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SUPPLEMENT

Version 2.1C

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Introduction

This publication updates the 2.1B version of the DOE-2 Supplement and is a companion volume to the DOE-2 Reference Manual, Version 2.1A, dated May 1981. It contains detailed discussions and instructions for using the new features and enhancements introduced into the 2.1B and 2.1C versions of the program. It assumes a thorough understanding of the basic manual, and is not intended for stand-alone use by new users of the program.

The Supplement is arranged by subprogram and within each subprogram, first, by new features, and second, by enhancements to existing commands and keywords in the order in which they appear in the DOE-2 Reference Manual. Please refer to pages iv through ix for a listing of commands and keywords covered in this Supplement.

Asterisks next to articles in the Table of Contents, and also in the far-right column of the guide to commands, keywords, and code-words that follows, indicate that these are associated with the new DOE-2.1C documentation, to distinguish them from the previous 2.1B material. Also, any changes made in the text published in that previous volume are indicated by vertical lines appearing in the margin of the page.

Included as Appendix A to this volume is an updated listing of all of the Hourly Report Variables available in the program. This new listing replaces the three individual lists found in the DOE-2 Reference Manual under the HOURLY-REPORT command at the end of LOADS, SYSTEMS, and PLANT. The Daylighting Sample Run has been moved to the DOE-2 Sample Run Book, Version 2.1C, LBL-8679, Rev.2.

The DOE-2 BDL Summary, Version 2.1C, contains an integrated listing of all of the DOE-2 commands and keywords together with their abbreviations, defaults, minimums, and maximums.

Acknowledgment

The organization of materials in this document was derived from the DOE-2 Reference Manual, edited by Group Q-11, Solar Energy Group, Los Alamos National Laboratory, in collaboration with the Building Energy Simulation Group at Lawrence Berkeley Laboratory.

Steven D. Gates, to whom we extend our thanks, was the Principal Consultant for the Plant Cogeneration and the Refrigerated Case Work algorithms.

We also wish to express our appreciation for the work done by the RAMSES Group, Laboratoire de l'Accélérateur Linéaire, Université Paris-Sud, Orsay, France, on the metrification of the program.

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* denotes that this article documents a new 2.1C feature.

DOE-2.1B and DOE-2.1C

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Suppl. Page	Existing Command	Associated Keyword	New Commands/ Keywords/Code-words	Added in DOE-2.1C
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Suppl. Page	Existing Command	Associated Keyword	New Commands/ Keywords/Code-words	Added in DOE-2.1C
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Suppl. Page	Existing Command	Associated Keyword	New Commands/ Keywords/Code-words	Added in DOE-2.1C
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A command, keyword, or code-word with lines through it indicates that it has been removed from the DOE-2.1C version of the program. If there is a replacement, it appears in the column to its immediate right.

Suppl. Page	Existing Command	Associated Keyword	New Commands/ Keywords/Code-words	Added in DOE-2.1C
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		~~DIESEL-JAC-FPLR~~	—	*
		~~DIESEL-STACK-FU~~	—	*

A command, keyword, or code-word with lines through it indicates that it has been removed from the DOE-2.1C version of the program. If there is a replacement, it appears in the column to its immediate right.

Suppl. Page	Existing Command	Associated Keyword	New Commands/ Keywords/Code-words	Added in DOE-2.1C
4-8	EQUIPMENT-QUAD - Cont.	~~GTURB-EXH-FT~~	—	*
		~~GTURB-I/O-FT~~	—	*
		~~GTURB-STACK-FU~~	—	*
		~~GTURB-TEX-FT~~	—	*
		ABSOR1-HIR-FPLR	—	*
		—	DIESEL-I/O-FPLR	*
		.	DIESEL-EXH-FPLR	*
		.	DIESEL-TEX-FPLR	*
		.	DIESEL-JCLB-FPLR	*
		.	GTURB-CAP-FT	*
		.	GTURB-I/O-FPLR	*
		.	GTURB-EXH-FPLR	*
		.	GTURB-TEX-FPLR	*
		.	STURB-ENTH-FPIX	*
		.	STURB-I/O-FPLR	*
4-2	LOAD-ASSIGNMENT			*
4-2	HEAT-RECOVERY			*
4-15	~~ENERGY-COST~~		ENERGY-RESOURCE command	*
4-15	PLANT-REPORT	VERIFICATION SUMMARY	~~PV-B~~, ~~PV-H~~ code-words ~~PS-J~~ code-word	* *
1-15		—	REPORT-FREQUENCY	*
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	—	.	SCHEDULE command and associated keywords	*
	—	.	ENERGY-COST command and associated keywords	*
	—	.	CHARGE-ASSIGNMENT command and associated keywords	*
	—	.	COST-PARAMETERS command and associated keywords	*
	ECONOMICS-REPORT	VERIFICATION SUMMARY	EV-B code-word ES-D, ES-E, ES-F code-words	* *

A command, keyword, or code-word with lines through it indicates that it has been removed from the DOE-2.1C version of the program. If there is a replacement, it appears in the column to its immediate right.

BDL

FUNCTIONAL VALUES

Expert user control and direct interface with the operation of the DOE-2.1C program is now possible in the LOADS part of the program through the use of the new FUNCTION command. Future additions will make Functional Values also applicable to SYSTEMS.

This feature is entirely optional, and is beyond the normal scope of the beginning user. There are two types of applications of Functional Values:

(1) Calculation of variables which influence the program results, allowing the user to modify or replace the algorithms used by the program without recompiling the program.

(2) Calculation of variables for reporting or debugging purposes.

Functional Values are input by the user in BDL. The user specifies the values to be calculated and where in the hourly LOADS simulation they are to be used. In order to use Functional Values, the user must have access to the LOADS simulation variables, their definitions, and the locations of the final calculation of their values. Appendix B in this Supplement contains a flowchart indicating the calculational sequence and looping structure of LOADS. Note that not all of the LOADS subroutines are accessible; an asterisk (*) indicates those which are available for use in functions. (For exact location of function access points, consult the Compiler Listing, described below, and look for CALLs to subroutine FINTL. A list of all of the CALLs can be found at the end of the flowchart.) The flowchart should be used in conjunction with 1) the Global Variables Listing, 2) the Cross-Reference Listing of LOADS Global Variables, and 3) the Compiler Listing of Subprograms That Contain Function Access Points, to determine the location and method of calculation of accessible variables. These latter three listings are available as print files on the program tape. They reside on File 17, labelled LDSDOC.SRC. Request your Computer Operations personnel to print out these files if you plan to use the Functional Values capability; these tools are essential to the use of the feature. (See also the LOADS section of the DOE-2 Engineers Manual for algorithm descriptions.)

Functions are contained within the hourly loop of the program and therefore will be performed at each hour of the input run period. The new commands and keywords associated with Functional Values are the following (examples of the use of these commands and keywords are given at the end of this section):

FUNCTION Command

FUNCTION	tells LOADS that the data to follow specify the characteristics of a function. Allowable number of FUNCTIONs is 100.
Note:	FUNCTIONs must be specified after the END command and before the COMPUTE LOADS command.

NAME	specifies a unique user-assigned name for the function (up to 16 alphanumeric characters).
LEVEL	This keyword defines the location of the function within the hierarchy of the DOE-2.1C logical flow. The valid arguments, which correspond but differ slightly from certain of the DOE-2.1C commands used to describe the building input, are as follows: BUILDING or BLDG, SPACE, EXTERIOR-WALL or E-W, UNDERGROUND-WALL or U-W, WINDOW, and DOOR. Thus, for LEVEL = SPACE, the function would be performed and defined within the space loop of the program.

Each of the following LOADS commands, BUILDING-LOCATION, SPACE, EXTERIOR-WALL, DOOR, WINDOW, and UNDERGROUND-WALL, has a new keyword also called FUNCTION associated with the relevant function.

FUNCTION	takes up to two arguments, (*u-name1*,*u-name2*), which refer to where in the looping structure of the program the function is to be calculated. Assigning u-name1 means that the calculation is to be done prior to the program´s normal execution of the item in question (space load, etc.); whereas, assigning u-name2 means that the calculation will be done upon completion of the execution. If both u-names are assigned, the function with u-name1 will be calculated before, and the function with u-name2 will be calculated after the subroutine´s execution. See Example 6 below. If only one argument is specified, the remaining one must be blank (retaining the comma if u-name1 is the unused one) or defined as *NONE*.

There are four optional keywords for special-use functions. Under the BUILDING-LOCATION command:

DAYL-FUNCTION	is the special function used with the subroutine DEXTIL, which determines the hourly exterior horizontal illuminance for the daylighting simulation.

Under the SPACE command:

DAYL-ILLUM-FN	is the special function used in the subroutine DINTIL, which determines the hourly daylight illuminance and glare index at each reference point in a space (see Example 4).
DAYL-LTCTRL-FN	is the special function used in the subroutine DLTCTRL, which determines the electric lighting reduction in response to daylight illuminance at each reference point in a space (see the Daylighting example in the DOE-2.1C version of the Sample Run Book).

And under the WINDOW command:

WINDOW-SPEC-FN is the special function used in subroutines CALWIN, DCOF, DINTIL, and DREFLT. This function is used to alter variables involved in the daylighting calculation. WINDOW-SPEC-FN takes only one u-name, surrounded by asterisks, but without parentheses.

ASSIGN Command

ASSIGN Variables used within the function are declared through the use of the ASSIGN command. These assignments are made through the definition of local variable names (1 to 7-character names chosen by the user) or table variable names.

either

local variable name =

(1) simulation variable from the Global Variables Listing which contains variables used in the DOE-2.1C program.

(2) numeric value.

(3) previously defined PARAMETER name that is set equal to a numeric constant.

(4) the keyword SCHEDULE-NAME(u-name of a previously defined schedule) such that for the date and hour in question, the schedule value will be used within the function. This will overwrite the value in the original SCHEDULE for that hour for the rest of the run. E.g.,

```
PEOP1 = SCHEDULE (. . . . .)
          .
          .
SOUTH = SPACE  PEOPLE-SCHEDULE = PEOP1
               FUNCTION = (*SPXX*,*NONE*)
          .
          .
END
FUNCTION  NAME = SPXX  LEVEL = SPACE
ASSIGN  Y = SCHEDULE-NAME(PEOP1)
          .
          .
```

(5) the keyword SCHEDULE(global variable name) where the global variable name is that pointer found in the Global Variables Listing which corresponds to a previously defined SCHEDULE. The schedule value for the hour in question will be used (without overwriting the original value). Changing the example above, the input would be:

```
ASSIGN  Y = SCHEDULE(KZPPL)                        ..
```

(6) previously defined PARAMETER name that is set equal to a SCHEDULE-NAME u-name. The schedule value for the hour in question will be used.

```
PARAMETER   VTMULT = TVIS-SCH-1                     ..
    .
    .
TVIS-SCH-1 = SCHEDULE  THRU DEC 31
                       (ALL)(1,24)(.35)             ..
    .
    .
WINDOW    VIS-TRANS-SCH = TVIS-SCH-1
          FUNCTION = (*WINXX*,*NONE*)
                .
                .                                   ..
END                                                 ..
FUNCTION  NAME = WINXX  LEVEL = WINDOW              ..
ASSIGN  Y = SCHEDULE-NAME(VTMULT)                   ..
      .
      .                                             ..
```

<u>or</u>

table variable name = values associated with the piecewise linear interpolation of curves defined through the new keyword TABLE (see the following example).

TABLE This keyword specifies x-y pairs of data points which define a curve that is to be piecewise linearly interpolated to enable the calculation of y-values, given x-values in the function. The x-values should be in increasing order. There is no limit on the number of pairs which define the curve. Also, each TABLE keyword should have its own ASSIGN command. Mixing of TABLE and the other ASSIGN forms is not permitted. The x-y arguments can be defined through the use of the DOE-2.1C PARAMETER technique if desired.

In the CALCULATE section of a FUNCTION, the utility routine PWL returns the y-value of the piecewise linear curve given the x-value and the table variable name, as shown in the following example:

```
FUNCTION
   .
   .                                                        ..

ASSIGN   X1 = simulation variable from
              Global Variables Listing                      ..

ASSIGN   TAB1 = TABLE (0.,10) (.2,20) (.4,30)
                      (.6,36) (.8,38) (1.0,40)              ..
   .
   .

CALCULATE                                                   ..
         Y1 = PWL(TAB1,X1)
             .
             .
         END
```

In this function, the value of Y1 is determined from the value of X1 by linear interpolation between the points (0.,10), (.2,20), etc., defined by TABLE. Thus, for example, if X1 = 0.1, then Y1 = 15. (If X1 is outside the range of x-values in TABLE, PWL linearly extrapolates to get the corresponding Y1 value.) See Example 4, below, for another example of using TABLE.

CALCULATE Command

CALCULATE	The CALCULATE command informs the LOADS program that the following statements, which are written in a pseudo-FORTRAN language, are to be used to define the function. The valid FORTRAN declarative and executable statements and operations are presented in Table 1, page 1-14. Also presented is a new subprogram called PWL which performs the piecewise linear interpolation discussed above under the ASSIGN command. All statements following the CALCULATE command must begin in or after column 7, except for statement numbers which begin in column 1. Column 6 is used to designate the continuation of a statement as is the case with standard FORTRAN. The executable statement END terminates the CALCULATE section and must be present. Variables used in the FUNCTION are all classified as real; other types do not exist. Integers may be used, but they will be treated as real.

END-FUNCTION Command

END-FUNCTION	This command informs the LOADS program that the function definition is complete.

Example 1. This function prints out the incident solar radiation and outside surface temperature of an exterior wall.

```
EW1 = EXTERIOR-WALL
            .                                       Applicable
            .                                      Exterior Wall
            .
       FUNCTION = (*NONE*,*FNEW1*)  ..
 .
 .
 .
END ..
FUNCTION
          NAME  = FNEW1
          LEVEL = EXTERIOR-WALL  ..
ASSIGN
          QI = SOLI
          TO = T  ..
CALCULATE  ..
```

(Note: Begin the FUNCTION statements in column 7 or later)

```
      PRINT 100, QI,TO
100   FORMAT(1H ,2F12.3)
      END                   (required)
END-FUNCTION   ..
COMPUTE LOADS  ..
```

Example 2. This function changes the value of window infiltration CFM so that the solar heat gain plus conduction through the window is balanced by infiltration.

```
WINDOW-1 = WINDOW
             .                                        Applicable
             .                                          Window
             .
           FUNCTION = (*NONE*,*FNWIN1*)  ..
 .
 .
 .
END  ..
FUNCTION
           NAME  = FNWIN1
           LEVEL = WINDOW  ..
ASSIGN
           TO = DBTR
           TS = TZONER
           PR = PATM
           QS = QSOLG
           QC = QCON
           CI = CFMW  ..
CALCULATE  ..
```

```
C  ADD SOLAR GAIN AND CONDUCTANCE THRU WINDOW

      X = QS + QC

C  IF LOAD LESS THAN OR EQUAL TO ZERO OR OUTSIDE WARMER
C  THAN THE INSIDE, DON'T ALTER INFILTRATION.

      IF (X .LE. 0.0) GO TO 80
      IF (TO .GE. TS) GO TO 80

C  CALCULATE INFILTRATION CFM.

      DEN = PR/(.754*TZONER)
      CI = X/(14.4*DEN*(TO-TS))
80    CONTINUE
      END

END-FUNCTION  ..
COMPUTE LOADS  ..
```

Example 3. This function re-defines the outside film heat transfer coefficient of an external wall so that wind direction is accounted for. It uses Kimura's algorithm to get local windspeed at the wall surface as a function of global windspeed (from the weather file) and orientation of wall with respect to the global wind direction (Kimura, Scientific Basis of Air Conditioning, 1977, p. 85 ff.)

```
EW-2 = EXTERIOR-WALL
           .                                    Applicable
           .                                   Exterior Wall
           .
       FUNCTION = (*FNEW2*,*NONE*)  ..
  .
  .
  .
END  ..

FUNCTION
          NAME  = FNEW2
          LEVEL = EXTERIOR-WALL  ..

ASSIGN
          WS = WNDSPD
          WD = WNDDRR
          WA = XSAZM
          FU = FILMU  ..

CALCULATE  ..

      RWD = WA + 3.1415 - WD
      IF(RWD .GT. 3.1415) RWD = 6.283 - RWD

C  CONVERT GLOBAL WINDSPEED FROM KNOTS TO M/S

      VV = .553*WNDSPD
```

```
C  GET WINDSPEED AT WALL SURFACE

       IF(RWD .LT. 1.5708 .AND. VV .GT. 2.) VC = .25*VV
       IF(RWD .LT. 1.5708 .AND. VV .LE. 2.) VC = .5
       IF(RWD .GE. 1.5708) VC = .3 + .05*VV

C  CONVERT BACK TO KNOTS

       VC = 1.808*VC

C  COMBINED CONVECTIVE PLUS RADIATIVE CONDUCTANCE FOR
C  ROUGHNESS = 3  (SEE ENGINEERS MANUAL, P.III.59)

       FU = 1.90 + .38*VC
       END

END-FUNCTION   ..
COMPUTE LOADS  ..
```

Example 4. This function calculates daylight levels in a space using coefficients obtained by the user from physical scale model measurements of the ratio of interior to exterior illuminance. In the function, the coefficients are multiplied by the hourly total exterior illuminance from sun and sky to give the interior daylight illuminance. The measured coefficients for solar altitudes of 0, 10, 30, 50, and 70 degrees are entered using TABLE.

Notes:

(1) This function assumes there are no movable shading devises on the windows which would alter the interior illuminance depending on whether the shades were open or closed.

(2) This function does not re-calculate glare, so that the glare levels reported by the program should be ignored.

(3) This function is illustrative only; the coefficients in an actual case could also depend on other factors, such as solar azimuth, cloud cover, etc.

```
SPACE1 = SPACE
           .                                  Applicable
           .                                     Space
         DAYLIGHTING = YES
           .
           .  other daylighting-related keywords
           .
         DAYL-ILLUM-FN = (*NONE*,*MODEL-DATA-FN*)  ..
 .
 .
 .
END ..
FUNCTION
         NAME  = MODEL-DATA-FN
```

```
         LEVEL = SPACE  ..
ASSIGN
        RDNCC = RDNCC           $ DIRECT NORMAL SOLAR RADIATION, BTUH/SF $
        BSCC  = BSCC            $ SKY DIFFUSE SOLAR RADIATION ON $
                                $ HORIZONTAL, BTUH/SF $
        RAYCOS3 = RAYCOS3       $ SINE OF SOLAR ALTITUDE $
        PHSUND = PHSUND         $ SOLAR ALTITUDE IN DEGREES $
        ILLUM = DAYLIGHT-ILLUM1 $ DAYLIGHT ILLUMINANCE AT REF. POINT 1 $
        ..                      $ FOOTCANDLES (REF.PT. 2 NOT USED) $
ASSIGN
        TAB1 = TABLE (0,0)(10,.005)(30,.007)(50,.0085)
                     (70,.01)(90,.01)  ..
CALCULATE  ..

C  EXTERIOR HORIZONTAL ILLUMINANCE FROM DIRECT SUN (ASSUMES
C  LUMINOUS EFFICACY OF DIRECT SOLAR RADIATION = 100 LUMENS/WATT)

      IDIRH = RDNCC * RAYCOS3 * 100

C  EXTERIOR HORIZONTAL ILLUMINANCE FROM SKY (ASSUMES LUMINOUS
C  EFFICACY OF DIFFUSE SOLAR RADIATION = 125 LUMENS/WATT)

      IDIFH = BSCC * 125

C  TOTAL EXTERIOR ILLUMINANCE

      ITOTH = IDIRH + IDIFH

C  INTERIOR DAYLIGHT ILLUMINANCE FOR CURRENT SOLAR ALTITUDE

      ILLUM = PWL (TAB1,PHSUND) * ITOTH
      END

END-FUNCTION   ..
COMPUTE LOADS  ..
```

Example 5. This function demonstrates looping logic.

```
SPACE1 = SPACE
           .                                   Applicable
           .                                      Space
           .
         FUNCTION = (*NONE*,*SP-FN-TEST-1*)  ..
 .
 .
 .
END  ..

FUNCTION
         NAME  = SP-FN-TEST-1
         LEVEL = SPACE  ..

ASSIGN
         HR = IHR     DAY = IDAY   MON = IMO
```

```
         YR = IYR       MZ = MZ      ZAREA = ZFLRAR
         S = SCHEDULE(SCHED-1)    QZTOT = QZTOT
         MX = MX       MZEXT = MZEXT
         NEXTS = NEXTS     XSQCOMP = XSQCOMP
         LMX = LMX       MWI = MWI   LMWI = LMWI
         MXWIN = MXWIN   WIAREA = WIAREA  ..

CALCULATE  ..

      PRINT 1
1     FORMAT(21H TEST OF SP-FN-TEST-1)
      PRINT 2, YR,MON,DAY,HR,S
2     FORMAT(1X,4F10.1,F8.2)
      PRINT 3, ZAREA,QZTOT
3     FORMAT(10X,6HZAREA=,F6.1,5X,6HQZTOT=,F8.1)

C  INITIALIZE EXTERIOR-WALL POINTER AND COUNTER.

      MX=MZEXT
      NX=0

C  LOOP THRU EXTERIOR-WALLS.

100   NX=NX+1

C  INCREMENT EXTERIOR-WALL COUNT AND EXIT EXTERIOR-WALL LOOP
C  IF FINISHED.

      IF(NX .GT. NEXTS)GO TO 900
      PRINT 4, NX,XSQCOMP
4     FORMAT(30X,3HNX=,F3.0,8HXSQCOMP=,F10.1)

C  INITIALIZE WINDOW POINTER AND COUNTER.

             MWI=MXWIN
             NW=0

C  INCREMENT WINDOW COUNT AND EXIT WINDOW LOOP IF FINISHED.

200          NW=NW+1
             IF(NW .GT. NWIN) GO TO 400
                 PRINT 5, NW, WIAREA
5                FORMAT(40X,3HNW=,F3.0,3X,7HWIAREA=,F10.1)

C  INCREMENT WINDOW POINTER TO GET NEXT WINDOW.

                 MWI=MWI+LMWI
                 GO TO 200
400          CONTINUE

C  INCREMENT EXTERIOR-WALL POINTER TO GET NEXT EXTERIOR-WALL.

      MX=MX+LMX
      GO TO 100
900   CONTINUE
```

```
C  STOP SIMULATION AT HOUR 9.
      IF(HR .EQ. 9) STOP
      END
END-FUNCTION   ..
COMPUTE LOADS  ..
```

Example 6. This function is used to vary the shading coefficient and visible transmittance of all windows in the building. It first tests the value of the total (direct plus diffuse) solar radiation transmitted through the window. If that value, QTOT, is below a certain level, in this case, 10 Btuh/ft^2, the original values of the shading coefficient and visible transmittance are used. If QTOT is above the trigger level of 10 Btuh/ft^2, the shading coefficient and visible transmittance are varied according to a defined function and these new values are then used in calculating thermal gains and daylight illuminance through the window.

```
WINDOW-1 = WINDOW
           .                                     Applicable
           .                                       Window
           .
           FUNCTION = (*WSCSGC*,*PRINTQ*)
           WINDOW-SPEC-FN = *WSCSGS*        ..
 .
 .
 .
END  ..
FUNCTION
           NAME = WSCSGC
           LEVEL = WINDOW  ..
ASSIGN
       IPRDFL = IPRDFL         MR = MR
       C1 = CAM1               MWI = MWI
       C2 = CAM2               ETA = ETA
       C3 = CAM3               RR = RDIR
       C4 = CAM4               TDIF = CAM9
       JJ = IHR                RDIF = RDIF
       DAY = IDAY              GSHACOE = GSHACO-EDTT
       MON = IMO               SHACO = GSHACO
       HR = ISCHR              VISTRAN = VIS-TRANS
       SPACE = IZNM            FNTYPE = FNTYPE  ..
CALCULATE  ..
C  FNTYPE DETERMINES THE LOCATION OF THE CALL TO
C  FUNCTION (U-NAME) IN VARIOUS WINDOW-RELATED
C  SUBROUTINES.
C  FNTYPE = 0 FOR "BEFORE" FUNCTION,
C         = 1 FOR "AFTER" FUNCTION,
C         = 3 WINDOW-SPECIAL FUNCTION IN (CALWIN.49)
C         = 4 WINDOW-SPECIAL FUNCTION IN (DINTIL.87)
C         = 5 WINDOW-SPECIAL FUNCTION IN (DCOF.699)
C         = 6 WINDOW-SPECIAL FUNCTION IN (DREFLT.84)
C  SEE COMPILER LISTING OF SUBPROGRAMS FOR THESE ROUTINES.
```

```
      IF((FNTYPE.NE.0.0).AND.(FNTYPE.NE.3.0))RETURN
      SHACO = GSHACOE
C  GET THE CURRENT VALUE OF THE FRACTION OF THE WINDOW
C  SHADED (FWSHDD) FROM THE AA ARRAY.   MWI+JJ+34 IS
C  ITS SPECIFIC LOCATION IN THE AA ARRAY (SEE GLOBAL
C  VARIABLES LISTING).
      FWSHDD = ACCESS(MWI+JJ+34)
C  CALCULATE THE TRANSMITTANCE OF THE WINDOW.
      TR = AMAX1(0.,C1+ETA*(C2+ETA*(C3+ETA*C4)))
C  CALCULATE THE DIRECT SOLAR RADIATION TRANSMITTED
C  THROUGH THE WINDOW.
      QR = (1.-FWSHDD)*RR*TR*SHACO
C  CALCULATE THE DIFFUSE SOLAR RADIATION TRANSMITTED
C  THROUGH THE WINDOW.
      QDIF = RDIF*TDIF*SHACO
C  ADD THE DIRECT AND DIFFUSE TRANSMITTED QUANTITIES
C  TO GET TOTAL SOLAR RADIATION TRANSMITTED THROUGH
C  THE WINDOW.
      QTOT = QR + QDIF
C  STORE THE INCIDENT DIFFUSE AND INCIDENT DIRECT
C  SOLAR RADIATION ON THE WINDOW IN LOCAL VARIABLES
C  FOR PRINTING.
      QFPR1 = RDIF
      QRPR1 = RR
C  THIS PART OF THE FUNCTION CALCULATES THE NEW
C  SHADING COEFFICIENT AND VISIBLE TRANSMITTANCE.
      SHACO = (-0.00667*QTOT)+0.8667
      IF (QTOT.LE.10.) SHACO = 0.8
      IF (QTOT.GE.100.) SHACO = 0.2
      VISTRAN = SHACO
C  IPRDFL IS A COUNTER USED FOR BUILDING STARTUP.
C  WHEN THE BUILDING HAS CYCLED THROUGH 3 DAYS,
C  IPRDFL GOES TO 0.  IN EFFECT, THIS STATEMENT
C  DOES NOT ALLOW ANY FUNCTIONAL PRINTS BEFORE
C  THE BUILDING HAS CYCLED THROUGH STARTUP.
      IF (IPRDFL.GT.0.)RETURN
C  ALLOWS ONLY VALUES BETWEEN THE HOURS OF 6
C  AND 21 TO BE PRINTED.
      IF ((HR.LT.6.).OR.(HR.GT.21))RETURN
C  STANDARD FORTRAN PRINT STATEMENTS.
      IF (FNTYPE.EQ.0.0)RETURN
      PRINT 10,SPACE,MON,DAY,HR
   10 FORMAT(1H,6HSPACE=,A4,5X,6HMONTH=,F3.0,5X,4HDAY=,
     1F3.0,5X,4HSHR=,F5.0)
```

```
       PRINT 20,QDIF,TDIF,QR,TR
  20   FORMAT(1H,5HQDIF=,F8.2,3X,5HTDIF=,F5.2,3X,
      15HQDIR=,F8.2,3X,5HTDIR=,F5.2,3X,10HSHACO=0.80)
       PRINT 30,QFPR1,QRPR1
  30   FORMAT(1H,6HQFPR1=,F8.2,3X,6HQRPR1=,F8.2)

       END

END-FUNCTION  ..

FUNCTION
           NAME = PRINTQ
           LEVEL = WINDOW  ..

ASSIGN
       IPRDFL = IPRDFL        QDIF = QDIF
       HR = ISCHR             QDIR = QDIR
       TDIF = TDIF            TDIR = TDIR
       SPACE = IZNM           SHACO = GSHACO  ..

CALCULATE  ..

C  PRINTQ IS USED AT THE END OF THE SUBROUTINE'S
C  EXECUTION.  IT'S PURPOSE IN THIS EXAMPLE IS
C  TO VERIFY VALUES GENERATED BY WSCSGC.

C  CALCULATE THE DIFFUSE AND DIRECT SOLAR RADIATION
C  TRANSMITTED THROUGH THE WINDOW.

       QTDIF=QDIF*TDIF*SHACO
       QTDIR=QDIR*TDIR*SHACO

C  AGAIN, DO NOT PRINT ANY VALUES UNTIL BUILDING
C  STARTUP IS COMPLETE.  PRINT VALUES BETWEEN THE
C  HOURS OF 6 AND 21 ONLY.

       IF(IPRDFL.GT.0.)RETURN
       IF((HR.LT.6.).OR.(HR.GT.21.))RETURN

C  STANDARD FORTRAN PRINT STATEMENTS

       PRINT 30,QDIF,QDIR
  30   FORMAT(1H,6HQFPR2=,F8.2,3X,6HQRPR2=,F8.2)
       PRINT 20,QTDIF,TDIF,QTDIR,TDIR,SHACO
  20   FORMAT(1H,6HQTDIF=,F8.2,3X,5HTDIF=,F5.2,3X,
      16HQTDIR=,F8.2,3X,5HTDIR=,F5.2,3X,7HSHACO=,F5.2//)
       END

END-FUNCTION   ..

COMPUTE LOADS  ..
```

TABLE 1 - VALID FORTRAN STATEMENTS AND OPERATIONS

Arithmetic Operators

+, -, /, *, **, =, (,)

Logical Operators

OR, AND, NOT, EQ, NE, GT, GE, LT, LE

Standard Functions

ABS(x)
ACCESS(x)*
ALOG(x)
ALOG10(x)
AMAX1(x1,x2)
AMIN1(x1,x2)
AMOD(x1,x2)
ATAN(x)
EXP(x)
COS(x)
IACCES(x)*
INT(x)
SIN(x)
SQRT(x)
PWL (Piecewise linear interpolation(table,x)
DOE-2.1C utility routine)

Declarative Statements

FORMAT
SUBROUTINE

Executable Statements

CALL
CONTINUE
END
ENDFILE
GO TO
IF
PRINT
READ (unformatted or formatted)
RETURN
REWIND
STOP (For debugging only.
Program stops execution
without printing reports)
WRITE (unformatted or formatted)

---

* ACCESS will access the current value of a given variable in the program's main blank common real valued array (the AA array).

IACCES will access the current value of a given variable in the program's main blank common integer array (the IA array). See Global Variables Listing for AA and IA array locations.

HOURLY REPORT FREQUENCIES AND SUMMARIES

There is a new keyword in the LOADS-REPORT, SYSTEMS-REPORT, and PLANT-REPORT commands that allows the user to control the frequency at which hourly report data are printed.

REPORT-FREQUENCY may be set to HOURLY (the default), DAILY, MONTHLY, or YEARLY. If REPORT-FREQUENCY is not specified, the program will generate reports with the same format as before except that summary values (minimum, maximum, total, and average) will be printed at the end of each day and month, and at the end of the run period specified in the REPORT-SCHEDULE. When REPORT-FREQUENCY is set to DAILY, the hourly data are suppressed and only summary values are printed for each day and at the end of the month and run period. Similarly, when REPORT-FREQUENCY is set to MONTHLY, only the summary statistics for months and the run period are printed. Specifying frequency equal to YEARLY results in a single summary report covering the entire run period. Only scheduled hours are included in the summaries. REPORT-FREQUENCY may be abbreviated R-F.

<u>Example:</u>

```
LOADS-REPORT  VERIFICATION = (LV-A)
              SUMMARY = (SS-A,SS-E)
              REPORT-FREQUENCY = DAILY                ..

REPORT-BLOCK
    .
    .                                                 ..

HOURLY-REPORT
    .
    .                                                 ..
```

When REPORT-FREQUENCY is used in conjunction with the HOURLY-REPORT keyword, OPTION = PLOT, only the TOTAL values are plotted. If REPORT-FREQUENCY is not specified, i.e., hourly data are printed, the plots are unchanged.

Note that some averages may be misleading, e.g., the average solar altitude if the schedule contains night-time hours during which the solar altitude values are zero.

Example output may be found in the <u>DOE-2 Sample Run Book</u>, Version 2.1C, under the Daylighting and Sunspace examples.

A new feature in DOE-2.1B and 2.1C is the metric option. With this option, it is possible to enter and have reported out numerical values in the metric unit system. In addition, metric output units can be requested from an English unit system input deck, and vice versa. The metric units employed by DOE-2 are those used by professionals in Europe; they differ slightly from those of the International System of Units. The ranges and defaults have been calculated from the DOE-2 English ranges and defaults. The table at the end of this section indicates the unit conversion from English to metric.

To invoke the metric option, specify the following new keywords in the INPUT ... or PARAMETRIC-INPUT ... command at the beginning of each subprogram:

INPUT-UNITS	informs the particular subprogram of the type of units being input. It takes the code-words ENGLISH and METRIC. ENGLISH is the default. Units are always reported as a COMMENT in the echo of the LOADS input.
OUTPUT-UNITS	instructs the subprogram to report out in the unit-type specified. It takes the code-words ENGLISH and METRIC. ENGLISH is the default. Units are always reported as a COMMENT in the echo of the LOADS input.
Rule 1.	The LDL, SDL, PDL, and EDL subprograms always default to English units. Therefore if the user wants metric throughout, he must specify INPUT-UNITS = METRIC at each level, including parametric runs. The user should understand that the program calculations are always performed in English units and that all files are passed or saved in English. BDL converts metric input to English, and the Report Generators convert English to metric output. It is also therefore possible to switch from one unit system to the other, between subprograms, in a single run.

In addition to these generic commands, the LIBRARY-INPUT LOADS command also takes the keyword INPUT-UNITS, which specifies the type of units used in a library run.

Rule 1.	An individual library can contain only one type of units.
Rule 2.	The user cannot use a library created in one unit-system in a production run employing the other unit-system.
Rule 3.	If INPUT-UNITS = METRIC, the preassembled DOE-2 library cannot be accessed (see LAYERS and CONSTRUCTION commands), nor can it be augmented.

Acknowledgement

The metric conversion is the result of the combined efforts of the RAMSES Group, Laboratoire de l'Accélérateur Linéaire, Université Paris-Sud, Orsay, France, and the Building Energy Simulation Group, Lawrence Berkeley Laboratory.

As a convenience to metric users, synonyms have been developed for keywords which contain English units as an integral part of their names. For instance, to avoid confusion in a metric input deck, LIGHTING-W/SQFT may be specified as its metric equivalent, LIGHTING-W/AREA (abbreviated as L-W-A). The following table gives the equivalent metric term which can be substituted wherever the English term is encountered in a keyword.

English	Metric	Metric Abbrev.
BTU/HR	POWER	P
CFM	FLOW	F
FCFM	FFLOW	FF
SQFT	AREA	A
THERMS	POWER	P

These synonyms will also appear in the diagnostics and output reports, if OUTPUT-UNITS = METRIC has been specified.

There are, in addition to these synonymous keywords, several new keywords unique to the metric option.

Ordinarily, the values assigned to SCHEDULE commands are pure numbers (i.e., dimensionless) and do not require conversion. The two exceptions are temperature and solar radiation values. In order for BDL to convert these two types of values to metric, the DAY-SCHEDULE command must contain explicit directions to do so.

Therefore, the following two new keywords have been added under the DAY-SCHEDULE command in LOADS and SYSTEMS. In SYSTEMS, only the keyword TEMPERATURES applies.

TEMPERATURES	replaces the keyword VALUES and is required for schedules that take temperatures as input. The range is from -50.0 to 100.0°C, and there is no default. The abbreviation is TEMP. (If specified in an English input deck, this keyword will have no effect.)
RADIATIONS	replaces the keyword VALUES and is required for schedules that take intensity of radiations as input. At present, the only schedule which requires this keyword is that which is assigned to MAX-SOLAR-SCH, if this keyword is specified under the WINDOW command. (See Section "Daylighting" in this Supplement for use of this new keyword.) The range is from 0.0 to 1200.0 W/m^2, and there is no default. The abbreviation is RADT. (If specified in an English input deck, this keyword will have no effect.)

For example:

```
DS1 = DAY-SCHEDULE  HOURS = (1,6)   TEMPERATURES = (16)
                    HOURS = (7,18)  TEMPERATURES = (21)
                    HOURS = (19,24) TEMPERATURES = (16)          ..

DS2 = DAY-SCHEDULE  HOURS = (1,24)  RADIATIONS = (420)           ..
```

where these DAY-SCHEDULES are then assigned to WEEK-SCHEDULEs and SCHEDULEs.

Rule 1. All schedules that take °C temperatures as input must be associated with a DAY-SCHEDULE of the form:

```
HOURS = (...) TEMPERATURES = (...).
```

Rule 2. RADIATIONS should only be specified if MAX-SOLAR-SCH is input in the WINDOW command.

Rule 3. Since the TEMPERATURES and RADIATIONS keywords are required for schedules accepting non-dimensionless values, these DAY-SCHEDULEs <u>cannot</u> be nested. E.g.,

```
S1 = SCHEDULE THRU DEC 31 (ALL) HOURS = (1,24) TEMP = (21) ..
```

will produce an ERROR message since the only keyword allowed in nested SCHEDULEs is THRU; DAY-SCHEDULE must be explicitly input.

Under the SPACE-CONDITIONS command, the English keyword RES-INF-COEF has been <u>replaced</u>, for metric input only, by three new keywords:

RES-INF-CST	has a range from 0.0 to 20.0 (mixed units), and the default is 0.252.
RES-INF-WND	has a range from 0.0 to 39.0 sec/meter, and the default is 0.0488.
RES-INF-TEMP	has a range from 0.0 to 36.0 1/K, and the default is 0.0151.

where

infiltration = RES-INF-CST + (RES-INF-WND x windspeed) + (RES-INF-TEMP x ΔT)

In the LOADS-REPORT command, there is a new report LV-M — DOE-2 UNITS TABLE, which is the English/metric conversion table reproduced (in part) below. Also note that LV-G, the schedules verification report, reports out schedules in ENGLISH units only.

In SYSTEMS, under the DAY-RESET-SCH command, the following four new keywords are to be used, in the metric option only, when specifying ratios. As with temperatures, if ratios are input, all four of the keywords are required.

SUPPLY-HI-R	which represent the output ratios to be used instead of the temperature values, SUPPLY-HI, SUPPLY-LO, OUTSIDE-HI, and OUTSIDE-LO, respectively. Values of temperatures and ratios cannot be used interchangably in the metric option. Ranges are from 0.0 to 1.0, and there are no defaults.
SUPPLY-LO-R	
OUTSIDE-HI-R	
OUTSIDE-LO-R	

In SYSTEMS and PLANT, under the CURVE-FIT command, there is a new keyword:

INPUT-TYPE	specifies the type of DATA being input for independent variables. It takes the code-words NON-DIMENSIONAL and TEMPERATURES; NON-DIMENSIONAL is the default. If TEMPERATURES is specified, then the values are assumed to be in ^{o}C.

Please also note the following rules:

- In PLANT, under the EQUIPMENT-QUAD command, the quadratics, TWR-RFACT-FRT and TWR-APP-FRFACT, must be fitted from English input data.
- Under the CONNECT command, if an input-name is connected to a CONSTANT value, the value must be entered in the same units as specified in the keyword OUTPUT-UNITS in the INPUT PLANT command (DOE-2.1B only; the Solar Simulator has been removed from DOE-2.1C).
- In the Solar Simulator, whenever the keyword EFF-COEF is applicable to a component, the coefficients must be entered in ENGLISH units (DOE-2.1B only).

This report is provided for use with the metric option. It gives the conversion factors used to convert the English minimums, maximums, and default values for metric input and output.

LV-M - DOE-2 UNITS TABLE (excerpt)

ENGLISH	MULTIPLIED BY =	METRIC
Btu	.292875	W-hr
Btu/lb-^{o}F	4183.83	Joule/kg-K
Btu/hr-ft^{2}-^{o}F	5.67446	W/m^{2}-K
ft^{2}	.092903	m^{2}
ft^{3}	.0283168	m^{3}
lb/ft^{3}	16.01846	kg/m^{3}
mph	.44704	m/sec

LV-M - DOE-2 UNITS TABLE (excerpt)

ENGLISH	MULTIPLIED BY =	METRIC
Btu/hr-^{o}F	.527178	W/K
ft	.3048	m
Btu/hr-ft-^{o}F	1.7296	W/m-K
Btu/hr-ft^{2}	3.15248	W/m^{2}
in	2.54	cm
units/in	.3937	units/cm
lbs	.45359	kg
ft^{3}/min	1.69901	m^{3}/hr
in-water	25.4	mm-water
lb/ft^{2}	4.8824	kg/m^{2}
W/ft^{2}	10.76392	W/m^{2}
therms	25.0	thermies
knots	.51444	m/sec
hr-ft^{2}-^{o}F/Btu	.176228	m^{2}-K/W
gallons/min/ton	1.078	liters/min/kW
Btu/lb	.645683	W-hr/kg
lbs/in^{2}-gage	68.94757	mbar-gage
lbs/kW	.65359	kg/kW
gal	3.78541	liter
Btu/^{o}F	1897.8	Joule/K
kW/cfm	.5885	kW/m^{3}hr
Btu/ft^{2}-^{o}F	20428.4	Joules/m^{2}-K
Btu/ft-^{o}F	6226.48	Joules/m-K
ΔT^{o}F	.555556	ΔT^{o}C
inch mercury	33.8638	mbar
units/gal/min	.26417	units/liter/min
kBtu/hr	.0310563	kW
cfm	.4719	l/sec
cfm/ft^{2}	18.288	m^{3}/hr-m^{2}
1/R	1.7999	1/K
1/knots	1.94386	sec/m
footcandles	10.76391	lux
footlamberts	3.426259	candela/m^{2}

LOADS

SUNSPACES

Overview

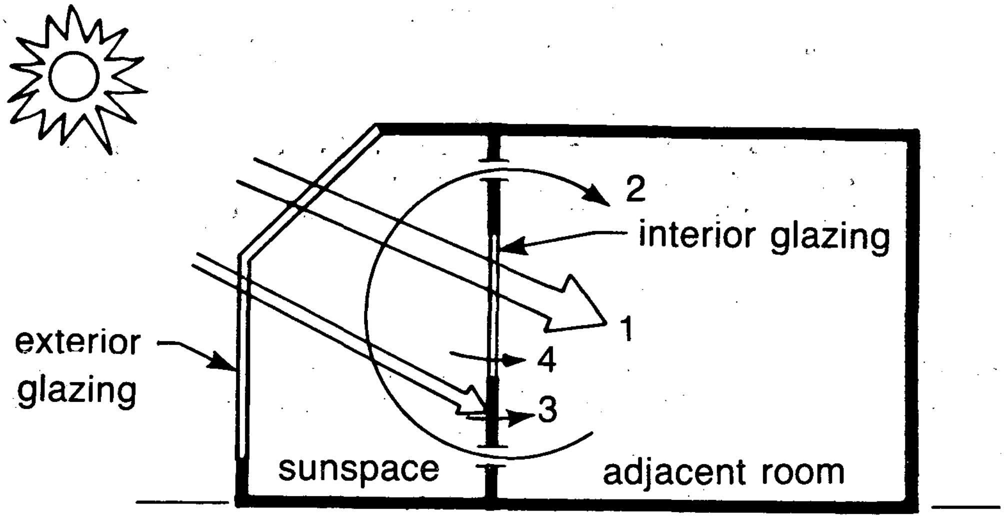
Algorithms have been added to DOE-2.1C to allow the program to model the different forms of heat transfer that can occur between a sunspace (or atrium) and adjacent spaces. These include (see Fig. 1):

(1) direct and diffuse solar gain through interior glazing,

(2) forced or natural convection through vents or an open doorway,

(3) quick or delayed conduction through an interior wall, taking into account solar radiation absorbed on the sunspace side of the wall,

(4) conduction through interior glazing.



XBL 843-10167

Fig. 1. Different forms of heat transfer calculated by the sunspace model: (1) direct and diffuse solar gain through interior windows; (2) forced or natural convection; (3) quick or delayed conduction through interior walls including effect of absorbed solar radiation; (4) conduction through interior windows.

The model also simulates venting of the sunspace with outside air to prevent overheating and, for residential application, the use of a sunspace to preheat outside ventilation air.

The user can control the airflow from the sunspace with a schedule or on the basis of a threshold temperature difference between the sunspace and the adjacent space.

Capabilities already existing in DOE-2.1B allow the user to simulate additional features which are important for solar-driven spaces, including sun-control with movable window shades, movable insulation on exterior windows, shading by fins and overhangs, sloped glazing, and the effects of thermal mass.

The model is intended primarily for residential and small commercial building applications. Because DOE-2 calculates only a single, average air temperature in a space, this simulation cannot be expected to give accurate results for multi-story atriums unless there is sufficient air mixing to eliminate temperature stratification.

Table 1 gives a comparison of modeling capabilities for sunspaces in DOE-2.1C vs. DOE-2.1B.

TABLE 1

Comparison of Modelling Capabilities for Sunspaces
in DOE-2.1C vs. DOE-2.1B

2.1B	2.1C
Solar radiation absorbed by interior surfaces (annual average) is used only in Custom Weighting Factor calculation.	Solar radiation absorbed by sunspace INTERIOR-WALLs is determined hourly and used in conduction calculation.
INTERIOR-WALL position is unused (except for TILT in daylighting calculation).	Sunspace INTERIOR-WALLs can be positioned with X, Y, Z, AZIMUTH, and TILT.
Conduction across INTERIOR-WALLs can be quick only.	Conduction across sunspace INTERIOR-WALLs can be quick or delayed.
INTERIOR-WALLs cannot have WINDOWs.	Sunspace INTERIOR-WALLs can have WINDOWs. Solar gain through these WINDOWs from sunspace to adjacent spaces is calculated. Conduction across interior WINDOWs is calculated. Interior WINDOWs can have movable insulation and shading. They can be shaded by BUILDING-SHADEs inside or outside the sunspace.

Comparison of Modelling Capabilities for Sunspaces in DOE-2.1C vs. DOE-2.1B (cont.)

2.1B	2.1C
Convection across an INTERIOR-WALL can be approximated by assigning an effective U-value to the wall. Non-linear ΔT dependence of natural convection cannot be modeled. Convection cannot be controlled.	Sunspace INTERIOR-WALLs can have openings through which fan-forced or natural convective heat transfer between sunspaces and adjacent spaces can occur. For natural convection, non-linear ΔT dependence is accounted for. Convection can be controlled thermostatically or via schedule.
Only the RESYS system has venting. The venting is controlled by the temperature of the control zone.	A sunspace can be vented with outside air to prevent overheating. Venting is independent of temperature of other zones. It works with any SYSTEM-TYPE except PIU.
Moisture gain for ZONE-TYPE = PLENUM is not considered.	Moisture gain in a sunspace (or non-sunspace) is accounted for both ZONE-TYPE = CONDITIONED and ZONE-TYPE = PLENUM.
Zone-level exhaust via EXHAUST-CFM works only for ZONE-TYPE = CONDITIONED.	EXHAUST-CFM works for ZONE-TYPE = CONDITIONED and PLENUM.

Sunspace-Related Keywords

LOADS

SPACE-CONDITIONS

SUNSPACE	takes code-word values YES or NO (the default). If YES, the space can be directly vented with outside air to prevent overheating (see keywords SS-VENT-SCH, SS-VENT-T-SCH, etc., below), and, if the space has INTERIOR-WALLs, the heat transfer across these walls into adjacent spaces by

convection, delayed conduction, and solar transmission will be calculated. The abbreviation is SUNSP.

Notes:

(1) A building can have more than one sunspace (i.e., SPACE with SUNSPACE = YES). There can be more than one sunspace on a system.

(2) A sunspace can have several INTERIOR-WALLs, i.e., a sunspace can have more than one adjoining space.

(3) A space can have at most one INTERIOR-WALL with convective heat exchange (AIR-FLOW-TYPE = FORCED-RECIRC, FREE-RECIRC, OPEN-DOORWAY, or FORCED-OA-PREHT in the WALL-PARAMETERS command).

(4) A sunspace and an adjacent non-sunspace can share several INTERIOR-WALLs (only one of which can have convective heat transfer). The conductive heat exchange is calculated separately for each INTERIOR-WALL.

(5) Two sunspaces can be adjacent, but any windows in the common INTERIOR-WALL will be ignored, convective exchange across the wall will not be calculated, and the effect on the conduction through the wall due to absorbed solar radiation will not be considered.

(6) A daylighting simulation can be done for a sunspace (by entering DAYLIGHTING = YES and setting daylighting related keywords), but the program cannot directly calculate daylight passing through interior windows from the sunspace to adjacent spaces.

INTERIOR-WALL

X Y Z	give the coordinates (in the coordinate system of the space in which the wall is defined) of the lower left-hand corner of the wall as viewed from the NEXT-TO space (see Fig. 2).
AZIMUTH	is the azimuth of the wall in the coordinate system of the space in which the wall is defined (see Fig. 2). The outward normal used to determine the azimuth points into the NEXT-TO space.
Note:	HEIGHT, WIDTH, X, Y, Z, AZIMUTH, and TILT are required for an INTERIOR-WALL in a sunspace so that the amount of solar radiation falling on the wall from exterior windows in the sunspace can be calculated. If the sunspace has no exterior windows, which is an exceptional case, these

geometrical quantities do not have to be specified. These keywords take the same defaults, meanings, and abbreviations as those under EXTERIOR-WALL.

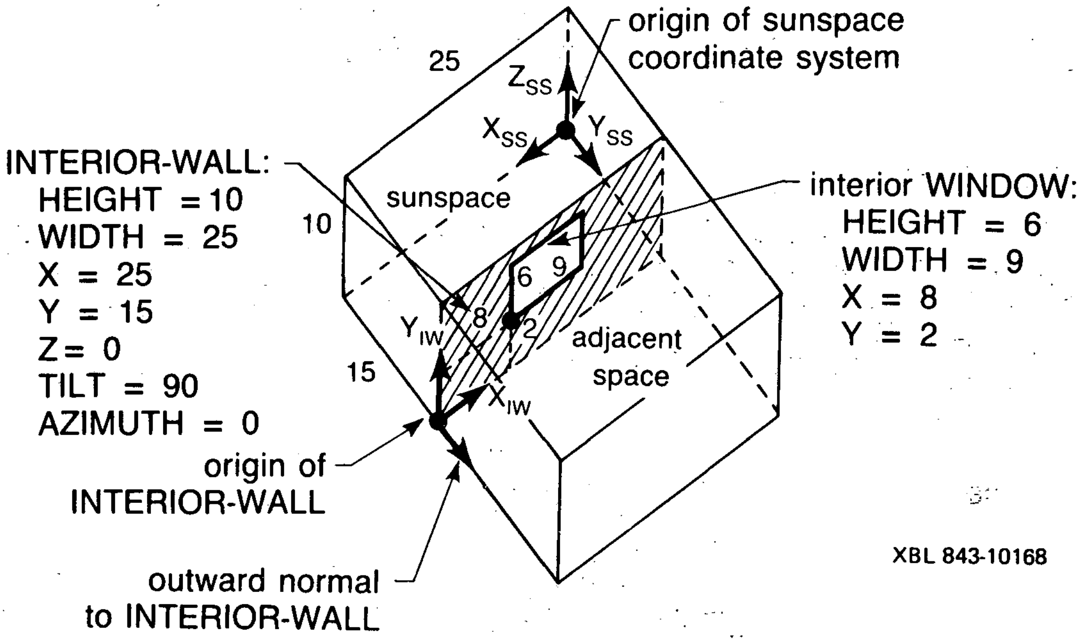


Fig. 2. A sunspace and an adjacent space showing the geometrical positioning of the INTERIOR-WALL separating them. The INTERIOR-WALL has been defined in the sunspace. The lower left-hand corner of the wall (as viewed from the adjacent space) is located at X = 25, Y = 15, Z = 0 in the sunspace coordinate system. The azimuth of the INTERIOR-WALL is 0°, which is the angle between the sunspace Y-axis, Y_{SS}, and the outward normal to the INTERIOR-WALL. The wall contains a 6′ x 9′ WINDOW with lower left-hand corner at X = 8, Y = 2 with respect to the wall origin.

WINDOW

SOL-TRANS-SCH	is the u-name of a schedule which gives the solar transmittance of a window shading device when it covers the window. This keyword is used only for exterior windows in a sunspace. The program multiplies the schedule value by the direct and diffuse solar radiation striking the shade to determine the hourly amount of solar radiation (assumed diffuse) which is transmitted by the shade. The SHADING-SCHEDULE value will be used if this keyword is not specified. The abbreviation is S-T-SCH. Note: This keyword should be defined in addition to, not in place of, SHADING-SCHEDULE. Also, the value of SOL-TRANS-SCH in a given hour must not exceed the corresponding SHADING-SCHEDULE value. If it does, the

program will reset it equal to the SHADING-SCHEDULE value.

Note: WIN-SHADE-TYPE = FIXED-EXTERIOR or MOVABLE-EXTERIOR should be entered if a sunspace exterior window has a shading device on the outside of the window. Otherwise, the program will assume the shade is on the inside.

Interior Windows

Interior windows can be specified by following an INTERIOR-WALL command by one or more WINDOW commands. The keywords for such windows are the same as those for windows in an EXTERIOR-WALL with some exceptions:

(1) The following keywords are unused:

SETBACK
GND-FORM-FACTOR
SHADING-DIVISION
INF-COEF
OVERHANG-A, etc.
LEFT-FIN-A, etc.
RIGHT-FIN-A, etc.
WIN-SHADE-TYPE
VIS-TRANS-SCH
GLARE-CTRL-PROB

(2) SKY-FORM-FACTOR multiplies the total diffuse radiation incident on an interior window. If the interior window has a setback (relative to the sunspace) or there are obstructions inside the sunspace which shade the interior window, a value of SKY-FORM-FACTOR less than 1.0 should be specified (the default value is 1.0).

Shading devices on interior windows, like Venetian blinds, drapes, or pull-down shades, can be simulated via the keywords SHADING-SCHEDULE and MAX-SOLAR-SCH. Movable insulation on interior windows can be modeled using keywords CONDUCT-SCHEDULE and CONDUCT-TMIN-SCH.

For an accurate calculation of the solar radiation transmitted by a sunspace interior window, it is important to specify the X and Y coordinates of the window. These coordinates are measured with respect to the lower-left hand corner of the INTERIOR-WALL as viewed in the NEXT-TO space (see Fig. 2). The position of exterior windows should also be carefully specified.

The program will only recognize interior windows in an INTERIOR-WALL between a sunspace and a non-sunspace.

Sliding glass doors can be modeled as interior WINDOWs. If the INTERIOR-WALL containing the glass door has AIR-FLOW-TYPE = FREE-DOORWAY (see WALL-PARAMETERS, below), the door will be assumed to be open, and convection through the opening will be calculated, if

T(sunspace) - T(adjacent space) > AIR-FLOW-CTRL-DT.

Additional control of the opening and closing of the door can be obtained by using SS-FLOW-SCH (see description of new ZONE-AIR keywords, below).

An unglazed opening in a sunspace INTERIOR-WALL can be input as a WINDOW with GLASS-TYPE-CODE = 0 and GLASS-CONDUCTANCE = 0. The program will calculate the solar radiation passing through the opening by using a transmittance of 1.0 for all angles of incidence. WALL-PARAMETERS data, described below, would be entered for the INTERIOR-WALL to specify the convective air flow through the opening.

Interior Doors

The DOOR command cannot be used with INTERIOR-WALL. However, an opaque interior door with a conductance significantly different from the sunspace interior wall containing it can be input as a separate INTERIOR-WALL. Alternatively, the door can simply be ignored if the conduction across it is small compared to the overall conduction across the wall. The program will calculate convection through a fully or partially open door if AIR-FLOW-TYPE = FREE-DOORWAY and appropriate values of DOORWAY-H and DOORWAY-W are specified (see WALL-PARAMETERS, below).

GLASS-TYPE

It is strongly recommended that exterior WINDOWs in a sunspace be described with GLASS-TYPE-CODE rather than SHADING-COEF. This allows the program to accurately calculate the hourly direct and diffuse radiation transmitted by the glazing. This is not possible with SHADING-COEF except for standard 1/8" clear glass.

WALL-PARAMETERS

This command is used to specify data which is used by the program to calculate air flow across a sunspace INTERIOR-WALL. The u-name of this command is referenced by the CONSTRUCTION command for the INTERIOR-WALL. The sequence is as follows:

```
WP-1    = WALL-PARAMETERS FOR INTERIOR-WALL
                       .
                       .                              ..

IWCON-1 = CONSTRUCTION
            WALL-PARAMETERS = WP-1
                       .
                       .                              ..

IW-1    = INTERIOR-WALL
             CONSTRUCTION = IWCON-1
                       .
                       .                              ..
```

The keywords for WALL-PARAMETERS are:

FOR — now accepts the value INTERIOR-WALL (in addition to the Trombe wall code-words).

AIR-FLOW-TYPE — is the type of air flow across the INTERIOR-WALL. The abbreviation is A-F-T. The default is NO-AIR-FLOW, and the other allowed values, which are illustrated in Fig. 3, are:

FORCED-RECIRC — A fan blows air through a vent from the sunspace to the adjacent space. Air is recirculated back to the sunspace through another vent. All of the fan heat is assumed to be picked up by the airstream flowing into the adjacent space.

FORCED-OA-PREHT — A fan draws outside air into the sunspace where it is pre-heated, then transferred across the INTERIOR-WALL into the adjacent space. The fan is assumed to be located in the building exhaust airstream so that no fan heat is delivered to the building.

FREE-RECIRC — Air circulates through upper and lower vents in the INTERIOR-WALL by natural convection. The heat transfer from sunspace to adjacent space is calculated by the program as

$$Q = 31267 \ C_p \ P \left[\frac{h \left| T_S - T_R \right|}{T_S \ T_R \left[\frac{T_S}{A_U^2} + \frac{T_R}{A_L^2} \right]} \right]^{\frac{1}{2}} \left[T_S - T_R \right]$$

where

Q is in Btuh,
C_p = heat capacity of air [Btu/lb-^{o}F],
P = atmospheric pressure [in. Hg],
h = vertical separation between vents [ft],
T_S = sunspace air temperature [^{o}R],
T_R = air temperature of adjacent space [^{o}R],
A_U = upper vent area [ft^2],
A_L = lower vent area [ft^2].

FREE-DOORWAY Air circulates by natural convection through a doorway in the INTERIOR-WALL. The heat transfer from sunspace to adjacent space when the doorway is fully open is given by

$$Q = 4.6 \, W \, H^{\frac{3}{2}} \left| T_S - T_R \right|^{\frac{1}{2}} \left[T_S - T_R \right] ,$$

where

Q is in Btuh,
W = width of opening [ft],
H = height of opening [ft],
T_S = sunspace air temperature [^oF].
T_R = air temperature of adjacent space [^oF].

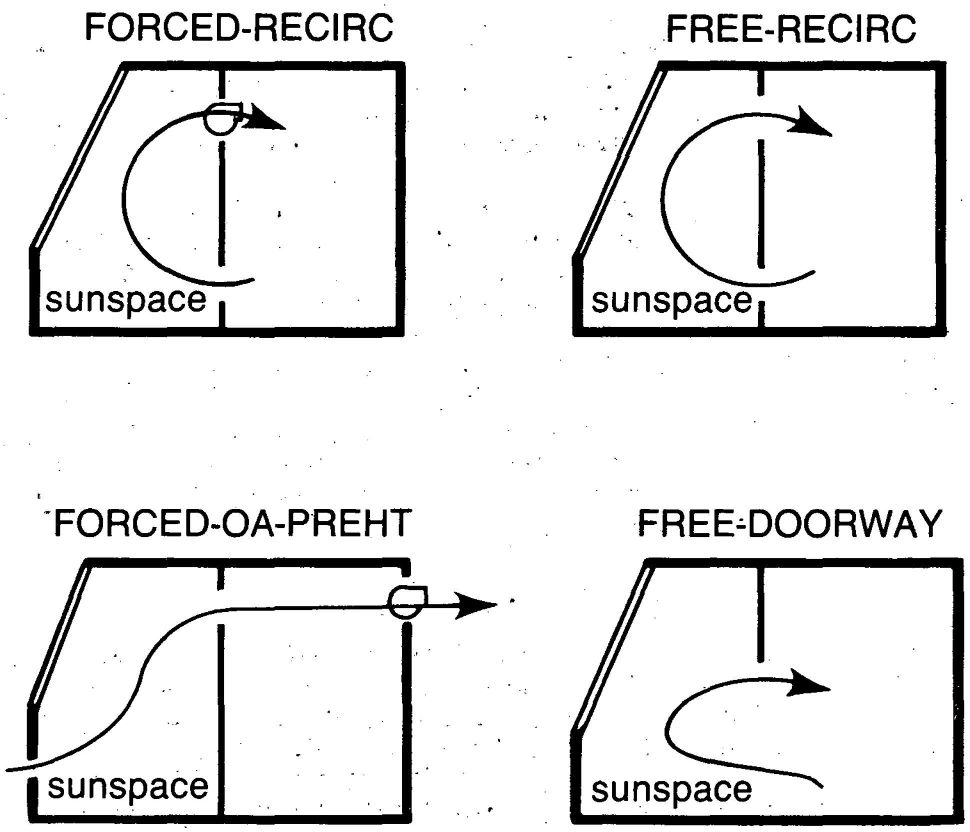


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Fig. 3. Air-flow configurations for different values of AIR-FLOW-TYPE.

The applicability of the following keywords depends on AIR-FLOW-TYPE, as shown in Table 2.

LOWER-VENT-AREA UPPER-VENT-AREA	are the cross-sectional areas (ft^2) of the lower and upper vents, respectively, for AIR-FLOW-TYPE = FREE-RECIRC.
VERT-VENT-SEP	is the center-to-center vertical separation (ft) between the upper and lower vents for AIR-FLOW-TYPE = FREE-RECIRC.
AIR-FLOW-RATE	is the air flow rate (cfm) across a sunspace INTERIOR-WALL for AIR-FLOW-TYPE = FORCED-RECIRC or FORCED-OA-PREHT. The abbreviation is A-F-R, the range is from 0.0 to 999999.0 ft^3/min, and there is no default.
AIR-FLOW-CTRL-DT	is the threshold temperature difference ($^{\circ}$F) for control of air flow across a sunspace INTERIOR-WALL. Air flow will occur only if: T(sunspace) - T(adjacent space) > AIR-FLOW-CTRL-DT The default value is 3.0°F for all AIR-FLOW-TYPEs except FORCED-OA-PREHT, in which case it is -100.0°F (therefore the keyword has no effect if not specified for FORCED-OA-PREHT). The abbreviation is A-F-C-DT.
FAN-KW	is the electrical power per unit air flow (kW/cfm) of the fan for AIR-FLOW-TYPE = FORCED-RECIRC or FORCED-OA-PREHT. The default is 0.00003, ranges from 0.0 to 0.1, and may be abbreviated as F-KW.
DOORWAY-H DOORWAY-W	are the height and width, respectively, in feet, of the opening through which air flow occurs for AIR-FLOW-TYPE = FREE-DOORWAY. The abbreviations are D-H, with a range from 0.0 to 8.0 ft, and D-W, with a range from 0.0 to 99.0 ft, respectively, and there are no defaults.

Notes:

(1) To get solar radiation transmitted across an unglazed opening, a WINDOW with GLASS-TYPE-CODE = 0, GLASS-CONDUCTANCE = 0, HEIGHT = same value as DOORWAY-H, and WIDTH = same value as DOORWAY-W, should be entered in the sunspace INTERIOR-WALL.

(2) A non-rectangular doorway opening should be approximated by rectangular opening of the same area.

(3) Multiple openings of height H_i and width W_i in the same wall can be represented by a single opening with

$$\text{DOORWAY-H} = \langle H \rangle \quad \text{and} \quad \text{DOORWAY-W} = \sum_i W_i \, H_i^{1.5} \, / \, \langle H \rangle^{1.5} ,$$

where $\langle H \rangle$ is the average of the H_i.

Note: The rate of air flow, natural or forced, determined by the program from the above WALL-PARAMETERS data and the temperature difference across the INTERIOR-WALL, is multiplied each hour by the value of SS-FLOW-SCH (default 1.0) which is specified in the SYSTEMS ZONE-AIR input for the sunspace.

Example: A 500 CFM fan circulates air between sunspace and adjacent room if the sunspace is 5° warmer than the room. The fan power is 25W. The WALL-PARAMETERS input would be:

```
WP-1 = WALL-PARAMETERS  FOR INTERIOR-WALL
                        AIR-FLOW-TYPE = FORCED-RECIRC
                        AIR-FLOW-RATE = 500
                        AIR-FLOW-CTRL-DT = 5
                        FAN-KW = .00005                    ..
```

TABLE 2

WALL-PARAMETERS keyword applicability for INTERIOR-WALL.
The X´s show keywords which are used for each AIR-FLOW-TYPE.

	AIR-FLOW-TYPE			
	FORCED-RECIRC	FORCED-OA-PREHT	FREE-RECIRC	FREE-DOORWAY
LOWER-VENT-AREA			X	
UPPER-VENT-AREA			X	
VERT-VENT-SEP			X	
AIR-FLOW-RATE	X	X		
AIR-FLOW-CTRL-DT	X	X	X	X
FAN-KW	X	X		
DOORWAY-H				X
DOORWAY-W				X

EXTERIOR-WALL, ROOF, UNDERGROUND-WALL, UNDERGROUND-FLOOR, INTERIOR-WALL

INSIDE-SOL-ABS is the inside surface solar absorptance. For INTERIOR-WALL, a list of two values is required, where the first value is the absorptance on the side of the interior wall that is in the space the wall is defined in, and the second value is the absorptance of the other side of the wall.

The default value of INSIDE-SOL-ABS is 0.3 if the surface is a floor (TILT $> 170^{\circ}$), 0.5 if a wall ($10^{\circ} \leq$ TILT $\leq 170^{\circ}$), and 0.8 if a ceiling (TILT $< 10^{\circ}$). The abbreviation is I-S-A.

SYSTEMS

ZONE-AIR (or ZONE)

Venting of a sunspace with outside air to prevent overheating can be specified with the following keywords:

SS-VENT-SCH	is the u-name of a schedule which determines when a sunspace can be vented. The allowed schedule values are 0 if venting is not allowed and 1 if venting is allowed (subject to the temperature conditions described under SS-VENT-T-SCH, below). The default is no venting if this schedule is not input. The abbreviation is SS-V-SCH.
SS-VENT-T-SCH	is the u-name of a schedule of sunspace air temperatures (in ^{o}F) above which venting will occur if the outside air temperature is low enough. Letting T(vent) be the value of SS-VENT-T-SCH, venting will take place if, T(sunspace) > T(vent), and T(outside air) < SS-VENT-LIMIT-T, and T(outside air) < T(sunspace), and SS-VENT-SCH value = 1. The venting temperature is input as a schedule in order to allow seasonal variation. For example, the venting temperature might be set higher in the winter to increase the amount of heat convected or conducted from the sunspace to adjacent rooms. The abbreviation is SS-V-T-SCH.
SS-VENT-CST SS-VENT-WND SS-VENT-TEMP	are coefficients in the following expression which gives the number of outside-air changes per hour when venting by <u>natural convection</u>, which is assumed to occur if SS-VENT-KW = 0: Venting ach = (SS-VENT-CST) + (SS-VENT-WND) * (windspeed in knots) + (SS-VENT-TEMP) * |T(sunspace) - T(outside air)| If SS-VENT-KW > 0, the venting is assumed to be <u>fan-forced</u> at a constant air change rate given by SS-VENT-CST. In this case, SS-VENT-WND and

	SS-VENT-TEMP are ignored. The abbreviations are SS-V-CST, with a range of 0.0 to 20.0, and a default of 5.0, SS-V-WND, with a range of 0.0 to 5.0 1/knot, and a default of 0.0, and SS-V-TEMP, with a range of 0.0 to 1.0 1/°F, and a default of 0.0.
SS-VENT-LIMIT-T	is the outside drybulb temperature below which venting can occur (see description of SS-VENT-T-SCH, above). The default value is 120°F, and the abbreviation is SS-V-L-T.
SS-VENT-KW	is the electrical power per unit air flow (kW/cfm) of the venting fan. The default value is 0.0. If this keyword is not specified, or is set equal to 0.0, venting is assumed to be by natural convection. The abbreviation is SS-V-KW.

Notes:

(1) For the RESYS system, sunspace venting is done independently of the natural ventilation of other zones (which is determined by the SYSTEM-AIR keywords NATURAL-VENT-AC, NATURAL-VENT-SCH, and VENT-TEMP-SCH).

(2) If a sunspace is vented, the program will bypass mechanical cooling that hour even if venting cannot bring the sunspace temperature down to the cooling setpoint.

(3) If venting can reduce the sunspace temperature below T(vent), the program will automatically reduce the fraction of the hour that venting takes place to give a final temperature exactly equal to T(vent). The average venting CFM during the hour and the venting fan electrical consumption are adjusted accordingly.

Example: A sunspace is mechanically vented at 10 ach from 8:00 AM to 7:00 PM during the summer months if the inside temperature exceeds 80°F and the outside temperature is below 75°F. The venting fan uses .05 Watts/cfm.

```
INPUT SYSTEMS                                                 ..
      .
      .
      .

V-SCH-1  = SCHEDULE  THRU MAR 31 (ALL) (1,24) (0)
                     THRU OCT 31 (ALL) (1,8) (0)
                                       (9,19) (1)
                                       (20,24) (0)
                     THRU DEC 31 (ALL) (1,24) (0)            ..

TV-SCH-1 = SCHEDULE  THRU DEC 31 (ALL) (1,24) (80)           ..
              .
              .
              .
```

```
ZA-1     = ZONE-AIR  SS-VENT-SCH = V-SCH-1
                     SS-VENT-T-SCH = TV-SCH-1
                     SS-VENT-CST = 10
                     SS-VENT-LIMIT-T = 75
                     SS-VENT-KW = 0.00005
                          .
                          .
                          .                    ..

SUNSP    = ZONE  ZONE-AIR = ZA-1
                     .
                     .
                     .                         ..
```

The following two keywords are defined for a sunspace. They modify the flow of air across an INTERIOR-WALL between the sunspace and adjoining zone, as determined by the AIR-FLOW-RATE, AIR-FLOW-CTRL-DT, AIR-FLOW-TYPE, etc. parameters for the wall (see description of the WALL-PARAMETERS command for INTERIOR-WALL).

SS-FLOW-SCH	is the u-name of a schedule, with values between 0 and 1, which multiply the air flow across an INTERIOR-WALL between a sunspace and an adjoining zone. This schedule could be used, for example, to turn off flow at night or during the summer months. If SS-FLOW-SCH is not specified for a sunspace, the flow multiplier defaults to 1.0, and so has no effect. It may be abbreviated as SS-F-SCH.
SS-FLOW-T-SCH	is specified to prevent warm air from a sunspace from overheating the adjacent zone. The air flow, forced or natural, from the sunspace is turned off if T(zone adjacent to sunspace) > SS-FLOW-T-SCH value. The default is 74^{o}F, and there is no abbreviation.

Note: If SS-FLOW-SCH or SS-FLOW-T-SCH is defined for a non-sunspace, it will be ignored.

Warning: The PIU (powered induction unit) system should not be used to serve a sunspace or a zone adjacent to a sunspace if the two zones are convectively coupled, or if the sunspace is vented.

Sunspace Modeling Guidelines

In the following, "sunspace" is a SPACE with SUNSPACE = YES; "room" is a SPACE with SUNSPACE = NO (the default) which is adjacent to a sunspace.

Control of Air Flow

It is usually necessary to control the airflow between a sunspace and adjacent rooms. This is done for one or more of the following reasons: (1) to avoid overheating the room with warmer air from the sunspace; (2) to prevent circulating cold air from the sunspace during the heating season; (3) to run the sunspace fan only when the sunspace-room air temperature differential is large enough to give effective heat transfer at design airflow.

In the DOE-2.1C sunspace simulation, the following control mechanisms are available. They can be used singly or in combination.

Differential Control Using AIR-FLOW-CTRL-DT in WALL-PARAMETERS gives differential temperature control for flow across a sunspace INTERIOR-WALL. Air flow across the wall occurs only if T(sunspace)-T(room) > AIR-FLOW-CTRL-DT. AIR-FLOW-CTRL-DT is generally chosen to be a few ^{o}F. For AIR-FLOW-TYPE = FREE-RECIRC, this assumes that the vents have back-flow dampers which prevent reverse circulation. For AIR-FLOW-TYPE = FREE-DOORWAY, this assumes occupants open and close the intervening doorway as relative temperature conditions change. For AIR-FLOW-TYPE = FORCED-RECIRC, it assumes that the fan is controlled by a differential thermostat.

Time-Clock Control For seasonal or day-night control, SS-FLOW-SCH can be specified under the systems ZONE or ZONE-AIR command for the sunspace. The airflow from a sunspace is multiplied by the hourly SS-FLOW-SCH value. If the value is 0, the flow is cut off completely as in the following example where there is no flow at night or from June to September.

```
FLOWSCH-1 = SCHEDULE  THRU MAY 31 (ALL) (1,8) (0) (9,17) (1)
                                        (18,24) (0)
                      THRU SEP 30 (ALL) (1,24) (0)
                      THRU DEC 31 (ALL) (1,8) (0) (9,7) (1)
                 .                      (18,24) (0)
                 .
                 .
SUNSP-1     = ZONE  SS-FLOW-SCH = FLOWSCH-1   $ SUNSPACE $
                          .
                          .
                          .
```

Room Thermostat Flow Control SS-FLOW-T-SCH allows control of airflow from a sunspace to an adjacent room based on room air temperature. If T(room) is higher than the SS-FLOW-T-SCH value, airflow from the sunspace is turned off. If T(room) is lower than the SS-FLOW-T-SCH value (and the SS-FLOW-SCH value is non-zero) airflow occurs if T(sunspace) - T(room) > AIR-FLOW-CTRL-DT. Generally, SS-FLOW-T-SCH values should be between the room heating and cooling setpoints. If SS-FLOW-T-SCH is not specified, the program will use a default value of 74°F for all hours.

Sun Control Methods

Sun control is generally needed to reduce solar heat gain in a sunspace during the summer. This can be accomplished with external projections such as overhangs, by making some or all of the sunspace glazing reflective or heat absorbing, or by using window coverings. The window coverings may be fixed or movable as determined by SHADING-SCHEDULE. They can also be deployed whenever transmitted solar gain exceeds a threshold value as specified by MAX-SOLAR-SCH.

The degree of shading that a sunspace requires depends, of course, on the extent to which it is used as a living space.

Example:

Window coverings with a shading coefficient multiplier of 0.3 and 20% solar transmittance are used from June through October whenever transmitted solar radiation exceeds 50 Btu/ft^2-hr:

```
SOLTRANS-1    = SCHEDULE  THRU DEC 31 (ALL) (1,24) (0.2)          ..
SHMULT-1      = SCHEDULE  THRU DEC 31 (ALL) (1,24) (0.3)          ..
SOL-THRESH-1  = SCHEDULE  THRU MAY 31 (ALL) (1,24) (1000)
                          THRU OCT 30 (ALL) (1,24) (50)
                          THRU DEC 31 (ALL) (1,24) (1000)         ..
                  .
                  .
                  .

SUNSPWIN      = WINDOW  SOL-TRANS-SCH = SOLTRANS-1
                        SHADING-SCHEDULE = SHMULT-1
                        MAX-SOLAR-SCH = SOL-THRESH-1
                                     .
                                     .
                                     .                            ..
```

Sun control may also be desirable for interior windows in a sunspace to prevent excessive direct solar gain into the adjoining room. SHADING-SCHEDULE and MAX-SOLAR-SCH can be used for interior windows in the same way as they are used for exterior windows. Another way of shading interior windows is to locate one or more BUILDING-SHADEs inside the sunspace.

Reducing Conductive Heat Loss From Sunspace Exterior Glazing

Sunspaces typically have large glazed areas. The high U-value of bare, single glazing (about 1.0 Btu/ft^2-hr-F) leads to significant conductive heat loss to the outside in the winter except in very mild climates. Some ways of ameliorating this heat loss are:

(1) Use double or even triple glazing (PANES = 2 or 3, respectively).

(2) Use movable insulation by inputting a CONDUCT-SCHEDULE which decreases the overall window conductance at night, or specify CONDUCT-TMIN-SCH which moves insulation into place when the outside temperature is low.

Example:

R-5 insulating panels cover a single-glazed sunspace exterior window November through April whenever the outside air temperature falls below 40^{o}F. The shading coefficient multiplier of the insulation is 0.1. The solar transmittance is 2%.

```
CONDMULT-1 = SCHEDULE  THRU DEC 31 (ALL) (1,24) (.12)          ..
SHMULT-1   = SCHEDULE  THRU DEC 31 (ALL) (1,24) (.1)           ..
TMIN-1     = SCHEDULE  THRU APR 30 (ALL) (1,24) (40)
                       THRU OCT 31 (ALL) (1,24) (0)
                       THRU DEC 31 (ALL) (1,24) (40)
SOLTRANS-1 = SCHEDULE  THRU DEC 31 (ALL) (1,24) (.02)          ..
                 .
                 .
                 .
SUNSPWIN   = WINDOW  CONDUCT-SCHEDULE = CONDMULT-1
                     SHADING-SCHEDULE = SHMULT-1
                     CONDUCT-TMIN-SCH = TMIN-1
                     SOL-TRAN-SCH = SOLTRANS-1
                              .
                              .
                              .                                ..
```

In this example, the value for the conductance multiplier is the ratio of the window conductance (excluding outside air film) with and without insulation: $(5+.68)^{-1}/(.68)^{-1} = .176/1.47 = .12$.

(3) Use translucent insulating panels in place of some or all of the clear glazing by inputting values for SHADING-COEF and GLASS-CONDUCTANCE obtained from manufacturer's data.

(4) Use glass with a low emissivity coating on the inside (heat mirror). The coating reduces the inside air film conductance giving an overall U-value similar to double glazing. See description of the INSIDE-EMISS keyword in the WINDOW command.

The above measures can also be modeled for interior glazing. In this case, the program expects outside air temperatures for CONDUCT-TMIN-SCH (as for exterior windows), not sunspace air temperatures.

Positioning of Sunspace Surfaces

For an accurate calculation of solar radiation falling on the INTERIOR-WALLs of a sunspace, the bounding surfaces of the sunspace need to be geometrically positioned. This applies to the EXTERIOR-WALLs and ROOFs and their associated windows, and the INTERIOR-WALLs and their associated windows. INTERIOR-WALL keywords X,Y,Z and AZIMUTH, formerly unused, are now operational (along with TILT) for geometrical positioning. It is recommended that INTERIOR-WALLs between a sunspace and adjacent room be defined in the sunspace. Otherwise, the adjacent room must be properly located with respect to the sunspace. If this is not done, the interior walls and windows will be mis-positioned relative to the sunspace exterior windows, and the projection of solar radiation from the windows onto the interior walls will be incorrect. This will result in a wrong calculation of the solar radiation transferred from sunspace to room. Even in this case, there will be no fictitious overall gain or loss of solar gain since the solar which stays in the sunspace plus that transferred to adjacent rooms is constrained by the program to equal that entering the sunspace. There will, however, be an error message if the transferred solar exceeds the entering solar, which would give a net negative solar gain in the sunspace. This may occur if interior walls or windows on them overlap, if MULTIPLIER is used on an interior window, or if MULTIPLIER is used on rooms adjacent to a sunspace.

Massive Interior Walls

Sunspace interior walls are often fairly massive, leading to a significant time delay in the heat transfer across them by conduction. Such walls should be described by response factors, i.e. with a delayed-type construction. This is a new feature in 2.1C. Previously, INTERIOR-WALL response factors were used only in the Custom Weighting Factor calculation; hourly conduction through all INTERIOR-WALLs was calculated as quick.

The order of defining layers in a delayed INTERIOR-WALL is from "outside" to "inside", where "outside" is the side of the wall in the NEXT-TO space, and "inside" is the side in the space in which the wall was defined.

Delayed conduction through INTERIOR-WALLs is calculated only for INTERIOR-WALLs between a sunspace and a non-sunspace. For other INTERIOR-WALLs the hourly conduction is quick.

Delayed conduction through an INTERIOR-WALL between two non-sunspaces can be obtained simply by assigning SUNSPACE = YES to one of the spaces, even though the space is not actually a sunspace. If the solar flux on the "sunspace" side of the wall is small, it is recommended that INSIDE-SOL-ABS = (0,0) be input for the wall in order to zero out absorption of solar radiation. Otherwise, all interior and exterior walls and windows in the "sunspace" should be geometrically positioned as described in Positioning of Sunspace Surfaces.

Solar Radiation Absorbed by Interior Walls

The program calculates conduction through a sunspace INTERIOR-WALL by doing a heat balance on both surfaces. The hourly solar radiation absorbed by the sunspace side of the wall is included in the heat balance. Part of this solar radiation is conducted into the adjacent room.

The amount of solar radiation absorbed depends on the incident flux and the absorptance of the wall. The section Interior Solar Radiation describes how the incident flux is determined. The absorptance is input via the keyword INSIDE-SOL-ABS for INTERIOR-WALL. Typical solar absorptance values are listed in a table under the CONSTRUCTION command in the Reference Manual. If not specified, absorptance defaults to 0.5 for walls, 0.8 for floors, and 0.3 for ceilings.

For the purposes of the conduction calculation, the direct and diffuse solar radiation absorbed by an interior wall is uniformly distributed over its surface. If part of the wall gets significantly more radiation, the user can improve the conduction calculation by dividing the wall into two or more sections. The sections would then be input as separate INTERIOR-WALLs of the same AZIMUTH and TILT, but with X,Y,Z,HEIGHT, and WIDTH chosen to give correct geometrical positioning.

Interior Solar Radiation

In DOE-2.1B, the solar radiation entering a space is counted as a heat gain only for that particular space. In 2.1C, however, part of the solar radiation entering a sunspace can be transferred directly to adjacent rooms through interior glazing, or indirectly via solar radiation absorbed by the opaque part of INTERIOR-WALLs.

To find the beam radiation falling on an inside surface, the program projects the image of each sunspace exterior window onto the surface. This is done using the DOE-2 shadow routines. Summing the contribution from all the exterior windows then gives the net beam radiation incident on the surface. If the surface is an interior window, the transmission and absorption properties of the glazing are used to find the solar gain through the window into the adjacent space. If the surface is opaque, part of the absorbed radiation is conducted to the neighboring space.

The diffuse solar radiation striking sunspace interior walls is also calculated. This radiation has three sources: diffuse radiation from exterior windows; diffuse radiation coming from beam radiation reflected from interior surfaces; and diffuse radiation coming from diffuse radiation from exterior windows which reflects from interior surfaces. The diffuse irradiance inside a sunspace is assumed to be uniform.

If a shading device is present on a sunspace exterior window in a given hour, it is assumed that the radiation transmitted by the shade is totally diffuse; i.e., there is no transmitted beam component. The transmittance of the shade is assumed to be the same for direct and diffuse incident radiation and given by SOL-TRANS-SCH. Solar transmittances for various window treatments can be obtained from Table 3 or from manufacturer´s data.

TABLE 3

Description of Window Treatments and Performance*

Window Treatment	Fabrication/Finish/Color	Solar Characteristics**		
		Transmittance Percent	Reflectance Percent	Absorptance Percent
Lined Drapery				
1	Satin/NFF[†]/Goldenrod Lining: Plain/Opaque/White	15	66	19
2	Satin/NFF/Dark Brown Lining: Plain/Opaque/White	02	57	41
3	Satin/NFF/White Lining: Plain/Opaque/White	18	68	14
4	Mali/NFF/Beige w/brown accents Lining: Plain/Translucent/Beige	34	47	19
Unlined Satin Drapery				
1	Brocade/Acrylic Foam Back/Beige	08	70	21
2	Brocade/Acrylic Foam Back/Beige	10	67	24
3	Modified Satin/Acrylic Foam Back/Beige	17	73	10
4	Modified Satin/Acrylic Foam Back/Green	09	75	16
5	Modified Satin/NFF Variegated Brown	30	51	19
nlined Casement Drapery				
1	Mali/NFF/Beige	54	41	05
2	Mali/NFF/Variegated Brown	29	54	16
3	Mali/NFF/Beige	56	37	07
4	Mali/NFF/Beige	36	42	23
Shirred Curtains				
1	Plain (ninon)/NFF/Beige	65	27	08
2	Plain (ninon)/NFF/White	66	29	05
3	Leno (marquisette)/NFF/White	86	14	00
Pleated Curtains				
1	Plain (ninon)/NFF/Beige	27	37	37
Venetian Blinds				
1	2" Slats/Steel/NFF/White(slats closed)	04	55	41
2	1" Slats/Alum/NFF/White(slats closed)	02	57	41
Vertical Blinds				
1	3.5" Film/Polyvinylchloride/NFF/Wt(slats closed)	01	70	28
2	3.5" Plain Weave/NFF/White(slats closed)	31	58	11
Translucent Roller Shade				
1	Open Plain Weave/Vinyl Coated Fiberglass/White	48	43	09
2	Plain Weave/Vinyl Coated Cotton/Beige	19	65	16

TABLE 3 (continued)

Opaque Roller Shade				
1	Plain Weave/Vinyl Coated Cotton Embossed/Beige	00	66	34
2	Plain Weave/Vinyl Coated layer/Wt	00	74	26
3	Plain Weave/Laminated Embossed/White	00	75	26
4	Film/Vinyl Coated Embossed/White	15	67	18
Rollup Shade				
1	Modified Plain Weave/Vinyl Tube Yarns/NFF/Beige	33	53	14
Drapery Liner				
1	Plain Weave/Acrylic Coated/White	18	66	16
2	Plain Weave/Acrylic Coated/White	17	70	13
Wooden Shutter				
1	Wood/NFF/Beige/Louvers Closed	00	63	37
Wooden Shutter Frame with Fabric				
1	Wood/NFF/Beige; Fabric: Ninon/NFF White/ Width: 3-times Frame Opening/Shirred	62	35	04
2	Wood/NFF/Beige; Fabric: Ninon/NFF White/ Width: 6-times Frame Opening/Shirred	32	51	17

---

† NFF - No Functional Finish relevant to Heat Flux

* From "Solar Optical Properties of Accepted Interior Window Treatments", Eleanor Woodson, Patricia Horridge, Samina Kahn, and Richard William Tock, ASHRAE Journal, August 1983, p.40.

** Due to roundoff, sum of transmittance, reflectance, and absorptance may not be 100%.

The solar energy absorbed by sunspace INTERIOR-WALLs is deducted from the sunspace load. The solar energy transmitted through sunspace interior glazing is also deducted from the sunspace load but is not credited to the load on adjacent rooms until the SYSTEMS calculation. For this reason, automatic sizing in SYSTEMS, which is based on peak loads from the LOADS program, should be used with caution.

Up to 20-25% of the solar radiation entering the sunspace can be reflected back out the exterior windows. The exact percentage depends on inside surface reflectances, glazing fraction, and glass shading coefficient, as described in Section 2.3.4.2 of the DOE-2.1A Engineers Manual. This loss is included in the Custom Weighting Factors for solar gain; therefore, it is accounted for in the weighted solar load for the space (but not in the instantaneous solar gain). The loss is not accounted for in the ASHRAE weighting factors, so that Custom Weighting Factors, obtained by specifying FLOOR-WEIGHT = 0, should be used for sunspaces.

The program does not account for the loss of radiation entering one exterior window and leaving another exterior window without an intermediate reflection. This radiation is included in the solar gain.

Use of Multipliers

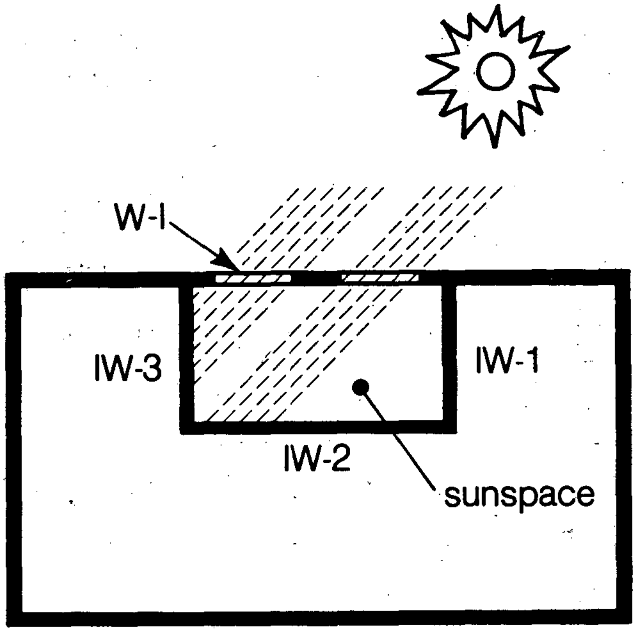
To obtain an accurate interior solar radiation calculation, it is recommended that MULTIPLIER not be used for sunspace exterior WINDOWS, interior WINDOWS, or EXTERIOR-WALLs (if they have windows). In addition, it is recommended that MULTIPLIER not be used on a SPACE adjacent to a sunspace.

The dangers of using MULTIPLIERs are illustrated in Figs. 4 and 5. If the two identical exterior WINDOWs in Fig. 4 are entered as a single WINDOW W-1 with MULTIPLIER = 2, no direct radiation will be calculated to fall on interior wall IW-2, whereas the radiation on IW-3 will be over-estimated by a factor of 2. The two windows should be input separately or represented by an "effective" window (see Walls with Multiple Windows in the Section "Daylighting" in this Supplement). In Fig. 5 beam radiation strikes the interior window between sunspace and B, but not the one between sunspace and A. If the "identical" SPACE's A and B are input as A with MULTIPLIER = 2, there will be zero beam radiation transmitted to these SPACEs from the sunspace.

If the radiation inside the sunspace is predominately diffuse, which would be the case if beam radiation were blocked by overhangs or window shades, the various MULTIPLIERs discussed can be used with little loss of accuracy.

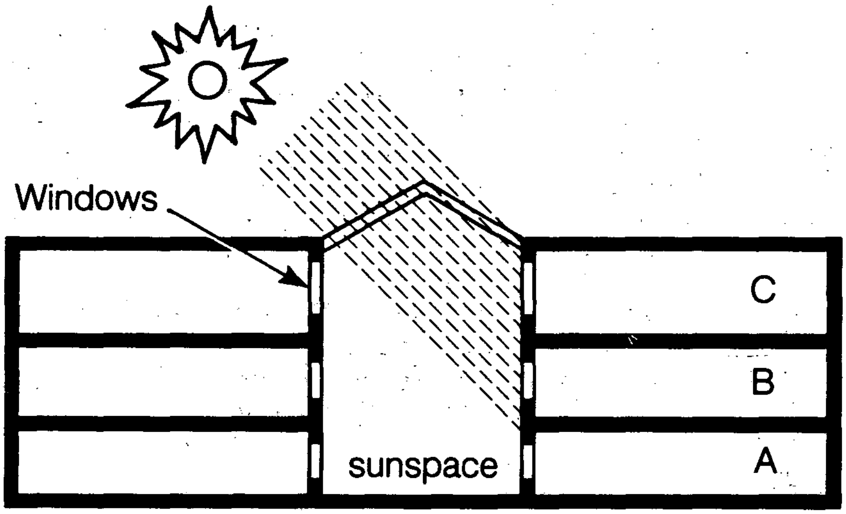
Translucent Glazing

Translucent exterior glazing in a sunspace should be modeled with GLASS-TYPE-CODE = 1 and with SHADING-SCHEDULE values equal to the shading coefficient of the glazing. (A SHADING-SCHEDULE is used here to give a window which is diffusely transmitting.) A SOL-TRANS-SCH should also be specified, with a constant value equal to T/0.878, where T is



XBL 849-8739

Fig. 4. If the two exterior WINDOWs are input as a single window W-1 with MULTIPLIER = 2, the program will get zero beam radiation striking interior wall IW-2 and twice the actual amount striking IW-3.



XBL 849-8738

Fig. 5. If SPACEs A and B are input as a single space A with MULTIPLIER = 2, the beam radiation transmitted through the interior windows in these spaces will be calculated to be zero.

the solar transmittance of the glazing at normal incidence. (0.878 is the transmittance at normal incidence for the clear reference glass used in DOE-2.)

Example:

A sunspace has single-pane translucent exterior glazing with a shading coefficient of 0.71 and solar transmittance of 0.82:

```
GT-1        = GLASS-TYPE  GLASS-TYPE-CODE = 1                        ..
                    .
                    .
                    .

SHSCH-1     = SCHEDULE  THRU DEC 31 (ALL) (1,24) (.71)               ..
SOLTRSCH-1  = SCHEDULE  THRU DEC 31 (ALL) (1,24) (.93)               ..
                                             $ .93 = .82/.878 $
                    .
                    .
                    .

SUNSPWIN-1  = WINDOW  GLASS-TYPE = GT-1
                      SHADING-SCHEDULE = SHSCH-1
                      SOL-TRANS-SCH = SOLTRSCH-1
                              .
                              .
                              .                                      ..
```

Moisture from Plants and Trees

Atriums often have plants and trees. Moisture transpiring from leaves and evaporating from soil can produce a significant latent load. To model this load, plants can be described using the "SOURCE" keywords in SPACE or SPACE-CONDITIONS as follows:

```
SOURCE-TYPE = PROCESS
SOURCE-LATENT = 1.0
SOURCE-SENSIBLE = 0.0
SOURCE-BTU/HR = latent load from plants and soil
SOURCE-SCHEDULE = u-name of schedule (which could
                   vary seasonally or with time of
                   of day, if desired).
```

Baffles and Louvers

Baffles and louvers on sunspace exterior windows, which block and/or diffuse incoming beam radiation, can be modeled as shading devices by specifying SOL-TRANS-SCH and SHADING-SCHEDULE. This method is very approximate, however, since the transmittance of devices of this kind is usually very incidence-angle dependent. Furthermore, very little measured data is currently available that would be useful in choosing average transmittance values.

Atrium as Return Air Plenum

In some commercial building designs, some or all of the return air from conditioned zones is passed to a central sunspace/atrium, from which it is passed back to the central air handling system or exhausted. The atrium thus behaves like a return air plenum. This arrangement can be modeled by assigning ZONE-TYPE = PLENUM to the atrium zone and including the atrium u-name in the PLENUM-NAMES list for the system.

If only part of the system return air goes to the atrium, two PLENUM zones can be defined, one of them being the atrium and the other being a real or dummy plenum. In a system with two plenums, the return air is split by DOE-2 between the plenums, in proportion to their floor areas, as given by the AREA keyword in the SPACE commands. Thus, if a fraction f of return air goes to the atrium, the atrium AREA divided by the AREA of the second plenum should be f/(1-f).

If some of the return air is exhausted directly from the atrium, EXHAUST-CFM can be specified for the atrium zone. Previously, this keyword worked only for ZONE-TYPE = CONDITIONED. (EXHAUST-CFM will also work for PLENUMs which are not sunspaces, ie., have SUNSPACE = NO.)

The program accounts for the various forms of sensible and latent heat gain or loss, such as solar gain, infiltration, and moisture from people, for ZONE-TYPE = PLENUM just as it does for ZONE-TYPE = CONDITIONED. There are two important restrictions, however. The atrium as PLENUM cannot be mechanically cooled (although it can be vented) and it can be heated only with baseboards (see the Section "Baseboard Heating in Plenums" in this Supplement).

Example:

Two-thirds of the return air from five identical conditioned zones goes to a 10000 sq.ft. atrium; the remaining one-third goes directly back to the air handling system.

```
INPUT LOADS
        .
        .
        .

CONDZONES = SPACE  MULTIPLIER = 5
                   ZONE-TYPE = CONDITIONED
                          .
                          .
                          .

ATRIUM     = SPACE  AREA = 10000
                    SUNSPACE = YES
                    ZONE-TYPE = PLENUM
                          .
                          .
                          .
```

```
DUMPLEN     = SPACE  AREA = 5000
                     ZONE-TYPE = PLENUM
                           .
                           .
                           .                                        ..

INPUT SYSTEMS                                                       ..
     .
     .
     .

CONDZONES   = ZONE
                .
                .
                .                                                   ..

ATRIUM      = ZONE
                .
                .
                .                                                   ..

DUMPLENS    = ZONE
                .
                .
                .                                                   ..

SYS-1       = SYSTEM  ZONE-NAMES = (CONDZONES, ATRIUM, DUMPLEN)
                      PLENUM-NAMES = (ATRIUM, DUMPLEN)
                           .
                           .
                           .                                        ..
```

Heating, Cooling, and Venting of Residential Sunspaces

For SYSTEM-TYPE = RESYS, sunspaces are not heated by the central system; a sunspace can be heated only with thermostatic baseboards (BASEBOARD-CTRL = THERMOSTATIC). Unlike baseboard heating of the other zones in this system, baseboard heating of a sunspace is independent of the heating requirements of the control zone (the first zone in the ZONE-NAMES list).

Sunspaces in SYSTEM-TYPE = RESYS are not cooled by the central system. They can, however, be vented with outside air, as explained in the keyword descriptions for SS-VENT-SCH, SS-VENT-T-SCH, etc., in the ZONE-AIR command. The venting of a sunspace in this system is independent of the natural ventilation of the other zones as determined by NATURAL-VENT-SCH, etc., in SYSTEM-AIR.

Use of Custom Weighting Factors for Sunspaces

It is recommended that Custom Weighting Factors (CWF) be used for sunspaces for several reasons:

(1) For high conductance spaces, the precalculated (ASHRAE) weighting factors in DOE-2 overestimate heating and cooling loads. The overestimate can be as high as 25-30% for heavily glazed spaces.

(2) The CWF account for loss of solar gain due to reflection of sunlight back out of exterior windows.

(3) The CWF give a more accurate calculation of the generally large temperature swings in a solar-driven space.

CWF's will automatically be calculated for any space with FLOOR-WEIGHT = 0. Otherwise, the program will use ASHRAE weighting factors. See the Reference Manual, Chap. III, Sec. C, for CWF input guidelines.

Hourly Report Variables for Sunspace Analysis

Nine new hourly report variables (56 through 64) have been added in SYSTEMS to VARIABLE-TYPE = u-name of ZONE for sunspace analysis. Also, the LOADS VARIABLE-TYPE = u-name of WINDOW variable descriptions have been updated to reflect the addition of sunspace-related interior windows. See the Appendix at the end of this volume for a full listing of the program hourly variables.

Sunspace-related Error, Caution, and Warning Messages

In the following, "sunspace" means a SPACE with SUNSPACE = YES; "non-sunspace" means a SPACE with SUNSPACE = NO (the default).

Error Message (1)	INTERIOR-WALL <u-name>, WHICH IS BETWEEN A SUNSPACE AND A NON-SUNSPACE, HAS AREA SPECIFIED RATHER THAN HEIGHT AND WIDTH. HEIGHT AND WIDTH ARE REQUIRED FOR CALCULATION OF SOLAR RADIATION ABSORBED ON THE SUNSPACE SIDE OF THIS WALL.
Meaning:	Self-explanatory.
User-Action:	Specify HEIGHT and WIDTH for this wall.
Error Message (2)	EXTERIOR-WALL <u-name>, IN SUNSPACE <u-name>, HAS A MULTIPLIER OF <value>. THE MULTIPLIER ON AN EXTERIOR-WALL (WITH WINDOWS) IN A SUNSPACE SHOULD BE 1.0.
Meaning:	A sunspace has an EXTERIOR-WALL with a MULTIPLIER different from 1.0. Since this wall has one or more WINDOWs, the use of a MULTIPLIER will give an inaccurate calculation of the interior solar radiation distribution from these windows.
User-Action:	Do not use a MULTIPLIER on sunspace EXTERIOR-WALLs.
Error Message (3)	FOR SUNSPACE <u-name> ON MONTH <value>, DAY <value>, HOUR <value>, THE SUM OF THE SOLAR RADIATION ABSORBED BY INTERIOR WALLS (<value> BTU) AND TRANSMITTED BY INTERIOR WINDOWS TO THE ADJACENT SPACES (<value> BTU) EXCEEDS THE TOTAL SOLAR GAIN FROM EXTERIOR WINDOWS IN THE SPACE (<value> BTU). CHECK POSITION AND DIMENSIONS OF INTERIOR-WALLS.
Meaning:	An unphysical amount of solar radiation is being absorbed by or transmitted through sunspace interior surfaces. This may be due to (1) overlapping INTERIOR-WALLs; (2) overlapping WINDOWs on an INTERIOR-WALL; (3) MULTIPLIER not 1.0 on adjacent space; (4) MULTIPLIER not 1.0 on interior WINDOW; (5) mispositioned INTERIOR-WALL or interior WINDOW.

User-Action: Check geometry and multipliers on all interior surfaces. See Fig. 4 and subsection Positioning of Sunspace Surfaces, above.

Error Message (4) SPACE <u-name> HAS <value> SUNSPACE COMMON WALLS WITH CONVECTIVE HEAT TRANSFER (AIR-FLOW-TYPE = FORCED-RECIRC, FORCED-OA-PREHT, FREE-RECIRC, OR FREE-DOORWAY. AT MOST ONE COMMON WALL WITH CONVECTIVE TRANSFER IS ALLOWED IN A SPACE.

Meaning: A space can not have more than one interior wall across which convective flow is specified using the AIR-FLOW-TYPE keyword in the WALL-PARAMETERS command.

User-Action: Reduce number of interior walls with convection to one.

Warning Message (1) WINDOW <u-name> ON INTERIOR WALL <u-name> HAS X=0, Y=0 AND THEREFORE HAS PROBABLY NOT BEEN CORRECTLY POSITIONED. THIS MAY CAUSE AN INACCURATE SOLAR RADIATION TRANSMISSION CALCULATION.

Meaning: The user has probably forgotten to geometrically position the interior WINDOW.

User-Action: Specify X, Y, HEIGHT and WIDTH for the WINDOW. See Fig. 4 and subsection Positioning of Sunspace Surfaces, above.

Warning Message (2) <u-name> IS AN INTERIOR-WALL BETWEEN SUNSPACE <u-name> AND SPACE <u-name>. SINCE THE INTERIOR-WALL WAS DEFINED IN <u-name> IT IS IMPORTANT THAT THIS SPACE BE CORRECTLY POSITIONED WITH RESPECT TO THE SUNSPACE TO OBTAIN AN ACCURATE CALCULATION OF SOLAR RADIATION INCIDENT ON THE WALL FROM EXTERIOR WINDOWS IN THE SUNSPACE.

Meaning: A sunspace INTERIOR-WALL was defined in the adjacent space rather than in the sunspace.

User-Action: Be sure that the SPACE in which the INTERIOR-WALL was defined is geometrically positioned with respect to the sunspace. Alternatively, define the INTERIOR-WALL in the sunspace.

Warning Message (3) SPACE <u-name>, WHICH IS NEXT TO SUNSPACE <u-name> HAS MULTIPLIER <value>. A MULTIPLIER DIFFERENT FROM 1.0 MAY CAUSE AN INACCURATE CALCULATION OF HEAT TRANSFER FROM THE SUNSPACE.

Meaning: The use of a MULTIPLIER on a SPACE adjacent to a sunspace multiplies the common INTERIOR-WALL. This may give an incorrect calculation of the total solar radiation absorbed by the wall and transmitted by windows in the wall.

User-Action: See subsection *Use of Multipliers*, above.

Warning Message (4) WINDOW <u-name> IN INTERIOR-WALL <u-name> HAS MULTIPLIER <value>. A MULTIPLIER DIFFERENT FROM 1.0 MAY CAUSE AN INACCURATE SOLAR RADIATION TRANSMISSION CALCULATION.

Meaning: The location of sunspace interior glazing is important in the calculation of the amount of solar radiation striking the glazing.

User-Action: Do not use a MULTIPLIER. Input WINDOWs separately. Alternatively, use an "effective window" as described in subsection *Walls with Multiple Windows* in the Section "Daylighting" in this Supplement.

Caution Message (1) SUNSPACE INTERIOR WALL <u-name> HAS X=0, Y=0 AND THEREFORE MAY NOT BE CORRECTLY POSITIONED. THIS MAY CAUSE AN INACCURATE CALCULATION OF SOLAR RADIATION ABSORBED BY THE WALL.

Meaning: The user has probably forgotten to geometrically position a sunspace INTERIOR-WALL.

User-Action: Specify X, Y, Z, AZIMUTH, TILT, HEIGHT, and WIDTH. See Fig. 4 and subsection *Positioning of Sunspace Surfaces*, above.

Caution Message (2) WINDOW <u-name> IN SUNSPACE EXTERIOR-WALL <u-name> HAS MULTIPLIER <value>. A MULTIPLIER DIFFERENT FROM 1.0 MAY CAUSE AN INACCURATE CALCULATION OF THE AMOUNT OF SOLAR RADIATION FROM THIS WINDOW WHICH STRIKES THE INTERIOR WALLS OF THE SUNSPACE.

Meaning: The geometrical position of a sunspace exterior WINDOW is important in the interior solar radiation calculation.

User-Action: Do not use MULTIPLER; input windows separately. Alternatively, use an "effective window" as described in subsection *Walls with Multiple Windows* in the Section "Daylighting" in this Supplement.

Caution Message (3) WINDOW <u-name> IS IN INTERIOR WALL <u-name> WITH TYPE=[AIR, ADIABATIC, or INTERNAL]. THIS WINDOW WILL BE IGNORED.

Meaning: The program calculates heat transfer through interior windows only if they are in an INTERIOR-WALL with INT-WALL-TYPE = STANDARD (the default) and this INTERIOR-WALL is between a sunspace and a non-sunspace. In all other cases, INTERIOR-WALLs are considered as being without WINDOWS.

User-Action: Remove WINDOW from wall, or change INT-WALL-TYPE to STANDARD if heat transfer calculation across the wall is desired.

Caution Message (4) WINDOW <u-name> IS IN INTERIOR-WALL <u-name> BETWEEN TWO SUNSPACES. THIS WINDOW WILL BE IGNORED.

Meaning: The program calculates heat transfer through interior windows only if they are in an INTERIOR-WALL with INT-WALL-TYPE = STANDARD (the default) and this INTERIOR-WALL is between a sunspace and a non-sunspace. In all other cases, INTERIOR-WALLs are considered as being without WINDOWS.

User-Action: Check whether the spaces on either side of this wall should both be sunspaces. If not, assign SUNSPACE = NO to one of them. Otherwise, remove WINDOW from wall.

Caution Message (5) WINDOW <u-name> IS IN INTERIOR-WALL <u-name> BETWEEN TWO NON-SUNSPACES. THIS WINDOW WILL BE IGNORED. (HEAT TRANSFER WILL BE CALCULATED ONLY FOR WINDOWS IN A STANDARD-TYPE INTERIOR WALL BETWEEN A SUNSPACE AND A NON-SUNSPACE.)

Meaning: The program calculates heat transfer through interior windows only if they are in an INTERIOR-WALL with INT-WALL-TYPE = STANDARD (the default) and this INTERIOR-WALL is between a sunspace and a non-sunspace. In all other cases, INTERIOR-WALLs are considered as being without WINDOWS.

User-Action: Check whether the spaces separated by this wall should both be non-sunspaces. If not, assign SUNSPACE = YES to one of them. Otherwise, remove WINDOW from wall.

WINDOW MANAGEMENT AND SOLAR RADIATION

Window Management

There are several ways of controlling the operation of window shading devices in DOE-2. In DOE-2.1A, the shading-coefficient and conductance of a window could be modified each hour to account for the presence of a shading device by specifying a SHADING-SCHEDULE and CONDUCT-SCHEDULE for the window. We call these "schedule controls". This option was retained in 2.1B; in addition, options to control shading devices when solar gain, outside temperature, or daylight glare exceed user-specified threshold values were added in 2.1B. We call these "threshold controls".

The 2.1B options made use of the following keywords:

MAX-SOLAR-SCH
SUN-CTRL-PROB
CONDUCT-TMIN-SCH
WIN-SHADE-TYPE

Please refer to the "Daylighting" Section in this Supplement for a discussion on the use of these keywords (whether or not daylighting is to be employed).

The various control options for window management and their input requirements are summarized in Table 1 under Window Management in the "Daylighting" Section. Note in Table 1B the additional input requirements for windows in spaces for which a daylighting calculation has been requested by specifying DAYLIGHTING=YES in SPACE or SPACE-CONDITIONS.

Conditional Shading-Device Control

A new keyword has been introduced in 2.1C, in the WINDOW command, to be used in conjunction with window management:

WINDOW

OPEN-SHADE-SCH	is the u-name of a schedule whose value in any given hour is the probability that the shading device will be opened if both the solar gain and the glare (with shade open) would be below the limits set by MAX-SOLAR-SCH in the WINDOW command and MAX-GLARE in the SPACE-CONDITIONS command. If OPEN-SHADE-SCH is not specified, the shading devices will be reopened as soon as both the heat gain and glare fall below the specified limits. The shading devices are reopened at midnight in any case. The abbreviation is O-S-SCH.

Example:

Drapes on a window are closed from April to October whenever the transmitted direct solar gain (with the drapes open) exceeds a threshold value of 15 Btu/ft^2-hr. From November to March, the drapes are closed when the solar gain exceeds 50 Btu/ft^2-hr. The shading coefficient multiplier for the drapes when they are closed is 0.3. The drapes have a negligible effect on the window conductance. There is a 10% probability each hour that the occupants will re-open the drapes if the transmitted solar gain falls below the above threshold values.

```
DRAPEMULTSCH-1 = SCHEDULE  THRU DEC 31 (ALL) (1,24) (0.3)          ..

MAXSOLSCH-1    = SCHEDULE  THRU MAR 31 (ALL) (1,24) (50)
                           THRU OCT 31 (ALL) (1,24) (15)
                           THRU DEC 31 (ALL) (1,24) (50)           ..

REOPEN-PROB-1  = SCHEDULE  THRU DEC 31 (ALL) (1,24) (0.1)          ..
                     .
                     .
                     .

WIN-1          = WINDOW  SHADING-SCHEDULE = DRAPEMULTSCH-1
                         MAX-SOLAR-SCH = MAXSOLSCH-1
                         OPEN-SHADE-SCH = REOPEN-PROB-1
                                     .
                                     .
                                     .                             ..
```

Diffuse Solar Gain

The algorithm that computes the diffuse component of the solar radiation on building surfaces has been improved to estimate more accurately the correlation of the diffuse component with the hourly position of the sun and with the amount of cloud cover. Users of DOE-2.1C will notice a significant drop (~10%) in the peak solar gain reported from windows in comparison to all previous versions of the program. This algorithm is used only when the user allows the keywords SKY-FORM-FACTOR and GND-FORM-FACTOR to default in the EXTERIOR-WALL command. Since the effective sky form factor varies each hour as the distribution of diffuse radiation changes, whereas user input values are constant, the user is advised not to use these keywords.

The default value for the GND-FORM-FACTOR is computed in the program (and in the input below) as (1.0 - cos(TILT))/2. Since this value enters into calculations multiplied by GND-REFLECTANCE, the user can modify the latter to account for values of GND-FORM-FACTOR that differ from the default for unshaded windows. For windows with overhangs, the input below could be modified.

The only time that one might desire to change the default situation for the SKY-FORM-FACTOR is when there are shading surfaces that reduce the amount of diffuse (as well as, of course, direct) solar radiation incident on the building surface. Since the BUILDING-SHADE and FIXED-SHADE commands and the SHADING-SURFACE and SETBACK keywords affect only direct radiation, it was the original purpose of the SKY-FORM-FACTOR keyword to provide a means of reducing the diffuse component as well, but only under the assumption that the diffuse radiation is distributed uniformly. It is now possible to handle the shading of diffuse solar radiation without using the SKY-FORM-FACTOR keyword by using the functional values approach for certain shading configurations (see Section "Functional Values" in this Supplement).

Overhangs Over Windows or Doors

If there are overhangs over a window or if the window has a setback (refer to Fig. 1), the following input will approximate the correct effective SKY-FORM-FACTOR:

1. In each WINDOW command with an overhang or setback enter the keyword-value pair:

   ```
   FUNCTION = (*OVERHANG*,*NONE*)
   ```

   where the u-name OVERHANG can be changed if there are more than one overhang configurations in the building.

2. After the END .. statement in the LOADS input, enter the following commands (if there are several overhang configurations, there will be a corresponding number of sets of the following commands):

   ```
   FUNCTION  NAME = OVERHANG  LEVEL = WINDOW                                ..

   ASSIGN    S1  = SOLDF1  S2 = SOLDF2   $ DIFFUSE SOLAR COEF $
             S3  = SOLDF3  S4 = SOLDF4  S5 = SOLDF5
             SFF = <WISKYFF>             $ SKY AND GROUND FF  $
             GFF = <WIGNDFF>
             IS  = ISUNUP                $ SUN UP FLAG        $
             TI  = XSTLT                 $ TILT OF WALL       $         ..

   CALCULATE                                                            ..

         IF (IS .EQ. 0) RETURN
         GFF = (1.0 - COS(TI)) * 0.5
         SFF = S1 * const1 + S2 * const2 + S3 * const3 + S4 * const4
        1      + S5 * const5
         END

   END-FUNCTION                                                         ..
   ```

   The constants, const1, const2, const3, const4 and const5 must be calculated by the user from the formulas below:

$$\text{const}\,1 = \frac{\cos\gamma}{\cos\beta} \cdot \frac{\cos\gamma - \cos\alpha}{\sin(\alpha - \beta)} \qquad (1.1)$$

$$\text{const}\,2 = \frac{\tan\alpha - \tan\gamma - (\alpha - \gamma)}{\tan\alpha - \tan\beta} \qquad (1.2)$$

$$\text{const}\,3 = \frac{(\cos\gamma - \cos\alpha)(1-\cos\gamma\cos\alpha)}{(\tan\alpha - \tan\beta)\cos\alpha\cos\gamma} \qquad (1.3)$$

$$\text{const}\,4 = \frac{\tan\alpha - \tan\gamma}{\tan\alpha - \tan\beta} \qquad (1.4)$$

$$\text{const}\,5 = \frac{2(\alpha\tan\alpha - \gamma\tan\gamma)}{\pi(\tan\alpha - \tan\beta)} \qquad (1.5)$$

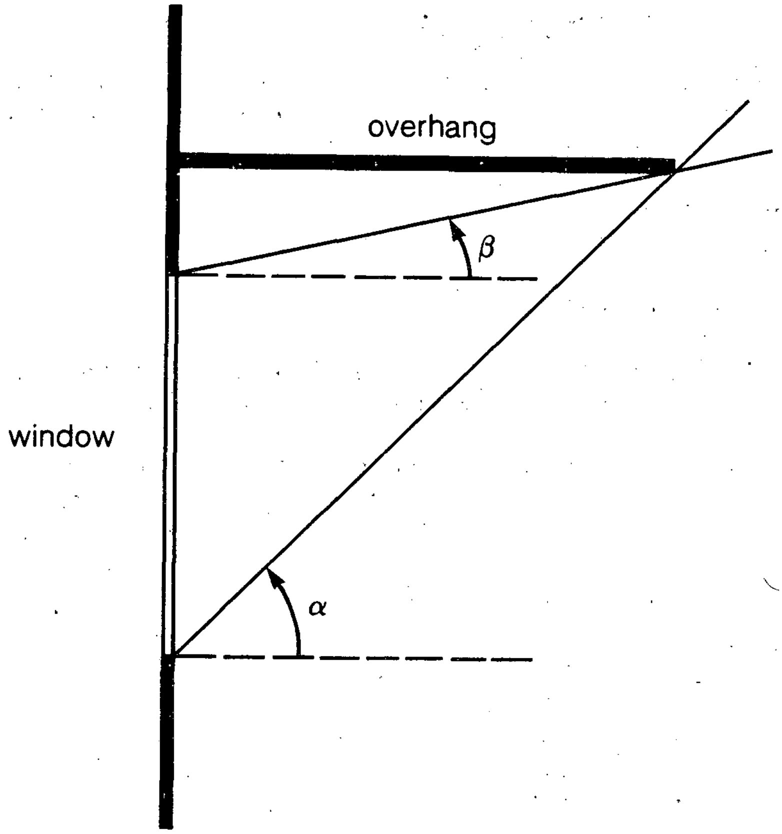


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Fig. 1

τ is the TILT of the wall in radians and γ is the maximum of $\tau - \pi/2$ and β, where β is the angle in radians between the normal to the window and the edge of the overhang as seen from the top of the window and α is the same for the bottom of the window. If the overhang is just at the top of a vertical window, then $\beta = 0$, $\tau = \pi/2$ and $\gamma = 0$ and the expressions for the constants become:

$$\text{const}\,1 = \frac{1 - \cos\alpha}{\sin\alpha} \qquad (2.1)$$

$$\text{const}\,2 = 1 - \frac{\alpha}{\tan\alpha} \qquad (2.2)$$

$$\mathrm{const3} = \frac{(1 - \cos\alpha)^2}{\sin\alpha} \tag{2.3}$$

$$\mathrm{const4} = 1.0 \tag{2.4}$$

$$\mathrm{const5} = \frac{2\alpha}{\pi} \tag{2.5}$$

If there is no overhang, the expression for SFF reduces to S1 + S2 + S3 + S4 + S5. In this case there would be no need for using the FUNCTION approach at all, since this is the default.

Strictly speaking, these formulae apply to overhangs that are infinitely wide. Thus, when used with finite overhangs, an error will be introduced and the diffuse component of the solar radiation will be underestimated because of radiation that can come in from the sides of the overhang. Obviously, the more the overhang extends beyond the window, the less the error. In the present formulation of the algorithm, there is no accurate solution to this problem.

For doors, exactly the same input is required, except that in the FUNCTION command the keyword LEVEL = DOOR.

Eaves on Roofs

If there are eaves extending out horizontally from the roof and one wants to take into account the reduction of diffuse radiation on the exterior wall and its windows and doors, it is again better to use the Functional Values approach. In this case the following input is recommended:

1. In each EXTERIOR-WALL command with an overhang enter the keyword-value pair:

   ```
   FUNCTION = (*EAVE*,*NONE*)
   ```

   where the u-name EAVE can be changed if there are more than one eave configurations in the building.

2. After the END .. statement in the LOADS input, enter the following commands (if there are several eave configurations, there will be a corresponding number of sets of the following commands):

   ```
   FUNCTION  NAME = EAVE  LEVEL = EXTERIOR-WALL                    ..

   ASSIGN    S1   = SOLDF1  S2 = SOLDF2 $ DIFFUSE SOLAR COEF $
             S3   = SOLDF3  S4 = SOLDF4  S5 = SOLDF5
             SKY  = BSCC              $ DIFFUSE HORIZONTAL SOLAR $
             DNC  = RDNCC             $ DIRECT NORMAL SOLAR $
             GND  = GNDREF            $ GROUND REFLECTANCE $
             BG   = BG                $ RAD FROM GROUND $
             XG   = XGOLGE            $ PERCENT SHADING OF WALL $
   ```

```
          COST = RAYCOS3          $ COS SOLAR ANG. FROM ZENITH $
          RT   = RTOT             $ TOTAL RAD. INTENSITY $
          RR   = RDIR             $ DIRECT RAD. INTENSITY $
          RD   = RDIF             $ DIFFUSE RAD. INTENSITY $
          SO   = SOLI             $ NET RAD. INTENSITY $
          SFF  = FFS  GFF = FFG   $ SKY AND GROUND FF $
          IS   = ISUNUP           $ SUN UP FLAG $
          TI   = XSTLT            $ TILT OF WALL $                    ..

CALCULATE                                                             ..

      IF (IS .EQ. 0) RETURN
      GFF = (1.0 - COS(TI)) * 0.5
      SFF = S1 * const1 + S2 * const2 + S3 * const3 + S4 * const4
     +      + S5 * const5
      BG = GND * (SKY + DNC * COST)
      RD = SFF * SKY + GFF * BG
      RT = RD + RR
      SO = RT - RR * XG
      END
END-FUNCTION                                                          ..
```

const1, const2, const3, const4 and const5 should be taken from Equation (2) for vertical walls and α is the angle the edge of the eave makes with the normal to the wall as seen from the bottom of the wall. For the unlikely case of a tilted wall with an "eave" projecting at right angles to the top of the wall, the constants should be taken from Equation (1).

If the windows and doors have no further overhangs, the input for them should be as discussed above where the eave is treated as an overhang. If there are overhangs over the windows as well as eaves over the roof, the user must determine whether the overhang or the eave obscures more of the sky and use the corresponding input for the window.

DAYLIGHTING

Overview

The DOE-2 daylighting calculation has three main stages: (1) a preprocessor calculates in detail a set of "daylight factors" (interior illuminance divided by exterior horizontal illuminance) for later use in the hourly loads calculation. The user specifies the coordinates of one or two reference points in a space. DOE-2 then integrates over the area of each window to obtain the contribution of direct light from the window to the illuminance at the reference points, and the contribution of light from sky and ground which enters the window and reflects from the walls, floor, and ceiling before reaching the reference points. Taken into account are such factors as window size and orientation, glass transmittance, inside surface reflectance of the space, sun-control devices such as blinds and overhangs, and the luminance distribution of the sky. Since this distribution depends on the position of the sun and cloudiness of the sky, the calculation is carried out for standard clear and overcast sky conditions for a series of 20 different solar altitude and azimuth values covering the annual range of sun positions. Analogous factors for discomfort glare are also calculated and stored.

(2) An hourly daylight illuminance and glare calculation is performed. The illuminance contribution from each window is found by interpolating the stored daylight factors using the current-hour sun-position and cloud cover, then multiplying by the current-hour exterior horizontal illuminance obtained from measured horizontal solar radiation, if present on the weather file, or from a calculation. If the glare-control option has been specified, the program will automatically close window blinds or drapes in order to decrease glare below a predefined comfort level. (A similar option is available to use window shading devices to automatically control solar gain.) Adding the illuminance contributions from all the windows then gives the total number of footcandles at each reference point.

(3) Stepped and continuously dimming control systems are simulated to determine the electrical lighting energy needed to make up the difference, if any, between the daylighting level and the required illuminance. Finally, the zone lighting electrical requirements are passed to the DOE-2 thermal loads calculation.

Acknowledgement

The Daylighting Program was developed in collaboration with the Windows and Daylighting Group, LBL.

Guidelines for daylighting modeling in DOE-2

Following are some guidelines for preparing DOE-2 input to model the effects of daylighting. Before studying these guidelines, however, the user should read the description of each daylighting keyword* in the "DOE-2 Daylighting Keywords" Section and go over the sample daylighting run in the DOE-2 Sample Run Book, Version 2.1C.

As is the case when custom weighting factors are being used, all of the bounding surfaces of a space should be input, even INTERIOR-WALLs across which negligible heat transfer takes place.

Thermal Zoning

To correctly calculate both direct and inter-reflected illuminance, one should try to model thermal zones consisting of several rooms separated by interior walls as a representative room with a multiplier. An example of this is shown in Fig. 1. ROOM-1 is the representative room, with MULTIPLIER = 4. INTERIOR-WALLs IW-1 and IW-2 should have INT-WALL-TYPE = ADIABATIC. INTERIOR-WALL IW-3 could be INT-WALL-TYPE = STANDARD or ADIABATIC. (See Section "Floor Multipliers and Interior Wall Types" in this Supplement for a description of this new command.) The floor and ceiling of ROOM-1 would probably be input as interior walls with INT-WALL-TYPE = ADIABATIC.

Sometimes a representative room cannot be found. Fig. 2 shows a section of a building with four rooms having different daylight characteristics because of floor area, orientation, and window size. In this case, the analyst must choose between two alternatives: (1) simplify input by lumping the rooms into a single thermal zone, neglect partitions, and thereby get a possibly questionable daylighting result; or (2) describe each room as a separate thermal zone, input the partitions, and obtain an accurate daylighting calculation.

---

* The daylighting keywords are:

in BUILDING-LOCATION: ATM-MOISTURE, ATM-TURBIDITY;

in GLASS-TYPE: VIS-TRANS;

in BUILDING-SHADE and FIXED-SHADE: SHADE-VIS-REFL, SHADE-GND-REFL;

in SPACE-CONDITIONS: DAYLIGHTING, LIGHT-REF-POINT1, LIGHT-REF-POINT2, ZONE-FRACTION1, ZONE-FRACTION2, LIGHT-SET-POINT1, LIGHT-SET-POINT2, LIGHT-CTRL-TYPE1, LIGHT-CTRL-TYPE2, MIN-POWER-FRAC, MIN-LIGHT-FRAC, LIGHT-CTRL-STEPS, LIGHT-CTRL-PROB, DAYLIGHT-REP-SCH, MAX-GLARE, VIEW-AZIMUTH;

in WINDOW: WIN-SHADE-TYPE, VIS-TRANS-SCH, MAX-SOLAR-SCH**, SUN-CTRL-PROB**, GLARE-CTRL-PROB, CONDUCT-TMIN-SCH**, OPEN-SHADE-SCH**;

in WINDOW, DOOR, EXTERIOR-WALL, ROOF, UNDERGROUND-WALL, UNDERGROUND-FLOOR, and INTERIOR-WALL: INSIDE-VIS-REFL.

** can also be used without daylighting

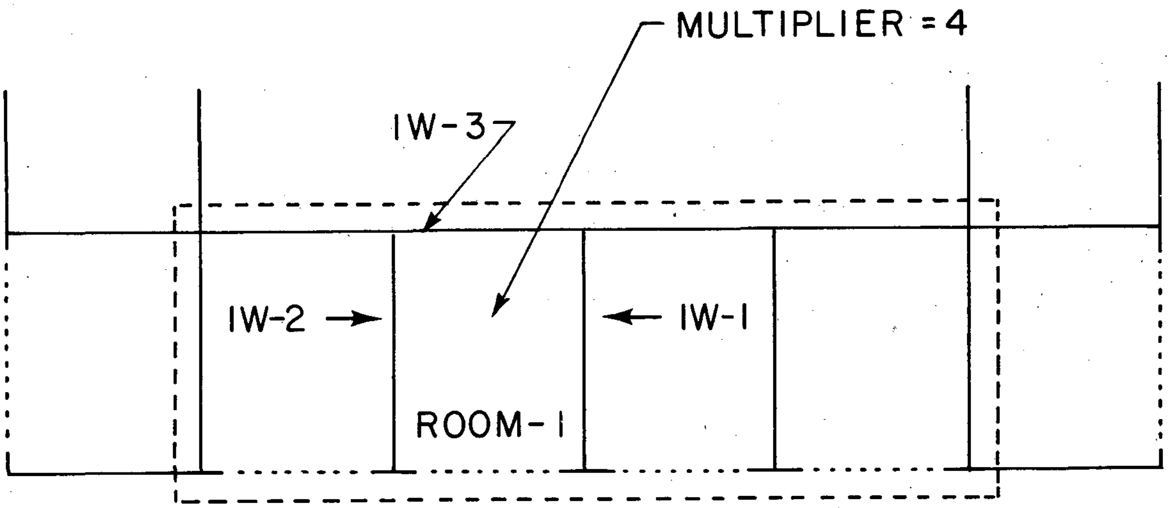

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Fig. 1. For daylighting purposes the thermal zone indicated by the dashed boundary line should be modelled as a typical room with a MULTIPLIER of 4.

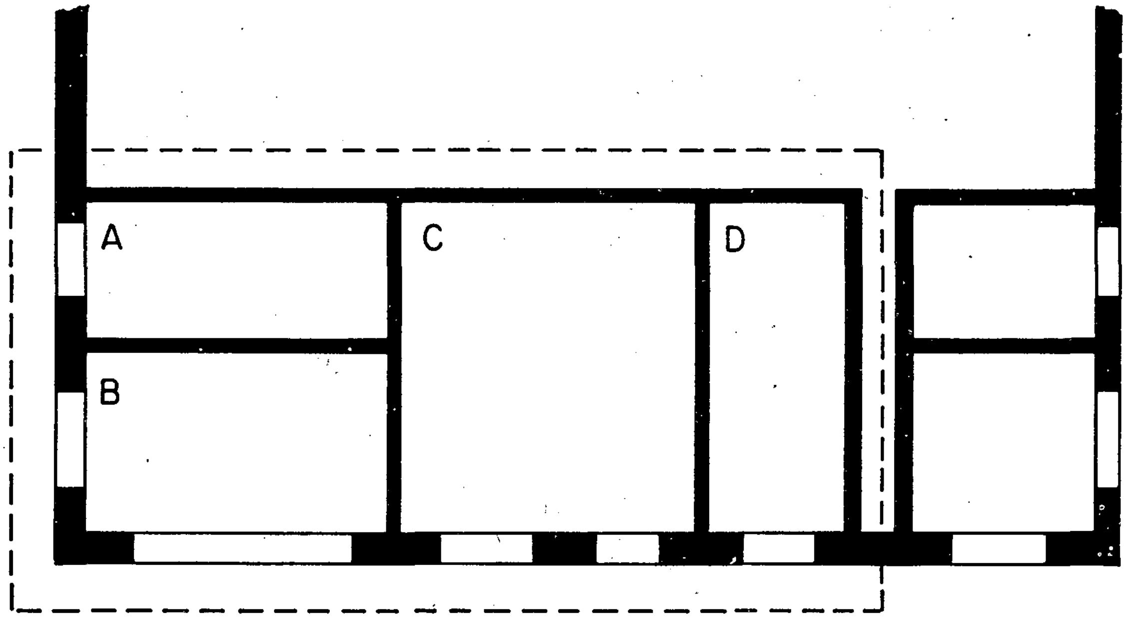

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Fig. 2. Rooms A, B, C, and D have different daylighting characteristics. If lumped into a single zone, input is simplified, but daylighting calculation will be inaccurate.

Surface Orientation

In the calculation of inter-reflected illuminance, the daylighting program uses surface tilt to distinguish between floors, walls, and ceilings. It is therefore important that the TILT values of all the bounding surfaces of a space be correctly specified. This applies not only to EXTERIOR-WALLs, but also to INTERIOR-WALLs, and UNDERGROUND-FLOORs and UNDERGROUND-WALLs.

Multiple Lighting Zones

The daylighting program allows a thermal zone to be divided into two independently-controlled lighting zones. An example is shown in Fig. 3a, where a relatively deep thermal zone has two lighting zones of equal area.

It is also possible to daylight only part of a thermal zone. Fig. 3b shows an example in which room A, with 40% of the zone's floor area, is daylit, whereas B, C, and D, having no windows, are not daylit. Note that a reference point and zone fraction are specified only for the daylit room.

Translucent Glazing

Windows with diffusing glass, translucent fabric roofs, etc., can be modeled as clear glazing with a diffusing shade. For example, the input for a window with specularly-reflective, diffusely-transmitting glass, having a visible transmittance at normal incidence of 0.14 and a shading coefficient of 0.20, might be as follows:

```
GT-1        =  GLASS-TYPE  VIS-TRANS = 1.0
                           SHADING-COEF = 1.0                  ..

VT-MULT-1   =  SCHEDULE  THRU DEC 31 (ALL) (1,24) (.14)        ..
SC-MULT-1   =  SCHEDULE  THRU DEC 31 (ALL) (1,24) (.20)        ..
                 .
                 .
                 .

               WINDOW  GLASS-TYPE = GT-1
                       VIS-TRANS-SCH = VT-MULT-1
                       SHADING-SCHEDULE = SC-MULT-1
                       WIN-SHADE-TYPE = FIXED-INTERIOR
                                 .
                                 .
                                 .                             ..
```

If the outside surface of the glazing material reflects diffusely, rather than specularly, WIN-SHADE-TYPE = FIXED-EXTERIOR is recommended.

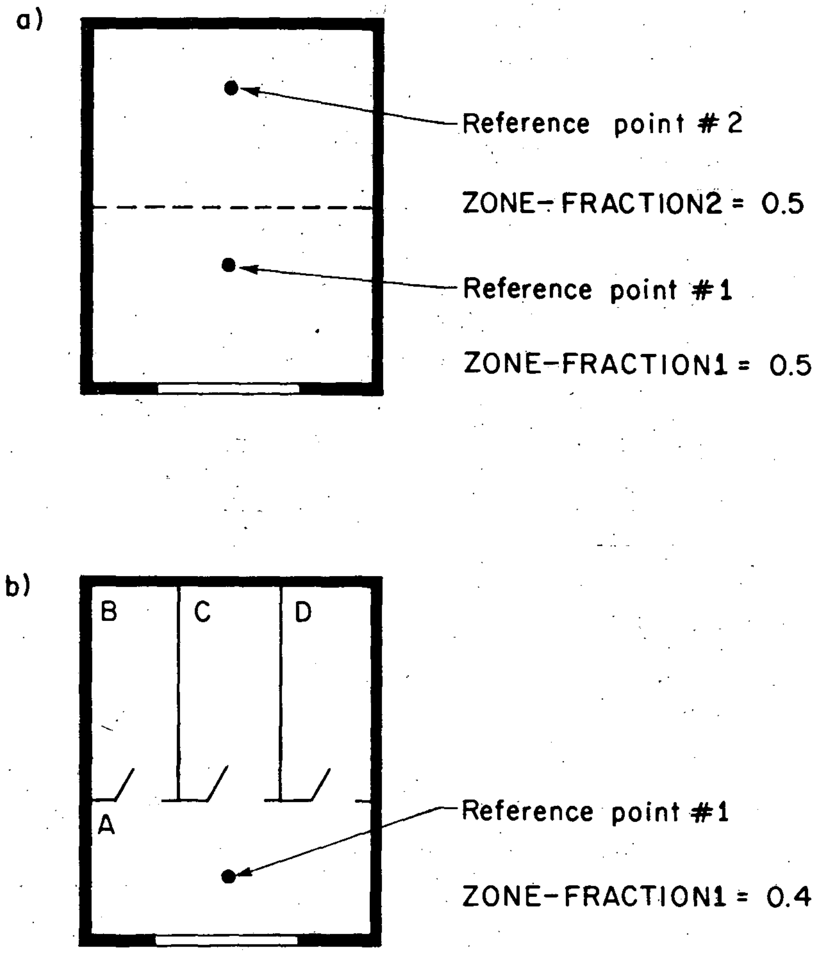

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Fig. 3. Examples of multiple lighting zones in a single thermal zone. (a) Two independently controlled lighting zones, each with 50% of the area of the thermal zone; (b) A thermal zone with 4 rooms. Only room A, with 40% of the floor area, is daylit.

Fins, Overhangs, and Other Shading Surfaces

The daylighting program accounts for the presence of overhangs and other shading surfaces which affect the amount of solar radiation and visible light that strikes the windows (see Section "Fixed Shades, Fins, and Overhangs" in this Supplement). There are five categories of shading surfaces in DOE-2.1B and 2.1C:

1) Shades defined by BUILDING-SHADE
2) Shades defined by FIXED-SHADE
3) Shades defined by EXTERIOR-WALLs with SHADING-SURFACE = YES ("self shades")

global shades

4) Shades associated with window SETBACK
5) Overhangs and fins generated by the WINDOW keywords OVERHANG-A, LEFT-FIN-A, RIGHT-FIN-A, etc. ("overhangs" and "fins")

local shades

For daylighting, the program assumes local shades are opaque and black, i.e., they neither transmit nor reflect incident light. A horizontal "overhang", for example, is modeled as blocking part of the diffuse light from the sky and the direct light from the sun, and reflecting none of the light from the ground.

Global shades are also assumed to be opaque, but, unlike local shades, they are assumed to have luminance due to the light from the sky and ground which they reflect. (However, the building itself is assumed to have no effect on this luminance. For this reason, light shelves cannot be accurately modelled.) Only one side of the shade is taken to be luminous. For BUILDING-SHADE and FIXED-SHADE, this is the side from which the surface outward normal points. For "self shades", it is the outside of the wall. To receive reflected light from BUILDING-SHADEs and FIXED-SHADEs (which may represent neighboring buildings, trees, etc.,) the shade azimuth should be chosen so that the surface outward normal points toward the building, as shown in Fig. 4. The visible reflectance of BUILDING-SHADEs and FIXED-SHADEs is given by the SHADE-VIS-REFL keyword and the ground reflectance by the SHADE-GND-REFL keyword. The visible reflectance of "self shades" is calculated from the absorptance of the exterior wall which generates the "self shade".

In general, it is recommended that building projections be described as "fins" and "overhangs", category (5).

It is important to keep in mind that shading surfaces in the daylighting calculation affect both the direct and diffuse light striking a window, whereas in the solar gain calculation they affect only the direct component of solar radiation. To account for diffuse shading in the solar gain calculation, functional input can be used (see Overhangs Over Windows or Doors in the "Window Management and Solar Radiation" section of this Supplement) or the SKY-FORM-FACTOR and GND-FORM-FACTOR keywords in the WINDOW command can be specified. (These keywords have no effect on the daylighting calculation.)

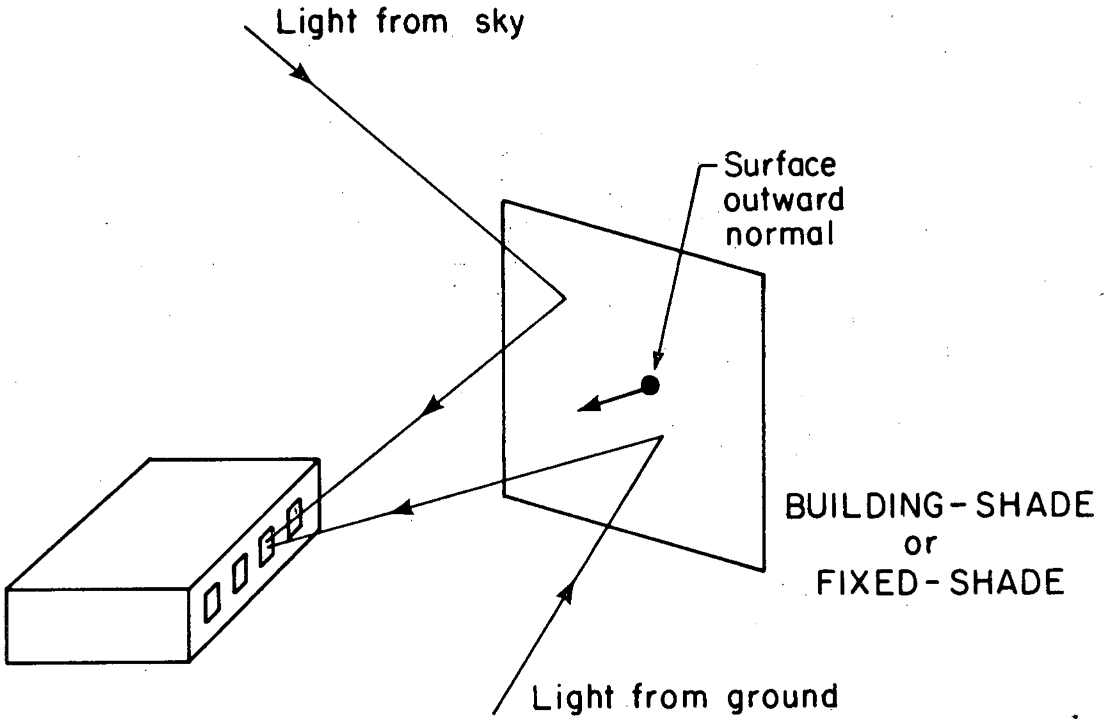

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Fig. 4. Shading surface oriented so that building sees luminous side of shade (the other side of the shade is assumed to be non-reflective).

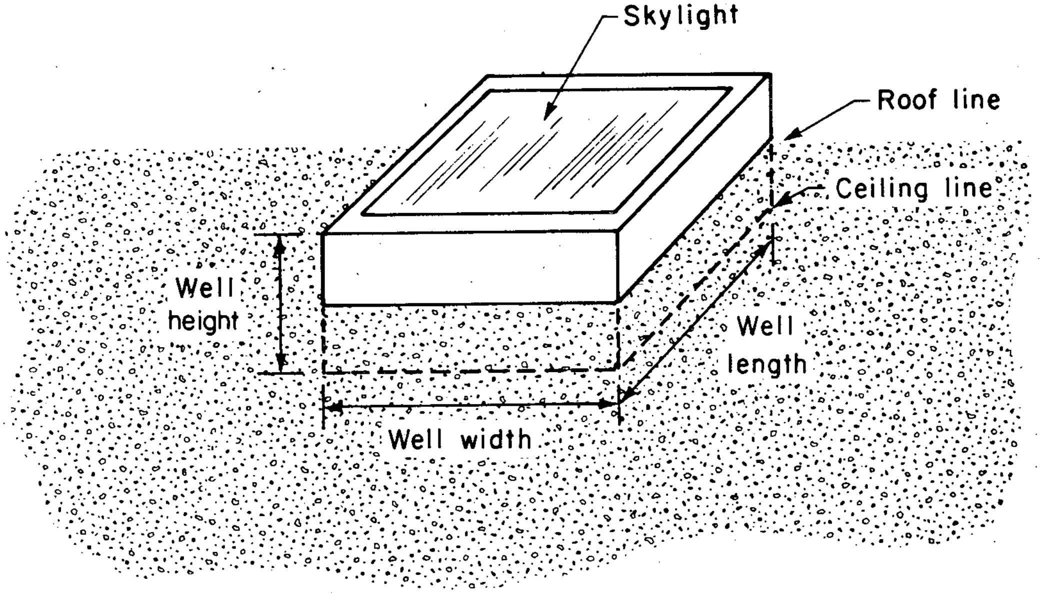

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Fig. 5. Skylight with light well

Skylight with Light Well

Skylights often have a rectangular light well (Fig. 5) which is deep enough to cause substantial attenuation of the light which is transmitted into the room below. This attenuation can be approximately accounted for by multiplying T_{vis}, the visible transmittance of the skylight glazing material, by W_e, the light well efficiency factor [Ref. 1] given in Fig. 6. W_e is determined by the well wall reflectance and by the well index, which is related to the dimensions of the well.

For example, if well height = 3 ft,
well width = 4 ft,
and well length = 6 ft,

$$\text{well index} = \frac{\text{well height x (well width + well length)}}{\text{2 x well length x well width}}$$

$$= \frac{3 \times (4 + 6)}{2 \times 4 \times 6} = 0.63$$

If the well wall reflectance is 80%, Fig. 6 gives $W_e = 0.74$. If T_{vis} is 90%, then the effective skylight transmittance that would be input to DOE-2 is

$$\text{VIS-TRANS} = T_{vis} \times W_e = 0.90 \times 0.74 = 0.67.$$

Domed Skylights

The visible transmittance of the acrylic material commonly used in domed skylights is generally given for the flat-sheet material before it is formed. The forming process produces a dome with a thickness that decreases towards the center. To account for the effect of this thickness variation and for the shape of the dome, the following equation can be used [Ref 1.] to determine an effective transmittance:

$$T_{eff} = 1.25\ T_{vis}\ (1.18 - 0.416\ T_{vis})$$

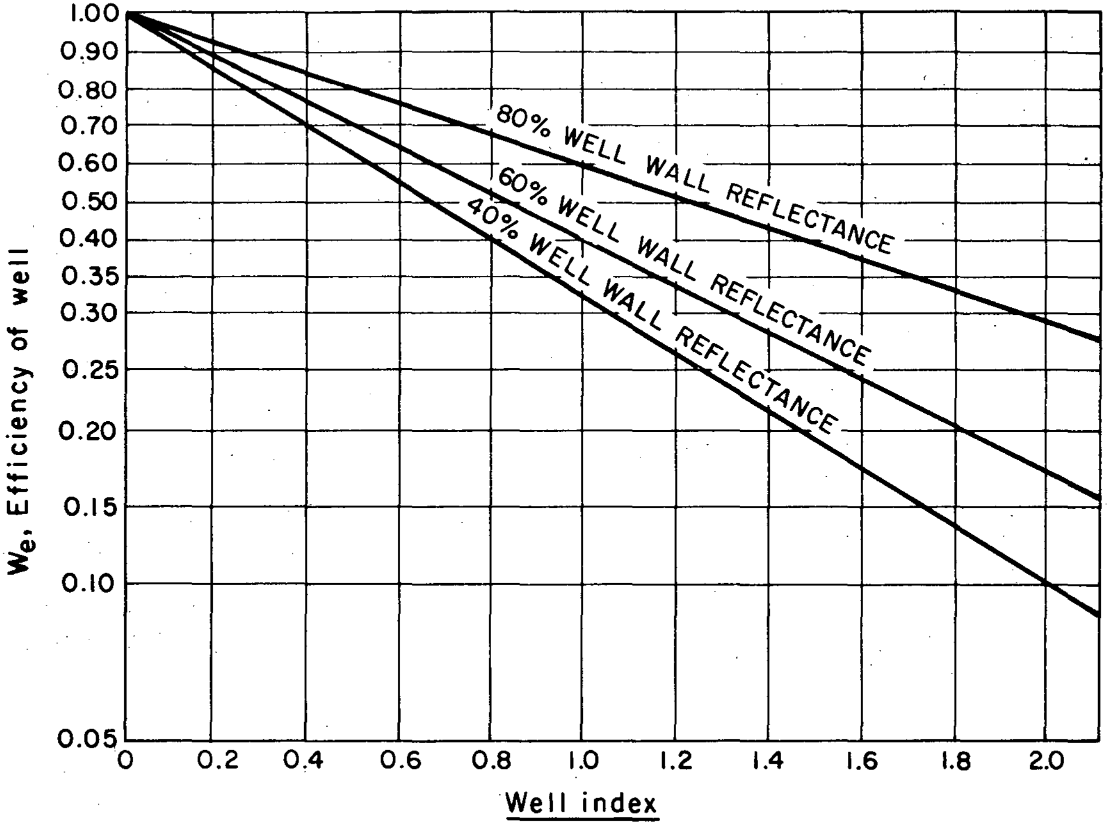
where T_{vis}, the acrylic sheet's unformed visible transmittance at normal incidence, can be obtained from skylight manufacturer's data. (If the skylight has a light well, the above value of T_{eff} should also be multiplied by the well efficiency factor, W_e, as described in the previous section.)

Example: a skylight consists of a double dome. The outer dome is transparent with an unformed visible transmittance of 90%. The inner dome is translucent with an unformed transmittance of 40%. The effective transmittance of the outer dome is

$$1.25 \times 0.9\ (1.18 - 0.416 \times 0.9) = 0.91$$

Reference [1]: IES Lighting Handbook, 1981 Reference Volume, Illuminating Engineering Society of North America, p. 9-84 ff.

EFFICIENCY FACTORS FOR VARIOUS DEPTHS OF LIGHT WELLS



Based on well interflectance values where:

$$\text{Well index} = \frac{\text{well height} \times (\text{well width} + \text{well length})}{2 \times \text{well length} \times \text{well width}}$$

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Fig. 6. Reprinted with permission from the <u>IES Lighting Handbook, 1981 Reference Volume</u>, Fig. 9-75, Illuminating Engineering Society of North America.

The effective transmittance of the inner dome is

$$1.25 \times 0.4\ (1.18 - 0.416 \times 0.4) = 0.51$$

The effective transmittance of both layers (neglecting inter-reflection between the domes) is then 0.91 x 0.51 = 0.46. If the well efficiency factor is 0.67, as in the example in the previous section, the value entered into DOE-2 for the net effective transmittance would be

VIS-TRANS = 0.46 x 0.67 = 0.31

Note that, since the inner dome in this example is translucent, a diffusing shade should be assigned with a visible transmittance of 1.0 (see Translucent Glazing, above).

Window Management

There are several ways of controlling the operation of window shading devices in DOE-2. In DOE-2.1A, the shading-coefficient and conductance of a window could be modified each hour to account for the presence of a shading device by specifying a SHADING-SCHEDULE and CONDUCT-SCHEDULE for the window. We call this "preset schedule control". This option is retained in 2.1B; in addition, there are options to control shading devices when solar gain, outside temperature, or daylight glare exceed user-specified threshold values. We call these "threshold controls".

The various control options and their input requirements are summarized in Table 1. Note in Table 1B the additional input requirements for windows in spaces for which a daylighting calculation has been requested by specifying DAYLIGHTING = YES in SPACE or SPACE-CONDITIONS.

Notes: (1) For threshold controls, the preset schedule values given by SHADING-SCHEDULE, CONDUCT-SCHEDULE, or VIS-TRANS-SCH are still used, but only when the shading device is closed, i.e., only when a threshold condition is exceeded. When the shading device is open, the schedule values are automatically replaced with a value of 1.0.

(2) If two or more threshold controls are specified for the same window (e.g., if MAX-SOLAR-SCH and MAX-GLARE are both input), the shading device will be deployed if either threshold condition is met.

(3) The program cannot model windows with more than one operable shading device. However, windows with one fixed and one operable shading device can be handled by describing the operable shade with SHADING-SCHEDULE, VIS-TRANS-SCH, etc., and describing the properties of the window-plus-fixed-shade combination in the GLASS-TYPE keywords SHADING-COEF, GLASS-CONDUCTANCE, and VIS-TRANS.

(4) CONDUCT-SCHEDULE will have no effect on a window unless a corresponding SHADING-SCHEDULE is also given.

(5) WIN-SHADE-TYPE is required only for windows in daylit spaces.

Limitations of the Daylighting Calculation

The current daylighting model cannot reliably simulate the following:

(1) light shelves

(2) roof monitors

(3) window shading devices whose transmittance is highly directional (e.g., Venetian blinds).

TABLE 1

Window Shading Device Control Options

A. Windows in Non-Daylit Spaces (DAYLIGHTING = NO)

Control Type	Input Required	Effect
Preset schedule (2.1B and 2.1C)	SHADING-SCHEDULE*	Shading coefficient of glazing is multiplied hourly by SHADING-SCHEDULE value.
Solar gain control (2.1C)	MAX-SOLAR-SCH SHADING-SCHEDULE* (SUN-CTRL-PROB and OPEN-SHADE-SCH optional)	Shade is fully closed if transmitted direct solar gain exceeds MAX-SOLAR-SCH value.
Heat loss control with movable insulation (2.1C)	CONDUCT-TMIN-SCH CONDUCT-SCHEDULE SHADING-SCHEDULE (OPEN-SHADE-SCH optional)	Insulation is moved into place if outside drybulb temperature falls below CONDUCT-TMIN-SCH value.

B. Windows in Daylit Spaces (DAYLIGHTING = YES)

Control Type	Input Required	Effect
Preset schedule (2.1B)	VIS-TRANS-SCH SHADING-SCHEDULE*	Glass visible transmittance and shading coefficient are multiplied hourly by VIS-TRANS-SCH and SHADING-SCHEDULE, respectively
Solar gain control (2.1C)	MAX-SOLAR-SCH VIS-TRANS-SCH SHADING-SCHEDULE* WIN-SHADE-TYPE† (SUN-CTRL-PROB and OPEN-SHADE-SCH optional)	Shade is fully closed if transmitted direct solar gain exceeds MAX-SOLAR-SCH value
Heat loss control with movable insulation (2.1C)	CONDUCT-TMIN-SCH CONDUCT-SCHEDULE VIS-TRANS-SCH** SHADING-SCHEDULE WIN-SHADE-TYPE† (OPEN-SHADE-SCH optional)	Insulation is moved into place if outside drybulb temperature falls below CONDUCT-TMIN-SCH value.
Glare control (2.1C)	MAX-GLARE (in SPACE command) VIS-TRANS-SCH SHADING-SCHEDULE* WIN-SHADE-TYPE† (OPEN-SHADE-SCH optional)	Shade is fully closed if daylight glare at either lighting reference point exceeds MAX-GLARE value

---

* CONDUCT-SCHEDULE should also be input if shading device significantly effects window conductance.

** Since VIS-TRANS-SCH can be assigned, the insulation need not be opaque.

† Must be either MOVABLE-INTERIOR (the default) or MOVABLE-EXTERIOR.

DOE-2 Daylighting Keywords

BUILDING-LOCATION

ATM-MOISTURE is a list of twelve monthly values of the amount of precipitable moisture in the atmosphere, in inches. The values should be chosen from Table 1 at the end of this section. If the location being analyzed is not in this Table, choose values for a location with a similar climate.

If a similar climate cannot be found, a set of twelve constant monthly values can be assigned according to the following climate types:

Climate Type	Atmospheric Moisture (in.)
Desert (dry air)	0.4
Temperate	0.7 (default)
Tropical (humid air)	1.3

ATM-TURBIDITY is a list of twelve monthly values of atmospheric turbidity (a measure of the amount of aerosols, i.e., particulate pollutants in the atmosphere). The values should be chosen from Table 2 at the end of this section. If the location being analyzed is not in this Table, choose values for a location with a similar level of atmospheric pollution.

If a similar climate cannot be found, a set of twelve constant monthly values can be assigned according to the following categories:

Category	Atmospheric Turbidity
Rural Area	0.07
Urban Area	0.12 (default)
Industrial Area	0.16

Note: ATM-MOISTURE and ATM-TURBIDITY are used by the program to calculate the luminance of clear skies.

BUILDING-SHADE and FIXED-SHADE

SHADE-VIS-REFL is the visible reflectance of that side of a BUILDING-SHADE or FIXED-SHADE from which the outward normal points (see text). The other side of the shading surface is assumed to be black, i.e., to have zero reflectance.

SHADE-GND-REFL	is the visible reflectance of the ground in the vicinity of the BUILDING-SHADE or FIXED-SHADE.

GLASS-TYPE

VIS-TRANS	is the visible (daylight) transmittance of glazing at normal incidence. Values, which can be found in glass manufacturer´s product data sheets, vary from about 0.91 for clear, 1/8" sheet glass, to about 0.07 for some kinds of reflective, heat-absorbing multi-pane glazing. Note: visible transmittance, which determines how much daylight is transmitted by the glass, should not be confused with total solar transmittance, which determines how much solar radiation (ultra-violet, visible, and infra-red) is transmitted. For most commercially available glass, visible transmittance is higher than total solar transmittance; in some cases it is significantly higher. For example, blue-green single glazing is available which has a visible transmittance of 0.74 vs a total solar transmittance of 0.48.

SPACE-CONDITIONS

DAYLIGHTING	takes code-word values YES or NO (the default). If YES, a daylighting calculation will be done for the space.
LIGHT-REF-POINT1 LIGHT-REF-POINT2	give the x,y,z coordinates (in the space coordinate system) of the reference points at which daylight illuminance levels are to be calculated. If DAYLIGHTING = YES, LIGHT-REF-POINT1 must be specified. If the user wishes to divide a thermal zone into two independently-controlled lighting zones, then LIGHT-REF-POINT2 should also be specified. It is assumed that the photocells which control the electric lighting system respond to the light levels at the specified reference points. Example: The lighting reference point is located at x = 20, y = 10, and z = 2.5ft (desk height). Then LIGHT-REF-POINT1 = (20,10,2.5). Since the location of the reference point(s) is used to determine if the design illuminance condition is met, specification of these points must be done with some care if the daylighting results are to be meaningful. Zones are generally laid out parallel to the plane of the glazing and a typical depth is 15 ft. Thus, a row of perimeter offices may be treated as a single SPACE

with a MULTIPLIER, with results from a single sensor being used to determine daylighting savings for the entire row. If the reference point is placed too near the window, the levels will be high relative to the rest of the space and will overpredict savings. A point at the back of the room will underpredict total savings. Since the drop-off in illuminance is a function with an exponentially declining shape, a point just beyond the mid-point is normally selected as a reasonable location. Until more definitive data is available, the reference point(s) should be placed two-thirds of the zone depth back from the window wall.

These guidelines assume the use of a ceiling-mounted sensor. Although these sensors may be located at a specific point in the room, they generally "view" the reflected light from a larger area in the room. Thus, the sensor itself tends to see an average light level.

ZONE-FRACTION1 ZONE-FRACTION2	give the fraction of the floor-area of the thermal zone (SPACE) which is controlled by LIGHT-REF-POINT1 and LIGHT-REF-POINT2, respectively. If only one reference point (i.e. LIGHT-REF-POINT1) is specified, then ZONE-FRACTION1 should not exceed 1.0. If ZONE-FRACTION1 is less than 1.0, then a fraction of the thermal zone equal to 1.0-ZONE-FRACTION1 is assumed to be non-daylit. If two reference points are specified (i.e. LIGHT-REF-POINT1 and LIGHT-REF-POINT2), then the sum of ZONE-FRACTION1 and ZONE-FRACTION2 should not exceed 1.0. If ZONE-FRACTION1 + ZONE-FRACTION2 is less than 1.0, then a fraction of the thermal zone equal to 1-(ZONE-FRACTION1 + ZONE-FRACTION2) is assumed to be non-daylit.
LIGHT-SET-POINT1 LIGHT-SET-POINT2	give the desired lighting level, in footcandles, at LIGHT-REF-POINT1 and LIGHT-REF-POINT2, respectively. Recommended values, which depend on type of activity, occupant age, and other factors, may be found on p. 2.5ff of the IES Lighting Handbook, 1981 Application Volume. It is assumed that this lighting level will be produced by the electric lights at full input power as specified by keywords LIGHTING-KW or LIGHTING-W/SQFT.
LIGHT-CTRL-TYPE1 LIGHT-CTRL-TYPE2	take code-words which specify the type of electric lighting control system at LIGHT-REF-POINT1 and LIGHT-REF-POINT2, respectively. Allowed values are CONTINUOUS and STEPPED.

	Codeword CONTINUOUS gives the dimmable control system shown in Fig. 1 in which light output varies linearly* and continuously with input power. Specifically, the fractional light output (light output at partial power divided by light output at full power) decreases from 1.0 at full power to a value MIN-LIGHT-FRAC at minimum power fraction MIN-POWER-FRAC (see keyword definitions below).
	Codeword STEPPED gives the control system shown in Fig. 2, in which power input and light output vary in discrete, equally spaced steps. The number of steps (excluding zero) is given by keyword LIGHT-CTRL-STEPS.
MIN-POWER-FRAC	specifies the lowest input power fraction for a continuously dimmable lighting control system (see Fig. 1). See manufacturer's data for appropriate value.
MIN-LIGHT-FRAC	specifies the fractional light output that a continuously dimmable lighting control system produces at the minimum fractional input power given by MIN-POWER-FRAC (see Fig. 1). See manufacturer's data for appropriate value.
LIGHT-CTRL-STEPS	gives the number of steps, excluding zero, in a stepped lighting control system. The steps are assumed to be equally spaced, as shown in Fig. 2.
LIGHT-CTRL-PROB	may be specified if a stepped lighting control system is manually operated, such as in a simple one-step, on-off system. This keyword gives the probability the occupants of a daylit space will set the electric lights to the correct level to obtain the required illuminance. The rest of the time the lights are assumed to be set one step too high. For example, if an on-off system is specified with LIGHT-SET-POINT1 = 60, LIGHT-CTRL-TYPE1 = STEPPED, LIGHT-CTRL-STEPS = 1, and LIGHT-CTRL-PROB = 0.7, then, when daylighting exceeds 60 fc, the electric lights will be off 70% of the time and on 30% of the time.
DAYLIGHT-REP-SCH	is the name of a schedule which specifies the time periods over which various entries in daylighting reports LS-G and LS-J are to be accumulated. See description of these reports for more details.

---

* Non-linear dimming control can be modelled using the DOE-2.1C functional input capability. See the "Functional Values" section in this Supplement and the Daylighting Sample in the DOE-2 Sample Run Book, Version 2.1C.

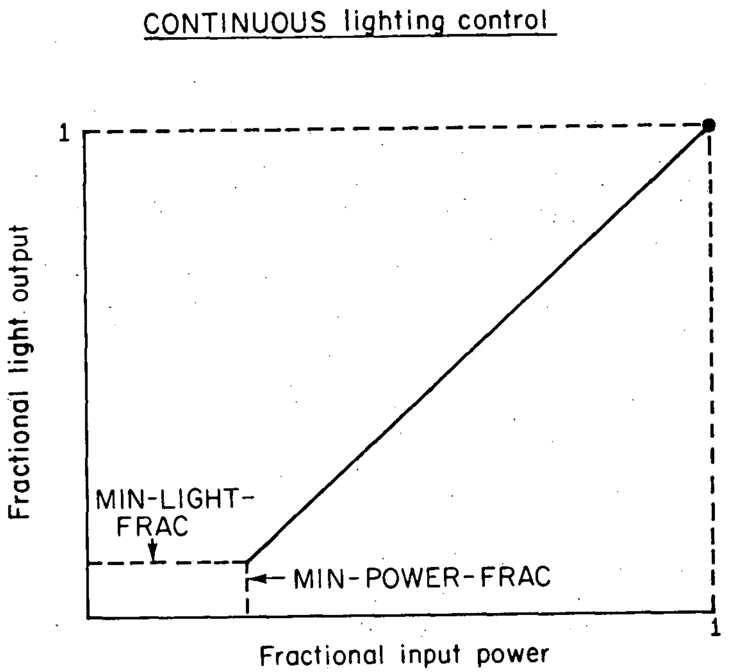

Fig. 1. Light output vs. input power for continuously dimmable lighting control system.

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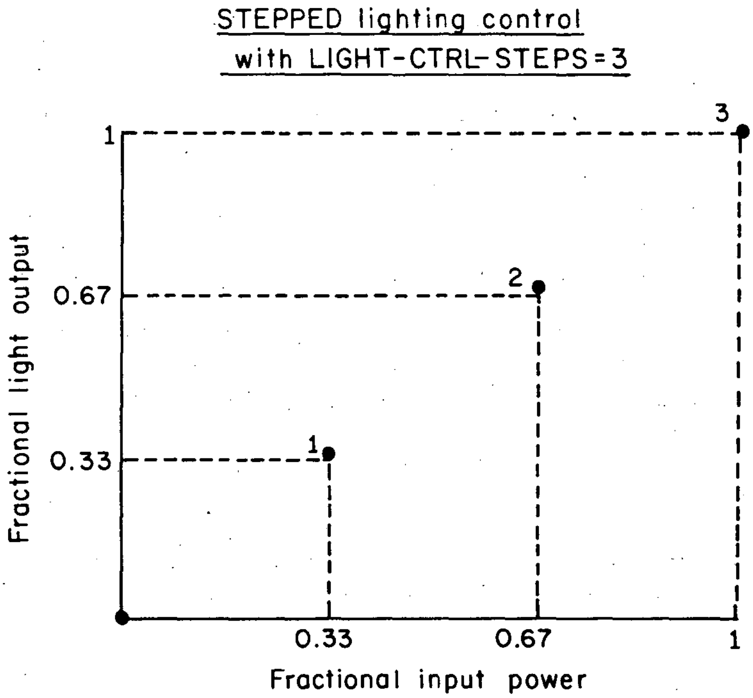

Fig. 2. Light output vs. input power for a stepped lighting control system with LIGHT-CTRL-STEPS=3.

Example: For space SP-1, accumulate report entries, such as percent lighting energy reduction by daylighting in report LS-G, only from 7am to 6pm on weekdays, i.e., only for the hours that the space is occupied.

```
OCC-HOURS-1 = SCHEDULE  THRU DEC 31
                        (MON,FRI) (1,7) (0) (8,18) (1)
                        (19,24) (0)
                        (SAT) (1,24) (0)
                        (SUN,HOL) (1,24) (0)        ..
                  .
                  .

SP-1        = SPACE  DAYLIGHTING = YES
              DAYLIGHT-REP-SCH = OCC-HOURS-1
                   .
                   .
                   .                                ..
```

MAX-GLARE

The program will automatically deploy window shading devices (if WIN-SHADE-TYPE = MOVABLE-INTERIOR or MOVABLE-EXTERIOR) to reduce daylight glare whenever glare with bare windows exceeds the MAX-GLARE value. Table 3 gives recommended MAX-GLARE values for different situations. For example, MAX-GLARE = 22 would be specified for general office work.

If a space has two or more windows, the shading devices will be deployed one by one in the order in which the windows are input, until the glare level at each lighting reference point falls below MAX-GLARE. If MAX-GLARE is not specified, no glare control will occur.

VIEW-AZIMUTH

is the direction of occupant view (in the horizontal plane), measured as a clockwise angle from the space y-axis (see Fig. 3). It is used by the program to calculate daylight glare. If not specified, VIEW-AZIMUTH will be calculated by the program for a view direction parallel to the first window in the space (obtained by rotating clockwise by 90° the horizontal projection of the window outward normal). In general, the daylight glare contribution from a particular window is highest when the occupant faces the window.

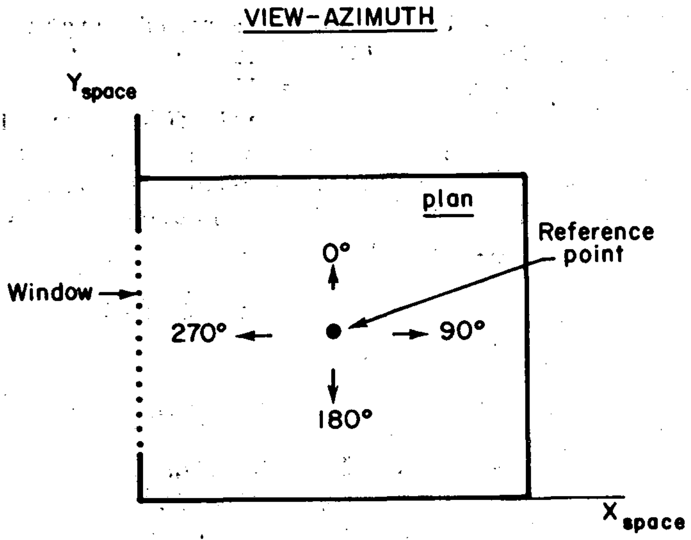

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Fig. 3. VIEW-AZIMUTH for four different occupant view directions. Daylight glare from the window will be greatest when occupant faces window, which corresponds to VIEW-AZIMUTH=270^o in this example.

Daylighting input examples for SPACE-CONDITIONS

Example (1): A space has a single lighting zone with 2.4 watts/ft^2 of installed electric lighting power. The photocell of a 5-step lighting control responds to the lighting level at x = 10, y = 20, z = 2.5ft. The illuminance set point is 60 footcandles.

The SPACE-CONDITIONS (or SPACE) daylighting input would then be

```
$
$ ---.ONE LIGHTING ZONE WITH STEPPED SYSTEM --- $
$
SCON-1 = SPACE-CONDITIONS
         DAYLIGHTING = YES
         LIGHTING-W/SQFT = 2.4
         LIGHT-REF-POINT1 = (10,20,2.5)
         ZONE-FRACTION1 = 1.0 (the default)
         LIGHT-SET-POINT1 = 60
         LIGHT-CTRL-TYPE1 = STEPPED
         LIGHT-CTRL-STEPS = 5
                   .
                   .
                   .
```

Example (2): An office space with 2 watts/ft^2 of installed electric lighting power has three lighting zones. The first lighting zone, with 40% of the floor area, has a continuously dimmable control system with a setpoint of

60 footcandles and a minimum light output of 10 footcandles at 30% input power. The lighting reference point is at x = 10, y = 10, z = 2.5ft. The second lighting zone, with 50% of the floor area, has a 4-step control system with a setpoint of 60 footcandles. The lighting reference point is at x = 10, y = 25, z = 2.5ft. A third lighting zone with 10% of the floor area is not daylit.

The SPACE-CONDITIONS (or SPACE) daylighting input would then be:

```
$
$ --- THREE LIGHTING ZONES --- $
$
SCON-2 = SPACE-CONDITIONS
         DAYLIGHTING = YES
         LIGHTING-W/SQFT = 2
         LIGHT-REF-POINT1 = (10,10,2.5)
         ZONE-FRACTION1 = 0.4
         LIGHT-SET-POINT1 = 60
         LIGHT-CTRL-TYPE1 = CONTINUOUS
         MIN-LIGHT-FRAC = 0.167
         MIN-POWER-FRAC = 0.3
         LIGHT-REF-POINT2 = (10,25,2.5)
         ZONE-FRACTION2 = 0.5
         LIGHT-SET-POINT2 = 60
         LIGHT-CTRL-TYPE2 = STEPPED
         LIGHT-CTRL-STEPS = 4
              .
              .
              .                                  ..
```

Note that no entry is required for the third, non-daylit lighting zone.

Example (3): A space has a task-ambient lighting system. Task lighting is provided by electric lights with an installed power of 0.5 watts/ft^2. Ambient lighting with a setpoint of 10 footcandles is provided by daylight plus installed electric lighting at 0.4 watts/ft^2 controlled by a 3-step control system. The ambient lighting reference point is at x = 15, y = 20, z = 2.5ft.

The SPACE CONDITIONS (or SPACE) daylighting input would then be:

```
$
$ --- TASK-AMBIENT SYSTEM --- $
$
SCON-3 = SPACE-CONDITIONS
         DAYLIGHTING = YES
         TASK-LT-W/SQFT = 0.5
         LIGHTING-W/SQFT = 0.4
         LIGHT-REF-POINT1 = (15,20,2.5)
         ZONE-FRACTION1 = 1.0 (the default)
         LIGHT-SET-POINT1 = 10
         LIGHT-CTRL-TYPE1 = STEPPED
              .
              .
              .
```

WINDOW

WIN-SHADE-TYPE specifies a codeword giving the type of shading device when a shading device is present on the window for sun and/or glare control. The choices are:

MOVABLE-INTERIOR	(the default) interior shade which can be retracted, such as drapes or Venetian blinds.
MOVABLE-EXTERIOR	exterior shade which can be retracted.
FIXED-INTERIOR	interior shade which cannot be retracted.
FIXED-EXTERIOR	exterior shade which cannot be retracted.

Note: If SHADING-SCHEDULE is not assigned to a window, the window will be considered to have no shading device and WIN-SHADE-TYPE will be ignored. (The 2.1B codeword, NO-SHADE, is no longer being used.)

VIS-TRANS-SCH is the u-name of a schedule which gives the daylight transmittance of the window shading device when it covers the window. (If WIN-SHADE-TYPE = MOVABLE-INTERIOR or MOVABLE-EXTERIOR, the program will use a transmittance multiplier value of 1.0 when the shade is retracted.) Typical visible transmittance values for translucent drapes and shades are given in Table 4. A transmittance schedule is used, rather than a single fixed value, to allow seasonal change in the transmittance of the shading device.

Note: this schedule is used only for windows in a space with DAYLIGHTING = YES.

Note: for windows with a shading device in a daylit space, be sure to specify not only VIS-TRANS-SCH, but also SHADING-SCHEDULE (and CONDUCT-SCHEDULE if the change in window conductance with the shade in place is significant).

Note: In the daylighting calculation, shading surfaces are modeled as perfect diffusers with a daylight transmittance which is independent of angle of incidence. For this reason, slat-type devices, such as Venetian blinds, cannot be accurately modeled.

MAX-SOLAR-SCH	is the u-name of a schedule of direct solar gain values in Btu/ft^2-hr. The program will automatically deploy a shading device if the heat gain per ft^2 from direct (beam) solar radiation transmitted through the window exceeds the specified value. If MAX-SOLAR-SCH is specified, a corresponding SHADING-SCHEDULE (and CONDUCT-SCHEDULE, if desired) should be assigned to the window. In addition, if the space is daylit, a VIS-TRANS-SCH should be assigned and WIN-SHADE-TYPE should be set equal to MOVABLE-INTERIOR or MOVABLE-EXTERIOR.
SUN-CTRL-PROB	may be specified if the sun control device on a window is manually operated. This keyword gives the probability that the occupants of a space will deploy the shading device if the transmitted direct solar gain exceeds the MAX-SOLAR-SCH value.
GLARE-CTRL-PROB	may be specified if manual operation of a window shading device for glare control is desired. This keyword gives the probability that the occupants of a space will deploy a shading device when the MAX-GLARE value (see SPACE-CONDITIONS) is exceeded.
CONDUCT-TMIN-SCH	is a schedule of values of outside drybulb temperature below which movable insulation will be deployed on a window. If this keyword is specified, a corresponding SHADING-SCHEDULE and CONDUCT-SCHEDULE should be assigned to the window. In addition, if the space is daylit, a VIS-TRANS-SCH should be assigned and WIN-SHADE-TYPE should be set equal to MOVABLE-INTERIOR or MOVABLE EXTERIOR. Note that the CONDUCT-SCHEDULE, in the WINDOW command, will have no effect on a window unless a corresponding SHADING-SCHEDULE is also given.

Example of window shading device assignment

Window glazing has a visible transmittance of 0.83. Operable drapes have a visible transmittance multiplier of 0.35, a shading coefficient multiplier of 0.25, and a conductance multiplier of 0.85. The drapes will be closed when transmitted direct solar gain exceeds 30 Btu/ft^2-hr.

The input might be

```
             SC-MULT-1   = SCHEDULE  THRU DEC 31 (ALL)(1,24)(0.25)   ..
             TVIS-SCH-1  = SCHEDULE  THRU DEC 31 (ALL)(1,24)(0.35)   ..
             COND-MULT-1 = SCHEDULE  THRU DEC 31 (ALL)(1,24)(0.85)   ..
             SOL-SCH-1   = SCHEDULE  THRU DEC 31 (ALL)(1,24)(30)     ..
                                 .
                                 .
             GT-1        = GLASS-TYPE
                           VIS-TRANS = 0.83
                                 .
                                 .                                   ..
             SP-1        = SPACE
                           DAYLIGHTING = YES
                                 .
                                 .                                   ..
             WIN-1       = WINDOW
                           GLASS-TYPE = GT-1
                           WIN-SHADE-TYPE = MOVABLE-INTERIOR
                           VIS-TRANS-SCH = TVIS-SCH-1
                           MAX-SOLAR-SCH = SOL-SCH-1
                           SHADING-SCH = SC-MULT-1
                           CONDUCT-SCH = COND-MULT-1
                                .
                                .
                                .                                    ..
```

WINDOW, DOOR, EXTERIOR-WALL, ROOF, UNDERGROUND-WALL, UNDERGROUND-FLOOR, INTERIOR-WALL

INSIDE-VIS-REFL is the inside surface visible reflectance (hemispherical average). For INTERIOR-WALL a list of two values is required, where the first value is the reflectance on the side of the interior wall that is in the space the wall is defined, and the second value is the the reflectance on the other side of the wall.

For EXTERIOR-WALL, ROOF, UNDERGROUND-WALL, UNDERGROUND-FLOOR, and INTERIOR-WALL, the default value of INSIDE-VIS-REFL is 0.2 if surface is a floor (TILT $> 170^{o}$), 0.5 if a wall ($10^{o} \leq$ TILT $\leq 170^{o}$), and 0.7 if a ceiling (TILT $< 10^{o}$).

Table 1. Monthly Average Atmospheric Moisture (inches of water) for U.S. Cities

City	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
Montgomery, AL	.65	.56	.65	.85	1.00	1.31	1.58	1.60	1.39	.95	.67	.69
Ft. Smith, AR	.48	.47	.56	.78	1.08	1.39	1.66	1.56	1.16	1.03	.53	.48
Little Rock, AR	.51	.46	.55	.81	.94	1.26	1.47	1.42	1.29	.86	.63	.59
Ft. Huachuca, AZ	.27	.27	.24	.26	.36	.59	1.01	1.01	.73	.48	.31	.27
Phoeniz, AZ	.42	.38	.38	.45	.51	.67	1.29	1.31	.92	.63	.43	.40
China Lake, CA	.28	.25	.28	.34	.38	.40	.66	.68	.47	.33	.29	.32
Oakland, CA	.52	.49	.48	.45	.53	.63	.64	.67	.64	.59	.61	.50
Point Mugu, CA	.46	.45	.48	.51	.65	.79	1.04	.97	.89	.69	.54	.49
San Diego, CA	.46	.46	.47	.50	.60	.71	.98	1.04	.83	.62	.60	.48
San Nicolas Is., CA	.47	.42	.43	.42	.52	.65	.85	.80	.73	.61	.53	.46
Santa Maria, CA	.48	.48	.48	.52	.61	.68	.82	.80	.74	.63	.55	.49
Santa Monica, CA	.48	.51	.49	.56	.65	.75	.93	.95	.85	.72	.54	.50
Denver, CO	.20	.19	.21	.27	.41	.57	.75	.71	.51	.35	.25	.20
Grand Junction, CO	.25	.24	.24	.28	.39	.51	.73	.72	.52	.41	.31	.26
Cocoa Beach, FL	.86	.85	.95	1.03	1.26	1.60	1.73	1.79	1.76	1.37	1.02	.90
Key West, FL	1.04	1.03	1.06	1.13	1.34	1.65	1.64	1.71	1.78	1.53	1.20	1.05
Miami, FL	.96	.95	1.00	1.10	1.31	1.64	1.69	1.74	1.77	1.50	1.16	1.10
Atlanta, GA	.54	.52	.56	.72	.95	1.26	1.48	1.45	1.20	.83	.59	.54
Boise, ID	.35	.32	.30	.34	.44	.59	.60	.60	.52	.42	.40	.32
Joliet, IL	.36	.32	.40	.53	.76	1.11	1.21	1.12	.88	.66	.43	.35
Peoria, IL	.30	.31	.37	.55	.76	1.02	1.17	1.13	.96	.65	.46	.36
Salem, IL	.31	.35	.41	.57	.72	1.09	1.19	1.19	1.12	.74	.46	.42
Dodge City, KS	.28	.27	.30	.42	.61	.86	1.09	1.04	.81	.53	.37	.30
Boothville, LA	.82	.72	.78	1.00	1.13	1.41	1.69	1.72	1.60	1.17	.87	.94
Lake Charles, LA	.74	.72	.77	.95	1.17	1.45	1.70	1.67	1.50	1.05	.83	.78
Nantucket, MA	.38	.36	.40	.53	.73	.97	1.15	1.26	.95	.71	.56	.42
Caribou, ME	.23	.22	.26	.36	.55	.79	.95	.90	.74	.55	.40	.27
Portland, ME	.30	.29	.33	.46	.66	.93	1.08	1.05	.87	.63	.49	.34
Flint, MI	.27	.26	.31	.46	.64	.89	.99	.97	.86	.61	.43	.33
Sault Ste. Marie, MI	.23	.22	.27	.39	.57	.83	.92	.93	.78	.58	.39	.28
Int´l Falls, MN	.19	.19	.23	.35	.52	.77	.90	.87	.68	.49	.30	.22
St. Cloud, MN	.22	.23	.27	.42	.63	.86	1.00	.99	.77	.56	.34	.26
Columbia, MO	.36	.32	.42	.62	.78	1.10	1.23	1.21	.98	.70	.52	.42
Jackson, MS	.59	.60	.65	.87	1.05	1.36	1.59	1.56	1.36	.92	.71	.65
Glasgow, MT	.23	.24	.25	.34	.49	.68	.77	.73	.57	.42	.31	.25
Great Falls, MT	.23	.22	.23	.27	.39	.54	.58	.58	.46	.34	.28	.23
North Platte, NB	.26	.28	.30	.41	.62	.85	1.02	.99	.72	.49	.33	.28
Omaha, NB	.28	.29	.35	.50	.74	1.03	1.18	1.13	.87	.62	.40	.31
Cape Hatteras, NC	.59	.52	.56	.70	.96	1.20	1.57	1.57	1.25	.97	.67	.63
Greensboro, NC	.47	.45	.50	.65	.90	1.18	1.39	1.37	1.11	.77	.55	.47
Bismarck, ND	.22	.24	.26	.38	.56	.81	.93	.88	.65	.47	.31	.25
Rapid City, ND	.26	.26	.28	.37	.53	.75	.87	.81	.59	.42	.30	.26
Ely, NE	.21	.20	.20	.22	.31	.42	.54	.57	.38	.29	.26	.21
Albuquerque, NM	.21	.20	.21	.24	.33	.47	.80	.79	.58	.38	.27	.22
Albany, NY	.30	.28	.35	.48	.70	.98	1.11	1.10	.93	.65	.49	.36
Buffalo, NY	.30	.29	.34	.47	.66	.91	1.04	1.02	.87	.63	.46	.35
New York City, NY	.34	.33	.40	.54	.76	1.02	1.18	1.16	1.01	.69	.55	.42
Dayton, OH	.33	.33	.39	.56	.74	1.00	1.13	1.08	.93	.65	.47	.38

Table 1 (continued)

Medford, OR	.46	.42	.40	.41	.51	.65	.67	.67	.59	.52	.53	.43
Salem, OR	.52	.48	.45	.47	.56	.71	.73	.76	.70	.62	.60	.51
Pittsburgh, PA	.34	.32	.38	.52	.72	.97	1.09	1.06	.90	.63	.47	.37
Charleston, SC	.65	.63	.68	.83	1.11	1.42	1.67	1.66	1.43	1.02	.75	.66
Nashville, TN	.45	.41	.49	.70	.85	1.13	1.33	1.31	1.19	.77	.55	.53
Amarillo, TX	.28	.26	.30	.39	.55	.80	1.03	1.00	.80	.52	.37	.30
Brownsville, TX	.90	.90	.94	1.12	1.31	1.48	1.57	1.60	1.64	1.31	1.07	.96
Midland, TX	.34	.33	.37	.48	.65	.89	1.06	1.10	.97	.64	.44	.36
El Paso, TX	.29	.28	.30	.33	.44	.67	.98	1.00	.83	.52	.37	.32
Ft. Worth, TX	.48	.51	.58	.80	1.06	1.32	1.48	1.46	1.28	.90	.65	.54
Salt Lake City, UT	.29	.26	.25	.30	.40	.54	.66	.66	.50	.38	.34	.27
Quillayute - Tatoosh Is., WA	.46	.47	.44	.48	.57	.71	.77	.82	.75	.67	.55	.50
Green Bay, WI	.23	.23	.28	.44	.63	.89	1.02	.99	.82	.60	.39	.28
Huntington, WV	.39	.37	.47	.62	.82	1.08	1.25	1.19	1.04	.72	.53	.45
Lander, WY	.18	.17	.18	.24	.33	.47	.54	.53	.40	.29	.23	.18

Source: George A. Lott, "Percipitable Water Over the United States, Volume 1: Monthly Means", National Oceanic and Atmospheric administration Technical Report NWS 20, November 1976.

Table 2. Monthly Average Atmospheric Turbidity for U. S. Cities

City	Source	Month											
		J	F	M	A	M	J	J	A	S	O	N	D
Eielson AB, AL	2	.03	.03	.11	.11	.20	.07	.09	.12	.07	.04	.04	.04
Little Rock, AR	2	.11	.16	.17	.22	.22	.20	.22	.20	.19	.13	.10	.09
Tucson, AZ	1	.05	.05	.06	.07	.07	.07	.07	.07	.07	.06	.06	.07
Edwards AFB, CA	2	.02	.02	.06	.09	.09	.08	.08	.08	.07	.06	.04	.04
Los Angeles, CA	1	.11	.14	.15	.16	.18	.21	.20	.21	.19	.17	.11	.11
Alamosa, CO	2	.09	.11	.12	.15	.13	.10	.10	.06	.07	.07	.07	.07
Boulder, CO	1	.04	.05	.07	.09	.08	.07	.07	.07	.07	.05	.05	.04
Washington, DC	1	.11	.12	.15	.17	.19	.21	.24	.20	.17	.13	.13	.13
Miami, FL	2	.19	.29	.30	.31	.36	.54	.51	.55	.40	.33	.31	.24
Tallahassee, FL	2	.12	.18	.19	.20	.28	.34	.35	.25	.25	.19	.18	.12
Idaho Falls, ID	1	.03	.04	.06	.07	.07	.07	.06	.06	.06	.05	.04	.03
Chicago, IL	1	.15	.18	.21	.18	.18	.19	.22	.16	.16	.14	.13	.15
Salem, IL	2	.09	.10	.16	.17	.21	.22	.23	.21	.17	.16	.10	.09
Topeka, KS	1	.05	.07	.07	.07	.09	.12	.09	.07	.07	.06	.04	.04
Blue Hill, MA	1	.07	.07	.09	.11	.13	.16	.17	.13	.08	.07	.07	.06
Baltimore, MD	1	.12	.18	.18	.19	.22	.27	.31	.32	.31	.12	.17	.18
College Park, MD	2	.07	.08	.13	.17	.23	.21	.13	.23	.17	.13	.08	.07
St. Cloude, MN	2	.08	.06	.08	.13	.11	.09	.11	.10	.08	.06	.05	.05
St. Louis, MO	1	.12	.12	.16	.17	.21	.20	.22	.19	.19	.12	.12	.11
Meridian, MS	1	.07	.07	.07	.09	.12	.15	.15	.13	.11	.07	.07	.07
Missoula, MT	1	.06	.07	.07	.08	.09	.07	.07	.06	.09	.08	.07	.07
Greensboro, NC	1	.07	.08	.09	.11	.14	.24	.22	.21	.14	.08	.07	.07
Raleigh, NC	2	.06	.10	.10	.10	.12	.14	.24	.15	.13	.06	.06	.04
Bismarck, ND	2	.04	.02	.04	.08	.08	.07	.05	.06	.07	.08	.08	.05
Albany, NY	1	.10	.09	.11	.12	.14	.14	.15	.15	.14	.11	.10	.09
Brookhaven, NY	1	.07	.07	.10	.11	.12	.14	.15	.11	.12	.07	.07	.07
New York City, NY	1	.11	.11	.12	.15	.17	.22	.21	.24	.20	.15	.11	.11
Cincinnati, OH	1	.07	.09	.12	.13	.14	.20	.20	.19	.17	.12	.10	.08
Toledo, OH	2	.09	.08	.12	.11	.15	.13	.15	.11	.09	.05	.06	.06
Youngstown, OH	2	.14	.14	.16	.19	.25	.29	.22	.28	.22	.17	.15	.13
Pendleton, OR	2	.10	.12	.16	.20	.19	.19	.16	.15	.11	.09	.09	.09
Philadelphia, PA	1	.12	.15	.18	.20	.22	.25	.27	.23	.17	.15	.14	.14
Huron, SD	1	.04	.05	.07	.07	.08	.09	.08	.07	.07	.06	.05	.04
Memphis, TN	1	.08	.08	.10	.16	.15	.18	.19	.16	.16	.09	.10	.08
Oak Ridge, TN	2	.10	.14	.13	.17	.33	.26	.37	.31	.25	.13	.09	.09
College Stn., TX	1	.10	.10	.11	.12	.13	.08	.15	.12	.11	.09	.08	.07
Grand Prarie, TX	2	.07	.12	.16	.16	.36	.35	.36	.53	.45	.23	.19	.21
Victoria, TX	2	.03	.03	.05	.02	.08	.08	.06	.05	.04	.04	.03	.02
Green Bay, WI	2	.09	.09	.15	.16	.19	.17	.16	.10	.09	.10	.05	.06
Elkins, WV	1	.07	.07	.09	.14	.15	.21	.21	.19	.14	.07	.07	.07

Source: 1. E. C. Flowers, R. A. McCormick, and K. R. Kurfis, "Atmospheric Turbidity over the United States, 1961-66", Journal of Applied Meteorology, Vol. 8, No. 6, 1969, pp. 955-962.

2. "Global Monitoring of the Environment for Selected Atmospheric Constituents, 1977", Environmental Data and Information Service, National Climatic Center, Asheville, NC, June 1980.

Note: This table contains values for the Angstrom turbidity coefficient (β).

Table 3. Recommended MAX-GLARE Values

Location or Building Type	Maximum Daylight Glare Index
Factories	
Rough Work	28
Engine Assembly	26
Fine Assembly	24
Instrument Assembly	22
Laboratories	22
Museums	20
Art Galleries	16
Offices	
General	22
Drafting	20
School Classrooms	20
Hospital Wards	18

Note: The values in this table were obtained from the relationship MAX-GLARE = 2/3 (14 + I_{max}), where I_{max} is the limiting IES (London) glare index for artificial lighting given in R. G. Hopkinson, P. Petherbridge and J. Longmore, "Daylighting", Heinemann, London, 1966, p. 309.

Table 4.

Daylight Transmittance of Different Window Shading Devices

Shading Device	Daylight Transmittance (VIS-TRANS-SCH Value)
Translucent Drapes[1]	
Light (white)	.35
Medium (grey)	.23
Dark (tan)	.14
Translucent Shades[2]	
Glossy white	.18
Flat white	.23

Data Sources:

1. Pennington, C. W., et. al., "Experimental Analysis of Solar Heat Gain Through Insulating Glass with Indoor shading", ASHRAE Journal, February 1964.

2. Jordan, R. C., and Threlkeld, J. L., "Determination of the Effectiveness of Window Shading Materials on the Reduction of Solar Radiation Heat Gain", ASHRAE Transactions, Volume 65, 1959.

Note: Refer to manufacturer's data for specific products.

REPORT LV-L — DAYLIGHT FACTOR SUMMARY

This report is printed for each combination of window and reference point in a daylit space. The first section of the report summarizes some of the daylighting-related input information for the space, window, and reference point. The second section lists the daylight factors which were calculated by the daylighting preprocessor for 20 values of solar altitude and azimuth covering the annual range of sun positions at the location being analyzed.

Section 1

Space-Related Quantities

SPACE --	is the u-name of space.
AREA	is the floor area of space (before multiplication by space multiplier).
AV REFL	is the area-weighted average inside surface visible reflectance of space which is calculated from INSIDE-VIS-REFL values for EXTERIOR-WALL, INTERIOR-WALL, UNDERGROUND-FLOOR, UNDERGROUND-WALL, and WINDOW.
MAX-GLARE	is the threshold for closing window shades to control glare (MAX-GLARE keyword value; defaults to 100, which means no glare control).
VW-AZ	(view azimuth) is the azimuth angle, measured clockwise from the building y-axis, of the occupant's direction of view used to calculate the daylight glare index. It is entered with the VIEW-AZIMUTH keyword.

Window-Related Quantities

WINDOW --	is the window u-name.
SH-COEF	is the shading coefficient of glazing as entered with SHADING-COEF keyword under GLASS-TYPE.
VIS-TRANS	is the visible transmittance of the window glazing at normal incidence, as entered with VIS-TRANS keyword under GLASS-TYPE.
H	is the height of window.

W	is the width of window.
AZIM & TILT	are the azimuth and tilt angle, respectively, of the window outward normal in the building coordinate system. (AZIM is measured clockwise from the building y-axis).
DAY-X-DIV DAY-Y-DIV	are the number of elements into which the window is divided along its WIDTH and HEIGHT, respectively, for the integration which determines the daylight reaching the reference point from the window. DAY-X-DIV and DAY-Y-DIV are automatically determined by the program to insure an accurate integration.
X,Y,Z	are the coordinates of the window origin in the space coordinate system. For vertical windows, Z is the sill height.
WIN-SHADE-TYPE	is the type of shading device on the window, if any, as entered with the WIN-SHADE-TYPE keyword.

Reference Point Related Quantities

REF PT NO. --	is the number of reference point (1 or 2)
X,Y,Z	are the coordinates of reference point in the space coordinate system.
ZONE-FRACTION	is the fraction of the space floor area controlled by the lighting system at this reference point (value of ZONE-FRACTION1 or ZONE-FRACTION2 keyword).
LTG-SET-POINT	is the illuminance set point as entered with keyword LIGHT-SET-POINT1 for reference point 1, or with LIGHT-SET-POINT2 for reference point 2.
LTG-CTRL-TYPE	is the lighting control type as entered with keyword LIGHT-CTRL-TYPE1 for reference point 1, or with or LIGHT-CTRL-TYPE2 for reference point 2.

Section 2

Calculated Daylight Factors

SUN POS NO.	(sun position number) is the sun-position index corresponding to different pairs of solar altitude and azimuth values (see SUN ALT and SUN AZIM, below).
DAY TYP	(day type) is 1 for clear sky and 2 for overcast sky. For the latter, the daylight factors for only one sun position are calculated.

WIN SHD IND	(window shade index) is 1 for bare window (shading device off), and 2 for window with shading device on. (Visible transmittance of shade is taken to be 1.0 for daylight factor calculation.)
SUN ALT	altitude of sun above the horizon. It has four equally-spaced values ranging from 10^{o} to the maximum altitude the sun can reach at the location being analyzed.
SUN AZIM	is the azimuth of sun measured clockwise from North.
EXT ILL -SKY	is the exterior horizontal illuminance due to diffuse light from sky (excludes direct sun).
EXT ILL -SUN	is the exterior horizontal illuminance due to direct sun.
	EXT ILL -SKY and EXT ILL -SUN are calculated for standard CIE skies using, for clear sky, the atmospheric turbidity and moisture for the month of May.

The following quantities relate to the interior of the space. For WIN SHD IND = 2 (window with shade), the shade is assumed to have 100% transmittance; the actual shade transmittance is taken into account in the hourly loads calculation.

DIR ILL -SKY	(direct illuminance -sky) is the direct horizontal illuminance at the reference point produced by light which originates in the sky and reaches the reference point without reflection from the interior surfaces of the space. For an unshaded window (WIN SHD IND = 1), this includes the light coming directly from the sky, or by reflection of sky light from exterior BUILDING-SHADEs. For a window with shade (WIND SHD IND = 2 and WIN-SHADE-TYPE other than NO-SHADE), the light source is the shade itself, a diffusely transmitting surface illuminated by direct light from the sky, sky light reflected from the ground, and sky light reflected from exterior obstructions.
REFL ILL -SKY	(reflected illuminance -sky) is the illuminance at the reference point produced by daylight which originates in the sky and reaches the reference point after reflecting from the interior surfaces of the space.
DIR ILL -SUN	(direct illuminance -sun): for an unshaded window (WIN SHD IND = 1), the program does not calculate the illuminance due to sunlight (and it therefore prints zero) since it is assumed that a shade will be used whenever direct sun can reach the reference

	point. For a window with shade (WIN SHD IND = 2), the light source is the shade illuminated by direct sunlight and by sunlight reflected by the ground and exterior obstructions.
REFL ILL -SUN	(reflected illuminance -sun) is the indirect horizontal illuminance at the reference point produced by sunlight which reflects from interior surfaces before reaching the reference point.
DAY ILL FAC -SKY	(daylight illuminance factor -sky) is the ratio (DIR ILL -SKY + REFL ILL -SKY)/(EXT ILL -SKY).
DAY ILL FAC -SUN	(daylight illuminance factor -sun) is the ratio (DIR ILL -SUN + REFL ILL -SUN)/(EXT ILL -SUN).
WIN LUM FAC -SKY	(window luminance factor -sky) is the average luminance of the window (as seen from the reference point) due to light originating in the sky, divided by EXT ILL -SKY. It has units footlamberts/footcandle (English) or candelas/m^2/lux (metric).
WIN LUM FAC -SUN	(window luminance factor -sun) is the ratio between the average luminance of the window (as seen from the reference point) due to light originating at the sun, divided by EXT ILL -SUN. This quantity is not calculated for an unshaded window.
BACKG LUM FAC -SKY	(background luminance factor -sky) is the average luminance of interior surfaces due to light originating in the sky, divided by EXT ILL -SKY. It has units footlamberts/footcandle (English) or candelas/m^2/lux (metric).
BACKG LUM FAC -SUN	(background luminance factor -sun) is the average luminance of interior surfaces due to light originating at the sun, divided by EXT ILL -SUN.
GLARE INDEX	is the daylight glare index at the reference point due to this window. (It assumes 100% shade transmittance for a shaded window (WIN SHD IND = 2). The actual glare index in the hourly calculation will generally be lower for shade transmittance < 100%.)

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DAYLIGHTING EXAMPLE                    FLOOR OF OFFICE BUILDING IN CHICAGO                6-FEB-85    12:40:4    LDL  RUN 1
30-FT DEEP PERIM OFFS DAYLIT TO 15 FT   AUTO SHADE MANAGEMENT FOR SUN CONTROL
REPORT- LV-L  DAYLIGHT FACTOR SUMMARY FOR          NORTHZONE
---------------------------------------------------------------------------------------------------------------------------------

SPACE--NORTHZONE               WINDOW--NORTHWIND                                     REF PT NO.--1
AREA(SQFT)        600.0        SH-COEF          .83  VIS-TRANS  0.68                  X(FT)   10.0  Y(FT)   10.0  Z(FT)    2.5
AV REFL             0.46       H(FT)            3.0  W(FT)      20.0                  ZONE-FRACTION        0.50
MAX-GLARE         100.0        AZIM(DEG)        0.0  TILT(DEG)  90.0                  LTG-SET-POINT(FC)      50.0
VW-AZ(DEG)         90.0        DAY-X-DIV          8  DAY-Y-DIV     8                  LTG-CTRL-TYPE       CONTINUOUS
                               X(FT)     0.0  Y(FT)     0.0  Z(FT)     4.0
                               WIN-SHADE-TYPE       MOVABLE-INTERIOR

                                  EXT      EXT      DIR      REFL      DIR      REFL     DAY      DAY      WIN      WIN     BACKG    BACKG
SUN     WIN   SUN     SUN         ILL      ILL      ILL      ILL       ILL      ILL      ILL      ILL      LUM      LUM      LUM      LUM
POS DAY SHD   ALT     AZIM       -SKY     -SUN     -SKY     -SKY      -SUN     -SUN     FAC      FAC      FAC      FAC      FAC      FAC    GLARE
NO. TYP IND (DEG)    (DEG)       (FC)     (FC)     (FC)     (FC)      (FC)     (FC)    -SKY     -SUN     -SKY     -SUN     -SKY     -SUN    INDEX

  1   1   1   10.     290.    1331.8    112.7     63.3     21.0       0.0      3.1  0.0633   0.0273   1.7388   0.0000   0.0073   0.0126    15.2
  1   1   2   10.     290.    1331.8    112.7     35.7     27.9       5.4      4.3  0.0477   0.0860   0.8656   1.5607   0.0097   0.0175    13.2
  1   2   1   10.     290.     366.9      0.0      7.5      3.2       0.0      0.0  0.0291   0.0000   0.6355   0.0000   0.0041   0.0000     4.9
  1   2   2   10.     290.     366.9      0.0      5.1      4.0       0.0      0.0  0.0246   0.0000   0.4461   0.0000   0.0050   0.0000     2.9
  2   1   1   10.     235.    1331.8    112.7     43.6     13.8       0.0      0.3  0.0431   0.0029   1.1225   0.0000   0.0048   0.0013    13.6
  2   1   2   10.     235.    1331.8    112.7     22.3     17.4       0.3      0.2  0.0299   0.0050   0.5417   0.0909   0.0061   0.0010    10.7
  3   1   1   10.     180.    1331.8    112.7     49.0     14.0       0.0      0.3  0.0473   0.0029   1.2276   0.0000   0.0049   0.0013    14.0
  3   1   2   10.     180.    1331.8    112.7     22.6     17.7       0.3      0.2  0.0303   0.0050   0.5491   0.0909   0.0062   0.0010    10.8
  4   1   1   10.     125.    1331.8    112.7     43.6     13.8       0.0      0.3  0.0431   0.0029   1.1225   0.0000   0.0048   0.0013    13.6
  4   1   2   10.     125.    1331.8    112.7     22.3     17.4       0.3      0.2  0.0299   0.0050   0.5417   0.0909   0.0061   0.0010    10.7
  5   1   1   10.      70.    1331.8    112.7     63.3     21.0       0.0      3.1  0.0633   0.0273   1.7388   0.0000   0.0073   0.0126    15.2
  5   1   2   10.      70.    1331.8    112.7     35.7     27.9       5.4      4.3  0.0477   0.0860   0.8656   1.5607   0.0097   0.0175    13.2
  6   1   1   31.     290.    2104.9   2126.2     85.4     28.9       0.0     20.5  0.0543   0.0096   1.4371   0.0000   0.0064   0.0045    16.1
  6   1   2   31.     290.    2104.9   2126.2     48.5     37.9      32.7     25.5  0.0411   0.0274   0.7447   0.4965   0.0083   0.0056    15.4
  7   1   1   31.     235.    2104.9   2126.2     55.9     19.2       0.0      6.1  0.0357   0.0029   0.9123   0.0000   0.0042   0.0013    14.6
  7   1   2   31.     235.    2104.9   2126.2     30.4     23.8       6.0      4.7  0.0257   0.0050   0.4668   0.0909   0.0052   0.0010    12.7
  8   1   1   31.     180.    2104.9   2126.2     59.2     18.7       0.0      6.1  0.0370   0.0029   0.9448   0.0000   0.0041   0.0013    14.7
  8   1   2   31.     180.    2104.9   2126.2     29.5     23.0       6.0      4.7  0.0249   0.0050   0.4525   0.0909   0.0051   0.0010    12.6
  9   1   1   31.     125.    2104.9   2126.2     55.9     19.2       0.0      6.1  0.0357   0.0029   0.9123   0.0000   0.0042   0.0013    14.6
  9   1   2   31.     125.    2104.9   2126.2     30.4     23.8       6.0      4.7  0.0257   0.0050   0.4668   0.0909   0.0052   0.0010    12.7
 10   1   1   31.      70.    2104.9   2126.2     85.4     28.9       0.0     20.5  0.0543   0.0096   1.4371   0.0000   0.0064   0.0045    16.1
 10   1   2   31.      70.    2104.9   2126.2     48.5     37.9      32.7     25.5  0.0411   0.0274   0.7447   0.4965   0.0083   0.0056    15.4
 11   1   1   51.     290.    2565.4   4644.8     84.2     29.8       0.0     25.4  0.0444   0.0055   1.1134   0.0000   0.0054   0.0025    15.8
 11   1   2   51.     290.    2565.4   4644.8     48.9     38.2      35.4     27.7  0.0339   0.0136   0.6155   0.2465   0.0069   0.0028    15.5
 12   1   1   51.     235.    2565.4   4644.8     59.8     21.9       0.0     13.4  0.0319   0.0029   0.7948   0.0000   0.0040   0.0013    14.8
 12   1   2   51.     235.    2565.4   4644.8     34.3     26.8      13.1     10.2  0.0238   0.0050   0.4317   0.0909   0.0048   0.0010    13.7
 13   1   1   51.     180.    2565.4   4644.8     58.9     20.8       0.0     13.4  0.0310   0.0029   0.7744   0.0000   0.0037   0.0013    14.7
 13   1   2   51.     180.    2565.4   4644.8     32.1     25.1      13.1     10.2  0.0223   0.0050   0.4042   0.0909   0.0045   0.0010    13.5
 14   1   1   51.     125.    2565.4   4644.8     59.8     21.9       0.0     13.4  0.0319   0.0029   0.7948   0.0000   0.0040   0.0013    14.8
 14   1   2   51.     125.    2565.4   4644.8     34.3     26.8      13.1     10.2  0.0238   0.0050   0.4317   0.0909   0.0048   0.0010    13.7
 15   1   1   51.      70.    2565.4   4644.8     84.2     29.8       0.0     25.4  0.0444   0.0055   1.1134   0.0000   0.0054   0.0025    15.8
 15   1   2   51.      70.    2565.4   4644.8     48.9     38.2      35.4     27.7  0.0339   0.0136   0.6155   0.2465   0.0069   0.0028    15.5
 16   1   1   72.     290.    3143.7   6439.3     86.1     31.7       0.0     22.4  0.0375   0.0035   0.9082   0.0000   0.0047   0.0016    15.9
 16   1   2   72.     290.    3143.7   6439.3     51.0     39.9      25.3     19.8  0.0289   0.0070   0.5244   0.1270   0.0059   0.0014    15.3
 17   1   1   72.     235.    3143.7   6439.3     71.6     27.1       0.0     18.6  0.0314   0.0029   0.7654   0.0000   0.0040   0.0013    15.3
 17   1   2   72.     235.    3143.7   6439.3     42.4     33.1      18.1     14.2  0.0240   0.0050   0.4357   0.0909   0.0049   0.0010    14.6
 18   1   1   72.     180.    3143.7   6439.3     68.2     25.7       0.0     18.6  0.0299   0.0029   0.7292   0.0000   0.0038   0.0013    15.2
 18   1   2   72.     180.    3143.7   6439.3     39.9     31.2      16.1     14.2  0.0226   0.0050   0.4099   0.0909   0.0046   0.0010    14.5
 19   1   1   72.     125.    3143.7   6439.3     71.6     27.1       0.0     18.6  0.0314   0.0029   0.7654   0.0000   0.0040   0.0013    15.3
 19   1   2   72.     125.    3143.7   6439.3     42.4     33.1      18.1     14.2  0.0240   0.0050   0.4357   0.0909   0.0049   0.0010    14.6
 20   1   1   72.      70.    3143.7   6439.3     86.1     31.7       0.0     22.4  0.0375   0.0035   0.9082   0.0000   0.0047   0.0016    15.9
 20   1   2   72.      70.    3143.7   6439.3     51.0     39.9      25.3     19.8  0.0289   0.0070   0.5244   0.1270   0.0059   0.0014    15.3


NOTE -- ABOVE VALUES ASSUME VISIBLE TRANSMITTANCE = 1.0 FOR WINDOW GLASS AND SHADING DEVICE.
       ACTUAL TRANSMITTANCES ARE USED IN THE HOURLY CALCULATION.
```

New Daylighting Summary Reports

REPORT LS-G — SPACE DAYLIGHTING SUMMARY

This report gives monthly-average lighting energy reduction, illuminance, and glare for each daylit space. If only one lighting reference point is specified, the entries under REF PT 2 will be zero. Task lighting energy, as determined by TASK-LIGHTING-KW or TASK-LT-W/SQFT, is not considered.

1. PERCENT LIGHTING ENERGY REDUCTION BY DAYLIGHTING (ALL HOURS) gives the percentage by which electric lighting energy is reduced, due to daylighting, for the entire space (TOTAL ZONE), and for the lighting zones at each lighting reference point (REF PT 1 and REF PT 2). In this section of the report, all hours of the day are taken into account, including night-time hours when the lighting energy reduction due to daylighting is zero.

2. PERCENT LIGHTING ENERGY REDUCTION BY DAYLIGHTING (REPORT SCHEDULE HOURS) gives the percentage by which electric lighting energy is reduced, due to daylighting, for the entire space (TOTAL ZONE), and for the lighting zones at each lighting reference point (REF PT 1 and REF PT 2). In this section of the report, only those hours are taken into account for which the value of DAYLIGHT-REP-SCH for this space is non-zero (the default). If DAYLIGHT-REP-SCH is not defined the entries will be the same as those in Part 1 above.

In the following four sections, only those hours are taken into account for which the sun is up and the value of DAYLIGHT-REP-SCH is non-zero (the default).

3. AVERAGE DAYLIGHT ILLUMINANCE (FOOTCANDLES) gives the average illuminance due to daylight at each lighting reference point.

4. PERCENT HOURS DAYLIGHT ILLUMINANCE ABOVE SETPOINT gives the percentage of hours that the illuminance from daylight exceeds the required illuminance level as specified by LIGHT-SET-POINT1 at REF PT 1 and LIGHT-SET-POINT2 at REF PT 2. (See Report LS-J for the frequency of occurrence distribution for daylight illuminance.)

5. AVERAGE GLARE INDEX gives the average daylight glare index at each lighting reference point (REF PT 1 and REF PT 2).

6. PERCENT HOURS GLARE TOO HIGH gives the percentage of hours at each lighting reference point that the daylight glare index exceeds the MAX-GLARE value (or a value of 22, the maximum recommended for general office work, if MAX-GLARE has not been specified).

```
DAYLIGHTING EXAMPLE                      FLOOR OF OFFICE BUILDING IN CHICAGO          DOE-2.1C  11-JAN-85    16:26:3    LDL RUN 1
30-FT DEEP PERIM OFFS DAYLIT TO 15 FT    AUTO SHADE MANAGEMENT FOR SUN CONTROL
REPORT- LS-G  SPACE DAYLIGHTING SUMMARY                                                 WEATHER FILE- TRY  CHICAGO
--------------------------------------------------------------------------------------------------------------------------------

SPACE  NORTHZONE

                                                                      ----------------REPORT SCHEDULE HOURS WITH SUN UP---------------

                  PERCENT LIGHTING           PERCENT LIGHTING               AVERAGE       PERCENT HOURS
                  ENERGY REDUCTION           ENERGY REDUCTION              DAYLIGHT           DAYLIGHT
                    BY DAYLIGHTING             BY DAYLIGHTING           ILLUMINANCE        ILLUMINANCE            AVERAGE      PERCENT HOURS
                       (ALL HOURS)      (REPORT SCHEDULE HOURS)        (FOOTCANDLES)      ABOVE SETPOINT       GLARE INDEX     GLARE TOO HIGH
         --------------------      --------------------          --------------     --------------     --------------     --------------
          TOTAL  REF PT  REF PT      TOTAL  REF PT  REF PT          REF PT  REF PT     REF PT  REF PT     REF PT  REF PT     REF PT  REF PT
MONTH      ZONE       1       2       ZONE       1       2               1       2          1       2          1       2          1       2
-----     -----  ------  ------      -----  ------  ------          ------  ------     ------  ------     ------  ------     ------  ------

JAN         9.3    18.6     0.0       11.9    23.9     0.0            20.9     0.0        0.0     0.0        7.4     0.0        0.0     0.0

FEB        13.2    26.5     0.0       16.5    33.0     0.0            24.8     0.0        8.3     0.0        8.4     0.0        0.0     0.0

MAR        17.2    34.4     0.0       21.1    42.1     0.0            29.1     0.0       14.7     0.0        9.4     0.0        0.0     0.0

APR        23.7    47.5     0.0       28.5    56.9     0.0            37.3     0.0       29.3     0.0       10.7     0.0        0.0     0.0

MAY        25.5    51.1     0.0       29.8    59.7     0.0            40.1     0.0       21.1     0.0       11.2     0.0        0.0     0.0

JUN        34.5    68.9     0.0       39.4    78.7     0.0            54.6     0.0       48.5     0.0       12.4     0.0        0.0     0.0

JUL        39.5    79.0     0.0       44.6    89.1     0.0            70.2     0.0       74.2     0.0       13.4     0.0        0.0     0.0

AUG        30.2    60.3     0.0       34.6    69.2     0.0            45.0     0.0       32.6     0.0       11.7     0.0        0.0     0.0

SEP        33.2    66.4     0.0       38.7    77.4     0.0            46.9     0.0       51.1     0.0       11.8     0.0        0.0     0.0

OCT        24.6    49.2     0.0       30.2    60.4     0.0            36.2     0.0       30.5     0.0       10.5     0.0        0.0     0.0

NOV        11.9    23.8     0.0       15.0    29.9     0.0            24.5     0.0        2.2     0.0        8.4     0.0        0.0     0.0

DEC         9.0    18.1     0.0       11.5    22.9     0.0            18.0     0.0        0.0     0.0        6.8     0.0        0.0     0.0
          -----  ------  ------      -----  ------  ------          ------  ------     ------  ------     ------  ------     ------  ------

ANNUAL     22.8    45.7     0.0       27.0    54.1     0.0            37.4     0.0       26.1     0.0       10.2     0.0        0.0     0.0
```

REPORT LS-H —
PERCENT LIGHTING ENERGY REDUCTION BY DAYLIGHTING VS HR OF DAY

This report gives, for each daylit space, the monthly lighting energy reduction due to daylighting for each hour of the day, and for all hours of the day combined (including night-time hours). HOUR OF DAY is given in standard time, even if DAYLIGHT-SAVINGS=YES. Hour 1 is 12 pm to 1 am, hour 2 is 1 am to 2 am, etc. The schedule DAYLIGHT-REP-SCH has no effect on this report. Task lighting energy, as determined by TASK-LIGHTING-KW or TASK-LT-W/SQFT, is not considered.

See Report LS-I for lighting energy reduction vs. hour of day for the entire building.

```
DAYLIGHTING EXAMPLE                FLOOR OF OFFICE BUILDING IN CHICAGO          DOE-2.1C   6-FEB-85    12:40:4    LDL RUN 1
30-FT DEEP PERIM OFFS DAYLIT TO 15 FT   AUTO SHADE MANAGEMENT FOR SUN CONTROL
REPORT- LS-H PERCENT LIGHTING ENERGY REDUCTION BY DAYLIGHT  NORTHZONE                   WEATHER FILE- TRY  CHICAGO
-------------------------------------------------------------------------------------------------------------------------


SPACE   NORTHZONE


                                             HOUR OF DAY
                                                                                                         ALL
MONTH     1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24   HOURS
-----   --- --- --- --- --- --- --- --- --- --- --- --- --- --- --- --- --- --- --- --- --- --- --- ---   -----

JAN       0   0   0   0   0   0   0   4   7  11  15  15  16  15  13  10   6   0   0   0   0   0   0   0       9

FEB       0   0   0   0   0   0   0   9  13  19  22  21  21  17  15  13   9   7   0   0   0   0   0   0      13

MAR       0   0   0   0   0   0  11  14  18  20  25  25  25  25  19  16  17  10   0   0   0   0   0   0      17

APR       0   0   0   0   0  11  15  21  29  31  33  34  33  31  28  22  17  13   7   0   0   0   0   0      24

MAY       0   0   0   0  13  20  27  29  30  30  33  33  32  30  27  25  19  18  11   0   0   0   0   0      26

JUN       0   0   0   0  19  18  29  32  39  40  41  42  43  41  39  37  32  26  22  18   0   0   0   0      34

JUL       0   0   0   0  31  31  37  43  43  45  46  46  47  45  45  41  38  35  26  20   0   0   0   0      39

AUG       0   0   0   0   3  22  27  31  32  34  37  40  36  36  31  34  30  27  19   0   0   0   0   0      30

SEP       0   0   0   0   0  20  34  36  38  39  41  42  42  40  37  35  30  26   6   0   0   0   0   0      33

OCT       0   0   0   0   0   4  16  26  29  32  34  37  37  31  27  24  16   5   0   0   0   0   0   0      25

NOV       0   0   0   0   0   0   9  12  16  19  20  22  20  15  11   7   4   0   0   0   0   0   0   0      12

DEC       0   0   0   0   0   0   0   7  11  14  16  16  14  12  10   7   4   0   0   0   0   0   0   0       9
        --- --- --- --- --- --- --- --- --- --- --- --- --- --- --- --- --- --- --- --- --- --- --- ---   -----

ANNUAL    0   0   0   0   6  13  22  28  26  28  30  30  32  28  25  23  16  12   8   3   0   0   0   0      23



NOTE- THE ENTRIES IN THIS REPORT ARE NOT
      SUBJECT TO THE DAYLIGHTING REPORT SCHEDULE
```

REPORT LS-I — PERCENT LIGHTING ENERGY REDUCTION BY DAYLIGHTING VS HR OF DAY, *** BUILDING ***

This report gives, for the building as a whole, the monthly lighting energy reduction due to daylighting for each hour of the day, and for all hours of the day combined (including night-time hours). HOUR OF DAY is given in standard time, even if DAYLIGHT-SAVINGS=YES. Hour 1 is 12 pm to 1 am, hour 2 is 1 am to 2 am, etc. All spaces in the building are included in this report, even those which are not daylit (i.e. have DAYLIGHTING=NO). This report is not effected by DAYLIGHT-REP-SCH. Task lighting energy, as determined by TASK-LIGHTING-KW or TASK-LT-W/SQFT, is not considered.

See Report LS-H for lighting energy reduction vs. hour of day for individual daylit spaces.

```
DAYLIGHTING EXAMPLE                FLOOR OF OFFICE BUILDING IN CHICAGO          DOE-2.1C   6-FEB-85    12:40:4    LDL RUN 1
30-FT DEEP PERIM OFFS DAYLIT TO 15 FT   AUTO SHADE MANAGEMENT FOR SUN CONTROL
REPORT- LS-I PERCENT LIGHTING ENERGY REDUCTION BY DAYLIGHT                           WEATHER FILE- TRY  CHICAGO
---------------------------------------------------------------------------------------------------------------------------

*** BUILDING ***


                                                HOUR OF DAY
                                                                                                                 ALL
MONTH      1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  HOURS
-----    --- --- --- --- --- --- --- --- --- --- --- --- --- --- --- --- --- --- --- --- --- --- --- ---  -----

JAN        0   0   0   0   0   0   0   1   1   2   3   3   3   3   2   2   1   0   0   0   0   0   0   0      2

FEB        0   0   0   0   0   0   0   2   2   3   4   4   4   3   3   2   2   1   0   0   0   0   0   0      2

MAR        0   0   0   0   0   0   2   2   3   4   4   4   4   4   3   3   3   2   0   0   0   0   0   0      3

APR        0   0   0   0   0   2   3   4   5   5   6   6   6   6   5   4   3   2   1   0   0   0   0   0      4

MAY        0   0   0   0   2   4   5   5   5   5   6   6   6   5   5   4   3   3   2   0   0   0   0   0      5

JUN        0   0   0   0   3   3   5   6   7   7   7   7   8   7   7   7   6   5   4   3   0   0   0   0      6

JUL        0   0   0   0   5   5   7   8   8   8   8   8   6   8   8   7   7   6   5   3   0   0   0   0      7

AUG        0   0   0   0   1   4   5   6   6   6   6   7   7   6   6   6   5   5   3   0   0   0   0   0      5

SEP        0   0   0   0   0   4   6   6   7   7   7   7   7   7   7   6   5   5   1   0   0   0   0   0      6

OCT        0   0   0   0   0   1   3   5   5   6   6   6   6   5   5   4   3   1   0   0   0   0   0   0      4

NOV        0   0   0   0   0   0   2   2   3   3   4   4   4   3   2   1   1   0   0   0   0   0   0   0      2

DEC        0   0   0   0   0   0   0   1   2   2   3   3   2   2   2   1   1   0   0   0   0   0   0   0      2
         --- --- --- --- --- --- --- --- --- --- --- --- --- --- --- --- --- --- --- --- --- --- --- ---  -----

ANNUAL     0   0   0   0   1   2   4   5   5   5   5   5   6   5   4   4   3   2   1   0   0   0   0   0      4


NOTE- THE ENTRIES IN THIS REPORT ARE NOT
      SUBJECT TO THE DAYLIGHTING REPORT SCHEDULE
```

REPORT LS-J — DAYLIGHT ILLUMINANCE FREQUENCY OF OCCURRENCE

This report gives, for each daylit space, the monthly daylight-illuminance frequency-of-occurrence distribution at each lighting reference point. If only one lighting reference point is specified, the entries under REF PT 2 will be zero.

1. PERCENT OF HOURS IN ILLUMINANCE RANGE gives the percentage of hours (with sun up and DAYLIGHT-REP-SCH value non-zero) that the daylight illuminance falls in the indicated range: 0-10, 10-20, ..., 70-80, and greater than 80 footcandles. (Note that, because of roundoff, the sum of these percentages for any given month may not be exactly 100.)

2. PERCENT OF HOURS ILLUMINANCE LEVEL EXCEEDED gives the percentage of hours (with sun up and DAYLIGHT-REP-SCH value non-zero) that the daylight illuminance is higher than the indicated illuminance level.

```
DAYLIGHTING EXAMPLE                      FLOOR OF OFFICE BUILDING IN CHICAGO           DOE-2.1C   6-FEB-85    12:40:4     LDL RUN 1
30-FT DEEP PERIM OFFS DAYLIT TO 15 FT    AUTO SHADE MANAGEMENT FOR SUN CONTROL
REPORT- LS-J  DAYLIGHT ILLUMINANCE FREQUENCY OF OCCURRENCE  NORTHZONE                        WEATHER FILE- TRY  CHICAGO
------------------------------------------------------------------------------------------------------------------------------------

SPACE  NORTHZONE

                        PERCENT OF HOURS IN ILLUMINANCE RANGE                     PERCENT OF HOURS ILLUMINANCE LEVEL EXCEEDED
                        -------------------------------------                     -------------------------------------------

                           ILLUMINANCE RANGE (FOOTCANDLES)                              ILLUMINANCE LEVEL (FOOTCANDLES)
       REF
MONTH   PT    0 -- 10 -- 20 -- 30 -- 40 -- 50 -- 60 -- 70 -- 80 -ABOVE        0    10    20    30    40    50    60    70    80

JAN    -1-      21    45     7    10    16     0     0     0     0          100    79    34    27    16     0     0     0     0
       -2-       0     0     0     0     0     0     0     0     0            0     0     0     0     0     0     0     0     0

FEB    -1-      12    37    20     6    17     8     0     0     0          100    88    51    31    25     8     0     0     0
       -2-       0     0     0     0     0     0     0     0     0            0     0     0     0     0     0     0     0     0

MAR    -1-       7    29    31    11     8     9     6     0     0          100    93    65    33    22    15     6     0     0
       -2-       0     0     0     0     0     0     0     0     0            0     0     0     0     0     0     0     0     0

APR    -1-       0    12    29    23     6    14    15     0     0          100   100    88    59    36    29    15     0     0
       -2-       0     0     0     0     0     0     0     0     0            0     0     0     0     0     0     0     0     0

MAY    -1-       0     5    25    35    14     4    10     7     0          100   100    95    70    35    21    17     7     0
       -2-       0     0     0     0     0     0     0     0     0            0     0     0     0     0     0     0     0     0

JUN    -1-       0     0    10    25    16     7     7    20    14          100   100   100    90    64    49    41    34    14
       -2-       0     0     0     0     0     0     0     0     0            0     0     0     0     0     0     0     0     0

JUL    -1-       0     0     6    13     6    10     8     6    51          100   100   100    94    81    74    65    57    51
       -2-       0     0     0     0     0     0     0     0     0            0     0     0     0     0     0     0     0     0

AUG    -1-       0     3    11    36    18     6    19     8     0          100   100    97    86    50    33    27     8     0
       -2-       0     0     0     0     0     0     0     0     0            0     0     0     0     0     0     0     0     0

SEP    -1-       0     4    17    19    10    13    38     0     0          100   100    96    80    61    51    38     0     0
       -2-       0     0     0     0     0     0     0     0     0            0     0     0     0     0     0     0     0     0

OCT    -1-       1    14    28    13    13    30     0     0     0          100    99    85    56    43    30     0     0     0
       -2-       0     0     0     0     0     0     0     0     0            0     0     0     0     0     0     0     0     0

NOV    -1-      16    26    27    11    18     2     0     0     0          100    84    59    32    20     2     0     0     0
       -2-       0     0     0     0     0     0     0     0     0            0     0     0     0     0     0     0     0     0

DEC    -1-      25    50     9     6    10     0     0     0     0          100    75    25    16    10     0     0     0     0
       -2-       0     0     0     0     0     0     0     0     0            0     0     0     0     0     0     0     0     0
              ---------------------------------------------------------   ----------------------------------------------------

ANNUAL -1-       7    19    18    17    13     9     9     3     5          100    93    75    56    39    26    17     9     5
       -2-       0     0     0     0     0     0     0     0     0            0     0     0     0     0     0     0     0     0

 NOTE- THE HOURS CONSIDERED IN THIS REPORT ARE THOSE
       WITH SUN UP AND DAYLIGHTING REPORT SCHEDULE ON
```

New Hourly Report Variables for Daylighting

Twelve new LOADS GLOBAL variables (48 through 59), nine new SPACE variables (49 through 57), and nine new WINDOW variables (19 through 27), have been added for daylighting analysis. See the Appendix at the end of this Supplement for a complete description of the new variables.

TROMBE WALLS

DOE-2.1B and 2.1C have available models for two types of Trombe walls: vented and unvented. The following describes the input needed to use the Trombe wall simulation.

The simulation requires the following sets of information:

(A) The size, location, and orientation of the Trombe wall.

(B) The size and type of glazing of the window. The amount and scheduling of window insulation.

(C) The material description of the wall.

(D) The channel width of the air gap and the emissivity of the wall.

(E) The cross-sectional area of the upper and lower vents and the vertical distance separating the vents (vented Trombe walls only).

(F) The venting schedule (vented Trombe walls only).

Most of the information is handled in a way familiar to DOE-2 users. The new command is TROMBE-WALL-V (T-W-V) or TROMBE-WALL-NV (T-W-NV).

TROMBE-WALL-V TROMBE-WALL-NV	The Trombe walls are synonymous with EXTERIOR-WALLs. Thus, all information (see A above) is entered exactly like the information for an EXTERIOR-WALL command. Specifying TROMBE-WALL-V or TROMBE-WALL-NV tells the program to model a vented or unvented Trombe wall in the given space.

The TROMBE-WALL-V or TROMBE-WALL-NV command is immediately followed by a WINDOW command, which contains the information in (B). Note that the use of the keywords SHADING-SCHEDULE and CONDUCT-SCHEDULE allows the user to simulate movable insulation being placed over the glass.

The material description of the wall (C) is entered in the same way as a regular wall — through the MATERIAL, LAYERS, and CONSTRUCTION commands.

The remaining physical description of the Trombe wall ((D) and (E)) is entered by means of a new command:

WALL-PARAMETERS	which is referenced by the CONSTRUCTION command. The keywords for WALL-PARAMETERS (abbreviated as W-P) are:

u-name WALL-PARAMETERS

Keyword	Abbrev.	Input Desc.	Default	Min.	Max.
FOR	—	Code-word	Note 1		
EMISSIVITY	EM	fraction	0.93	0.0	1.0
CHANNEL-WIDTH	C-W	ft	required	0.0	1.0
LOWER-VENT-AREA	L-V-A	ft^2	Note 2	0.0	100.0
UPPER-VENT-AREA	U-V-A	ft^2	Note 2	0.0	100.0
VERT-VENT-SEP	V-V-S	ft	Note 2	0.0	20.0

Note 1: Required; legal values are TROMBE-WALL-V and TROMBE-WALL-NV.

Note 2: Required for TROMBE-WALL-V; unused by TROMBE-WALL-NV.

Rule: The keyword FOR must be the first keyword entered. It operates just as it does in SET-DEFAULT.

One additional keyword is used (in SDL) to specify a venting schedule, for the vented Trombe wall only. The keyword is in the ZONE command and is TROM-VENT-SCH (T-V-SCH).

TROM-VENT-SCH	This keyword allows the user to define which hours the Trombe wall is allowed to vent to the occupied space. A schedule value of 1 means venting is allowed. A value of 0 means venting is not allowed. The venting is done by natural convection and not by mechanical means, i.e., fans.

General Rules:

1. Only one TROMBE-WALL-V or TROMBE-WALL-NV is allowed per SPACE.
2. The wall is denoted a Trombe wall by use of the commands TROMBE-WALL-V or TROMBE-WALL-NV.
3. Each TROMBE-WALL-V or TROMBE-WALL-NV command must be followed by one, and only one, WINDOW command.
4. The window area must equal the Trombe wall area.
5. The CONSTRUCTION command referenced by the TROMBE-WALL-V or TROMBE-WALL-NV command must, in turn, reference a WALL-PARAMETERS command.

Warning:

There are certain restrictions on the use of Trombe walls in combination with other DOE-2 features.

Use of the vented Trombe wall should be avoided in combination with systems which use the COOL-CONTROL = WARMEST or HEAT-CONTROL = COLDEST option. In the warmest/coldest calculations, the thermal gains from the vented trombe wall are not included. This could cause the hot or cold duct supply temperatures to be incorrectly set, resulting in excess energy consumption, or underheated or undercooled zones. The system types involved are MZS, DDS, SZCI, HVSYS, TPIU, FPIU, VAVS, RHFS, CBVAV, PMZS, and PVAVS. This problem will not occur in these systems if other control methods are used.

For similar reasons, the use of Trombe walls in combination with optimum start (see Section "Optimum Start" in this Supplement) should be avoided in DOE-2.1C.

Example:

We add a Trombe wall (vented) to the Sample Run Building 3A.

```
TWLAY  = LAYERS     MAT= (CB32)                                      ..

TWCONS = CON    LAYERS = TWLAY
                WALL-PARAMETERS = TWPARS                             ..

TWPARS = WALL-PARAMETERS  FOR TROMBE-WALL-V
                          CHANNEL-WIDTH = .3333   LOWER-VENT-AREA = 15
                          UPPER-VENT-AREA = 15    VERT-VENT-SEP = 7  ..

TROMWGLASS = GLASS-TYPE   GLASS-TYPE-CODE = 1    PANES = 2           ..

         .
         .
         .

SPACE1-1   = SPACE     SPACE-CONDITIONS = OFFICE    etc.             ..

FRONT-1    = TROMBE-WALL-V   HEIGHT = 8  WIDTH = 100
                             X = 0       Y = 0
                             Z = 0       AZ = 180
                             CONSTRUCTION = TWCONS                   ..

WF-1       = WINDOW    HEIGHT = 8    WIDTH = 100
                       GLASS-TYPE = TROMWGLASS                       ..

         .
         .
         .

INPUT SYSTEMS                                                        ..

VENT-1  = DAY-SCHEDULE  (1,7) (0)  (8,18) (1)  (19,24) (0)           ..
```

```
VENT-2    = DAY-SCHEDULE  (1,24) (0)                                 ..
VENT-WEEK = WEEK-SCHEDULE (MON,FRI) VENT-1
                          (WEH) VENT-2                               ..
VENT-SCH  = SCHEDULE   THRU DEC 31   VENT-WEEK                       ..

        .
        .
        .

SPACE1-1  = ZONE    ZONE-TYPE = CONDITIONED
                    ZONE-CONTROL = CONTROL
                    TROM-VENT-SCH = VENT-SCH                         ..
```

Reporting

No new hourly report variables have been added, but some of the existing ones for wall and window can be informative. Variables of interest are Q (E-W(5)), the heat conducted into the space through the wall, and T (E-W(6)), the outside surface temperature of the wall. In the window variables, QTRANS, (WI(13)), the amount of solar passing through the window (and hence the energy available to the Trombe wall), and QCON, (WI(15)), the heat lost back out the window by conduction, are very useful. These variables are of interest only for the unvented Trombe wall. For the vented Trombe wall, all calculations are done in SYSTEMS and no useful hourly report variables are available.

FIXED SHADES, FINS, AND OVERHANGS

The shading routines in DOE-2.1B and 2.1C have been substantially upgraded to allow the user to experiment with the location of surrounding objects that throw shade on the building, as well as to model fins and overhangs on exterior walls and to simplify the input for self-shading exterior surfaces.

The new command is FIXED-SHADE (F-S):

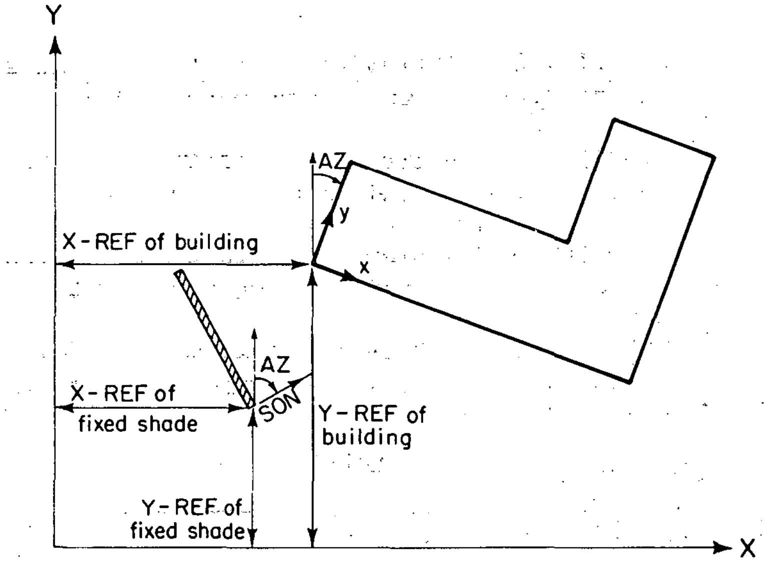
FIXED-SHADE This command is used to specify stationary shading surfaces which are NOT rotated and translated with the building when AZIMUTH is given a value under the BUILDING-LOCATION command (whereas BUILDING-SHADE does rotate). Its keywords are the same as the BUILDING-SHADE command, with the exception of X-REF, Y-REF, and Z-REF, which replace X, Y, and Z. X-REF, Y-REF, and Z-REF are the coordinates of the fixed shade. See Fig. 1.

Associated with the FIXED-SHADE command are two new keywords in the BUILDING-LOCATION command:

X-REF
Y-REF are new coordinates which are used to translate the building coordinate system with respect to a reference coordinate system. For example, specifying X-REF, Y-REF, and AZIMUTH in the BUILDING-LOCATION command, is used in Fig. 2 to rotate an L-shaped building as well as to move it with respect to the fixed shade. The difference between the original X-REF and Y-REF and the new X-REF and Y-REF (represented by the dashed lines) would be the dimensions that the building would move. The reference coordinate system is used only for buildings in conjunction with fixed shades. X-REF and Y-REF are expressed in feet, 0.0 is the default, and there are no limits.

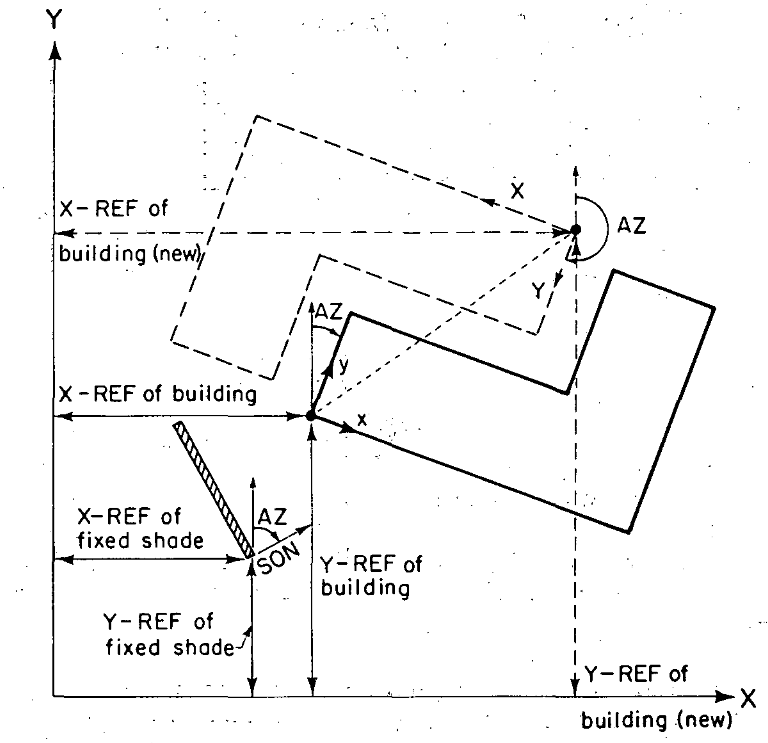
Overhangs and Fins

Note that even though overhangs and/or fins are specified under the WINDOW or DOOR command, these shading surfaces are attached to the wall where the window or door is located. These attached shades are used in shading calculations for this wall and for all of the windows and doors on this wall. Also, if this WINDOW or DOOR is referred to in another WINDOW or DOOR command with the LIKE keyword, the attached shades are also copied.



XBL 8211 – 7334

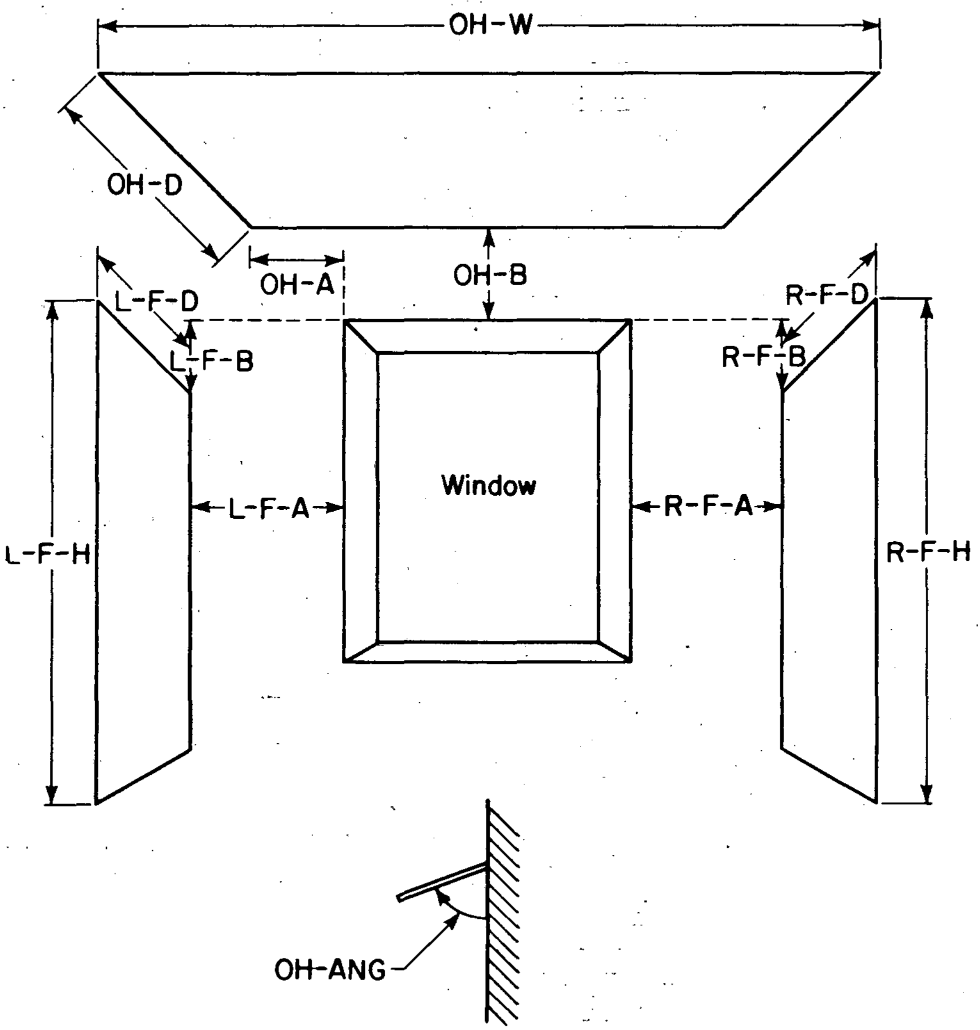
Fig. 1



XBL 8211-7334 A

Fig. 2

OVERHANG-A	See Fig. 3. Abbreviation is OH-A. Units are feet, 0.0 is the default, and there are no limits.
OVERHANG-B	See Fig. 3. Abbreviation is OH-B. Units are feet, 0.0 is the default, and there are no limits.
OVERHANG-W	See Fig. 3. Abbreviation is OH-W. Units are feet, 0.0 is the default, and the range is 0.0 to no limits.
OVERHANG-D	See Fig. 3. Abbreviation is OH-D. Units are feet, 0.0 is the default, and the range is 0.0 to no limits.



XBL 8210-4858

Fig. 3. The values in this figure are all positive. If the value for L-F-B is input as negative, then the left fin will originate at a point above the top edge of the window, and similarly, for R-F-B.

OVERHANG-ANGLE	is the angle between the overhang and the window. When set at 90^{o}F, the overhang is perpendicular to the window (the default); if < 90^{o}F, it is tilted down; if > 90^{o}F, it is tilted up. The range is 0 to 180^{o}. Abbreviation is OH-ANG.

Note: For overhang shading calculations to be performed, both OVERHANG-W and OVERHANG-D <u>must</u> be specified. If either of them is specified, but not both, a WARNING message is printed and overhang shading is not performed.

LEFT-FIN-A	See Fig. 3. Abbreviation is L-F-A. Units are feet, 0.0 is the default, and there are no limits.
LEFT-FIN-B	See Fig. 3. Abbreviation is L-F-B. Units are feet, 0.0 is the default, and there are no limits.
LEFT-FIN-H	See Fig. 3. Abbreviation is L-F-H. Units are feet, 0.0 is the default, and the range is 0.0 to no limits.
LEFT-FIN-D	See Fig. 3. Abbreviation is L-F-D. Units are feet, 0.0 is the default, and the range is 0.0 to no limits.
RIGHT-FIN-A	See Fig. 3. Abbreviation is R-F-A. Units are feet, 0.0 is the default, and there are no limits.
RIGHT-FIN-B	See Fig. 3. Abbreviation is R-F-B. Units are feet, 0.0 is the default, and there are no limits.
RIGHT-FIN-H	See Fig. 3. Abbreviation is R-F-H. Units are feet, 0.0 is the default, and the range is 0.0 to no limits.
RIGHT-FIN-D	See Fig. 3. Abbreviation is R-F-D. Units are feet, 0.0 is the default, and the range is 0.0 to no limits.

Note: For fin shading calculations to be performed, both of the pair, —FIN-H and —FIN-D, <u>must</u> be specified. If either one of the pair is specified, but not both, a WARNING message is printed and fin shading is not performed.

There is also a new keyword under both the FIXED-SHADE and the BUILDING-SHADE command:

SHADE-SCHEDULE	is the u-name of a schedule which gives the time dependent transmittance value of the shading device. This keyword can be used to simulate movable exterior devices or deciduous trees. The values in the schedule override the TRANSMITTANCE keyword values. A value of 0.0 in the schedule represents an opaque device and any greater value represents a device that passes direct solar such as a tree. The diffuse solar is unaffected by the shading. Abbreviation is S-SCH.

There is a new keyword in the EXTERIOR-WALL command:

SHADING-SURFACE	takes a code-word value of YES or NO. (NO is the default.) YES causes this EXTERIOR-WALL surface to be considered also as a BUILDING-SHADE surface with TRANSMITTANCE=0. Whenever an exterior wall is capable of shading another exterior surface, setting SHADING-SURFACE=YES greatly simplifies shading surface input. Abbreviation is S-S.

Note: Like BUILDING-SHADE, these new shading "methods" (FIXED-SHADE, overhangs and fins, and SHADING-SURFACE) affect only the direct component of solar radiation; except for the daylighting calculation, they have no effect on diffuse solar radiation.

DISTRIBUTION OF HEAT FROM LIGHTS

The heat from the lights in a space can, in principle, be considered to be deposited in three places: in the space itself, in an adjoining unconditioned space on the other side of the fixture, and in the return air stream. This distribution of light heat is determined by the keywords, LIGHT-TO-SPACE, LIGHT-TO-OTHER, and LIGHT-TO-RETURN under the SPACE-CONDITIONS command. The heat transfer to the space and/or to the adjoining space is considered to be partially radiative and partially convective. This split is determined by the keyword LIGHT-RAD-FRAC and is only applicable if Automatic Custom Weighting Factors have been specified (FLOOR-WEIGHT = 0). The convective portion is treated as an instantaneous load, whereas the radiative portion is assumed to be absorbed by the mass in the space and released in time according to the lighting weighting factors.

SPACE-CONDITIONS

LIGHT-TO-SPACE	is the fraction of the light heat in a given hour that is to be treated in LOADS as heat gain in the space.
LIGHT-TO-OTHER	is the fraction of light heat in a given hour that is deposited in an adjacent space. Unless the light fixture is in contact with an adjacent space or unless the "interior wall" between this space and the adjacent space is translucent or transparent, LIGHT-TO-OTHER should be zero.
LIGHT-TO-RETURN	is the fraction of light heat in a given hour that goes directly into the return air stream. Unless the return air passes through the light fixtures, LIGHT-TO-RETURN should be zero.

The sum of LIGHT-TO-SPACE + LIGHT-TO-OTHER + LIGHT-TO-RETURN must be 1.0 and the program will increase LIGHT-TO-RETURN to ensure this total, if the sum is less than 1.0. If the sum is greater than 1.0, an ERROR message will be issued. When it is appropriate to have a non-zero value for LIGHT-TO-OTHER, its value should be chosen in the following way: assume that the return air path is through a duct and estimate the values of LIGHT-TO-SPACE and LIGHT-TO-RETURN under conditions of maximum air flow. Set LIGHT-TO-OTHER = 1.0 - (LIGHT-TO-SPACE) - (LIGHT-TO-RETURN). This procedure is valid, even if the user intends to simulate return air plenums in SYSTEMS.

LIGHT-HEAT-TO	takes the u-name of an unconditioned or plenum space as a value and indicates the space that is the recipient of the fraction of light heat specified as LIGHT-TO-OTHER. This is a required keyword, if LIGHT-TO-OTHER > 0. In DOE-2.1B and 2.1C, only unconditioned or plenum spaces may be the recipients of such heat from lights.

LIGHT-RAD-FRAC	takes a list of two fractions: the first is the fraction of the light heat to a space that is radiative, the second is the fraction of light heat to an adjacent space that is radiative. The second fraction, although required if this keyword is used, is not used if LIGHT-TO-OTHER = 0. This keyword only applies if Automatic Custom Weighting Factors are requested by specifying FLOOR-WEIGHT = 0.

The LIGHTING-TYPE keyword now has the effect of determining defaults for the keywords, LIGHT-TO-SPACE, LIGHT-TO-RETURN, and LIGHT-RAD-FRAC, described above. If these keywords are defined explicitly by the user, LIGHTING-TYPE may be allowed to default. In particular, if there is a mixture of types of lighting within a space, the user should select appropriate values for LIGHT-TO-SPACE, LIGHT-TO-OTHER, LIGHT-TO-RETURN, and LIGHT-RAD-FRAC corresponding to a weighted average for the lighting types present.

Default Values For Lighting Types

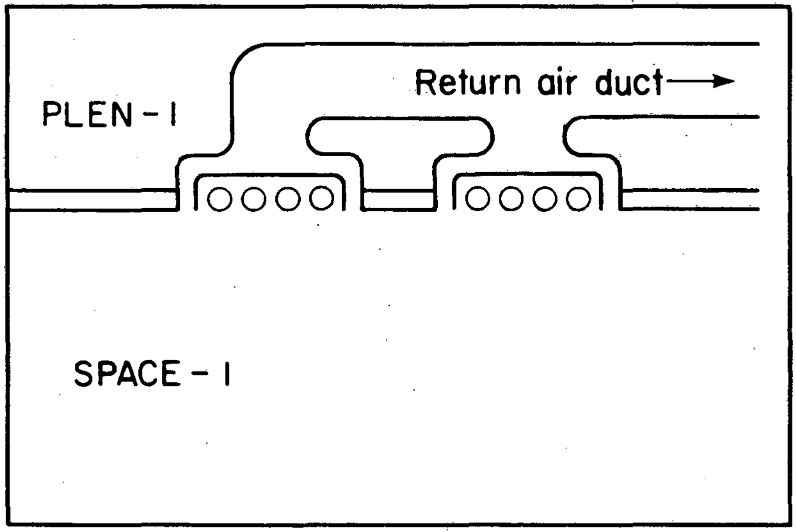
	SUS-FLUOR	REC-FLUOR-RV	REC-FLUOR-RSV	INCAND	REC-FLUOR-NV
LIGHT-TO-SPACE	1.0	0.8	0.8	1.0	1.0
LIGHT-TO-OTHER	0.0	0.0	0.0	0.0	0.0
LIGHT-TO-RETURN	*	*	*	*	*
LIGHT-RAD-FRAC:					
in this space	0.67	0.59	0.19	0.71	0.67
in other space	1.0	0.09	0.09	1.0	0.09

* Defaults to 1.0 minus LIGHT-TO-SPACE minus LIGHT-TO-OTHER.

Depending upon the type of system being modeled in SYSTEMS, or upon the choice for RETURN-AIR-PATH in the SYSTEM command, the light heat that has been assigned by the user to the return air path through the use of the keyword LIGHT-TO-RETURN (referred to here as QRETURN) will be treated as follows. If the HVAC system is zonal (that is, if SYSTEM-TYPE in the SYSTEM command is UHT, UVT, HP, TPFC, FPFC, TPIU, FPIU, or PTAC) or RETURN-AIR-PATH = DIRECT, QRETURN will be added to the zone load in SYSTEMS. If plenum zones are defined in SYSTEMS, then the return air path, along with QRETURN, is assumed to pass through the plenum zones. If there is a variable volume fan, then the light heat to the return air is proportional to the airflow rate to the zone, with the residue of QRETURN being added to the zone load.

As an example of these lighting keywords, consider the situation depicted in Fig. 1. A 2500 ft^2 conditioned zone SPACE-1 is illuminated to an intensity of 2 watts/ft^2 with recessed fluorescent light fixtures, designed so that the return air passes through the fixture into a return air duct. It is estimated that at design air flow, 30% of the heat given off from the fixture goes directly into the return air stream and 45% remains in the space. The remaining 25% is dissipated from the back of the fixture into the unconditioned space PLEN-1. Measurements indicate that 75% of the heat that goes into SPACE-1 is radiative (the other

25% being convective), while only 5% of the heat into PLEN-1 is radiative.



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The DOE-2 input for this situation is:

```
SPACE-1 = SPACE       ...
                         AREA = 2500
                         LIGHTING-W/SQFT = 2.0
                         LIGHT-TO-SPACE = .45
                         LIGHT-TO-OTHER = .25
                         LIGHT-HEAT-TO  = PLEN-1
                         LIGHT-RAD-FRAC = (.75,.05)
                                .
                                .
                                .                         ..
```

Note that no value for LIGHT-TO-RETURN has been entered. It could have been entered as .30, but the program will adjust its default value of 0.2 to ensure that the sum of the three fractions is 1.0.

In SYSTEMS the keyword RETURN-AIR-PATH will be given the value DUCT. Suppose that the system being simulated is a constant volume system. In that case, the heat added to the return air will be a constant 1.5 kW (30% of 2500 ft^2 times 2 $watts/ft^2$). If the system were a variable air volume system with a minimum cfm ratio of 0.4, then at the minimum air flow the light heat going into the return air would be 0.6 kW (0.4 times 1.5 kW). The 0.9 kW difference between 1.5 kW and 0.6 kW would be added to the zone load.

The meanings of the code-words applicable to RETURN-AIR-PATH have been revised as follows:

Code-Word	RETURN-AIR-PATH
DIRECT	This code-word is used when the return air flows back to the air-handler or relief point (central exhaust) via the zones, hallways or stairwells. Any heat from lights that was specified in LOADS to go to the return air through the LIGHT-TO-RETURN keyword will be added to the zone load.
DUCT	Use of this code-word causes a fraction of the heat from lights, specified through the LIGHT-TO-RETURN keyword in LOADS, to be added to the return air stream. If there is a variable air volume system, the fraction is the ratio of the cfm to the zone that hour to the maximum design cfm to the zone. This code-word should be used in two main cases: (1) when return air duct work actually exists in the building and (2) when the return air passes through a plenum and the plenum is essentially at the same temperature as the zone it serves. The second case allows a great simplification of input for high-rise office buildings where there are plenum zones in the intermediate floors. The user specifies the conditioned spaces large enough to include the plenum areas and does not input a plenum at all. The heat from lights that goes to the plenum is specified through the LIGHT-TO-RETURN keyword (not the LIGHT-TO-OTHER keyword). In the first case, if the return air ducts are located in an unconditioned zone, that zone should be identified in SYSTEMS as ZONE-TYPE = UNCONDITIONED.
PLENUM-ZONES	This code-word is used when the return air path is through plenums and the heat exchange between the return air and the plenum wall mass is important. Heat from lights can be added in two ways: directly through the LIGHT-TO-OTHER keyword in LOADS and through the LIGHT-TO-RETURN. The former assignment will allow some of the light heat to be stored in the plenum wall mass, while the latter will show up as an instantaneous cooling load in the return air. This keyword must be chosen if there are zones in this system, defined as ZONE-TYPE = PLENUM and listed under the SYSTEM command in the PLENUM-NAMES keyword.

Because of these improvements in the calculation of the distribution of heat from lights, it is now necessary that the user be more specific in the definition of ZONE-TYPEs in the SPACE-CONDITIONS command. The user must also be sure that the ZONE-TYPEs in the SYSTEMS ZONE command are in perfect agreement with those specified in LOADS.

There are two major reasons for this. First, the program now sorts the spaces by ZONE-TYPE to assure that the heat of lights is first calculated for CONDITIONED spaces prior to calculating PLENUMs and UNCONDITIONED spaces and any light heat going into the latter types of spaces.

The second reason is to insure that the spaces specified in the SYSTEMS input as UNCONDITIONED are not included in the building coincident peak loads calculation. An inconsistancy between LDL and SDL can result in a calculated SUPPLY-CFM greater than the sum of the zone CFMs.

Associated with this new treatment of heat from lights are changes in certain hourly report variables. In LOADS, for VARIABLE-TYPE = u-name of SPACE, VARIABLE-LIST numbers 15 and 34 now have the following meanings:

15	QPLENUM	Light heat gain to return air
34	ZLTOTH	Light heat gain to other space

In SYSTEMS, for VARIABLE-TYPE = u-name of ZONE, the new meaning of VARIABLE-LIST number 4, <QP>, is "Light heat to return air — from LOADS (Btu/hr)".

For VARIABLE-TYPE = u-name of SYSTEM, the description of VARIABLE-LIST number 16, QPSUM, has been changed to "Total system light heat to return (Btu/hr)".

See Appendix A at the end of this Supplement for an updated list of all of the program hourly variables.

SHERMAN-GRIMSRUD INFILTRATION METHOD

An additional method of computing residential air infiltration has been added to the program using a model developed by Sherman and Grimsrud[1]. It is applicable only to RESYS. This method is accessed by specifying the new code-word, S-G, in the keyword INF-METHOD in the SPACE-CONDITIONS command.

Also under the SPACE-CONDITIONS command, there are three new keywords:

HOR-LEAK-FRAC	To compute the stack effect term in the S-G infiltration method, the leakage area and the leakage distribution are needed. HOR-LEAK-FRAC is the fraction of the leakage that is in the floor and ceiling. A value of 0.3 is appropriate if there are few ceiling penetrations. Otherwise, the default of 0.4 may be used.
NEUTRAL-LEVEL	is the dimensionless height of the neutral level for the S-G infiltration method. That is, it is the fraction of the height of the space at which the indoor-outdoor pressure is zero. In general, this keyword can be allowed to default (to 0.5).
FRAC-LEAK-AREA	is the total leakage area expressed as a fraction of the floor area used in the S-G infiltration method. This number can be obtained from a pressurization measurement. Otherwise, values may be selected from the following table. The default is 0.0005.

Type of construction	FRAC-LEAK-AREA
Tight	0.0003
Average	0.0005
Loose	0.001

---

[1] The Sherman-Grimsrud infiltration model[2] was developed at Lawrence Berkeley Laboratory for inclusion in CIRA[3]. It is applicable only to single-zone simulations of residences.

[2] M.H. Sherman and D.T. Grimsrud, "Measurement of Infiltration Using Fan Pressurization and Weather Data," October 1980, LBL-10852.

[3] CIRA 1.0 Reference Manual, March 1982, LBL PUB 442, tables reprinted with permission.

Under the BUILDING-LOCATION command, there are the following new keywords:

SHIELDING-COEF	is the shielding coefficient in the Sherman-Grimsrud infiltration method. This coefficient modifies the wind speed term in the model to account for changes in the wind pressure caused by local obstructions. A value should be selected from the following table.

SHIELDING-COEF	Description
0.32	No obstructions or local shielding whatsoever, e.g., desert.
0.29	Light local shielding with few obstructions, perhaps a few trees or a small shed.
0.24	Moderate local shielding, some obstructions within two house heights, a thick hedge or a solid fence, or one neighboring house.
0.19	Heavy shielding, obstructions around most of perimeter, buildings or trees within 30 feet in most directions, typical suburban shielding.
0.10	Very heavy shielding, large obstructions surrounding perimeter within two house heights, typical downtown shielding.

TERRAIN-PAR1	is a constant used to modify the free stream wind speed to account for ground roughness and height above ground level at the building site. A value should be selected from the following table.
TERRAIN-PAR2	is a constant used to modify the free stream wind speed to account for ground roughness and height above ground level at the building site. A value should be selected from the following table.

TERRAIN-PAR1 WS-TERRAIN-PAR1	TERRAIN-PAR2 WS-TERRAIN-PAR2	Description
1.30	0.10	Ocean or other body of water with at least 5 km of unrestricted expanse.
1.00	0.15	Flat terrain with some isolated obstacles, e.g., buildings or trees well separated from each other.
0.85	0.20	Rural area with low buildings, trees, etc.
0.67	0.25	Urban, industrial, or forest area.
0.47	0.35	Center of big city, e.g., Manhattan

WS-TERRAIN-PAR1	is a constant corresponding to TERRAIN-PAR1, but for the location of the wind speed measurement; i.e., the weather station. Obtain a value from the table above.
WS-TERRAIN-PAR2	is a constant corresponding to TERRAIN-PAR2, but for the location of the wind speed measurement; i.e., the weather station. Obtain a value from the table above.
WS-HEIGHT	is the height (in feet) above ground level at which the wind speed measurement was made. For most weather stations, this information can be obtained from Local Climatological Data — Annual Summaries for 1981, published by NOAA.

Associated with the new infiltration method are three new variables appearing in the LV-C report. Under INFILTRATION, (if INF-METHOD=S-G) these are:

```
FRAC.OF          S-G      HOR-LEAK
LEAKAGE      NEUTRAL         AREA/
   AREA        LEVEL    FLOOR AREA
```

A new keyword has been introduced into the GLASS-TYPE command:

INSIDE-EMISS	is the inside surface infra-red emissivity for single glazing. This keyword should only be specified if PANES = 1 and the glass has a special coating on the inside surface which lowers the surface emissivity from that of ordinary glass (0.84). The effect of such a coating, which is used, for example, in "heat mirrors", is to increase the inside air film resistance by decreasing long-wave radiation from the glass. (INSIDE-EMISS should not be used with GLASS-TYPE-CODE 9, 10, or 11, since the transmission and absorption coefficients in this case were calculated for a reflective coating with an emissivity of 0.84).
GLASS-CONDUCTANCE	If GLASS-CONDUCTANCE is not specified, a default value is assigned that depends on the number of panes and GLASS-TYPE-CODE. These default values are given in Table 1, which is a revision of Table III.1 in the *Reference Manual*. In DOE-2.1B and 2.1C, the default GLASS-CONDUCTANCE for single glazing only (PANES = 1) varies hourly depending on the inside-outside air temperature difference and the inside surface emissivity of the glass (see INSIDE-EMISS keyword). This temperature-and-emissivity-dependence will be ignored if the user specifies a value for GLASS-CONDUCTANCE for single glazing.

SHADING-COEF versus GLASS-TYPE-CODE

The choice between using SHADING-COEF and GLASS-TYPE-CODE depends on whether the glass is shaded by blinds, drapes, louvers, etc., or is unshaded (shading here does not refer to that from fins, overhangs, etc.).

If the glass is *unshaded*, use GLASS-TYPE-CODE. This approach guarantees that the program will use the proper dependence of the transmission and absorption coefficients on the angle of incidence of solar radiation. (See Example 1, below.)

If the glass is *shaded*, then the SHADING-COEF should be specified. The value to use can be obtained from manufacturer's data. (See Examples 3 and 4, below.) The user should be aware that this approach uses the angular dependence of the transmission and absorption coefficients for a single pane of 1/8-inch thick clear glass; it does *not* account for the angular dependence of the shading device, or of the additional panes of glass if PANES = 2 or 3 is specified.

Sometimes, parametric runs are made changing from no shade to varying degrees of shading on the glass. In this case, for consistency, SHADING-COEF should be used for each step, even the unshaded case. (Manufacturers also give shading coefficients for unshaded glass.)

Table 1

TRANSMITTANCE, REFLECTANCE, DEFAULT CONDUCTANCE, AND U-VALUES FOR DIFFERENT GLASS-TYPE-CODE VALUES AND NUMBER OF PANES

	GLASS-TYPE-CODE	Transmittance$^{(1)}$ (percent)	Reflectance$^{(2)}$ (percent)	Default Conductance (excludes outside air film) (Btu/hr-ft^2-$^\circ$F)	U-Value corresponding to the Default Cond. (includes outside air film at 7.5 mph windspeed) (Btu/hr-ft^2-$^\circ$F)
SINGLE PANE					
uncoated	1	88	7	1.42	
	2	83	7	(3)	1.00
	3	79	7	1.24	0.90
	4	75	7		
	5	61	6		
	6	50	6		
	7	41	6		
	8	34	5		
with reflective coating(5)	9	50	30	1.42	
	10	20	45	(4)	1.00
	11	10	50	1.24	0.90
DOUBLE-PANE					
uncoated	1	75	16		
	2	71	16		
	3	68	14		
	4	64	14		
	5	53	11	0.574	0.49
	6	43	9		
	7	35	8		
	8	29	7		
with reflective coating(5)	9	45	31		
	10	19	45	0.311	0.285
	11	9	51		
TRIPLE-PANE					
uncoated	1	68	18		
	2	64	16		
	3	61	15		
	4	58	14		
	5	47	10	0.305	0.279
	6	39	7		
	7	32	6		
	8	26	5		
with reflective coating(5)	9	40	33		
	10	17	45	0.232	0.217
	11	8	51		

(1) Transmittance at normal incidence for overall solar spectrum (not just visible portion).

(2) Reflectance at normal incidence for overall solar spectrum.

(3) Varies with emissivity (ϵ) of inside glass surface and with inside-outside temperature difference. First value given here is for ϵ = 0.84 and winter temperature condition of 32^{o}F outside air temperature, 70^{o}F room temperature; second value is for ϵ = 0.84 and summer temperature condition of 90^{o}F outside air temperature, 75^{o}F room temperature.

(4) Varies with with inside-outside temperature difference. First value given here is for winter temperature condition of 32^{o}F outside air temperature, 70^{o}F room temperature; second value is for summer temperature condition of 90^{o}F outside air temperature, 75^{o}F room temperature.

(5) Coating is on inside of outer pane; all panes are clear glass.

Examples

DOUBLE THERMOPANE INSULATING GLASS

DOUBLE THERMOPANE INSULATING GLASS

GLASS	THICKNESS		TRANSMITTANCE		U-VALUE		SHADING-COEFFICIENTS			
			Average Daylight	Total Solar	Summer (7.5 mph windspeed)	Winter (15 mph windspeed)	No shade	Draperies		
	in	mm	%	%				Light	Med	Dark
BRONZE	1/4	6	44	36	.57	.49	.54	.37	.42	.43

Shown above is an excerpt from a glass manufacturer's product data sheet. It gives data for double-pane insulating glass with a heat-absorbing outer pane. Following are some examples of DOE-2 input for this glass.

1. Using GLASS-TYPE-CODE, no shading device

```
INSUL-GLASS-1 = GLASS-TYPE       PANES=2
                                 GLASS-TYPE-CODE=7
                                 GLASS-CONDUCTANCE=0.54       ..
```

GLASS-TYPE-CODE = 7 was chosen since this gives, from Table 1, a total solar transmittance of 35%, which is close to the 36% transmittance of the glass in question. The GLASS-CONDUCTANCE value of 0.54 was determined using

$$\text{GLASS-CONDUCTANCE} = \left[\frac{1}{U} - R_{film}\right]^{-1}, \text{ with}$$

U = 0.49, the manufacturer's winter U-value for 15 mph windspeed, and R_{film} = [-0.001661 * v^2 + 0.302 * v + 1.45]$^{-1}$ = .20 hr-ft^{2}-^{o}F/Btu, with v = 15 mph / 1.15 = 13.04 knots.

2. Using SHADING-COEF, no shading device

```
INSUL-GLASS-2 = GLASS-TYPE        PANES=2
                                  SHADING-COEF=0.54
                                  GLASS-CONDUCTANCE=0.54        ..
```

The shading coefficient in this case is just the "No shade" value from the data sheet. GLASS-CONDUCTANCE is calculated as in Example 1.

3. Using SHADING-COEF, with light-colored drapes always in place

```
INSUL-GLASS-3 = GLASS-TYPE        PANES=2
                                  SHADING-COEF=0.37
                                  GLASS-CONDUCTANCE=0.54        ..
```

The shading coefficient here is for the window-plus-drape combination and is taken from the "Draperies-Light" entry on the data sheet. GLASS-CONDUCTANCE is calculated as in Example 1 assuming that the drapes have a negligible effect on the conductance.

4. Using SHADING-COEF, with light-colored drapes which are in place only in the afternoon

```
SHADE-SCH-4 = SCHEDULE  THRU DEC 31 (ALL) (1,12) (1.0)
                                          (13,24) (.69)         ..
                                  .
                                  .
                                  .
INSUL-GLASS-4 = GLASS-TYPE        PANES=2
                                  SHADING-COEF=0.54
                                  GLASS-CONDUCTANCE=0.54        ..
                                  .
                                  .
                                  .
WIN-4   = WINDOW     GLASS-TYPE=INSUL-GLASS-4
                     SHADING-SCHEDULE=SHADE-SCH-4
                              .
                              .
                              .
                                                                ..
```

The SHADING-COEF here is the "No shade" value from the data sheet, as in Example 2. The shading schedule gives a window-plus-drapes shading coefficient of 1.0 * 0.54 = 0.54 before 12 noon, and 0.69 * 0.54 = 0.37 after 12 noon.

FLOOR MULTIPLIERS AND INTERIOR WALL TYPES

With the addition of Custom Weighting Factors and Daylighting, the requirement to input all of the interior surfaces of a space becomes mandatory. Thus a long-standing problem with space multipliers (see DOE-2.1A Reference Manual, Section III.B.14 for discussion) has been addressed by the addition of new keywords as discussed below.

MULTIPLIER	may be used to specify the total number of identical spaces. Use of this keyword reduces the amount of required data entry, but does not actually create other spaces. The program will calculate the loads for the space defined and multiply these loads by MULTIPLIER. If a STANDARD or AIR type INTERIOR-WALL (see discussion immediately following) is defined within the space, the heat transfer to the NEXT-TO space is multiplied by MULTIPLIER. In effect, the area of the INTERIOR-WALL, as seen from the NEXT-TO space, is larger than that entered by a factor of MULTIPLIER. The user must enter a wall AREA for INTERIOR-WALLs corresponding to that in the space being multiplied. Because it creates an ambiguity with regard to the area of the interior wall between them, it is always an ERROR for MULTIPLIER to be different from 1.0 in both of two adjacent spaces connected by STANDARD or AIR type INTERIOR-WALLs.
FLOOR-MULTIPLIER	may also be used, like MULTIPLIER, to multiply the loads from one of a number of essentially identical spaces. Unlike MULTIPLIER, there is no multiplication of heat transfer through INTERIOR-WALLs. The major function of FLOOR-MULTIPLIER (abbreviated as F-M) is to simplify the input for a multi-storied building where a number of the floors are thermodynamically identical and where there is negligible heat transfer from floor-to-floor. The default is 1.0 and the range is from 1.0 to 200.0.

The MULTIPLIER or FLOOR-MULTIPLIER keywords in the SPACE command should be used only when the several spaces being modeled in this fashion are equivalent with respect to thermodynamics and/or daylighting. Exterior shading, for example, must be the same for each of the spaces included. When there are adjacent spaces that are presumably identical, there should not be heat transfer between the spaces and it might be supposed that the wall could be ignored. When precalculated weighting factors are used and daylighting is not important, this solution is satisfactory. However, if Custom Weighting Factors are to be calculated or daylighting is being invoked, the wall must be described. The common wall must be described as INT-WALL-TYPE = ADIABATIC.

In the INTERIOR-WALL command, the MULTIPLIER keyword has been removed and a new keyword added:

INT-WALL-TYPE	indicates the type of interior wall. It can take the following code-word values:
STANDARD	designates a physical interior wall that separates two spaces and is capable of transmitting heat between the spaces. STANDARD is the default. Such a wall typically has non-zero values for both INSIDE-VIS-REFL and SOLAR-FRACTION. It may be defined with LAYERS-type CONSTRUCTION or with U-VALUE-type CONSTRUCTION. In either case its overall U-value must be less than UCRIT = 0.709 Btu/ft^{2}-^{o}F, since that is the value for a wall of R-value .05 ft^{2}-^{o}F/Btu with an inside film resistance on both sides. If the user inputs a U-value for a STANDARD wall that is greater than UCRIT, the INT-WALL-TYPE is changed to AIR. The NEXT-TO keyword is required for this wall type. If the NEXT-TO space is the same as the space under which the interior wall is defined, the value of INT-WALL-TYPE will be changed to ADIABATIC. A STANDARD wall will contribute to the overall conductance of the zone.
AIR	specifies an artifice intended to approximate the convective coupling between two spaces that are separated by an imaginary wall. It must be defined with a U-VALUE-type CONSTRUCTION. If the U-value is less than UCRIT, a CAUTION message is printed stating that the U-value is low for air. The NEXT-TO keyword is required for AIR type walls. If the NEXT-TO space is the same as the space under which the interior wall is defined, the value of INT-WALL-TYPE will be changed to ADIABATIC. An AIR wall contributes to the overall conductance of a zone, but not to the Custom Weighting Factors. The U-value should not exceed a U=2.7, as discussed under CONSTRUCTION.

If the AIR wall is part of a daylit space, its INSIDE-VIS-REFL values need to be specified (even though it is not a physical wall) since daylight can be reflected back across the AIR wall from the adjacent space. If an AIR wall of area A (defined in space 1) separates spaces 1 and 2 with inside surface area, S_i (excluding the AIR wall) and average reflectance, ρ_i (excluding the AIR wall), then

$$\text{INSIDE-VIS-REFL} = (R_2, R_1),$$

where R_i is the cavity reflectance of space i, given by

$$R_i = \frac{A \rho_i}{S_i - (S_i - A) \rho_i} .$$

For example, if A=200 ft^2, S_1=1500 ft^2, S_2=2000 ft^2, and $\rho_1 = \rho_2 = 0.5$,

$$R_1 = 0.12$$
$$R_2 = 0.09$$

This gives

INSIDE-VIS-REFL = (.09,.12)

If the AIR wall were defined in space 2,

INSIDE-VIS-REFL = (.12,.09)

ADIABATIC

ADIABATIC interior walls have been introduced to allow the user to model daylighting and/or to calculate Custom Weighting Factors for similar spaces using the MULTIPLIER keyword in the SPACE command. Such walls may have reflective and absorptive properties, as well as the ability to store heat. They will not, however, allow heat to be transferred between spaces (and thus the name). The NEXT-TO keyword is not used for this type wall. Since such walls will not contribute to Custom Weighting Factors unless they are massive, a WARNING message will be issued if a U-VALUE-type CONSTRUCTION is used.

Generally, ADIABATIC interior walls should be used to separate two spaces that are considered to be identical and are defined via the MULTIPLIER or FLOOR-MULTIPLIER keywords in a SPACE command (see discussion below). Examples are (1) identical spaces that are side-by-side on one floor of a building and (2) identical spaces that are above one another in a high rise building. The wall or ceiling/floor that separates these spaces should be designated as ADIABATIC. In this way, the representative space will have appropriate boundaries even though there is no named space to be NEXT-TO. Another type of use arises when one is modeling only part of a building, e.g., an office building abutting two adjacent buildings. The wall that separates that portion of the building that is being modeled from the rest of the structure should be ADIABATIC. The assumption here is that there is no appreciable heat flow through these boundaries. ADIABATIC walls will not contribute to the conductance of the space.

INTERNAL — The last type of interior wall has been introduced to permit the treatment of another kind of thermal mass interior to a space. Like furniture, the INTERNAL wall will contribute only to the calculation of Custom Weighting Factors and therefore must be of LAYERS-type CONSTRUCTION. This type of wall is ignored by the daylighting calculation, and therefore daylighting-related keywords do not apply. On the other hand, SOLAR-FRACTION is applicable. The NEXT-TO keyword is not used with this type of interior wall. One possible use for walls of this type is to model water walls.

Example

Assume one wants to simulate a multistory office building with an elevation as in Fig. 1 and a typical floor plan as in Fig. 2.

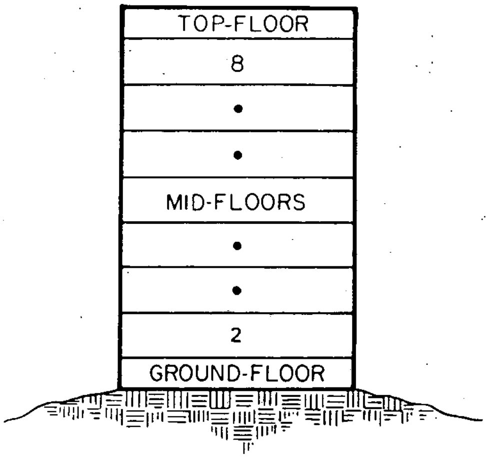


Fig. 1

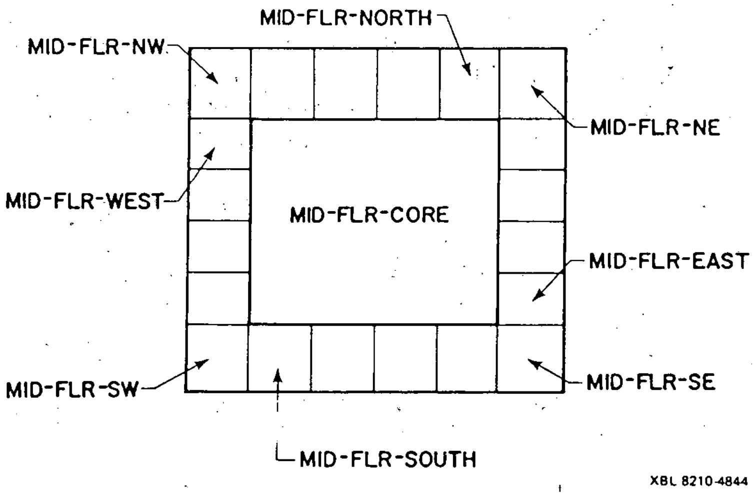


Fig. 2

The floors named TOP-FLOOR and GROUND-FLOOR are both unique. Floors 2 through 8, typified by the floor labeled MID-FLOORS, are identical enough to permit the use of the FLOOR-MULTIPLIER keyword. Similarly, the non-corner spaces on each exposure are sufficiently alike to permit the use of the MULTIPLIER keyword. Using MULTIPLIER rather than FLOOR-MULTIPLIER for these spaces will permit the treatment of heat transfer between the peripheral spaces and the core space. Omitting keywords and commands not pertinent to this discussion and illustrating only the East exposure, the input for the building in Figs. 1 and 2 is:

```
TOP-FLOOR = SPACE
              .
              .
              .                                                         ..

    FLOOR = INTERIOR-WALL INT-WALL-TYPE = ADIABATIC                     ..

MID-FLR-CORE = SPACE
                      FLOOR-MULTIPLIER = 7   $-- FLOORS 2 THRU 8 --$
                                .
                                .
                                .                                       ..

   CORE-FLOR = INTERIOR-WALL  INT-WALL-TYPE = ADIABATIC                 ..
   CORE-CEIL = INTERIOR-WALL  INT-WALL-TYPE = ADIABATIC                 ..

MID-FLR-EAST = SPACE
                      FLOOR-MULTIPLIER = 7  MULTIPLIER = 4
                                .
                                .
                                .                                       ..

  EAST-FLOR = INTERIOR-WALL  INT-WALL-TYPE = ADIABATIC                  ..
  EAST-CEIL = INTERIOR-WALL  INT-WALL-TYPE = ADIABATIC                  ..
  EAST-CORE = INTERIOR-WALL  INT-WALL-TYPE = STANDARD
                             NEXT-TO MID-FLR-CORE                       ..
                .
                .    $-- OTHER MID-FLOOR SPACES --$
                .
GROUND-FLOOR = SPACE
                .
                .
                .                                                       ..

  CLNG = INTERIOR-WALL  INT-WALL-TYPE = ADIABATIC                       ..
                .
                .
                .                                                       ..
```

Of the walls entered above only those between the peripheral spaces and the core space will permit the transfer of heat between the spaces. On the other hand, thermal mass and daylighting effects will be accounted for correctly.

In the UNDERGROUND-WALL (or UNDERGROUND-FLOOR) command, the keyword MULTIPLIER is now used to specify the total number of identical underground wall or floor panels. Its effect is to multiply the AREA by MULTIPLIER.

In SYSTEMS, MULTIPLIER, in the ZONE command, now refers to the number of identical zones in the building served by the same system and in thermal contact with an adjoining zone, e.g., a plenum or core zone. This keyword is analogous to the MULTIPLIER keyword in the SPACE command in LOADS and will default to the value of that keyword, if not entered in the ZONE command.

Added to SYSTEMS, under the ZONE command, FLOOR-MULTIPLIER is analogous to the FLOOR-MULTIPLIER in the SPACE command in LOADS and will default to the value given that keyword in the space with the same u-name as the current zone.

Associated with the new interior wall types are two new ERROR messages in the Custom Weighting Factors Generation Program.

Error Message (4)	CUSTOM WEIGHTING FACTOR CALCULATION FAILED FOR SPACE <U-name>. USE ASHRAE WEIGHTING FACTORS FOR THIS SPACE.
Meaning:	The weighting factor calculation does not converge.
User Action:	Check for odd constructions such as upside-down floors with carpets on underside (as a result of incorrectly entering material layers), or too massive or lightweight walls. If nothing out of the ordinary can be found, the user is advised to abandon the Custom Weighting Factor approach and to use pre-calculated weighting factors (either custom weighting factors calculated earlier and stored in a library or ASHRAE weighting factors using the FLOOR-WEIGHT keyword with a non-zero value).
Error Message (5)	INTERNAL TYPE INTERIOR WALLS MUST HAVE DELAYED CONSTRUCTION.
Meaning:	U-VALUE-type CONSTRUCTION has been used to describe an INTERNAL type INTERIOR-WALL. Since the only purpose for INTERNAL type walls is to provide another thermal mass in the space, the user must use a massive (LAYERS) type CONSTRUCTION for this type of wall.
User Action:	Use a LAYERS-type CONSTRUCTION for INTERNAL-type INTERIOR-WALLS.

NEW LOADS REPORTS

Two new VERIFICATION reports, LV-L — DAYLIGHT FACTOR SUMMARY, and LV-M — DOE-2 UNITS TABLE, have been added in conjunction with the daylighting and metric options. For descriptions of these reports, please refer to the Daylighting and Metric Option sections, respectively, in this Supplement.

REPORT LS-K — SPACE INPUT FUELS SUMMARY

This report gives monthly summaries of the fuel inputs required by each space for lighting, equipment, and processes. Following the reports for each space is a separate building level report that gives the sum of the input fuels for the building as a whole.

Lighting, equipment, and process are the three major sections of this report, which is printed once for each space and once for the building as a whole.

1. TASK LIGHTING	(kilowatt hours) is the electricity used by the space for all task lighting.
2. TOTAL LIGHTING	(kilowatt hours) is the electricity used by the space for all lighting including task and overhead.
3. GENERAL EQUIPMENT	(kilowatt hours) is the electricity used by the space for running all equipment (i.e., computers, typewriters, etc.). For the building report, this includes building equipment such as elevators which may not be included in any space.
4. PROCESS ELECTRIC	(kilowatt hours) is all electricity used to maintain any of the processes in the space.
5. PROCESS GAS	(millions of Btu) is all gas used to maintain any of the processes in the space.
6. PROCESS HOT WATER	(millions of Btu) is the total hot water used in all processes in the space.

```
SIMPLE STRUCTURE RUN 3, CHICAGO                                                            DOE-2.1C  11-JAN-85    09:13:5    LDL RUN 3
REPORT- LS-K  SPACE INPUT FUELS SUMMARY                           SPACE4-1                          WEATHER FILE- TRY  CHICAGO
----------------------------------------------------------------------------------------------------------------------------------

SPACE  SPACE4-1

          - - - - L I G H T I N G - - - -  E Q U I P M E N T - - - - - - - - - - P R O C E S S - - - - - - - - - -

          TASK LIGHTING    TOTAL LIGHTING   GENERAL EQUIPMENT  PROCESS ELECTRIC   PROCESS GAS     PROCESS HOT WATER
              (KWH)            (KWH)              (KWH)              (KWH)            (MBTU)              (MBTU)
MONTH

JAN               0.00           347.19              83.60               0.00           0.0000              0.0000

FEB               0.00           301.86              72.46               0.00           0.0000              0.0000

MAR               0.00           333.72              80.10               0.00           0.0000              0.0000

APR               0.00           345.55              83.38               0.00           0.0000              0.0000

MAY               0.00           347.19              83.60               0.00           0.0000              0.0000

JUN               0.00           318.61              76.39               0.00           0.0000              0.0000

JUL               0.00           347.19              83.60               0.00           0.0000              0.0000

AUG               0.00           347.19              83.60               0.00           0.0000              0.0000

SEP               0.00           318.61              76.39               0.00           0.0000              0.0000

OCT               0.00           347.19              83.60               0.00           0.0000              0.0000

NOV               0.00           305.14              72.90               0.00           0.0000              0.0000

DEC               0.00           333.72              80.10               0.00           0.0000              0.0000

            ----------        ---------         ----------         ----------       -----------         -----------

ANNUAL            0.00          3993.19             959.71               0.00           0.0000              0.0000
```

REPORT LS-L — MANAGEMENT AND SOLAR SUMMARY FOR THE SPACE

The following report gives monthly summaries of window shade management and solar radiation into the space.

1. The first column is the count of the number of hours that window shade management would be employed in the space for each month. Management is employed under any of the following conditions:

    a) The shading schedule specifies management.

    b) If the transmitted direct solar gain into the space exceeds a pre-specified value MAX-SOLAR-SCH, then, with probability SUN-CTRL-PROB, shades will be in effect.

    c) If daylighting is requested (DAYLIGHTING=YES) and the daylight glare exceeds a pre-specified value MAX-GLARE, then the shades will be in effect.

2. The second column is the average solar radiation into the space through all glazing areas in Btu per day.

3. Column 3 is the maximum solar radiation into the space through all glazing areas for all hours in the month. The unit of measure is Btu per hour.

```
SIMPLE STRUCTURE RUN 3, CHICAGO                                                  DOE-2.1C  11-JAN-85    09:13:5    LDL RUN 3
REPORT- LS-L  MANAGEMENT AND SOLAR SUMMARY FOR SPACE       SPACE4-1                         WEATHER FILE- TRY  CHICAGO
-----------------------------------------------------------------------------------------------------------------------------

DATA FOR SPACE    SPACE4-1

       NUMBER OF HOURS   AVERAGE DAILY     MAXIMUM HOURLY
         MANAGEMENT     SOLAR RADIATION   SOLAR RADIATION
         WOULD BE         INTO SPACE        INTO SPACE
MONTH     EMPLOYED        (BTU/DAY )         (BTU/HR  )


JAN            0.          12564.316          2026.295

FEB            0.          19922.465          3612.860

MAR            0.          29432.954          4546.181

APR            0.          45208.376          6873.628

MAY            0.          55990.650          8090.777

JUN            0.          66950.191          8469.924

JUL            0.          67201.302          8611.484

AUG            0.          54183.237          7494.979

SEP            0.          40387.324          5880.732

OCT            0.          22700.075          4091.992

NOV            0.          13817.344          2400.009

DEC            0.          10647.411          1841.115

          --------    ------------      --------------

ANNUAL         0.          36665.858          8611.484
```

SYSTEMS

POWERED INDUCTION UNIT (PIU)

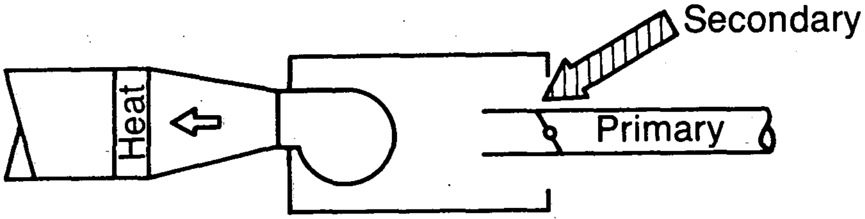
Overview

The PIU system is basically just a VAV terminal box with a small fan that pulls some amount of air from a ceiling plenum. PIU's have two functions:

1) moving warm air from a core area through the plenum to exterior zones which require heat, thus conserving heating energy;

2) providing increased air movement in zones normally served by VAV terminals; such zones often suffer from stagnant air when the primary air damper is in its minimum position.

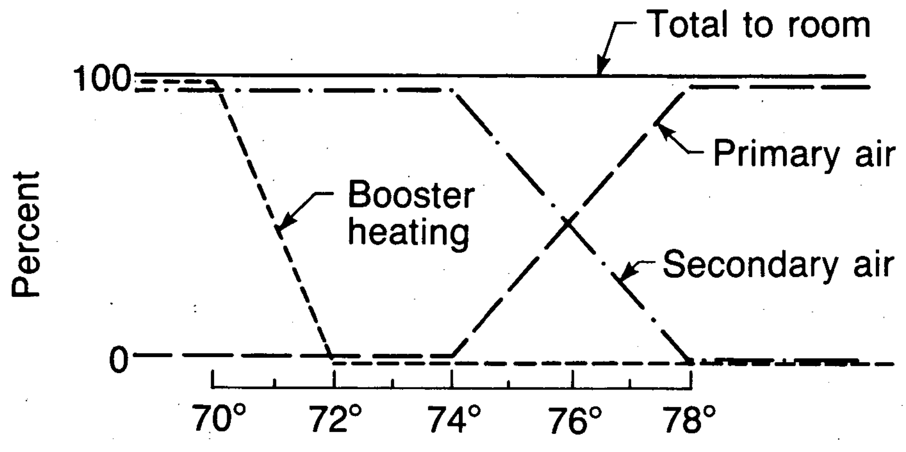
Two types of PIU are modeled — series and parallel. These are sometimes also called constant, and intermittent fan powered units. In the series unit (schematically shown above), the fan draws air from both the secondary and primary air streams. The proportion of secondary to primary air is controlled by the primary air dampers. The amount of secondary plus primary air is constant, and the blower runs all the time (when the central fans are on) at constant speed. The booster (reheat) coil can be located in the secondary air inlet to save energy when cooling is near a maximum. The fan can run when the central system is off for ventilation or heating. Generally, the blower is sized by the zone recirculation air requirements (AIR-CHANGES/HR, CFM/SQFT). It must be sized equal to or greater than the primary air cfm.



XBL 843-10166

Series PIU

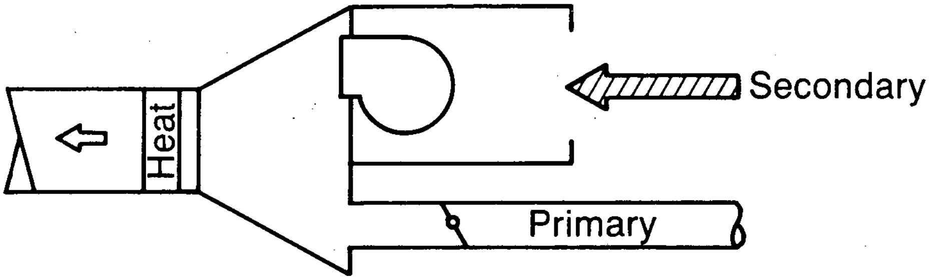
The series unit is controlled much like a normal VAV unit. At maximum cooling, the primary air damper is open and only a small amount ($\leq 5\%$) of secondary air is induced. As the space temperature falls, the primary air damper gradually closes. Unlike VAV units, the PIU can throttle primary air down to essentially zero. Once the primary air damper is closed, booster heating (reheat in VAV) can be supplied to meet any heating demand not met by the secondary air from the warm ceiling plenum. The fan can be used at night to limit the lowest building temperature. The fan will normally be off when the central fans are off, but when the zone temperature falls below the night set point, the fan turns on and the booster coil is activated.



Series PIU

XBL 843-10169

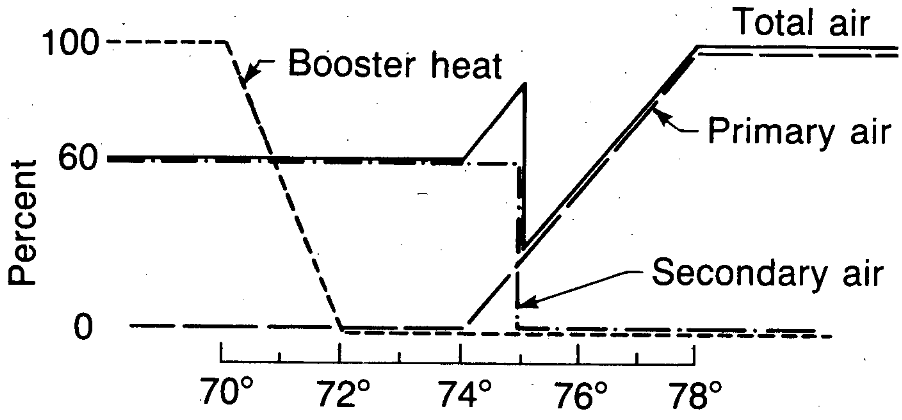
The parallel fan unit is slightly more complicated. As is shown in the schematic, the parallel unit draws air from the secondary air stream only. In addition, the operation of the parallel blower is intermittent. A thermostat set point regulates turning the fan on and off. When cooling is required, the fan is generally off. Thus we have normal variable volume - constant temperature cooling with the primary air. When the primary air damper is closed and the fan is on, we have constant volume ventilating/heating. Thus total air to the zone is not a constant, as in the series cases.



XBL 843-10164

Parallel PIU

For parallel PIU´s, the blower may be any size. It is commonly <u>less</u> than the primary cold air cfm.



Parallel PIU

XBL 843-10170

At maximum cooling, the blower is off and the primary air damper is open. As the space temperature drops, the damper closes. At a temperature selected by the designer, the blower turns on, and secondary air is mixed with the primary air. As the temperature continues to fall, the primary air damper closes to its minimum position, and the booster heater eventually turns on. The heating coil can (and probably should) be located in the secondary air stream.

The blowers operate at a very low static pressure — 0.2 or 0.3 inches are common. A 1400 cfm blower against 0.2-inch static pressure will use about 400 watts.

Input for PIU

The PIU system is selected by using the new code-word PIU in the SYSTEM command:

SYSTEM-TYPE = PIU

There are three new ZONE keywords.

ZONE

TERMINAL-TYPE This keyword specifies the type of terminal serving the zone. The same type of terminal box does not have to be used for the entire system. Typically, a PIU system will contain a mixture of fan powered terminal boxes and regular VAV or constant volume reheat units. Abbreviated as TER-TYPE, the available code-words are:

SVAV	(the default) stands for Standard Variable Air Volume; .i.e., regular VAV or constant volume.
SERIES-PIU	means that the fan draws air from both the secondary and primary air streams, and that the blower runs all the time.
PARALLEL-PIU	means that the fan draws air from the secondary air stream only, and that the blower runs intermittently.

INDUCED-AIR-ZONE	This keyword takes as a value the u-name of another zone. It is assumed that the PIU zone is taking its secondary air from the return air of the zone named as the INDUCED-AIR-ZONE. Normally, the core zone, served by a non-PIU terminal, will be designated the INDUCED-AIR-ZONE. Zones with PIU boxes will normally be exterior zones that need the heat reclaimed from the core zone. An exception would be a zone (such as a classroom) in which the primary concern is air movement, not energy conservation. In such a case, the corridors can be specified as the INDUCED-AIR-ZONE even though there is no heat to reclaim from them. The program treats this situation in the same way as it does when a core plenum is at a temperature lower than the exterior zone. For zones in which TERMINAL-TYPE = SERIES-PIU or PARALLEL-PIU, this keyword is required. The abbreviation is I-A-Z.
REHEAT-DELTA-T	should be specified, at the ZONE level, if reheat or booster heat is desired. This keyword used to be on the SYSTEM level only. Now, for the PIU system only, it is a keyword in both the SYSTEM and ZONE commands, and the ZONE level use takes precedence over the SYSTEM level. Its meaning remains the same as before.

MIN-CFM-RATIO should be specified in ZONE, just as it is for VAV systems. The usual input for PIU terminals should be to specify a ratio that just satisfies the minimum ventilation air requirements of the zone.

There is a new zone-level command which is a subcommand of the ZONE command, ZONE-FANS, which may be abbreviated as Z-F.

ZONE-FANS

ZONE-FAN-CFM	If TERMINAL-TYPE = SERIES-PIU or PARALLEL-PIU, the user can size the fan with this keyword. If ZONE-FAN-CFM is not specified, the program will size the fan. For series PIU fans, this is a straightforward process. The blower is sized to the zone cfm; i.e., the maximum of the cfm input via ASSIGNED-CFM, AIR-CHANGES/HR, or CFM/SQFT; or the cfm derived from

	the heating and cooling peaks from LOADS. For parallel PIU's, if ZONE-FAN-CFM is not input, the blower is sized from the heating peak. The ZONE level cfm keywords are assumed to refer to the primary air from the central system. It is recommended that the user explicitly size the fans, since the use of the heating peak to size the parallel PIU might result in a ridiculously small fan. The abbreviation is Z-F-CFM, and the range is from 0.0 to 99999999.0 ft^3/min.
ZONE-FAN-RATIO	For TERMINAL-TYPE = SERIES-PIU or PARALLEL-PIU, the user may enter a value which sets the ZONE-FAN-CFM as a ratio of the primary air. If both ZONE-FAN-CFM and ZONE-FAN-RATIO are specified, ZONE-FAN-CFM takes precedence.
ZONE-FAN-KW	For TERMINAL-TYPE = SERIES-PIU or PARALLEL-PIU, this keyword specifies the power consumption of the fan. The default is .00033 kW/cfm. The abbreviation is Z-F-KW, and the range is from 0.0 to 0.01.
ZONE-FAN-T-SCH	is the u-name of a schedule which gives, for zones with parallel PIU's, the space temperature at which the terminal blower turns on. This temperature must be above the heating range. This keyword is required for zones with TERMINAL-TYPE = PARALLEL-PIU. The abbreviation is Z-F-SCH.

In addition, there is a new code-word for NIGHT-CYCLE-CTRL in the SYSTEM-FANS command.

SYSTEM-FANS

NIGHT-CYCLE-CTRL

ZONE-FANS-ONLY	If input, the main or central system fan will remain off. However, the individual zone terminal fans will cycle on separately to satisfy the heating setback temperature for each zone.

HEAT RECOVERY FROM REFRIGERATED CASE WORK

A new set of keywords has been added to the PSZ (Packaged Single Zone) system to allow simulation of refrigerated case work, such as those found in supermarkets, with or without heat recovery. The routines can also be used to simulate ice rinks with or without heat recovery. The user can specify refrigerated case work up to three different temperature levels and specify a corresponding load for each level. The temperature levels reflect the evaporator temperatures of different types of display cases for various products such as frozen foods, meats, dairy products, and produce. However, these routines are only applicable to the situation of one main zone, served by a single PSZ unit, and all case work contained within that zone. This does not preclude splitting a supermarket into two or more zones, each with separate PSZ units. Subzones are allowed, such as office mezzanines, but the refrigerated cases, space temperature control, and heat recovery only apply to the <u>first</u>-named main zone in the ZONE-NAMES list. Therefore, subzone reheat can not be simulated as recovered heat.

<u>ZONE</u>

The ZONE keyword additions are as follows:

REFG-ZONE-LOAD	is the total cooling effect (sensible + latent) to the zone due to air spilling from the open cases and by heat radiating from other surfaces to the cold surfaces of the cases. A list of up to three entries is allowed, all at zone design drybulb and relative humidity defined under keywords REFG-ZONE-DES-T and REFG-ZONE-DES-RH, see below. The list entries must be made in order, starting with the coldest and progressing to the warmest evaporator temperature. This keyword is required for the simulation, and can range from -99999999.0 to 0.0 Btu/hr. Manufacturers of supermarket cases usually do not list the total cooling effect of their cases directly. Instead, they list the compressor capacity at a standard suction temperature required per lineal foot of case work. The sensible cooling effect is typically 65% of this number, and the latent cooling effect is about 10%. The total cooling effect is then about 75% of the listed compressor capacity per lineal foot, multiplied by the lineal feet of case work.
REFG-ZONE-SHR	is the ratio of sensible to total heat. List of three entries (order corresponds to REFG-ZONE-LOAD entries) at all zone design drybulb and relative humidity defined under keywords REFG-ZONE-DES-T and REFG-ZONE-DES-RH, see below. The default is 0.8.

REFG-ZONE-DES-T	is the zone drybulb temperature at which the case is rated (usually 75°F) as referenced by REFG-ZONE-LOAD. List of three entries (order corresponds to REFG-ZONE-LOAD entries). The range is from 30.0 to 100.0°F and the default is 75°F. Values must be greater than the corresponding REFG-EVAP-T values.
REFG-ZONE-DES-RH	is the zone relative humidity at which the case is rated (usually 55 RH) as referenced by REF-ZONE-LOAD. List of three entries (order corresponds to REFG-ZONE-LOAD entries). The range is from 20.0 to 100.0°F and the default is 55°F.
REFG-DISCHARGE-T	is the temperature of the air inside the cases. List of three entries (order corresponds to REFG-ZONE-LOAD entries). This keyword is required, and can range from -40.0 to 60.0°F. Note: A simulation ERROR will occur if the zone temperature is ever allowed to float below the warmest temperature in this list.
REFG-EVAP-T	is the apparatus dew point temperature. List of three entries (order corresponds to REFG-ZONE-LOAD entries). Values default to the corresponding REFG-DISCHARGE-T - 10.0°F, and the range is from -40.0 to 60.0°F.
REFG-SENS-SCH	accepts schedules to simulate covers on case work at night and holidays to inhibit loss of cooling effect to the zone. List of three u-names (order corresponds to REFG-ZONE-LOAD entries).
REFG-LAT-SCH	accepts schedules to simulate covering case work and the effect on moisture condensing inside the cases. List of three u-names (order corresponds to REFG-ZONE-LOAD entries).
REFG-AUX-KW	is the rated capacity of lights, fans, anti-sweat heaters, or other electrical equipment within the case. List of three entries (order corresponds to REFG-ZONE-LOAD entries). Values default to 0.4 * the corresponding REFG-ZONE-LOAD / 12000, and ranges from 0.0 to 100.0.
REFG-AUX-HEAT	allows for the entry of non-electrical loads, such as hot water resurfacing of an ice rink. List of three entries (order corresponds to REFG-ZONE-LOAD entries). The default is 0.0 Btu/hr, and can range from 0.0 to 99999999.0.
REFG-AUX-SCH	accepts schedules for turning off lights, anti-sweat heaters, etc, and applies to both REFG-AUX-KW and REFG-AUX-LOAD. List of three u-names (order corresponds to REFG-ZONE-LOAD entries).

REFG-DEF-MECH	accepts code-words for type of defrost (RESISTANCE, FREON, TIME-OFF, NO-DEFROST) for the cases. List of three code-words (order corresponds to REFG-ZONE-LOAD entries).

RESISTANCE	is electric resistance defrost (the default).
FREON	is hot gas defrost.
TIME-OFF	is timer controlled off cycle for frost melt.
NO-DEFROST	is for use with units that never need defrosting, or for ice rinks.

REFG-DEF-EFF	is the efficiency of the defrost mechanism. Based on the humidity ratio in the zone, the program calculates the moisture that condenses on each evaporator. It assumes that all condensation freezes and the energy required to defrost is equal to: POUNDS FROST * PHASE CHANGE ÷ DEF-EFF. List of three entries (order corresponds to REFG-ZONE-LOAD entries). Values default to 0.9, unless REFG-DEF-MECH = TIME-OFF, in which case the corresponding value defaults to 1.0.
REFG-DEF-CTRL	is the type of defrost control. Code words are either TIMER (for a timed defrost cycle) or THERMOSTATIC (for a timed start with thermostat controlled off cycle). List of three entries (order corresponds to REFG-ZONE-LOAD entries). The default is THERMOSTATIC.

SYSTEM

The SYSTEM keyword additions are as follows:

REFG-SIZING-RAT	is a single input to adjust the capacity of all compressors in the system. It is the ratio of compressor size to the total evaporator load (which includes the case work plus lights, anti-sweat heaters, etc.). It defaults to 1.2, and ranges from 0.8 to 2.0.
REFG-COMP-CAP	allows the user to enter the installed compressor capacity at each temperature level. List of three entries (order corresponds to REFG-ZONE-LOAD entries of the ZONE input). The range is from 0.0 to 99999999.0 Btu/hr. The default is the refrigeration equipment design load multiplied by REFG-SIZING-RAT.

Manufacturers of supermarket cases nominally rate compressors at a standard suction temperature which is usually not the actual suction temperature of the case. The input for this keyword must be the compressor capacity at the actual suction temperature of the case.

REFG-COMP-EER — allows the user to input the compressor unit efficiency at each temperature level. If not input, the program will calculate these values as a linear relationship between a range of 3.5 Btu/W at -30°F and 7.3 Btu/W at 25°F. The range is from 0.0 to 20.0 Btu/W. List of three entries (order corresponds to REFG-ZONE-LOAD entries of the ZONE input).

REFG-COMP-GROUP — allows the user to specify whether the compressors are multiplexed or serve separate refrigeration circuits. The code-words are SEPARATE (the default) and COMMON. For example, if the first (lowest temperature level) is separate, and the remaining two levels multiplexed, then the input must be as follows: REFG-COMP-GROUP = (SEPARATE, COMMON, COMMON). A mistaken input, such as (SEPARATE, COMMON, SEPARATE), will be interpreted as (SEPARATE, SEPARATE, SEPARATE).

When separate refrigeration circuits share a COMMON compressor, the compressor must operate at a suction temperature low enough to match the coldest evaporator temperature in the multiplexed circuits. The energy consumption of the compressor is determined as though the total load of the multiplexed circuits occurred at the coldest evaporator temperature.

Multiplexing circuits will affect the input of other keywords pertaining to the compressors. Consider the following input for three circuits:

```
REFG-COMP-GROUP = (COMMON,COMMON,SEPARATE)
REFG-COMP-EER = (3.5, 20.0, 5.7)
           .
           .
           .
```

Since the first two circuits are multiplexed, the program will use the value 3.5 Btu/W in calculating the energy consumption of the compressor serving these two circuits. The value of 20.0 input for the second circuit is ignored. It (or any other legal value) was input simply to mark the second position in the list, so that the value for the third circuit could be input in the third position.

REFG-FAN-KW	is the total value in KW to be assigned to either the fans of air cooled condensers or the fans of cooling towers. The default is 0.105 kW per ton of compressor capacity. The range is from 0.0 to 100.0 kW.
REFG-PUMP-KW	is the total value in KW to be assigned to the condenser water pumps for cooling towers. The default is 0.025 kW per ton of compressor capacity. The range is from 0.0 to 100.0 kW.
REFG-MIN-COND-T	is the setpoint of a thermostat located in the outside air that modulates condensing capacity of either air cooled condensers or cooling towers to maintain an approximate 10°F higher (than setpoint) condensing temperature. In situations where the condensing temperature is not allowed to "float", this value should be set 10°F lower than the rated condensing temperature of the equipment. The range is from 50.0 to 110.0°F, and defaults to 60.0°F.
REFG-COND-TYPE	allows the user to input a code-word for either WATER (the default) for cooling towers or AIR for air cooled condensers. It is assumed that all condensing is of one type.
REFG-MAX-HTREC	is the input value of total BTUH of all recoverable heat. The range is from 0.0 to 99999999.0 Btu/hr, and the default is that all compressor heat is recoverable.
REFG-HTREC-UNITS	is the code-word of either YES (the default) or NO, which allows the user to specify which compressors operating at different evaporator temperature levels are available for heat recovery. List of three entries (order corresponds to REFG-ZONE-LOAD entries of the ZONE input).
REFG-HTREC-GROUP	accepts the entry of a single code-word of either SEPARATE or COMMON (the default). Using SEPARATE, DOE-2 simulates the compressors operating at the highest evaporator temperature level as the first units to switch to the heat recovery mode, and thus forced to operate at a higher condensing temperature, given by REFG-HTREC-T. Using COMMON, DOE-2 simulates all compressors specified as being available for heat recovery as being switched to the heat recovery mode and the higher condensing temperature whenever the space temperature requires heating.
REFG-HTREC-T	is the input value of the condensing setpoint during the heat recovery mode. The default is 90°F, and can range from 80.0 to 120.0°F.

REFG-FAN-T	is the low limit setpoint at which the cooling tower fans or air cooled condenser fans shut off. The default is 30°F, and can range from 0.0 to 100.0°F.

SYSTEM-EQUIPMENT

Four new curves have been added to the SYSTEM-EQUIPMENT command.

REFG-KW-FTCOND	accepts the u-names of the curves input by the user to replace default curves of KW as a function of condensing temperature. List of three entries (order corresponds to REFG-ZONE-LOAD entries of the ZONE input). The default coefficients are 0.713536, -0.004959, 0.0000980.
REFG-KW-FPLR	accepts the u-names of the curves input by the user to replace default curves of KW as a function of part load ratio of the compressors. List of three entries (order corresponds to REFG-ZONE-LOAD entries of the ZONE input). The default coefficients are 0.03829, 1.077839, -0.116129.
TWR-RFACT-FRT	accepts a u-name of a curve input by the user that replaces the default curve. (See description of this same keyword in PLANT in the Reference Manual.) The default coefficients are 1.484326, 0.129479, -0.004014, -0.054336, 0.0003120, -0.000147.
TWR-APP-FRFACT	accepts a u-name of a curve input by the user that replaces the default curve. (See description of this same keyword in PLANT in the Reference Manual.) The default coefficients are 4.981467, -6.761789, 24.709033, 0.114499, -0.000612, -0.250651.

Example:

Consider a supermarket which has three sets of cases: 1) frozen foods, 2) meat, dairy, and deli, and 3) produce. There are two sets of compressors, one set for the frozen foods and one set for the rest. Only the compressor set serving the meat, dairy, deli, and produce cases is available for heat recovery. All of the cases are covered at night.

```
                              $ SUPERMARKET CASE SCHEDULES $

FOOD-SENS-SCH  = SCHEDULE  THRU DEC 31 (ALL)
                             (1,9) (0.4)   $ COVER CUTS SENSIBLE BY 60% $
                             (10,21) (1.0) $ UNCOVERED $
                             (22,24) (0.4) $ COVERED AGAIN $              ..

FOOD-LAT-SCH   = SCHEDULE  THRU DEC 31 (ALL)
                             (1,9) (0.7)   $ COVER CUTS LATENT BY 30% $
                             (10,21) (1.0)
                             (22,24) (0.7)                                ..
```

```
FOOD-AUX-SCH    = SCHEDULE  THRU DEC 31 (ALL)
                                (1,9) (0.2)   $ AT NIGHT ONLY CASE FANS AND
                                (10,21) (1.0) $ SWEAT HEATERS RUN.  LIGHTS
                                (22,24) (0.2) $ TURNED OFF.             ..
                          .
                          .
                          .

MARKET          = ZONE  ZONE-TYPE = CONDITIONED
                                .
                                .
                                .
                        REFG-ZONE-LOAD = (-70000., -100000., -40000.)
                         $ FROZEN FOOD, MEAT/DAIRY/DELI, AND PRODUCE INPUT
                         $ AS NEGATIVE BECAUSE THIS IS THE EFFECT ON THE ZONE.

                        REFG-ZONE-SHR = (0.9, 0.8, 0.9)
                         $ THE MEAT/DAIRY/DELI CASE SET IS MULTI-SHELF
                         $ AND INCURS A LARGER LATENT LOAD.

                        REFG-DISCHARGE-T = (-10.0, 35.0, 45.0)
                         $ ORDER OF ALL LISTS IS COLDEST TO WARMEST.

                        REFG-EVAP-T = (-25.0, 25.0, 36.0)
                        REFG-SENS-SCH = (FOOD-SENS-SCH, FOOD-SENS-SCH,
                                         FOOD-SENS-SCH)
                         $ SCHEDULES COULD BE DIFFERENT.

                        REFG-LAT-SCH = (FOOD-LAT-SCH, FOOD-LAT-SCH,
                                        FOOD-LAT-SCH)
                        REFG-AUX-KW = (2.0, 8.0, 1.0)
                        REFG-AUX-SCH = (FOOD-AUX-SCH, FOOD-AUX-SCH,
                                        FOOD-AUX-SCH)
                        REFG-DEF-MECH = (RESISTANCE, FREON, NO-DEFROST)
                         $ NOTE THAT THIS INPUT FOR PRODUCE CASE IS
                         $ IRRELEVANT; SINCE EVAP-T IS ABOVE FREEZING,
                         $ NO DEFROST WILL OCCUR REGARDLESS.

                        REFG-DEF-EFF = (0.95, 0.85)
                           $ THE HEAT THAT DOESNT MELT ICE WILL BECOME A
                           $ COMPRESSOR LOAD. VALUE FOR PRODUCE NOT INPUT
                           $ BECAUSE NOT NEEDED.

                        REFG-DEF-CTRL (THERMOSTATIC, TIMER)          ..
                   .
                   .
                   .

MARKET-SYS     = SYSTEM  SYSTEM-TYPE = PSZ
                                 .
                                 .
                                 .

                        REFG-SIZING-RAT = (1.3, 1.2, 1.2)
                         $ WANT EXTRA SAFETY FOR FROZEN FOOD CIRCUIT.
```

```
REFG-COMP-GROUP = (SEPARATE, COMMON, COMMON)
 $ MEAT/DAIRY/DELI CIRCUIT SHARES COMPRESSORS
 $ WITH PRODUCE CIRCUIT.

REFG-MAX-HTREC = 90000.
 $ HEAT RECOVERY COIL SIZED TO 90000 BTU.

REFG-HTREC-UNITS = (NO, YES)
 $ NO HEAT RECOVERY FROM FROZEN FOOD CASE;
 $ ONLY TWO VALUES INPUT BECAUSE THIRD SET
 $ SHARES COMPRESSORS WITH THE SECOND.
```

Reporting

A new SUMMARY report, REFG, has been added for refrigerated case work, and the SV-A report has been expanded to print verification values for case work energies at design temperatures, compressor efficiencies, and condenser energies. The REFG report and the expanded SV-A will automatically be printed whenever REFG-type keywords have been specified in system type PSZ.

In addition, seven new hourly report variables (82 through 88) have been added to SYSTEMS, VARIABLE-TYPE = u-name of SYSTEM. See the Appendix to this Supplement for descriptions of these new variables.

REPORT REFG — REFRIGERATION EQUIPMENT SUMMARY

This report gives monthly energy use for each system in which there is refrigerated case work.

1. ZONAL SENSIBLE ENERGY (MBTU) is the sensible heat gain to the zone from the refrigerated case work.

2. ZONAL LATENT ENERGY (MBTU) is the latent heat gain to the zone from the refrigerated case work.

3. CONDENSER RECOVERED ENERGY (MBTU) is the energy recovered from the condensers and used for space heating in the heat recovery mode.

4. CONDENSER REJECTED ENERGY (MBTU) is the energy rejected from the condensers.

5. ELECTRIC COMPRESSOR ENERGY (KWH) is the electrical energy consumed by the compressors.

6. ELECTRIC DEFROST ENERGY (KWH) is the electrical energy consumed by the defrosters.

7. ELECTRIC AUXILIARY ENERGY (KWH) is the electrical energy consumed by lights, fans, and anti-sweat heaters in the refrigerated cases.

8. ELECTRIC TOTAL ENERGY (KWH) is the total electric energy used by the refrigerated case work.

```
SAMPLE REFRIGERATED CASEWORK                                                DOE-2.1C   7-FEB-85    10:11:0    SDL RUN 1

REPORT- REFG  REFRIGERATION EQUIPMENT SUMMARY IN    ATR-SYSTEM      FOR ATR-ZONE            WEATHER FILE- SEATTLE, WA   WYEC
-----------------------------------------------------------------------------------------------------------------------------

           - - -  Z O N A L  - - -         -  C O N D E N S E R  -         - - - - - - - - - - E L E C T R I C - - - - - - - - - -

             SENSIBLE        LATENT        RECOVERED       REJECTED         COMPRESSOR       DEFROST     AUXILIARY          TOTAL
               ENERGY        ENERGY           ENERGY         ENERGY             ENERGY        ENERGY        ENERGY         ENERGY
     MONTH     (MBTU)        (MBTU)           (MBTU)         (MBTU)              (KWH)         (KWH)         (KWH)          (KWH)

     JAN     -235.503       -21.960          283.884        882.995         110990.428      7149.059    166213.791     284353.332

     FEB     -215.427       -19.938          228.433        829.664         100634.036      6490.963    151389.434     258514.385

     MAR     -241.837       -25.699          235.115        947.834         112625.757      8366.435    167609.684     288601.844

     APR     -237.398       -26.844          189.419        962.938         109582.303      8739.368    162202.934     280524.621

     MAY     -248.718       -32.196          148.869       1053.578         114207.414     10481.729    167609.684     292298.820

     JUN     -245.612       -40.358          114.044       1074.005         113234.105     13138.711    162202.934     288575.730

     JUL     -258.291       -45.403           71.886       1171.173         119002.400     14781.173    167609.684     301393.270

     AUG     -256.264       -47.708           90.392       1155.404         119647.728     15531.452    167609.684     302788.852

     SEP     -244.085       -42.200          116.360       1074.928         114030.467     13738.496    162202.934     289971.879

     OCT     -246.200       -37.794          174.632       1035.299         115315.979     12303.907    167609.684     295229.565

     NOV     -231.439       -25.659          231.252        909.916         108435.717      8353.571    162105.234     278894.496

     DEC     -238.010       -25.101          263.996        911.481         111752.721      8171.851    167567.809     287492.352
            ---------     ---------        ---------      ---------         ----------     ---------     ---------    -----------

     TOTAL  -2898.786      -390.860         2148.281      12009.215        1349459.063    127246.716   1971933.516    3448639.156
```

AIR SOURCE HEAT PUMP ENHANCEMENTS

1. Expanded supplemental heat source options

A new keyword has been added to the SYSTEM-EQUIPMENT (and SYSTEM) command to allow user specification of the type of heat used to supplement the heat pump.

SYSTEM-EQUIPMENT

HP-SUPP-SOURCE	Input for this keyword is a code-word which specifies the source for the heat pump supplemental heating. Legal values for this keyword are ELECTRIC, HOT-WATER, GAS-FURNACE, and OIL-FURNACE. If the code word HEAT-PUMP is mistakenly entered, it will be changed to ELECTRIC before the simulation. The default value is ELECTRIC. The abbreviation is SUPP-S.

In addition, the names of two existing keywords in the SYSTEM-EQUIPMENT command have been changed. This change allows simulation of heat pumps with supplemental heat sources other than electric resistance.

HP-SUPP-HT-CAP	Replaces ELEC-HEAT-CAP as the keyword used to specify the capacity of the heat pump supplemental heating. The value, in negative Btu/hr, can range from 0.0 to -99999999.0. The abbreviation is S-H-C.
MAX-HP-SUPP-T	Replaces MAX-ELEC-T as the keyword used to specify the temperature above which the supplemental heat will not operate (except when the unit is defrosting). The value, in degrees °F, can range from -30. to 70. The abbreviation is M-SUPP-T.

The above changes allow for the simulation of air source heat pumps which use something other than electric resistance for the supplemental heating unit. For example, residential add-on heat pump units can be modeled by specifying HEAT-SOURCE = HEAT-PUMP, and HP-SUPP-SOURCE = GAS-FURNACE or OIL-FURNACE with system type RESYS.

2. Addition of heatpumps to single duct packaged systems.

Heat pumps as a heat source are now available for use in the packaged single zone system, PSZ. All ten of the heat pump keywords, HEAT-CAP-FT, HEATING-EIR, HEAT-EIR-FT, HEAT-EIR-FPLR, HP-SUPP-HT-CAP, HP-SUPP-SOURCE, MIN-HP-T, MAX-SUP-T, DEFROST-T, and DEFROST-DEGRADE, are now applicable to the PSZ system type.

3. Report changes for the new heat pump simulation.

One additional field has been added to the SV-A report when a heat pump has been specified as the heat source with system types RESYS, PSZ, and PTAC. The new field, labeled HEAT PUMP SUPP HEAT, displays the capacity in Btu/hr of the heat pump supplemental heating element. For PTAC systems this value will be used with each unit.

In the SYSTEMS hourly reports, variable 43 (QHR) is now the adjusted capacity of the heat pump this hour in Btu/hr for system types RESYS and PSZ. A new variable, 81 (QHSUP), has been added for system types RESYS, PSZ, and PTAC. This variable displays the total supplemental heat load for the system if HP-SUPP-SOURCE = HOT-WATER or HOT-WATER/SOLAR.

ZONE hourly report variable 48, (FCHPS(15)), has been changed for system type PTAC. It now displays the supplemental heat load for this zone's heat pump this hour in Btu/hr. The load displayed here is independent of the supplemental heat source.

4. New heat pump sizing policy.

Changes in the design routine effect the way the sizing of the heat pump and the supplemental heat is done. If there is no user input capacity for the heat pump, the program computes a capacity as before. However, this value is now compared to the calculated or user input cooling capacity. If these values differ by more than 15%, the heating capacity is reset equal to the cooling capacity, and the warning message:

```
HEAT PUMP CAPACITY CHANGED FROM xxxxxx TO xxxxxx
      TO MATCH DX CAPACITY IN <name>
```

is printed. If the heat pump heating capacity is user input, the same comparison is made. If the values differ by more than 15%, the message:

```
A HEATING CAPACITY OF xxxxxxxx IS INCONSISTENT WITH A COOLING
           CAPACITY OF xxxxxxxxx IN <name>
```

is printed, but in this case the value will not be changed.

The sizing of the supplemental heat capacity for the PTAC system was changed to correct a bug. The supplemental heat was sized for the load in the last zone on the system. It is now sized for all zones to the largest load in any zone on the system.

OPTIMUM FAN START OPTION

SYSTEM-FANS

FAN-SCHEDULE as in the previous versions of the program, is the u-name of a schedule instruction that specifies fan operation for each hour. If the hourly value is (1), the fans are on. If the hourly value is (0), the fans are off but may be turned on by NIGHT-CYCLE-CTRL if ZONE temperatures warrant it. If the hourly value is (-1), the fans are not permitted to be on for any reason.

The program now accepts hourly values of (-999.0) to define an optimum start period of up to six hours duration. During this period the fan start time is delayed until the fan run time matches that which is needed to meet the desired ZONE temperatures. Notice that this decision is made on an hourly basis, whereas in the real world, it is made on much smaller increments of time (i.e., ten minutes or less). For the hourly calculation, the number of hours needed to bring each ZONE on the system up or down to its set point is estimated. If the number of such hours for the majority of the zones is equal to or greater than the number of hours remaining in the start period, the fans are turned on. The target zone temperatures used in the calculation are the heating and cooling set temperatures scheduled in HEAT-TEMP-SCH and COOL-TEMP-SCH that correspond to the first hour following the scheduled optimum start period.

Rules:

1. The optimum start period may be less than but not greater than six hours.

2. The fan must be scheduled on using the value (1) for the first hour following the optimum start period.

3. An optimum start period must be defined within a contiguous set of hours. Therefore, the optimum start period cannot begin before 1:00 A.M. E.g., the following example is not valid:

```
F1  = D-SCH (1,4) (-999) (5,18) (1) (19,22) (0) (23,24) (-999)    ..
```

Cautions:

1. Zones with Trombe walls should not be used with optimum start.

2. Optimum start will not work well on systems serving zones which are not evenly balanced with respect to their start up duration.

3. If the system is under-sized, or can not supply sufficient air at its minimum or maximum supply temperature, the start time will be delayed too long and there will be excessive hours reported with loads not met. A VAV system with a low MIN-CFM-RATIO and a thermostat type that is not REVERSE-ACTION fits this description.

4. The results for short RUN-PERIODs of just a few days will not produce results as good as those for longer RUN-PERIODs since the program attempts to learn (simulating feedback) to improve on its estimating abilities.

5. During hours of the optimum start period in which the fan has not been started, the system will behave as if the fan schedule that hour were (0). Thus, the fan can cycle on during this period if NIGHT-CYCLE-CTRL is used.

6. For Air/Air Heat Pumps, where the primary interest is one of minimizing the use of electric resistance heating during start-up, it is suggested that the set point temperature be ramped upward. This should start with the first hour during a normal fan start period.

Example input/output may be found in the DOE-2 Sample Run Book, Version 2.1C, in the 31-Story Office Building, Runs 1 through 6.

NIGHT VENTILATION

Several new keywords have been added to the program to allow the simulation of night-time ventilation cooling using outside air and an alternative set of fans which run when the FAN-SCHEDULE is off. The keyword NIGHT-VENT-CTRL, in the SYSTEM or SYSTEM-FANS command has five legal code-words which define the operation of fans when the FAN-SCHEDULE is off (and the NIGHT-CYCLE-CTRL has not caused the fans to cycle on). The user should consult the new SS-K report for assistance in determining the potential for night ventilation. (See Section "New SYSTEMS Reports" in this Supplement.) The NIGHT-VENT-CTRL code-words are as follows:

NOT-AVAILABLE	(the default) means that, when the FAN-SCHEDULE is off, no other fans can be on.
NIGHT-FAN	means that, when the main fans are scheduled off, the night fan(s) always run to pressurize, for instance, a fabric roof system. One can also think of this as the main fans running but at a reduced volume.
NIGHT-FAN+REVERT	means that, when the main fans are scheduled off, the night fan(s) run unless any zone falls below its heating throttling range or rises above its cooling throttling range, in which case the main fans are turned on that hour.
WHEN-SCHEDULED	means that, when the main fans are scheduled off, the night ventilation fan(s) will turn on if the NIGHT-VENT-SCH is on and the outside drybulb temperature is at least NIGHT-VENT-DT degrees below the temperature in the first zone specified in the ZONE-NAMES list.
SCHEDULED+DEMAND	is the same as WHEN-SCHEDULED except that, in addition, at least one conditioned zone in the ZONE-NAMES list must be above the VENT-TEMP-SCH value.

The following keywords supply the additional information for simulating the night fans and night ventilation options:

NIGHT-VENT-SCH	is a required entry in the SYSTEM or SYSTEM-FANS command, when NIGHT-VENT-CTRL is equal to WHEN-SCHEDULED or SCHEDULE+DEMAND. It is the u-name of a schedule that defines the hours when the night ventilation fans are allowed to run, if the main fans are scheduled off. A zero or non-zero value is used to specify that the night ventilation fans are either not allowed or allowed, respectively, to turn on.
NIGHT-VENT-DT	in the SYSTEM or SYSTEM-FANS command, is the minimum number of degrees that the outside drybulb temperature must be below the inside temperature for the night ventilation fans to operate. This inside temperature is that of the first zone specified in the ZONE-NAMES list. The value is usually set equal to at least the temperature rise across the ventilation fans plus a couple of degrees to ensure that a reasonable cooling capacity is available before ventilation cooling is used. The default is 5°F.

NIGHT-VENT-RATIOS	is a required entry in the SYSTEM or SYSTEM-FANS command when NIGHT-VENT-CTRL is not equal to NOT-AVAILABLE. It is a list of six values that are ratios of night fan parameters to the normal operating fan parameters. The first three values define the ratios of flowrate, kW per unit flowrate, and fan temperature rise of the night supply fans to the normal supply fans. The last three values define the same three ratios of the night return fans to the normal return fans.

Q_N, night fan flowrate = SUPPLY-CFM * NIGHT-FAN-RATIOS(1)

P_N, night fan power/flowrate = SUPPLY-KW * NIGHT-FAN-RATIOS(2)

DT_N, night fan temperature rise = SUPPLY-DELTA-T * NIGHT-FAN-RATIOS(3)

where Q_N*P_N = night supply fan total energy use

Similar relationships are true for the return fans during night operation. If no return fans are used during the night operation, the last three values of NIGHT-FAN-RATIOS should be set equal to zero. Note that the ratios of power/flowrate and temperature rise are normally similar and larger than the flowrate ratio (this is especially true if the night and day fans are the same fans operated under different control or pressure conditions). If the night and normal fans are, in fact, the same set run in the identical manner, all six values should be set to 1.0.

VENT-TEMP-SCH	in the SYSTEM or SYSTEM-AIR command, is the u-name of a schedule used to define the setpoint for forced or natural ventilation. Natural ventilation is appropriate to the RESYS system only. The hourly values specified in the referenced SCHEDULE are the indoor dry-bulb temperatures to which the zone is to be cooled by natural ventilation, in lieu of mechanical cooling. For forced ventilation, this value is used when NIGHT-VENT-CTRL is equal to SCHEDULED+DEMAND. The night ventilation fan, in this case, will operate only if any conditioned zone specified in the ZONE-NAMES list is above this value. If this keyword is not defined, the top of the zones´ heating throttling range (defined by value of HEAT-TEMP-SCH plus 0.5 * THROTTLING-RANGE) is used.

Report SS-C now reports out the number of hours of night venting. This report has been enhanced in other ways as well; it now also reports the number of hours the terminal unit is operating in the dead-band (HOURS FLOATING), the number of hours of heating and cooling available, number of hours the fans are on, fans cycling on, and number of hours the terminal unit is operating in the dead-band when the fans are on (HOURS FLOATING WHEN FANS ON).

Note: NIGHT-CYCLE-CTRL now also cycles fans on when the temperature goes above the COOL-TEMP-SCH´s throttling range.

USER-DEFINED CURVE-FIT BOUNDARIES

Two new keywords have been added to the CURVE-FIT command in SYSTEMS and PLANT that allow the user to establish both the lower and upper boundaries beyond which the curve is not valid. The keywords are:

OUTPUT-MIN	defines the lower boundary of the dependent variable, and
OUTPUT-MAX	defines the upper boundary of the dependent variable.

* * * * *

BASEBOARD HEATING IN PLENUMS

Several zone level keywords have been activated for PLENUM type zones. The use of these keywords allows "baseboards" to be placed in plenums. This allows the simulation of outside or space temperature controlled heaters in the return air space. The newly allowed keywords are:

HEAT-TEMP-SCH	to define the thermostat setpoint for the plenum heater when it is THERMOSTATICally controlled.
BASEBOARD-RATING	to define the size of the heating unit.
BASEBOARD-CTRL	to define the control method as THERMOSTATIC using HEAT-TEMP-SCH as the setpoints, or OUTDOOR-RESET to allow BASEBOARD-SCH reset control.
THROTTLING-RANGE	to define the throttling range around HEAT-TEMP-SCH.

The plenum heater is activated based on outside air temperature and reset schedule when it is outside controlled. When it is space temperature controlled, and if the interaction with the return air does not result in a temperature above the scheduled value, the heater is turned on. In both cases, the source of energy input to the heater is defined by the specified or defaulted value for BASEBOARD-SOURCE.

MIN-CFM-SCH AND OTHER NEW SCHEDULE USES

A schedule keyword has been added to allow an hourly variation of the MIN-CFM-RATIO.

MIN-CFM-SCH	in the ZONE command, is the u-name of a schedule which has values that are to be used in place of the MIN-CFM-RATIO keyword to allow an hourly variation of MIN-CFM-RATIO. This schedule will always override the value specified or calculated for MIN-CFM-RATIO, unless the scheduled value is equal to -999.0 for an hour. When the value is equal to -999.0, then the calculated or specified value of MIN-CFM-RATIO (found on report SV-A for each zone) is used for that hour. This schedule can be used with a value of 1.0 during warmup periods and -999.0 for other hours to simulate full open VAV boxes during a warmup cycle.
MIN-AIR-SCH	The MIN-AIR-SCH keyword used in the SYSTEM or SYSTEM-AIR command defines the hourly value of the minimum outside air damper position as a ratio of design flowrate. The two exceptions to this definition are when the schedule has a value of either zero or -999.0; in which case special meanings are assumed. When the value is zero, a no outside air situation with no moveable dampers (economizer inactive if specified) is simulated. This usage is common for night-time heating or a warmup cycle. If this schedule has a value of -999.0, the calculated or specified value for MIN-OUTSIDE-AIR (found on report SV-A for the SYSTEM or for each zone for zonal systems) is used as the minimum damper position for the current hour. If this value is zero, the discussion above for that special value applies. During a warmup period, this schedule is normally set to zero and can then be set to -999.0 during other hours to allow the specified or calculated ventilation minimum damper position to be used.
HEATING-SCHEDULE COOLING-SCHEDULE	The HEATING-SCHEDULE and COOLING-SCHEDULE in the SYSTEM or SYSTEM-CONTROL commands are equal to the schedules whose values define the availability of active heating and cooling, respectively. A zero value for one of these schedules means that heating or cooling is not available except through ventilation. A non-zero value indicates that mechanical heating or cooling is available. Additionally, if either of the schedules has a value greater than 1.0, a special meaning is inferred. If the HEATING-SCHEDULE is set to a value greater than 1.0, heating is available only if the outside drybulb temperature is less than or equal to the specified value. In a similar manner, if the COOLING-SCHEDULE is set to a value greater than 1.0, cooling is available only if the outside drybulb temperature is greater than or equal to the specified value.

VARIOUS CONTROL ENHANCEMENTS

A new keyword has been added to define the source of heat used to provide humidification in those SYSTEM-TYPEs that allow MIN-HUMIDITY to be specified. Note that humidification has been added to the HVSYS system.

HUMIDIFIER-TYPE	in the SYSTEM command, is given one of the standard heat source code-word values: HOT-WATER, ELECTRIC, GAS-FURNACE, or OIL-FURNACE. The gas and oil furnace sources should be used with caution since the same HIR and part load functions are used as for other furnaces specified in the same system. The defaults for HUMIDIFIER-TYPEs are the same as those for BASEBOARD-TYPE.
MAX-HUMIDITY	in the SYSTEM or SYSTEM-CONTROL command causes the simulation to function differently for system types SZRH, PSZ, and PVAVS than previously described. For SZRH, if the MAX-HUMIDITY level is exceeded, the system reverts to a full reheat. The cooling coil leaving air temperature is driven lower and reheat is added at the fan unit to satisfy the first-named zone. Further, for PSZ and PVAVS systems, specification of MAX-COND-RCVRY will activate the use of condenser recovery to accomplish a similar result.

A new keyword has been added to the SYSTEM and SYSTEM-CONTROL commands that adds an additional control to the outside air economizer cycle.

ECONO-LOW-LIMIT	defines the outdoor drybulb temperature below which the outside dampers are returned to their minimum position (see Fig. 1). This is analogous to the ECONO-LIMIT-T, except that it is a low limit rather than a high limit. The range is from 0.0 to 80.0°F, and the abbreviation is E-L-L.

Note that Fig. 1 assumes some relative values for outside drybulb and return air drybulb temperatures. The purpose of this keyword is to allow the user to simulate the loading of an evaporator on a double bundle chiller (DBUN-CHLR) to satisfy the heating load. The value input for ECONO-LOW-LIMIT is the outside air temperature at which the outside air economizer damper is forced to a minimum position. This, in effect, increases the load on the evaporator and the additional heat rejected is available to satisfy the heating load. The economizer is only active between the outside temperature specified for ECONO-LOW-LIMIT and ECONO-LIMIT-T as seen in Fig. 1.

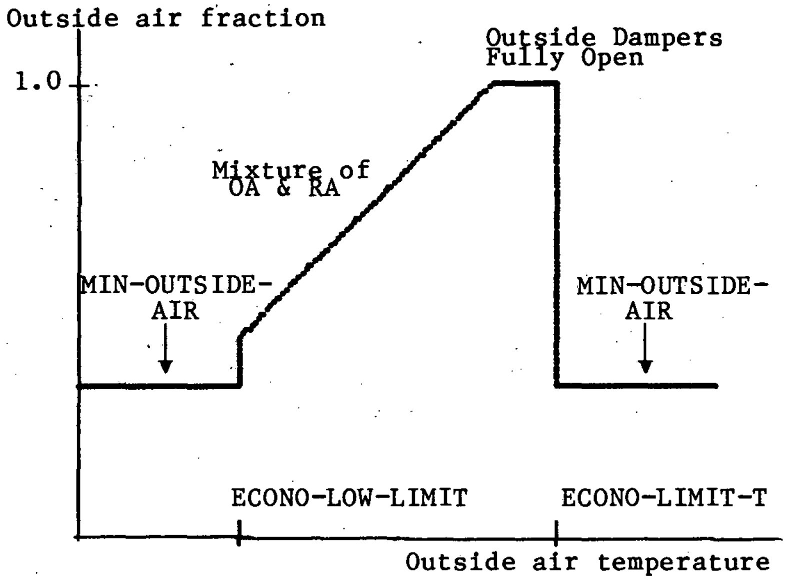


Figure 1

Another use of the ECONO-LOW-LIMIT keyword is to simulate the closing (to minimum position) of outside air dampers when humidification is required. There would be no direct tie to the humidifier controller as ECONO-LOW-LIMIT is only based on drybulb temperatures. However, the user could address the savings of humidifying minimum versus maximum outside air quantities.

Control of air flow rate to zones has been upgraded:

CFM/SQFT and AIR-CHANGES/HR	under the ZONE-AIR command have taken on new meanings. In the previous versions of the program, these two keywords always overrode the calculated zone CFM´s and set them to satisfy these criteria. They now allow the user to set a minimum air flow rate to the zone, and only override the calculated value when the latter is less than the minimum criteria. The keyword ASSIGNED-CFM is now the only method the user has to set a value at the ZONE level.
SUPPLY-CFM	in the SYSTEM-AIR command has not been changed in meaning; however, the method of proportioning the specified total supply air into zone air quantities has been made more exact in the following manner.

$$\text{Adj. CFM} = \left[\frac{\text{<SUPPLY-CFM>}}{\sum \text{Calculated Zone Air CFMs}} \right] * (\text{Calculated Zone Air})$$

where Adj. CFM = Adjusted Zone Air CFM.

Note that user inputs of ZONE-level ASSIGNED-CFM and EXHAUST-CFM (but only when the latter exceeds calculated zone CFM) replaces the other "Calculated Zone Air CFM" in the summation.

When the user allows the program to calculate MIN-CFM-RATIO (rather than input it), the values for Minimum Flow Ratio (see SV-A Report) are corrected relative to the values of "Adjusted Zone Air CFM", taking into account the specified outside/exhaust air or the peak heating load. Likewise, user input of MIN-OUTSIDE-AIR would result in new quantities of Outside Air Flow (see SV-A report) as these values would be simply the ratio of the the zone flowrate and the SUPPLY-CFM value times the MIN-OUTSIDE-AIR value.

NEW SYSTEM-EQUIPMENT DEFAULT CURVES

The default curves for most of the keywords in the SYSTEM-EQUIPMENT command have been upgraded in order to more closely resemble equipment now on the market. The table presented on the next two pages replaces Chap. IV, Table 39, of the DOE-2 Reference Manual. Also introduced are four new keywords and accompanying default curves for special use in the PSZ system (see Section "Heat Recovery From Refrigerated Case-work" in this Supplement).

The new curves were developed from rated data using various representative equipment specifications found in manufacturers' catalogs:

RESYS	36,000 Btu/hr air-cooled condensing unit, rated 3 tons @ ARI, 1200 CFM, 3 row, 13-14 fins per inch (fpi), 4.5 ft/sec (indoor), 20 fpi, 3.5 ft/sec (outdoor).
PTAC	A combination of data from three units, from 6,900 Btu/hr to 11,800 Btu/hr in size.
HP	35,000 Btu/hr cooling, 39,000 Btu/hr heating, shr = 0.74, 26,000 Btu/hr sensible, 4.5 GPM 20° ΔT, 4 row, 12 fpi, 500 ft/min.
PSZ PMZS PVAVS	360,000 Btu/hr, 30 tons, 2 compressors unloading to 15%, 3 condensor fans, 3 row, 15 fpi, 7 ft/sec (outdoor condensor) 4 row, 15 fpi, 8 ft/sec (indoor evaporator).
Builtup	Plate and fin, 6 row, 15 fpi, 600 ft/min, 86°DB/67°WB, 45° entering water, 10° ΔT, 4 ft/sec.
TPFC FPFC	4 row, 14 fpi, 600 ft/min, 44° entering water, 12°ΔT, 6 ft/sec.

Curve SDL-C18, COOL-EIR-FPLR for Packaged Units PSZ, PMZS, and PVAVS, comes from data in the ICES Report ANL/CES/TE 78-2. This curve corresponds to Curve 4 on p. 10 of that report. Coefficients for Curves 1 (Hot gas bypass), 2 (Back pressure valve), and 3 (Suction valve-lift unloading, single compressor) from this same report have been added to the program's predefined curves. However, they are not used as defaults for any of the equipment, but may be specified as alternatives to SDL-C18. The curve numbers are SDL-C117 (Hot gas bypass), SDL-C118 (Back pressure valve) and SDL-C119 (Suction valve). See table below for coefficients.

The hydronic heat pump curves have been normalized to a water temperature of 70°F. In earlier versions of the code, 60° was used. This change reflects a change in the ARI reference conditions from ARI 240-75 to ARI 320-76, and to ASHRAE Std. 90A-1980, Table 6.10.

SYSTEM-EQUIPMENT DEFAULT CURVES

Equations are assumed to take the form:
linear, or $z = a + bx$
bi-linear, or $z = a + bx + dy$
quadratic, or $z = a + bx + cx^2$
bi-quadratic, or $z = a + bx + cx^2 + dy + ey^2 + fxy$
cubic, or $z = a + bx + cx^2 + dx^3$

Default Curve U-name	Keyword	Independent Variable(s)*	Applicable SYSTEM-TYPE	Default Curve Coefficients					
				a	b	c	d	e	f
SDL-C1	COOL-CAP-FT	WB/ODB	RESYS	0.60034040	0.00228726	-0.0000128	0.00138975	-0.0000806	0.00014125
SDL-C2	COOL-CAP-FT	WB/ODB	PTAC	1.1839345	-0.0081087	0.00021104	-0.0061425	0.00000162	-0.0000030
SDL-C3	COOL-CAP-FT	WB/ODB	PSZ,PMZS,PVAVS	0.87403018	-0.0011416	0.00017110	-0.0029570	0.00001018	-0.00005917
SDL-C5	COOL-CAP-FT	WB/WT	HP	-0.2780377	0.02483069	-0.00000954	-0.0032731	0.00000703	-0.0000272
SDL-C7	COOL-CAP-FT	WB/DB	Builtup	2.5882585	-0.2305879	0.00383591	0.10258116	0.00059844	-0.0028721
SDL-C10	COOL-CAP-FT	WB/DB	TPFC,FPFC	0.50388665	-0.0869176	0.00168467	0.03363036	0.00024777	-0.00102968
SDL-C11	COOL-EIR-FT	WB/ODB	RESYS	-0.9617787	0.04817751	-0.0002311	0.00324392	0.00014876	-0.0002952
SDL-C12	COOL-EIR-FT	WB/ODB	PTAC	-0.6550461	0.03889096	-0.0001925	0.00130464	0.00013517	-0.0002247
SDL-C13	COOL-EIR-FT	WB/ODB	PSZ,PMZS,PVAVS	-1.063931	0.03065843	-0.0001269	0.01542130	0.00004973	-0.0002096
SDL-C15	COOL-EIR-FT	WB/WT	HP	2.0280385	-0.0423091	0.00030539	0.01496715	0.00002438	-0.00016396
SDL-C16	COOL-EIR-FPLR	PLR	RESYS	0.125	0.875	0.0	0.0	0.0	0.0
SDL-C17	COOL-EIR-FPLR	PLR	PTAC	0.125	0.875	0.0	0.0	0.0	0.0
SDL-C18	COOL-EIR-FPLR	PLR	PSZ,PMZS,PVAVS	0.20123007	-0.0312175	1.9504979	-1.1205104	0.0	0.0
SDL-C20	COOL-EIR-FPLR	PLR	HP	0.125	0.875	0.0	0.0	0.0	0.0
SDL-C21	COOL-SH-FT	WB/ODB	RESYS	6.5275698	-0.1261375	0.00056879	0.00907575	-0.0000483	-0.00000875
SDL-C22	COOL-SH-FT	WB/ODB	PTAC	6.3112709	-0.1129951	0.00043336	0.00377381	-0.0000499	0.00006375
SDL-C23	COOL-SH-FT	WB/ODB	PSZ,PMZS,PVAVS	4.8352962	-0.0575307	0.00006155	-0.0052683	0.00000317	0.00003375
SDL-C25	COOL-SH-FT	WB/WT	HP	1.0181313	0.04775910	-0.0006660	-0.0081062	0.00001950	0.00005371
SDL-C27	COOL-SH-FT	WB/DB	Builtup	0.89827669	-0.1312367	0.00196883	0.08966396	0.00057034	-0.00200873
SDL-C30	COOL-SH-FT	WB/DB	TPFC,FPFC	-1.228054	-0.0320956	0.00043381	0.05749134	0.00013737	-0.0005685
SDL-C31	COIL-BF-FCFM	CFM-PLR	RESYS	-3.012800	6.5856000	-2.572800	0.0	0.0	0.0
SDL-C32	COIL-BF-FCFM	CFM-PLR	PTAC	-2.277000	5.2114000	-1.934400	0.0	0.0	0.0
SDL-C33	COIL-BF-FCFM	CFM-PLR	PSZ,PMZS,PVAVS	-0.2542341	1.2182557	0.03597841	0.0	0.0	0.0
SDL-C35	COIL-BF-FCFM	CFM-PLR	HP	-0.8281602	14.317915	-21.88944	9.3996894	0.0	0.0
SDL-C37	COIL-BF-FCFM	CFM-PLR	Builtup	0.39660574	0.14964713	0.45374713	0.0	0.0	0.0
SDL-C40	COIL-BF-FCFM	CFM-PLR	TPFC,FPFC	-0.7177876	1.9070782	-0.1892906	0.0	0.0	0.0
SDL-C41	COIL-BF-FT	WB/DB	RESYS	-4.797791	0.14048147	-0.0001864	-0.0095173	0.00011125	-0.0004521
SDL-C42	COIL-BF-FT	WB/DB	PTAC	-1.571369	0.04696328	0.00031518	-0.0065347	0.00011055	-0.0003719
SDL-C43	COIL-BF-FT	WB/DB	PSZ,PMZS,PVAVS	1.0660054	-0.0005170	0.00005672	-0.0129181	-0.00000169	0.00015027
SDL-C45	COIL-BF-FT	WB/WT	HP	-29.93911	0.87534545	-0.0057055	0.16144500	0.00029073	-0.0031523
SDL-C50	COIL-BF-FT	WB/DB	TPFC,FPFC	1.2049495	-0.0034963	0.00011357	-0.0008867	0.00000759	-0.00008548
SDL-C51	HEAT-CAP-FT	ODB/DB	RESYS	0.29495686	0.01425344	-0.0000117	0.00000059	0.0	0.0
SDL-C52	HEAT-CAP-FT	ODB/DB	PTAC	0.25367141	0.01043512	0.00018606	-0.00000149	0.0	0.0
SDL-C55	HEAT-CAP-FT	DB/WT	HP	0.48865341	-0.0067774	0.0	0.01408231	0.0	0.0

Default Curve U-name	Keyword	Independent Variable(s)*	Applicable SYSTEM-TYPE	Default Curve Coefficients a	b	c	d	e	f
SDL-C56	HEAT-EIR-FT	ODB/DB	RESYS	2.1855478	-0.0494718	0.00070417	-0.00000401	0.0	0.0
SDL-C57	HEAT-EIR-FT	ODB/DB	PTAC	2.4600299	-0.0622539	0.00088002	-0.0000046	0.0	0.0
SDL-C60	HEAT-EIR-FT	DB/WT	HP	1.3876102	0.00604794	0.0	-0.0115852	0.0	0.0
SDL-C61	HEAT-EIR-FPLR	PLR	RESYS	0.08565215	0.93881371	-0.1834361	0.15897022	0.0	0.0
SDL-C62	HEAT-EIR-FPLR	PLR	PTAC	0.08565215	0.93881371	-0.1834361	0.15897022	0.0	0.0
SDL-C65	HEAT-EIR-FPLR	PLR	HP	0.08565215	0.93881371	-0.1834361	0.15897022	0.0	0.0
SDL-C66	DEFROST-DEGRADE	OWB/ODB	RESYS,PTAC	0.03300000	0.0	0.0	0.0	0.0	0.0
SDL-C76	RATED-CCAP-FCFM	CFM-PLR	RESYS	0.80000000	0.20000000	0.0	0.0	0.0	0.0
SDL-C77	RATED-CCAP-FCFM	CFM-PLR	PTAC	0.80000000	0.20000000	0.0	0.0	0.0	0.0
SDL-C78	RATED-CCAP-FCFM	CFM-PLR	PSZ,PMZS,PVAVS	0.47278589	1.2433415	-1.0387055	0.32257813	0.0	0.0
SDL-C79	RATED-CCAP-FCFM	CFM-PLR	HP	0.93940260	-0.3005555	0.54955622	-0.1884034	0.0	0.0
SDL-C80	RATED-CCAP-FCFM	CFM-PLR	Builtup	0.18883215	1.0928053	-0.2816374	0.0	0.0	0.0
SDL-C81	RATED-CCAP-FCFM	CFM-PLR	TPFC,FPFC	0.18273451	1.0990207	-0.2817552	0.0	0.0	0.0
SDL-C83	RATED-SH-FCFM	CFM-PLR	RESYS	0.60000000	0.40000000	0.0	0.0	0.0	0.0
SDL-C84	RATED-SH-FCFM	CFM-PLR	PTAC	0.60000000	0.40000000	0.0	0.0	0.0	0.0
SDL-C85	RATED-SH-FCFM	CFM-PLR	PSZ,PMZS,PVAVS	0.34465606	0.89289891	-0.3554498	0.11789480	0.0	0.0
SDL-C86	RATED-SH-FCFM	CFM-PLR	HP	-0.1300253	2.1583062	-1.601682	0.57340154	0.0	0.0
SDL-C87	RATED-SH-FCFM	CFM-PLR	Builtup	0.20164516	0.85537158	-0.0570167	0.0	0.0	0.0
SDL-C88	RATED-SH-FCFM	CFM-PLR	TPFC,FPFC	0.15461794	1.0052259	-0.15984383	0.0	0.0	0.0
SDL-C91	RATED-CEIR-FCFM	CFM-PLR	RESYS	1.1560000	-0.1816000	0.02560000	0.0	0.0	0.0
SDL-C92	RATED-CEIR-FCFM	CFM-PLR	PTAC	1.1552000	-0.1808000	0.02560000	0.0	0.0	0.0
SDL-C93	RATED-CEIR-FCFM	CFM-PLR	PSZ,PMZS,PVAVS	1.0079484	0.34544129	-0.6922891	0.33889943	0.0	0.0
SDL-C94	RATED-CEIR-FCFM	CFM-PLR	HP	0.99987312	0.28009428	-0.4356050	0.15563756	0.0	0.0
SDL-C98	RATED-HCAP-FCFM	CFM-PLR	RESYS	0.84000000	0.16000000	0.0	0.0	0.0	0.0
SDL-C99	RATED-HCAP-FCFM	CFM-PLR	PTAC	0.84000000	0.16000000	0.0	0.0	0.0	0.0
SDL-C100	RATED-HCAP-FCFM	CFM-PLR	PSZ,PMZS,PVAVS	—					
SDL-C101	RATED-HCAP-FCFM	CFM-PLR	HP	0.48381838	0.81807753	-0.3018959	0.0	0.0	0.0
SDL-C102	RATED-HCAP-FCFM	CFM-PLR	TPFC,FPFC	—					
SDL-C105	RATED-HEIR-FCFM	CFM-PLR	RESYS	1.3824000	-0.4336000	0.05120000	0.0	0.0	0.0
SDL-C106	RATED-HEIR-FCFM	CFM-PLR	PTAC	1.3924000	-0.4468000	0.05440000	0.0	0.0	0.0
SDL-C108	RATED-HEIR-FCFM	CFM-PLR	HP	1.4606527	-0.7969647	0.33631204	0.0	0.0	0.0
SDL-C111	FURNACE-HIR-FPLR	PLR	All Types	0.01861	1.094209	-0.112819	0.0	0.0	0.0
SDL-C112	REFG-KW-FTCOND	TTWR	PSZ	0.7135360	-0.004959	0.0000980	0.0	0.0	0.0
SDL-C113	REFG-KW-FPLR	PLR	PSZ	0.0382900	1.0778390	-0.116129	0.0	0.0	0.0
SDL-C114	TWR-RFACT-FRT	RNG/OWB	PSZ	1.4843260	0.1294790	-0.004014	-0.054336	0.0003120	-0.000147
SDL-C115	TWR-APP-FRFACT	RF/OWB	PSZ	4.9814670	-6.761789	24.709033	0.1144990	-0.000612	-0.250651
SDL-C117	—	PLR	PSZ,PMZS,PVAVS	1.0758898	-0.6164059	0.93401744	-0.39350141	0.0	0.0
SDL-C118	—	PLR	PSZ,PMZS,PVAVS	0.21039364	2.2429549	-2.319486	0.86613714	0.0	0.0
SDL-C119	—	PLR	PSZ,PMZS,PVAVS	0.03125391	1.4895131	-0.7868148	0.26604779	0.0	0.0

* WB = entering wet-bulb temperature (^{o}F)
ODB = outside dry-bulb temperature (^{o}F)
WT = entering water temperature (^{o}F)
OWB = outside wet-bulb temperature (^{o}F)
RNG = range, temperature drop through tower
RF = rating factor

DB = entering dry-bulb temperature (^{o}F)
PLR = part-load ratio (fraction)
CFM-PLR = change in full load capacity as a function of supply air flow rate
TTRW = cooling tower temperature (^{o}F)

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REPORT SS-K — SPACE TEMPERATURE SUMMARY REPORT

The following report gives monthly summaries of various space temperature quantities. Blank entries in the report indicate that no hours existed in a particular category. The first five columns list average space temperatures during particular subsets of hours. The next three columns give calculated average temperature differences between the room air and outside air under different categories of hours. Columns 9 and 10 give total summed temperature differences between outside and room air rather than averages. Finally, an average humidity ratio difference between outside and room air is printed.

1. AVERAGE SPACE TEMP ALL HOURS gives the temperature averaged over all hours in the run.

2. AVERAGE SPACE TEMP COOLING HOURS gives the temperature only in hours when cooling was required.

3. AVERAGE SPACE TEMP HEATING HOURS gives the average temperature only in hours when heating was required.

4. AVERAGE SPACE TEMP FAN ON HOURS gives the average temperature only when the fans are running.

5. AVERAGE SPACE TEMP FAN OFF HOURS gives the average temperature only when the fans are not running.

6. AVERAGE TEMPERATURE DIFFERENCE OUTDOOR-ROOM AIR ALL HOURS takes the sum of (outdoor temperature-room air temperature) over all hours and divides this quantity by the number of hours.

7. AVERAGE TEMPERATURE DIFFERENCE OUTDOOR-ROOM AIR FAN ON HOURS takes the sum of (outdoor temperature-room air temperature) over hours when the fans are on and divides this quantity by the number of hours the fans are on.

8. AVERAGE TEMPERATURE DIFFERENCE OUTDOOR-ROOM AIR FAN OFF HOURS takes the sum of (outdoor temperature-room air temperature) over hours when the fans are off and divides this quantity by the number of hours the fans are off.

9. SUMMED TEMP DIFFERENCE OUTDOOR-ROOM AIR HEATING HOURS gives the sum of the absolute values of (outdoor temperature-room air temperature) over all hours when heating is required.

10. SUMMED TEMP DIFFERENCE OUTDOOR-ROOM AIR ALL HOURS gives the sum of the absolute values of (outdoor temperature-room air temperature) over all hours in the run.

11. HUMIDITY RATIO DIFFERENCE BETWEEN OUTDOOR AND ROOM AIR gives the average of (outdoor humidity ratio-room air humidity ratio) over all hours in the run.

```
SIMPLE STRUCTURE RUN 3, CHICAGO                                                                         DOE-2.1C  11-JAN-85    09:13:5    SDL RUN 1

REPORT- SS-K  SPACE TEMPERATURE SUMMARY                                      SYST-1                                WEATHER FILE- TRY  CHICAGO
---------------------------------------------------------------------------------------------------------------------------------------------------

            A V E R A G E    S P A C E    T E M P               AVERAGE TEMPERATURE DIFFERENCE       SUMMED TEMP DIFFERENCE
                                                                BETWEEN     BETWEEN      BETWEEN      BETWEEN          BETWEEN          HUMIDITY RATIO
                                                                OUTDOOR&    OUTDOOR&     OUTDOOR&     OUTDOOR&         OUTDOOR&           DIFFERENCE
                                                                ROOM AIR    ROOM AIR     ROOM AIR     ROOM AIR         ROOM AIR           BETWEEN
        ALL      COOLING     HEATING     FAN ON     FAN OFF     ALL         FAN ON       FAN OFF      HEATING          ALL                OUTDOOR AND
        HOURS    HOURS       HOURS       HOURS      HOURS       HOURS       HOURS        HOURS        HOURS            HOURS              ROOM AIR
MONTH   (F)      (F)         (F)         (F)         (F)         (F)         (F)          (F)          (F)              (F)             (PERCENT-RH


JAN     61.90                65.10       65.13       59.46      -36.56      -40.16       -33.82       536.01          1133.36             -0.00139

FEB     61.77                65.18       65.18       59.34      -34.25      -37.07       -32.25       432.44           959.13             -0.00115

MAR     64.94                67.76       68.26       63.18      -26.57      -30.72       -24.37       304.48           828.43             -0.00109

APR     72.34       75.62    69.64       73.54       71.77      -20.75      -20.75       -20.74        66.72           624.69             -0.00109

MAY     75.55       77.63    70.00       76.26       75.24      -18.77      -16.49       -19.75        13.96           583.77             -0.00038

JUN     79.78       78.37                78.30       80.38      -12.68       -6.59       -15.19                        389.71             -0.00066

JUL     83.74       79.95                79.95       85.58       -8.17       -2.24       -11.05                        304.96              0.00096

AUG     81.35       79.02                79.02       82.44       -9.50       -3.02       -12.55                        324.93              0.00079

SEP     77.23       78.06    70.12       77.21       77.23      -15.84      -10.13       -18.12         8.00           485.43             -0.00122

OCT     72.78       76.39    69.92       74.31       72.10      -19.13      -17.24       -19.97        50.36           593.11             -0.00118

NOV     65.92       77.27    68.88       69.71       64.30      -24.98      -29.15       -23.19       243.98           749.32             -0.00093

DEC     62.30                65.58       65.58       60.06      -30.57      -33.85       -28.33       425.90           947.69             -0.00136

ANNUAL  71.11       78.37    66.54       72.11       71.48      -21.23      -21.94       -21.14      2081.84          7924.53             -0.00071
```

REPORT SS-L — FAN ELECTRIC ENERGY FOR A SPACE

The following report gives a breakdown of fan electric energy for each month for each space. The quantities are given for heating hours only, cooling hours only, simultaneous heating and cooling hours, and floating hours.

1. FAN ELECTRIC ENERGY DURING HEATING gives the total electric energy used by the fan in all hours when heating is required.

2. FAN ELECTRIC ENERGY DURING COOLING gives the total electric energy used by the fan in all hours when cooling is required.

3. FAN ELECTRIC ENERGY DURING HEATING-COOLING gives the total electric energy used by the fan in all hours when either heating or cooling is required.

4. FAN ELECTRIC ENERGY DURING FLOATING gives the total electric energy used by the fan when the system terminal is operating within the deadband range.

```
SIMPLE STRUCTURE RUN 3, CHICAGO                                                    DOE-2.1C  11-JAN-85    09:13:5    SDL RUN 1

REPORT- SS-L  FAN ELECTRIC ENERGY                           SYST-1                           WEATHER FILE- TRY  CHICAGO
--------------------------------------------------------------------------------------------------------------------------


         FAN ELECTRIC     FAN ELECTRIC     FAN ELECTRIC       FAN ELECTRIC
         ENERGY DURING    ENERGY DURING    ENERGY DURING      ENERGY DURING
            HEATING          COOLING       HEATING-COOLING      FLOATING
 MONTH       (KWH)            (KWH)            (KWH)              (KWH)



  JAN      360.218            0.000            0.000              0.909

  FEB      316.950            0.000            0.000              0.000

  MAR      237.799            0.000            0.000             24.537

  APR       58.474          102.274            0.000            109.358

  MAY       11.814          329.396            0.000            133.870

  JUN        0.000          857.813            0.000              3.635

  JUL        0.000         1565.425            0.000              0.000

  AUG        0.000         1318.194            0.000              0.000

  SEP        7.270          573.467            0.000             56.762

  OCT       44.596          152.352            0.000             86.388

  NOV      198.511           29.636            0.000             16.239

  DEC      331.561            0.000            0.000              0.000
         ------------     ------------     --------------     ------------

  ANNUAL  1567.193         4928.556            0.000            431.698
```

REPORT SS-M — FAN ELECTRIC ENERGY FOR THE PLANT

The following report gives a breakdown of fan electric energy for each month passed to PLANT. The quantities are given for heating hours only, cooling hours only, simultaneous heating and cooling hours, and floating hours. The quantities are calculated by summing the individual space quantities. If any space requires heating then the system is considered in the heating mode. The same is true for the other three categories.

1. FAN ELECTRIC ENERGY DURING HEATING gives the total electric energy used by the fan in all hours when heating is required.

2. FAN ELECTRIC ENERGY DURING COOLING gives the total electric energy used by the fan in all hours when cooling is required.

3. FAN ELECTRIC ENERGY DURING HEATING-COOLING gives the total electric energy used by the fan in all hours when either heating or cooling is required.

4. FAN ELECTRIC ENERGY DURING FLOATING gives the total electric energy used by the fan when the system terminal is operating within the deadband range.

```
SIMPLE STRUCTURE RUN 3, CHICAGO                                                     DOE-2.1C  11-JAN-85    09:13:5    SDL RUN 1
REPORT- SS-M  FAN ELECTRIC ENERGY FOR PLANT                    DEFAULT-PLANT                      WEATHER FILE- TRY  CHICAGO
------------------------------------------------------------------------------------------------------------------------------------

         FAN ELECTRIC    FAN ELECTRIC    FAN ELECTRIC      FAN ELECTRIC
         ENERGY DURING   ENERGY DURING   ENERGY DURING     ENERGY DURING
            HEATING         COOLING      HEATING-COOLING      FLOATING
MONTH        (KWH)           (KWH)           (KWH)             (KWH)


 JAN        360.218          0.000             0.000             0.909

 FEB        316.950          0.000             0.000             0.000

 MAR        237.799          0.000             0.000            24.537

 APR         58.474        102.274             0.000           109.358

 MAY         11.814        329.396             0.000           133.870

 JUN          0.000        857.813             0.000             3.635

 JUL          0.000       1565.425             0.000             0.000

 AUG          0.000       1318.194             0.000             0.000

 SEP          7.270        573.467             0.000            56.762

 OCT         44.596        152.352             0.000            86.388

 NOV        198.511         29.636             0.000            16.239

 DEC        331.561          0.000             0.000             0.000
         ------------    ------------    --------------    ------------

 ANNUAL    1567.193       4928.556             0.000           431.698
```

REPORT SS-N — HUMIDITY RATIO SCATTER PLOT FOR <system>

In this scatter plot, the ordinate, appearing in the left column, is a relative humidity range. The abscissa shown at the top is the hours of the day. Entered in each cell of the plot is the number of hours during the year for which the relative humidity was in the particular range for this particular hour of the day. The relative humidity is calculated, for the purposes of this report, at the return air duct. Hours when the fans were off do not show up in the plot.

The far right column is the sum of the entries in each row and shows the relative frequency of relative humidity throughout the year. Since the relative humidity counts are made only for hours when the fans are on, summing the totals column will not sum to the number of hours in the run.

Note: If fans were on due to NIGHT-CYCLE-CTRL, the hours will not be counted in the plot.

```
SIMPLE STRUCTURE RUN 3, CHICAGO                                                        DOE-2.1C  11-JAN-85    09:13:5    SDL RUN 1
REPORT- SS-N  HUMIDITY RATIO SCATTER PLOT FOR           SYST-1                          WEATHER FILE- TRY  CHICAGO
-------------------------------------------------------------------------------------------------------------------------------

                              TOTAL HOURS AT RELATIVE HUMIDITY LEVEL AND TIME OF DAY

        HOUR  1AM    2    3    4    5    6    7    8    9   10   11   12  1PM    2    3    4    5    6    7    8    9   10   11   12  TOTAL
              ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  -----

81-100          0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0      0

71-80           0    0    0    0    0    0    0    0    0    0    0    0    0    1    0    0    0    0    0    0    0    0    0    0      1

61-70           0    0    0    0    0    0    0    0    0    0    0    0    0    0    1    1    1    1    0    0    0    0    0    0      4

51-60           0    0    0    0    0    0    0   13   24   19   12   11    9    6    6    7    9    4    0    0    0    0    0    0    120

41-50           0    0    0    0    0    0    0   78   85   93   96   85   95   99  101   98   93   13    0    0    0    0    0    0    936

31-40           0    0    0    0    0    0    0   32   92   77   73   54   27   46   49   48   50   35    0    0    0    0    0    0    583

0-30            0    0    0    0    0    0    0    3   51   63   71  102  121  100   95   98   99   73    0    0    0    0    0    0    876

              ===  ===  ===  ===  ===  ===  ===  ===  ===  ===  ===  ===  ===  ===  ===  ===  ===  ===  ===  ===  ===  ===  ===  ===  =====
```

REPORT SS-O — TEMPERATURE SCATTER PLOT FOR EACH SPACE

In this scatter plot, the ordinate, appearing in the left column, is a temperature range. The abscissa shown at the top is the hours of the day. Entered in each cell of the plot is the number of hours during the year for which the temperature was in the particular range for this particular hour of the day. Hours when the fans were off do not show up in the plot.

The far right column is the sum of the entries in each row and shows the relative frequency of temperature throughout the year. Since the temperature counts are only made for hours when the fans are on, summing the totals column will not sum to the number of hours in the run.

Note: If fans were on due to NIGHT-CYCLE-CTRL, the hours will not be counted in the plot.

```
SIMPLE STRUCTURE RUN 3, CHICAGO                                              DOE-2.1C  11-JAN-85    09:13:5    SDL RUN 1
REPORT- SS-O  TEMPERATURE SCATTER PLOT  SYST-1          FOR SPACE5-1                      WEATHER FILE- TRY  CHICAGO
------------------------------------------------------------------------------------------------------------------------

                                        TOTAL HOURS AT TEMPERATURE LEVEL AND TIME OF DAY

                 HOUR  1AM    2    3    4    5    6    7    8    9   10   11   12  1PM    2    3    4    5    6    7    8    9   10   11   12  TOTAL
                       ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  -----

ABOVE 85                 0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0      0

81-85                    0    0    0    0    0    0    0    5    5    6    5    4    5    8    8   10   13    0    0    0    0    0    0    0     69

76-80                    0    0    0    0    0    0    0   95  106  109  114  118  124  130  136  136  137   26    0    0    0    0    0    0   1231

71-75                    0    0    0    0    0    0    0   26  132  129  133  130  122  113  107  105  101   99    0    0    0    0    0    0   1197

66-70                    0    0    0    0    0    0    0    0    9    8    0    0    1    1    1    1    1    1    0    0    0    0    0    0     23

61-65                    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0      0

BELOW 60                 0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0      0

                       ===  ===  ===  ===  ===  ===  ===  ===  ===  ===  ===  ===  ===  ===  ===  ===  ===  ===  ===  ===  ===  ===  ===  ===   ====
```

PLANT

INTRODUCTION TO PLANT CHANGES

The DOE-2.1C version of PLANT has been substantially upgraded to include (1) a very sophisticated approach to the allocation of loads to electrical generators and chillers for cogeneration, (2) simpler functional forms for the input/output relationships of these generators, and (3) variable-speed, optionally-sized pumps. The calculation of energy costs has been shifted from PLANT to ECONOMICS so that income from the sale of electricity produced by on-site generators is now possible. The PLANT routine now creates a file of 8760 hours of energy use and ECONOMICS reads this file to calculate energy costs that involve time-of-day and ratcheted demand charges. See the Section "Expanded Treatment of Energy Costs" of this Supplement.

The DOE-2.1C options for the control of electrical generators are an extension of the work described in the documentation of DOE-2.1B. The keywords and techniques for invoking the 2.1B options (i.e. ELEC-GEN-MODE and the use of negative NUMBERs in a LOAD-ASSIGNMENT) have been eliminated.

DOE-2 Solar Simulator

The SOLAR calculational section of the program has been eliminated from the DOE-2.1C version of the program, as it is no longer being supported at Lawrence Berkeley Laboratory. Users who wish to model active solar buildings must use the 2.1B (or 2.1A) version of the code and documentation.

PLANT EQUIPMENT OPERATING MODES

The 2.1C version of DOE-2 features an entirely reworked conception of the operation of chillers and, more importantly, electricity-generating prime movers. Earlier versions of the code simply assumed that, in the case of the electricity generators, only the electrical demands of a facility were important to decisions concerning the operation of a central plant. This reasoning stemmed from the fact that utility and regulatory attitudes toward the on-site generation of power often meant that a decision to generate power on-site was tantamount to leaving the electric grid entirely. The Public Utilities Regulatory Policy Act of 1978 mandated changes in those attitudes by requiring that utilities abandon discriminatory practices and offer fair rates and prices to cogenerators and small power producers. The outcome of this change is that the actual electrical loads of a facility need not be the only consideration utilized in determining the output of primary energy conversion equipment in a central plant.

The concept embodied in DOE-2.1C treats the diesel engine and gas turbine as energy conversion devices with two useful outputs. Accordingly, the choice of which output to use in controlling the operation of these machines has been made an explicit option specifiable by the user. That is, the user can now specify that the machines generate enough heat to meet thermal loads irrespective of the amount of electricity produced and vice versa.

Two new PLANT-PARAMETERS keywords, COGEN-TRACK-MODE and COGEN-TRACK-SCH, are now used to specify the load (thermal or electrical) to be used in controlling the output of either the DIESEL-GEN or GTURB-GEN electrical generators. A third keyword, MIN-TRACK-LOAD, is used to specify the minimum thermal load that will be tracked. A fourth keyword specifies which thermal output(s) (jacket/lube-oil heat, exhaust heat, or both) are to be used for control of thermal-tracking for diesel engines (DIESEL-TRACK-MODE).

A fifth keyword (DBUN-MIN-HEAT) has been added to PLANT-PARAMETERS. It sets the minimum thermal load for heat recovery chillers when operating in tandem with standard chillers. When the DBUN-CHLR is operating alone, it responds to the evaporator load and not the thermal load.

This new freedom to choose which loads the central plant equipment is to meet has resulted in a substantial reworking of the equipment allocation routines and the HEAT-RECOVERY links. For example, the default allocation routines now ensure that the thermal and electrical output of the generators, when coupled with absorption and compression chillers, will be balanced when meeting heating and cooling loads. The input formats to the LOAD-ASSIGNMENT and the HEAT-RECOVERY commands have not changed, although the commands have taken on new capabilities.

PLANT-PARAMETERS

The following keywords have been eliminated:

ELEC-GEN-MODE
MAX-GTURB-EXH
MAX-DIESEL-EXH
STURB-SPEED

COGEN-TRACK-MODE	accepts a code-word that specifies the cogeneration scheme to be used in controlling the output of electrical generators equipped with heat recovery equipment. The allowable code-words are TRACK-ELEC (the default value), TRACK-THERMAL, TRACK-LESSER (of the two previous options), its antithesis TRACK-GREATER, MAX-OUTPUT (full-out electrical generating), and DONT-RUN.
COGEN-TRACK-SCH	accepts the u-name of a schedule of cogeneration schemes. A DAY-SCHEDULE command does not accept code-words, therefore the following values are used to indicate the desired cogeneration scheme: DONT-RUN = 0, TRACK-ELEC = 1, TRACK-THERMAL = 2, TRACK-LESSER = 3, TRACK-GREATER = 4, MAX-OUTPUT = 5. An example of such a schedule appears in Example 3 below.
MIN-TRACK-LOAD	specifies the minimum thermal load that the generators will attempt to track before shifting down. The default is 0.0 Btu/hr, and it can range from 0.0 to 1000.0.
DIESEL-TRACK-MODE	accepts a code-word that specifies which diesel engine heat recovery source(s) will be used to control the output of the engine when tracking thermal loads. The allowable code-words are TRACK-EXH (exhaust heat only), TRACK-JAC/LUB (jacket and lube-oil), and TRACK-BOTH (the default).
DBUN-MIN-HEAT	is the minimum thermal load at which the heat recovery chiller(s) are allowed to operate when in the heat recovery mode and when tracking thermal loads. This keyword will default to 0.0 MBtu. The range is from 0.0 to 1000000.0 MBtu.

LOAD-ASSIGNMENT

LOAD-ASSIGNMENTs for electrical generators are always defined in terms of electrical, not thermal, loads. If cogeneration equipment is to be controlled on the basis of thermal loads (COGEN-TRACK-MODE = TRACK-THERMAL) and a LOAD-ASSIGNMENT(s) is to be used to determine which pieces of cogeneration equipment are to run, the program will use the LOAD-ASSIGNMENT as follows: For every electrical LOAD-RANGE the user inputs under the cogeneration LOAD-ASSIGNMENT the program will calculate an equivalent thermal load range that is the sum of the nominal recoverable outputs of all equipment listed under that LOAD-RANGE Thus, when the program is controlling cogeneration equipment on the basis of a thermal load, the program will compare the hourly thermal load to the thermal load ranges corresponding to the electrical LOAD-RANGE(s) input by the user. The LOAD-RANGE selected will be the one whose equivalent thermal load range matches the hourly thermal load.

To make this discussion more apparent, consider the comments contained in this example input for diesel generators.

```
LOAD-RANGE = 1.0
$THE DOE-2 EQUIVALENT THERMAL-LOAD-RANGE IS ~1.2 MBTU$
PLANT-EQUIPMENT = 300KW-GEN  NUMBER = 1
LOAD-RANGE = 2.6
$THE DOE-2 EQUIVALENT THERMAL-LOAD-RANGE IS ~3.2 MBTU$
PLANT-EQUIPMENT = 750KW-GEN  NUMBER = 1                          ..
```

The thermal-load-ranges are calculated by the program and not input by the user. At peak capacity (100% part load ratio), the diesel generator is operating at 35% efficiency with a 20% exhaust heat efficiency and 23% jacket/lube-oil heat efficiency (the defaults). Therefore, the thermal load range at that full load condition is equal to the electric load range times (20 + 23) / 35 (or 1.22). This relationship changes as the generator loading drops, which lowers the efficiency of the diesel engine. This results in a consequent increase in the ratio of recoverable energy to electrical output. Notice that the thermal load range of a gas turbine at full load (using the default efficiencies) is 55 / 19 (or 2.89) times the electrical output.

Note on the Default Operation of Chillers

In the absence of user-defined operation of chillers via the LOAD-ASSIGNMENT and LOAD-MANAGEMENT commands, the default algorithms utilize information from the keyword SOURCE-SITE-EFF under the ENERGY-RESOURCE command (as well as the EIRs and HIRs of the equipment) to determine whether a heat-driven chiller is more efficient than an electrically-driven one, on the basis of source Btu consumption. A cogeneration plant, of course, produces electricity more efficiently than does a central plant, provided the waste heat is utilized. Therefore, SOURCE-SITE-EFF for RESOURCE = ELECTRICITY should be revised to, say, 0.5 (implying a net heat rate of about 6800 Btu/kWh). The disadvantage of this modification, however, is that the source Btu number in the BEPS report will be inconsistent with the generally agreed upon figures.

HEAT-RECOVERY

Associated with these new keywords are the following new rules for the HEAT-RECOVERY command:

Rules:

1) If a diesel is to thermal track, the exhaust heat and jacket heat should not be entered at the same heat recovery supply level, unless the diesel is to track both the exhaust and jacket heat. If the diesel is to track on the basis of the exhaust at ~600 F or the jacket at ~240 F, the two supplies should be input at different levels.

2) If diesels and gas turbines are in the same plant and exhaust heat is to be recovered from both, the exhaust supplies should be entered at the same level.

3) If diesels and gas turbines are in the same plant, and the diesels are to thermal track, they should not be allowed to track on the basis of jacket heat; they should track either on exhaust heat, or both exhaust and jacket heat.

4) The program assumes that cogeneration equipment with heat recovery will not coexist in a plant with double bundle chillers. If this situation does exist, the user is directed to control the operation of equipment with LOAD-ASSIGNMENTs.

5) When both absorption and compression chillers are in the same plant with cogeneration equipment, and the program is to optimize the cooling operation, the user should exercise care in the assignment of the heat recovery linkages. Normally, space heating and other thermal demands should be input before absorption demands so that the absorption chillers will be given only enough of the cooling load needed to use up the excess waste heat. The compression chillers will then be used to satisfy the remainder of the cooling load. This sequence will prevent the boilers from operating unnecessarily. See Example 1 below.

6) The default operation of the double-bundle chiller is one of tracking the thermal heating loads whenever standard chiller(s) are operated in tandem with double-bundle chillers. When the standard chiller(s) shut down for lack of a sufficient minimum part-load, the double-bundle chiller must track the cooling load. The user is directed to input a LOAD-ASSIGNMENT, if both standard and double-bundle chillers are to be loaded evenly with respect to their evaporators.

Examples

Example 1: We begin the examples with a complete input for a plant with a two-stage absorption chiller, a compression chiller, a gas turbine, and a boiler. Subsequent examples will build upon and modify this input. In this example, the user wants the gas turbine to run full out at all times. By omitting any specification of a LOAD-ASSIGNMENT for the chillers the program will balance the distribution of the cooling load between the absorption and compression chiller to minimize wasting heat.

```
BOIL      = PLANT-EQUIPMENT  TYPE = STM-BOILER
                             SIZE = 5.0  MAX-NUMBER-AVAIL = 1          ..

ELEC-CHLR = PLANT-EQUIPMENT  TYPE = OPEN-CENT-CHLR
                             SIZE = 2.0  MAX-NUMBER-AVAIL = 1          ..

STM-CHLR  = PLANT-EQUIPMENT  TYPE = ABSOR2-CHLR
                             SIZE = 3.0  MAX-NUMBER-AVAIL = 1          ..

TWR       = PLANT-EQUIPMENT  TYPE = COOLING-TWR
                             SIZE = -999                               ..

ELEC-GENR = PLANT-EQUIPMENT  TYPE = GTURB-GEN
                             SIZE = 3.0  MAX-NUMBER-AVAIL = 1          ..

            PLANT-PARAMETERS  COGEN-TRACK-MODE = MAX-OUTPUT            ..

            HEAT-RECOVERY
              SUPPLY-1 = (GTURB-GEN)    $ SPACE HEAT HAS PRIORITY ON WASTE
              DEMAND-1 = (SPACE-HEAT)   $ HEAT.  ABSORPTION CHILLER ONLY
              SUPPLY-2 = (GTURB-GEN)    $ GETS THE EXCESS.  CENTRIFUGAL
              DEMAND-2 = (ABSOR2-CHLR)  $ WILL PICK UP THE REST OF THE
                                        $ COOLING LOAD.  THIS MINIMIZES
                                        $ THE BOILER OPERATION. $      ..
```

Example 2: In this example, diesel generators of 300 kW and 750 kW replace the gas turbine in Example 1. A LOAD-ASSIGNMENT is used to stage the generators. The 300 kW diesel is to be run first, followed by the 750 kW diesel, but never both (or else the facility will violate air quality standards). The user wants the diesels to be controlled by heating loads, and both the jacket and exhaust heat are recoverable for space heating but the recovered heat is not at a high enough temperature for a two-stage absorption chiller so it is changed to single-stage machine ABSOR1-CHLR. The thermal outputs at full load are 1.2 and 3.2 MBtu respectively. The revised input, replacing ELEC-GENR in the previous example, is:

```
300KW-GEN = PLANT-EQUIPMENT  TYPE = DIESEL-GEN  SIZE = 1.0
                             MAX-NUMBER-AVAIL = 1                      ..

750KW-GEN = PLANT-EQUIPMENT  TYPE = DIESEL-GEN  SIZE = 2.6
                             MAX-NUMBER-AVAIL = 1                      ..

            PLANT-PARAMETERS  COGEN-TRACK-MODE = TRACK-THERMAL
                              DIESEL-TRACK-MODE = TRACK-BOTH           ..

            HEAT-RECOVERY  SUPPLY-1 = (DIESEL-GEN,DIESEL-JACKET)
```

```
                           DEMAND-1 = (SPACE-HEAT)
                           SUPPLY-2 = (DIESEL-GEN,DIESEL-JACKET)
                           DEMAND-2 = (ABSOR1-CHLR)                ..

COGEN    = LOAD-ASSIGNMENT  TYPE = ELECTRIC
                            LOAD-RANGE = 1.0
                            PLANT-EQUIPMENT = 300KW-GEN
                            NUMBER = 1
                            LOAD-RANGE = 3.0
                            PLANT-EQUIPMENT = 750KW-GEN
                            NUMBER = 1                             ..

           LOAD-MANAGEMENT  PRED-LOAD-RANGE = 999
                            LOAD-ASSIGNMENT = (DEFAULT,DEFAULT,COGEN) ..
```

The SIZEs of the cogeneration equipment is in terms of electrical capacity, and so are the LOAD-RANGEs. When the cogeneration equipment is thermal tracking, the program will convert the LOAD-RANGEs to equivalent thermal load ranges, which are based on the full load thermal output of the equipment listed under the load range (see the discussion of how the operation of LOAD-ASSIGNMENTs is modified above).

Example 3: This final example demonstrates the use of the keyword that allows cogeneration modes to be scheduled and would be an insert at the PLANT-PARAMETERS command in Example 2. A contractual agreement with the utility requires that the full capacity of the electrical plant be on-line during the on-peak hours of the utility. During the off-peak hours the machines revert to the thermal tracking mode to ensure that the fuel consumed by the generators will be utilized fully. This input corresponds to the ECONOMICS input in Example 7 of the discussion entitled "Expanded Treatment of Energy Costs" in this Supplement.

```
              PLANT-PARAMETERS  DIESEL-TRACK-MODE = TRACK-BOTH
                               COGEN-TRACK-SCH = UTL-CONTRCT       ..

WINTER-WD   = DAY-SCHEDULE  (1,8) (2)      $ TRACK-THERMAL IS CODE 2
                            (9,22) (5)     $ MAX-OUTPUT IS CODE 5
                            (23,24)  (2)                          ..

WINTER-WEH  = DAY-SCHEDULE  (1,24) (0)     $ DONT-RUN IS CODE 0   ..

SUMMER-WD   = DAY-SCHEDULE  (1,8) (2) (9,20) (5) (21,24) (2)      ..

SUMMER-WED  = DAY-SCHEDULE  (1,24)  (0)                           ..

UTL-CONTRCT = SCHEDULE  THRU  MAY 15 (WD) WINTER-WD
                                     (WEH) WINTER-WEH
                        THRU  SEP 15 (WD) SUMMER-WD
                                     (WEH) SUMMER-WEH
                        THRU  DEC 31 (WD) WINTER-WD
                                     (WEH) WINTER-WEH             ..
```

NEW ELECTRICAL EQUIPMENT SIMULATIONS

The algorithms used to model the performance of electrical generators have been modified to permit easier translation of manufacturer's information to actual simulations. The modifications take the form of simpler transfer functions relating the inputs and outputs of the equipment being modeled. A PLANT-PARAMETERS command specifies the full-load conversion efficiency of an input to an output. The EQUIPMENT-QUAD command is then used to relate the full-load performance to operations at fractions of full-load. The default values for the part-load operation of the generators have also been changed. Finally, there are new hourly report variables for the Diesel (11 through 17), Gas Turbine (10 through 13), and Steam Turbine (8 through 13). See the Appendix at the end of this volume for full descriptions.

PLANT-PARAMETERS

Note that MAX-DIESEL-EXH, MAX-GTURB-EXH, and STURB-SPEED have been eliminated.

DIESEL-GEN-EFF	specifies the diesel engine conversion efficiency of fuel to electricity at full-load. The un-loading curve is given by DIESEL-I/O-FPLR. The default is 0.35, and the range is from 0.+ to 1.0.
DIESEL-EXH-EFF	specifies the diesel engine conversion efficiency of fuel to recovered energy from exhaust gasses at full-load. The un-loading curve is given by DIESEL-EXH-FPLR. The default is 0.23, and the range is from 0.+ to 1.0.
DIESEL-J/L-EFF	specifies the diesel engine conversion efficiency of fuel to recovered energy from the jacket and lube-oil at full-load. The un-loading curve is given by DIESEL-JCLB-FPLR. The default is 0.20, and the range is from 0.+ to 1.0.
GTURB-GEN-EFF	specifies the gas turbine conversion efficiency of fuel to electricity at full-load. The un-loading curve is given by GTURB-I/O-FPLR. The default is 0.19, and the range is from 0.+ to 1.0.
GTURB-EXH-EFF	specifies the gas turbine conversion efficiency of fuel to recovered energy from exhaust gasses at full-load. The un-loading curve is given by GTURB-EXH-FPLR. The default is 0.55, and the range is from 0.+ to 1.0.
STURB-MECH-EFF	specifies the mechanical efficiency of the steam turbine in converting theoretical work (defined as an isentropic enthalpy drop through the turbine, see discussion under EQUIPMENT-QUAD) to an electrical output at full-load. The un-loading curve is STURB-I/O-FPLR. The default is 0.60, and the range is from 0.+ to 1.0.

STEAM-SATURATION-T	remains unchanged in its definition, but is no longer used by the diesel and gas turbine simulation routines to calculate the amount of heat recoverable from exhaust gas.

EQUIPMENT-QUAD

Note that the following curves have been eliminated: DIESEL-JAC-FPLR, DIESEL-LUB-FPLR, DIESEL-STACK-FU, GTURB-EXH-FT, GTURB-I/O-FT, GTURB-STACK-FU, GTURB-TEX-FT. Also the functional form of ABSOR1-HIR-FPLR has been changed to a linear or quadratic equation from a cubic one. Table 2 contains a list of the default values for the new curves described below, as well as changes in some existing ones. Table 1 contains a list of the new default values for the minimum, maximum, and optimum PART-LOAD-RATIOs for the electrical generators.

Diesel

DIESEL-I/O-FPLR	accepts the u-name of a CURVE-FIT instruction that defines a linear or quadratic equation. This equation correlates full-load fuel consumption to the fraction of that consumption consumed at other loads (expressed as part-load ratios). In conjunction with PLANT-PARAMETERS instruction DIESEL-GEN-EFF, the equation is used to calculate the amount of diesel fuel energy required to generate a given electrical load.
DIESEL-EXH-FPLR	accepts the u-name of a CURVE-FIT instruction that defines a linear or quadratic equation. This equation correlates the full-load exhaust heat recovery to the fraction of that recovery recovered at other loads (expressed as part-load ratios). In conjunction with PLANT-PARAMETERS instruction DIESEL-EXH-EFF, the equation is used to calculate the amount of exhaust heat recovered at a given electrical load.
DIESEL-JCLB-FPLR	accepts the u-name of a CURVE-FIT instruction that defines a linear or quadratic equation. This equation correlates the full-load jacket and lube oil heat recovery to the fraction of that recovery recovered at other loads (expressed as part-load ratios). In conjunction with PLANT-PARAMETERS instruction DIESEL-J/L-EFF, the equation is used to calculate the amount of jacket and lube oil heat recovered at a given electrical load.
DIESEL-TEX-FPLR	accepts the u-name of a CURVE-FIT instruction that defines a linear or quadratic equation. This equation correlates the temperature of the exhaust gasses to the load being met (expressed as a part-load ratio).

Gas Turbine

GTURB-CAP-FT	accepts the u-name of a CURVE-FIT instruction that defines a linear or quadratic equation. This equation adjusts the nominal capacity rating of a gas turbine as a function of outdoor dry bulb temperature. The adjustment takes the form of a new value for RMAX corresponding to the ratio of highest generating capacity attainable, given the outdoor dry bulb temperature, to the nominal rating.
GTURB-I/O-FPLR	accepts the u-name of a CURVE-FIT instruction that defines a linear or quadratic equation. This equation correlates full-load fuel consumption to the fraction of that consumption consumed at other loads (expressed as part-load ratios). In conjunction with PLANT-PARAMETERS instruction GTURB-GEN-EFF, the equation is used to calculate the gas turbine fuel energy required to generate a given electrical load.
GTURB-EXH-FPLR	accepts the u-name of a CURVE-FIT instruction that defines a linear or quadratic equation. This equation correlates full-load exhaust heat recovery to the fraction of that recovery recovered at other loads (expressed as part-load ratios). In conjunction with PLANT-PARAMETERS instruction GTURB-EXH-EFF, the equation is used to calculate exhaust heat recovered at a given electrical load.
GTURB-TEX-FPLR	accepts the u-name of a CURVE-FIT instruction that defines a linear or quadratic equation. This equation correlates the temperature of the exhaust gasses to the load being met (expressed as a part-load ratio).

Steam Turbine

STURB-ENTH-FPIX	accepts the u-name of a CURVE-FIT instruction that defines a bi-quadratic equation. This equation correlates inlet and exhaust pressures to an isentropic enthalpy drop, which is expressed as a theoretical steam rate (lbs/kWh). Note: When performing curve-fits for STURB-ENTH-FPIX, the user is cautioned to ensure consistency between the enthalpy of the inlet pressure implied by the PLANT-PARAMETERS keywords STURB-T and STURB-PRES, and the isentropic enthalpy drop derived from tables of theoretical steam rates.
STURB-I/O-FPLR	accepts the u-name of a CURVE-FIT instruction that defines a linear or quadratic equation. This equation expresses the electrical output of a steam turbine at part-loads as a function of full-load. In conjunction

with STURB-MECH-EFF, this curve will determine the fraction of the theoretical steam rate (calculated with STURB-ENTH-FPIX) that is converted to electricity.

TABLE 1

New Default Values for PART-LOAD-RATIO

Plant-Equipment	MIN	MAX	OPT
DIESEL-GEN	0.15	1.1	0.95
GTURB-GEN	0.30	1.1	1.0
STURB-GEN	0.10	1.1	1.0

TABLE 2

New Default Performance Curves for EQUIPMENT-QUAD*

Equations are assumed to take the form: $F = a + bx + cx^2 + dy + ey^2 + fxy$ or $F = a + bx + cx^2 + dx^3$

		Default Curve Coefficients						
Keyword	Independent Variable(s)	a	b	c	d	e	f	Curve U-name
Diesel								
DIESEL-I/O-FPLR	PLR	0.107000	0.8930000	—	—	—	—	FUELD
DIESEL-EXH-FPLR	PLR	0.024516	0.3323871	0.6430968	—	—	—	THMHI
DIESEL-JCLB-FPLR	PLR	0.287936	1.0204516	-0.3083871	—	—	—	THMLO
DIESEL-TEX-FPLR	PLR	383.3300	466.67000	—	—	—	—	EXTEMP
Gas Turbine								
GTURB-CAP-FT	ODB	1.240000	-0.0041000	—	—	—	—	GTCAP
GTURB-I/O-FPLR	PLR	0.442979	0.3974000	0.1569621	—	—	—	FUELG
GTURB-EXH-FPLR	PLR	0.295626	0.4930194	0.2113548	—	—	—	THMXH
GTURB-TEX-FPLR	PLR	442.0910	255.73000	144.00000	—	—	—	EXTMP
Steam Turbine								
STURB-ENTH-FPIX	Pin,Pout	38.79236	-0.2113856	0.00052878	1.0200875	0.0009166	-0.00349944	KEENAN
STURB-I/O-FPLR	PLR	0.488308	0.994154	-0.482462	—	—	—	TURBD
Absorption-Chiller								
ABSOR1-HIR-FPLR	PLR	0.877733	0.7449211	0.1673056	—	—	—	HIRPLR1

* The following curves have been eliminated:

DIESEL-JAC-FPLR
DIESEL-LUB-FPLR
DIESEL-STACK-FU

GTURB-EXH-FT
GTURB-I/O-FT
GTURB-STACK-FU
GTURB-TEX-FT

REVISED CIRCULATION PUMP SIMULATIONS

Variable speed and methods of sizing circulation pumps can now be specified with the use of six new PLANT-PARAMETERS keywords. In earlier versions of the code, the simulation of hot and cold water circulation pumps was restricted to fixed speed pumps that were sized to meet the peak demands of the previous SYSTEM run. The new options allow for the sizing of the pumps to be based on either the SYSTEM peak (as before) or the sum of the installed capacities of either the heating equipment or cooling equipment. Once sized, the pumps may be run in either a fixed speed or variable speed mode. For the latter mode, a minimum part-load ratio may be specified to place a floor on the electrical consumption of the pumps. The pipe distribution losses are considered a constant loss with either FIXED-SPEED or VARIABLE-SPEED pumps.

PLANT-PARAMETERS

CCIRC-SIZE-OPT	accepts a code-word that indicates the load that the chilled water circulation pumps will be sized to meet. The allowable code-words are SYSTEM-PEAK (the default) and INST-PLANT-EQUIP. Specifying SYSTEM-PEAK will result in the pumps being sized to meet the peak load passed from SYSTEMS. Specifying INST-PLANT-EQUIP will result in the pumps being sized to meet the total installed capacity of PLANT-EQUIPMENT specified (regardless of whether this equipment was specified by default or input by the user).
HCIRC-SIZE-OPT	accepts a code-word that indicates the load that the hot water circulation pumps will be sized to meet. The allowable code-words and definitions are identical to those available for CCIRC-SIZE-OPT.
CCIRC-PUMP-TYPE	accepts a code-word that specifies whether the chilled water circulation pumps are fixed or variable speed pumps. The allowable code-words are FIXED-SPEED (the default) and VARIABLE-SPEED. If this keyword is set equal to VARIABLE-SPEED, then losses will be determined on the basis of the actual loads being served by the pumps.
HCIRC-PUMP-TYPE	accepts a code-word that specifies whether the hot water circulation pumps are fixed or variable speed pumps. The allowable code-words and definitions are identical to those available for CCIRC-PUMP-TYPE.
CCIRC-MIN-PLR	accepts a numeric value between 0. and 1. that places a floor on the electricity consumption of the chilled water circulation pumps It is expressed as as a fraction of the full load electricity consumption of the pumps. The default is 0.50, and the range is from 0.+ to 1.0.

HCIRC-MIN-PLR	accepts a numeric value between 0. and 1. that places a floor on the electricity consumption of the hot water circulation pumps. It is expressed as fraction of the full load electricity consumption of the pumps. The default is 0.50, and the range is from 0.+ to 1.0.

REPLACEMENT OF ENERGY-COST COMMAND

The calculation of energy costs has been moved from the PLANT simulation to ECONOMICS (see the Section "Expanded Treatment of Energy Costs in this Supplement). This change has not altered the choice of fuels or utilities available for use in the operation of central plants. The existing ENERGY-COST command has been replaced by an ENERGY-RESOURCE command, which may be entered for each fuel or utility. Two keywords, which are identical to the RESOURCE and SOURCE-SITE-EFF in the old ENERGY-COST command, are used in conjunction with ENERGY-RESOURCE.

Several PLANT reports have been modified or eliminated to reflect the removal of energy cost calculations from PLANT. The eliminated reports are PV-D, Cost of Utilities, PV-H, Life-Cycle Parameters, and PS-J, Plant Life-Cycle Cost Summary. Summary report PS-B, Monthly Peak and Total Energy Use, has been modified so that the information pertaining to energy costs no longer appears.

ENERGY-RESOURCE

RESOURCE	accepts a codeword, which informs the simulation that a fuel or utility will be used. The acceptable codewords are STEAM, CHILLED-WATER, ELECTRICITY, NATURAL-GAS, FUEL-OIL, DIESEL-OIL, LPG, COAL, METHANOL, BIOMASS. Note that, as with the existing ENERGY-COST command, an ENERGY-RESOURCE command must be entered, if a steam/hot-water (codeword STEAM) or a chilled water (codeword CHILLED-WATER) utility is to be used.
SOURCE-SITE-EFF	accepts a numeric value, which indicates the generating efficiency of the fuel or utility prior to its use in the facility being simulated. Failure to specify an ENERGY-RESOURCE command for a fuel or utility will result in the use of the default values for SOURCE-SITE-EFF listed below.

Default Values for ENERGY-RESOURCE

RESOURCE	SOURCE-SITE-EFF
CHILLED-WATER	1.5*
STEAM	0.60**
ELECTRICITY	0.333***
NATURAL-GAS	1.0
FUEL-OIL	1.0
COAL	1.0
DIESEL-OIL	1.0
METHANOL	1.0
LPG	1.0
BIOMASS	1.0

* Efficient electrically-driven chillers in a central chilled-water plant.

** Steam produced by heat-only boiler in a central steam generation plant.

*** California Energy Commission conversion factor for electricity: 10,239 Btu/kWh.

ECONOMICS

EXPANDED TREATMENT OF ENERGY COSTS

The calculation of energy costs has been moved from the PLANT subprogram of DOE-2 to ECONOMICS (see the "Replacement of ENERGY-COST Command" Section in this Supplement). New commands and keywords have been added to encompass a wider variety of tariff schedules for energy. Seasonal and time-of-day rates can now be accounted for and the existing block rate structure has been upgraded. Major modifications have been made to enhance the treatment of electricity, including more sophisticated demand ratchet mechanisms and the Congressionally-mandated options for the sale of electricity to a utility.

Three new commands for all utilities (ENERGY-COST, CHARGE-ASSIGNMENT, DAY-CHARGE-SCH) and one special command for electricity (COST-PARAMETERS) are used in ECONOMICS for the calculation of energy costs. The interactions among them can be summarized as follows: The most basic features of a tariff — units, uniform cost rates, monthly charges, etc. — are all contained in an ENERGY-COST command, which is entered for each fuel or utility used in the previous PLANT run. The CHARGE-ASSIGNMENT is used primarily to specify block-rate structures but can also be used for simple uniform rate charges on demands as well as energy. CHARGE-ASSIGNMENTs can be referenced by the ENERGY-COST command in two ways, directly or through a SCHEDULE. Seasonal and time-of-day variations in tariffs require the use of a SCHEDULE (referenced in the ENERGY-COST command for that utility or fuel), which reference DAY-CHARGE-SCHs that, in turn, reference CHARGE-ASSIGNMENTs. The complex features of tariffs for electricity, which include provisions for demand ratchets and the sell-back of electricity to a utility, are specified through COST-PARAMETERS.

Certain summary and verification reports pertaining to energy use and costs have been modified, or completely eliminated, from PLANT. They have been replaced in, or supplemented by, ECONOMICS in the following reports: EV-B, Cost of Fuels and Utilities, ES-D, Summary of Fuel and Utility Use and Costs, ES-E, Summary of Electricity Charges, and ES-F, Summary of Electricity Sales. Samples of the new reports appear at the end of this article.

The discussion of the new commands and associated keywords appear more complex than the actual sample inputs found at the end of this discussion, which display various rates, and can be studied in close conjunction with the following descriptions.

ENERGY-COST

For each utility or fuel used in PLANT, a separate ENERGY-COST command must be entered. The ENERGY-COST command has associated with it several keywords pertaining to the specified utility or fuel, which are similar to the old ENERGY-COST command found in PLANT. For a simple energy cost calculation in which all units consumed are valued at one rate, only the ENERGY-COST command and the associated keywords need be entered. Failure to specify an ENERGY-COST command for a utility or fuel used in PLANT will result in the use of the default values listed in Table 1. For more complex tariffs, involving either blocks or time-of-use/seasonal features, two additional new commands, CHARGE-ASSIGNMENT and DAY-CHARGE-SCH, are required.

RESOURCE	is a required keyword that informs the program which fuel or utility is being valued. The code-words associated with this keyword are identical to those available in PLANT (STEAM, CHILLED-WATER, ELECTRICITY, NATURAL-GAS, LPG, FUEL-OIL, DIESEL-OIL, COAL, METHANOL, BIOMASS). The abbreviation is R.
UNIT	accepts a numeric input that specifies the number of Btu´s in the unit to which the following tariff rates or schedules apply. This value can range from 0.+ to 100000000.0 Btu/unit. Table 1 presents a list of the default values for this keyword by resource. The abbreviation is U.
UNIFORM-COST	accepts a numeric input that allows the user to bypass the more complex energy cost tariffs in favor of a uniform charge rate in dollars per unit. This value can range from 0.0 to 100000.0 $/unit. In the absence of references to a CHARGE-ASSIGNMENT, either directly or through a schedule, this keyword will default in accordance with Table 1. The abbreviation is U-C.
ESCALATION	accepts a numeric input in percent that specifies the annual rate of "real" escalation (relative to the general inflation rate) to be used in life-cycle cost calculations. This value can range from 0.0 to 100.0 %. The default values are listed on Table 1. The abbreviation is E.

TABLE 1

Default Values for ENERGY-COST

RESOURCE	UNIT	UNIFORM-COST ($/Unit)	ESCALATION (%/Year)
STEAM	1000000.00 Btu/unit	13.00	5.0
CHILLED-WATER	1000000.00 Btu/unit	13.4	5.0
ELECTRICITY	3412.97 Btu/kWh	0.0686	5.0
NATURAL-GAS	1031000.00 Btu/MCF	5.53	5.0
LPG	95500.00 Btu/gal.	1.50	5.0
FUEL-OIL	138700.00 Btu/gal.	1.186	5.0
DIESEL-OIL	138700.00 Btu/gal.	1.005	5.0
COAL	24580000.00 Btu/ton	30.00	5.0
METHANOL	63500.00 Btu/gal.	1.13	5.0
BIOMASS	1000000.00 Btu/unit	0.95	5.0

MIN-MONTHLY-CHG	accepts a numeric input that places a floor on the cost of a fuel or utility for each month that costs are calculated. This value can range from 0.0 to 100000.0 $/month and defaults to 0.0. The abbreviation is M-M-C.
FIXED-MONTH-CHG1	accepts a numeric value that adds a fixed charge to each month in the first SEASON, as designated in the CHARGE-ASSIGNMENTs for this utility or fuel. If no CHARGE-ASSIGNMENTs are used, SEASON is always assumed to be the first. If CHARGE-ASSIGNMENTs with different SEASONs overlap in one month, FIXED-MONTH-CHG1 is pro-rated by hours with FIXED-MONTH-CHG2. This value can range from 0.0 to 100000.0 $/month and defaults to 0.0. The abbreviation is F-M-C1.
FIXED-MONTH-CHG2	is identical to FIXED-MONTH-CHG1 except that it applies to the second SEASON specified in a CHARGE-ASSIGNMENT and, if allowed to default, will be set equal to FIXED-MONTH-CHG1. The abbreviation is F-M-C2.
RATE-LIMITATION	accepts a numeric value in dollars per unit that places a ceiling on the effective rate that will be assessed on a utility or fuel for any month. This value can range from 0.0 to 100000.0 $/unit and defaults to 10000.0. The abbreviation is R-L.
ASSIGN-CHARGE	accepts, in parentheses, the u-names of up to two CHARGE-ASSIGNMENTs. There is no default for this keyword. The abbreviation is A-C.
ASSIGN-SCHEDULE	accepts, not in parentheses, the u-name of a SCHEDULE that references CHARGE-ASSIGNMENTs (through WEEK-SCHEDULEs and DAY-CHARGE-SCHs). There is no default for this keyword. The abbreviation is A-SCH.

CHARGE-ASSIGNMENT

The CHARGE-ASSIGNMENT command is used to specify block-style tariffs and has been structured in a manner that is roughly analogous to the LOAD-ASSIGNMENT command in PLANT. That is, several keywords associated with this command may be entered more than once. Note that the repeatable keywords, beginning with TYPE (defined below) must be entered after the non-repeatable keywords (RESOURCE, C-A-LINK, and SEASON) or an error will result. CHARGE-ASSIGNMENTs for a utility or fuel are referenced through the ENERGY-COST command in a manner similar to the way in which the LOAD-MANAGEMENT command in PLANT references LOAD-ASSIGNMENTs, directly or through a schedule. In the latter case, the DAY-CHARGE-SCH command is used in conjunction with the existing SCHEDULE and WEEK-SCHEDULE commands to reflect seasonal and time-of-day tariff schedules. A total of six CHARGE-ASSIGNMENTs may be entered for each utility or fuel. Additional CHARGE-ASSIGNMENTs will generate a warning indicating that they will be ignored. The abbreviation is C-A.

u-name	is a unique user-defined name that must be entered to identify this instruction.
RESOURCE	is a required keyword that identifies the fuel or utility that this CHARGE-ASSIGNMENT is to be applied against. The codewords are STEAM, CHILLED-WATER, ELECTRICITY, LPG, NATURAL-GAS, DIESEL-OIL, FUEL-OIL, COAL, METHANOL, BIOMASS. The abbreviation is R.
C-A-LINK	accepts the u-name of a different CHARGE-ASSIGNMENT, which becomes linked to the present one. This keyword is only used when the RESOURCE is ELECTRICITY and charges are being assessed for demand (kW); it will not affect the calculation of charges, if specified for other fuels or utilities. This link will be used to allocate charges between CHARGE-ASSIGNMENTs in the event that, as a result of scheduling, more than one appears in the same month. For example, if summer on-peak demands switch to winter on peak-demands in mid-September, only the fraction the demand charge corresponding to the ratio of hours of winter on-peak to total on-peak hours (and vice-versa) will be assessed. This prevents the double counting of two "whole-month" demand charges in a single month. The abbreviation is C-A-L.
SEASON	accepts a integer value of 1 or 2 (default = 1) that is used when there are seasonal changes in a set of scheduled CHARGE-ASSIGNMENTs. This keyword will be used to determine which FIXED-MONTH-CHG(1 or 2) or demand ratchet option (see COST-PARAMETERS) will be used. As with C-A-LINK, if there are overlaps in a month, FIXED-MONTH-CHG will be prorated on the basis of hours. The abbreviation is S.
TYPE	accepts a codeword which determines the type of units for energy upon which the charge assignment is to be applied. The codeword ENERGY means that this type of charge is for units per month, and the code-word DEMAND means that the type is for units per hour. With the exception of electricity (see discussion of demand ratchets in COST-PARAMETERS), DEMAND is always taken to be the highest use of energy (or "peak") per hour in the hours of the month to which the CHARGE-ASSIGNMENT applies. ENERGY is the default value. TYPE is the first repeatable keyword allowed in a CHARGE-ASSIGNMENT; a maximum of two TYPEs may appear in one CHARGE-ASSIGNMENT. Note that the keywords listed before TYPE (RESOURCE, C-A-LINK, SEASON), if they are to be entered, must be entered before TYPE.

UNIFORM-CHARGE	accepts a numeric value that specifies a uniform charge rate in dollars per unit, where unit is determined by the previous TYPE. The use of this keyword implies that there is no block rate structure to follow, all units of energy are priced equally. Only one UNIFORM-CHARGE is allowed per TYPE. The range is from 0.0 to 1000.0 $/unit, and there is no default. The abbreviation is U-C.
OVER-BLOCK-RANGE	accepts a numeric value in units of TYPE that define ranges of applicability for the keywords that follow. It corresponds exactly to the LOAD-RANGE keyword in a LOAD-ASSIGNMENT. Up to three OVER-BLOCK-RANGEs can be specified for each TYPE so that the user can specify up to three ranges for which a different set of tariffs is to apply. In operation the code will check to see that the value for TYPE (ENERGY or DEMAND) is less than or equal to the value of OVER-BLOCK-RANGE in order for the following keywords to apply. If it exceeds this value, the code will skip to the next OVER-BLOCK-RANGE and repeat this check until the appropriate set of tariffs is found. If no OVER-BLOCK-RANGE can be found large enough, a warning is issued and no charges are assessed for this TYPE. If no OVER-BLOCK-RANGE is specified, it is assumed that there is only one OVER-BLOCK-RANGE of a very large size. The range is from 0.0 to 10^9 units. The abbreviation is O-B-R.
BLOCK-UNIT	accepts a codeword that can be used to change the units of TYPE being assessed within the OVER-BLOCK-RANGE. The codewords are ENERGY, DEMAND, and KWH/KW. If not specified, BLOCK-UNIT will default to either the previous BLOCK-UNIT or TYPE specified in the OVER-BLOCK-RANGE. BLOCK-UNITs must be consistent with one another; BLOCK-UNITs of DEMAND and ENERGY can not appear in the same OVER-BLOCK-RANGE. Note that KWH/KW is used to specify blocks of energy whose size is a function of demand and therefore is a unit consistent with ENERGY. The abbreviation is B-U.
BLOCK-RANGE	accepts a list enclosed by parentheses of up to ten values indicating the size of the blocks to be used in assessing block-charges. Blocks are increments; hence each successive block covers the next size increment. Rates written as "up to X" must be translated (see Example 2, below). The range is from 0.0 to 10^9, and there is no default. The abbreviation is B-R.
BLOCK-CHARGE	accepts a list enclosed by parentheses of up to ten values corresponding to the charges to be assessed for each of the blocks previously specified in the BLOCK-RANGE. Up to two sets of BLOCK-RANGE/BLOCK-CHARGEs can be specified in each

OVER-BLOCK-RANGE. The range is from -1000.0 to 1000.0 $/unit, and there is no default. The abbreviation is B-C.

DAY-CHARGE-SCH

DAY-CHARGE-SCH	This command accepts, in parentheses, integer values referring to hours and for each of these groups of hours, also in parentheses, up to two u-names of CHARGE-ASSIGNMENTs. In a manner similar to the DAY-ASSIGN-SCH command used in PLANT to schedule LOAD-ASSIGNMENTs, DAY-CHARGE-SCH is referenced by u-name in a WEEK-SCHEDULE command, which, in turn, is referenced by a SCHEDULE command (the reader is referred to the discussion of scheduling concepts contained in the Reference Manual section labeled BDL). The u-name for the SCHEDULE is referenced in the ENERGY-COST command by the keyword ASSIGN-SCHEDULE. DAY-CHARGE-SCH u-names can be nested in the SCHEDULE, thus by-passing WEEK-SCHEDULE. The abbreviation for DAY-CHARGE-SCH is D-C-SCH.
u-name	A unique user-defined name must be entered to identify this instruction.

COST-PARAMETERS

A final command, COST-PARAMETERS, abbreviated as C-P, is used to specify the special features of tariffs for electricity. These include the characteristics of demand ratchets, where the billing demand (kW) is taken to be the larger of the highest demand in the relevant period of the month and a "ratchet" based on previous recorded demands. In calculating demand ratchets, previous recorded demands can include months in the simulation that are "downstream" of the current one. That is, since DOE-2 run periods are for a single year, information from the entire year may be used in calculating the ratchet for a particular month. The COST-PARAMETERS command also accepts keywords that specify how electricity generated on-site (via diesel engines, gas and steam turbines; see the description of PLANT-EQUIPMENT in the "Plant Equipment Operation Modes" Section of this Supplement) is to be accounted for with respect to interconnection with a utility.

DEM-RATCHET-T1	accepts a codeword that identifies how the demand is billed for SEASON = 1. The codewords are MEASURED, HIGHEST, and AVERAGE. MEASURED (the default) implies no ratchet and the billing demand is the highest measured demand for any hour in every given month. HIGHEST implies a ratchet based on the highest demand in the period(s) defined in the ASSIGN-SCHEDULE. AVERAGE implies a ratchet based on an average of highest demand in the period(s) defined in the ASSIGN-SCHEDULE. The abbreviation is D-R-T1.

DEM-RATCHET-T2	is identical to DEM-RATCHET-T1, but applies to the SEASON = 2 as defined by the ASSIGN-SCHEDULE. The default value is that specified (or defaulted) for DEM-RATCHET-T1. The abbreviation is D-R-T2.
DEM-PERIOD-T1	accepts a codeword that limits the duration of a ratchet. The codewords are SEASON and WHOLE-YEAR (the default). SEASON limits the ratchet to a comparison against the highest demand in the months of SEASON = 1. WHOLE-YEAR allows the ratchet to carry for twelve months and, hence, into SEASON = 2 as well. The abbreviation is D-P-T1.
DEM-PERIOD-T2	is identical to DEM-PERIOD-T1, but applies to SEASON = 2. Note that if winter is season 1 and summer is season 2, setting DEM-PERIOD-T1 = SEASON and DEM-PERIOD-T2 = WHOLE-YEAR causes the winter months to be charged the higher of either winter or summer ratchet. For summer months, only the summer ratchet (i.e., highest demand during summer season) applies. The default is DEM-PERIOD-T1. The abbreviation is D-P-T2.
DEM-AVERAGE-MON1	accepts an integer value of 2 (the default) or 3. The program seeks the peak demand for SEASON = 1 as defined in the CHARGE-ASSIGNMENT commands, averages the highest demands for the month on each side of the peak, then compares and selects the higher peak average. The value of 2 limits this comparison to months on each side of the peak month. The value of 3 means that the selection is from the highest average from the combination of one month on either side of the peak, two consecutive months before, or two consecutive months after. The abbreviation is D-A-M1.
DEM-AVERAGE-MON2	is identical to DEM-AVERAGE-MON1, except that it applies to SEASON = 2. The default value is DEM-AVERAGE-MON1, and the abbreviation is D-A-M2.
DEM-RATCHET-FRC1	accepts a numeric value between 0.0 and 1.0 that is multiplied against either the highest or averaged value for months in the first season. The default value is 1.0, and the abbreviation is D-R-F1.
DEM-RATCHET-FRC2	is identical to DEM-RATCHET-FRC1 except that it applies to ratchets calculated in the second season. The default is DEM-RATCHET-FRC1, and the abbreviation is D-R-F2.
POWER-FACT-CORR	accepts a numeric value between 0.0 and 1.0 that is divided into the kW demand or ratchet (whichever is greater) to arrive at the billing demand. Electricity demands are thus adjusted for power phase imbalances between the utility and the site. The default value

	is 1.0, and the abbreviation is P-F-C.
KWH/KW-DEM-TYPE	accepts a codeword that indicates which demand is being used to partition blocks of energy charges in a CHARGE-ASSIGNMENT. The codewords are RECORDED (the default) and BILLING. The codeword RECORDED means that the highest measured demand will be used, when BLOCK-UNIT is KWH/KW. The codeword BILLING means that the billing demand, as determined by the above COST-PARAMETERS keywords will be used. The abbreviation is K-D-T.
ELEC-SALES-OPT	accepts a codeword that indicates the electricity sales option that will be used to value electricity that is generated on-site. The codewords are NET-SALE, SIM-BUY/SELL, and NONE (the default). The codeword NET-SALE indicates that only electricity generated beyond the needs of the facility in a given hour will be sold. Correspondingly, only electricity needed beyond that generated will be purchased in the form of kWh or kW. The codeword SIM-BUY/SELL means that all of the electricity generated on-site will be sold to the utility and all the electricity required on-site will be purchased from the utility. This option represents an accounting fiction that has been mandated to give on-site generators the ability to exploit arbitrage situations, which may arise when the prices paid for electricity sold are different from those paid when it is purchased. The keyword NONE indicates that there is no sales agreement to an outside buyer so that no excess electricity generated on-site can be sold, while any un-met requirements on-site must be purchased from the utility. If either NET-SALE or SIM-BUY/SELL are specified, a ELEC-SALES-ASG or ELEC-SALES-SCH must also be specified. The abbreviation for ELEC-SALES-OPT is E-S-O.
ELEC-SALES-ASG	accepts, in parentheses, the u-name of a CHARGE-ASSIGNMENT with RESOURCE = ELECTRICITY that can be used to value electricity sales to a utility. The CHARGE-ASSIGNMENT is then treated as before except that the charges are treated as income and credited against expenditures for other fuels and utilities. Up to two ELEC-SALES-ASGs may be specified. The abbreviation is E-S-A.
ELEC-SALES-SCH	accepts, not in parentheses, the u-name of a SCHEDULE that references WEEK-SCHEDULEs that reference DAY-CHARGE-SCHs containing u-names of CHARGE-ASSIGNMENTs for use in valuing electricity sales. The abbreviation is E-S-SCH.

CAPACITY-PAYMENT	accepts a numeric value in dollars per year that represents a fixed annual payment for a contracted capacity sold to the utility. The value can range between -100000.0 and 1000000.0 $/yr and the default is 0.0. The abbreviation is C-P.
ELEC-SALES-ESCL	accepts a numeric value between 0.0 and 100.0 that represents in percent per year the rate at which the value of electricity sold to the utility escalates relative to inflation (i.e., "real" escalation). The default value is the value given in the ESCALATION keyword used in the ENERGY-COST command for electricity. The abbreviation is E-S-E.

Examples

To illustrate the use of the new ECONOMICS commands and keywords, a series of examples will be presented. The examples will all be for various electricity tariffs commonly found in the United States but, with the exception of COST-PARAMETERS keywords, can be extended to other fuels and utilities.

Example 1: The most basic tariff is a uniform-charge levied on all units consumed in a month. For this example, all kilowatt-hours cost $.05 and there is a monthly customer charge of $15.00. The minimum bill is $17.00 and there are no demand charges.

```
ENERGY-COST
   RESOURCE=ELECTRICITY          $ THIS IS A REQUIRED KEYWORD $
   UNIT = 3413.                  $ THIS IS THE DEFAULT VALUE $
   UNIFORM-COST = .05
   MIN-MONTHLY-CHG = 17.
   FIXED-MONTH-CHG1 = 15.                                         ..
```

Example 2: Although block rates have been used for years, many of them now incorporate marginal-cost and equity-related concerns. A recent example of the latter, currently in wide usage among residential customers, are inverted block rates. The basic idea is that increased consumption is discouraged by increased per unit costs. A simple inverted block has three tiers. In this example, the first 500 kWh of consumption (sometimes referred to as a "baseline" or "lifeline" quantity) are charged at $.0535 per kWh. All kWh consumed in excess of 500 kWh, but less than 900 kWh, are charged at $.0725 per kWh. The third tier covers all consumption in excess of 900 kWh at a charge of $.1245 per kWh. There is no seasonal variation in this rate and we will ignore minimum and fixed monthly charges in this example.

```
ENERGY-COST
   RESOURCE = ELECTRICITY          $ THIS KEYWORD IS REQUIRED $
   ASSIGN-CHARGE = (INVBLK)                                       ..
```

```
   INVBLK = CHARGE-ASSIGNMENT
      RESOURCE = ELECTRICITY          $ THIS KEYWORD IS REQUIRED $
      TYPE = ENERGY                   $ THIS IS THE DEFAULT VALUE $
      BLOCK-RANGE = (500,400,10000000) $ THE SECOND ENTRY IS THE SIZE OF
                                      $ THE "NEXT" BLOCK AND THE THIRD
                                      $ IS JUST SOME LARGE NUMBER $
      BLOCK-CHARGE = (.0535,.0725,.1245)                              ..
```

Example 3: Most utilities are faced with demands for electricity that are not evenly distributed throughout the year. They reflect the fact that changing levels of demand result in differing costs of service by introducing seasonal variations in the rates for electricity. These variations may have different size blocks associated with them, as well. In this next example, there is a winter season that lasts from October to May and a summer season that lasts from June to September. This utility is winter-peaking, but recognizes the need for increased lifeline allowances at this time of year.

```
    ENERGY-COST
      RESOURCE = ELECTRICITY
      ASSIGN-SCHEDULE = TWOSEASON                                     ..

    WINTERBLK = CHARGE-ASSIGNMENT
      RESOURCE = ELECTRICITY
      BLOCK-RANGE = (1000,1000000)    $ SECOND ENTRY IS A BIG
                                      $ NUMBER $
      BLOCK-CHARGE = (.07,.10)                                        ..

    SUMMERBLK = CHARGE-ASSIGNMENT
      RESOURCE = ELECTRICITY
      BLOCK-RANGE = (500,1000000)
      BLOCK-RANGE = (.06,.09)                                         ..

    WINTERDY = DAY-CHARGE-SCH
      (1,24) (WINTERBLK)                                              ..

    SUMMERDY = DAY-CHARGE-SCH
      (1,24) (SUMMERBLK)                                              ..

    TWOSEASON = SCHEDULE
      THRU MAY 31  (ALL)  WINTERDY  $ NOTE NESTING
      THRU SEP 30  (ALL)  SUMMERDY    OF WEEK-SCHEDULE $
      THRU DEC 31  (ALL)  WINTERDY                                    ..
```

Example 4: Some block rate structures partion energy use by blocks, whose size is determined by demands (kW). There may also be instances where it is not clear which such schedule of charges to apply because this decision is determined by, say, the kW demand, which is not yet known. In this example, the OVER-BLOCK-RANGE is used to decide which schedule to use and BLOCK-UNITs are used to set the actual charges. For this utility, a demand greater than 50 kW means using one schedule of charges, while a demand of less than or equal to 50 kW requires using another. The schedules are identical in the manner in which the blocks are sized, but the charges differ.

	≤50 kW	>50kW	
first 1000 kWh	.050	.060	$/kWh
next 4000 kWh	.045	.055	
next 200 kWh per kW demand	.040	.050	
all remaining kWh	.035	.045	

```
ENERGY-COST
   RESOURCE = ELECTRICITY
   ASSIGN-CHARGE = (KWHKWBLOCK)                                   ..

KWHKWBLOCK = CHARGE-ASSIGNMENT
   RESOURCE = ELECTRICITY   TYPE = DEMAND
      OVER-BLOCK-RANGE = 50          $ THIS SAYS TO USE THE
                                     $ FOLLOWING CHARGES WHEN
                                     $ DEMAND IS LESS THAN
                                     $ 50 KW $
        BLOCK-UNIT = ENERGY
        BLOCK-RANGE = (1000,4000)
        BLOCK-CHARGE = (.05,.045)
        BLOCK-UNIT = KWH/KW
        BLOCK-RANGE = (200,1000000)  $ THE SECOND ENTRY IS
                                     $ JUST SOME LARGE NUMBER $
        BLOCK-CHARGE = (.040,.035)
      OVER-BLOCK-RANGE = 1000000     $ ANOTHER LARGE NUMBER
                                     $ INDICATING THAT DEMANDS
                                     $ WILL BE GREATER THAN
                                     $ THE PREVIOUS ONE FOR
                                     $ FOR THIS SET OF CHARGES $
        BLOCK-UNIT = ENERGY
        BLOCK-RANGE = (1000,4000)
        BLOCK-CHARGE = (.06,.055)
        BLOCK-UNIT = KWH/KW
        BLOCK-RANGE = (200,1000000)
        BLOCK-CHARGE = (.050,.045)                                ..
```

Note in this example that, if the demand to be used in determining the size of the third block is the billing demand not the measured demand, the following command must be included:

```
COST-PARAMETERS
  KWH/KW-DEM-TYPE = BILLING        $ THE DEFAULT VALUE IS
                                   $ MEASURED $
                                                                  ..
```

Example 5: The most significant difference between residential and commercial electricity tariffs is the inclusion of demand charges. Typically, the highest measured demand (integrated over some fraction of an hour) is compared against a "ratchet" chosen or calculated from some set of previous highest demands and the larger of the two is taken to be the billing demand. These tariffs can also include rate limitation features to ensure that when the charges are all totaled the effective rate per kWh is less than or equal to a specified amount. We first present an example in which the ratchet is taken to be 90% of the highest demand recorded in the previous 12 months and the charge is $12.00 per kW. There is a flat charge on energy of $.05 per kWh but in no circumstance can the effective rate (i.e., including the demand charges) exceed $.07 per kWh.

```
ENERGY-COST
  RESOURCE = ELECTRICITY
  RATE-LIMITATION = .07
  ASSIGN-CHARGE = (HIDEMAND)                                        ..

HIDEMAND = CHARGE-ASSIGNMENT
  RESOURCE = ELECTRICITY
  TYPE = ENERGY
    UNIFORM-CHARGE = .05
  TYPE = DEMAND
    UNIFORM-CHARGE = 12.00                                          ..

COST-PARAMETERS
  DEM-RATCHET-T1 = HIGHEST
  DEM-PERIOD-T1  = WHOLE-YEAR
  DEM-RATCHET-FRC1 = .90                                            ..
```

We can alter this example by specifying the ratchet to be the average of the two highest demands in the previous twelve simply by substituting codewords in the COST-PARAMETERS command as follows:

```
COST-PARAMETERS
  DEM-RATCHET-T1 = AVERAGE
  DEM-PERIOD-T1  = WHOLE-YEAR
  DEM-AVERAGE-MON1 = 2                                              ..
```

Example 6: The most recent innovation in rate design has been the introduction of time-of-use rates wherein the time of day, week, and year that energy is consumed get broken into different costing periods and have different charges assigned to them. The charges, moreover, can be for demand and energy and for each of these the definition of the periods can change. In this example, there is a winter and summer season, for each season an on-peak, and off-peak period for each weekday, and only off-peak on Saturday, Sunday and holidays. There is no demand ratchet but there are two demand charge periods corresponding to the the month in each season.

```
ENERGY-COST
  RESOURCE = ELECTRICITY
  ASSIGN-SCHEDULE = TIMEOFUSE                                     ..

WINDEM = CHARGE-ASSIGNMENT
  RESOURCE = ELECTRICITY
  SEASON = 1                     $ FOR THIS EXAMPLE
  C-A-LINK = SUMDEM              $ WINTER=1 SUMMER=2 $
  TYPE = DEMAND
  UNIFORM-CHARGE = 5.00                                           ..

WINOFF = CHARGE-ASSIGNMENT
  RESOURCE = ELECTRICITY
  SEASON = 1                     $ C-A-LINK ONLY FOR DEMANDS.
  TYPE = ENERGY                  $ NOT NEEDED FOR THIS C-A $
  UNIFORM-CHARGE = .04                                            ..

WINON = CHARGE-ASSIGNMENT
  RESOURCE = ELECTRICITY
  SEASON = 1
  TYPE = ENERGY                  $ ENERGY IS THE DEFAULT VALUE $
  UNIFORM-CHARGE = .06                                            ..

SUMDEM = CHARGE-ASSIGNMENT
  RESOURCE = ELECTRICITY
  SEASON = 2
  C-A-LINK = WINDEM
  TYPE = DEMAND
  UNIFORM-CHARGE = 15.00                                          ..

SUMOFF = CHARGE-ASSIGNMENT
  RESOURCE = ELECTRICITY
  SEASON = 2
  TYPE = ENERGY
  UNIFORM-CHARGE = .05                                            ..

SUMON = CHARGE-ASSIGNMENT
  RESOURCE = ELECTRICITY
  SEASON = 2
  TYPE = ENERGY
  UNIFORM-CHARGE = .07                                            ..

WINWEEKDY = DAY-CHARGE-SCH
  (1,8)   (WINOFF,WINDEM)
  (9,22)  (WINON,WINDEM)
  (23,24) (WINOFF,WINDEM)                                         ..

WINWKND = DAY-CHARGE-SCH
  (1,24)  (WINOFF,WINDEM)                                         ..

SUMWEEKDY = DAY-CHARGE-SCH
  (1,8)   (SUMOFF,SUMDEM)
  (9,20)  (SUMON,SUMDEM)
  (21,24) (SUMOFF,SUMDEM)                                         ..
```

```
   SUMWKND = DAY-CHARGE-SCH
     (1,24)  (SUMOFF,SUMDEM)                                          ..

   TIMEOFUSE = SCHEDULE
     THRU MAY 15  (WD)  WINWEEKDY
                  (WEH) WINWKND
     THRU SEP 15  (WD)  SUMWEEKDY
                  (WEH) SUMWKND
     THRU DEC 31  (WD)  WINWEEKDY
                  (WEH) WINWKND                                       ..
```

We now modify the time-of-day example by substituting a DAY-CHARGE-SCH that has shoulder- or partial-peak periods in addition to on- and off-peak periods. For this sub-example, we ignore the specification of the corresponding CHARGE-ASSIGNMENTs beyond mention of the U-name in the DAY-CHARGE-SCH command.

```
WWKDY        =  DAY-CHARGE-SCH
     (1,8) WOFF   (9,16) WPAR   (17,20) WON
     (21,22) WPAR   (23,24) WOFF  $ WPAR IS WINTER  $                 ..
                                  $ PARTIAL-PEAK    $
WWKND        =  DAY-CHARGE-SCH
     (1,24) WOFF                                                      ..

SWKDY        =  DAY-CHARGE-SCH
     (1,8) SOFF   (9,12) SPAR   (13,17) SON
     (18,21) SPAR   (22,24) SOFF  $ SPAR IS SUMMER  $                 ..
                                  $ PARTIAL-PEAK    $
SWKND        =  DAY-CHARGE-SCH
     (1,24) SOFF                                                      ..

TIME-OF-DAY  =  SCHEDULE
     THRU  MAY 15  (WD)  WWKDY   (WEH)  WWKND
     THRU  SEP 15  (WD)  SWKDY   (WEH)  SWKND
     THRU  DEC 31  (WD)  WWKDY   (WEH)  WWKND                         ..
```

Example 7: The Public Utilities Regulatory Policy Act (PURPA) guaranteed on-site generators of electricity fair and equitable access to the utility grid for the purpose of either selling or buying electricity. The Act also mandated that the revenues from the sale of power could be valued in two ways. The first option, called Net-Sale, has the utility purchase only power generated in excess of on-site requirements, while the facility is only billed for electricity required when the on-site requirements exceed the capacity of the on-site generators. The second option, called Simultaneous Buy/Sell, has the utility purchase the full output of the generators (as though this output were dumped directly into the grid), while the facility is billed for the entire amount of electricity consumed on-site (as though there were no generators on-site). Further, utilities were directed to offer payments reflecting the capacity value of the generators. In this example, the simultaneous buy/sell option has been chosen because the utility is currently paying more for electricity it purchases ($.08/kWh) than it charges for what it sells (we will use the time-of-day prices in the previous example). A contract has also been signed with the utility for $80./kW guaranteeing that the cogenerator's capacity of 1 MW will always be available to the utility during the on-peak hours (see Example 3 in the "Plant Equipment Operation Modes" Section of this Supplement).

```
ENERGY-COST
  RESOURCE = ELECTRICITY
  ASSIGN-SCHEDULE = TIMEOFUSE         $ SEE EXAMPLE 6 $
                                                                   ..

COST-PARAMETERS
  ELEC-SALES-OPT = SIM-BUY/SELL
  ELEC-SALES-ASG = SELLELEC
  CAPACITY-PAYMENT = 80000.           $ 1 MW * 80 = 80000. $
                                                                   ..

SELLELEC = CHARGE-ASSIGNMENT
  RESOURCE = ELECTRICITY
  TYPE = ENERGY
  UNIFORM-CHARGE = .08                                             ..
```

ECONOMICS REPORTS

Associated with the movement of energy cost calculations to ECONOMICS is the addition of one new VERIFICATION and three new SUMMARY reports.

REPORT EV-B - COST OF FUELS AND UTILITIES

This verification report lists the user-input and defaulted values for each fuel or utility required by the previous PLANT run. The information is an echo of the inputs to the ENERGY-COST command for each fuel or utility, as understood by the ECONOMICS program. The default values are listed on Table 1.

REPORT ES-D - SUMMARY OF FUEL AND UTILITY USE AND COSTS

This summary report lists the consumption, peak hourly demand, and total cost of each fuel and utility on a monthly and yearly basis. It is analogous to the PLANT summary report PS-B, but differs in that consumption and peak demand are reported in the units used for billing rather than MBtu. The unit, specified by the UNIT keyword in ENERGY-COST, is printed in the heading for each fuel or utility.

```
31-STORY OFFICE BLDG, CHICAGO - LOAD2     RUN 5 POWERED INDUCTION UNITS                DOE-2.1C   9-JAN-85    11:06:10    PDL  RUN 5
                                          SINGLE ZONE UNIT IN BASEMENT
REPORT- ES-D  SUMMARY OF FUEL AND UTILITY USE AND COSTS
---------------------------------------------------------------------------------------------------------------------------------------
                                        ELECTRIC      NTRL-GAS      DIES-OIL
 MONTH                                     UNIT=         UNIT=         UNIT=
                                         3413.90    1000000.00     140000.00
-------                                 --------      --------      --------
 JAN
   ENERGY CONSUMPTION (UNIT/MO)          425795.          317.        22521.
   PEAK DEMAND (UNIT/HR)                   1568.           11.          109.
   TOTAL COST ($)                       33883.42       1567.22      25899.42
 FEB
   ENERGY CONSUMPTION (UNIT/MO)          356069.          183.        19129.
   PEAK DEMAND (UNIT/HR)                   1496.           11.          109.
   TOTAL COST ($)                       32060.56        913.46      21998.70
 MAR
   ENERGY CONSUMPTION (UNIT/MO)          377615.           85.        18185.
   PEAK DEMAND (UNIT/HR)                   1467.           11.          109.
   TOTAL COST ($)                       32678.91        425.83      20912.94
 APR
   ENERGY CONSUMPTION (UNIT/MO)          392002.           60.        17447.
   PEAK DEMAND (UNIT/HR)                   1797.            5.          109.
   TOTAL COST ($)                       33038.59        298.80      20063.91
 MAY
   ENERGY CONSUMPTION (UNIT/MO)          415912.           38.        19006.
   PEAK DEMAND (UNIT/HR)                   2259.            2.          109.
   TOTAL COST ($)                       33636.34        191.47      21856.74
 JUN
   ENERGY CONSUMPTION (UNIT/MO)          443043.           27.        21697.
   PEAK DEMAND (UNIT/HR)                   2527.            3.          109.
   TOTAL COST ($)                       34466.49        135.53      24951.98
 JUL
   ENERGY CONSUMPTION (UNIT/MO)          579923.          197.        25644.
   PEAK DEMAND (UNIT/HR)                   2789.           11.          109.
   TOTAL COST ($)                       40247.00        985.42      29490.21
 AUG
   ENERGY CONSUMPTION (UNIT/MO)          540107.           38.        25374.
   PEAK DEMAND (UNIT/HR)                   2576.            4.          109.
   TOTAL COST ($)                       37330.46        190.75      29179.69
 SEP
   ENERGY CONSUMPTION (UNIT/MO)          403108.           32.        18435.
   PEAK DEMAND (UNIT/HR)                   2430.            2.          109.
   TOTAL COST ($)                       33316.25        159.28      21200.47
 OCT
   ENERGY CONSUMPTION (UNIT/MO)          402967.           45.        17746.
   PEAK DEMAND (UNIT/HR)                   1962.            4.          109.
   TOTAL COST ($)                       33312.71        224.25      20407.89
 NOV
   ENERGY CONSUMPTION (UNIT/MO)          357346.           70.        16800.
   PEAK DEMAND (UNIT/HR)                   1539.            7.          109.
   TOTAL COST ($)                       32105.25        349.77      19319.83
 DEC
   ENERGY CONSUMPTION (UNIT/MO)          403329.          169.        21424.
   PEAK DEMAND (UNIT/HR)                   1546.           11.          109.
   TOTAL COST ($)                       33321.77        842.51      24637.33
------                                  --------      --------      --------
 TOTAL
   ENERGY CONSUMPTION (UNIT/YR)         5097214.         1261.       243408.
   PEAK DEMAND (UNIT/HR)                   2789.           11.          109.
   TOTAL COST ($)                      409397.77       6303.80     279919.13
```

REPORT ES-E - SUMMARY OF ELECTRICITY CHARGES

This summary report contains detailed, month-by-month information on the components of the electricity charges for each CHARGE-ASSIGNMENT in the month.

1. CHARGE-ASSIGNMENT	The u-name of each CHARGE-ASSIGNMENT for each month in which the CHARGE-ASSIGNMENT has been assigned and in which electricity is consumed.
2. HOURS	The number of hours that the CHARGE-ASSIGNMENT was accruing electricity consumption for charges.
3. ENERGY	The total amount of electricity consumed.
4. ENERGY CHARGE	The charges assessed for the electricity consumed.
5. MEASURED DEMAND	The highest demand measured in the hours that the CHARGE-ASSIGNMENT was in effect.
6. BILLING DEMAND	The demand used for assessing demand charges. This quantity is the greater of the measured demand or the ratchet in effect, adjusted by the POWER-FAC-CORR.
7. DEMAND CHARGE	The charges assessed for electricity demand.
8. TOTAL CHARGES	For each month, the sum of the demand and energy charges of each charge assignment, plus any FIXED-MONTH-CHGs, adjusted for MIN-MONTH-CHG and RATE-LIMITATION. For the year, the sum of the monthly total charges.

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31-STORY OFFICE BLDG, CHICAGO - LOAD2    RUN 5 POWERED INDUCTION UNITS            DOE-2.1C   9-JAN-85    11:06:0    EDL  RUN 5
                                         SINGLE ZONE UNIT IN BASEMENT
REPORT- ES-E  SUMMARY OF ELECTRICITY CHARGES
-------------------------------------------------------------------------------------------------------------------------------

         CHARGE-                                 CONSUMPTION      ENERGY        MEASURED      BILLING       DEMAND        TOTAL
 MONTH   ASSIGNMENT                  LENGTH        BY C-A         CHARGE         DEMAND        DEMAND        CHARGE        CHARGES
          (U-NAME)                   (HR/MO)       (KWH)           ($)            (KW)          (KW)          ($)           ($)
 ------- ----------------            -------     ----------     ----------     --------      --------      ----------    ----------

 JAN
         ENCOST                        744         425795.       13800.27        1568.         2510.        20083.15
                                                                                                                          33883.42
 FEB
         ENCOST                        672         356069.       11977.40        1496.         2510.        20083.15
                                                                                                                          32060.56
 MAR
         ENCOST                        744         377615.       12595.76        1467.         2510.        20083.15
                                                                                                                          32678.91
 APR
         ENCOST                        720         392002.       12955.44        1797.         2510.        20083.15
                                                                                                                          33038.59
 MAY
         ENCOST                        744         415912.       13553.19        2259.         2510.        20083.15
                                                                                                                          33636.34
 JUN
         ENCOST                        720         443043.       14248.34        2527.         2527.        20218.15
                                                                                                                          34466.49
 JUL
         ENCOST                        744         579923.       17932.39        2789.         2789.        22314.61
                                                                                                                          40247.00
 AUG
         ENCOST                        744         540107.       16723.54        2576.         2576.        20606.92
                                                                                                                          37330.46
 SEP
         ENCOST                        720         403108.       13233.10        2430.         2510.        20083.15
                                                                                                                          33316.25
 OCT
         ENCOST                        744         402967.       13229.56        1962.         2510.        20083.15
                                                                                                                          33312.71
 NOV
         ENCOST                        720         357346.       12022.10        1539.         2510.        20083.15
                                                                                                                          32105.25
 DEC
         ENCOST                        744         403329.       13238.62        1546.         2510.        20083.15
                                                                                                                          33321.77
----------                                     ------------   ------------                               ------------  ------------
 TOTAL                                           5097214.      165509.71                                   243889.07     409397.77
```

REPORT ES-F - SUMMARY OF ELECTRICITY SALES

This summary report prints details of sales of electricity to the utility on a monthly basis for each CHARGE-ASSIGNMENT in the month. The report will only appear, if the report is requested and ELEC-SALES-OPT is set to NET-SALE or SIM-BUY/SELL.

1. CHARGE-ASSIGNMENT	The u-name of each CHARGE-ASSIGNMENT in the month.
2. ENERGY AVAILABLE	The total amount of electricity sold to the utility, as determined by ELEC-SALES-OPT.
3. PEAK GENERATION	The greatest amount of electricity sold to the utility in one hour, as determined by ELEC-SALES-OPT.
4. TOTAL REVENUES	The revenues generated by the sale of electricity to the utility. The year-end total includes any CAPACITY-PAYMENT specified for electricity sales.

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31-STORY OFFICE BLDG, CHICAGO - LOAD2    RUN 5 POWERED INDUCTION UNITS               DOE-2.1C   9-JAN-85    11:06:0    EDL  RUN 5
                                         SINGLE ZONE UNIT IN BASEMENT
REPORT- ES-F  SUMMARY OF ELECTRICITY SALES
---------------------------------------------------------------------------------------------------------------------------------

         CHARGE-                                AVAILABLE       PEAK          TOTAL
 MONTH   ASSIGNMENT               LENGTH         FOR SALE    GENERATION      REVENUE
          (U-NAME)               (HR/MO)          (KWH)         (KW)           ($)
 ------- ----------------        -------       ----------    ----------    ----------

 JAN
         SELLEC                     744          321189.         1575.       25695.12
 FEB
         SELLEC                     672          272691.         1575.       21815.27
 MAR
         SELLEC                     744          258414.         1575.       20673.14
 APR
         SELLEC                     720          249243.         1575.       19939.47
 MAY
         SELLEC                     744          272144.         1575.       21771.55
 JUN
         SELLEC                     720          310912.         1575.       24872.98
 JUL
         SELLEC                     744          369129.         1575.       29530.33
 AUG
         SELLEC                     744          364789.         1575.       29183.13
 SEP
         SELLEC                     720          264050.         1575.       21124.02
 OCT
         SELLEC                     744          253602.         1575.       20288.15
 NOV
         SELLEC                     720          239383.         1575.       19150.64
 DEC
         SELLEC                     744          304987.         1575.       24398.97

 -----                                         ----------                  ----------
 TOTAL                                         3480535.                    354442.77
```

ECONOMICS

Error, Warning, and Caution Messages

Error Message (1)	SCHEDULE FOR <u-name> HAS HOURS UNACCOUNTED FOR.
Meaning:	If ASSIGN-SCHEDULE is to be used, all hours of the RUN-PERIOD must have a CHARGE-ASSIGNMENT associated with them via a DAY-CHARGE-SCH.
User-Action:	Specify a CHARGE-ASSIGNMENT for the missing hours.
Error Message (2)	RESOURCE <code-word> IN CHARGE-ASSIGNMENT <u-name> DOES NOT MATCH FUEL TYPE.
Meaning:	Either the RESOURCE is mis-specified or the CHARGE-ASSIGNMENT is for a different fuel or utility.
User-Action:	Ensure that the RESOURCE matches the fuel or utility that the CHARGE-ASSIGNMENT is to be used for.
Error Message (3)	INCONSISTENT UNITS FOR BLOCKS IN OVER-BLOCK-RANGE <value> IN CHARGE-ASSIGNMENT <u-name>.
Meaning:	When there are two sets of BLOCKS in an OVER-BLOCK-RANGE, the units must be consistent. KWH/KW and ENERGY are consistent, but DEMAND is consistent only with itself.
User-Action:	Check BLOCK-UNITS in the OVER-BLOCK-RANGE for consistency.
Error Message (4)	MUST ENTER ELEC-SALES-ASG OR ELEC-SALES-SCH FOR ELECTRICITY SALES.
Meaning:	If there is a possibility of electricity sales to the utility (ELEC-SALES-OPT = NET-SALE or SIM-BUY/SELL), then a CHARGE-ASSIGNMENT for sales must be entered and accessed through ELEC-SALES-ASG or ELEC-SALES-SCH.
User-Action:	Enter a CHARGE-ASSIGNMENT for electricity sales and access it through ELEC-SALES-ASG or ELEC-SALES-SCH.

Warning Message (1) PLANT UTILITY <code-word> NOT ENTERED - DEFAULTS ASSUMED.

Meaning: A fuel or utility used in the previous PLANT run was not entered with an ENERGY-COST command in this ECONOMICS run. The default values for UNIT, UNIFORM-COST, and ESCALATION will be used.

User-Action: Enter an ENERGY-COST command for this resource, if values other than the defaults are to be used.

Warning Message (2) TOO MANY CHARGE-ASSIGNMENTS FOR <code-word> <u-name> WILL BE IGNORED.

Meaning: Up to six CHARGE-ASSIGNMENTs may be used with each fuel or utility, additional ones will be ignored.

User-Action: Restrict number of CHARGE-ASSIGNMENTs to six.

Warning Message (3) ASSIGN-CHARGE OR ASSIGN-SCHEDULE FOR <code-word> INCOMPATIBLE WITH UNIFORM-COST - WILL BE IGNORED.

Meaning: Within the ENERGY-COST command a RESOURCE may have a UNIFORM-COST or CHARGE-ASSIGNMENT(s) via ASSIGN-CHARGE or ASSIGN-SCHEDULE, but not both. The UNIFORM-COST will be used.

User-Action: Remove the UNIFORM-COST, if the ASSIGN-CHARGE or ASSIGN-SCHEDULE keyword is to be used.

Warning Message (4) RAN OUT OF OVER-BLOCK-RANGES IN CHARGE-ASSIGNMENT <u-name> - NO CHARGE WILL BE ASSESSED.

Meaning: The value being used to determine which OVER-BLOCK-RANGE is to be used for assessing charges exceeds the value of the largest OVER-BLOCK-RANGE. No charges are assessed.

User-Action: Increase the value of the largest OVER-BLOCK-RANGE.

Warning Message (5) NOT ENOUGH BLOCKS IN OVER-BLOCK-RANGE <value> IN CHARGE-ASSIGNMENT <u-name> - ADDITIONAL USAGE WILL NOT BE INCLUDED IN CHARGES.

Meaning: For this OVER-BLOCK-RANGE, the quantity being charged extends beyond the range of the BLOCKS. The additional usage will have no charge associated with it.

User-Action: Increase the value of the last block.

Caution Message (1) UTILITY <code-word> NOT USED IN PLANT - WILL BE IGNORED.

Meaning: An ENERGY-COST command is entered for a RESOURCE that was not used by the previous PLANT run.

User-Action: Either remove the ENERGY-COST command or enter the RESOURCE in the PLANT run with an ENERGY-RESOURCE command.

APPENDIX A

HOURLY REPORT VARIABLES FOR LOADS, SYSTEMS, AND PLANT

HOURLY-REPORT VARIABLE LIST

LOADS

VARIABLE-TYPE = GLOBAL

VARIABLE-LIST Number	Variable in FORTRAN Code	Description
1	CLRNES	Clearness number
2	TGNDR	Ground temperature (Rankine)
3	WBT	Wet-bulb temperature (^{o}F)
4	DBT	Dry-bulb temperature (^{o}F)
5	PATM	Atmospheric pressure (in. Hg)
6	CLDAMT	Cloud amount, 0 to 10
7	ISNOW	Snow flag (1 = snowfall); not used in simulation.
8	IRAIN	Rain flag (1 = rainfall); not used in simulation.
9	IWNDDR	Wind direction (0-15) (see table, RM Chap. III, Sec. B.3)
10	HUMRAT	Humidity ratio (lb H_2O/lb air)
11	DENSTY	Density of air (lb/ft^3)
12	ENTHAL	Specific enthalpy of air (Btu/lb)
13	DIFSOL	Diffuse horizontal solar radiation from the weather file; zero when no solar on weather file (Btu/hr-ft^2). [Used only in France]
14	DIRSOL	Total direct normal solar radiation from the weather file; zero when no solar on weather file. (Btu/hr-ft^2)
15	SOLRAD	Total horizontal solar radiation from the weather file (Btu/hr-ft^2)
16	ICLDTY	Cloud type (0, 1, or 2) (see table, RM, Chap. III, Sec. B.3)
17	WNDSPD	Wind speed (knots)
18	DPT	Dew-point temperature; only for design days, otherwise, zero (^{o}F)
19	WNDDRR	Wind direction in radians (clockwise from North)
20	CLDCOV	Cloud cover multiplier (fraction of sky covered by cloud) (0 to 1)
21	RDNCC	Clear day direct normal solar radiation times CLDCOV; if solar tape, then set equal to DIRSOL (Btu/hr-ft^2)
22	BSCC	Clear day diffuse solar radiation on a horizontal surface times CLDCOV (Btu/hr-ft^2)
23	SKYA	Heat lost by horizontal exterior wall to sky (Btu/hr-ft^2)
24	DBTR	Dry-bulb temperature (Rankine)
25	ISUNUP	Sun-up flag (= 1 if sun is up; = 0 if down)
26	GUNDOG	Hour angle of sunrise for the day (radians)
27	HORANG	Current hour angle (radians)
28	TDECLN	Tangent of solar declination angle
29	EQTIME	Value of the solar equation of time (hr)
30	SOLCON	Direct normal extraterrestrial solar radiation (Btu/hr-ft^2)
31	ATMEXT	Atmospheric extinction coefficient
32	SKYDFF	Sky diffusivity factor
33	RAYCOS(1)	Solar direction cosine (x)

VARIABLE-TYPE = GLOBAL (cont.)

VARIABLE-LIST Number	Variable in FORTRAN Code	Description
34	RAYCOS(2)	Solar direction cosine (y)
35	RAYCOS(3)	Solar direction cosine (z)
36	RDN	Direct normal solar radiation intensity on a clear day (Btu/hr-ft^2)
37	BSUN	Diffuse solar intensity on a horizontal surface on a clear day (Btu/hr-ft^2)
38	IYR	Year
39	IMON	Month
40	IDAY	Day
41	IHR	Hour (local time; including Daylight Saving Time, if appropriate)
42	IDOY	Day of year (1-365)
43	IDOW	Day of week (1-7)
44	ISCHR	Schedule hour (DST corrected, IHR + IDSTF)
45	ISCDAY	Schedule day (Day of week; 1 = Sunday, 2 = Monday,..., 8 = Holiday)
46	IDSTF	Daylight saving time flag (1 if daylight saving is in effect, 0 if not)
47	PTWV	Pressure caused by wind velocity (inches of water)
48	ATMTUR(IMO)	Atmospheric turbidity factor according to Angstrom.
49	ATMMOI(IMO)	Atmospheric moisture (inches of perceptible water).
50	PHSUND	Solar altitude (degrees above horizon).
51	THSUND	Solar azimuth (degrees) measured clockwise from North
52	ETACLD	Cloudiness factor. Ranges from 0 for overcast sky to 1.0 for clear sky.
53	CHISKF	Exterior horizontal illuminance from clear part of sky (footcandles).
54	OHISKF	Exterior horizontal illuminance from overcast part of sky (footcandles).
55	HISUNF	Exterior horizontal illuminance from direct sun (footcandles).
56	ALFAD	Ratio of exterior horizontal illuminance calculated from measured insolation to exterior horizontal illuminance calculated from theoretical CIE sky luminance distributions.
57	CDIRLW	Luminance efficacy of direct solar radiation (lumens/watt).
58	CDIFLW	Luminance efficacy of diffuse solar radiation from clear part of sky (lumens/watt).
59	ODIFLW	Luminance efficacy of diffuse solar radiation from overcast part of sky (lumens/watt).

VARIABLE-TYPE = BUILDING

For each hour, entries are summed for all spaces with a heating load that hour and appear in BLDDTH (1-18), VARIABLE-LIST numbers 1-18; similarly, entries are summed for all zones with a cooling load and appear in BLDDTC (1-18), VARIABLE-LIST numbers 19-36. For example, if a building has three spaces, S1, S2, and S3, and for a given hour, S1 and S2 each have a net heating load, and S3 has a net cooling load, then: (1) the sensible heating load for S1 and S2 appears in VARIABLE-LIST number 1, the latent heating load appears in VARIABLE-LIST number 2, etc.; (2) the sensible cooling load for S3 appears in VARIABLE-LIST number 19, the latent cooling load for S3 appears in VARIABLE-LIST number 20, etc. All values for VARIABLE-LIST = 1 through 36 are <u>weighted</u> values. All loads are in Btu/hr.

Variable-List Number	Variable in FORTRAN Code	Description
1	BLDDTH(1)	Building heating load (sensible)
2	BLDDTH(2)	Building heating load (latent)
3	BLDDTH(3)	Building wall heating load
4	BLDDTH(4)	Building roof heating load
5	BLDDTH(5)	Building heating load from window conduction
6	BLDDTH(6)	Building heating load from solar radiation through windows
7	BLDDTH(7)	Building sensible heating load from infiltration
8	BLDDTH(8)	Building heating load from interior walls
9	BLDDTH(9)	Building heating load from conduction through underground walls and floors
10	BLDDTH(10)	Building lighting heating load
11	BLDDTH(11)	Building heating load from doors
12	BLDDTH(12)	Building equipment (electrical) heating load (sensible)
13	BLDDTH(13)	Building source heating load (sensible)
14	BLDDTH(14)	Building people heating load (sensible)
15	BLDDTH(15)	Building people heating load (latent)
16	BLDDTH(16)	Building equipment (electrical) heating load (latent)
17	BLDDTH(17)	Building source heating load (latent)
18	BLDDTH(18)	Building infiltration heating load (latent)
19	BLDDTC(1)	Building cooling load (sensible)
20	BLDDTC(2)	Building cooling load (latent)
21	BLDDTC(3)	Building wall cooling load
22	BLDDTC(4)	Building roof cooling load
23	BLDDTC(5)	Building cooling load from window conduction
24	BLDDTC(6)	Building cooling load from solar radiation through windows
25	BLDDTC(7)	Building cooling sensible infiltration load
26	BLDDTC(8)	Building cooling load from conduction through interior walls

VARIABLE-TYPE = BUILDING (cont.)

Variable-List Number	Variable in FORTRAN Code	Description
27	BLDDTC(9)	Building cooling load from conduction through underground walls and floors
28	BLDDTC(10)	Building lighting cooling load
29	BLDDTC(11)	Building cooling load from doors
30	BLDDTC(12)	Building equipment (electrical) cooling load (sensible)
31	BLDDTC(13)	Building source cooling load (sensible)
32	BLDDTC(14)	Building people cooling load (sensible)
33	BLDDTC(15)	Building people cooling load (latent)
34	BLDDTC(16)	Building equipment (electrical) load cooling (latent)
35	BLDDTC(17)	Building source cooling load (latent)
36	BLDDTC(18)	Building infiltration cooling load (latent)
37	QBELEC	Building electric total
38	QBGAS	Building gas total
39	QBHW	Building hot water total
40	QBEQEL	Building equipment electric total
41	QBLTEL	Building light electric total
42	QBELR	Building electric from BUILDING-RESOURCE command
43	QBGASR	Building gas from BUILDING-RESOURCE command
44	QBHWR	Building hot water from BUILDING-RESOURCE command
45	QBELV	Building elevator (included in No. 37, but not in No. 40)

VARIABLE-TYPE = u-name of SPACE

All space gains and loads are in Btu/hr, including electric. The walls below are exterior surfaces with tilt greater than or equal to 45°; roofs are exterior surfaces with tilt less than 45°. (All gains and loads reported here are calculated at constant space air temperatures. Corrections for variable space temperature are made in the SYSTEMS calculation.)

Variable-List Number	Variable in FORTRAN Code	Description
1	QWALQ	Quick wall gain
2	QCELQ	Quick roof gain
3	QWINC	Window conduction gain
4	QWALD	Delayed wall gain
5	QCELD	Delayed roof gain
6	QINTW	Interior wall gain
7	QUGF	Underground floor gain
8	QUGW	Underground wall gain
9	QDOOR	Door gain
10	QEQPS	Electrical equipment sensible gain
11	QEQPS2	Source sensible gain
12	QPPS	People sensible gain
13	QTSKL	Task light gain
14	QSOL	Glass solar gain
15	QPLENUM	Light heat gain to return air
16	QWALD	Quick wall load
17	QCELQ	Quick roof load
18	QWINC	Window conduction load
19	QWALD	Delayed wall load
20	QCELD	Delayed roof load
21	QINTW	Interior wall load
22	QUGF	Underground floor load
23	QUGW	Underground wall load
24	QDOOR	Door load
25	QEQPS	Equipment sensible load
26	QEQPS2	Source sensible load
27	QPPS	People sensible load
28	QPPL	People latent gain
29	QEQPL	Equipment latent gain
30	QEQPL2	Source latent gain
31	QINFL	Infiltration latent gain
32	QTSKL	Task lighting load
33	QSOL	Glass solar load
34	ZLTOTH	Light heat gain to other space
35	QLITE	Light gain
36	QLITEW	Light load
37	QINFS	Infiltration sensible gain
38	QELECT	Electric load for space
39	CFMINF	Infiltration flowrate (cfm)

VARIABLE-TYPE = u-name of SPACE (cont.)

Variable-List Number	Variable in FORTRAN Code	Description
40	QSUMW	Sum of all weighted loads except infiltration and latent
41	ZCOND	Space conductance (Btu/hr-°F)
42	QZS	Space sensible load
43	QZL	Space latent load
44	QZTOT	Space total load
45	QZLTEL	Space electric from lights
46	QZEQEL	Space electric from equipment
47	QZGAS	Space gas
48	QZHW	Space hot water
49	RDAYIL(1)	Daylight illuminance at LIGHT-REF-POINT1 (footcandles).
50	RDAYIL(2)	Daylight illuminance at LIGHT-REF-POINT2 (footcandles).
51	BACLUM(1)	Background luminance (footlamberts) for glare calculation at LIGHT-REF-POINT1.
52	BACLUM(2)	Background luminance (footlamberts) for glare calculation at LIGHT-REF-POINT2.
53	GLRNDX(1)	Daylight glare index at LIGHT-REF-POINT1 calculated after window management (if any) has been employed as a response to MAX-GLARE, MAX-SOLAR-SCH, and/or CONDUCT-TMIN-SCH.
54	GLRNDX(2)	Daylight glare index at LIGHT-REF-POINT2 calculated after window management (if any) has been employed as a response to MAX-GLARE, MAX-SOLAR-SCH, and/or CONDUCT-TMIN-SCH.
55	FPHRP(1)	Multiplier, due to daylighting, on electric lighting power for the lighting zone at LIGHT-REF-POINT1 (varies from 1.0 if no lighting energy reduction to 0.0 if lighting energy reduced to zero).
56	FPHRP(2)	Multiplier, due to daylighting, on electric lighting power for the lighting zone at LIGHT-REF-POINT2 (varies from 1.0 if no lighting energy reduction to 0.0 if lighting energy reduced to zero).
57	<POWER-RED-FAC>	Net multiplier, due to daylighting, on electric lighting power for the entire space (= FPHRP(1) * ZONE-FRACTION1 + FPHRP(2) * ZONE-FRACTION2 + {1- (ZONE-FRACTION1) - (ZONE-FRACTION2)]).

VARIABLE-TYPE = u-name of EXTERIOR-WALL

Variable-List Number	Variable in FORTRAN Code	Description
1	SOLI	Solar radiation on wall after shading (Btu/hr-ft^2)
2	XGOLGE	Fraction of the wall that is shaded
3	FILMU	Outside air film U-value (Btu/hr-ft^2-^{o}F)
4	PCO	Pressure difference across wall caused by wind velocity and stack effect (in. of H_2O)
5	Q	Heat transfer from the wall to the zone (Btu/hr)
6	T	Outside surface temperature for delayed walls (Rankine)
7	CFM	Crack method air flow for wall (cfm)
8	C2	Used in response factor determination of Q and T for delayed walls
9	C3	
10	SUMXDT	
11	SUMYDT	
12	DT	
13	XSXCMP	
14	XSQCMP	
15	ETA	Cosine of the angle between the direction of the sun and the surface outward normal
16	BG	Solar radiation on the wall reflected from ground (Btu/hr-ft^2)
17	RDIR	Intensity of direct solar radiation on the surface, shading neglected (Btu/hr-ft^2)
18	RDIF	Intensity of diffuse solar radiation on the surface (Btu/hr-ft^2)
19	RTOT	Total solar radiation on the surface, shading neglected (Btu/hr-ft^2)

VARIABLE-TYPE = u-name of WINDOW

Except as noted, the following variables are applicable to both exterior windows (WINDOW in EXTERIOR-WALL) and interior windows (WINDOW in INTERIOR-WALL between a sunspace and a non-sunspace).

Variable-List Number	Variable in FORTRAN Code	Description
1	UW	Net overall window U-value (glass U-value multiplied by CONDUCT-SCHEDULE if defined; includes inside and outside film coefficients of the glass) (Btu/hr-ft^2-^{o}F).
2	TDIR	Direct radiation transmission coefficient of all panes of glass in window.
3	ADIRO	Direct radiation absorption coefficient (outer pane(s)).
4	TDIF	Net diffuse radiation transmission coefficient of all panes of glass in window.
5	ADIFO	Diffuse radiation absorption coefficient (outer pane(s)).
6	ADIRI	Direct radiation absorption coefficient (inner pane(s)).
7	ADIFI	Diffuse radiation absorption coefficient (inner pane(s)).
8	FI	Inward flowing fraction of heat from solar radiation absorbed by inner pane(s).
9	FO	Inward flowing fraction of heat from solar radiation absorbed by outer pane(s).
10	AGOLGE	Fraction of window area that is shaded from direct solar radiation. [Exterior WINDOW only]
11	QDIR	Direct solar radiation incident on unshaded part of window, divided by total window area (Btu/hr-ft^2).
12	QDIF	Diffuse solar radiation incident on window divided by total window area (Btu/hr-ft^2).
13	QTRANS	Direct and diffuse solar energy transmitted through glass, divided by total window area (Btu/hr-ft^2), before multiplication by glass shading coefficient, if applicable, and by SHADING-SCHEDULE value. [Exterior WINDOW only]

VARIABLE-TYPE = u-name of WINDOW (cont.)

Variable-List Number	Variable in FORTRAN Code	Description
14	QABS	Direct and diffuse solar energy absorbed by glass and conducted into the space, divided by total window area (Btu/hr-ft^2), before multiplication by glass shading coefficient, if applicable, and by SHADING-SCHEDULE value. [Exterior WINDOW only]
15	QSOLG	Heat gain by solar radiation transmitted through window (Btu/hr): For exterior WINDOW: (QTRANS)*(window area)*(shading coefficient of glass)*(SHADING-SCHEDULE value if defined and shade is in place). For interior WINDOW: (QTRANS + QABS)*(window area)*(shading coefficient of glass)*(SHADING-SCHEDULE value if defined and shade is in place). [Shading coefficient of glass is 1.0 if GLASS-TYPE-CODE is used.]
16	GSHACO	Shading coefficient of glass (1.0 if GLASS-TYPE-CODE is used).
17	QCON	Heat through window by conduction (Btu/hr): QCON = UW*(window area)*(outside DBT - zone temp.) + QABS*(window area)*GSHACO*(SHADING-SCHEDULE value if defined and shade is in place). [Exterior WINDOW only; for interior WINDOWs, see Variable #58, VARIABLE-TYPE = ZONE, in SYSTEMS program.]
18	CFMW	Crack method infiltration air flow through window (Btu/hr). [Exterior WINDOW only]
19	SHMULT	Value by which shading-coefficient of glazing is multiplied when window is covered by a shading device. Determined by SHADING-SCHEDULE.
20	SOLGMX	Transmitted direct solar gain threshold for activation of window shading device (Btu/ft^2-hr). Determined by MAX-SOLAR-SCH.
21	<VIS-TRANS>	Visible transmittance (at normal incidence) of of window glazing (excluding shading device). Given by VIS-TRANS keyword value. [Exterior WINDOW only]
22	TAU1	Value by which visible transmittance of glazing is multiplied when window is covered by a shading device. Determined by VIS-TRANS-SCH. [Exterior WINDOW only]

VARIABLE-TYPE = u-name of WINDOW (cont.)

Variable-List Number	Variable in FORTRAN Code	Description
23	<SHADING-FLAG>	Disposition of window shading device: 0 = no shade assigned to window; 1 = shade assigned but open this hour; 2 = shade assigned and closed this hour due to solar-gain, outside-drybulb-temperature, or glare test, or for daylit spaces, because WIN-SHADE-TYPE = FIXED-INTERIOR or FIXED-EXTERIOR; 3 = shade assigned and closed this hour but no solar-gain, outside-drybulb-temperature, or glare test requested (preset schedule control).
24	<ILLUMW>$_1$	Contribution of window to daylight illuminance at LIGHT-REF-POINT1 with no shading device on window (footcandles). [Exterior WINDOW only]
25	<ILLUMW>$_2$	Contribution of window to daylight illuminance at LIGHT-REF-POINT2 with no shading device on window (footcandles). [Exterior WINDOW only]
26	<ILLUMW>$_3$	Contribution of window to daylight illuminance at LIGHT-REF-POINT1 with window covered by shading device (footcandles). [Exterior WINDOW only]
27	<ILLUMW>$_4$	Contribution of window to daylight illuminance at LIGHT-REF-POINT2 with window covered by shading device (footcandles). [Exterior WINDOW only]

VARIABLE-TYPE = u-name of DOOR

Variable-List Number	Variable in FORTRAN Code	Description
1	FILMU	Outside film U-value (Btu/hr-ft^2-^{o}F)
2	DRGOLG	Fraction of door shaded from direct solar
3	SOLID	Solar radiation on door (Btu/hr-ft^2)
4	TSOLD	Outside surface temperature (^{o}R)
5	QD	Heat flow through door (Btu/hr-ft^2)
6	CFMD	Crack method infiltration air flow (cuft/min)

SYSTEMS

VARIABLE-TYPE = GLOBAL

VARIABLE-LIST Number	Variable in FORTRAN Code	Description
1	IYR	Year of simulation run
2	IMO	Month of simulation run
3	IDAY	Day of simulation run
4	IHR	Hour of simulation run
5	ISCDAY	Day-of-the-week for simulation run (1-7 = Sun-Sat; 8 = holiday)
6	ISCHR	Current hour of simulation run plus daylight saving time flag. (Hour of schedule to be used.)
7	WBT	Outdoor wet-bulb temperature (°F)
8	DBT	Outdoor dry-bulb temperature (°F)
9	PATM	Outdoor atmospheric pressure (in-Hg)
10	HUMRAT	Outdoor humidity ratio (lb H_2O/lb dry air)
11	DENSTY	Outdoor air density (lb/ft^3)
12	ENTHAL	Outdoor air enthalpy (Btu/lb)

The above variables are appropriate to all SYSTEM-TYPEs.

VARIABLE-TYPE = u-name of ZONE

VARIABLE-LIST Number	Variable in FORTRAN Code	Description
1	<QS>	Sensible load at constant temp - from LOADS (Btu/hr)
2	<QL>	Latent load at constant temp, excluding infiltration - from LOADS (Btu/hr)
3	<ZKW>	Zone electrical load - from LOADS (kW)
4	<QP>	Light heat to return air - from LOADS (Btu/hr)
5	<CFMINF>	Outdoor air infiltration rate from LOADS (cfm)
6	<TNOW>	Current hour zone temp (°F)
7	<TSET>	Current hour zone thermostat setting - a diagnostic variable that is not meaningful when <TNOW> is not within HEAT-TEMP-SCH or COOL-TEMP-SCH throttling range (°F)
8	<QNOW>	Current hour heat extraction rate - a diagnostic variable that is not meaningful when <TNOW> is not within HEAT-TEMP-SCH or COOL-TEMP-SCH throttling range (Btu/hr) Excludes heat extraction due to interzone convection across interior wall between sunspace and non-sunspace. For sunspaces, excludes heat extraction due to venting.
9	<CONDUCHR>	Sum of exterior wall + interior wall thermal conductances from LOADS (Btu/hr-°F)
10	Unused	Unused
11	EXCFM	Exhaust air flow rate (cfm)
12	FH	Hot air flow rate (cfm)
13	FC	Cold air flow rate (cfm)
14	CFMZ	Zone design supply air flow rate (cfm)
15	QHBZ	Baseboard heat output to zone (Btu/hr)
16	QOVER	Amount of extra heat extraction needed to hold set point (Btu/hr)
17	THZ	Thermostat set point for heating (°F)
18	TCZ	Thermostat set point for cooling (°F)
19	ERMAX	Maximum heat extraction rate - meaningful only within the current thermostat band (Btu/hr)
20	ERMIN	Minimum heat extraction rate - meaningful only within the current thermostat band (Btu/hr)
21	TRY	Trial zone temperature (if no zone coil activity) (°F)
22	FTD	F in temperature variation calculation (TEMDEV subroutine) (Btu/hr)
23	CORINT	A part of the correction in SYSTEMS for the contribution to the zone load due to conduction from adjacent zones (partially calculated in LOADS) (Btu/hr)
24	G0	Air temperature weighting factors (Btu/hr-°F)
25	G1	
26	G2	
27	G3	
28	SIGMAG	G0 + G1 + G2 + G3 (Btu/hr-°F)

VARIABLE-TYPE = u-name of ZONE (cont.)

VARIABLE-LIST Number	Variable in FORTRAN Code	Description
29	TL	Induced air temperature for TPIU, FPIU, SZCI (^{o}F)
30	ZQHR	Portion of reheat load that would bring the supply temperature to the zone temperature (Btu/hr)
31	TAVE	The average temperature during this hour (^{o}F) This is the value used for the energy calculation
32	ZQH	Zone coil heating (Btu/hr)
33	ZQC	Zone coil cooling (Btu/hr)

The following 15 variables apply only to the systems indicated:

		TPFC FPFC	HP	UHT	UVT	PTAC	
34	FCHPS (1)	TC	TS	-	TS	TS	Cold deck temperature (^{o}F)
35	FCHPS (2)	QH	ZQH	ZQH	ZQH	ZQH	Total and zone heating (Btu/hr)
36	FCHPS (3)	QC	ZQC	-	-	ZQC	Total and zone cooling (Btu/hr)
37	FCHPS (4)	SFKW+RFKW	ZFANKW	ZFANKW	ZFANKW	ZFANKW	Total and zone fan energy (Btu/hr)
38	FCHPS (5)	TM	TM	-	TM	TM	Temperature of mixed air (^{o}F)
39	FCHPS (6)	WR	TC	-	-	TC	WR = return humidity ratio and TC is coil leaving temperature
40	FCHPS (7)	WM	WM	-	-	WM	Mixed air humidity ratio (lb H_2O/lb dry air)
41	FCHPS (8)	WCOIL	WCOIL	-	-	WCOIL	Humidity ratio of air leaving cooling coil (lb H_2O/lb dry air)
42	FCHPS (9)	PO	PO	-	PO	PO	Ratio of outside air to total supply air
43	FCHPS(10)	QCLAT	QCLATZ	-	-	QCLATZ	Latent load (Btu/hr)
44	FCHPS(11)	PLRC	PLRC	-	-	PLRC	Capacity part load ratio (cooling)
45	FCHPS(12)	-	PLRH	-	-	PLRH	Capacity part load ratio (heating)
46	FCHPS(13)	-	EIR	-	-	EIR	Electric input ratio
47	FCHPS(14)	WBTZ	WBTZ	-	-	WBTZ	Zone wet-bulb temperature (^{o}F)
48	FCHPS(15)	-	-	-	-	EIRM3	Supplemental heat load for zone's heat pump this hour (Btu/hr)
49	ACFM						Weighted plenum flowrate (cuft/min)
50	ZKW						Total zone electrical (kW)
51	TCMINZ						Minimum supply temperature for the zone (^{o}F)
52	THMAXZ						Maximum supply temperature for the zone (^{o}F)
53	ERMAXM		All air systems				The extraction rate (Btu/hr) at the top of the dead band
54	ERMINM		All air systems				The extraction rate at the bottom of the dead band (Btu/hr)
55	THR		All air systems				(THROTTLING-RANGE)/2.0 (^{o}F)

VARIABLE-TYPE = u-name of ZONE (cont.)

In the following, "sunspace" is a SPACE with SUNSPACE = YES; "room" is a SPACE with SUNSPACE = NO (the default) which is adjacent to a sunspace.

VARIABLE-LIST Number	Variable in FORTRAN Code	Description
56	<SGIW0>	For room only: total heat gain (unweighted) due to solar radiation coming from adjacent sunspaces through interior windows (Btu/hr).
57	<SLIW0>	For room only: total solar load (weighted) through interior windows from all adjacent sunspaces (Btu/hr).
58	QGWIN	For room or sunspace: heat gain by conduction (unweighted) through interior windows (Btu/hr), calculated with the air temperature of the zone in question fixed at the LOADS calculation temperature and actual temperatures for adjacent zones.
59	QSNABT	For room or sunspace: solar radiation absorbed on the sunspace side (opaque part) of interior walls (Btu/hr).
60	QGOPWL	For room or sunspace: heat gain by conduction (unweighted) through opaque part of interior walls (Btu/hr), calculated with the air temperature of the zone in question fixed at the LOADS calculation temperature and actual temperatures for adjacent zones.
61	QGVEC	For room or sunspace: heat extraction from convection across interior wall. For room, includes contribution from fan heat if AIR-FLOW-TYPE = FORCED-RECIRC (Btu/hr).
62	CFMCVT	For room or sunspace: average airflow due to convection across interior wall (cfm).
63	SSFPT	For sunspace only: sum of the power of venting fan (as specified by SS-VENT-KW) and fan moving air across interior wall (as specified by FAN-KW and AIR-FLOW-RATE in WALL-PARAMETERS) (KW).
64	<QGVNT>	For sunspace only: heat extraction due to venting (Btu/hr)

SYSTEMS

VARIABLES BY SYSTEM-TYPE FOR VARIABLE-TYPE = u-name of ZONE

V-L No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SYSTEM-TYPE	SENSIBLE LOAD-IN	LATENT LOAD-IN	ELECTRIC LOAD-IN	PLENUM LOAD-IN	INFIL. CFM	ZONE TEMP	THERMOST SETPOINT	EXTRACTN RATE	TOTALUA FOR HOUR	UNUSED	EXHAUST CFM	HOT DECK CFM	COLD DECK CFM	SUPPLY CFM
SUM	A	A	A	A	A	A	A	A	A	N	N	N	N	N
SZRH	A	A	A	A	A	A	A	A	A	N	A	N	N	A
MZS	A	A	A	A	A	A	A	A	A	N	A	A	A	A
DDS	A	A	A	A	A	A	A	A	A	N	A	A	A	A
SZCI	A	A	A	A	A	A	A	A	A	N	A	N	N	A
UHT	A	A	A	A	A	A	A	A	A	N	N	A	N	A
UVT	A	A	A	A	A	A	A	A	A	N	N	A	N	A
FPH	A	A	A	A	A	A	A	A	A	N	N	N	N	N
TPFC	A	A	A	A	A	A	A	A	A	N	A	N	N	A
FPFC	A	A	A	A	A	A	A	A	A	N	A	N	N	A
TPIU	A	A	A	A	A	A	A	A	A	N	A	N	N	A
FPIU	A	A	A	A	A	A	A	A	A	N	A	N	N	A
VAVS	A	A	A	A	A	A	A	A	A	N	A	N	N	A
PIU	A	A	A	A	A	A	A	A	A	N	A	N	N	A
RHFS	A	A	A	A	A	A	A	A	A	N	A	N	N	A
HP	A	A	A	A	A	A	A	A	A	N	A	A	A	A
HVSYS	A	A	A	A	A	A	A	A	A	N	A	N	N	A
CBVAV	A	A	A	A	A	A	A	A	A	N	A	N	N	A
RESYS	A	A	A	A	A	A	A	A	A	N	N	N	N	N
PSZ	A	A	A	A	A	A	A	A	A	N	A	N	N	A
PMZS	A	A	A	A	A	A	A	A	A	N	A	A	A	A
PVAVS	A	A	A	A	A	A	A	A	A	N	A	N	N	A
PTAC	A	A	A	A	A	A	A	A	A	N	N	A	A	A

Legend:
A = Appropriate
N = Not appropriate
S = System (or configuration) dependent

SYSTEMS

VARIABLES BY SYSTEM-TYPE FOR VARIABLE-TYPE = u-name of ZONE (cont.)

V-L No.	15	16	17	18	19	20	21	22	23	24	25	26	27	28
SYSTEM-TYPE	BASEBRD HTG RATE	LOAD NOT MET	HTG SET POINT	CLG SET POINT	MAXIMUM COOLING	MAXIMUM HEATING	FLOAT TEMP	F IN TEMDEV	INT TRAN TO ZONE	TEMDEV VAR G0	TEMDEV VAR G1	TEMDEV VAR G2	TEMDEV VAR G3	TEMDEV SIGMAG
SUM	A	A	A	A	A	A	A	D	A	D	D	D	D	D
SZRH	A	A	A	A	A	A	A	D	A	D	D	D	D	D
MZS	A	A	A	A	A	A	A	A	D	D	D	D	D	
DDS	A	A	A	A	A	A	A	D	A	D	D	D	D	D
SZCI	A	A	A	A	A	A	A	D	A	D	D	D	D	D
UHT	A	A	A	A	A	A	A	D	A	D	D	D	D	D
UVT	A	A	A	A	A	A	A	D	A	D	D	D	D	D
FPH	A	A	A	A	A	A	A	D	A	D	D	D	D	D
TPFC	A	A	A	A	A	A	A	D	A	D	D	D	D	D
FPFC	A	A	A	A	A	A	A	D	A	D	D	D	D	D
TPIU	A	A	A	A	A	A	A	D	A	D	D	D	D	D
FPIU	A	A	A	A	A	A	A	D	A	D	D	D	D	D
VAVS	A	A	A	A	A	A	A	D	A	D	D	D	D	D
PIU	A	A	A	A	A	A	A	D	A	D	D	D	D	D
RHFS	A	A	A	A	A	A	A	D	A	D	D	D	D	D
HP	A	A	A	A	A	A	A	D	A	D	D	D	D	D
HVSYS	A	A	A	A	A	A	A	D	A	D	D	D	D	D
CBVAV	A	A	A	A	A	A	A	D	A	D	D	D	D	D
RESYS	A	A	A	A	A	A	A	D	A	D	D	D	D	D
PSZ	A	A	A	A	A	A	A	D	A	D	D	D	D	D
PMZS	A	A	A	A	A	A	A	D	A	D	D	D	D	D
PVAVS	A	A	A	A	A	A	A	D	A	D	D	D	D	D
PTAC	A	A	A	A	A	A	A	D	A	D	D	D	D	D

Legend:

A = Appropriate
N = Not appropriate
S = System (or configuration) dependent
D = For program code debugging only

VARIABLES BY SYSTEM-TYPE FOR VARIABLE-TYPE = u-name of ZONE (cont.)

V-L No.	29	30	31	32	33	34	35	36	37	38	39	40	41	42
SYSTEM-TYPE	IND UNIT AIR TEMP	HEAT TO ZONE T	COOL TO ZONE T	HEATING BY COILS	COOLING BY COILS	UNIT SUP TEMP	UNIT HEATING	UNIT COOLING	UNIT FAN KW	UNIT MIX TEMP	UNIT WR or TC	UNIT MIX HUM	UNIT COIL HUM	UNIT OA-RATIO
SUM	N	N	N	N	N	N	N	N	N	N	N	N	N	N
SZRH	N	A	N	A	N	N	N	N	N	N	N	N	N	N
MZS	N	N	N	N	N	N	N	N	N	N	N	N	N	N
DDS	N	N	N	N	N	N	N	N	N	N	N	N	N	N
SZCI	A	A	N	A	N	N	N	N	N	N	N	N	N	N
UHT	N	N	N	A	A	A	A	A	A	A	S	A	A	A
UVT	N	N	N	A	A	A	A	A	A	A	S	A	A	A
FPH	N	N	N	A	N	N	N	N	N	N	N	N	N	N
TPFC	N	N	N	A	A	A	A	A	A	A	S	A	A	A
FPFC	N	N	N	A	A	A	A	A	A	A	S	A	A	A
TPIU	A	N	N	A	N	N	N	N	N	N	N	N	N	N
FPIU	A	N	N	A	N	N	N	N	N	N	N	N	N	N
VAVS	N	A	N	A	N	N	N	N	N	N	N	N	N	N
PIU	N	A	N	A	N	N	N	N	N	N	N	N	N	N
RHFS	N	A	N	A	N	N	N	N	N	N	N	N	N	N
HP	N	N	N	A	A	A	A	A	A	A	A	A	A	A
HVSYS	N	A	N	A	N	N	N	N	N	N	N	N	N	N
CBVAV	N	A	N	A	N	N	N	N	N	N	N	N	N	N
RESYS	N	N	N	N	N	N	N	N	N	N	N	N	N	N
PSZ	N	A	N	A	N	N	N	N	N	N	N	N	N	N
PMZS	N	N	N	N	N	N	N	N	N	N	N	N	N	N
PVAVS	N	A	N	A	N	N	N	N	N	N	N	N	N	N
PTAC	N	N	N	A	A	A	A	A	A	A	S	A	A	A

Legend:

A = Appropriate

N = Not appropriate

S = System (or configuration) dependent

SYSTEMS

VARIABLES BY SYSTEM-TYPE FOR VARIABLE-TYPE = u-name of ZONE (cont.)

V-L No.	43	44	45	46	47	48	49	50	51	52	53	54	55
SYSTEM-TYPE	UNIT LAT COOL	UNIT COOL PLR	UNIT HEAT PLR	UNIT EIR	UNIT WETBULB	UNIT DEFROST	WEIGHTED CFM	TOTAL ELEC	MINIMUM COOL T	MAXIMUM HEAT T	DEADBAND MAX EXTR	DEADBAND MIN EXTR	THROTTLE OVER TWO
SUM	N	N	N	N	N	N	N	A	N	N	N	N	N
SZRH	N	N	N	N	N	N	A	A	A	A	A	A	A
MZS	N	N	N	N	N	N	A	A	A	A	A	A	A
DDS	N	N	N	N	N	N	A	A	A	A	A	A	A
SZCI	N	N	N	N	N	N	A	A	A	A	A	A	A
UHT	A	A	A	A	A	N	N	A	A	A	A	A	A
UVT	A	A	A	A	A	N	N	A	A	A	A	A	A
FPH	N	N	N	N	N	N	N	A	N	N	N	N	N
TPFC	A	A	A	A	A	N	N	A	A	A	A	A	A
FPFC	A	A	A	A	A	N	N	A	A	A	A	A	A
TPIU	N	N	N	N	N	N	A	A	A	A	A	A	A
FPIU	N	N	N	N	N	N	A	A	A	A	A	A	A
VAVS	N	N	N	N	N	N	A	A	A	A	A	A	A
PIU	N	N	N	N	N	N	A	A	A	A	A	A	A
RHFS	N	N	N	N	N	N	A	A	A	A	A	A	A
HP	A	A	A	A	A	A	N	A	A	A	A	A	A
HVSYS	N	N	N	N	N	N	A	A	A	A	A	A	A
CBVAV	N	N	N	N	N	N	A	A	A	A	A	A	A
RESYS	N	N	N	N	N	N	N	A	A	A	A	A	A
PSZ	N	N	N	N	N	N	A	A	A	A	A	A	A
PMZS	N	N	N	N	N	N	A	A	A	A	A	A	A
PVAVS	N	N	N	N	N	N	A	A	A	A	A	A	A
PTAC	A	A	A	A	A	A	N	A	A	A	A	A	A

Legend:
A = Appropriate
N = Not appropriate
S = System (or configuration) dependent

SYSTEMS

VARIABLES BY SYSTEM-TYPE FOR VARIABLE-TYPE = u-name of ZONE (cont.)

V-L No. SYSTEM-TYPE	56 COM WIN SOL GAIN BTU/HR	57 COM WIN SOL LOAD BTU/HR	58 COM WIN CONDUCTN BTU/HR	59 COM WALL ABSD SOL BTU/HR	60 COM WALL CONDUCTN BTU/HR	61 CONVEC HT GAIN BTU/HR	62 CONVEC AIR FLOW CFM	63 SUNSPACE FAN PWR KW	64 SUNSPACE VENT FLW CFM
SUM	A	A	A	A	A	A	A	A	A
SZRH	A	A	A	A	A	A	A	A	A
MZS	A	A	A	A	A	A	A	A	A
DDS	A	A	A	A	A	A	A	A	A
SZCI	A	A	A	A	A	A	A	A	A
UHT	A	A	A	A	A	A	A	A	A
UVT	A	A	A	A	A	A	A	A	A
FPH	A	A	A	A	A	A	A	A	A
TPFC	A	A	A	A	A	A	A	A	A
FPFC	A	A	A	A	A	A	A	A	A
TPIU	A	A	A	A	A	A	A	A	A
FPIU	A	A	A	A	A	A	A	A	A
VAVS	A	A	A	A	A	A	A	A	A
PIU	A	A	A	A	A	A	A	A	A
RHFS	A	A	A	A	A	A	A	A	A
HP	A	A	A	A	A	A	A	A	A
HVSYS	A	A	A	A	A	A	A	A	A
CBVAV	A	A	A	A	A	A	A	A	A
RESYS	A	A	A	A	A	A	A	A	A
PSZ	A	A	A	A	A	A	A	A	A
PMZS	A	A	A	A	A	A	A	A	A
PVAVS	A	A	A	A	A	A	A	A	A
PTAC	A	A	A	A	A	A	A	A	A

Legend:
A = Appropriate
N = Not appropriate
S = System (or configuration) dependent

VARIABLE-TYPE = u-name of SYSTEM

VARIABLE-LIST Number	Variable in FORTRAN Code	Description
1	TH	Temperature of air leaving heating coil - hot deck temperature (^{o}F)
2	TC	Temperature of air leaving cooling coil - cold deck temperature (^{o}F)
3	TM	Temperature of air entering coil (^{o}F)
4	TR	Return air temperature on the downstream side of the return fan and plenums (^{o}F)
5	QH	Total central heating coil energy input (Btu/hr)
6	QC	Total central cooling coil energy input (Btu/hr)
7	QHZ	Total zone heating energy input (Btu/hr)
8	QCZ	Total zone cooling energy input (Btu/hr). Note: For SYSTEM-TYPE = RESYS this is the total of mechanical cooling and cooling by natural ventilation (excluding sunspace ventilation)
9	QHB	Total baseboard heating energy input (Btu/hr)
10	QHP	Total preheat coil energy input (Btu/hr)
11	QHUM	Humidification energy input (electrical resistance heat load for RESYS) (Btu/hr)
12	QDHUM	Sensible dehumidification reheat input (defrost load for RESYS) (Btu/hr)
13	TCMIN	Minimum temperature air handler could supply (^{o}F)
14	THMAX	Maximum temperature air handler could supply (^{o}F)
15	QLSUM	Total system latent heat load from LOADS (Btu/hr)
16	QPSUM	Total system light heat to return (Btu/hr)
17	CFM	Total system supply air flow rate (cfm)
18	CFMH	Total system hot supply air flow rate (DDS, MZS, PMZS) (cfm)
19	CFMC	Total system cold supply air flow rate (DDS, MZS, PMZS) (cfm)
20	RCFM	Total system return air flow rate (cfm)
21	ECFM	Total system exhaust air flow rate (cfm)
22	CINF	Outside air infiltration rate (cfm)
23	FON	Fan on/off flag (1 = on, 0 = off, -1 = cannot cycle on for NIGHT-CYCLE-CTRL)
24	HON	Heating on/off flag (1 = on, 0 = off)
25	CON	Cooling on/off flag (1 = on, 0 = off)
26	BON	Baseboard heater on-off flag (ratio from RESET-SCHEDULE)
27	CONS(1)	in the equation Q = CONS(1) * CFM * ΔT CONS(1) = (.24 + .44*HUMRAT)*60.0/V(DBT, HUMRAT, PATM) = 1.08 at standard conditions
28	CONS(2)	in the equation CONS(2) = 1061.0 * 60.0/V(DBT, HUMRAT, PATM) = 4790. at standard conditions
29	CONS(3)	in the equation CONS(3) = .3996/CONS(1) = .363 at standard conditions

VARIABLE-TYPE = u-name of SYSTEM (cont.)

VARIABLE-LIST Number	Variable in FORTRAN Code	Description
30	PH	For dual duct systems: Ratio of hot duct cfm to total cfm
31	PC	For dual duct systems: Ratio of cold duct cfm to total cfm
32	SKW	Hourly total electrical consumption (kW)
33	FANKW	Total of supply fan, return fan, and exhaust fan electrical consumption (kW)
34	DTREC	Makeup air temperature obtainable from recovery system (°F)
35	WR	Return air humidity ratio (lb H_2O/lb dry air)
36	WM	Mix air humidity ratio (lb H_2O/lb dry air)
37	WCOIL	Humidity ratio of air leaving cooling coil (lb H_2O/lb dry air)
38	WW	Moisture added or removed from air for (de)humidification (lb H_2O/lb dry air)
39	PO	Ratio of outside air to total supply air
40	D	Density of air x 60 min/hr (lb/ft^3 x min/hr)
41	FTEMP	Temperature of circulating fluid for HP system (°F)
42	TCR	Effect of controller on cooling coil set point (°F)
43	QHR	Adjusted capacity of heat pump this hour for RESYS and PTAC (Btu/hr)
44	QCR	Unused
45	SGAS	Total gas heating (Btu/hr)
46	SKWQH	Electrical input to heating (kW)
47	SKWQC	Electrical input to cooling (kW)
48	QCLAT	Latent part of total cooling (Btu/hr)
49	SFKW	Supply fan electrical (kW)
50	RFKW	Return fan electrical (kW)
51	FONNGT	If system cycled on at night, = -1 for heating, = 0 for no cycle, = +1 for cooling
52	WSURF	Humidity ratio at saturation at coil surface temperature
53	WSURFM	WSURF for coil temperature TSURFM
54	TSURF	coil surface temperature at supply set point (°F)
55	TSURFM	Minimum obtainable surface temperature for humidity control (°F)
56	CBF	Coil bypass factor: (COIL-BF) * CBF1 * CBF2
57	CBF1	Temperature correction to COIL-BF
58	CBF2	Cfm correction to COIL-BF
59	SOIL	Oil consumption by system (Btu/hr)
60	PLRCFM	(Current hour cfm)/(design cfm)
61	PLRC	Capacity part load ratio for cooling
62	PLRH	Capacity part load ratio for heating
63	QCM1	Temperature correction to COOLING-CAPACITY
64	QCM2	Temperature correction to COOL-SH-CAP
65	QHM1	Temperature correction to HEATING-CAPACITY
66	EIRM1	Temperature correction to COOLING-EIR
67	EIRM2	Part load correction to COOLING-EIR

VARIABLE-TYPE = u-name of SYSTEM (cont.)

VARIABLE-LIST Number	Variable in FORTRAN Code	Description
68	EIR	(COOLING-EIR) * EIRM1 * EIRM2 (Btu/Btu)
69	OFKW	Outside fan power (kW)
70	QCT	Total cooling capacity (Btu/hr)
71	QCS	Sensible cooling capacity (Btu/hr)
72	WRMAX	Maximum humidity set point (lbs. water/lbs. air)
73	WRMIN	Minimum humidity set point (lbs. water/lbs. air)
74	CFMRAT	Maximum ratio of zone cfm that can be obtained this hour (mainly for COINCIDENT-sized fans)
75	PCH	For DDS, MZS, and PMZS the current hour value of HCOIL-WIPE-FCFM. For RESYS the value of 1. indicates venting and the value of 0. indicates no venting
76	unused	
77	unused	
78*	QHT	The total heating capacity (Btu/hr)
79*	TPOMIN	The mixed air temperature for minimum OA damper position (°F)
80*	POMIN	The minimum OA damper position (°F)
81	QHSUP	For RESYS, PSZ, and PTAC, the total supplemental heat load (Btu/hr)
82	QRSENS	Sensible heat gain to zone from refrigerated casework (PSZ only) (Btu/hr)
83	QRLAT	Latent heat gain to zone from refrigerated casework (PSZ only) (Btu/hr)
84	QRREC	Energy recovered from condenser and used for space heating in heat recovery mode (PSZ only) (Btu/hr)
85	QRREJ	Energy rejected from condenser (PSZ only) (Btu/hr)
86	RCOMKW	Electrical energy consumed by compressors (PSZ only) (kW)
87	RDEFKW	Electrical energy consumed by defrosters (PSZ only) (kW)
88	RAUXKW	Electrical energy consumed by lights, fans, and anti-sweat heaters in refrigerated casework (PSZ only) (kW)

*These variables do not apply to SUM, FPH, or any zonal SYSTEM-TYPEs.

SYSTEMS

VARIABLES BY SYSTEM-TYPE FOR VARIABLE-TYPE = u-name of SYSTEM

V-L No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SYSTEM-TYPE	HTG COIL AIR TEMP	CLG COIL AIR TEMP	MIXED AIR TEMP	RETURN AIR TEMP	TOT HTG COIL BTU	TOT CLG COIL BTU	TOT ZONE HTG BTU	TOT ZONE CLG BTU	TOT BSBD ENERGY	TOT PREH ENERGY	HUMIDCN HEATING	DEHUMID REHEAT	MIN SUP T	MAX SUP T
SUM	N	N	N	N	A	A	N	N	N	N	N	N	N	N
SZRH	N	A	A	A	A	A	A	A	A	A	A	A	A	A
MZS	A	A	A	A	A	A	N	N	A	A	A	A	A	A
DDS	A	A	A	A	A	A	N	N	A	A	A	A	A	A
SZCI	N	A	A	A	A	A	A	A	A	A	A	A	A	A
UHT	N	N	N	N	A	A	A	N	A	N	N	N	N	N
UVT	N	N	N	N	A	A	A	N	A	N	N	N	N	N
FPH	N	N	N	N	A	N	A	N	A	N	N	N	N	N
TPFC	N	N	N	N	A	A	A	A	A	N	A	A	N	N
FPFC	N	N	N	N	A	A	A	A	A	N	A	A	N	N
TPIU	N	A	A	A	A	A	A	A	A	A	A	A	A	A
FPIU	N	A	A	A	A	A	A	A	A	A	A	A	A	A
VAVS	N	A	A	A	A	A	A	A	A	A	A	A	A	A
PIU	N	A	A	A	A	A	A	A	A	A	A	A	A	A
RHFS	N	A	A	A	A	A	A	A	A	A	A	A	A	A
HP	N	N	N	N	A	A	A	A	A	N	N	N	N	N
HVSYS	A	N	A	A	A	N	A	N	A	A	A	N	A	A
CBVAV	N	A	A	A	A	A	A	A	A	A	A	A	A	A
RESYS	A	A	A	A	A	A	A	A	A	A	S	S	A	A
PSZ	N	A	A	A	A	A	A	A	A	A	A	A	A	A
PMZS	A	A	A	A	A	A	N	N	A	A	A	A	A	A
PVAVS	N	A	A	A	A	A	A	A	A	A	A	A	A	A
PTAC	A	N	N	N	A	A	A	A	A	N	N	N	N	N

Legend:

A = Appropriate
N = Not appropriate
S = System (or configuration) dependent

VARIABLES BY SYSTEM-TYPE FOR VARIABLE-TYPE = u-name of SYSTEM (cont.)

V-L No.	15	16	17	18	19	20	21	22	23	24	25	26	27	28
SYSTEM-TYPE	SUM ZONE LAT HEAT	SUM ZONE PLN HEAT	TOT SYST CFM	TOT HOT CFM	TOT COLD CFM	RETURN CFM	EXHAUST CFM	INFILTRN CFM	FANS ON-OFF	HEAT ON-OFF	COOL ON-OFF	BSBD SCH RATIO	CONSTANT (1.08)	CONSTANT (.6890)
SUM	A	A	N	N	N	N	N	A	A	A	A	N	N	N
SZRH	A	A	A	N	N	A	A	A	A	A	A	A	A	A
MZS	A	A	A	A	A	A	A	A	A	A	A	A	A	A
DDS	A	A	A	A	A	A	A	A	A	A	A	A	A	A
SZCI	A	A	A	N	N	A	A	A	A	A	A	A	A	A
UHT	N	N	N	N	N	N	N	N	A	A	A	A	A	A
UVT	N	N	N	N	N	N	N	N	A	A	A	A	A	A
FPH	N	N	N	N	N	N	N	N	N	A	N	A	N	N
TPFC	N	N	N	N	N	N	N	N	A	A	A	A	A	A
FPFC	N	N	N	N	N	N	N	N	A	A	A	A	A	A
TPIU	A	A	A	N	N	A	A	A	A	A	A	A	A	A
FPIU	A	A	A	N	N	A	A	A	A	A	A	A	A	A
VAVS	A	A	A	N	N	A	A	A	A	A	A	A	A	A
PIU	A	A	A	N	N	A	A	A	A	A	A	A	A	A
RHFS	A	A	A	N	N	A	A	A	A	A	A	A	A	A
HP	N	N	N	N	N	N	N	N	A	A	A	A	A	A
HVSYS	A	A	A	N	N	A	A	A	A	A	A	A	A	A
CBVAV	A	A	A	N	N	A	A	A	A	A	A	A	A	A
RESYS	A	A	A	N	N	N	N	A	A	A	A	A	A	A
PSZ	A	A	A	N	N	A	A	A	A	A	A	A	A	A
PMZS	A	A	A	A	A	A	A	A	A	A	A	A	A	A
PVAVS	A	A	A	N	N	A	A	A	A	A	A	A	A	A
PTAC	N	N	N	N	N	N	N	N	A	A	A	A	A	A

Legend:

A = Appropriate
N = Not appropriate
S = System (or configuration) dependent

SYSTEMS

VARIABLES BY SYSTEM-TYPE FOR VARIABLE-TYPE = u-name of SYSTEM (cont.)

V-L No.	29	30	31	32	33	34	35	36	37	38	39	40	41	42
SYSTEM-TYPE	CONSTANT (.363)	HOT AIR FRACTION	COLD AIR FRACTION	TOTAL ELEC KW	TOTAL FAN ELEC	DELTA-T RECOVERY	RETURN HUMID	MIX HUMID	HUMIDITY LVG COIL	MOIST CHANGE	OUTSIDE/ TOT CFM	DENSITY AIR*60	TEMP OF FLUID	COOL-CTR EFFECT
SUM	N	N	N	A	N	N	N	N	N	N	N	N	N	N
SZRH	A	N	N	A	A	A	A	A	A	A	A	A	N	A
MZS	A	A	A	A	A	A	A	A	A	A	A	A	N	A
DDS	A	A	A	A	A	A	A	A	A	A	A	A	N	A
SZCI	A	N	N	A	A	A	A	A	A	A	A	A	N	A
UHT	A	N	N	A	A	N	N	N	N	N	N	N	N	N
UVT	A	N	N	A	A	N	N	N	N	N	N	N	N	N
FPH	N	N	N	A	N	N	N	N	N	N	N	N	N	N
TPFC	A	N	N	A	A	N	N	N	N	N	N	N	N	N
FPFC	A	N	N	A	A	N	N	N	N	N	N	N	N	N
TPIU	A	N	N	A	A	A	A	A	A	A	A	A	N	A
FPIU	A	N	N	A	A	A	A	A	A	A	A	A	N	A
VAVS	A	N	N	A	A	A	A	A	A	A	A	A	N	A
PIU	A	N	N	A	A	A	A	A	A	A	A	A	N	A
RHFS	A	N	N	A	A	A	A	A	A	A	A	A	N	A
HP	A	N	N	A	A	N	N	N	N	N	N	N	A	N
HVSYS	A	N	N	A	A	A	A	A	A	A	A	A	N	N
CBVAV	A	N	N	A	A	A	A	A	A	A	A	A	N	A
RESYS	A	N	N	A	A	N	N	A	A	A	N	N	N	N
PSZ	A	N	N	A	A	A	A	A	A	A	A	A	N	A
PMZS	A	A	A	A	A	A	A	A	A	A	A	A	N	A
PVAVS	A	N	N	A	A	A	A	A	A	A	A	A	N	A
PTAC	A	N	N	A	A	N	N	N	N	N	N	N	N	N

Legend:
A = Appropriate
N = Not appropriate
S = System (or configuration) dependent

SYSTEMS

VARIABLES BY SYSTEM-TYPE FOR VARIABLE-TYPE = u-name of SYSTEM (cont.)

V-L No.	43	44	45	46	47	48	49	50	51	52	53	54	55	56
SYSTEM-TYPE	QHR	QCR	HEATING GAS	HEATING ELEC	COOLING ELEC	LATENT COOLING	SUPPLY ELEC	RETURN ELEC	CYCLE ON H/OFF/C	SURFACE HUMIDITY	SURFACE MIN HUM	SURFACE TEMP	SURFACE MIN TEMP	BYPASS FACTOR
SUM	N	N	A	A	N	N	N	N	A	N	N	N	N	N
SZRH	A	N	A	A	A	A	A	A	A	A	A	A	A	A
MZS	N	N	A	A	A	A	A	A	A	A	A	A	A	A
DDS	N	N	A	A	A	A	A	A	A	A	A	A	A	A
SZCI	A	N	A	A	A	A	A	A	A	A	A	A	A	A
UHT	N	N	A	A	N	N	N	N	A	N	N	N	N	N
UVT	N	N	A	A	N	N	N	N	A	N	N	N	N	N
FPH	N	N	N	A	N	N	N	N	A	N	N	N	N	N
TPFC	N	N	A	A	N	A	N	N	A	N	N	N	N	N
FPFC	N	N	A	A	N	A	N	N	A	N	N	N	N	N
TPIU	N	N	A	A	N	A	A	A	A	A	A	A	A	A
FPIU	N	N	A	A	N	A	A	A	A	A	A	A	A	A
VAVS	A	N	A	A	N	A	A	A	A	A	A	A	A	A
PIU	A	N	A	A	N	A	A	A	A	A	A	A	A	A
RHFS	A	N	A	A	N	A	A	A	A	A	A	A	A	A
HP	N	N	N	A	A	A	A	N	A	N	N	N	N	N
HVSYS	N	N	A	A	N	N	A	A	A	N	N	N	N	N
CBVAV	A	N	A	A	N	A	A	A	A	A	A	A	A	A
RESYS	N	N	A	A	A	A	A	N	A	A	A	A	A	A
PSZ	A	N	A	A	A	A	A	A	A	A	A	A	A	A
PMZS	A	N	A	A	A	A	A	A	A	A	A	A	A	A
PVAVS	A	N	A	A	A	A	A	A	A	A	A	A	A	A
PTAC	N	N	A	A	A	A	N	N	A	N	N	N	N	N

Legend:
A = Appropriate
N = Not appropriate
S = System (or configuration) dependent

SYSTEMS

VARIABLES BY SYSTEM-TYPE FOR VARIABLE-TYPE = u-name of SYSTEM (cont.)

V-L No.	57	58	59	60	61	62	63	64	65	66	67	68	69	70
SYSTEM-TYPE	CBF F(WB,DB)	CBF F(CFM)	HEATING OIL	PLR CFM	PLR COOLING	PLR HEATING	COOL-CAP F(WB,DB)	COOL-SH F(WB,DB)	HEAT-CAP F(TEMP)	EIR F(WB,DB)	EIR F(PLR)	EIR FAN KW	OUTSIDE CAPACITY	COOLING
SUM	N	N	A	N	N	N	N	N	N	N	N	N	N	N
SZRH	A	A	A	A	A	N	A	A	N	N	N	N	N	A
MZS	A	A	A	A	A	N	A	A	N	N	N	N	N	A
DDS	A	A	A	A	A	N	A	A	N	N	N	N	N	A
SZCI	A	A	A	A	A	N	A	A	N	N	N	N	N	A
UHT	N	N	A	N	N	N	N	N	N	N	N	N	N	N
UVT	N	N	A	N	N	N	N	N	N	N	N	N	N	N
FPH	N	N	A	N	N	N	N	N	N	N	N	N	N	N
TPFC	N	N	A	N	N	N	N	N	N	N	N	N	N	N
FPFC	N	N	A	N	N	N	N	N	N	N	N	N	N	N
TPIU	A	A	A	A	A	N	A	A	N	N	N	N	N	A
FPIU	A	A	A	A	A	N	A	A	N	N	N	N	N	A
VAVS	A	A	A	A	A	N	A	A	N	N	N	N	N	A
PIU	A	A	A	A	A	N	A	A	N	N	N	N	N	A
RHFS	A	A	A	A	A	N	A	A	N	N	N	N	N	A
HP	N	N	A	N	N	N	N	N	N	N	N	N	N	N
HVSYS	N	N	A	N	N	N	N	N	N	N	N	N	N	A
CBVAV	A	A	A	A	A	N	A	A	N	N	N	N	N	A
RESYS	A	A	A	A	A	A	A	A	A	A	A	A	A	A
PSZ	A	A	A	A	A	N	A	A	N	A	A	A	A	A
PMZS	A	A	A	A	A	N	A	A	N	A	A	A	A	A
PVAVS	A	A	A	A	A	N	A	A	N	A	A	A	A	A
PTAC	N	N	A	N	N	N	N	N	N	N	N	N	N	A

Legend:
A = Appropriate
N = Not appropriate
S = System (or configuration) dependent

VARIABLES BY SYSTEM-TYPE FOR VARIABLE-TYPE = u-name of SYSTEM (cont.)

V-L No.	71	72	73	74	75	76	77	78	79	80
SYSTEM-TYPE	SENSIBLE CAPACITY	MAX-HUMD SETPOINT	MIN-HUMD SETPOINT	VAV MAX CFM RAT	ITEM 75	UNUSED	UNUSED	HEATING CAPACITY	TEMP AT MIN OA	MINIMUM OA EST
SUM	N	N	N	N	N			N	N	N
SZRH	A	A	A	A	N			A	A	A
MZS	A	A	A	A	S			A	A	A
DDS	A	A	A	A	S			A	A	A
SZCI	A	A	A	N	N			A	A	A
UHT	N	N	N	N	N			N	N	N
UVT	N	N	N	N	N			N	N	N
FPH	N	N	N	N	N			N	N	N
TPFC	N	N	N	N	N			N	N	N
FPFC	N	N	N	N	N			N	N	N
TPIU	A	A	A	N	N			A	A	A
FPIU	A	A	A	N	N			A	A	A
VAVS	A	A	A	A	N			A	A	A
PIU	A	A	A	A	N			A	A	A
RHFS	A	A	A	A	N			A	A	A
HP	N	N	N	N	N			N	N	N
HVSYS	A	A	A	N	N			A	A	A
CBVAV	A	A	A	N	N			A	A	A
RESYS	A	A	A	N	A			N	N	N
PSZ	A	A	A	A	N			A	A	A
PMZS	A	A	A	A	S			A	A	A
PVAVS	A	A	A	A	N			A	A	A
PTAC	A	A	A	N	N			N	N	N

Legend:

A = Appropriate
N = Not appropriate
S = System (or configuration) dependent

SYSTEMS

VARIABLES BY SYSTEM-TYPE FOR VARIABLE-TYPE = u-name of SYSTEM (cont.)

V-L No.	81	82	83	84	85	86	87	88
SYSTEM-TYPE	HP SUPP HEAT	REFG ZONE SENS HT	REFG ZONE LAT HT	REFG SYS REC HT	REFG SYS REJ HT	REFG SYS COMP KW	REFG SYS DEF KW	REFG SYS AUX KW
SUM	N	N	N	N	N	N	N	N
SZRH	N	N	N	N	N	N	N	N
MZS	N	N	N	N	N	N	N	N
DDS	N	N	N	N	N	N	N	N
SZCI	N	N	N	N	N	N	N	N
UHT	N	N	N	N	N	N	N	N
UVT	N	N	N	N	N	N	N	N
FPH	N	N	N	N	N	N	N	N
TPFC	N	N	N	N	N	N	N	N
FPFC	N	N	N	N	N	N	N	N
TPIU	N	N	N	N	N	N	N	N
FPIU	N	N	N	N	N	N	N	N
VAVS	N	N	N	N	N	N	N	N
PIU	N	N	N	N	N	N	N	N
RHFS	N	N	N	N	N	N	N	N
HP	N	N	N	N	N	N	N	N
HVSYS	N	N	N	N	N	N	N	N
CBVAV	N	N	N	N	N	N	N	N
RESYS	A	N	N	N	N	N	N	N
PSZ	A	A	A	A	A	A	A	A
PMZS	N	N	N	N	N	N	N	N
PVAVS	N	N	N	N	N	N	N	N
PTAC	A	N	N	N	N	N	N	N

Legend:
A = Appropriate
N = Not appropriate
S = System (or configuration) dependent

VARIABLE-TYPE = u-name of PLANT-ASSIGNMENT

VARIABLE-LIST Number	Variable in FORTRAN Code	Description
1	<QCPL>	Total cooling load (Btu/hr)
2	<QHPL>	Total heating load (Btu/hr)
3	<PKW>	Total electrical load (kW)
4	<PGAS>	Total gas load (Btu/hr)
5	<PKWQH>	Portion of <PKW> used for heating (kW)
6	<PKWQC>	Portion of <PKW> used for cooling (kW)
7	<PFANKW>	Portion of <PKW> used for fans (kW)
8	<POIL>	Total oil load (Btu/hr)
9		unused
10		unused
11	QHMP	Main coil heating load (Btu/hr)
12	TMP	Main coil average entering temperature (^{o}F)
13	CFMP	Main coil flowrate (cfm)
14	QHPP	Preheat coil heating load (Btu/hr)
15	CFMPP	Preheat coil flowrate (if in outside air duct) (cfm)
16	QHZP	Zone coil load (Btu/hr)
17	TZP	Zone coil average entering temperature (^{o}F)*
18	CFMZP	Zone coil flowrate (cfm)
19	QHBP	Baseboard load (Btu/hr)**
20		unused

* Loop temperature for HP or zone temperature for RESYS.

** Includes HP load for loop.

SYSTEMS

VARIABLES BY SYSTEM-TYPE FOR VARIABLE-TYPE = u-name of PLANT-ASSIGMENT

V-L No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SYSTEM -TYPE	COOLING LOAD	HEATING LOAD	ELECT KW LOAD	HEATING GAS	HEATING ELEC KW	COOLING ELEC KW	FANS ELEC KW	HEATING OIL	UNUSED	UNUSED	MAIN HC CBS LOAD	MAIN HC CBS TEMP	MAIN HC CBS CFM	PREHEAT CBS LOAD
SUM	A	A	A	A	A	N	N	A			N	N	N	N
SZRH	A	A	A	A	A	N	A	A			A	A	A	A
MZS	A	A	A	A	A	N	A	A			A	A	A	A
DDS	A	A	A	A	A	N	A	A			A	A	A	A
SZCI	A	A	A	A	A	N	A	A			A	A	A	A
UHT	A	A	A	A	A	N	A	A			N	N	N	N
UVT	A	A	A	A	A	N	A	A			N	N	N	N
FPH	A	A	A	A	A	N	N	A			N	N	N	N
TPFC	A	A	A	A	A	N	A	A			N	N	N	N
FPFC	A	A	A	A	A	N	A	A			N	N	N	N
TPIU	A	A	A	A	A	N	A	A			A	A	A	A
FPIU	A	A	A	A	A	N	A	A			A	A	A	A
VAVS	A	A	A	A	A	N	A	A			A	A	A	A
PIU	A	A	A	A	A	N	A	A			A	A	A	A
RHFS	A	A	A	A	A	N	A	A			A	A	A	A
HP	A	A	A	A	A	A	A	A			N	N	N	N
HVSYS	A	A	A	A	A	N	A	A			A	A	A	A
CBVAV	A	A	A	A	A	N	A	A			A	A	A	A
RESYS	A	A	A	A	A	A	A	A			A	A	A	N
PSZ	A	A	A	A	A	N	A	A			A	A	A	A
PMZS	A	A	A	A	A	N	A	A			A	A	A	A
PVAVS	A	A	A	A	A	N	A	A			A	A	A	A
PTAC	A	A	A	A	A	A	A	A			N	N	N	N

Legend:

A = Appropriate
N = Not appropriate
S = System (or configuration) dependent

SYSTEMS

VARIABLES BY SYSTEM-TYPE FOR VARIABLE-TYPE = u-name of PLANT-ASSIGNMENT (cont.)

V-L No.	15	16	17	18	19
SYSTEM-TYPE	PREHEAT CBS CFM	ZONEHEAT CBS LOAD	ZONEHEAT CBS TEMP	ZONEHEAT CBS CFM	BASEBRD CBS LOAD
SUM	N	N	N	N	N
SZRH	A	A	A	A	A
MZS	A	N	A	A	A
DDS	A	N	A	A	A
SZCI	A	A	A	A	A
UHT	N	A	A	A	A
UVT	N	A	A	A	A
FPH	N	N	N	N	N
TPFC	N	A	A	A	A
FPFC	N	A	A	A	A
TPIU	A	A	A	A	A
FPIU	A	A	A	A	A
VAVS	A	A	A	A	A
PIU	A	A	A	A	A
RHFS	A	A	A	A	A
HP	N	N	N	N	A
HVSYS	A	A	A	A	A
CBVAV	A	A	A	A	A
RESYS	N	A	A	A	A
PSZ	A	A	A	A	A
PMZS	A	A	A	A	A
PVAVS	A	A	A	A	A
PTAC	N	A	A	A	A

Legend:
A = Appropriate
N = Not appropriate
S = System (or configuration) dependent

PLANT

VARIABLE-TYPE = GLOBAL

VARIABLE-LIST Number	Variable in FORTRAN Code	Description
1	TAIR	Outside dry-bulb temperature (^{o}F)
2	TWET	Outside wet-bulb temperature (^{o}F)

VARIABLE-TYPE = PLANT

VARIABLE-LIST Number	Variable in FORTRAN Code	Description
1	ENGYLD(1,IHR)	SYSTEMS heating load (Btu/hr)
2	ENGYLD(2,IHR)	SYSTEMS cooling load (Btu/hr)
3	ENGYLD(3,IHR)	SYSTEMS electric load (Btu/hr)
4	IHON	Standby heating flag
5	ICON	Standby cooling flag
6	—	—
7	—	—
8	PDEM(1)	Total PLANT heating load (Btu/hr)
9	PDEM(2)	Total PLANT cooling load (Btu/hr)
10	PDEM(3)	Total PLANT electric load (Btu/hr)
11	—	—
12	Note 1	Total PLANT fuel use (Btu/hr)
13	HSOLAR	Space heating load satisfied by solar (Btu/hr)
14	LATYPE(1)	Heating LOAD-ASSIGNMENT pointer
15	LATYPE(2)	Cooling LOAD-ASSIGNMENT pointer
16	LATYPE(3)	Electric LOAD-ASSIGNMENT pointer
17	GAS+OIL	Gas and oil resource consumed elsewhere than PLANT (Btu/hr)
18	HWTR(1HR)	Hot water resource consumed elsewhere than PLANT (Btu/hr)

Note 1. EQDEM(4,1) + EQDEM(4,2) + EQDEM(4,5) +
EQDEM(4,6) + EQDEM(4,22) + EQDEM(4,21)

VARIABLE-TYPE = HEAT-RECOVERY

VARIABLE-LIST Number	Variable in FORTRAN Code	Description
1	Note 1	Demand at level 1 (Btu/hr)
2	Note 2	Demand at level 2 (Btu/hr)
3	Note 3	Demand at level 3 (Btu/hr)
4	Note 4	Demand at level 4 (Btu/hr)
5	Note 5	Demand at level 5 (Btu/hr)
6	EHEAT	Heating load to be addressed by HEAT-RECOVERY. This load is the total heating load as reduced by the solar contribution to the space heating loads identified in Table V.31. (Btu/hr)
7	EBOILR	Heating load after all solar and heat recovery contribution, but before the contribution of hot water storage tank (Btu/hr)
8	ERECVR	Total recovered energy from all levels (Btu/hr)
9	EREJ	Total recoverable energy wasted (Btu/hr)
10	DBLEFT	Wasted recoverable double-bundle chiller heat (reject to tower) (Btu/hr)
11	STORED	Recovered energy stored in hot water storage tank this hour (Btu/hr)
12	HTREQD(19)	Energy demanded from boiler by hot water storage tank (Btu/hr)
13	HTAVAL(27)	Solar energy available for space heating (Btu/hr)
14	HTAVAL(28)	Solar energy available for process/dhw heating (Btu/hr)
15	HTAVAL(29)	Solar energy available for cooling (Btu/hr)
16	EXTSOL	Solar energy supplied through heat recovery (Btu/hr)

Note 1. HTREQD(KEY(1,2,1)) + HTREQD(KEY(2,2,1)) + HTREQD(KEY(3,2,1))

Note 2. HTREQD(KEY(1,2,2)) + HTREQD(KEY(2,2,2)) + HTREQD(KEY(3,2,2))

Note 3. HTREQD(KEY(1,2,3)) + HTREQD(KEY(2,2,3)) + HTREQD(KEY(3,2,3))

Note 4. HTREQD(KEY(1,2,4)) + HTREQD(KEY(2,2,4)) + HTREQD(KEY(3,2,4))

Note 5. HTREQD(KEY(1,2,5)) + HTREQD(KEY(2,2,5)) + HTREQD(KEY(3,2,5))

VARIABLE-TYPE = STM-BOILER (EQTYP = 1) or HW-BOILER (EQTYP = 2)

VARIABLE-LIST Number	Variable in FORTRAN Code	Description
1	EQDEM(1,IEQTYP)	Heating load (Btu/hr)
2	—	—
3	EQDEM(3,IEQTYP)	Electric input (Btu/hr)
4	EQDEM(4,IEQTYP)	Fuel input (Btu/hr)
5	—	—
6	ISIZE	Sizes running
7	OPCAP(IEQTYP)	Nominal capacity (Btu/hr)
8	PLR	Average part-load ratio
9	FRAC	Fraction of hour boiler was on
10	HIRCOR	Fuel consumption correction factor

VARIABLE-TYPE = ELEC-STM-BOILER (IEQTYP = 3),
ELEC-HW-BOILER (IEQTYP = 4), or ELEC-DHW-HEATER (IEQTYP = 7)

VARIABLE-LIST Number	Variable in FORTRAN Code	Description
1	EQDEM(1,IEQTYP)	Heating load (Btu/hr)
2	—	—
3	EQDEM(3,IEQTYP)	Electric energy consumption (Btu/hr)
4	—	—
5	—	—
6	ISIZE	Sizes running
7	OPCAP(IEQTYP)	Nominal capacity (Btu/hr)
8	LOSS	Losses from machine (Btu/hr)

VARIABLE-TYPE = ABSOR1-CHLR (IEQTYP = 13) or ABSOR2-CHLR (IEQTYP = 14)

VARIABLE-LIST Number	Variable in FORTRAN Code	Description
1	EQDEM(1,IEQTYP)	Cooling load (Btu/hr)
2	—	—
3	EQDEM(3,IEQTYP)	Electric energy consumed (Btu/hr)
4	EQDEM(4,IEQTYP)	Steam energy input (Btu/hr)
5	EQDEM(5,IEQTYP)	Cooling tower load (Btu/hr)
6	ISIZE	Sizes running
7	OPCAP(IEQTYP)	Nominal capacity (Btu/hr)
8	RCAP	Available capacity ratio (Btu/Btu)
9	CAP	Available capacity (Btu/hr)
10	PL	Average part-load ratio
11	PLR	Operating part-load ratio
12	TTOWR	Entering condenser temperature (^{o}F)
13	CHWT	Leaving chilled water temperature (^{o}F)
14	HIR1	Heat input ratio temperature correction
15	HIR2	Heat input ratio part-load correction
16	HIR	Adjusted heat input ratio
17	HIRS	Solar correction to heat input ratio

VARIABLE-TYPE = OPEN-CENT-CHLR (IEQTYP = 8), OPEN REC-CHLR (IEQTYP = 9), HERM-CENT-CHLR (IEQTYP = 10), HERM-REC-CHLR (IEQTYP = 11)

VARIABLE-LIST Number	Variable in FORTRAN Code	Description
1	EQDEM(1,IEQTYP)	Cooling load (Btu/hr)
2	EQDEM(2,IEQTYP)	False load (Btu/hr)
3	EQDEM(3,IEQTYP)	Electric energy consumed (Btu/hr)
4	—	—
5	EQDEM(5,IEQTYP)	Cooling tower load (Btu/hr)
6	ISIZE	Sizes running
7	OPCAP(IEQTYP)	Nominal capacity (Btu/hr)
8	RCAP	Available capacity ratio
9	CAP	Available capacity (Btu/hr)
10	PLR	Operating part-load ratio
11	FRAC	Fraction of hour machine ran
12	ECT	Entering condenser temperature (^{o}F)
13	CHWT	Leaving chilled water temperature (^{o}F)
14	EIR1	Electric input ratio temperature correction
15	EIR2	Electric input ratio part-load correction
16	EIRN	Adjusted electric input ratio
17	ELECH	Rejected electrical heat (Btu/hr)
18	FANE	Condenser fan energy (Btu/hr)

VARIABLE-TYPE = DBUN-CHLR (IEQTYP = 12)

VARIABLE-LIST Number	Variable in FORTRAN Code	Description
1	EQDEM(1,IEQTYP)	Cooling load (Btu/hr)
2	EQDEM(2,IEQTYP)	False load (Btu/hr)
3	EQDEM(3,IEQTYP)	Electric energy consumption (Btu/hr)
4	—	—
5	EQDEM(5,IEQTYP)	Cooling tower load (Btu/hr)
6	ISIZE	Sizes running
7	OPCAP(IEQTYP)	Nominal capacity (Btu/hr)
8	RCAP	Available capacity ratio
9	CAP	Available capacity (Btu/hr)
10	PLR	Operating part-load ratio
11	FRAC	Fraction of hour machine ran
12	ECT	Entering condenser water temperature (°F)
13	CHWT	Leaving chilled water temperature (°F)
14	EIR1	Electric input ratio temperature correction factor
15	EIR2	Electric input ratio part-load correction factor
16	EIR3	Electric input ratio heat recovery correction factor
17	EIRW	Corrected electric input ratio (Btu/Btu)
18	HTREC	Recoverable heat (Btu/hr)

VARIABLE-TYPE = COOLING-TWR (ITOWR = 17) or CERAMIC-TWR (ITOWR = 18)

VARIABLE-LIST Number	Variable in FORTRAN Code	Description
1	EQDEM(1,ITOWR)	Cooling tower load (Btu/hr)
2	—	—
3	EQDEM(3,ITOWR)	Electrical energy consumed (Btu/hr)
4,5	—	—
6	ISIZE	Number of cells running
7	OPCAP(ITOWR)	Nominal operating capacity (Btu/hr)
8	GPM	Water flow rate, gpm
9	MINCEL	Minimum number of cells that can run
10	RANGE	Temperature drop through tower (°R)
11	APP	Approach to wet-bulb (°R)
12	ISPEED	Fan speed index
13	R1	Rating factor correction for range
14	R2	Rating factor correction for approach and wet-bulb
15	RFACT	Rating factor at full cfm (TU/gpm)
16	RF	Rating factor at actual cfm (TU/gpm)
17	AREA	Tower area needed (TU/sqft)
18	NCELL	Number of cells running
19	TTOWR	Tower temperature (°F)
20	EFAN	Fan energy (Btu/hr)
21	EPUMP	Pump energy (Btu/hr)
22	RAPPLG	Approach needed when temperature floating
23	FRAC	Fraction of hour that fans ran at ISPEED
24	IDCSCH	Cooling tower direct cooling schedule
25	ISC	Cooling tower direct cooling flag

VARIABLE-TYPE = DIESEL-GEN (IEQTYP = 21)

VARIABLE-LIST Number	Variable in FORTRAN Code	Description
1	EQDEM(1,IEQTYP)	Electric load (Btu/hr)
2	—	—
3	—	—
4	EQDEM(4,IEQTYP)	Fuel energy consumed (Btu/hr)
5	—	—
6	ISIZE	Sizes running
7	OPCAP(IEQTYP)	Nominal capacity (Btu/hr)
8	ELECD	Operating load (Btu/hr)
9	PLR	Part load ratio
10	ELECFD	Efficiency of diesel engine (Btu/Btu)
11	THLOF	Ratio of jacket/lube-oil heat to fuel (Btu/Btu)
12	EJLD	Jacket/lube oil heat recovered (Btu/hr)
13	THHIF	Ratio of exhaust heat recovered to fuel (Btu/Btu)
14	EEXHD	Exhaust heat recovered (Btu/hr)
15	TEXD	Temperature of the exhaust (°F)
16	THTOF	Ratio of total heat recovered to fuel (Btu/Btu)
17	ETOT	Total heat recovered (Btu/hr)
18	—	—
19	—	—
20	—	—
21	—	—
22	—	—

VARIABLE-TYPE = GTURB-GEN (IEQTYP = 22)

VARIABLE-LIST Number	Variable in FORTRAN Code	Description
1	EQDEM(1,IEQTYP)	Electric load (Btu/hr)
2	—	—
3	—	—
4	EQDEM(4,IEQTYP)	Fuel energy consumed (Btu/hr)
5	—	—
6	ISIZE	Sizes running
7	OPCAP(IEQTYP)	Nominal capacity (Btu/hr)
8	ELECG	Operating load (Btu/hr)
9	PLR	Part load ratio
10	ELECFG	Efficiency of the gas turbine (Btu/Btu)
11	EEXHG	Exhaust heat recovered (Btu/hr)
12	EXHF	Ratio of exhaust heat recovered to fuel (Btu/Btu)
13	TEXG	Temperature of the exhaust (°F)
14	—	—

VARIABLE-TYPE = STURB-GEN (IEQTYP = 23)

VARIABLE-LIST Number	Variable in FORTRAN Code	Description
1	EQDEM(1,IEQTYP)	Electric load (Btu/hr)
2	—	—
3	—	—
4	EQDEM(4,IEQTYP)	Steam energy input (Btu/hr)
5	—	—
6	ISIZE	Sizes running
7	OPCAP(IEQTYP)	Nominal capacity (Btu/hr)
8	PLR	Part load ratio
9	TURBF	Internal turbine efficiency (Btu/Btu)
10	ELEFF	Efficiency of the steam turbine (Btu/Btu)
11	ENREC	Ratio of recovered heat to steam input (Btu/Btu)
12	FSLOSS	Condenser losses (Btu/hr)
13	WASTE	Recovered heat (Btu/hr)

VARIABLE-TYPE = HTANK-STORAGE (IEQTYP = 19)

VARIABLE-LIST Number	Variable in FORTRAN Code	Description
1	EQDEM(1,IEQTYP)	Energy delivered (Btu/hr)
2	—	—
3	EQDEM(3,IEQTYP)	Electric energy consumed (Btu/hr)
4	EQDEM(4,IEQTYP)	Energy stored (Btu/hr)
5	—	—
6	ISIZE	Sizes running
7	OPCAP(IEQTYP)	Operating capacity (Btu/hr)
8	HTGIVE	Heat available to be given out (Btu/hr)
9	HTASK	Heat requested for storage (Btu/hr)
10	HFREEZ-CFREEZ	Heat needed to prevent freezing (Btu/hr)
11	ISTORH	Storage demand flag
12	TEMPH	Tank temperature (^{O}F)
13	HLOSS	Tank loss (Btu/hr)
14	REALHT	Heat in tank (relative to 0^{O}F) (Btu/hr)
15	EHSTOR	Useful heat in tank (Btu/hr)

VARIABLE-TYPE = CTANK-STORAGE (IEQTYP = 20)

VARIABLE-LIST Number	Variable in FORTRAN Code	Description
1	EQDEM(1,IEQTYP)	Cooling energy delivered (Btu/hr)
2	—	—
3	EQDEM(3,IEQTYP)	Electric energy consumed (Btu/hr)
4	EQDEM(4,IEQTYP)	Cooling energy stored (Btu/hr)
5	—	—
6	ISIZE	Sizes running
7	OPCAP(IEQTYP)	Operating capacity (Btu/hr)
8	CDGIVE	Cooling energy available to be given out (Btu/hr)
9	CDASK	Cooling energy requested for storage (Btu/hr)
10	CFREEZ	Heat needed to prevent freezing (Btu/hr)
11	TEMPL	Tank temperature (^{O}F)
12	CLOSS	Tank loss (Btu/hr)
13	REALCD	Heat in tank (relative to 0^{O}F) (Btu/hr)
14	ECSTOR	Useful cold in tank (Btu/hr)

VARIABLE-TYPE = FURNACE

VARIABLE-LIST Number	Variable in FORTRAN Code	Description
1	EQDEM(1,5)	Space heating load (Btu/hr)
2	—	—
3	EQDEM(3,5)	Electric energy consumed (Btu/hr)
4	EQDEM(4,5)	Fuel consumed (Btu/hr)
5	—	—
6	ISIZE	Sizes running
7	OPCAP(5)	Operating capacity (Btu/hr)
8	PLR	Average part load ratio
9	HIRCOR	Fuel consumption correction factor

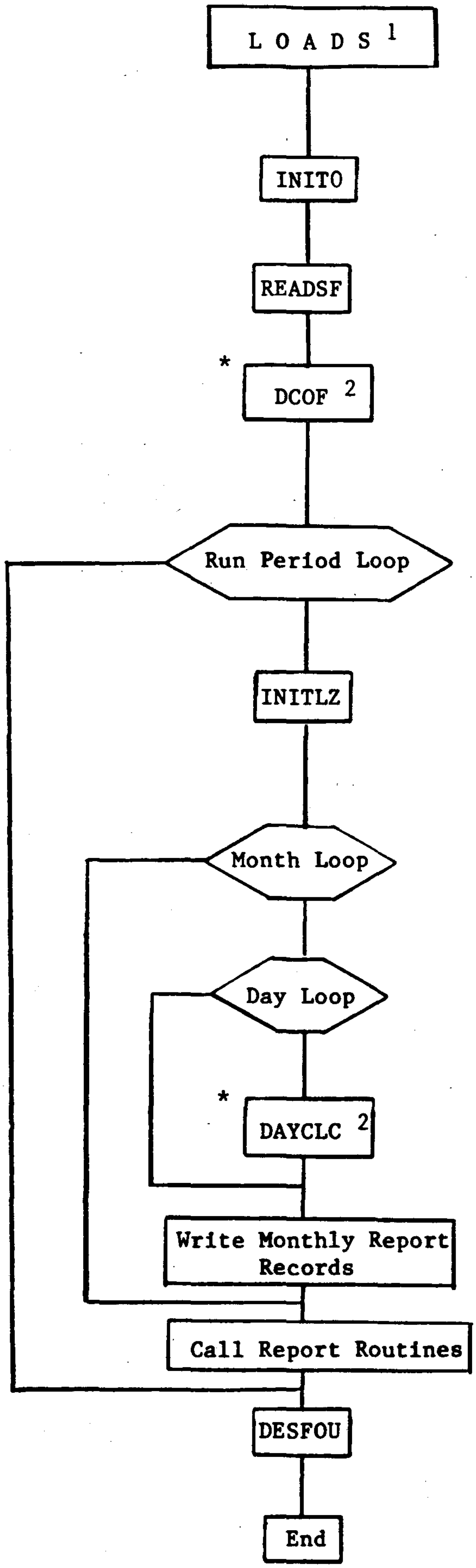
VARIABLE-TYPE = DHW-HEATER

VARIABLE-LIST Number	Variable in FORTRAN Code	Description
1	EQDEM(1,6)	Process or domestic hot water load (Btu/hr)
2	—	—
3	EQDEM(3,6)	Electricity consumed (Btu/hr)
4	EQDEM(4,6)	Fuel consumed (Btu/hr)
5	—	—
6	ISIZE	Sizes running
7	OPCAP(6)	Operating capacity (Btu/hr)
8	PLR	Part-load ratio
9	HIRCOR	Fuel consumption correction factor

APPENDIX B

FUNCTIONAL VALUES — LOADS FLOWCHART

—— LEVEL 1 ——



LOADS CALCULATION MAIN PROGRAM

Initialization.

Reads input file and sets pointers.

Calculates daylighting and glare factors for use in the hourly loop.

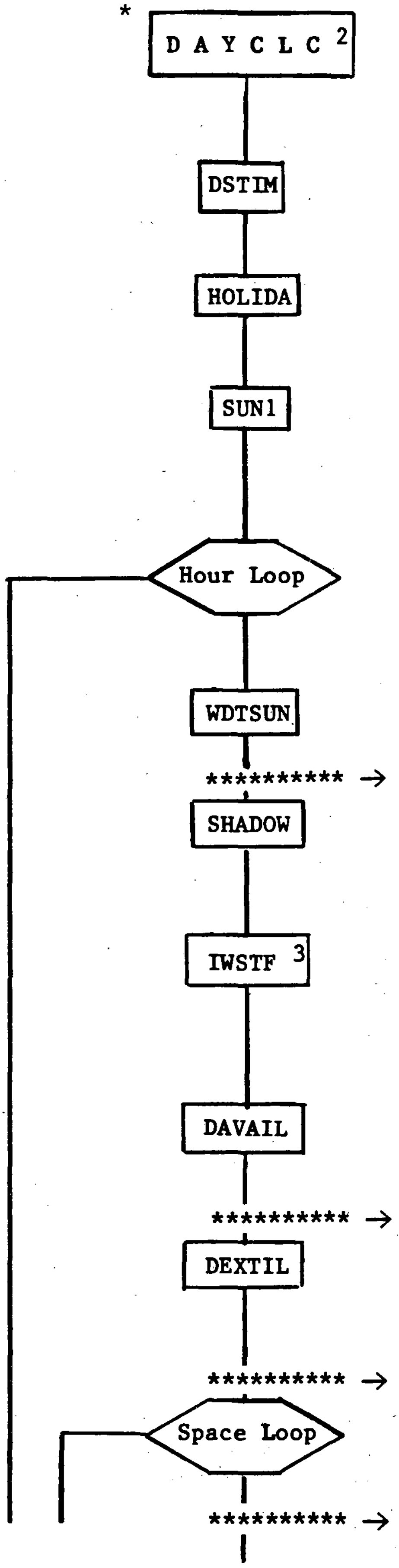
Initialization.

Performs the daily loads calculations.

Writes output design file for SYSTEMS.

* = function access location

—— LEVEL 2 ——



PERFORMS THE DAILY LOADS CALCULATIONS.

Defines the daylight savings flag.

Defines the schedule day.

Calculates solar declination angle, equation of time, solar constant, etc.

Defines hourly weather and solar data.

* Building "before" function.

Calculates the shadow ratios for exterior surfaces and attachments.

Calculates solar transfer factors between exterior windows in a sunspace and the interior surfaces.

Calculates availability of daylight for daylighting simulation; calculates luminous efficacv of solar radiation

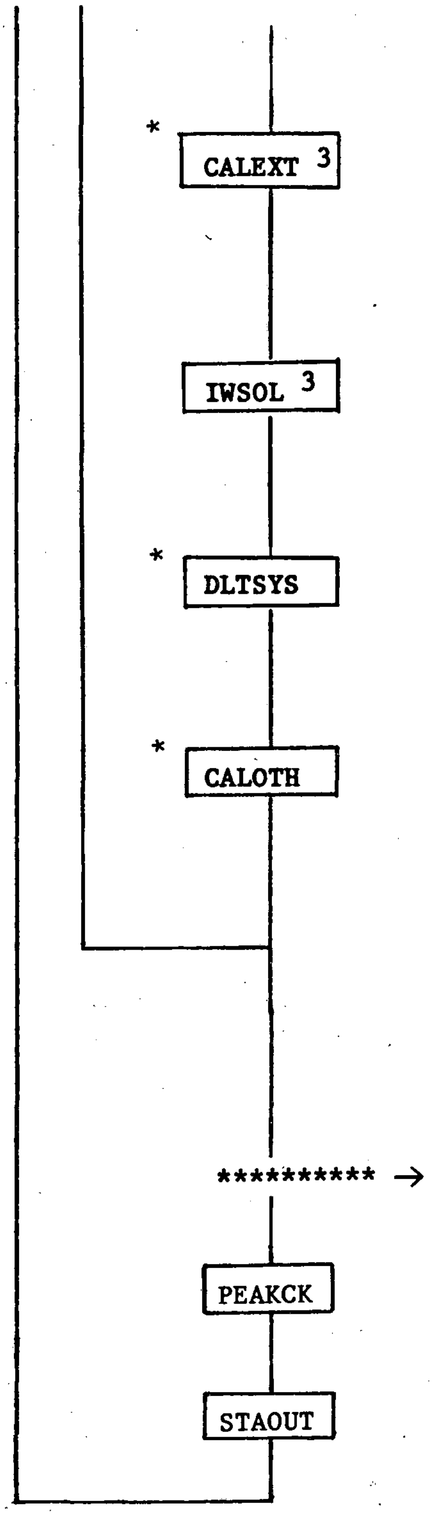
* Building daylight "before" function.

Calculates clear-sky and overcast-sky illuminance on an unobstructed exterior horizontal surface.

* Building daylight "after" function.

* Space "before" function.

* = function access location



Calculates loads due to solar gain through exterior windows, and conduction through exterior windows and walls.

For a sunspace, calculates solar radiation absorbed by interior walls and transmitted by interior windows into adjacent spaces.

Simulates lighting control system for daylit spaces; determines lighting power reduction factor due to daylighting.
* Space light control "before" function.
* Space light control "after" function.

* Underground surface "before" function.
Calculates heat gains due to heat transfer through underground surfaces.
* Underground surface "after" function.
Calculates heat gains due to interior walls, infiltration, people, lights, and equipment. Weights all heat gains (including exterior surface heat gains) to get loads.

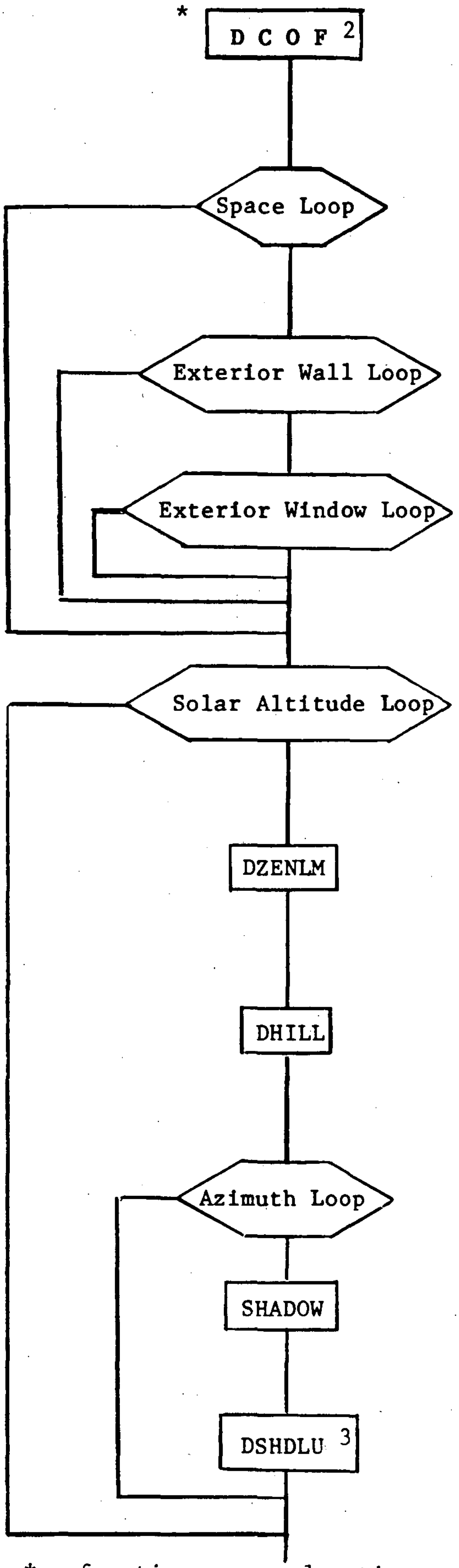
* Space "after" function is also contained in CALOTH.

* Building "after" function.

Determines building peak loads.

Computes hourly report averages and writes summary statistics to report file.

* = function access location



CALCULATES DAYLIGHTING AND GLARE FACTORS.

Initialization

Determines illuminance on ground, shadow ratios, and detached shade luminances.

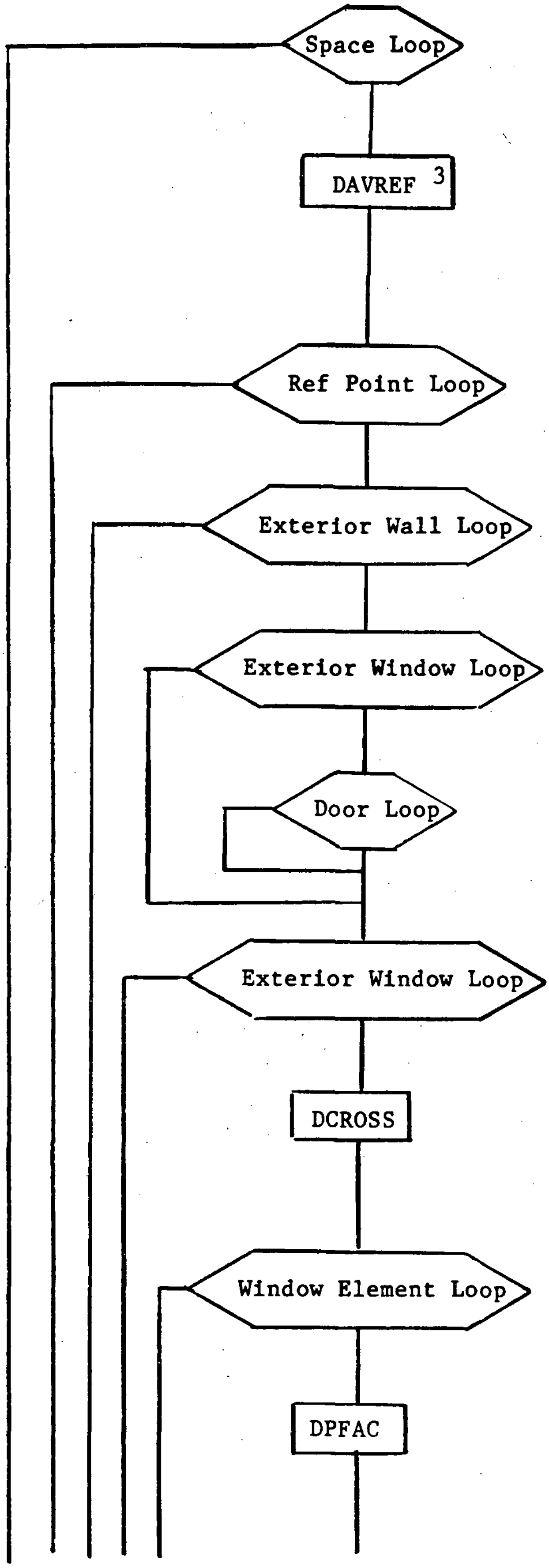
Sets turbidity coefficients and atmospheric moisture quantities.

Calculates illuminance on exterior horizontal surface.

Calculates shadow ratios for exterior surfaces.

Calculates luminance of detached building shades.

* = function access location



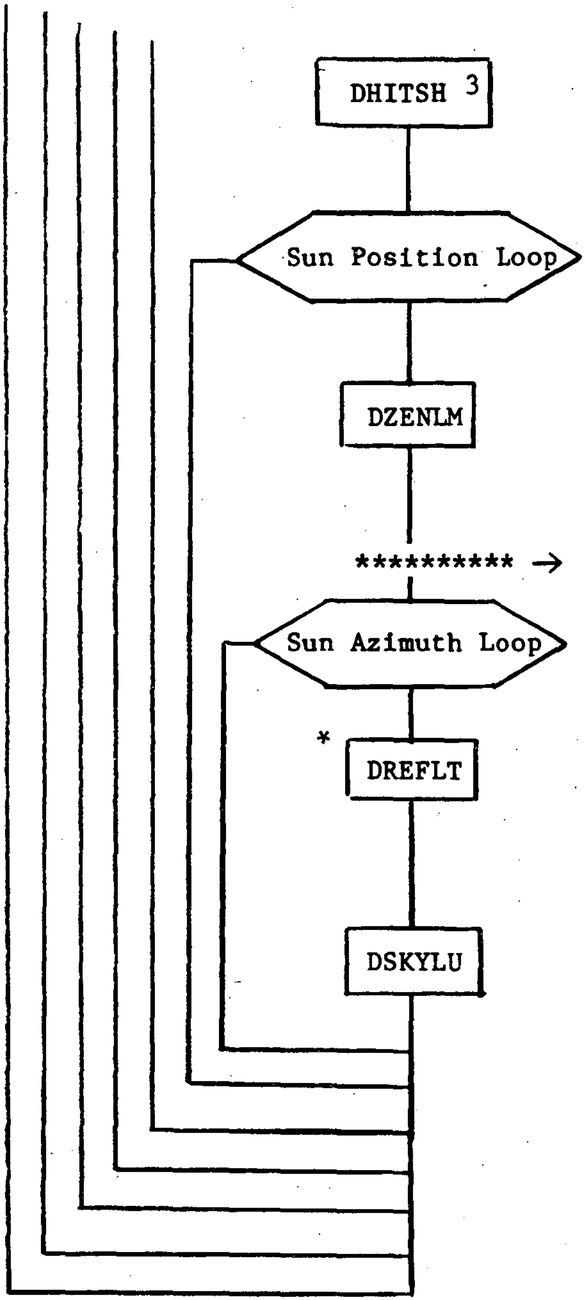
Performs main daylight and glare calculations.

Determines total area and average visible reflectance of inside surfaces of a space.

Calculates the cross product of two vectors.

Determines the Hopkinson position factor used in glare calculations.

* = function access location



Determines if ray from reference point to window elements intersects a building shade.

Sets turbidity coefficients and atmospheric moisture quantities; calculates clear sky zenith luminance.

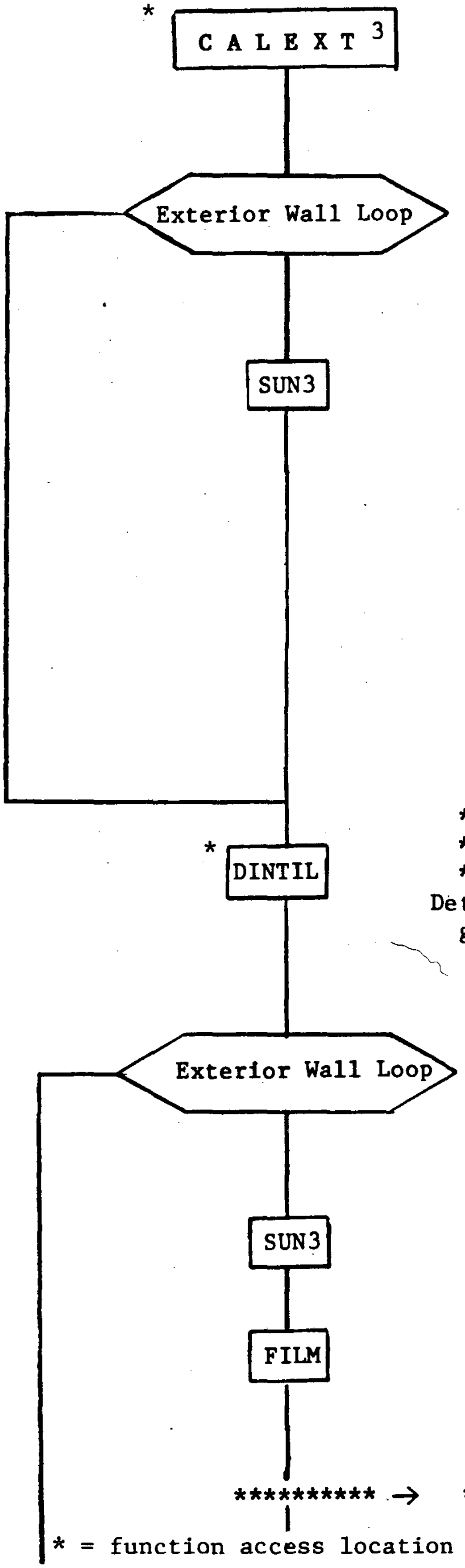
* Window "special" function with FNTYPE = 5.

Calculates illuminance at reference point due to internally reflected light.
* Window "special" function with FNTYPE = 6.

Calculates luminance of clear and overcast sky.

* = function access location

—— LEVEL 3 ——



CALCULATES EXTERIOR SURFACE LOADS.

Initialization.

Calculates direct and diffuse solar radiation on exterior wall.

* Space dayl-illum "before" function.
* Window "special" function with FNTYPE = 4.
* Space dayl-illum "after" function.
Determines hourly daylight illuminance and glare index at each reference point.

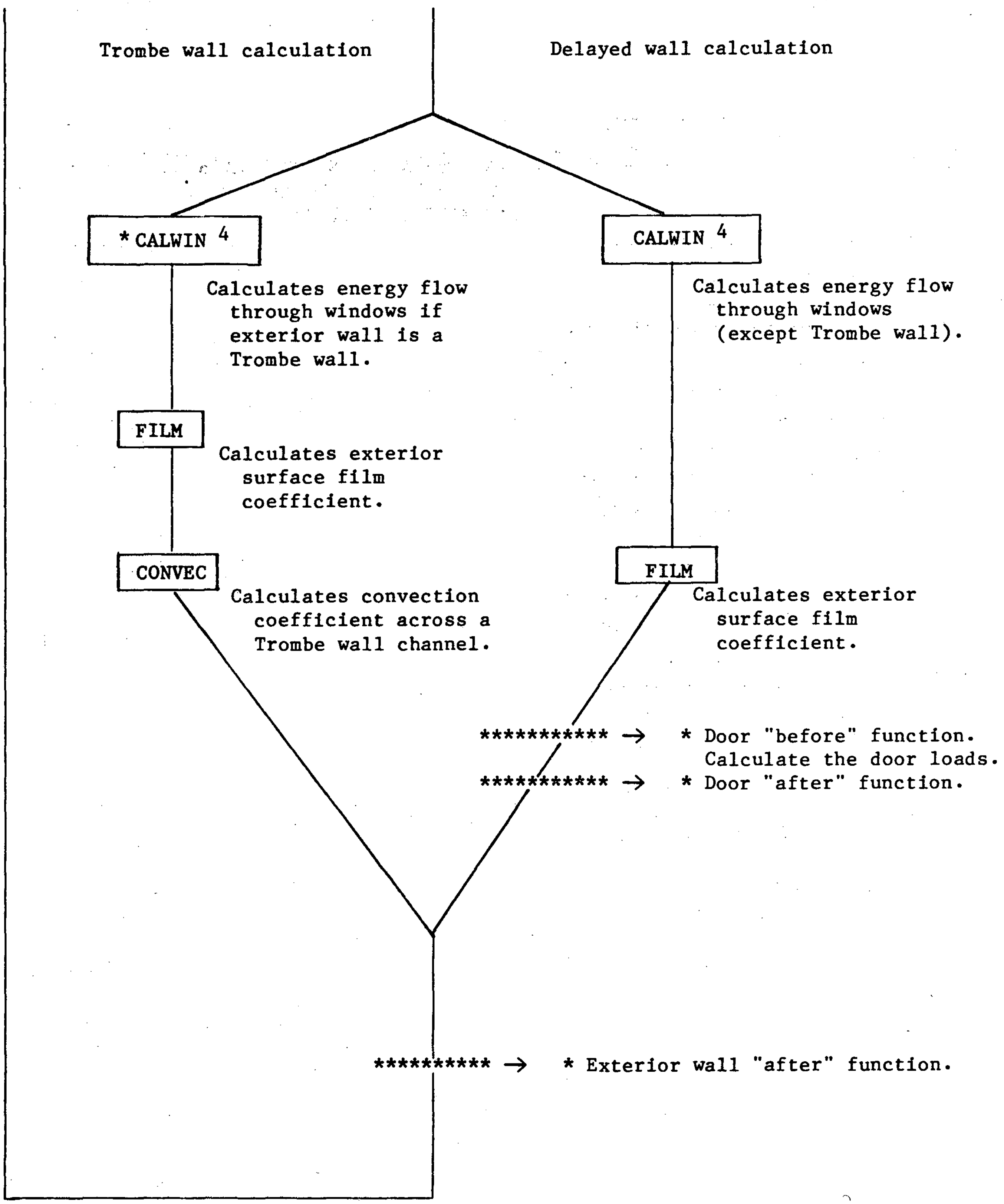
Load calculation.

Calculates direct and diffuse solar radiation on exterior wall.

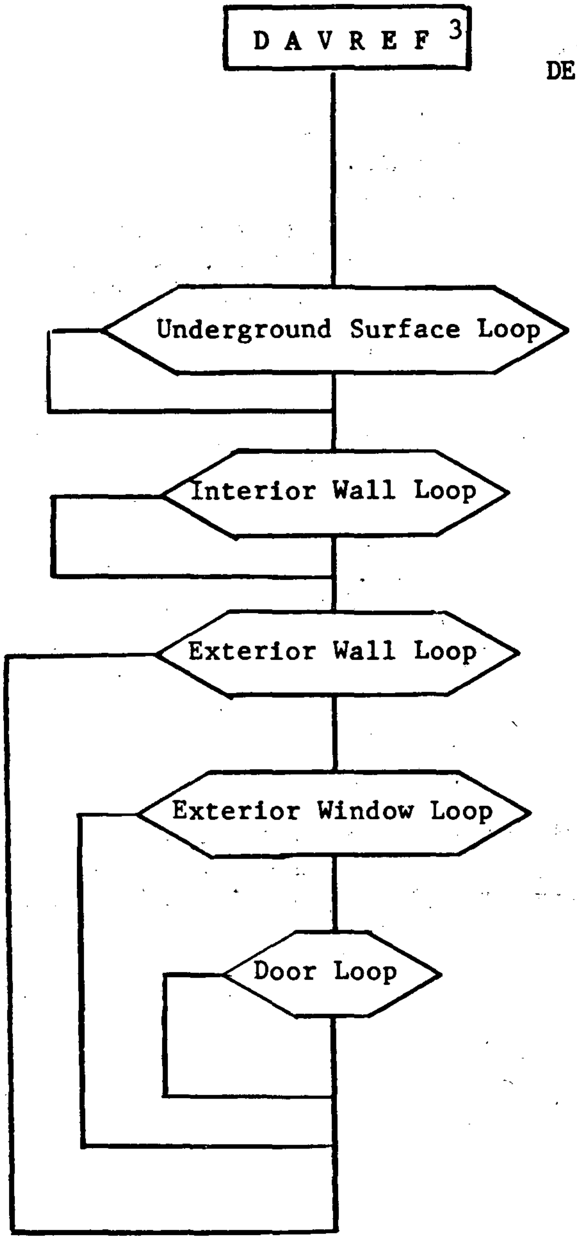
Calculates exterior surface film coefficient.

* Exterior wall "before" function.

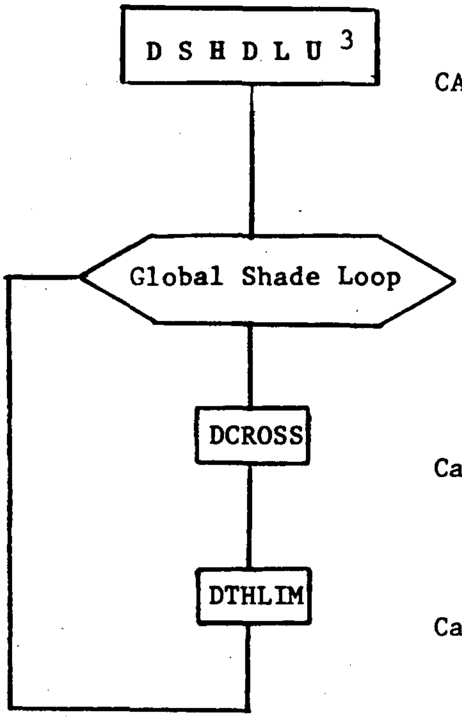
* = function access location



* = function access location



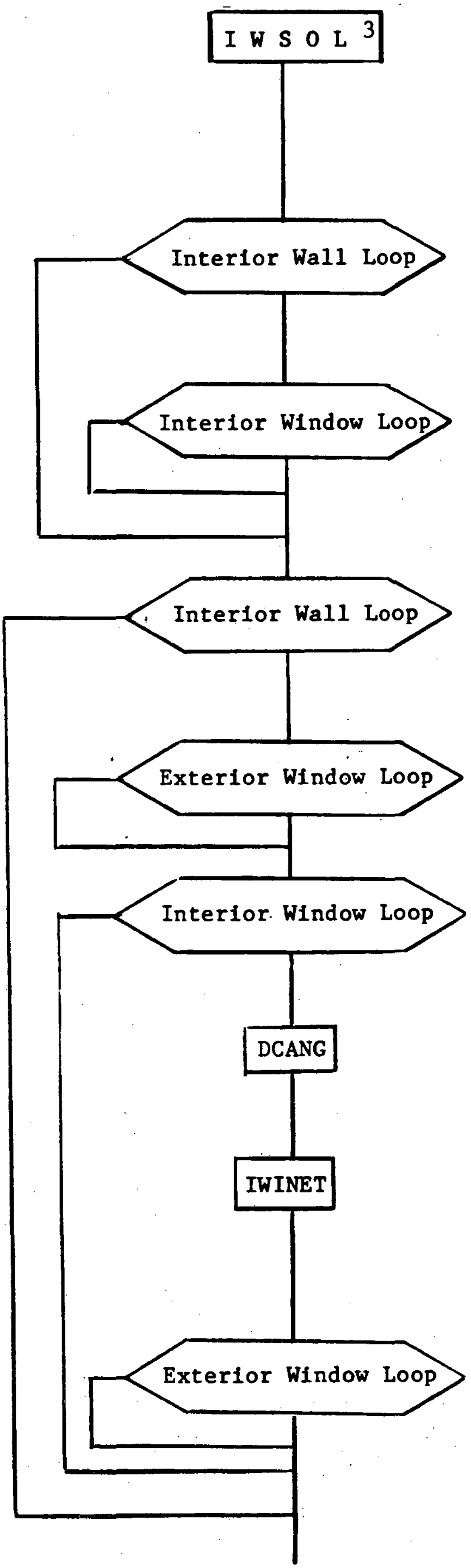
DETERMINES AREA WEIGHTED-AVERAGE VISIBLE REFLECTANCE AND TOTAL AREA OF ALL INSIDE SURFACES OF A SPACE.



CALCULATES LUMINANCE OF DETACHED BUILDING SHADES.

Calculates the cross product of two vectors.

Calculates the limits of integration of sky azimuth angle.



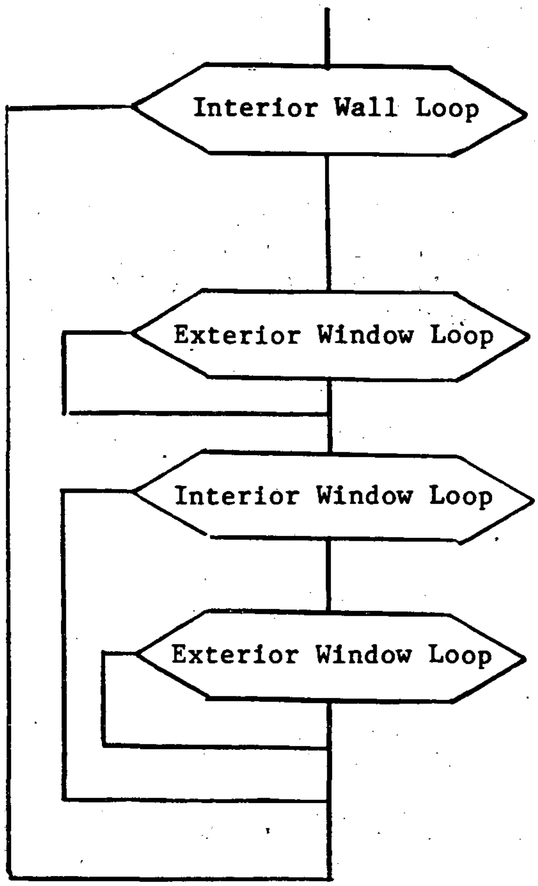
FOR A SUNSPACE, CALCULATES SOLAR RADIATION ABSORBED BY INTERIOR WALLS AND TRANSMITTED BY INTERIOR WINDOWS INTO ADJACENT SPACES.

Calculates UA sum for interior walls.

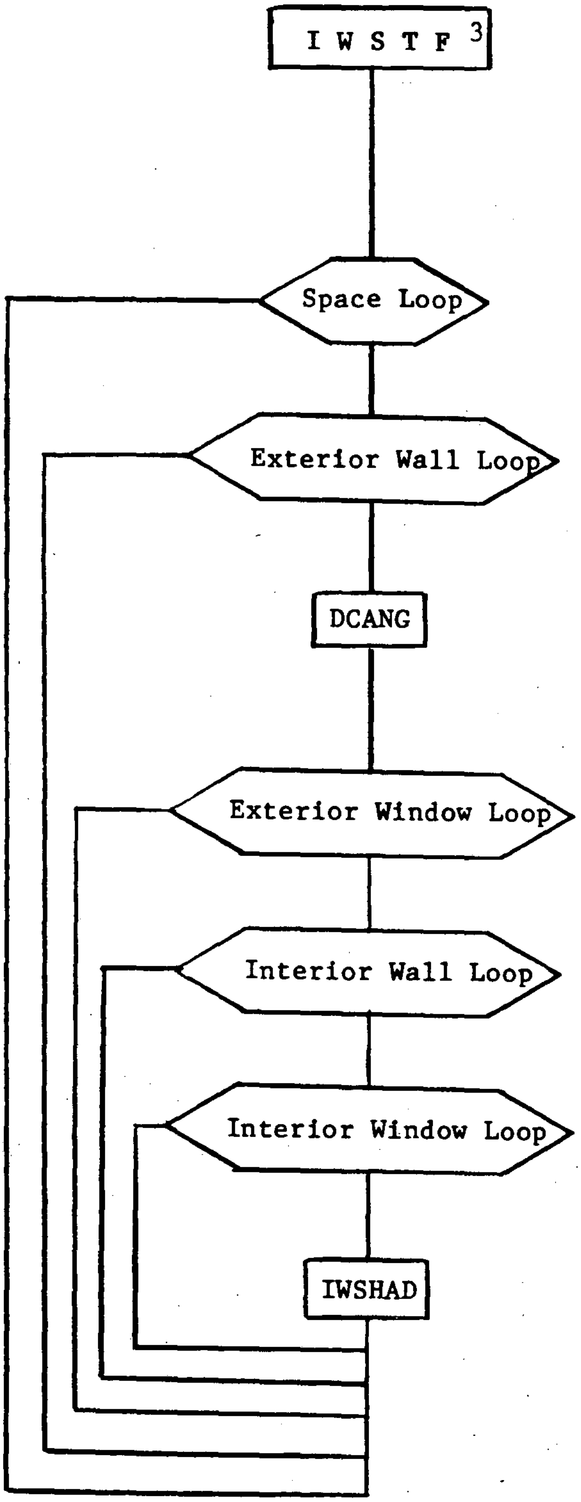
Calculates direct solar radiation absorbed by interior walls.

Calculates cosine of angle between sun and interior window.

Calculates effective solar transmittance of interior glazing.



Calculates diffuse solar radiation absorbed by interior walls.

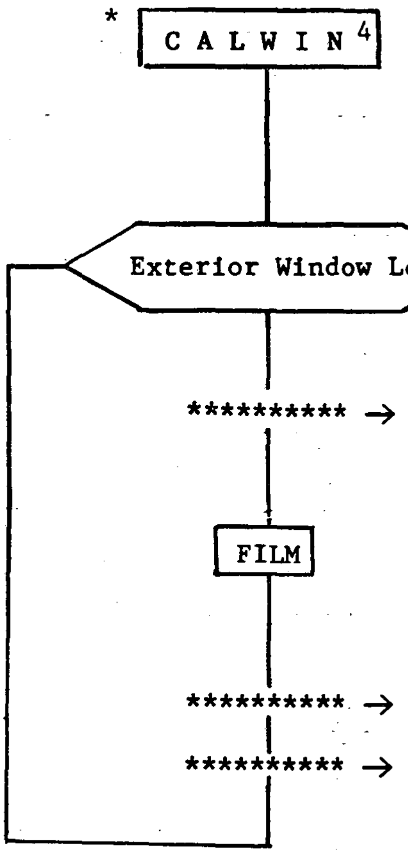


CALCULATES SOLAR TRANSFER FACTORS BETWEEN EXTERIOR WINDOWS IN A SUNSPACE AND THE INTERIOR SURFACES.

Calculates cosine of angle between sun and exterior wall.

Define sunlit area of interior wall.

—— LEVEL 4 ——



CALCULATES THE ENERGY FLOW THROUGH WINDOWS.

* Window "special" function with FNTYPE = 3.

Calculates the exterior surface film coefficient.

* Window "before" function.
Calculate the window loads.
* Window "after" function.

* = function access location

CALLs to FINTL

This list is to be used in conjunction with the Compiler Listing to determine the exact location of function access points.

CALL	Subroutine.Line Number
MEWFN1,0	CALEXT.180
MEWFN2,1	CALEXT.376
MDRFN1,0	CALEXT.345
MDRFN2,1	CALEXT.366
MUGFN1,0	CALOTH.23
MUGFN2,1	CALOTH.29
MZFN1,0	DAYCLC.196
MZFN2,1	CALOTH.101
MWISPFN,3	CALWIN.49
MWISPFN,4	DINTIL.87
MWISPFN,5	DCOF.699
MWISPFN,6	DREFLT.84
MWIFN1,0	CALWIN.114
MWIFN2,1	CALWIN.269
IBF1(1),0	DAYCLC.152
IBF2(1),1	DAYCLC.544
IBDYF1(1),0	DAYCLC.164
IBDYF2(1),1	DAYCLC.166
MZDAYILLUMFN1,0	DINTIL.29
MZDAYILLUMFN2,1	DINTIL.346
MZDAYLTCTLFN1,0	DLTSYS.16
MZDAYLTCTLFN2,1	DLTSYS.83

IMPORTANT MESSAGE

This package of updates to the DOE-2 documentation brings the previously published materials up to Version 2.1C of the DOE-2 program. The user may verify that the program being used is 2.1C by checking the first page of the output and also the upper right hand heading of any output page of the computer printout.

Volume I

DOE-2 BDL Summary and Users Guide

Remove the BDL Summary Version 2.1B, dated January 1983, and replace it with the enclosed 2.1C version. This revised document contains an integrated listing of all of the DOE-2 commands and keywords. It also has a listing and brief description of all of the SUMMARY and VERIFICATION reports, and a listing of the DOE-2 Materials Library. The Users Guide is not being updated.

Volume II

DOE-2 Sample Run Book

Replace the old DOE-2 Sample Run Book, Version 2.1, dated May 1980, with the enclosed 2.1C version. Retain the tabs, and insert in the new volume using the colored sheets as guides. (Not all will be needed, and four, the Office Building, Runs 9 and 10, and the Single Family Residence, Runs 2 and 3, should be relabelled to accommodate the Office Building, LOAD1 and LOAD2, the Daylighting Example, and the Sunspace Example, respectively.)

Volume III

The DOE-2 Supplement

Discard the old DOE-2 Supplement, dated January 1983, and place the enclosed 2.1C version in a three-ring binder (not included in this package). The new Supplement incorporates documentation for both 2.1B and 2.1C versions of the program. It also contains a new Appendix A, a compendium of all Variable Lists for the hourly reports.

DOE-2 Reference Manual, Part 1

Follow the instructions in the UPDATE TO THE DOE-2 REFERENCE MANUAL.

Bibliographic Note:

The following changes should be made to the binders and title pages of the DOE-2 Reference Manual, Parts 1 & 2:

The 4-digit LBL number should be updated from Rev. 3 to Rev. 4. The LA numbers are no longer in use.

The current version number is 2.1C.

The date is May 1984.

UPDATE TO THE DOE-2 REFERENCE MANUAL

1. Please replace the blue title page dated January 1983 with the enclosed revised title page dated May 1984.

2. Insert Sheets A, B, C, D, and E immediately before the Table of Contents for II.BDL, III.LOADS, IV.SYSTEMS, V.PLANT and VI.ECONOMICS, respectively.

3. The <u>DOE-2 Supplement,</u> Version 2.1C, contains detailed discussions and instructions for using the new 2.1B and 2.1C features and enhancements to existing commands and keywords. To derive the maximum benefit from this material, it is recommended that the user carefully follow the instructions below.

   In order to alert readers to the existence of new commands, keywords, and meanings, and to direct them to the Supplement, it is necessary to amend the <u>DOE-2 Reference Manual</u> in the following manner.

   Please take a high-lighting felt pen and line through, or mark in some distinguishing manner, all commands and keywords listed below. This mark will then act as a signal to the reader that more information concerning the command/keyword can be found in the Supplement.

BDL

Page:	Item to be high-lighted
II.15	INPUT and PARAMETRIC-INPUT

LOADS

Page:	Item to be high-lighted
III.30	BUILDING-LOCATION
III.35	BUILDING-SHADE
III.42	SPACE-CONDITIONS
III.44	LIGHTING-TYPE
III.46	LIGHT-TO-SPACE
III.49	INF-METHOD
III.53	ZONE-TYPE

Page:	Item to be high-lighted
III.80	CONSTRUCTION
III.87	GLASS-TYPE and GLASS-TYPE-CODE
III.88	GLASS-CONDUCTANCE
III.90	Table III.1
III.94	SPACE and MULTIPLIER
III.100	EXTERIOR-WALL (or ROOF)
III.107	WINDOW
III.110	DOOR
III.113	INTERIOR-WALL
III.114	MULTIPLIER[*]
III.118	UNDERGROUND-WALL (or UNDERGROUND-FLOOR)
III.123	LOADS-REPORT and VERIFICATION and SUMMARY

SYSTEMS

Page:	Item to be high-lighted
IV.20 through IV.102	Tables IV.4 through 24[**]
IV.180	CURVE-FIT
IV.188	ZONE-AIR

---

[*] Delete MULTIPLIER keyword and accompanying discussion. Append `See the *DOE-2 Supplement*, Version 2.1C, "Floor Multipliers and Interior Wall Types" Section for explanation´.

[**] Strike through all Applicability Tables; append `See the *DOE-2 BDL Summary*, Version 2.1C, for revised Applicability Tables´.

Page:	Item to be high-lighted
IV.189	AIR-CHANGES/HR and CFM/SQFT
IV.193	ZONE-CONTROL and HEAT-TEMP-SCH
IV.194	BASEBOARD-CTRL
IV.196	THROTTLING-RANGE
IV.198	ZONE and ZONE-TYPE
IV.199	MULTIPLIER
IV.200	BASEBOARD-RATING and MIN-CFM-RATIO
IV.203	SYSTEM-CONTROL and HEATING-SCHEDULE
IV.206	COOLING-SCHEDULE
IV.208	MAX-HUMIDITY and MIN-HUMIDITY
IV.210	ECONO-LIMIT-T and Fig.IV.22
IV.213	SYSTEM-AIR and SUPPLY-CFM
IV.215	MIN-AIR-SCH
IV.217	VENT-TEMP-SCH
IV.221	SYSTEM-FANS and FAN-SCHEDULE
IV.228	NIGHT-CYCLE-CTRL
IV.237	SYSTEM-EQUIPMENT
IV.251	ELEC-HEAT-CAP* and MAX-ELEC-T*

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* Delete keywords and accompanying discussions of them. Append `See the DOE-2 Supplement, Version 2.1C, "Air Source Heat Pump Enhancements" Section for explanation´.

Page:	Item to be high-lighted
IV.257	SYSTEM and SYSTEM-TYPE
IV.259	HEAT-SOURCE
IV.262	RETURN-AIR-PATH
IV.269	SYSTEMS-REPORT and SUMMARY

PLANT

Page:	Item to be high-lighted
V.22	PLANT-PARAMETERS
V.31	Generators and MAX-DIESEL-EXH* and MAX-GTURB-EXH*
V.33	STURB-SPEED*
V.38	EQUIPMENT-QUAD
V.40	ABSOR1-HIR-FPLR
V.46	DIESEL-JAC-FPLR* and DIESEL-LUB-FPLR* and DIESEL-STACK-FU* and GTURB-EXH-FT* and GTURB-I/O-FT*
V.47	GTURB-STACK-FU* and GTURB-TEX-FT*

---

* Delete keywords and accompanying discussions of them. Append `See the DOE-2 Supplement, Version 2.1C, "New Electrical Equipment Simulations" Section for explanation´.

Page:	Item to be highlighted
V.52	LOAD-ASSIGNMENT
V.53	NUMBER
V.66	HEAT-RECOVERY
V.83	ENERGY-COST*
V.84	PEAK-LOAD-CHG in Table V.12
V.100	PLANT-REPORT and VERIFICATION and SUMMARY
V.115-268	SOLAR-EQUIPMENT** and SOLAR Simulator Section**

ECONOMICS

Page:	Item to be high-lighted
VI.12	ECONOMICS-REPORT VERIFICATION and SUMMARY

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* Delete command, associated keywords, and accompanying discussions of them. Append `See the DOE-2 Supplement, Version 2.1C, "Replacement of ENERGY-COST Command" Section for explanation´.

** Delete entire section. The Solar Simulator has been removed from the 2.1C version of the program. Append `See the DOE-2 Supplement, Version 2.1C, "Introduction to PLANT Changes" Section for explanation´.

LBL-8706 Rev. 4.

DOE-2 REFERENCE MANUAL

(Version 2.1C)

Part 1

Group Q-11, Solar Energy Group
Los Alamos National Laboratory
Los Alamos, NM 87545

Building Energy Simulation Group
Applied Science Division
Lawrence Berkeley Laboratory
Berkeley, CA 94720

Edited by Don A. York, Charlene C. Cappiello, and Karen H. Olson

May 1984

(Revised 5/84)

Sheet A. BDL

The following commands have been upgraded or added in the DOE-2.1B and DOE-2.1C versions of the program. They should be noted or high-lighted in the body of the text to indicate the existence of new keywords. Please consult the The DOE-2 Supplement for discussion and use of these new features.

RM Page	Existing Command	Associated Keyword	New Commands/ Keywords	Suppl. Page
II.15	INPUT	—	INPUT-UNITS OUTPUT-UNITS	1-16
	and			
	PARAMETRIC-INPUT	—	INPUT-UNITS OUTPUT-UNITS	1-16
—	—	—	FUNCTION command ASSIGN command CALCULATE command END-FUNCTION command	1-1

Sheet B. LOADS

The following commands/keywords have been upgraded or added in the DOE-2.1B and DOE-2.1C versions of the program. They should be noted or high-lighted in the body of the text to indicate the existence of new commands, keywords, and meanings. Please consult The DOE-2 Supplement for discussion and use of the new features. Refer to the Supplement page numbers listed below.

RM Page	Existing Command	Associated Keyword	New Commands/ Keywords	Suppl. Page
III.30	BUILDING-LOCATION	—	X-REF Y-REF	2-83
		—	ATM-MOISTURE ATM-TURBIDITY	2-39
		—	SHIELDING-COEF TERRAIN-PAR1 TERRAIN-PAR2 WS-TERRAIN-PAR1 WS-TERRAIN-PAR2 WS-HEIGHT	2-93
		—	FUNCTION DAYL-FUNCTION	1-1
III.35	BUILDING-SHADE	—	SHADE-VIS-REFL SHADE-GND-REFL	2-39
		—	FIXED-SHADE command SHADE-SCHEDULE	2-83
III.42	SPACE-CONDITIONS	LIGHTING-TYPE LIGHT-TO-SPACE	LIGHT-TO-OTHER LIGHT-HEAT-TO LIGHT-TO-RETURN LIGHT-RAD-FRAC	2-88
		INF-METHOD	HOR-LEAK-FRAC NEUTRAL-LEVEL FRAC-LEAK-AREA	2-93
		—	DAYLIGHTING and other assoc. keywords	2-39
		—	SUNSPACE	2-1
III.80	CONSTRUCTION	—	WALL-PARAMETERS and WALL-PARAMETERS command	2-1 and 2-79
III.87	GLASS-TYPE	GLASS-CONDUCTANCE	INSIDE-EMISS	2-96
		—	VIS-TRANS	2-39
		GLASS-TYPE-CODE	Value = 0	2-1
III.94	SPACE	MULTIPLIER	FLOOR-MULTIPLIER	2-100
		—	FUNCTION	1-1

Sheet B. LOADS - continued

RM Page	Existing Command	Associated Keyword	New Commands/ Keywords	Suppl. Page
		—	DAYL-ILLUM-FN	1-1
		—	DAYL-LTCTRL-FN	1-1
III.100	EXTERIOR-WALL	—	SHADING-SURFACE	2-83
			INSIDE-VIS-REFL	2-39
		—	TROMBE-WALL command	2-79
		—	INSIDE-SOL-ABS	2-1
		—	FUNCTION	1-1
III.107	WINDOW	—	MAX-SOLAR-SCH SUN-CTRL-PROB CONDUCT-TMIN-SCH WIN-SHADE-TYPE VIS-TRANS-SCH GLARE-CTRL-PROB INSIDE-VIS-REFL	2-39
		—	Overhang and fin keywords	2-83
		—	SOL-TRANS-SCH	2-1
		—	OPEN-SHADE-SCH	2-33
		—	FUNCTION WINDOW-SPEC-FN	1-1
III.110	DOOR	—	INSIDE-VIS-REFL	2-39
		—	Overhang and fin keywords	2-83
		—	FUNCTION	1-1
III.113	INTERIOR-WALL	—	INT-WALL-TYPE	2-100
		—	INSIDE-VIS-REFL	2-39
		—	X Y Z AZIMUTH INSIDE-SOL-ABS	2-1
III.118	UNDERGROUND-WALL	—	INSIDE-VIS-REFL	2-39
		—	INSIDE-SOL-ABS	2-1
		—	FUNCTION	1-1
III.123	LOADS-REPORT	VERIFICATION	LV-L and LV-M code-words	2-106
		SUMMARY	LS-G through LS-L code-words	
		—	REPORT-FREQUENCY	1-15

Sheet C. SYSTEMS

The following commands/keywords have been upgraded, added, or deleted in the DOE-2.1B and DOE-2.1C versions of the program. They should be noted or high-lighted in the body of the text to indicate the existence of new commands, keywords, and meanings. Please consult The DOE-2 Supplement for discussion and use of the new features.

RM Page	Existing Command	Associated Keyword	New Commands/ Keywords	Suppl. Page
IV.180	CURVE-FIT	—	OUTPUT-MIN OUTPUT-MAX	3-21
IV.188	ZONE-AIR	AIR-CHANGES/HR CFM/SQFT		3-23
		—	SS-VENT-SCH SS-VENT-T-SCH SS-VENT-CST SS-VENT-WND SS-VENT-TEMP SS-VENT-LIMIT-T SS-VENT-KW SS-FLOW-SCH SS-FLOW-T-SCH	2-1
IV.193	ZONE-CONTROL	HEAT-TEMP-SCH BASEBOARD-CTRL THROTTLING-RANGE		3-21
IV.198	ZONE	MIN-CFM-RATIO	MIN-CFM-SCH	3-22
		MULTIPLIER	FLOOR-MULTIPLIER	2-100
		BASEBOARD-RATING		3-21
		—	TROM-VENT-SCH	2-79
		—	INDUCED-AIR-ZONE TERMINAL-TYPE REHEAT-DELTA-T	3-1
		—	REFG-ZONE-LOAD and assoc. keywords	3-6
		—	ZONE-FANS command	3-1
IV.203	SYSTEM-CONTROL	HEATING-SCHEDULE COOLING-SCHEDULE		3-22
		MIN-HUMIDITY MAX-HUMIDITY		3-23
		ECONO-LIMIT-T	ECONO-LOW-LIMIT	3-23
IV.215	SYSTEM-AIR	SUPPLY-CFM		3-23
		MIN-AIR-SCH		3-22
		VENT-TEMP-SCH		3-19

Sheet C. SYSTEMS - continued

RM Page	Existing Command	Associated Keyword	New Commands/ Keywords	Suppl. Page
IV.221	SYSTEM-FANS	—	NIGHT-VENT-CTRL NIGHT-VENT-SCH NIGHT-VENT-DT NIGHT-VENT-RATIOS	3-19
		NIGHT-CYCLE-CTRL	— and ZONE-FANS-ONLY code-word	3-19 and 3-1
		FAN-SCHEDULE	Value = -999.0	3-17
IV.237	SYSTEM-EQUIPMENT	~~ELEC-HEAT-CAP~~ ~~MAX-ELEC-T~~	HP-SUPP-HT-CAP HP-SUPP-SOURCE	3-15
		—	REFG-KW-FTCOND REFG-KW-FPLR TWR-RFACT-FRT TWR-APP-FRFACT	3-6
		—	New default curves	3-26
IV.257	SYSTEM	RETURN-AIR-PATH		2-88
		SYSTEM-TYPE	PIU codeword	3-1
		HEAT-SOURCE	HEAT-PUMP codeword	3-15
		—	HUMIDIFIER-TYPE	3-23
		—	REFG-SIZING-RAT and assoc. keywords	3-6
IV.269	SYSTEMS-REPORT	SUMMARY	SS-K through SS-O code-words	3-30
			REFG code-word	3-6
		—	REPORT-FREQUENCY	1-15

A command, keyword, or code-word with lines through it indicates that it has been removed from the DOE-2.1C version of the program. If there is a replacement, it appears in the column to its immediate right.

Sheet D. PLANT

The following commands/keywords have been upgraded, added, or deleted in the DOE-2.1C and DOE-2.1C versions of the program. They should be noted or high-lighted in the body of the text to indicate the existence of new or changed commands, keywords, and meanings. Please consult the The DOE-2 Supplement for discussion and use of these new features.

RM Page	Existing Command	Associated Keyword	New Commands/ Keywords	Suppl. Page
V.22	PLANT-PARAMETERS	~~ELEC-GEN-MODE~~	COGEN-TRACK-MODE COGEN-TRACK-SCH MIN-TRACK-LOAD DIESEL-TRACK-MODE DBUN-MIN-HEAT	4-2
		~~MAX-DIESEL-EXH~~ ~~MAX-GTURB-EXH~~ ~~STURB-SPEED~~	—	
		—	DIESEL-GEN-EFF DIESEL-EXH-EFF DIESEL-J/L-EFF GTURB-GEN-EFF GTURB-EXH-EFF STURB-MECH-EFF	4-8
		—	CCIRC-SIZE-OPT HCIRC-SIZE-OPT CCIRC-PUMP-TYPE HCIRC-PUMP-TYPE CCIRC-MIN-PLR HCIRC-MIN-PLR	4-13
V.38	EQUIPMENT-QUAD	~~DIESEL-LUB-FPLR~~ ~~DIESEL-JAC-FPLR~~ ~~DIESEL-STACK-FU~~ ~~GTURB-EXH-FT~~ ~~GTURB-I/O-FT~~ ~~GTURB-STACK-FU~~ ~~GTURB-TEX-FT~~	—	4-8
		ABSOR1-HIR-FPLR	—	
		—	DIESEL-I/O-FPLR DIESEL-EXH-FPLR DIESEL-TEX-FPLR DIESEL-JCLB-FPLR GTURB-CAP-FT GTURB-I/O-FPLR GTURB-EXH-FPLR GTURB-TEX-FPLR	

A command, keyword, or code-word with lines through it indicates that it has been removed from the DOE-2.1C version of the program. If there is a replacement, it appears in the column to its immediate right.

Sheet D. PLANT - continued

RM Page	Existing Command	Associated Keyword	New Commands/ Keywords	Suppl. Page
			STURB-ENTH-FPIX STURB-I/O-FPLR	
V.52	LOAD-ASSIGNMENT	—		4-2
V.66	HEAT-RECOVERY		—	4-2
V.83	~~ENERGY-COST~~		ENERGY-RESOURCE command	4-15
V.100	PLANT-REPORT	VERIFICATION SUMMARY	~~PV-D~~, ~~PV-H~~ code-words ~~PS-J~~ code-word	4-15
		—	REPORT-FREQUENCY	1-15
V.115	~~SOLAR-EQUIPMENT~~	and all of Solar Simulator	—	4-1

A command, keyword, or code-word with lines through it indicates that it has been removed from the DOE-2.1C version of the program. If there is a replacement, it appears in the column to its immediate right.

Sheet E. ECONOMICS

The following commands/keywords have been added or upgraded in the DOE-2.1C and DOE-2.1C versions of the program. They should be noted or high-lighted in the body of the text to indicate the existence of new commands, keywords, and code-words. Please consult the The DOE-2 Supplement for discussion and use of these new features.

RM Page	Existing Command	Associated Keyword	New Commands/ Keywords	Suppl. Page
—	—	—	DAY-CHARGE-SCH command WEEK-SCHEDULE command SCHEDULE command ENERGY-COST command CHARGE-ASSIGNMENT command COST-PARAMETERS command	5-1
VI.12	ECONOMICS-REPORT	VERIFICATION SUMMARY	EV-B code-word ES-D, ES-E, ES-F code-words	