative humidity associated with max temp in AC
RHMAX	= maximum relative humidity allowed
RHMEC1	= RHMAC1 but evap cooling
RHMIN	= minimum humidistat relative humidity
RHMXAC	= maximum relative humidity during AC operation
RHMXEC	= maximum relative humidity duing evap. cooler operation
RHSENS	= allowable deviation from RHSET (user supplied data)
RHSET	= humidistat set point (user supplied data)

'S'

SHDCF	= shading coefficient, (.95 if window is not shaded) to account for dirt and dust that accumulates. SHADCF is less than unity if window is shaded by drapes or blinds. (user supplied data)
SHGSUM	= directional solar heat gain sums per unit area of glass, Btuh-Sq·Ft
SHG1(4)	= the glass solar heat gain factor for the previous hour
SHG2(4)	= the glass solar heat gain factor two hours back in time
SHG4(1)	= solar power flux density through a south window, Btuh/Sq.Ft
SHG4(2)	= " " " " west " "
SHG4(3)	= " " " " north " "
SHG4(4)	= " " " " east " " (used in hourly response output)
SO	= solar power arriving through fenestration into south half of house
SLP1	= slope of temperature-time history curve of the floating house computed using TTL1, $^{o}F/hr$
SLP2	= new slope of the floating house temperature history curve, computed using TTL2, $^{o}F/hr$
SX	= cumulative value of degree days
SXX	= square of degree-day value
SXY	= power consumption--degree day product
SY	= hourly furnace power consumption, therms
S(1)	= latitude, degrees north positive
S(2)	= longitude, degrees west from Greenwich Meridian positive
S(3)	= time zone number ATLANTIC = 4 EASTERN = 5 CENTRAL = 6 MOUNTAIN = 7 PACIFIC = 8 (user supplied data)
S(36)	= the fraction of window that is sunlit
STABLE	= stability factor in choosing ISETPS, DTIME

'T'

TAMCOL	=	night cooldown temp if IFLAG10 is not zero
TAVAC	=	average temperature during AC
TAVEC	=	average temperature during evaporative cooling
TBFXFL	=	steady state transparency of the floor to heat Btuh/^{o}F, U_f * A_f * 0.5
TBFXGL	=	total steady state transparency of the glass to heat Btuh, Ug * Ag
TBFXWLS	=	total steady state transparency of the walls to heat Btuh, Uw * Aw
T(I,K)	=	temperature inside I^{th} wall K hours back in time, ^{o}F
TCOIL	=	AC minimum coil temperature
TDAYMN	=	daytime value of TLOW, i.e. the furnace thermostat setting, ^{o}F, (user supplied data)
TECMIN	=	minimum evap cooler temp allowed if IFLAG8=3
TEMPDIF	=	difference in temperature between inside and outside (DRYBLB-TTB)
THEOU	=	theoretical 'K' value of house, Btu/DDAY/Sq·Ft
THI	=	the temperature above which the house is unbearable, ^{o}F, (user supplied data)
THOLDAY	=	daytime holiday thermostat setting, ^{o}F (user supplied data)
THOLNT	=	nighttime holiday thermostat setting, ^{o}F (user supplied data)
TIME1	=	a real flag which, when - 1, allows exit from float branch
TIME2	=	location in time of the floating house, the incremental value of TIME
TLFXWL	=	steady-state difference between north and southzone, heat transfer rates, Btuh/^{o}F (use TTL)
TLOW	=	the house temperature below which the furnace turns on, ^{o}F
TLOWAC	=	furnace temperature during cooling season (user supplied data)

TMAXAC = max temp realized during AC operation

TMAXEC = same but evap cooling

TMXAC1 = temp associated with max relative humidity during AC

TMXEC1 = same but evap cooling

TNIGHT = nighttime furnace thermostat setting, ^{O}F, (user supplied data)

TNORTH = temperature in north zone of house, used as heading for hourly response output

TOFFEC = temp evap cooler shuts off at

TOUT = outdoor air temperature, used as heading for hourly response output

TOTLFRN = Total Furnace heat delivered

TPLOT = Real function of fix the scale of plots by subroutine Graffer.

TSET = cooling set temperature

TSLAIR = sol--air temperature, ^{O}F

TSOUTH = temperature in south half of house, used as heading for hourly response output

TSR(I) = inside temperature computed from TTB, wall heat transfer rate, & U-Values, used to compute heat gains to house upon exit from cooling branch

TTBOLD = the old value of TTB, one hour ago, ^{O}F

TTB = mean of north and south zone temperature, ^{O}F; TTB activates the thermostat

TTBR = TTB in absolute temp,

TTL = half the difference of north zone and south zone temperatures, ^{O}F

TTL1 = same as TTLOLD

TTL2 = new value of TTL1, computed from the average of the temp-time history curve and the time step increment

TTLASP = asymptotic temperature difference, i.e., the difference between the instantaneous house temperature and the equilibrium temperature of the house, ^{O}F

TTLOLD = old value of TTL, one hour ago, ^{O}F

'U'

UDAY	= overall heat transfer coefficient of the window glass during the day, (user supplied data)
UFLOOR	= overall heat transfer coefficient of floor, Btuh/Sq·Ft-^{o}F, (user supplied data)
UGLASS	= overall heat transfer coeff. of the window glass, Btuh/Sq·Ft-^{o}F = 0.6 for double paned windows = 1.1 for single paned windows
UNIGHT	= overall heat transfer coefficient of the window glass during the night, (user supplied data)
USEFL	= useful solar heat gain through windows, Btuh
USEFLT	= total useful solar heat gain to house through the windows, Btuh
UWALL	= overall heat transfer coefficient of wall, Btuh/Sq·Ft-^{o}F

'V'

V	= volume of moist air, cu. ft./lbm of dry air
VBOUY	= flow velocity of a buoyancy current as predicted from pressure difference between north and south zones of house
VBOUYB	= driving force behind buoyancy currents due to density differences alone
VLEFMN	= volume associated with minimum effect during evap cooler sizing (CFM)
VLEFMX	= volume associated with maximum effect during evap cooler sizing (CFM)
VOLAVE	= average volume during evap cooler sizing (CFM)
VOLM	= storage array for CFM during evap cooler sizing
VOLMAX	= maximum CFM during evap cooler sizing
VOLMIN	= minimum CFM during evap cooler sizing
VOLROM	= volume of house

'W'

W	= humidity ratio, lb water/lb dry air
WALLAR(1)	= amount of non-glass area on south face of house, Sq·Ft
WALLAR(2)	= " " west "
WALLAR(3)	= " " north "
WALLAR(4)	= " " east "
WALLAR(5)	= " " south roof "
WALLAR(6)	= (user supplied data) north roof "
WDATA(1)	= outside air temp. from drybulb ^{o}F, from weather tape
WDATA(2)	= " " wetbulb ^{o}F.
WDATA(3)	= dewpoint
WDATA(4)	= atmospheric pressure, inches Hg
WDATA(5)	= cloud amount
WDATA(6)	= cloud type
WDATA(7)	= wind speed, knots
WDATA(8)	= humidity ratio lb/lb
WDATA(9)	= density, lb/ft^3
WDATA(10)	= enthalpy, Btu/lb
WINECT	= total window heat flux during evap cooling
WGAIN	= total solar heat gain to the house through its glass, Btuh
WINGAIN(I)	= solar heat gain to the house through glass on I^{th} wall, Btuh
WINLOSS(I)	= convective heat transfer rate from the house through glass on I^{th} wall, Btuh
WINNET(I)	= net heat transfer to (from) house through I^{th} wall windows, Btuh
WINNETC(I)	= net heat gain (loss) to house through windows on I^{th} wall during air conditioner operation, Btuh
WINPORT	= that portion of furnace load due to window losses, Btuh
WLCPORT	= heat gain or loss through walls due to cooling operation, Btuh
WLCTOT	= net gain (loss) to house through walls during air conditioner operation, Btuh
WLDOTQ	= algebraic heat into house, Btuh, through walls = WALLAR(1) * QDWALL(1) + ... + WALLAR(6) * QDWALL(6)
WLECPT	= wall loads evap cooling apportioning
WLECT	= total wall heat flux during evap cooling

'W' (continued)

WLOSS = total heat loss from house due to convection at windows, Btuh

WLPORT = that portion of furnace load due to wall losses, Btuh

WLTOT = total heat transfer rate to house through the four walls, Btuh

WNCPORT = heat gain or loss through windows due to cooling operation, Btuh

WNECPT = window loads evap cooling apportioning

WROOM = humidity ratio (lbs H2O/lbs dry air) in house

'X'

XMAX	= limits of X axis of OUTPUT graph
XMIN	= " " " "

'Y'

YMAX = limits of y axis (Btuh) of OUTPUT graph

YMIN = limits of y axis (Btuh) of OUTPUT graph

'Z'

Z = the steady-state "UA" products for windows and walls multiplied by the house average equilibrium temperature "AA/BB"--essentially T * steady-state losses

ZST = zonal standard time at the site, in hours (0-23)

ZSTORE = varies from 1 to 24, the stored value of zonal standard time used in the monthly cumulative furnace and air conditioner loads accounting output summary.

8. IMPORTANT VARIABLES IN TWOZONE SUBROUTINES AND FUNCTIONS

(Only important variables from TWOZONE subroutines and functions are listed here. But all the subroutine and function names are included in case the user wishes to write any notes in front of any of them)

<u>ACDGDY</u>

ACDGDY = accumulated cooling degree-days

BASE = base temperature used in the calculation

IBUF = array of weather data

<u>ACDGHR</u>

ACDGHR = accumulated cooling degree-hours/day

IBASE = base temperature used in the calculation

IBUF = array of weather data

<u>CCM</u>

<u>CODE</u>

<u>COOLIT</u>

AIRINF = mass of air that infiltrates house during AC

CCC = apportioning factor for sensible loads

CCLAT = apportioning factor for latent loads

COMPHR = total time AC compressor was on

EFECT = variable value of effect

FANHR = total time air conditioner was on

FANMAS = mass of air blown through air conditioner

FRAC1 = fraction of time compressor is on in AC

H = enthalpy of air

HIN = enthalpy of air into air conditioner

HOUT = enthalpy of air leaving air conditioner

H2OINF = pounds of water that infiltrates

H2OINT = pounds of water from internal latent loads

H2OREM = water removed by air conditioner (lbs)

H9ORH = air enthalpy at 90 percent relative humidity

IJ = counter for humidistat iterations in evap cooling

PSF = pressure in lbs/square feet

QCHECK = variable used to see if air conditioner has exceeded its capacity

QDXDT = DSX*DTIME (used in AC)

QLACT = air conditioners hourly latent load

QLATAC = air conditioners latent load during DTIME

QLTINF = air conditioner latent infiltration load during DTIME

QSENAC = sensible AC load during DTIME

RHOAIR = density of air

TBAR = room temperature used in intermediate cooling calculations

TEC = temperature of air discharged from evaporative cooler

TIN = used like TBAR

TINOLD = TIN at previous DTIME

TOUT = temperature of air coming from air conditioner

VOL = present CFM of evap cooler

W = humidity ratio (lbs H2O/lbs dry air)

WACOUT = humidity ratio of air coming out of air conditioner

WROM = humidity ratio in room

WSAMB = saturated humidity ratio outside (at WETBULB temp)

WSAT = saturated humidity ratio

DEGDAY

BASE = reference temperature for heating degree-day calculation, 65°F

DEGDAY = accumulated degree-days/month calculated once a day

IBUF = array of weather data

DEGHR

IBASE = reference temperature for heating degree-hours/day, 65°F

DEGHR = accumulated degree-hours/day, calculated once a day

IBUF = array of weather data

DEGNITE

DEGNITE = accumulated degree-hours for the first eight hours after midnight/day

IBASE = reference temperature for heating degree - hours, 65°F

ENVELOP

FIXSET

GLASS

GLAZE = see input variables

GLTYP = see input variables

SHDCF = shading coeff of window, see input variables

SHG = window area * SHDCF * SHGF, BTUH

SHGF = solar heat gain factor through glass, BTUH/Sq.Ft

GRAFFER

HOLIDAY

KALEND

IDAY = the Julian day for Jan. 1st of test yr.

LDAY = the Julian day

RANGER

READP

NAME (L,I) = alphanumeric description of L^{th} component of I^{th} wall

PSY1

CDB = drybulb temp, °C

CWB = wetbulb temp, °C

DB = drybulb temp, °F

PB = barometric pressure, inches Hg

WSTAR = specific humidity

<u>SHG</u>

<u>SKINS</u>

<u>SUN</u>

C1 = cos(x)
C2 = cos (2x)
C3 = cos (3x)

H = the hour angle, degrees

HP = cosine of sunrise hour angle

HP1 = sunrise or sunset hour angle, in degrees, mornings positive

KS = an integer center to calculate declination, equation of time, and solar factors A,B & C

LATD = latitude of location, degrees positive north

LOND = difference in longitude between location of house and standard meridian of time zone, degrees

LONG = longitude of location, degrees west positive

MERID = 15 * TIME ZONE NUMBER, the standard meridian longitude

SHADE(I) = array: fraction of I^{th} wall or roof which is in sunlight I = 1-5

STEST = COS(s), direction cosine

STEST1 = internal test for altering sign of COS(S)

S(4) = days from start of year
S(5) = time, hours after midnight
S(6) = daylight saving time indicator; 1 if DST is in effect, 0 otherwise
S(7) = ground reflectivity
S(8) = clearness number

S(9) = wall azimuth angle, degrees from south
S(10) = wall tilt angle, degrees from horizon
S(11) = sunrise time, hours after midnight
S(12) = sunset time

<u>SUN</u> - (continued)

S(13)	=	cos(Z), cosine of zenith angle (angle between incident beam and vertical), for a horizontal surface only.
S(14)	=	cos(W), cosine of angle between incident beam and N-S axis of earth
S(15)	=	cosine(S) = SQRT(1 - $\cos^2$(Z) - $\cos^2$(W))
S(16)	=	ALPHA = cosine of wall tilt angle
S(17)	=	BETA = sin(WA) * sin(WY), a measure of how much the surface has been raised from horizontal and pivoted east or west
S(18)	=	GAMMA = cos(WA) * SIN(WY), a projection of the tilted surface onto a N-S line
S(19)	=	cosine of angle of incident beam radiation
S(20)	=	the solar altitude angle, in degrees from the horizon
S(21)	=	the solar azimuth angle, in degrees from south
S(22)	=	diffuse sky radiation on a horizontal surface, S(22) = BS * CCM.
S(23)	=	diffuse ground reflected radiation, S(23) = BG & CCM. S(23) = GROUND REFLECTIVITY * (DIFFUSE SKY RAD, on a HORIZ. SURF. + DIR. NORMAL RAD. * COS(Z)).
S(24)	=	direct normal radiation, S(24) = IDN * CCM. S(24) = SOLAR FACTOR 'A' * CLEARNESS NUMBER & CLOAD COVER MODIFIER EXP(SOLAR FACTOR 'B"/COS(Z))
S(25)	=	total solar radiation intensity--direct, diffuse, and diffuse ground reflected components
S(26)	=	diffuse sky radiation intensity--S(26) = S(22) * DECLINATION ANGLE.
S(27)	=	ground reflected diffuse radiation intensity S(27) = DIFFUSE GROUND REFLECTED RADIATION * (1. - COS(WALL TILT ANGLE))/2
S(28)	=	sundeclination angle, degrees
S(29)	=	equation of time, in minutes
S(30)	=	SOLAR FACTOR 'A'
S(31)	=	SOLAR FACTOR 'B'
S(32)	=	SOLAR FACTOR 'C:'

Variables S(28) thru S(32) are same as in NBSLD, page 53d.[8]

S(33)	=	CLOUD COVER MODIFIER
S(34)	=	intensity of direct solar radiation on surface
S(34)	=	IDN * CCM * COS OF INCIDENCE ANGLE
S(35)	=	hour angle, in degrees, mornings positive, afternoons negative.

X = 2n/366, where n is the Julian day

XS = solar factor 'B'/cosine of zenith angle

X1 = magnitude of sunrise or sunset hour angle, degrees
X2 = magnitude of hour angles, degrees

SUN - continued

Y = sun declination angle, radians

YY = latitude, north positive, radians

TAR

WARNUM

WTHR

SHGF = solar heat gain through glass, Btu/Sq.Ft

WRSHF = solar energy incident on external surface of wall or roof, Btuh/Sq·Ft

WXDATA

X-LABEL

Y-LABEL

GRAFPAC

JDAY

NUMARG

9. SUBROUTINE AND FUNCTION PROGRAM DESCRIPTIONS

REAL FUNCTION ACDGDY(MO, KDAY) - Calculates the air-conditioning degree-days with a base temperature of 78°F, or user's choice.

REAL FUNCTION ACDGHR(MO, KDAY) - Calculates the air-conditioning degree hours with a base temp. of 78°F, or user's choice.

FUNCTION CCM(SALT, NTYPE, TC) - Calculates a cloud cover modifier term (for use in subroutine SUN) which is dependent on the solar altitude angle, the cloud type, and the total sky cover. Data for CCM factors CC1 through CC4 are taken from the NECAP Engineering Manual, pg, 3-24.[5] Note that CC1 and CC3 are for solar altitude angles of less than 45°. Depending on the value of NTYPE, cirrus and cirrostratus clouds or stratus clouds are assumed. For figuring NTYPE, the lowest cloud types are used. CCM used when calculating the amount of solar insolation striking a given surface.

COOLIT (TTB, QDX, CLD, ECLD) - Calculates the cooling load and new house temperature when given the old temperature and the sensible and latent heat loads. The subroutine will simulate either an air conditioner or an evaporative cooler depending on which flags the user sets in the input deck. Data is stored for output at the end of the run. For a more detailed description, see Appendix I.

CODE - used to label axes in the program output.

REAL FUNCTION DEGDAY(MO, KDAY) - This function calculates the heating degree-day value for a data base of 65°F, or user's choice.

REAL FUNCTION DEGHR(MO,KDAY) - This function calculates degree hours on any day from a base temp of 65°F, or user's choice for purposes of heating load calculations.

REAL FUNCTION DEGNITE (MO, KDAY) - Calculates the degree hours for the first eight hours after midnight, with a base temp of 65°F, or user's choice.

ECON - The subroutine ECON is called at the end of the main program if IFLAG11 has been set greater than or equal to 1 in the input deck. It calculates resource use and costs by fuel category for the current run and compares with the base case data if available. If all base case fuel uses were set to zero in the input deck, BFLAG is set to 1 and control is returned to the main program, where a base case report is printed. If non-zero value is found, the beginning and end dates of the current run are compared with those of the base case to insure that legitimate loads comparisons can be made. If the dates differ, control is returned to the main program with BFLAG set to zero. This causes the printing of a user error message. If the dates agree, the subroutine goes on to calculate economic statistics which evaluate the alternative conservation strategy and compare it to the base case. These statistics are returned to the main program, with BFLAG set to 2. This causes the printing of an economic report.

The input to ECON is contained in cards 34, 35, and 36 of the input deck. A blank for any of the values read from the input deck will cause an abort. No default values are assigned. Either FANP and COMPP or EER in card 36 are used. EER takes precedence if it is set greater than zero.

The other inputs to ECON come from the main program and the subroutine COOLIT. These include the heating load (QTOTAL, HEAT), number of Kwh used by the evaporative cooler (GTB(5), ECOOL), the cooling load (ACTOTAL, ACOOL), AC compressor hours (COMPHR), and AC fan hours (FANHR).

The subroutine begins by scaling several factors and calculating the DINF array, which is the discount-inflation factor for each fuel. Heating, cooling, and total fuel use and costs are calculated as linear functions of the equipment and economic parameters and the loads. This is an approximation used to simplify the input to the program. If the current run is a base run, control returns to the main program and these results are used in a base case report. If the current run is a legitimate comparison run, ECON then calculates the costs for the base case fuel uses.

In the next sections replacement years and a study life are calculated from the lifetimes of the options. In no case does the life of the comparison exceed 25 years, as per ERDA guidelines. The capital costs of replacement are reduced to present values and totaled. The residual value of the equipment at the end of the study life is calculated using straight-line depreciation, and then discounted to present value. The incremental capital cost of the alternative is then found. This equals the present value of the extra capital outlays necessary. The loop that follows calculates the present value of the cost of fuel and differential maintainance for the length of the study. In both the base and alternative cases the fuel costs computed earlier are multiplied by the appropriate discount-inflation factor for each year and then accumulated. These are later combined with the present value of maintenance to arrive at the present value of all the years' savings. The discounted payback period is equal to the number of years needed for the discounted yearly savings to equal the incremental capital cost of the alternative. If the incremental cost is negative (a net capital savings) the payback period is meaningless and left set to zero. If the payback period exceeds the study life, it is set to 9999 to indicate that it goes beyond the bounds of the study. The final calculations provide the savings-per-investment ratio, the number of Btu's saved per year, and the number of Btu's saved per annual discounted investment dollar. Control returns to the main program, where a final report is printed out, including explanatory labels.

ENVELOPE - used by GRAFFER

SUBROUTINE FIXSET (A,B,C,D,E,F,G,N) - Calculates values of heat loads from a representative hour during the night time thermostat setback for use when apportioning so that the furnace load can be apportioned correctly in the morning. The next entry is from the heating branch via statement TW0Z0484. The logic is repeated, and new values of the variables listed above are stored for furnace load apportionment. Factors A through G(I) are defined as the previously stored variables AA through GG(I), so that the latest values of hourly losses are always in storage.

N = 1 stores information

N = 2 retrieves information

This routine is also used for holiday setbacks.

SUBROUTINE GLASS (SHGF) - This subroutine is called by subroutine WTHR for the purposes of establishing the solar heat gain factor for the window glass of the house. "GLASS" first defines variables TR(7) through TR(9), and then calls subroutine TAR(TR) to compute transmission, absorption and reflection coefficients of the window glass for both direct and diffuse components of solar radiation.

Using data from subroutines SUN(I) and TAR(TR), subroutine GLASS initializes variables SH(1) through SH(17) and supplies these as input data to NBSLD subroutine SHG(SH). "SHG" calculates the solar heat gain through the windows, SH(18), by actually setting up a resistance network for the window pane(s). SH(18) is returned to subroutine GLASS, which defines the solar heat gain factor, SHGF, to be equal to SH(18). The SHGF parameter is returned to subroutine WTHR for computation of the room response to the solar radiation.

GRAFFER - Generates the printer plot the program OUTPUT.

SUBROUTINE HOLIDAY (KDAY, MO, IYR, HOL) - This subroutine checks each day to see if it is a holiday according to federal Monday holiday law. It establishes "HOL," the holiday indicator, which is employed in the core of the program to alter furnace logic according to holiday thermostat settings.

FUNCTION JDAY (KDAY, MO, IYR) - Calculates the Julian day, conducts a check to see if the test year is a leap year, and supplies the Julian day in correct format. For example, March 2, 1976, would be written 76062 for program use.

SUBROUTINE KALEND (MO, KDAY, IYR) - For tape input only, this subroutine calculates the Julian day, subtracts one day from the Julian day, and uses this as a check for program termination. (One year of data is the maximum amount allowed.) KALEND then positions the weather tape.

RANGER - chooses an appropriate scale for graffer.

SUBROUTINE READP - The purpose of subroutine READP is to read data from the INPUT deck concerning the type and fraction of each wall component, read the transfer function coefficients for each component of the walls and ceiling, sum the BN, CN, and DN values and conduct a check on their validity, calculate U-VALUES for the walls and ceiling from these transfer function coefficients, read a schedule of internal loads, and execute a program termination control routine.

The program is presently set up for two-component wall, which is analyzed for eight hours backward in time. It is assumed that all walls are constructed alike -- the ceiling may be defined differently.

SUBROUTINE PSY1 (DB, WB, PV, W, H, V, RH) - Calculates vapor pressure (PV), humidity ratio (W), enthalpy (H), volume (V), relative humidity (RH), and dew-point temperature when the dry-bulb temperature (DB), wet bulb temperature (WB), and barometric pressure (PB) are given. PB must be in inches of Mercury. (RE: NBSLD subroutine PSY1). Used during air-conditioning.

FUNCTION PVSF(X) - Calculates the relative humidity as a function of temperature and vapor pressure in inches of mercury. Called by PSY1.

SUBROUTINE SHG(SH) - Refer to the discussion of subroutine GLASS(SHGF).

SUBROUTINE SKINS (MO, KDAY, NHR, TTB, TTL) - This subroutine computes the hourly heat transfer through walls and roof.

SUBROUTINE SUN(I) - This is a major subroutine which can be subdivided into two parts:

PART I - SUN2/SUN144

This section computes solar angles and all other parameters necessary to calculate the intensity of direct solar radiation on each wall.

PART II - SUN146/SUN189

Part II employs tangents of angles calculated in subroutine TANGLE to compute the amounts of shadowing and shading of walls due to neighboring houses, trees, and overhangs at ceiling and windows.

SUBROUTINE TAR(TR) - Its function is to compute the transmission, absorption and reflection coefficients of window glass for direct and diffuse components of solar radiation for the case of single or double-glazed windows.

SUBROUTINE WTHR (MO, KDAY, NHR) -

WTHR calls:

WXDATA - To read the weather data,

SUN(I) - to compute the solar radiation intensity and shadowing for each wall,

and GLASS - to compute solar heat gain through windows.

Subroutine WTHR uses this information to compute the effective solar heat gain through GLASS using exponential delay with a three-hour time constant, and to compute the solar heat gain through walls and roof.

SUBROUTINE WXDATA (MO, KDAY, NHR, WDATA) - This subroutine reads the weather tapes, converts the weather data to real numbers, and supplies these data to subroutine WTHR. TWOZONE requires ten weather variables as input: drybulb and wetbulb temperatures, dew point, barometric pressure in inches of mercury, cloud amount, cloud type, wind speed in knots, humidity ratio, density, and enthalpy. The program currently employs test reference year tapes obtained from NOAA.[1] For California, CTZ tapes are also available. On the LBL system, the weather tapes are stored in a packed format in the CALERDA weather library. To read non-packed tapes, a different subroutine is available.

X-LABEL - both of these make labels for GRAFFER.
Y-LABEL

GRAFPAC - used with GRAFFER.

NUMARG - used by GRAFFER.

ACKNOWLEDGMENT

This work was supported by the U.S. Department of Energy under Contract Number W-7405-ENG-48.

REFERENCES

1. ASHRAE, Test Reference Year, Tape Format and Documentation, U.S. Dept. Commerce, NOAA Form 79-344, Sept. 1976.

2. Dean, E. and Arthur Rosenfeld. "Modeling Natural Energy Flows in Houses," Energy and Buildings 1:1 May 1977, pp. 19-26.

3. MacPhee, C. (ed.) ASHRAE Handbook of Fundamentals, American Society of Heating, Refrigerating and Air Conditioning Engineers, NY, 1972, or 1977.

4. Mitalas, G. P. & J. G. Arseneault, NBS Use of Computer Science for Environmental Engineering Related to Buildings, Ed. T. Kusuda, USDC: Building Science Series 39, Oct. 1971, "Fortran IV Program to Calculate Z - Transfer Functions for the Calculation of Transient Heat Transfer through Walls and Roofs," pp 633-67.

5. NECAP Engineers Manual.

6. Stephenson, D. G. and G. P. Mitalas, Calculation of heat conduction transfer functions for multi-layer slabs; submitted to ASHRAE for presentation, January, 1971.

7. Wall, L.W., Tom Dey, Ashok J. Gadgil, Alan B. Killy and Arthur H. Rosenfeld 'Conservation Options in Residential Energy Use: Studies Using the Computer Program TWOZONE,' LBL, UCB, report LBL-5271.

8. Kusuda, NBSLD, the Computer Program for Heating and Cooling Loads in Buildings, U.S. Department of Commerce, National Bureau of Standards, NBS Building Science Series, 69, July 1976.

APPENDIX I: Subroutine COOLIT

Author: Steven Gates

Subroutine COOLIT simulates the operation of either an air conditioner and/or an evaporative cooler. This subroutine is called by the cooling branch of the main program. Subroutine PSY1 is called by COOLIT for psychometric calculations.

INPUT

Hourly input to this subroutine is house temperature (TTB), heat fluxes (QDX, WLDOTQ, CLDOTQ, INLOAD, INFILOS, WLOSS, WGAIN), scheduled internal latent heat gains (HLATNT), internal humidity ratio (WROOM), weather data (WDATA), the fraction of the hour during which cooling is needed (FRAC), and the present time (NHR).

Evaporative cooling parameters initialized in the main program at the beginning of the run are mode flags (IFLAG8, IFLAG9, IFLAG10), relative humidity control values (RHSET, RHMAX, RHMIN), the maximum possible effective wet bulb depression (EFFECT), evaporative cooler speeds and wattages (ECVOL(4), EWATT(4), ISPEED), and the temperature at which the cooler turns off.

Air conditioning parameters initialized in the main program at the beginning of the run are the mode flags (IFLAG8, IFLAG9, IFLAG10), the air conditioner capacity (ACAPAC), fan volume (FANVOL), the number of parts the hour will be broken into for latent load stability (ISTEPS, DTIME), sensible and latent infiltration coefficients (A, B, ALAT, BLAT) a stability factor for adjusting ISTEPS and DTIME if the air conditioner is being sized (STABLE), and minimum coil temperature and enthalpy (TCOIL, HCOIL).

Miscellaneous input includes the nighttime summer cooling temperature (TAMCOL), and the hours of the day that the occupants go to bed and get up (BED, BRKFST). Parameters initialized by the main program are RHMAX, RHMN, ISPEED, ISTEPS, DTIME, and STABLE. The rest are specified by the user.

OUTPUT

Hourly output from COOLIT consists of the house temperature at the end of the hour (TTB), the air conditioning or evaporative cooling load (CLD, ECLD), and the humidity ratio (WROOM).

Evaporative cooling variables stored for the main program for output at the end of the run are heat gains (window, wall, ceiling, floor, infiltration, and internal-load), apportioning variables (WINECT + WNECPT, WLECT + WLECPT, CLECT + CLECPT, FLECT, INFECT, INLECT + INLECPT), comfort analysis (temperature + relative humidity) variables (ITEC, IRHEC, IRHECT, TAVEC, TMAXEC, RHMEC1, RHAVEC, RHMXEC, TMEC1) for a comfort table of temperature vs relative humidity, the amount of water used in the cooler (H2OEC), and, if flagged, sizing variables (VOLM, EFT, EFTT, VOLMAX, EFTVMX, VOLMIN, EFTVMN, EFTMAX, VLEFMX, EFTMIN, VLEFMN, VOLAVE, EFTAVE) for a sizing table.

Air conditioning variables stored for the main program for output at the end of the run are heat gain and apportioning variables (WINNETC + WNCPORT; WLCTOT + WLCPORT, CLCTOT + CLCPORT, FLCTOT, + INFCPOR, INLCTOT + INLCPOR), comfort analysis variables (ITAC, IRHAC, IRHACT, TAVAC, TMAXAC, RHMAC1, RHAVAC, RHMXAC, TMXAC1) for a temperature vs relative humidity comfort table and, if flagged, sizing variables (ACSIZE, CLDMAX, CLDMIN) for a sizing table.

MODES OF OPERATION

The mode flags, IFLAG8, IFLAG9, and IFLAG10, determine how the cooling equipment is to be operated. IFLAG8 determines the evaporative cooler mode. IFLAG8 = 0 (or not specified) does not allow evaporative cooling. IFLAG8 = 1 runs the cooler on the basis of internal temperature only. IFLAG8 = 2 runs the cooler on the basis of both house temperature and internal relative humidity (i.e., a humidistat). IFLAG8 = 3 is like IFLAG8 = 2 but also assigns a minimum temperature to the air leaving the cooler (this is not a control currently available on evaporative coolers but may be useful if it is desired to cool a house at night without circulating uncomfortably cold air). IFLAG8 = 4 sizes the evaporative cooler to whatever size is necessary to hold the house at THI. IFLAG8 = 5 is like IFLAG8 = 4 but sizes on the basis of both internal relative humidity and temperature. When one of the sizing modes is specified, a sizing chart of volume vs EFECT (number of hours at each volume and effectiveness) is printed at the end of the run. If IFLAG8 = 4, the user specifies effectiveness (usually around 0.8), if IFLAG8 = 5, the routine specifies the effectiveness as a function of the desired relative humidity, RHSET.

IFLAG9 determines the air conditioner mode. IFLAG9 = 0 (or unspecified) does not allow air conditioning, unless overridden by IFLAG10. IFLAG9 = 1 runs the specified air conditioner in the mode determined by other flags (see table below). IFLAG9 = 2 sets the size of the air conditioner to whatever capacity is needed in order to handle all the sensible and latent load and keep the house at THI. When IFLAG9 = 2, a chart of the number of hours at each air conditioner capacity is printed at the end of the run. Whenever IFLAG9 is not equal to zero, a chart of temperature vs. relative humidity is printed at the end of the run.

IFLAG10 determines the night time cooling mode between the hours of BED and BRKFST. IFLAG10 = 0 (or unspecified) does not allow any special cooling strategies at night. IFLAG10 = 1 allows the house to vent down to the temperature set by TAMCOL during the cooling season. IFLAG10 = 2 sets the cooling thermostat temperature to TAMCOL at night. IFLAG10 = 3 runs the evaporative cooler at night (set temperature = TAMCOL) and the air conditioner during the day (set temperature = THI). IFLAG10 = 2 will override IFLAG9 = 0 if IFLAG8 = 0. IFLAG10 = 3 will always override IFLAG9 = 0.

IFLAG8, IFLAG9, and IFLAG10 are used in combination to determine the cooling strategy of the air conditioning months. Some combinations are useful while others may give meaningless results. The following table is a summary.

TABLE OF COOLING MODES

IFLAG8,	IFLAG9,	IFLAG10	COMMENTS
0	0	0	No AC, no evaporative cooling, no special night-time venting-strategy
1	0	0	Normal evaporative cooling controlled to THI
2	0	0	Evaporative cooling controlled to RHSET and THI
3	0	0	Evaporative cooling controlled to TECMIN in the cooler, RHSET and THI in the house.
4	0	0	Sizes the cooler on the basis of temperature
5	0	0	Sizes the cooler on the basis of both relative humidity and temperature.

TABLE OF COOLING MODES (continued)

IFLAG8,	IFLAG9,	IFLAG10	COMMENTS
0	1	0	Air conditions to THI.
0	2	0	Sizes the air conditioner to THI
0	0	1	Vent the house to TAMCOL at night during the cooling season
0	0	2	Run cooling equipment to TAMCOL at night during the cooling season
1	0	3	Runs the evaporative cooler to TAMCOL at night and the air conditioner to THI during the day.
1,2,3	1	0,1,2,3	Runs the evaporative cooler preferentially over the air conditioner in the modes specified. If the house temperature rises above THI, or the relative humidity is greater than RHSET + RHSENS, the air conditioner of specified capacity is turned on.
1,2,3	2	0,1	Runs the evaporative cooler preferentially over the air conditioner in the modes specified. If the house temperature rises above THI, or the relative humidity is greater than RHSET + RHSENS, an air conditioner of required capacity is turned on (this is a sizing run for the air conditioner in this operating mode).
0	2	0,1	Sizes the air conditioner in the modes specified
4,5	0	0,1	Sizes the evaporative cooler in the modes specified
4,5	0	2,3	Program will give meaningless data. Equipment should not be operated at night during sizing runs

TABLE OF COOLING MODES (continued)

IFLAG8,	IFLAG9,	IFLAG10	COMMENTS
0	2	2,3	As above, sizing should not be done when operating the cooling equipment at night.
4,5	1,2	0	Meaningless, since air conditioning will never be turned on during an evaporative cooler sizing run (the converse is not true).

Flags to be set to 0 may be left blank in the INPUT DECK.

CALCULATION OF VARIABLES COMMON TO THE EVAPORATIVE COOLING AND AIR CONDITIONING BRANCHES

Humidity Ratio (W, sometimes specifically WROOM, WSAT, WAMB, etc.)

Humidity ratio w is defined as the lbs of H_2O/lbs dry air. A typical value is .01. The mass fraction of water in moist air is then W/(1+W) and the mass fraction of the dry air is 1/(1+W).

Relative Humidity (RH, in percent)

To calculate the internal relative humidity when the internal humidity ratio (WROOM) and internal temperature are known, the psychrometric routine PSY1 is called with the internal temperature as both the drybulb and wetbulb argument. The humidity ratio returned is the saturated humidity ratio (WSAT) at room temperature. The percent relative humidity is then

$$RH = WROOM/WSAT*100. \qquad \text{I-1}$$

Dry Air Density (RHOAIR)

RHOAIR is calculated using the gas law d=P/RT. To calculate the density of moist air, the gas constant R must be a composite value based on the weighted mass fractions of air and water

$$R_{total} = R_{air} * 1/(1+W) + R_{H_2O} * W/(1+W)$$

where W is the humidity ratio. I-2

$$= (R_{air} + W*R_{H_2O})/(1+W)$$

The density of dry air is then equal to the total density multiplied by the mass fraction of air.

$$RHOAIR = \frac{P}{R_{total}*T} * \frac{1}{1+W} \qquad \text{I-3}$$

$$= \frac{P}{(R_{air}+W*R_{H_2O})*T}$$

In Twozone,

RHOAIR = WDATA(4) * 70.749/((53.352 + WROOM * 85.778) * (T + 460.)) I-4

when WDATA(4) = barometric pressure, (in. of H_g)

70.749 = (lb. per Sq.Ft.)/(in. of Hg)

53.352 = R_{air}

85.778 = R_{H_2O}

T = Temperature ($^{\circ}F$)

Specific Heat of Moist Air

The specific heat of moist air is equal to the sum of the weighted specific heats of air and water

$$C_p = .24 * 1/(1+W) + .444 * W/(1+W) \qquad \text{I-5}$$

EVAPORATIVE COOLING BRANCH

Theory

Evaporative cooling is based on the principle that air can be cooled by allowing water to evaporate into it adiabatically. The amount of water than can be evaporated into a unit mass of air (and thus the degree of cooling) is a function of the temperature of the air and the amount of water already in the air. Air at a given temperature is considered to be saturated when no more water can be evaporated into it. In the following discussion, it is assumed that the reader is familiar with the psychrometric chart.

The most common method of measuring the degree of saturation of air is by measuring the drybulb and wetbulb temperatures of the air. The drybulb temperature is that temperature normally read on a thermometer. The wetbulb temperature is the temperature of the same air after it

CALCULATION OF VARIABLES COMMON TO THE EVAPORATIVE COOLING AND AIR CONDITIONING BRANCHES

Humidity Ratio (W, sometimes specifically WROOM, WSAT, WAMB, etc.)

Humidity ratio w is defined as the lbs of H_2O/lbs dry air. A typical value is .01. The mass fraction of water in moist air is then W/(1+W) and the mass fraction of the dry air is 1/(1+W).

Relative Humidity (RH, in percent)

To calculate the internal relative humidity when the internal humidity ratio (WROOM) and internal temperature are known, the psychrometric routine PSY1 is called with the internal temperature as both the drybulb and wetbulb argument. The humidity ratio returned is the saturated humidity ratio (WSAT) at room temperature. The percent relative humidity is then

$$RH = WROOM/WSAT*100. \qquad \text{I-1}$$

Dry Air Density (RHOAIR)

RHOAIR is calculated using the gas law d=P/RT. To calculate the density of moist air, the gas constant R must be a composite value based on the weighted mass fractions of air and water

$$R_{total} = R_{air} * 1/(1+W) + R_{H_2O} * W/(1+W)$$

where W is the humidity ratio. I-2

$$= (R_{air} + W*R_{H_2O})/(1+W)$$

The density of dry air is then equal to the total density multiplied by the mass fraction of air.

$$RHOAIR = \frac{P}{R_{total}*T} * \frac{1}{1+W} \qquad \text{I-3}$$

$$= \frac{P}{(R_{air}+W*R_{H_2O})*T}$$

In Twozone,

RHOAIR = WDATA(4) * 70.749/((53.352 + WROOM * 85.778) * (T + 460.)) I-4

when WDATA(4) = barometric pressure, (in. of H_g)

70.749 = (lb. per Sq.Ft.)/(in. of Hg)

53.352 = R_{air}

85.778 = R_{H_2O}

T = Temperature (^oF)

Specific Heat of Moist Air

The specific heat of moist air is equal to the sum of the weighted specific heats of air and water

$$C_p = .24 * 1/(1+W) + .444 * W/(1+W) \qquad \text{I-5}$$

EVAPORATIVE COOLING BRANCH

Theory

Evaporative cooling is based on the principle that air can be cooled by allowing water to evaporate into it adiabatically. The amount of water than can be evaporated into a unit mass of air (and thus the degree of cooling) is a function of the temperature of the air and the amount of water already in the air. Air at a given temperature is considered to be saturated when no more water can be evaporated into it. In the following discussion, it is assumed that the reader is familiar with the psychrometric chart.

The most common method of measuring the degree of saturation of air is by measuring the drybulb and wetbulb temperatures of the air. The drybulb temperature is that temperature normally read on a thermometer. The wetbulb temperature is the temperature of the same air after it has been adiabatically saturated with water. As water evaporates into air, the drybulb temperature falls and approaches the wetbulb temperature.

An evaporative cooler operates on this principle by drawing air through moist pads. As the water in the pad evaporates into the air, the air temperature falls. The change in air temperature, or wetbulb depression, is a function of the difference between drybulb and wetbulb temperature and of the effectiveness EFFECT of the pads in saturating the air with water. EFFECT = $\Delta W/\Delta W(max)$. Where ΔW is the change in the humidity ratio of incoming air. A typical value of EFFECT is 0.8.

ΔT = EFFECT * (DRYBULB - WETBULB)

The temperature TEC of the air leaving the Evaporative cooler is then

TEC = DRYBULB - EFFECT * (DRYBULB - WETBULB) I-6

This cooled air is blown into the house and allowed to escape through cracks, partially opened windows,etc. Since the air entering the house from the evaporative cooler may not be much cooler than the house, a large volume of air is usually required to keep the house cool, usually a complete house air change every two-three minutes.

The temperature change in the house during the period the evaporative cooler is operating is a function of the temperature of the air entering the house from the evaporative cooler, and the heat flux into the house (but without any infiltration terms, since it is assumed that the evaporative cooler pressurizes the house).

Model

The Evaporative Cooler branch deals only with the average temperature of the North and South zones (denoted by T or TTB below). The performance of the Evaporative Cooler is approximated by the following procedure.

(Here we introduce the convenient nomenclature of initially introducing dashes in the original FORTRAN variable names, to make them easily comprehensible. We will drop the dashes later.)

1) The temperature T-EC of air entering the house via the Evaporative Cooler is calculated.

2) The heat-flux QDX into the house during the present hour is obtained from the main program. The infiltration term is subtracted off since the house is pressurized due to the Evaporatice Cooler fan.

3) Using this heat-flux, and the volume, temperature, density and specific heat of air from the Evaporative Cooler, the house temperature of the current hour is calculated (see below).

QDX has been calculated using the eight hour history of inside and outside surface temperatures and heat fluxes of each wall and roof plus gains from sunlight and internal loads, minus the losses through glass (windows) and floor. Thus QDX itself depends to some extent on the inside air-temperature at the <u>present</u> hour. In the above model, we have taken QDX to be a fixed quantity. (This amounts to accepting a linear, rather than exponential behavior for the inside air temperature during the present hour, so far as the effect of QDX is concerned.) We have made this simplifying approximation after making sure that the more exact treatment, though considerably hairy, leads to difference of less than 1% in the energy-consumption of the Evaporative Cooler.

Thus, the simplified heat balance equation to be solved is,

$$\mathrm{cc} * \frac{dT}{dt} = (\mathrm{QDX} - \mathrm{INFLOS}) + \mathrm{ECVOL} * 60. * d * Cp * (\mathrm{TEC} - T) \qquad \text{I-7}$$

where T = house temp, later called TTB (see below)

cc = effective heat capacity of house

QDX - INFILOS = heat flux/hour

ECVOL = cubic feet of air per min from evap cooler (EC-VOL)

d = density of air from cooler

C_p = specific heat of air from cooler

We next collect terms in T on the left-hand side of the equation.

$$\frac{dT}{dt} + \text{ECVOL} * d * C_p * 60/cc * T = (\text{QDX}-\text{INFILOS})/cc + \text{ECVOL} * d * C_p * 60 * \text{TEC}/cc \qquad \text{I-8}$$

The solution to this differential equation is

$$T = C*\text{EXP}(-\text{ECVOL} * d * C_p * 60 * t/cc) + \frac{\text{QDX} - \text{INFILOS}}{\text{ECVOL} * d * C_p * 60} + \text{TEC} \qquad \text{I-9}$$

when t = 0, T = house Temp = TTB. This fixes the value of the constant C.

$$C = \text{TTB} - \frac{\text{QDX} - \text{INFILOS}}{\text{ECVOL}*d*C_p*60} - \text{TEC} \qquad \text{I-10}$$

substituting I-10 in I-9 yields

$$T = \text{TTB}*\text{EXP}(-\text{ECVOL}*d*C_p*t*60/cc) + \left(\frac{\text{QDX} - \text{INFILOS}}{\text{ECVOL}*d*C_p*60} + \text{TEC}\right) * (1-\text{EXP}(-\text{ECVOL}*d*Cp*t*60/cc)) \qquad \text{I-11}$$

when t = 1 hour

$$T = \text{TTB}*\text{EXP}(-\text{ECVOL}*d*C_p*60/cc) + \left(\frac{\text{QDX} - \text{INFILOS}}{\text{ECVOL}*d*C_p*60} + \text{TEC}\right) * (1-\text{EXP}(-\text{ECVOL}*d*Cp*60/cc)) \qquad \text{I-12}$$

This equation is the basis for calculating the new house temperature in COOLIT. TTB, QDX, INFILOS, and cc are variables given to COOLIT from the main program. ECVOL, d, C_p, and TEC pertain to air inside the evaporative cooler and must be calculated before solving for the new house temperature.

Selection of Cooler Fan Speed

During normal evaporative cooler operation (no humidistat controlling relative humidity inside the room), the variables named above are used to calcute TTB at the end of the hour, with ECVOL at the lowest speed. If TTB is above the thermostat setting THI, the cooler switches to the next higher speed and the calculation is repeated. The cycle is repeated until TTB is less than or equal to THI or the cooler is at its highest speed.

Evaporative Cooling While Controlling Relative Humidity

Simulating an evaporative cooler with a humidistat is a little more involved. The relative humidity (RH) in the house is a function of temperature (TTB) and humidity ratio (WROOM), where all the moisture is assumed to come solely from the evaporative cooler. The relative humidity in the room must be controlled by adjusting WROOM. This is accomplished by adjusting the effective wetbulb depression, EFECT, that occurs in the cooler. However, when WROOM is changed by adjusting EFECT, then TEC, d, C_p, TTB, and ECVOL may also change. The relations are as follows:

RH = f(TTB,WROOM)

WROOM = f(DRYBULB,WETBULB,EFECT)

or

EFECT = f(DRYBULB,WETBULB,WROOM)

but

$$TEC = f(DRYBULB, WETBULB, EFECT)$$

$$TTB = f(TTB_{old}, QDX, ECVOL, TEC)$$

$$ECVOL = f(TTB)$$

An inverse relationship exists between WROOM and TTB for a desired relative humidity. If the relative humidity at TTB is too high and WROOM is lowered by lowering EFFECT, TTB rises.

COOLIT uses an iterative technique for solving the above set of equations. Based on the temperature at the beginning of hour, WROOM is calculated for the desired relative humidity. From WROOM, the necessary EFECT is calculated and then TEC, ECVOL, and finally TTB for the end of the hour. Based on this new TTB and WROOM, the relative humidity is recalculated and compared to the desired relative humidity. If it is not close enough, WROOM is recalculated for the desired relative humidity at the new TTB. However, since TTB will rise or fall depending on whether WROOM is lowered or raised, substituting in this new value for WROOM will probably overshoot the desired relative humidity. Therefore, WROOM is set equal to the average of the WROOM at the new TTB and the WROOM at the old TTB. This averaged WROOM reduces overshoot and helps the routine to converge faster. The number of iterations required to satisfy the relative humidity criterion is related to the size of the tolerable relative humidity range (set by RHSENS in the input deck). Larger values of RHSENS take fewer iterations and save computer time. A reasonable input value for RHSENS is 5 (RH is measured in percent, see Eq. I-1). The relative humidity will then be controlled to RHSET $\pm$ RHSENS, in 1-2 iterations.

Evaporative Cooler Sizing

Remember that a "Sizing Runs" does not actually select a size, merely produces an hourly table of "ECVOL" vs. Time, (see sample OUTPUT).

During sizing runs, TTB is assumed to be constant at THI and dT/dt = 0. The house temperature equation is then solved for the volume required to keep TTB constant for a given heat flux and TEC.

$$VOL = (QDX-INFILOS)/\ d*C_p*(THI-TEC) \quad . \qquad \text{I-13}$$

If TEC is equal to THI, VOL is infinite. If TEC is greater than THI, VOL is negative. These two situations are impossible and the hours that these situations occur are counted as impossible hours and no sizing is done. TTB is still set at THI at the end of the hour so that the proper heat flux will be available at the next hour when sizing might be possible.

If sizing is to be done for a cooler with a humidistat, EFECT (and TEC) is adjusted for the proper humidity ratio at THI.

Shutdown During the Hour

If the house temperature falls below TOFFEC (T-Off-Evap.-Cooler, from card 9 of INPUT deck), the cooler shuts down during the hour. The fraction of the hour the cooler ran must be calculated so that the electricity and water consumption can be calculated.

The house temperature equation is solved for time with T set at TOFFEC.

Refrigerative Air Conditioning Branch

Theory

The load seen by a vapor compression cycle air conditioner is a combination of sensible and latent heat removal loads. A sensible load is associated with the heat extracted in changing the temperature of air, and a latent load is associated with the heat extracted in condensing water out of the air onto the coil of the air conditioner. Latent loads occur when the air immediately adjacent to the coil is cooled to its dewpoint temperature (100% relative humidity). The local temperature of this air is below the average temperature of the air moving through the coil, consequently condensation can occur even though the average temperature is higher than the dewpoint temperature. The average temperature at which condensation starts to occur is a function of the type of coil, the number of rows of tubes in the coil, and the face velocity of the air moving into the coil. This would be a difficult problem to model in this program; therefore COOLIT assumes that condensation (and latent load) begins when the air is cooled to an average temperature corresponding to 90% relative humidity. On the psychrometric chart this model of the air conditioner operation corresponds to cooling first along a constant humidity ratio line till the 90% relative humidity curve is reached. Moisture then starts to condense out of the air as the air is further cooled along the constant 90% relative humidity curve to the final temperature and enthalpy.

The latent load seen during an hour of air conditioning is a nonlinear function of room temperature, humidity ratio, room volume, fan speed, coil temperature, and air conditioner capacity. The matter is further complicated because the room humidity ratio is a function of latent heat gains internally (from occupants) and from infiltration (which in turn is a function of windspeed, outside humidity ratio and inside humidity ratio), and air conditioner latent heat extraction rate. The internal humidity ratio may vary substantially during the hour. Because of this, the latent load calculated at the beginning of the hour may be very different from the latent load seen at the end of the hour. An easy way to handle this in a numerical solution is to break the hour into smaller time steps. This is done in COOLIT.

The Model

The sensible and latent load calculation in COOLIT proceeds as follows: At the beginning of each time step the enthalpy (H-Inside, called HIN), of the air entering the air conditioner is calculated as the function of the inside air temperature (TIN) and room humidity ratio (WROOM). Using I-5 we have

HIN = 0.24 * TIN + (1061 + 0.444 * TIN) * WROOM . I-14

HIN is then related to both the enthalpy the air will have when it is cooled to 90% relative humidity (H90RH) and to the mass flow rate of air going through the coil (FANMAS) in order to determine if the air conditioner has sufficient capacity to cool the air further. If it does not, all the load is sensible. If it does, then both sensible and latent cooling occur. The exit enthalpy (HOUT) is then calculated

HOUT = HIN - ACAPAC/FANMASS . I-15

The program calculates the exit temperature of the air differently depending on whether the exit air enthalpy is on the constant humidity ratio line (sensible load only) or on the 90% relative humidity curve (sensible and latent loads) as determined above. The TOUT for sensible cooling only is calculated from the ASHRAE equation

TOUT = (HOUT - 1061. * WACOUT)/(0.24 + 0.444 * WACOUT)   I-16

where WACOUT = W - AC - OUT = humidity ratio of air coming out of the AC unit = WROOM, since we are not extracting any moisture from the air.

The HOUT for sensible plus latent cooling is calculated from a fit to the 90% relative humidity curve on the psychrometric chart at sea level

TOUT = .0384 * HOUT ** 2 + 3.446 * HOUT - 2.58   I-17

With HOUT being calculated from equation I-15 above.
TOUT is calculated in this manner during sensible plus latent cooling because the humidity ratio of the air leaving the air conditioner is not yet known. This humidity ratio (W-AC-OUT) can be found after TOUT is calculated by the ASHRAE equation

WACOUT = (HOUT - 0.24 * TOUT)/(1061. + 0.444 * TOUT) .   I-18

The sensible air conditioning load (Q-SEN-AC) and latent load (Q-LAT-AC) are then calculated for this time step

QSENAC = FANMAS * (TIN*(0.24 + 0.444*WROOM)

- TOUT*(0.24 + 0.444*WACOUT))   I-19

QLATAC = FANMAS * 1061.*(WROOM-WACOUT) .   I-20

The new room air temperature is calculated by the statement

TIN(new) = (QDXDT - QSENAC)/CC + TIN(old).   I-21

where QDXDT = QDX*DTIME, where DTIME is typically 1/4 hour or less. If TIN is below the thermostat setting (THI) of the A.C. unit, the sensible plus latent loads are scaled so that TIN = THI. WROOM at the end of this time step must now be recalculated. The total amount of water in the room is next calculated. We use the notation H20 (for H_2O), and set H20ROM = lb. of water vapor in room. At the beginning of the time step H2OROM (=WROOM*RHOAIR*VOLROM) is decreased by the amount of water removed by the air conditioner (REM = removed) H2OREM (=FANMAS*(WROOM-WACOUT)) and is increased because of the internal latent load H2OINT (e.g. from occupants) and infiltration H2OINF (=AIRINF*($W_{ambient}$-WROOM)). H2OROM at the end of the time step is then

H2OROM(new) = H2OROM(old) + H2OINF + H2OINT - H2OREM I-22

and

WROOM = H2OROM/(VOLROM*RHOAIR) I-23

This sequence is repeated until the end of the hour is reached. At the end of the hour, the total cooling load (CLD) is set equal to the total of the sensible plus latent loads over the whole hour.

A previously mentioned, the hour is broken up into smaller time steps DTIME so that the latent load can be calculated more accurately. It was shown in a prototype version of COOLIT that the latent load calculation can be very unstable with time steps = 1 hr or 1/2 hr, and can actually yield negative latent loads and negative relative humidities. A negative relative humidity will result if the latent load calculated at the beginning of the time step for a given humidity ratio is large enough so that all the water in the room will be removed during that time step, based on that humidity ratio.

The number of time steps needed for the calculation to be well behaved is a function of the humidity ratio, the fan speed, the air conditioner capacity, the coil temperature, and the volume of the room. The volume of the room, the humidity ratio, and the air conditioner capacity are the most important factors. Room volume and humidity ratio are a measure of how much water is in the room. Air conditioner capacity and humidity ratio are a measure of how quickly the water can be extracted. It was determined experimentally that the routine will always be stable with four time steps per hour when a 36000 Btu air conditioner is operated in a 1444 square foot house. For conditions other than this, the number of time steps is calculated (in Twozone) by the equation

ISTEPS = Integer of (3*(ACAPAC*1444)/(3600*ARFLOR) + 1)   I-24

We take into account the temperature of the cooling coils (T-COIL) as follows.

If we are in the sensible-only part of heat extraction it is clear that the temperature of the air leaving the A.C. (T-OUT) cannot be lower than TCOIL. If TOUT as calculated by I-16 is lower than TCOIL then clearly we cannot extract heat at the rate determined by ACAPAC. We take this into account by running the compressor of the A.C. unit only a fraction of the time.

If we are in the sensible-plus-latent part of heat extraction, we must compare the enthalpy of air leaving the A.C. (H-OUT) with the enthalpy H-COIL of air at 90% relative humidity at temperature TCOIL. If HOUT is less than HCOIL, the same kind of fractioning of compressor running time as described above is done.

If due to overcooling in the previous iteration the temperature TIN of air inside the room has fallen below the thermostat setting THI for the A.C. unit, compressor running-time is again scaled during the current iteration to correct for this.

Sizing the Air Conditioner

If IFLAG9=2 is specified, then the program sizes the air conditioner (i.e. produces a table of cooling load (CLD) vs. time at the end of the run). TCOIL is set to 50^{o}F. ACAPAC is set hourly to 2.5 times the heat flux for that hour. The factor 2.5 is chosen because experimenting with different weather tapes showed that in extreme cases the latent may be approximately the same as the sensible load for a couple of time steps, but is never substantially larger. The factor 2.5 makes sure that ACAPAC is large enough to handle the total cooling load. ISTEPS is then adjusted for the hour by the equation

ISTEPS = INT(ACAPAC * STABLE + 1.0)

where

STABLE = 4*1444/(36000*ARFLOR)   (calculated in Twozone)

The sensible and latent load calculation proceeds exactly as before. At the end of the hour, CLD (not ACAPAC) is stored in an array for the sizing report at the end of the run.

Psychrometric Curve Fits

The air conditioning routine makes use of several equations which are quadratic curve fits of the psychrometric chart at sea level.

HCOIL = 0.005 * TCOIL**2 + 0.1 * TCOIL + 2.475   (TWOZONE) I-25

HCOIL at 90% Relative Humidity.

H90RH = 23753*WROOM**2 + 22779.4*WROOM + 4.7507   I-26

TOUT = 0.038431*HOUT**2 + 3.44583 * HOUT - 2.58044   I-27

TOUT at 90% Relative Humidity.

The values for HCOIL(TCOIL,90% RH), H90RH(WROOM,90%RH) and TOUT(HOUT,90%RH) are needed by the routine, but are not calculated in the Ashrae psychrometric algorithms. Consequently, they were developed as curve fits to the phychometric chart at sea level. The curves were fit only over the range of values that could be reasonably expected in a house or in an air conditioner, but agree very closely to the chart in their range. Errors can develop for extreme input values, or if the barometric pressure is significantly different from sea level. The barometric pressure sensitivity of these equations has not been determined, but is probably not serious for altitudes less than 4000 ft.

Calculation of WROOM at the Beginning of the Hour

The air conditioning routine must know WROOM at the beginning of the hour in order to calculate the latent load. The hourly value of WROOM is calculated in TWOZONE during the non-air conditioning hours. At the beginning of the cooling season, WROOM is initialized to the outside humidity ratio. Whenever the house vents, (almost every day) WROOM is again reset to the outside humidity ratio. During the rest of the non-air conditioning hours, a calculation is performed each hour on WROOM to take into account the change in WROOM due to infiltration and internal latent heat gains. The calculation of WROOM is as follows:

$$\frac{d}{dt}(H2OROM) = AIRINF(W_{amb} - WROOM) + H2OINT \qquad \text{I-28}$$

or

$$\frac{d}{dt}(WROOM * RHOAIR * VOLROM) = AIRINF(W_{amb} - WROOM) + H2OINT \qquad \text{I-29}$$

rearranging,

$$\frac{d\ WROM}{dt} + \frac{AIRINF * WROM}{VOLROM*RHOAIR} = (AIRINF * W_{amb} + H2OINT)/(VOLROM * RHOAIR) \qquad \text{I-30}$$

where we have denoted the new value of WROOM by WROM.

Using the integrating factor

$$EXP \int \frac{AIRINF}{VOLROM * RHOAIR} dt$$

the solution to this equation is

$$WROM = C*EXP -(AIRINF * t)/(VOLROM * RHOAIR) + (AIRINF * Wamb + H20INT)/AIRINF \quad \text{I-31}$$

when t = 0, WROM = WROOM and this determines the value of C.

$$C = WROOM - (AIRINF * Wamb + H20INT)/AIRINF$$

for t = one hour the solution is then

$$WROM = (WROOM - Wamb - H20INT/AIRINF) * EXP(-AIRINF/(VOLROM * RHOAIR)) + Wamb + H20INT/AIRINF \quad \text{I-31}$$

with AIRINF $\neq$ 0.

When the evaporative cooler runs, WROOM is set by the humidity ratio of the air blown into the house by the cooler.

Caution: Setting the heat capacity of the house too small (below approximately 500 Btu/^{o}F) will cause an instability in the evaporative cooler routine.

APPENDIX II

BCD COEFFICIENT GENERATING PROGRAM

The coefficients used in the heat transfer functions of TWOZONE are obtained by the Mitalas and Arseneault method.[4,5] (See reference 4 for detailed theory and operating instructions. References preceed Appendix I.)

This "B,C,D" program will derive the Z-transfer functions for two types of boundary conditions. The form of boundary parameters must be specified.

1) Boundary conditions of the first kind (temperature given for both surfaces.)

A) ramp imput, ICASE = 1. This is the only case used by TWOZONE.

B) frequency response, ICASE =2

2) Second kind of boundary condition (flux given for both surfaces.)

A) step input, ICASE = 3

B) ramp input, ICASE = 4

C) frequency input, ICASE = 5

TWOZONE models the heat flow through a stud wall by computing the heat flow through the two pats assumed to be in parallel: The heat flow through the wall area filled with studs and the heat flow through the wall area filled with insulation (or just air space.) These two components of the wall are typically 15% and 85% of the total wall area for a wood-frame wall of a light construction house.

TWOZONE will need the Z-surface transfer functions for both the 'components' of a wall/roof. One must input the layers separately for each component to obtain the relevant Z-transfer functions.

The information required by the BCD program for each multi-layer slab (wall or roof) can be obtained from the ASHRAE handbook.[3] The outside and inside air-films should appear as layers in the layer-by-layer description of each slab. The following data are needed for each layer (of each component*) of a wall or a roof:

1. layer thickness
2. conductivity
3. density
4. specific heat

Input 1-4 <u>or</u> 5. If you input all five, the input for #5 will be ignored.

5. resistance

The output from the program will include a punched deck of the BCD coefficients required by the TWOZONE program. Four cards for each wall or ceiling component read by TWOZONE as input cards 15-18, 19-23, . . . -30. (Pages 13-15.)

<u>INPUT DECK FORMAT</u>

o Card 1 format (F10.3, I3)

Column 1-10 DT = sampling time interval, 1 hr. for TWOZONE

Column 13 PFLAG = punch flag to obtain data for TWOZONE on punched cards. 1=yes; 2=no.

o Card 2 format (80A1)

Description of the slab for title purposes only.

Card 3 always blank, must be included.

If there are M layers, I=1,2...M, we need one card for each layer I. This card will be at position (I+3) in the deck. <u>Begin with the outside air-film</u>.

o Card (I+3) format (5F10.4, 30A1)

Column 1-10 XL(I) = layer thickness in feet.

11-20 XK(I) = conductivity in Btuh/$^{\circ}$F-ft.

*component specifies either insulation space or stud space.

After computing the Z-transfer functions for a slab, the control returns to reading Card (1) for the next slab. Therefore, a blank card in this location terminates the program.

Fill in columns for XL(I), XK(I), D(I), and SH(I) or just fill in column RES(I).

21-30 D(I) = density (lb/ft^3)

31-40 SH(I) = specific heat

41-50 RES(I)= resistance of radiation path whenever applicable or thermal resistance of layer when there is negligible heat storage. (Btu/ft^2-hr-^oF)

51-80 TEXT = description of layer for identification of card.

(All these data are supplied in "British" units if the resulting coefficients are to be used in TWOZONE).

o Card (M+4). We have gone through all the layers I=1,M; we are now at card M+4, which is left blank, but must be included. This blank card signifies the end of slab description input.

o Card (M+5) format (2I1)

Column 1 ICASE = see program description above; ICASE = 1 for TWOZONE

2 NW = number of frequencies, to be used only when frequency response is involved[4]. Leave blank.

For each slab, add cards 1 through M+5 to the Input Deck. The program will calculate the Z-transfer functions for each slab in the input deck. Add blank cards at end of the input deck.

OUTPUT

The printed output of the program is a table of the Z-transfer functions for each slab defined in the input deck. The program will also punch the Z-transfer functions on cards, three cards of data for each slab in the input deck preceeded by echos of cars 2 and 3 from the input deck for the slab. These cards are punched in a Format accepted by TWOZONE input deck (see pages 13-14 of this manual).

The Meaning of BCD coefficients

The Z-transfer functions for each slab consist of three sequences B_n, C_n, D_n (n=1,2. . .) of coefficients of a time series (Hence the name 'BCD coefficient Generating Program'). TWOZONE uses an eight hour history of inside and outsode surface temperatures and history of the heat flux to compute the heat flux for the present hour through each component of slab by the following equation:

The heat flow at the present hour (QDX(1)) is given by:

$$QDX(1) = \sum_{K=1}^{8} BN(K)*TOUT(K) - \sum_{K=1}^{8} CN(K)*TIN(K) - \sum_{K=2}^{8} DN(k)*QDX(K)$$

where A = area of the wall

K = 1 means present hour

2 means one hour ago

etc.

BN(K), CN(K), DN(K) = B,C,D coefficients characterizing the particular construction

TOUT(K) = history of outside surface temperature of the wall

TIN(K) = history of the inside surface temperature of the wall

QDX(K) = history of the heat flow through the wall

These histories are stored and supplied by TWOZONE while making the calculation.

APPENDIX III

WEATHER FILE

Introduction

TWOZONE requires the following ten hourly weather data values (some of them redundant): drybulb and wetbulb temperature, dew point, barometric pressure, cloud amount, cloud type, wind speed, humidity ratio, density, and enthalpy. Subroutine WXDTA reads the weather files and supplies the necessary data to Subroutine WTHR. The most recent version of TWOZONE, BLUEL, uses subroutine WXDATA to read "packed" weather files from the DOE-2 weather library. The old version of subroutine WXDATA has been preserved to read non-packed files, and is available.

TRY weather tapes are available from NOAA[1]. A "Test Reference Year" (TRY) consists of hourly weather data values for a selected year. The principle of selection is to eliminate years containing months with extremely high or low mean temperatures until only the "TRY" year remains . The weather in the test year is considered a standard for comparison of heating and cooling systems. It is not considered sufficiently typical to yield reliable estimates of average energy requirements over several years. The NOAA weather tapes are not "packed" and so will need the old version of subroutine WXDATA for reading them.

A manual accompanies TRY weather tapes when ordered from NOAA. The NOAA TRY Weather Data Manual is available from The Director, National Climatic Center, Federal Building, Asheville, NC 28801. Telephone: (704) 254-0961.

TRY Tape Format

FORMAT

Each logical record (observation) is 80 bytes long. Archive files are blocked 24 logical records (1920 bytes) per physical tape record. Tapes may be ordered with different blocking factors at no additional cost.

The initial file contains TRY data for 60 stations, 20 stations on each reel of tape. An inventory showing stations and selected years is included in this appendix.

This Appendix also presents a description of the NOAA supplied tape format indicating Tape Fields, Tape Positions and Element Definition.

SPECIAL NOTE

On the TRY tapes, space has been designated for the inclusion of Solar Radiation values. At the present time this Tape Field will contain 9's.

At the conclusion of the Solar Radiation rehabilitation project it is expected that these data will be added to a small fraction of the TRY tapes.

Work supported by the U. S. Department of Energy.

APPENDIX III

WEATHER FILE

Introduction

TWOZONE requires the following ten hourly weather data values (some of them redundant): drybulb and wetbulb temperature, dew point, barometric pressure, cloud amount, cloud type, wind speed, humidity ratio, density, and enthalpy. Subroutine WXDTA reads the weather files and supplies the necessary data to Subroutine WTHR. The most recent version of TWOZONE, BLUEL, uses subroutine WXDATA to read "packed" weather files from the DOE-2 weather library. The old version of subroutine WXDATA has been preserved to read non-packed files, and is available.

TRY weather tapes are available from NOAA[1]. A "Test Reference Year" (TRY) consists of hourly weather data values for a selected year. The principle of selection is to eliminate years containing months with extremely high or low mean temperatures until only the "TRY" year remains . The weather in the test year is considered a standard for comparison of heating and cooling systems. It is not considered sufficiently typical to yield reliable estimates of average energy requirements over several years. The NOAA weather tapes are not "packed" and so will need the old version of subroutine WXDATA for reading them.

A manual accompanies TRY weather tapes when ordered from NOAA. The NOAA TRY Weather Data Manual is available from The Director, National Climatic Center, Federal Building, Asheville, NC 28801. Telephone: (704) 254-0961.

TRY Tape Format

FORMAT

Each logical record (observation) is 80 bytes long. Archive files are blocked 24 logical records (1920 bytes) per physical tape record. Tapes may be ordered with different blocking factors at no additional cost.

The initial file contains TRY data for 60 stations, 20 stations on each reel of tape. An inventory showing stations and selected years is included in this appendix.

This Appendix also presents a description of the NOAA supplied tape format indicating Tape Fields, Tape Positions and Element Definition.

SPECIAL NOTE

On the TRY tapes, space has been designated for the inclusion of Solar Radiation values. At the present time this Tape Field will contain 9's.

At the conclusion of the Solar Radiation rehabilitation project it is expected that these data will be added to a small fraction of the TRY tapes.

Work supported by the U. S. Department of Energy.

Data for each hourly observation is stored in eight words, and constitute one "card image" as follows:

TAPE FIELD NUMBER	COLUMN POSITIONS	ELEMENT
001	01 - 05	Station Number
002	06 - 08	Dry Bulb Temperature
003	09 - 11	Wet Bulb Temperature
004	12 - 14	Dew Point Temperature
005	15 - 17	Wind Direction
006	18 - 20	Wind Speed
007	21 - 24	Station Pressure
008	25	Weather
009	26 - 27	Total Sky Cover
010	28 - 29	Amount of Second Cloud Layer
011	30	Type of Lowest Cloud or Obscuring Phenomena
012	31 - 33	Height of Base of Lowest Layer
013	34 - 35	Amount of Second Cloud Layer
014	36	Type of Cloud - Second Layer
015	37 - 39	Height of Base of Second Layer
016	40 - 41	Summation Amount of First Two Layers
017	42 - 43	Amount of Third Cloud Layer
018	44	Type of Cloud - Third Layer
019	45 - 47	Height of Base of Third Layer
020	48 - 49	Summation Amount of First Three Layers
021	50 - 51	Amount of Fourth Cloud Layer
022	52	Type of Cloud - Fourth Layer
023	53 - 55	Height of Base of Fourth Layer
024	56 - 59	Solar Radiation
025	60 - 69	Blank
026	70 - 73	Year
027	74 - 75	Month
028	76 - 77	Day
029	78 - 79	Hour
030	80	Blank

8 word/observation = "card image"

Note: missing fields are 9 filled

TABLE-1

INVENTORY OF 60 STATIONS on the NOAA tapes ordered by WBAN.

WBAN NUMBER	STATION	SELECTED TRY
(Tape 1)		
03927	Fort Worth, TX	1975
03937	Lake Charles, LA	1966
03940	Jackson, MS	1964
12839	Miami, FL	1964
12842	Tampa, FL	1953
12916	New Orleans, LA	1958
12918	Houston, TX	1966
12919	Brownsville, TX	1955
12921	San Antonio, TX	1960
13722	Raleigh, NC	1965
13737	Norfolk, VA	1951
13739	Philadelphia, PA	1969
13740	Richmond, VA	1969
13743	Washington, DC	1957
13874	Atlanta, GA	1975
13876	Birmingham, AL	1965
13880	Charleston, SC	1955
13889	Jacksonville, FL	1965
13893	Memphis, TN	1964
13897	Nashville, TN	1972
(Tape 2)		
13967	Oklahoma City, OK	1951
13968	Tulsa, OK	1973
13983	Columbia, MO	1968
13985	Dodge City, KS	1971
13988	Kansas City, MO	1968
13994	St. Louis, MO	1972
14732	New York, NY	1951
14733	Buffalo, NY	1974
14735	Albany, NY	1974
14739	Boston, MA	1969
14742	Burlingame, VT	1966
14764	Portland, ME	1965
14819	Chicago, IL	1974
14820	Cleveland, OH	1969
14837	Madison, WI	1974
14922	Minneapolis, MN	1970
14942	Omaha, NE	1966
23042	Lubbock, TX	1955
23044	El Paso, TX	1967
23047	Amarillo, TX	1968

WBAN NUMBER	STATION	SELECTED TRY
(Tape 3)		
23050	Alburquerque, NM	1959
23174	Los Angeles, CA	1973
23183	Phoenix, AZ	1951
23188	San Diego, CA	1974
23232	Sacramento, CA	1962
23234	San Francisco, CA	1974
24011	Bismark, ND	1970
24018	Cheyene, WY	1974
24127	Salt Lake City, UT	1948
24131	Boise, ID	1966
24143	Great Falls, MT	1956
24225	Medford, OR	1966
24229	Portland, OR	1960
24233	Seattle-Tacoma, WA	1960
93193	Fresno, CA	1951
93814	Cincinnati, OH	1957
93819	Indianapolis, IN	1972
93821	Louisville, KY	1972
94823	Pittsburgh, PA	1957
94847	Detroit, MI	1968

We reproduce below the DOE-2 packed weathertapes for California available at LBL. (This table is taken from the DOE-2 Users Manual, section 8)

TABLE-2

California Climate Zone Weather File Inventory

Zone	Representative Cities	DOE-2 Filename
1. North Coast	Crescent City	CTZØ1
	Eureka	
	Fort Bragg	
	Orleans	
	Scotia	
2. North Coast Valley	Healdsburg	CTZØ2
	Napa	
	Petaluma	
	Santa Rosa	
	St. Helena	
	Ukiah	
3. San Francisco Bay Area	Berkeley	CTZØ3
	Hamilton AFB	
	Oakland	
	Redwood City	
	San Mateo	
	San Rafael	
	San Francisco	
4. Upper Coast Range Valley	Hollister	CTZØ4
	King city	
	Livermore	
	Los Gatos	
	Monterey	
	Salinas	
	San Jose	
	Santa Clara	
	Santa Cruz	
	Watsonville	
5. Lower Coast Range Valley	Lompoc	CTZØ5
	Ojai	
	Oxnard	
	Paso Robles	
	San Luis Obispo	
	Santa Barbara	
	Santa Paula	
	Santa Maria	

Zone	Representative Cities	DOE-2 Filename
6. Los Angeles Beach	Culver City Laguna Beach Los Angeles Airport Newport Beach Santa Monica Torrance	CTZØ6
7. San Diego	Chula Vista Escondido San Diego	CTZØ7
8. Santa Ana	El Toro Long Beach Santa Ana Yorba Linda	CTZØ8
9. Los Angeles City	Burbank Los Angeles Civic Center Pasadena San Fernando San Gabriel	CTZØ9
10. San Bernadino	Beaumont Corona Redlands Riverside San Bernadino San Jacinto Upland	CTZ1Ø
11. Northern Zone	Alturas Chico Colusa Marysville McCloud Oroville Orland Red Bluff Redding Susanville Willows Yreka	CTZ11

Zone	Representative Cities	DOE-2 Filename
12. Central Zone	Antioch	CTZ12
	Auburn	
	Davis	
	Lodi	
	Modesto	
	Nevada City	
	Placerville	
	Sacramento	
	Stockton	
	Tahoe City	
	Vacaville	
	Woodland	
13. San Joquin Valley	Bakersfield	CTZ13
	Coalinga	
	Fresno	
	Los Banos	
	Madera	
	Maricopa	
	Merced	
	Porterville	
	Visalia	
14. High Desert	Barstow	CTZ14
	Bishop	
	Daggett	
	Lake Arrowhead	
	Mt. Wilson	
	Palmdale	
	Sandberg	
	Trona	
	Twentynine Palms	
	Victorville	
15. Low Desert	Blythe	CTZ15
	Brawley	
	Eagle Mtn.	
	El Centro	
	Imperial	
	Indio	
	Iron Mtn.	
	Needles	
	Palm Springs	