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Thermal Analysis Research Program Reference Manual

U.S. DEPARTMENT OF COMMERCE
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Building Physics Division
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THERMAL ANALYSIS RESEARCH
PROGRAM REFERENCE MANUAL

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ABSTRACT

The Thermal Analysis Research Program (TARP) has been developed as a research tool for the thermal analysis of buildings. It especially aims to study the interactions of many complex heat transfer phenomena. TARP uses the detailed heat balance method for the simultaneous calculation of the energy requirements of multiple rooms. Interroom conductive and convective processes are simulated in detail. This program reference manual describes the algorithms, input, output, and program structure of TARP. The program is written to be portable and modifiable. It is written in FORTRAN 77 and has run on CDC and UNIVAC computers. Future expansions of the program are anticipated, particularly for the simultaneous simulation of the equipment performance and building thermal response.

Keywords: building energy analysis; load calculations; computer modeling; building heat transfer.

PREFACE

This report is one of a series documenting NBS research and analysis efforts in developing energy and cost data to support the Department of Energy/National Bureau of Standards Measurements Program. It was prepared by the Thermal Analysis Group, Building Physics Division, Center for Building Technology, National Engineering Laboratory, National Bureau of Standards (NBS). This work was jointly sponsored by NBS and the Department of Energy (DoE). The development of multiroom air flow modeling was supported by DoE/NBS Task Order A008 under Interagency agreement No. EA-77-A-01-6010. This report describes a computer program which was written as part of an effort to develop a comprehensive modeling technique for predicting the simultaneous transfer of air, moisture, and heat in and through multiroom buildings.

The author wishes to acknowledge the support and direction given by Dr. T. Kusuda, Thermal Analysis Group Leader.

The computer program described in this report is intended for research purposes only. It is furnished by the government and is accepted and used by any recipient with the expressed understanding that the United Stated Government makes no warranty, expressed or implied, concerning the accuracy, completeness, reliability, usability, or suitability for any particular purpose of the information and data contained in this program or furnished in connection therewith, and the United States shall be under no liability whatsoever to any person by reason of any use made thereof.

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I. INTRODUCTION

I.A BACKGROUND

The effort to encourage the design, construction, and retrofit of energy conserving buildings will be strengthened by the development of comprehensive methods for evaluating the thermal effectiveness of those buildings. Since the development of research programs such as NBSLD [1], there has been a proliferation of public and private energy analysis computer programs. Computer assisted analysis is increasingly used in building design. Public domain research programs have served as sources of validated algorithms and of simulated performance for the testing of the design programs. The majority of current building thermal simulation computer programs are based upon single room methods. It was assumed that the conditions in one room were not significantly affected by conditions in another. This was a good assumption because the low cost of energy made it common practice to keep near constant temperatures in all rooms. Similarly, occupant comfort was not a significant consideration in the early programs because sufficient energy would always be available to achieve comfort. Detailed analysis of moisture migration was unnecesary because moisture could always be mechanically removed to maintain comfort or prevent condensation. The increasing cost of energy has led to the use of natural heating and cooling techniques which have gone beyond those assumptions. Significant variations in room temperatures can be expected as unoccupied rooms are left unheated and uncooled or as "sun spaces" are built on homes to help heat them by natural convection. Increased temperature ranges are allowed in work areas with occupants expected to adjust amounts of clothing to maintain comfort. Natural ventilation cooling might lead to significant moisture problems. Many other phenomena are poorly understood or inadequately modeled in existing programs. Simulation of the complex interactions among the many phenomena in real buildings is especially important.

An improved research-oriented program is needed to allow the detailed study of simultaneous air, heat, and moisture transfer in and through a building with complex internal architecture. Such a research program must be easily expandable to test the simulation of new features. This requirement implies that the program should have a simple structure and be well-documented. The program should also be able to handle simple or very complex problems efficiently, and it should be portable so that many researchers can use it.

I.B OBJECTIVES

The objective of this effort is to develop a state-of-the-art research-oriented computer program for the thermal analysis of buildings together with the documentation necessary for its use.

This computer program is called the Thermal Analysis Research Program (TARP). The name was chosen to emphasize that this is to be more than an energy/loads predictor. It aims is to study the interactions of many factors of the thermal performance of buildings. Also, features which would have enhanced the usability of the program for building designers and engineers have given way to research features. In its present version it is capable of

computing room loads and temperatures by simultaneously considering conduction and air movements between all rooms in a building. This program provides the framework for the integration of many more advanced simulation features.

I.C   SCOPE

This report is the documentation of the algorithms, user-interface, and computer code of TARP in its present form. It provides a detailed description of the structure and mathematical methods of the program. It is not intended to be a tutorial for persons who are totally unfamiliar with energy analysis programs and methods.

Chapter II is an introduction to the capabilities, structure, and use of the program.

Chapter III reviews the algorithms that the program uses to compute the building energy and air flows.

Chapter IV explains how buildings are described by the input language.

Chapter V describes the various output reports available to the user.

Chapter VI gives the information necessary to understand (and hence modify) the computer code.

This report uses an outline organization to serve two purposes. It will allow easier updating of the documentation as the program evolves. It also allows a simple way to handle the many cross-references within the report. Any of the chapters may refer to details of the input or algorithms. The form of an input reference is: (3.2.5). It may consist of 1, 2, or 3 numbers separated by periods. It refers to the detailed input description in chapter IV, section C. The full reference may be considered (IV.C.3.2.5) with the "IV.C" implied. The form of an algorithm reference is: (B.2.4). It consists of a letter and optional numbers and refers to information in chapter III. The full reference may be considered (III.B.2.4).

References are indicated by brackets and are listed at the end of each section.

REFERENCES

[1] Kusuda, T., "NBSLD, the Computer Porgram for Heating and Cooling Loads in Buildings," NBS Building Science Series 69, (July 1976).

II.   PROGRAM OVERVIEW

II.A   SIMULATION CAPABILITIES

The Thermal Analysis Research Program uses detailed heat balance techniques to compute room loads. It may be used to evaluate single "design" days or it may use up to one year of measured weather data. A large number of occupant usage features may be scheduled with hourly, daily, and seasonal variations. The effects of temperature drifts in response to various control strategies can be accurately evaluated. Input and output may be in English or metric units. Other capabilities can be grouped by the three modes of heat transfer.

Conduction: Transient conduction effects are modeled by "conduction transfer functions" which are extensions of response factors. They model the heat storage effects of walls, furnishings, and partitions between rooms. Movable insulation is closely approximated by a massless insulation model with appropriate controls which may be applied over windows or walls.

Radiation: The transmittance and absorptance of windows is computed from the optical properties of the window panes. There may be up to four panes which may be heat absorbing or have reflective films. Shading coefficients may be used for windows which cannot be described in terms of their components. The shadowing and distribution of sunlight on surfaces may be calculated in several levels of detail up to the amount of light transmitted through windows onto each surface of the room. The effects of emissivity are modeled for both interior and exterior surfaces. There is a simple model to account for the energy savings of daylighting.

Convection: The program uses variable interior and exterior convection coefficients as functions of temperature difference and system induced flow velocity when appropriate. It can compute infiltration and the natural flow of air between rooms caused by wind and thermal forces. There is an alternative simple model for infiltration with options of ventilation cooling, a whole house fan, and controlled air mixing betwen two rooms.

TARP is an evolutionary development of the BLAST [1,2] computer program. BLAST is a user, rather than research, oriented program with equipment simulation capabilities not included in TARP. TARP provides more detailed models for air movement and multiroom analysis. It is also more portable and easier to modify.

II.B   PROGRAM STRUCTURE

The program is written almost entirely in FORTRAN 77. This is a standard language which has been or is being implemented on most large and medium size computers. The handling of character data and direct access files help to make this language machine independent. The TARP should be portable except for some conversions from single to double precision and replacing the use of BLAST weather tapes. The PARAMETER feature of FORTRAN 77 is used extensively in modifiable array dimensions so the TARP can handle different size problems.

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The TARP is divided into two subprograms: the input processor (IP) and the loads calculator (LC). This structure is illustrated in figure II.1. The IP checks the user input, prepares input files for the LC, and reports the array sizes that the LC will require. The LC performs the building loads simulation and reports the results. This separation of subprograms allows a reduction in computer core requirements. The IP uses minimal array sizes because it processes the input one element (surface, schedule, material, etc.) at a time. The LC uses large arrays which consider these elements simultaneously. The IP and LC may be run as separate jobs when it is necessary to recompile the LC for correct array sizes, or they may be run as a single job if the LC is known to have sufficiently large arrays.

The input processor is divided into four major sections. These correspond to the input language sections (III.C) which they process. This sectioning allows further reductions in core requirements by the use of overlays (or segments). A small input processor is important to allow the fast job turn-around necessary to quickly debug the user input deck. Each section contains several subroutines which process the input language "keys" plus others for special elements of certain keys. The largest of these special routines are the two groups of subroutines which evaluate the conduction transfer functions and the window optics.

The loads calculator is divided into three sections. The first reads the input file created by the IP and fills the LC arrays. It checks for sufficient array space and performs some checks which require that all data for the problem description be present in the arrays. The second section uses the geometric and optical descriptions of the building surfces to compute solar gain factors for various periods of the year. The third section does the actual heat balances necessary to compute the multi-room loads. It does this on an hour-by-hour basis.

II.C   EXAMPLE RUN

The following example calculation is designed to show how a building can be simulated with TARP. The building configuration was chosen to emphasize interzone effects. It is a "passive solar" design as shown in figure 2. The building is a townhouse configuration with 8 inch thick masonry walls separating it from identical units to the east and west. The gross floor area is 1584 ft^2. The exterior walls and roof are wood frame construction with insulation R values of 19 and 30 respectively. The house is divided into three major zones: a north zone for bedrooms, a center zone for the main living area, and a south zone for the kitchen/utility area. Each zone has a different internal gain profile consistant with its function. At the top of the center zone is a south-facing 120 ft^2 double pane clerestory which is intended to allow sun to shine directly onto the 8 inch thick masonry wall which separates the north and center zones. The south exterior walls includes 80 ft^2 (23 percent of wall area) of double pane window where the sun is intended to shine directly on the uncarpeted slab floor. The north and center zones have carpet on the slab. The partition between the south and center zones is a nonmassive wood frame and drywall construction.

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The TARP input for the example is shown in figure 3. The input begins by describing project data in the first nine lines between "PROJECT [" and "]". A project description is given; the location is described; ground temperatures are given. Then there is a description of the weather between "DDY(" and ")" on the following line. This sets up a mild, late winter condition when the solar and internal gains nearly offset the infiltration and conduction losses. The low temperature (LOW) for the day is 30F and the high (HIGH) is 50F. A clear sky (CLR) for 21 February (DATE) is assumed. A 15 mph (WS=1320 ft/min) wind blows from the northwest (DIR=315).

The next section is called the "LIBRARY". It is used to define certain features which are referred to by the name in later sections of the input. The first few entries in the library section begin with "DS" which stands for day-schedule. A day-schedule is a list of 24 values, one for each hour of the day. The third day-schedule is given the name "ON" to indicate that it is being used to describe the occupancy schedule in the north zone. This day-schedule is used in the week-schedule (WS) which has the name "OCCN". A week-schedule is a collection of day-schedules, one for each day of the week plus holidays and other special days. The command WD=ON will assign day-schedule ON to all week days. The same day-schedule will also apply for other day types by default since no other day types are specified. Building materials (MATL) are described in a similar manner. The first material is a gypsum wallboard given the name "GYP", and having a conductivity (K) of .42 Btu/h·ft·F, a density (D) of 45 lbm/ft^3, and a specific heat (CP) of 0.3 Btu/lbf. The wallboard is used in the first wall construction (CONS) named "WL-I". This lists the thickness and name of each material layer in the wall listed from outside to inside. There is 0.0521 ft (.625 in) of GYP as the inside surface. The final entries in the library ("CPFL", "CDS", and "CWS") describe the control of the zone temperatures.

The "BUILDING" section gives commands controlling the heat balance simulation and descriptions of the roof overhangs.

There are three "ZONE" sections to describe the three zones of the example building. Each zone is identified by a user supplied name, e.g., "NORTH". Activities related to the entire zone are the temperature control (CTRL) and people (PEO), lights (LIT), and equipment (EQP) loads. There are three people maximum (CAP=3) in the zone. The hourly number of people is determined by that maximum and the previously defined week-schedule (WS=OCCN). The other activities have similar capacities and schedules. The rest of the zone description defines the surfaces, both envelope and internal, of the zone. The mass (MASS) of furnishings is handled by a single surface of appropriate density and area. "SRF" then describes most of the north wall of the zone as an exterior (EX), opaque (OP), base surface (BS). It is made of the previously defined WL-I construction. The wall faces north (AZM=0) and is 41 ft long by 8 ft high (SIZE). It is located relative to the other surfaces of the building by the origin (ORG) command. The next line of input specifies a window on the wall. The window is an exterior (EX), transparent (TR), subsurface (SS) made of the WDW2 construction. Its size is made to represent all windows on the north wall. Openings in the wall for identification are combined into a single area under the "AFS" command. The next surface command describes the remainder of

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the north wall: the portion at the studs which is construction WL-S. Four lines later there is a description of the massive partition described as an interior (IN), opaque (OP), base surface (BS). It is thermally connected to the center zone by the command "ZONE=CENTER".

Figure 4 shows the computed loads for the sample run. The report is headed by the project, location, and environment descriptions. Then the following values are presented for each zone: Total heating and cooling requirements, peak heat and cooling loads, maximum zone air temperatures, hours at peak heating capacity (HX), other heating hours (HT), ventilating hours (V), cooling (below peak capacity) hours (CL), and hours at peak cooling capacity (CX). Building-wide values are summarized by the line labeled "TOTAL:". These values include the total heating and cooling requirements for all zones, the peak coincident heating and cooling loads, and maximum and minimum of all zone temperatures. The hour and day are reported for the occurance of the peak loads and temperatures.

This example was not intended to provide complete instruction. The user should read the remainder of the program documentation before attempting to run TARP.

REFERENCES

[1] Hittle, D. C., "The Building Loads Analysis and System Thermodynamics (BLAST) Program, Version 2.0: User Manual", CERL Technical Report E-153, (Construction Engineering Research Laboratory, 1979).

[2] Herron, D., Walton, G., Lawrie, L., "Building Loads Analysis and System Thermodynamics (BLAST) Program Users Manual -- Volume One Supplement (Version 3.0), CERL Technical Report E-171, (Construction Engineering Research Laboratory, 1981).
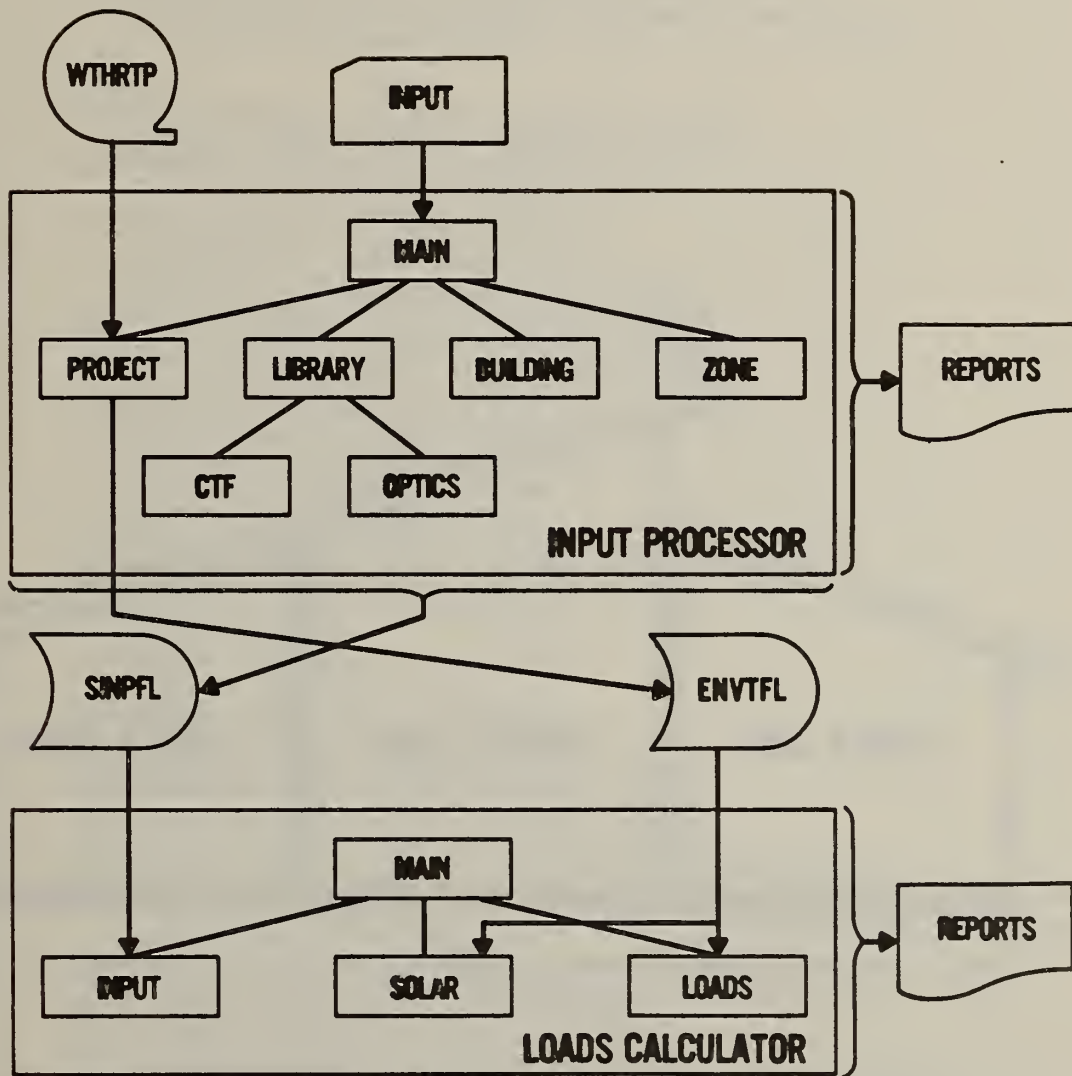
Figure II.1 Structure of the Thermal Analysis Research Program

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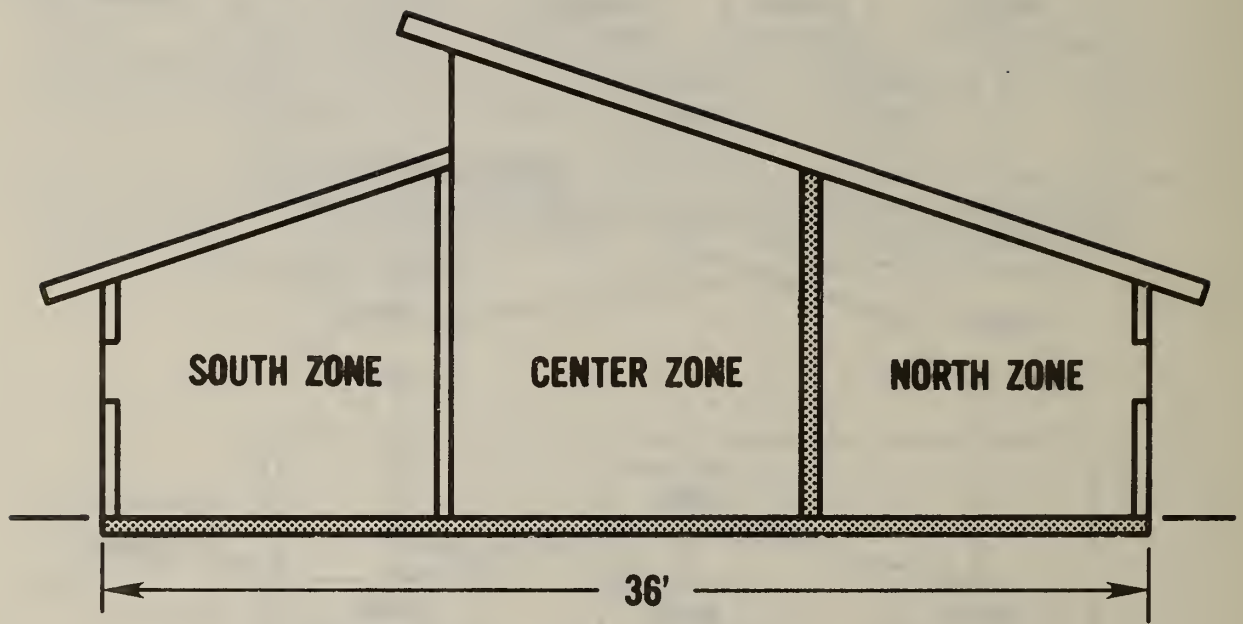
Figure II.2 House configuration for example problem

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```
 1   PROJECT [
 2     RC(DEM/UIN=ENGLISH/UOUT=ENGLISH/
 3         DESC='THERMAL MASS TEST - SIMULTANEOUS ZONES, DIRECT SUN')
 4     RPT(RNOS = 9)
 5     LOC(DESC='COLUMBIA, MO.'/LATD=38.9/LONG=92.3/TZ=6)
 6     GRND(GRT=40,42,48,55,62,67,70,69,63,55,48,42)
 7     DDY(DESC='MILD WINTER'/HIGH=50/LOW=30/WB=40/DATE=21FEB/
 8         CLR=1./MON/WS=1320/DIR=315)
 9     ]
10   LIBRARY  [
11     DS(NAME=NONE/DESC='ZERO ALL HOURS'/FFC=24*0)
12     DS(NAME=FULL/DESC='ONE ALL HOURS'/FFC=24*1)
13     DS(NAME=ON/DESC='NORTH OCCUPANCY'/
14         FFC=6*1,.5,.16,8*0,4*.16,2*.33,.67,1)
15     DS(NAME=OC/DESC='CENTER OCCUPANCY'/
16         FFC=16*0,3*.17,.67,.5,.67,.17,0)
17     DS(NAME=OS/DESC='SOUTH OCCUPANCY'/
18         FFC=6*0,.5,.5,8*0,2*.33,.67,2*.16,3*0)
19     WS(NAME=OCCN/DESC='NORTH OCCUPANCY'/WD=ON)
20     WS(NAME=OCCC/DESC='CENTER OCCUPANCY'/WD=OC)
21     WS(NAME=OCCS/DESC='SOUTH OCCUPANCY'/WD=OS)
22     DS(NAME=LN/DESC='NORTH LIGHTING'/
23         FFC=6*0,.7,.7,8*0,2*.33,4*.7,.4,0)
24     DS(NAME=LC/DESC='CENTER LIGHTING'/
25         FFC=16*0,.5,5*.7,.3,0)
26     DS(NAME=LS/DESC='SOUTH LIGHTING'/
27         FFC=6*0,.7,.7,8*0,5*.7,3*0)
28     WS(NAME=LITN/DESC='NORTH LIGHTING'/WD=LN)
29     WS(NAME=LITC/DESC='CENTER LIGHTING'/WD=LC)
30     WS(NAME=LITS/DESC='SOUTH LIGHTING'/WD=LS)
31     DS(NAME=EN/DESC='NORTH EQUIPMENT'/
32         FFC=20*0,3*1,0)
33     DS(NAME=EC/DESC='CENTER EQUIPMENT'/
34         FFC=16*0,4*1,4*0)
35     DS(NAME=ES/DESC='SOUTH EQUIPMENT'/
36         FFC=6*.3,2*1,8*.3,2*1,3*.7,3*.3)
37     WS(NAME=EQPN/DESC='NORTH EQUIPMENT'/WD=EN)
38     WS(NAME=EQPC/DESC='CENTER EQUIPMENT'/WD=EC)
39     WS(NAME=EQPS/DESC='SOUTH EQUIPMENT'/WD=ES)
40     WS(NAME=CONST/DESC='CONSTANT 100%'/ALL=FULL)
41     MATL(NAME=GYP/DESC='GYPSUM WALLBOARD'/K=.42/D=45./CP=.3)
42     MATL(NAME=WD-S/DESC='SOFTWOOD'/K=.0675/D=32./CP=.33)
43     MATL(NAME=SHTH/DESC='INTERMEDIATE DENSITY BUILDING BOARD SHEATHING'/
44         K=.034/D=22./CP=.31)
45     MATL(NAME=C-HW/DESC='HEAVY CONCRETE'/K=1.0/CP=.2/D=140.)
46     MATL(NAME=B1/DESC='AIRSPACE RESISTANCE'/R=.91/AIR)
47     MATL(NAME=R5/DESC='R5 POLYSTYRENE'/R=5.)
48     MATL(NAME=R19/DESC='R19 INSULATION'/R=19.)
49     MATL(NAME=R30/DESC='R30 INSULATION'/R=30.)
50     MATL(NAME=SPDS/DESC='STANDARD GLASS'/GLASS/R=.0236/TRNS=.86)
51     MATL(NAME=ASH/DESC='ASPHALT SHINGLES'/K=18.16/D=70/CP=.3)
52     MATL(NAME=DIRT/K=.1/D=65./A=.70)
```

Figure II.3   TARP input for example problem

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```
53     MATL(NAME=AL/DESC='ALUMINUM SIDING'/K=128/D=171./CP=.2)
54     MATL(NAME=CPT/DESC='CARPET & PAD'/R=2.08)
55     CONS(NAME=WL-I/DESC='EXTERIOR WALL - INSULATION AREA'/
56          MATL=.0052,AL,  .0417,SHTH,  0,R19,  .0521,GYP)
57     CONS(NAME=WL-S/DESC='EXTERIOR WALL- STUD AREA'/
58          MATL=.0052,AL,  .0417,SHTH,  0,R19,  .0521,GYP)
59     CONS(NAME=PTN-A/DESC='PARTITION - AIR SPACE AREA'/
60          MATL=.0521,GYP,  0,B1,  .0521,GYP)
61     CONS(NAME=PTN-S/DESC='PARTITION - STUD AREA'/
62          MATL=.0521,GYP,  .292,WD-S,  .0521,GYP)
63     CONS(NAME=WDW2/DESC='2 PANE WINDOW'/
64          MATL=0,SPDS,  0,B1,  0,SPDS)
65     CONS(NAME=FRAME/DESC='WINDOW FRAME'/MATL=0.1354,WD-S)
66     CONS(NAME=RF-T/DESC='CEILING/ROOF - TRUSS AREA'/
67          MATL=.0104,ASH,  .0417,WD-S,  .625,WD-S,  .0417,GYP)
68     CONS(NAME=RF-I/DESC='CEILING/ROOF - INSULATION AREA'/
69          MATL=.0104,ASH,  .0417,WD-S,  0,R30,  .0417,GYP)
70     CONS(NAME=PTN-M/DESC='MASSIVE PARTITION'/MATL=.667,C-HW)
71     CONS(NAME=SLAB-C/DESC='SLAB WITH CARPET'/
72          MATL=.5,DIRT,  0,R5,  .333,C-HW,  0,CPT)
73     CONS(NAME=SLAB-T/DESC='SLAB WITH TILE'/
74          MATL=.5,DIRT,  0,R5,  .333,C-HW)
75     CPFL(NAME=P1/DESC='HEATING SETBACK'/CAP=1,0/TMP=60,62)    .
76     CPFL(NAME=P2/DESC='STANDARD HEATING'/CAP=1,0/TMP=68,70)
77     CDS(NAME=HN/DESC='NORTH HEATING'/CPFL=6*P1,2*P2,8*P1,6*P2,2*P1)
78     CDS(NAME=HC/DESC='CENTER HEATING'/CPFL=16*P1,6*P2,2*P1)
79     CDS(NAME=HS/DESC='SOUTH HEATING'/CPFL=6*P1,2*P2,8*P1,5*P2,3*P1)
80     CWS(NAME=HEATN/DESC='NORTH HEATING'/WD=HN)
81 ·   CWS(NAME=HEATC/DESC='CENTER HEATING'/WD=HC)
82     CWS(NAME=HEATS/DESC='SOUTH HEATING'/WD=HS)
83     ]
84   BUILDING [
85     SIM(SLDS=3/HTB=0/FLOW/CNVG=.1,.01,.34,12)
86     DSS(AZM=180./TILT=153.4/ORG=0,12,16/SIZE=44,2)
87     DSS(AZM=180./TILT=206.6/ORG=0,0,8/SIZE=44,2)
88     DSS(AZM=0./TILT=116.6/ORG=0,36,8/SIZE=44,2)
89     ]
90   ZONE [
91     GEOM(NAME=NORTH)
92     CTRL(CWS=HEATN/HEAT=12)
93     PEO(WS=OCCN/CAP=3)
94     LIT(WS=LITN/CAP=1.4)
95     EQP(WS=EQPN/CAP=1.0)
96     MASS(CONS=PTN-A/AREA=480)
97     SRF(EX/OP/BS/CONS=WL-I/AZM=0/ORG=44,36,0/SIZE=41,8)
98       SRF(EX/TR/SS/CONS=WDW2/ORG=12,5,-.25/SIZE=20,2)
99       AFS(AREA=0.2/EXP=.65)
100    SRF(EX/OP/BS/CONS=WL-S/AZM=0/ORG=3,36,0/SIZE=3,8)
101    SRF(EX/OP/BS/CONS=RF-T/AZM=0/ORG=44,36,8/SIZE=41,8.95/TILT=26.6)
102      AFS(AREA=0.1/EXP=.65)
103    SRF(EX/OP/BS/CONS=RF-I/AZM=0/ORG=3,36,8/SIZE=3,8.95/TILT=26.6)
104    SRF(IN/OP/BS/CONS=PTN-M/AZM=180/ORG=0,24,0/SIZE=44,12/ZONE=CENTER)
```

Figure II.3 (continued)

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```
105        AFS(AREA=0.5/EXP=.50)
106     SRF(IN/OP/BS/CONS=PTN-M/AZM=270/ORG=0,36,0/VRTS=12,0, 12,12, 0,8)
107     SRF(IN/OP/BS/CONS=PTN-M/AZM=90/ORG=44,24,0/VRTS=12,0, 12,8, 0,12)
108     SRF(EX/OP/BS/CONS=SLAB-C/AZM=180/ORG=0,36,0/SIZE=44,12/TILT=180)
109       OSC(TGP=1)
110     ]
111  ZONE [
112    GEOM(NAME=CENTER)
113    CTRL(CWS=HEATC/HEAT=12)
114    PEO(WS=OCCC/CAP=3)
115    LIT(WS=LITC/CAP=1.4)
116    EQP(WS=EQPC/CAP=1.0)
117    MASS(CONS=PTN-A/AREA=480)
118    SRF(EX/OP/BS/CONS=FRAME/AZM=180/ORG=0,12,12/SIZE=44,3)
119      SRF(EX/TR/SS/CONS=WDW2/ORG=2,0,-.25/SIZE=40,3)
120      AFS(AREA=0.25/EXP=.65)
121    SRF(EX/OP/BS/CONS=RF-T/AZM=0/ORG=44,24,12/SIZE=41,8.95/TILT=26.6)
122      AFS(AREA=0.1/EXP=.65)
123    SRF(EX/OP/BS/CONS=RF-I/AZM=0/ORG=3,24,12/SIZE=3,8.95/TILT=26.6)
124    SRF(IN/OP/BS/CONS=PTN-A/AZM=180/ORG=3,12,0/SIZE=41,12/ZONE=SOUTH)
125      AFS(AREA=0.5/EXP=.50)
126    SRF(IN/OP/BS/CONS=PTN-S/AZM=180/ORG=0,12,0/SIZE=3,12/ZONE=SOUTH)
127    SRF(IN/OP/BS/CONS=PTN-M/AZM=0/ORG=44,24,0/SIZE=44,12/ZONE=NORTH)
128      AFS(AREA=0.5/EXP=.50)
129    SRF(IN/OP/BS/CONS=PTN-M/AZM=270/ORG=0,24,0/VRTS=12,0, 12,16, 0,12)
130    SRF(IN/OP/BS/CONS=PTN-M/AZM=90/ORG=44,12,0/VRTS=12,0, 12,12, 0,16)
131    SRF(EX/OP/BS/CONS=SLAB-C/AZM=180/ORG=0,24,0/SIZE=44,12/TILT=180)
132      OSC(TGP=1)
133     ]
134  ZONE [
135    GEOM(NAME=SOUTH)
136    CTRL(CWS=HEATS/HEAT=12)
137    PEO(WS=OCCS/CAP=3)
138    LIT(WS=LITS/CAP=1.4)
139    EQP(WS=EQPS/CAP=9.4/LOST=.4)
140    MASS(CONS=PTN-A/AREA=480)
141    SRF(EX/OP/BS/CONS=WL-I/AZM=180/ORG=0,0,0/SIZE=41,8)
142      SRF(EX/TR/SS/CONS=WDW2/ORG=12,3,-.25/SIZE=20,4)
143      AFS(AREA=0.2/EXP=.65)
144    SRF(EX/OP/BS/CONS=WL-S/AZM=180/ORG=41,0,0/SIZE=3,8)
145    SRF(EX/OP/BS/CONS=RF-T/AZM=180/ORG=0,0,8/SIZE=41,8.95/TILT=26.6)
146      AFS(AREA=0.1/EXP=.65)
147    SRF(EX/OP/BS/CONS=RF-I/AZM=180/ORG=41,0,8/SIZE=3,8.95/TILT=26.6)
148    SRF(IN/OP/BS/CONS=PTN-A/AZM=0/ORG=44,12,0/SIZE=41,12/ZONE=CENTER)
149      AFS(AREA=0.5/EXP=.50)
150    SRF(IN/OP/BS/CONS=PTN-S/AZM=0/ORG=3,12,0/SIZE=3,12/ZONE=CENTER)
151    SRF(IN/OP/BS/CONS=PTN-M/AZM=270/ORG=0,12,0/VRTS=12,0, 12,8, 0,12)
152    SRF(IN/OP/BS/CONS=PTN-M/AZM=90/ORG=44,0,0/VRTS=12,0, 12,12, 0,8)
153    SRF(EX/OP/BS/CONS=SLAB-T/AZM=180/ORG=0,12,0/SIZE=44,12/TILT=180)
154      OSC(TGP=1)
155     ]
```

Figure II.3 (concluded)

BUILDING LOADS FOR

 THERMAL MASS TEST - SIMULTANEOUS ZONES, DIRECT SUN

 COLUMBIA, MO.

 MILD WINTER

ZONE	TOTAL HEATING (KBTU)	TOTAL COOLING (KBTU)	PEAK HEATING (KBTUH)	PEAK COOLING (KBTUH)	MAX TEMP (F)	MIN TEMP (F)	HX	HT	V	CL	CX
NORTH	51.02	0.00	10.166	0.000	69.28	61.90	0	10	0	0	0
CENTER	1.13	0.00	1.126	0.000	73.10	64.10	0	2	0	0	0
SOUTH	.31	0.00	.308	0.000	77.86	67.96	0	1	0	0	0
TOTAL:	5.245E+01	0.	10.473	0.000	77.86	61.90					

MAX HEATING OCCURS AT HOUR 7 ON 21FEB
MAX TEMP OCCURS AT HOUR 18 ON 21FEB
MIN TEMP OCCURS AT HOUR 6 ON 21FEB

Figure II.4 Calculated loads for example problem

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III.A   INTRODUCTION

III.A.1   THE HEAT BALANCE METHOD

TARP is a large collection of algorithms which perform a simultaneous evaluation of multi-room temperatures and energy requirements as affected by dynamic external and internal thermal conditions. The overall simulation process is best explained in terms of a single room. The calculation of the room air temperature is based on a heat balance on the room air. The convective gains from the room surfaces and internal sources plus the sensible gain from incoming air plus the energy added by the air handling system must equal zero.

$$CE + \Sigma \; HC_i * S_i * (T_i - TZ) + \Sigma \; F_j * Cp * (TS_j - TZ) + L = 0 \qquad (A.1.1)$$

where

    CE   = energy convected from internal sources
    Si   = area of surface i
    HC_i = convection coefficient of surface i
    T_i = temperature of surface i
    TZ   = room air temperature
    F_j = mass flow of air through opening j
    Cp   = specific heat of air
    TS_j = temperature of the air through opening j
    L   = energy from the air handling system

The summations apply to all surfaces/openings which are part of the room. The values of the surface temperatures, T_i, are obtained by evaluating a heat balance at every surface of the room using an assumed room temperature. A better estimate of the room temperature is then obtained by solving equation A.1.1 for TZ. Repeating this process leads to successively better approximations of the surface and air temperatures. The process is rapidly convergent. Multiple rooms can be handled within the iterative scheme given an appropriate data structure and proper heat balances on the surfaces between rooms. Multiple rooms are thermally connected by conductive, convective, and radiative heat transfer. The following sections describe the algorithms for the various heat transfer mechanisms and thermal driving functions which culminate in multi-room heat balances.

III.A.2   TABLE OF SYMBOLS

The following symbols are used frequently in the algorithm descriptions. Symbols which are local to an algorithm are defined as they occur.

Subscripts:
      Subscripts may be omitted if context is clear.

Symbol   Meaning
a   ambient air
g   ground surface
i   surface i
j   surface j (usually meaning opposite side of surface i)
k   order of conduction transfer functions (CTF)
m   number of CTF
m   zone m (usually meaning adjacent to zone n)
n   zone n
t   time
s   sky
sg   surface to ground
ss   surface to sky

Summation limits:
NC   number of temperature CTF
NF   number of flux CTF (NF $\leq$ NC)
NS   number of surfaces
NZ   number of zones

Parameters:
Symbol   Units   Meaning
α_i absorptance of surface i for short wave radiation
ε_i emittance of surface i for long wave radiation
g m/s^2 gravitational constant (9.80)
ρ_i reflectance of surface i
σ W/m^2K^4 Stefan-Boltzman constant (5.6688E-8)
τ_i transmittance of surface i
θ_i angle of incidence of sun's rays on surface i
ϕ_i surface tilt angle
ψ_i surface azimuth angle
A_i m^2 area of opening i
C_p Wh/kgK   specific heat (often refers to air - 1004.)
CE_n W   convective gain from all internal sources in zone n
CI_i W/m^2 convective flux from zone air to (inside of) surface i
CO_i W/m^2 convective flux from environment to surface i
D kg/m^3 density
F   kg/s   mass flow rate
F_{ij} radiation interchange factor from surface i to surface j
HA_i W/m^2K surface i outside convection film coefficient
HC_i W/m^2K surface i inside convection film coefficient
HG_i W/m^2K surface i radiative conductance
                    (outside surface to ground radiant temperature)
HO_i W/m^2K overall outside surface conductance
HR_i W/m^2K surface i radiative conductance
                    (inside surface to zone mean radiant temperature)
HS_i W/m^2K surface i radiative conductance
                    (outside surface to sky radiant temperature)

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I_b	W/m^2	intensity of solar beam (direct) radiation
I_d	W/m^2	intensity of solar diffuse radiation
I_s	W/m^2	intensity of sky diffuse radiation (sky brightness)
I_g	W/m^2	intensity of ground reflected radiation
$J_{i,k}$		flux referring CTF
$KI_{i,t}$	W/m^2	inward conductive flux at inside of surface i at time t
$KIP_{i,t}$	W/m^2	portion of inward conductive flux based on previous temperature and flux history terms
$KO_{i,t}$	W/m^2	outward conductive flux at outside of surface i at time t
$KOP_{i,t}$	W/m^2	portion of outward conductive flux based on previous temperature and flux history terms
M	W/K	capacitance rate (mass flow times specific heat)
P	N/m^2	pressure
PB	N/m^2	barometric pressure
PS_i	N/m^2	pressure difference across surface i due to stack effect
PW_i	N/m^2	pressure difference across surface i due to wind
QI_i	W/m^2	total radiant flux absorbed at inside of surface i
QL_n	W	total long wave radiation created in zone n
QLI_i	W/m^2	long wave radiant flux absorbed at inside of surface i
QO_i	W/m^2	total radiant flux absorbed at outside of surface i
QS_n	W	total diffuse short wave radiation entering and created in zone n
QSI_i	W/m^2	short wave radiant flux absorbed at inside of surface i
QSO_i	W/m^2	short wave radiant flux absorbed at outside of surface i
S_i	m^2	area of surface i
T	C	temperature
$\bar{T}$	K	absolute temperature (= T + 273.15K)
$\bar{T}_a$	C	temperature of outside (ambient) air
T_g	C	ground surface (radiant) temperature
$TI_{i,t}$	C	temperature of inside of surface i at time t
TM	C	temperature of movable insulation (zone side or outside depending on placement)
$TO_{i,t}$	C	temperature of outside of surface i at time t
TR_n	C	mean radiant temperature of zone n
T_s	C	sky radiant temperature
TZ_n	C	temperature of zone air
U	W/m^2K	conductance (U-value) of a construct
UM_i	W/m^2K	conductance of movable insulation on surface i
V_a	m/s	wind speed (measured value)
V_{az}	m/s	wind speed at height z
$V_{az\psi}$	m/s	wind speed relative to surface at height z and orientation ψ
X	m	X-coordinate of a point
X_i		flow exponent
$X_{i,m}$	W/m^2K	outside (eXterior) CTF
Y	m	Y-coordinate of a point
$Y_{i,m}$	W/m^2K	cross CTF
Z	m	Z-coordinate of a point
Z	m	height (of surface i or zone n)
$Z_{i,m}$	W/m^2K	inside (Zone) CTF

III.B   ENVIRONMENT

III.B.1   TIME

III.B.1.1   TIME OF DAY

Currently, TARP uses a one hour time step. The time from midnight to
1:00 AM is hour number 1; from 1:00 to 2:00 AM is hour 2; ...; and from
11:00 PM to midnight is hour 24. The hour number (t_s) is used as an index in
the program to select array elements. Most driving functions, such as solar
radiation, wind, and scheduled activities, use their average values for the
hour. Temperatures are for the mid-point of the hour. The one hour time
step was chosen because it is the shortest for which weather data is commonly
available, and it is possibly the longest for significant detail in the thermal
analysis. The time step can be changed by slight modification of the program,
primarily in the handling of day (24 hour) schedules.

During some portions of the year, daylight savings time (DST) is in
effect. DST hour numbers (t_d) are given by: $t_d = t_s + 1$. TARP responds to
DST by operating scheduled activities according to td hour numbers and the
environmentally controlled activities and parameters according to t_s hours.

III.B.1.2   DATES

The TARP includes a package of routines to compute dates in various
forms for different calculational needs. All use integer arithmetic
(remainders of divisions are truncated). The starting values are the year
(YR), month (MO) and day-of-month (DM). For example the date December 31,
1980 has YR = 1980 (all 4 digits required), MO = 12, and DM = 31. The leap
year indicator (LY) is determined by the YR. LY = 1 if YR is a leap year,
0 if it is not. A year is not a leap year if it is not evenly divisible by
4, or if it is evenly divisible by 100 but not 400. Otherwise, it is a leap
year. Note that LY(1900) = 0 and LY(2000) = 1. The number of days in each
month (LM) is given by

    LM(MO=1) = 31
    LM(2) = 28 + LY
    LM(3) = 31
    LM(4) = 30
    etc.

The day-of-year number (DY) is a continuous count of days beginning at 1
January. It can be computed by

$$DY = DM + \sum_{m=0}^{MO-1} LM(m) \qquad (B.1.1)$$

For MO=1, the sum is zero.

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The Julian date (JD) is the most powerful date representation. It is a continuous count of days from 1 January 4713 B.C. Any number of days added to or subtracted from a JD is a valid JD. The following algorithms [1] convert between conventional and Julian dates:

$$L = (MO - 14) / 12$$
$$JD = DM - 32075 + 1461 * (YEAR + 4800 + L) / 4$$
$$+ 367 * (MO - 2 - 12*L) / 12$$
$$- 3 * ((YEAR + 4900 + L) / 100) / 4 \qquad (B.1.2)$$

$$J = JD + 68569$$
$$N = 4 * J / 146097$$
$$K = J - (146097*N + 3) / 4$$
$$YEAR' = 4000 * (K + 1) / 1461001$$
$$L = K - 1461 * YEAR' / 4 + 31$$
$$MO' = 80 * L / 2447$$
$$DM = L - 2447 * MO' / 80$$
$$M = MO' / 11$$
$$MO = MO' + 2 - 12 * M$$
$$YEAR = 100 * (N - 49) + YEAR' + M \qquad (B.1.3)$$

The cyclic date (CD) is used in TARP to represent time periods which begin and end certain functions. They are given by

$$CD = 32 * MO + DM \qquad (B.1.4)$$

The inverse relationships are equally simple.

$$MO = CD / 32 \qquad (B.1.5a)$$
$$DM = MOD(CD,32) \qquad (B.1.5b)$$

where
$$MOD(A,B) = \text{the remainder of } A/B$$
$$= A - (A/B)*B \qquad (MOD \text{ is a FORTRAN intrinsic function})$$

It is easy to use cyclic dates to determine if CD lies within a period from CD1 through CD2, inclusive.

If(CD2 > CD1), then (CD > CD1 and CD < CD2) for CD to be in the period.
If(CD1 > CD2), then (CD > CD1 or CD < CD2) for CD to be in the period.
(B.1.6)

A number such as 94 can be a valid cyclic date even though it represents an impossible conventional date - 30 February. This date can be used to end activities on the last day of February without considering leap year. The logic of B.1.6 still works because 1 March has cyclic date 97.

Day-of-week numbers (DW) are assigned according to: Sunday = 1, Monday = 2, ..., Saturday = 7. DW is given from JD by:

$$DW = MOD(JD+1, 7) + 1 \qquad (B.1.7)$$

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Building activities typically differ on holidays from normal schedules. The standard U. S. federal holidays are:

    1 January (New Year's day)
    3rd Monday in February (Washington's birthday)
    last Monday in May (Memorial day)
    4 July (Independence day)
    1st Monday in September (Labor day)
    2nd Monday in October (Columbus day)
    11 November (Veteran's day)
    4th Thursday in November (Thanksgiving day)
    25 December (Christmas)

If any of the four holidays with dates fall on a weekend, the nearest Friday or Monday becomes a holiday. Five tests can describe the federal holidays (given that MO is correct).

Mth (DW=N) in the month:

    If(DW = N and (DM+6)/7 = M), DM is the holiday.   (B.1.8a)

Last (DW=N) in the month:

    If(DW = N and DM > (LM-7)), DM is the holiday.   (B.1.8b)

Dated holiday (DM=J) on weekday:

    If(DM = J and DW $\neq$ 1 and DW $\neq$ 7), DM is the holiday.   (B.1.8c)

Dated holiday on Saturday:

    If(DM = J-1 and DW = 6), DM is the holiday.   (B.1.8d)

Dated holiday on Sunday:

    If(DM = J+1 and DW = 2), DM is the holiday.   (B.1.8e)

A test is also needed for the New Year's holiday on Friday, 31 December.

    Daylight savings time is in effect from the last Sunday in April through the Saturday before the last Sunday in October.

III.B.2   PSYCHROMETRICS

    The following algorithms are used to calculate the properties of moist air. They are presented as a package, but not all are required by TARP. The psychrometric package gives four ways to compute the humidity ratio depending on available information. Other values can then be computed from the humidity ratio, dry-bulb temperature, and barometric presure. The following nomenclature is used in the psychrometric package.

T_a = Dry-bulb temperature (C)
T_w = Wet-bulb temperature (C)
T_d = Dewpoint temperature (C)
TS = Saturation temperature of water at a given pressure
PB = Barometric pressure (Pa)
PS = Saturation pressure of water at a given temparature
Pw = Partial pressure of water (Pa)
W = Humidity ratio (kg/kg)
H = Enthalpy (kJ/kg)
RH = Relative humidity
V = Specific volume (m^3/kg)

TS and PS are computed from polynomial expressions obtained by fits to the detailed correlation [2]. These expressions are of the form

$$Y(X) = A_0 + A_1*X + A_2*X^2 + \ldots + A_N*X^N \qquad\qquad (B.2.1)$$

The coefficients for computing PS(T) ($\pm$0.02 %) are:

Range of T	A_0	A_1	A_2	A_3	A_4
-70. to -60.	187.72756	9.7388459	.19227592	.0017092958	5.7638449E-6
-60. to -50.	304.327455	17.544515	.38850839	.0039049250	1.4989099E-5
-50. to -35.	456.91552	30.071980	.77543816	.0092327737	4.2579887E-5
-35. to -20.	578.24965	43.849126	1.3678040	.020662996	.00012607288
-20. to 0.	611.12442	50.242069	1.8540594	.037851608	.00036358829
0. to 20.	617.57030	44.857183	1.4599520	.024895806	.00041888641
20. to 40.	674.80450	34.735044	2.1525746	.0029183585	.00069389647
40. to 70.	1882.1549	-75.905764	6.0054813	-.057650288	.0010572251
70. to 100.	10003.937	-537.34244	15.931817	-.15349268	.0014076596

The coefficients for computing TS(P) ($\pm$0.005 C) are:

Range of P	A_0	A_1	A_2	A_3
		A_4	A_5	A_6
0.2617 to 1.08	-80.481222	60.488509	-104.02603	116.27016
		-70.240148	17.403927	
1.08 to 3.94	-71.907528	17.059641	-7.6219223	2.2337690
		-.35643002	.023469826	
3.94 to 22.35	-62.643477	4.8931575	-.58140203	.047441082
		-.0023302718	6.2036235E-5	-6.8559241E-7
22.35 to 103.26	-50.166219	1.0796773	-.025433803	.00041771901
		4.1788472E-6	2.2878800E-8	-5.2415828E-11
103.26 to 617.56	-36.261166	.23970771	-.0010835426	3.3697165E-6
		-6.2986874E-9	6.3667218E-12	-2.6646050E-15
617.56 to 2364.9	-21.4716785	.052658152	-3.8998869E-5	1.9227789E-8
		-5.1661347E-12	5.7225294E-16	
2364.9 to 7471.5	-6.2548222	.017442339	-3.7406571E-6	5.4267058E-10
		-4.3379212E-14	1.4427502E-18	
7471.5 to 31605.7	9.3624054	.0065309333	-4.6769042E-7	2.4048849E-11
		-7.6034040E-16	1.3232127E-20	-9.6773935E-26
31605.7 to 102862.	33.328934	.0017898571	-2.7520024E-8	2.8970085E-13
		-1.6828604E-18	4.0679479E-24	

The polynomials are faster than the ASHRAE detailed algorithm which involves a logarithm and an exponential. The other relationships are based on the ideal gas law and are generally accurate to better than 0.7 percent. The humidity ratio may be obtained from one of the following algorithms [3].

$W (T_d, PB)$

$$P_w = PS(T_d)$$

$$W = 0.62198 * P_w / (PB - P_w) \qquad (B.2.2)$$

$W (T_a, T_w, PB)$

$$P' = PS(T_w)$$

$$W' = 0.62198 * P' / (PB - P')$$

$$W = [(2501. - 2.381*T_w)*W' - (T_a - T_w)]$$
$$/ (2501. + 1.805*T_a - 4.18*T_w) \qquad (B.2.3)$$

$W (T_a, RH, PB)$

$$P_w = RH * PS(T_a)$$

$$W = 0.62198 * P_w / (PB - P_w) \qquad (B.2.4)$$

$W (T_a, H)$

$$W = (H - T_a) / (2501. + 1.805*T_a) \qquad (B.2.5)$$

The following values may be computed when the humidity ratio is known.

$T_d (W, PB)$

$$P_w = PB * W / (0.62198 + W)$$

$$T_d = TS(P_w) \qquad (B.2.6)$$

$RH (T_a, T_d)$

$$RH = PS(T_d) / PS(T_a) \qquad (B.2.7)$$

$V (T_a, W, PB)$

$$V = 287.055 * (1. + 1.6078*W) * T_a / PB \qquad (B.2.8)$$

$H (T_a, W)$

$$H = T_a + W * (2501. + 1.805*T_a) \qquad (B.2.9)$$

$T_w (T_a, W, PB)$

T_w is computed by iterating (B.2.3).

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III.B.3   TEMPERATURES

III.B.3.1   AIR TEMPERATURES

All temperatures occur on the half-hour. Dry bulb temperature and
barometric pressure are read from the weather tape. The wet bulb temperature,
dew point, or relative humidity are also read to allow computation of the
humidity ratio and the wet bulb temperature. For design days a temperature
profile is generated between the maximum (T_a^+) and minimum (T_a^-) temperatures
for the day according to

$$T_{at} = T_a^+ - f_t * (T_a^+ - T_a^-)$$ (B.3.1)

where f_t is given by

t:	1	2	3	4	5	6	7	8	9	10	11	12
f:	.85	.90	.94	.98	1.0	.99	.95	.89	.78	.64	.48	.31

t:	13	14	15	16	17	18	19	20	21	22	23	24
f:	.17	.06	.00	.01	.07	.16	.23	.41	.53	.63	.72	.79

These values were obtain by interpolating between the hourly temperatures
given by ASHRAE [4]. This profile is for summer days. For design days the
user also gives PB and T_w corresponding to T_a^+. A humidity ratio is computed
from these and used with T_a and PB to compute Tw for every hour.

III.B.3.2   SKY TEMPERATURE

The net thermal radiative flux between a horizontal surface and the sky
(Q_{ss}) is given by

$$Q_{ss} = \epsilon_1 * (\sigma * TO_1^4 - \epsilon_s * \sigma * T_a^4)$$ (B.3.2)

with ϵ_s, the sky emmisivity, given by the correlation [5]

$$\epsilon_s = [0.787 + .764*\ln(T_d/273)]*(1 + .0224*N - .0035*N^2 + .00028*N^3)$$
    (B.3.3)

where

    N = tenths cloud cover

TARP uses a slightly different formula for computing Q_{ss}.

$$Q_{ss} = \epsilon_1 * \sigma * (TO_1^4 - T_s^4)$$ (B.3.4)

so that

$$T_s = \sqrt[4]{\epsilon_s} * T_a$$ (B.3.5)

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III.B.3.3 GROUND TEMPERATURES

The user specifies monthly ground temperatures. Useful advice for the selection of ground temperatures is a subject of ongoing research.

III.B.4 WIND

Wind speed increases with height according to the formula

$$V = V_O * \beta * (Z / Z_O)^\alpha \qquad (B.4.1)$$

where

V_O = wind speed at standard conditions
Z = height being considered
Z_O = standard height of wind measurements (10m)
α, β terrain dependent coefficients given below.

Terrain Parameters for Standard Terrain Classes [6]

Class	Description	α	β
1	ocean or other body of water with at least 5km of unrestricted expanse	0.10	1.30
2	flat terrain with some isolated obstacles (buildings or trees well separated from each other)	0.15	1.00
3	rural areas with low buildings, trees, etc.	0.20	0.85
4	urban, industrial, or forest area	0.25	0.67
5	center of large city (Manhattan)	0.35	0.47

Wind speeds are usually measured at class 2 sites (airports). Therefore, the reported velocity is V_O. Eq (B.4.1) can be rearranged to compute V_O for V measured at non-standard sites.

III.B.5 SOLAR RADIATION

The general factors in determining solar position and solar radiation intensity are described by ASHRAE [7]. Most of that information is not repeated in the following discussion.

III.B.5.1 SOLAR POSITION

The solar position is described in terms of three direction cosines which are convenient for determining the angle of incidence of the sun's rays on a building surface (E.2.2). The following procedure is used to determine the direction cosines. The values of the solar declination angle, δ, the equation of time, ϵ, and the distance form the earth to the sun, R (in AU: 1 AU = 149,504,000 km) are determined by a U.S. Naval Observatory algorithm [8].

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For a given JD, compute the number of centuries since 1900.

$$T = (JD - 2415020.5) / 36525. \tag{B.5.1}$$

Then compute the following fundamental angles (in degrees).
Mean anomaly of the sun:
$$G = 385.475833 + 35999.049750T - 0.000150T^2 \tag{B.5.2a}$$
Mean longitude of the sun:
$$L = 279.696678 + 36000.768920T + 0.000303T^2 \tag{B.5.2b}$$
Mean longitude of the moon:
$$C = 270.434164 + 481267.883144T - 0.001133T^2 \tag{B.5.2c}$$
Longitude of the ascending node of the moon's orbit:
$$N = 259.183275 - 1934.142008T + 0.002078T^2 \tag{B.5.2d}$$
Mean anomaly of Venus:
$$V = 212.603219 + 58517.803875T + 0.0001286T^2 \tag{B.5.2e}$$
Mean anomaly of Mars:
$$M = 319.529425 + 19139.858500T + 0.000181T^2 \tag{B.5.2f}$$
Mean anomaly of Jupiter:
$$J = 225.444651 + 3034.906654T \tag{B.5.2g}$$

Then compute the following values.

$$
\begin{aligned}
\theta = \ & 0.397930 \sin(L) + 0.009999 \sin(G-L) + 0.003334 \sin(G+L) \\
& - 0.000208 \, T \sin(L) + 0.000042 \sin(2G+L) - 0.000040 \cos(L) \\
& - 0.000039 \sin(N-L) - 0.000030 \, T \sin(G-L) - 0.000014 \sin(2G-L) \\
& - 0.000010 \cos(G-L-J) - 0.000010 \, T \sin(G+L)
\end{aligned}
\tag{B.5.3a}
$$

$$
\begin{aligned}
\rho = \ & 1.000421 - 0.033503 \cos(G) - 0.000140 \cos(2G) \\
& + 0.000084 \, T \cos(G) - 0.000033 \sin(G-J) + 0.000027 \sin(2G-2V)
\end{aligned}
\tag{B.5.3b}
$$

$$
\begin{aligned}
\phi = \ & -0.041295 \sin(2L) + 0.032116 \sin(G) - 0.001038 \sin(G-2L) \\
& - 0.000346 \sin(G+2L) - 0.000095 - 0.000080 \, T \sin(G) \\
& - 0.000079 \sin(N) + 0.000068 \sin(2G) + 0.000046 \, T \sin(2L) \\
& + 0.000030 \sin(C-L) - 0.000025 \cos(G-J) + 0.000024 \sin(4G-8M+3J) \\
& - 0.000019 \sin(G-V) - 0.000017 \cos(2G-2V)
\end{aligned}
\tag{B.5.3c}
$$

The maximum error in θ or ϕ is .0001 AU and the maximum error in ρ is .0001 AU^2 for the years 1800 through 2100. This is more accurate than is needed for building thermal analysis. Equations (B.5.3a-c) can be truncated with some loss in accuracy. That loss can be estimated by the sum of the magnitudes of the truncated coefficients. TARP uses the first 4, 4, and 5 terms of these equations, respectively. With the shortened equations, only G and L are evaluated.

Then compute the solar declination angle, equation of time, and the earth-sun distance.

$$\delta = \arcsin(\theta / \sqrt{\rho}) \tag{B.5.4a}$$

$$\epsilon = -\arcsin(\phi / \sqrt{\rho - \theta^2})/15. \qquad \text{[hours]} \tag{B.5.4b}$$

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$$R = \sqrt{\rho} \tag{B.5.4c}$$

The hour angle, H, is the number of hours from solar noon.

$$H = 15 (12 - t_s - \varepsilon - TZ) + LONG \tag{B.5.5}$$

where

t_s = standard time (hours) at midpoint of the timestep
TZ = time zone number (1.3.4)
$LONG$ = longitude (1.3.3)

The solar direction cosines can be determined from these values plus the latitude, λ (north positive, south negative), of the site.

$$CS_1 = \cos\delta \, \sin H \tag{B.5.6a}$$
$$CS_2 = \sin\delta \, \cos\lambda - \cos\delta \, \sin\lambda \, \cos H \tag{B.5.6b}$$
$$CS_3 = \sin\delta \, \sin\lambda + \cos\delta \, \cos\lambda \, \cos H \tag{B.5.6c}$$

CS_3 is the cosine of the solar zenith angle which also equals the sine of the solar altitude angle. The solar azimuth angle, ψ (relative to north), can be determined from

$$\sin \psi = CS_1 / \sqrt{1 - CS_3^2} \tag{B.5.7a}$$

$$\cos \psi = CS_2 / \sqrt{1 - CS_3^2} \tag{B.5.7b}$$

These angle calculations apply for the northern and southern hemispheres.

III.B.5.2   SOLAR INTENSITY

The calculation of direct normal solar intensity, I_b, and diffuse solar intensity, I_s, for clear design days is exactly as described in [7].

$$I_b = Ae^{-B/CS_3} \tag{B.5.8a}$$

$$I_s = C * I_b \tag{B.5.8b}$$

The values of A, B, and C are calculated by a truncated Fourier series fit to the data in Table 1 of [7]. Seasonal effects implicit in that table would not apply to the southern hemisphere. When the clearness number is less than 0.75, it is assumed to represent the ratio k_T defined as

$$k_T = I / I_0 \tag{B.5.9}$$

where

I = the total solar radiation on a horizontal surface

$$(= I_b * CS_3 + I_s)$$

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I_0 = the solar radiation on a horizontal surface above the earth's atmosphere [= $(I_{sc}/R^2)*CS_3$]
I_{sc} = the solar constant (1353 W/m^2)

On such cloudy design days the following correlation [9] is used.

$$I_s/I = \begin{cases} 1.0 - 0.249\ k_T & k_T < 0.35 \\ 1.557 - 1.84\ k_T & 0.35 < k_T < 0.75 \\ 0.177 & k_T > 0.75 \end{cases} \qquad (B.5.10)$$

Weather tape data is used by means of the BLAST program weather file processor. For transportability, a version of this processor should be incorporated into TARP. This version should include the most current solar radiation correlations.

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III.C   TRANSIENT HEAT CONDUCTION

III.C.1   USE OF CONDUCTION TRANSFER FUNCTIONS

The conventional equation for calculating steady state heat flux from the inside to the outside of a wall is

$$KO = U * (TI - TO) \qquad\qquad (C.1.1)$$

This equation is valid only when the wall is non-massive or when the inside or outside temperatures are constant in time. In the more common and complex situation where transient effects cannot be safely ignored, heat conduction calculations which properly account for the dynamic effects must be utilized. The methodology implemented in TARP is based on the standard response factor technique [1] developed by Stephenson and Mitalas [2] and Kusuda [3] modified for efficiency according to a suggestion by Peavy [4]. The modified response factors are called "conduction transfer functions" (CTF). The heat conduction at (and toward) the inside surface at time t is given by:

$$KI_t = \sum_{m=0}^{NT} Y_m * TO_{t-m} - \sum_{m=0}^{NT} Z_m * TI_{t-m} + \sum_{k=1}^{NF} J_k * KI_{t-k} \qquad (C.1.2)$$

The heat conduction flux at (and toward) the outside surface is

$$KO_t = \sum_{m=0}^{NT} Y_m * TI_{t-m} - \sum_{m=0}^{NT} X_m * TO_{t-m} + \sum_{k=1}^{NF} J_k * KO_{t-k} \qquad (C.1.3)$$

TARP uses the convention that the X CTF refer to outside (or eXterior) surface temperatures, and that the Z CTF refer to inside (or Zone side) temperatures as in [1]. The opposite convention is often used in other programs.

The current inside and outside conductive fluxes are functions of the current inside and outside temperatures plus a factor containing the previous temperatures and fluxes. TARP initializes the temperature and flux histories by starting from a steady state and repeatedly calculating the building thermal performance for the first day of the simulation period until essentially equal results are achieved. Equation (C.1.2) can be rewritten to emphasize the unknown values at time t.

$$KI_t = Y_0 * TO_t - Z_0 * TI_t + KIP_t \qquad\qquad (C.1.4)$$

where

$$KIP_t = \sum_{m=1}^{NT} Y_m * TO_{t-m} - \sum_{m=1}^{NT} Z_m * TI_{t-m} + \sum_{k=1}^{NF} J_j * KI_{t-k} \qquad (C.1.5)$$

Equation (C.1.3) may be similarly rewritten.

$$KO_t = Y_0 * TI_t - X_0 * TO_t + KOP_t \qquad\qquad (C.1.6)$$

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where

$$KOP_t = \sum_{m=1}^{NT} Y_m*TI_{t-m} - \sum_{m=1}^{NT} X_m*TO_{t-m} + \sum_{k=1}^{NF} J_k*KO_{t-k} \qquad (C.1.7)$$

For lightweight surfaces, such as sheet metal or thin glass, there are no CTF terms for m > 1 or k > 0. In that case $X_0 = Y_0 = Z_0 = U$, and equations (C.1.4) and (C.1.6) both reduce to equation (C.1.1). Air cavities are handled by massless 'slabs' which have only thermal resistance. This resistance cannot be described as temperature dependent. The conductive properties of a multi-pane window are described in this manner and appropriate conduction transfer functions are computed.

III.C.2   CALCULATION OF CONDUCTION TRANSFER FUNCTIONS

The CTF method is based upon the exact solution of a triangular temperature pulse on either side of the wall. A series of triangular temperature pulses can be superposed to produce a good approximation of a continuous temperature function. The triangular pulse is solved by a Laplace transform. TARP follows the calculation technique used in BLAST [5] and described in detail by Hittle [6]. That description is quite lengthy and is not repeated here.

One useful property of the CTF is that the steady state conductance of the wall is related to the CTF by

$$U = \sum_{m=0}^{NT} X_m \, / \, (1 - \sum_{k=1}^{NF} J_k)$$

$$= \sum_{m=0}^{NT} Y_m \, / \, (1 - \sum_{k=1}^{NF} J_k)$$

$$= \sum_{m=0}^{NT} Z_m \, / \, (1 - \sum_{j=1}^{NF} J_k) \qquad (C.2.1)$$

This provides the method for determining the number of CTF terms to produce the desired accuracy.

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III.D   WINDOW OPTICS

Windows are thermally critical elements of the building envelope. They
are difficult to insulate and produce much greater conductive gains and losses
than corresponding wall areas. Most can be opened to provide ventilation, but
then they are significant sources of infiltration. The unique characteristic
of windows is the transmission of light (short wavelength thermal radiation)
directly into the building. This transmitted light is usually a desirable
heat gain in the winter and an undesirable gain in the summer. It also pro-
vides natural lighting inside the building. The following sections describe
the TARP optical algorithms.

III.D.1   OPTICAL COEFFICIENTS

Figure D.1 shows how the solar-optical properties of typical uncoated
glazing materials vary with the incident angle of the light [1]. As the inci-
dent angle increases from $\theta = 0$ degrees (normal incidence), the transmittance
decreases, reflectance increases, and absorptance first increases due to the
lengthened optical path through the glass and then decreases as more incident
radiation is reflected away. These properties also vary with the wavelength
of the incident radiation. The total solar radiation incident on a window (Q)
is composed of beam and diffuse components,

$$Q = I_b * \cos\theta + I_d \qquad\qquad (D.1.1)$$

The beam component (I_b) comes directly fom the sun and is incident at angle θ.
The diffuse component (I_d) comes uniformly from all directions. Some of the
incident radiation is transmitted according to

$$QT = T_b * I_b * \cos\theta + T_d * I_d \qquad\qquad (D.1.2)$$

where
     T_b is the beam transmittance at θ and
     T_d is the transmittance for diffuse radiation.

Some is absorbed according to

$$QA = A_b * I_b * \cos\theta + A_d * I_d \qquad\qquad (D.1.3)$$

where A_b and A_d are the beam and diffuse absorptances. If an internal shade
is present, it also absorbs radiation with absorptances AS_b and AS_d.

$$QS = AS_b * I_b * \cos\theta + AS_d * I_d \qquad\qquad (D.1.4)$$

The energy absorbed in the shade is convected directly to the room air. The
energy absorbed in the glass is convected both into the room and to the outside
according to proportions (neglecting the thermal resistance of the glass which
is small compared to HI and HO) defined by

$$QA_{in} = QA * HI / (HI + HO) \tag{D.1.5a}$$

and

$$QA_{out} = QA * HO / (HI + HO) \tag{D.1.5b}$$

where

    HI = inside surface heat transfer coefficient and
    HO = outside surface heat transfer coefficient.

The expressions become more complicated for a two pane window.

$$QA_{in} = QAI * (U/HO + U/HS) + QAO * U/HO \tag{D.1.6a}$$

and

$$QA_{out} = QAI * U/HI + QAO * (U/HI + U/HS) \tag{D.1.6b}$$

where

    U = 1 / (1/HO + 1/HS + 1/HI),
    HS = heat transfer coefficient of the air gap,
    QAI = energy absorbed in the outer pane and
    QAO = energy absorbed in the outer pane.

In TARP a consistant description of absorption in single and multi pane windows is achieved by separating QA into equal components, QAI and QAO, for the single pane window. HS is then the U-value of the glass. The actual distribution of the QAI qnd QAO is handled by the more general surface heat balance equations (I.3.2) and (J.3.2).

The angle dependent properties of T_d, AO_d, AI_d, and AS_d are represented by polynomial equations in terms of $\cos\theta$. Two ranges of $\cos\theta$ are used for greater accuracy, so each property (X) has two equations

$$X = c_0 + c_1\cos\theta + c_2(\cos\theta)^2 + ... + c_4(\cos\theta)^4 \quad [\cos\theta > 0.5] \tag{D.1.7a}$$

and

$$X = d_1\cos\theta + d_2(\cos\theta)^2 + ... + c_6(\cos\theta)^6 \quad [\cos\theta < 0.5] \tag{D.1.7b}$$

The coefficients c_i and d_i are determined by curve fits to optical values computed by methods described in the following sections. TARP also computes transmittance and absorptances for diffuse radiation.

III.D.2   SHADING COEFFICIENTS

The solar optical properties of windows are often described by a shading coefficient, SC, [2] which is defined as

    SC = Solar Heat Gain of Window /
         Solar Heat Gain of Reference Glass   (D.2.1)

For single glazing this is

$$SC = [QT + QA*(HO+HI)/HO] /$$
$$[QT_{dsa} + QA_{dsa}*(HO+HI)/HO] \qquad\qquad (D.2.2)$$

where

QT   = radiation transmitted
QT_{dsa} = QT of DSA glass
QA   = radiation absorbed
QA_{dsa} = QA of DSA glass
HO   = outside surface heat transfer coefficient (= 22.7 W/m^2k)
HI   = inside surface heat transfer coefficient (= 8.3 W/m^2K)

The reference glazing material is double-strength sheet glass (DSA) with 0.86 transmittance, 0.08 reflectance, and 0.06 absorptance at normal incidence.

A shading coefficient is implemented in TARP by multiplying SC times the c_1 and d_1 of (D.1.7) computed for the reference glass. This gives correct steady state solar gains, but does not give correct proportions of transmitted and absorbed radiation (esecially for heat absorbing glasses). Correct proportions are necessary in dynamic simulation because the absorbed component produces an instantaneous convective gain to the space while the transmitted component is first absorbed by the surfaces of the space and produces a delayed gain. Therefore, the shading coefficient method is not recommended unless data for the following detailed method is unavailable.

III.D.3   UNCOATED PANE OPTICS

When a ray of light reaches a smooth interface between two non-conducting media, part of the ray is reflected and part is refracted as in figure D.2. The angle of reflection equals the angle of incidence (θ_1). The angle of refraction (θ_2) is given by Snell's law:

$$n_1 * \sin\theta_1 = n_2 * \sin\theta_2 \qquad\qquad (D.3.1)$$

where n_1 and n_2 are the indexes of refraction of the two media. The refractive index of air is effectively equal to unity. The refractive index of glass is dependent on both the composition of the glass and the wavelength of the light. The variation is small for typical wavelengths between 0.3 and 3.0 microns, but it is enough for a glass prism to separate a ray of white light into the spectrum of colors.

Reflectance is the ratio of the energy reflected from the interface to the energy incident upon it. The electromagnetic description of light shows that reflectance depends on the polarization of the incident light. The two components of polarization are perpendicular to the plane of incidence (also called transverse electric or TE) and parallel to the plane of incidence (called transverse magnetic or TM). A simple formula [3] for reflectance at the interface shown in figure D.2 is

$$\rho = [(p_1 - p_2)/(p_1 + p_2)]^2 \qquad\qquad (D.3.2)$$

$$p_i = \cos\theta_i * n_i \qquad \text{for TE light} \qquad (D.3.2a)$$

and

$$p_i = \cos\theta_i / n_i \qquad \text{for TM light} \qquad (D.3.2b)$$

Unpolarized light may be considered to consist of one half TE and one half TM polarized light. (D.3.2) is a computationally simpler form of the more familiar Fresnel equations.

The fraction of light transmitted through the interface is given by

$$\tau = (p_2/p_1)*[2*p_1/(p_1 + p_2)]^2 \qquad (D.3.3)$$

with the same polarization dependent values for p as above. It is easier to calculate transmittance from the simple energy balance: $\tau = 1 - \rho$.

Glass absorbs light passing through it in proportion to the intensity of the light. The fraction of light (τ_g) transmitted through a given distance (x) of glass is given by the exponential decay formula

$$\tau_g = e^{-kx} \qquad (D.3.4)$$

where k is the extinction coefficient of the glass. The value of k is wavelength dependent but independent of polarization. The fraction of light absorbed is ag = 1 - tg. For a glass plate of thickness L, the distance the light travels in passing from one side to the other is $x = L / \cos\theta_2$. Therefore,

$$\tau_g = e^{-kL/\cos\theta_2} \qquad (D.3.5)$$

A ray of light incident on a sheet of glass will be both reflected and refracted at the front surface. Part of the refracted component will be absorbed in the glass before reaching the back surface where it is again reflected and refracted. This continues until all the light is either absorbed or escapes from the front or back surfaces of the glass. Figure D.3 shows the first several reflections of the incident light ray. Summation of the transmitted, reflected, and absorbed components of the incident ray give the total transmittance (t), reflectance (r), and absorptance (a) of the sheet of glass. These values must be determined separately for both polarization components. ρ, τ ($= 1 - \rho$), τ_g, and α_g ($= 1 - \tau_g$) are functions of the angle of incidence and wavelength of the light. They are identical at both sides of the glass.

Single pane transmittance:

$$
\begin{aligned}
t &= (1-\rho)^2\tau_g + (1-\rho)^2\rho^2\tau_g^3 + (1-\rho)^2\rho^4\tau_g^5 + \ldots \\
&= (1-\rho)^2\tau_g (1 + \rho^2\tau_g^2 + \rho^4\tau_g^4 + \ldots) \\
&= \tau^2 \tau_g / (1 - \rho^2 \tau_g^2) \qquad (D.3.6)
\end{aligned}
$$

Single pane reflectance:

$$r = \rho + (1-\rho)^2 \rho \tau_g{}^2 + (1-\rho)^2 \rho^3 \tau_g{}^4 + \dots$$

$$= \rho + (1-\rho)2\rho\tau_g{}^2 (1 + \rho^2 \tau_g{}^2 + \rho^4 \tau_g{}^4 + \dots)$$

$$= \rho + \tau^2 \rho \tau_g{}^2 / (1 - \rho^2 \tau_g{}^2) \qquad (D.3.7)$$

Single pane absorptance:

$$a = [(1-\rho)-(1-\rho)\tau_g] + [(1-\rho)\rho\tau_g-(1-\rho)\rho\tau_g{}^2] + [(1-\rho)\rho^2\tau_g{}^2-(1-\rho)\rho^2\tau_g{}^3] + \dots$$

$$= (1-\rho)(1-\tau_g)(1 + \rho\tau_g + \rho^2\tau_g{}^2 + \dots)$$

$$= \tau \alpha_g / (1 - \rho \tau_g) \qquad (D.3.8)$$

The energy balance ($t + r + a = 1$) allows any one of the three components to be computed from the other two, or it allows a check for the consistancy of all three.

The extinction coefficient of a pane of glass can be computed from the thickness, normal incidence transmittance, and index of refraction. At normal incidence

$$\rho = [(n_1 - n_2)/(n_1 + n_2)]^2 \qquad (D.3.9a)$$

$$= [(n - 1)/(n + 1)]^2 \text{ for air and glass}$$

and

$$t = [(1 - \rho)^2 \tau_g]/[1 - \rho^2 \tau_g{}^2] \qquad (D.3.9b)$$

which combine to give a quadratic equation for τ_g. The solution of that equation is

$$\tau_g = (-B + \sqrt{B^2 + 4C}) / 2 \qquad (D.3.10)$$

where $B = (1-\rho)^2/(\rho^2 t)$ and $C = 1/\rho^2$. Finally, from (D.3.5)

$$k = - \ln(\tau_g) / L \qquad (D.3.11)$$

This provides a means of describing the glass pane in terms of simply measurable optical properties and makes it unnecessary to use the less exact shading coefficients when those properties are known.

III.D.4   REFLECTIVE COATINGS

A metallic film will be treated as a thin, smooth coating on one side of the pane of glass. Let medium 1 be the air, medium 2 the film, and medium 3 the glass substrate. The mathematical treatment of the optics of a metallic film [4, 5] is based on the index of refraction of the metal being a complex number (complex numbers indicated by ~)

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$$\tilde{n}_2 = n_2 - ik_2 \qquad\qquad [\ i = \sqrt{-1}\ ] \qquad\qquad (D.4.1)$$

where n_2 is the (real) index of refraction and k_2 is the extinction coefficient.

Snell's law still applies, but it leads to a complex value of $\cos\tilde{\theta}_2 = x + iy$. Let

$$c = [(n_1 * \sin\theta_1 * n_2)/(n_2{}^2 + k_2{}^2)]^2 \qquad\qquad (D.4.2a)$$

and

$$d = [(n_1 * \sin\theta_1 * k_2)/(n_2{}^2 + k_2{}^2)]^2 \qquad\qquad (D.4.2b)$$

Then

$$x = \sqrt{1 - c + d + \sqrt{(1-c+d)^2 + 4*c*d}}\ \ /\ 2 \qquad\qquad (D.4.2c)$$

and

$$y = c * k_2\ /\ (x * n_2) \qquad\qquad (D.4.2d)$$

The amplitude (not energy) reflectance at the interface between media i and j for light incident from medium i is given by

$$\tilde{\rho}_{ij} = (\tilde{p}_i - \tilde{p}_j)/(\tilde{p}_i + \tilde{p}_j) \qquad\qquad (D.4.3a)$$

where

$$\tilde{p}_i\ =\ \cos\tilde{\theta}_i * \tilde{n}_i \qquad\qquad [\text{TE polarization}] \qquad (D.4.3b)$$

$$\tilde{p}_i\ =\ \tilde{n}_i\ /\ \cos\tilde{\theta}_i \qquad\qquad [\text{TM polarization}] \qquad (D.4.3c)$$

The amplitude transmittance at an interface is given by

$$\tilde{\tau}_{ij} = 2 * \tilde{p}_i\ /\ (\tilde{p}_i + \tilde{p}_j) \qquad\qquad (D.4.3d)$$

Note that $\tilde{\rho}_{ji} = -\tilde{\rho}_{ij}$ and $\tilde{\tau}_{ij} * \tilde{\tau}_{ji} = 1 - \tilde{\rho}_{ij}{}^2$.

Amplitude transmittance ($\tilde{\tau}_f$) within the metallic film is based on its phase thickness defined as

$$\tilde{d} = 2 * \pi * D * \tilde{n}_2 * \cos\tilde{\theta}_2\ /\ \lambda \qquad\qquad (D.4.4a)$$

where
    D = thickness of the film and
    λ = wavelength of the light

so that

$$\tilde{\tau}_f = e^{-i\tilde{d}} \qquad\qquad [\ i = \sqrt{-1}\ ] \qquad\qquad (D.4.4b)$$

Considerations of multiple reflections within the film leads to expressions for the total amplitude reflectance and transmittance. For light incident from medium 1 the expressions are

$$\tilde{\rho}_{13} = (\tilde{\rho}_{12} + \tilde{\rho}_{23} * \tilde{\tau}_f{}^2)\ /\ (1 + \tilde{\rho}_{12} * \tilde{\rho}_{23} * \tilde{\tau}_f{}^2) \qquad\qquad (D.4.6a)$$

and

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$$\tilde{\tau}_{13} = \tilde{\tau}_{12} * \tilde{\tau}_{23} * \tilde{\tau}_f / (1 + \tilde{\rho}_{12} * \tilde{\rho}_{23} * \tilde{\tau}_f^2) \qquad \text{(D.4.6b)}$$

Reverse the subscripts for light incident from medium 3.

The energy reflectance and transmittance are given by

$$\rho_{13} = \tilde{\rho}_{13} * \bar{\rho}_{13} \qquad \text{(D.4.7a)}$$

and

$$\tau_{13} = \tilde{\tau}_{13} * \bar{\tau}_{13} * \tilde{p}_3 / \tilde{p}_1 \qquad \text{(D.4.7b)}$$

where $\bar{\rho}$ and $\bar{\tau}$ are the complex conjugates of $\tilde{\rho}$ and $\tilde{\tau}$. Energy is absorbed in the metallic film ($\rho_{13} + \tau_{13} < 1$).

Most of the above expression are complex. Rather than expanding them to get solutions in terms of real numbers, it is easier to let the computer evaluate the expressions by using complex arithmetic.

Coated glass has the same multiple reflection property as uncoated glass. Derivation of the total reflectance, transmittance, and absorptance is complicated by the fact that reflectances at the coatings depend on the direction of incidence. Again consider a light ray incident from the left (as was done in figure D.3). Properties (ρ, τ) for both the left and right surfaces of the glass are dependent on whether the light is incident from the left or right. Consider the left side to be the "front" and the right side to be the "back" of the glass. The following subscripts specify these conditions: ·

1: light incident on the left side from the left
2: light incident on the left side from the right
3: light incident on right side from the right (none)
4: light incident on right side from the left

so that for light incident from the front (superscript f)

$$r^f = \rho_1 + \rho_4 \tau_1 \tau_2 \tau_g^2 / (1 - \rho_2 \rho_4 \tau_g^2) \qquad \text{(D.4.8a)}$$

and

$$t^f = \tau_1 \tau_4 \tau_g / (1 - \rho_2 \rho_4 \tau_g^2) \qquad \text{(D.4.8b)}$$

A simple exchange of subscripts (1:3 and 2:4) will give the expressions for light incident from the back (superscript b).

$$r^b = \rho_3 + \rho_2 \tau_3 \tau_4 \tau_g^2 / (1 - \rho_4 \rho_2 \tau_g^2) \qquad \text{(D.4.9a)}$$

and

$$t^b = \tau_3 \tau_2 \tau_g / (1 - \rho_4 \rho_2 \tau_g^2) \qquad \text{(D.4.9b)}$$

Since light is absorbed in the glass and in the coatings on either side, it is easiest to compute absorptance from the energy balance: $a = 1 - r - t$. If both sides of the glass are uncoated, $\rho_1 = \rho_2 = \rho_3 = \rho_4$, and $\tau_1 = \tau_2 = \tau_3 = \tau_4$ and equations (D.4.8a and b and D.4.9a and b) reduce to (D.3.7) and (D.3.6).

The optical properties of a combination of two panes of glass can be determined from the properties of the component single panes. The values for the TE and TM polarization components must be determined separately and then added according to the relative proportions of each component [6].

Figure D.4 shows two panes of glass with fluxes of light going to both the right (I) and to the left (J). The radiation fluxes are made up of all transmitted and inter-reflected components. Let

t_n = transmittance of pane n (as an individual pane)

a_n^f = absorptance of pane n for flux from left (front)

a_n^b = absorptance of pane n for flux from right (back)

r_n^f = reflectance of pane n for light from the left (front)

r_n^b = reflectance of pane n for light from the right (back)

then

$$J_1 = I_1 * r_2^f + J_2 * t_2 \qquad \text{(D.5.1a)}$$

$$J_0 = I_0 * r_1^f + J_1 * t_1 \qquad \text{(D.5.1b)}$$

$$I_2 = I_1 * t_2 + J_2 * r_2^b \qquad \text{(D.5.1c)}$$

$$I_1 = I_0 * t_1 + J_1 * r_1^b \qquad \text{(D.5.1d)}$$

The optical properties for light incident only from the front are given by setting $J_2 = 0$, and substituting (D.5.1a-d) into the following definitions.

$$T^f = I_2 / I_0$$

$$= B * t_2 \qquad \text{(D.5.2a)}$$

$$R^f = J_0 / I_0$$

$$= r_1^f + B * r_2^f * t_1 \qquad \text{(D.5.2b)}$$

$$A_1^f = (a_1^f * I_0 + a_1^b * J_1) / I_0$$

$$= a_1^f + B * r_2^f * a_1^b \qquad \text{(D.5.2c)}$$

$$A_2^f = a_2^f * I_1 / I_0$$

$$= B * a_2^f \qquad \text{(D.5.2d)}$$

where

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$$B = t_1 / (1 - r_1{}^b * r_2{}^f) \qquad\qquad\text{(D.5.2e)}$$

For light incident from the back, set $I_0 = 0$, to obtain

$$T^b = J_0 / J_2 = C * t_1 \qquad\qquad\text{(D.5.3a)}$$

$$R^b = I_2 / J_2 = r_2{}^b + C * r_1{}^b * t_2 \qquad\qquad\text{(D.5.3b)}$$

$$A_2{}^b = (a_2{}^b * J_2 + a_2{}^f * I_1) / J_2 = a_2{}^b + C * r_1{}^b * a_2{}^f \qquad\qquad\text{(D.5.3c)}$$

$$A_1{}^b = a_1{}^b * J_1 / J_2 = C * a_1{}^b \qquad\qquad\text{(D.5.3d)}$$

where

$$C = t_2 / (1 - r_2{}^f * r_1{}^b) \qquad\qquad\text{(D.5.3e)}$$

Note that $T^f = T^b$. All other front and back coefficients may be different.

Similar heat balances can be set up for triple glazing. They lead to the following equations for front radiation.

$$T^f = E * D * t_3 \qquad\qquad\text{(D.5.4a)}$$

$$R^f = r_1{}^f + E * t_1 * (r_2{}^f + D * r_3{}^f * t_2) \qquad\qquad\text{(D.5.4b)}$$

$$A_1{}^f = a_1{}^f + a_1{}^b * E * (r_2{}^f + D * r_3{}^f * t_2) \qquad\qquad\text{(D.5.4c)}$$

$$A_2{}^f = E * (a_2{}^f + a_2{}^b * D * r_3{}^f) \qquad\qquad\text{(D.5.4d)}$$

$$A_3{}^f = a_3{}^f * E * D \qquad\qquad\text{(D.5.4e)}$$

where

$$D = t_2 / (1 - r_2{}^b * r_3{}^f) \qquad\qquad\text{(D.5.4f)}$$

and

$$E = t_1 / (1 - r_1{}^b * r_2{}^f - D * r_1{}^b * r_3{}^f * t_2) \qquad\qquad\text{(D.5.4g)}$$

There is a similar set of equations for radiation incident from the back. TARP also uses expressions for quadruple glazing, which are not repeated here.

III.D.6   DIFFUSE RADIATION

Diffuse radiation is considered to be of uniform intensity from all directions and to be unpolarized (equal amounts of TE and TM polarizations). Consider a small area, dA_1, under a hemisphere of uniform brightness I (figure D.5). The energy received is given by [7]

$$dQ = I \, dA_1 \, \cos\theta \, d\Omega \qquad\qquad\text{(D.6.1)}$$

where

dQ / dA_1 = energy per unit area

$d\Omega$ = the differential solid angle = dA_2 / r^2

$\quad\quad\quad = 2\ \pi\ (r\ \sin\theta)\ r\ d\theta\ /\ r2$

Let $X(\theta)$ be the transmittance, reflectance, or absorptance for beam radiation of a system of glass panes. Then the diffuse property, X_d, is given by

$$X_d = \int_0^{\pi/2} X(\theta)2\ \pi\ I\ \sin\theta\ \cos\theta\ d\theta\ /\ \int_0^{\pi/2} 2\ \pi\ I\ \sin\theta\ \cos\theta\ d\theta \quad\quad (D.6.2)$$

The integral is evaluated by Simpson's method using beam values of $X(\theta)$ at appropriate θ.

III.D.7   INTERIOR SHADING DEVICES

Windows commonly have drapes or blinds in addition to the panes of glass discussed so far. In TARP such interior shading devices are modeled as diffusely transmitting (ts), reflecting (rs) and absorbing (as) surfaces. When an interior shading device is added to the glazing system, a new set of inter-reflected components is created (figure D.6). The total forward flux on the shade is I_s ($=I_0 * T^f + J_s * R_d^b$). Note that we are interested in the diffuse back reflectance of the panes of glass. The total (diffusely) transmited flux through the shade is $I_t = I_s * t_s$. The total leftward flux is $J_s = I_s * r_s$. Therefore, $I_s = I_0 * T_f / (1 - r_s * R_d^b)$, and the total transmitted flux is

$$I_t = I_0 * T_f * t_s / (1 - r_s * R_d^b) \quad\quad\quad (D.7.1)$$

The total shade absorptance is

$$A_s = I_s * a_s / I_0 = T^f * t_s * a_s / (1 - r_s * R_d^b) \quad\quad\quad (D.7.2)$$

The total forward absorptance of each pane of glass is modified by

$$A_n^f = A_n^f + J_s * A_{nd}^b$$

$$\quad = A_n^f + A_{nd}^b * T^f * r_s / (1 - r_s * R_d^b) \quad\quad\quad (D.7.3)$$

Thus in the evaluation of the optical properties of a pane/shade system, it is first necessary to compute the diffuse back absorptance of each pane in the glass system by integrating beam A_n^b over θ. Then the pane/shade beam transmittance and absorptances are computed at the angles to be used in the optical properties curve fits. Finally the pane/shade diffuse properties can be computed.

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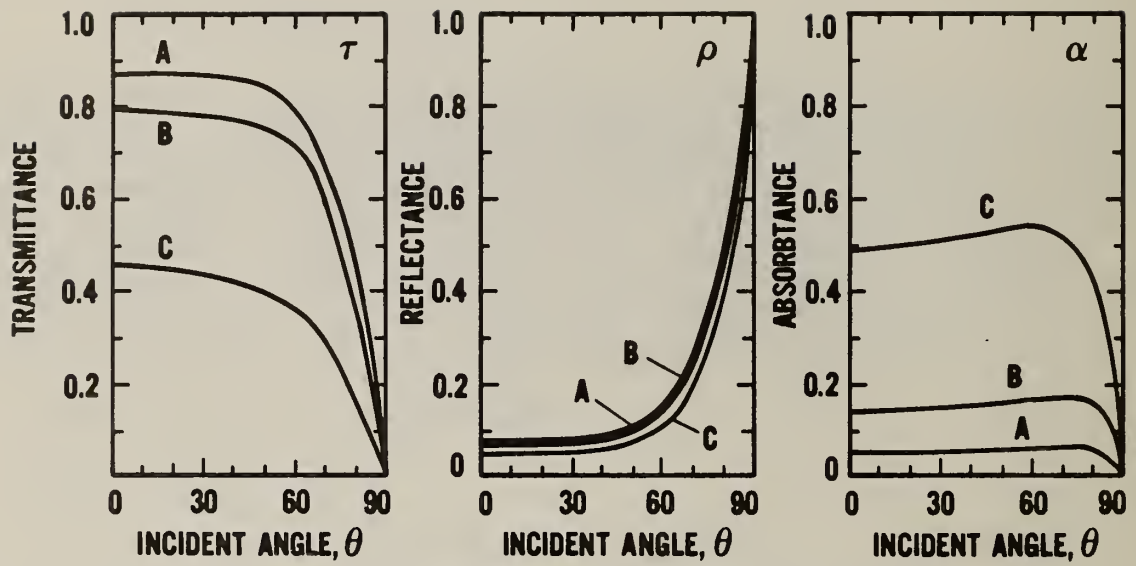
A = DSA glass
B = 6mm (0.25 in) clear glass
C = 6mm (0.25 in) heat absorbing glass

Figure III.D.1   Variation of solar-optical properties
with angle of incidence
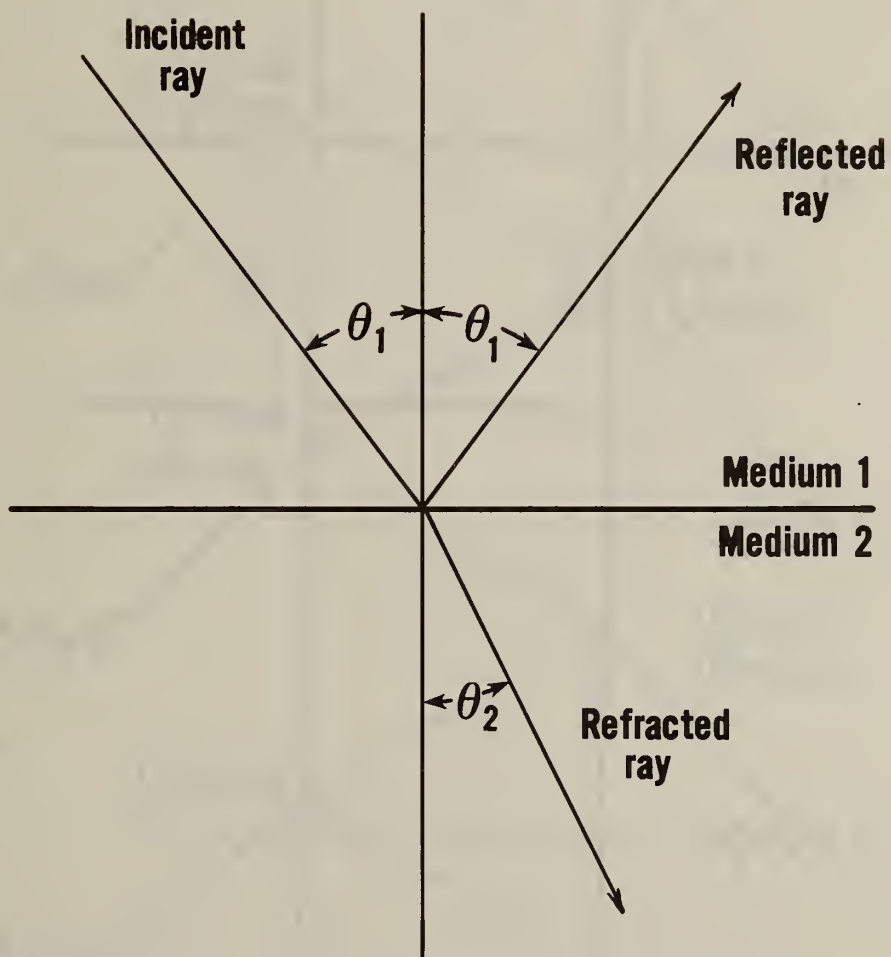
Figure III.D.2 Reflection and refraction at an interface
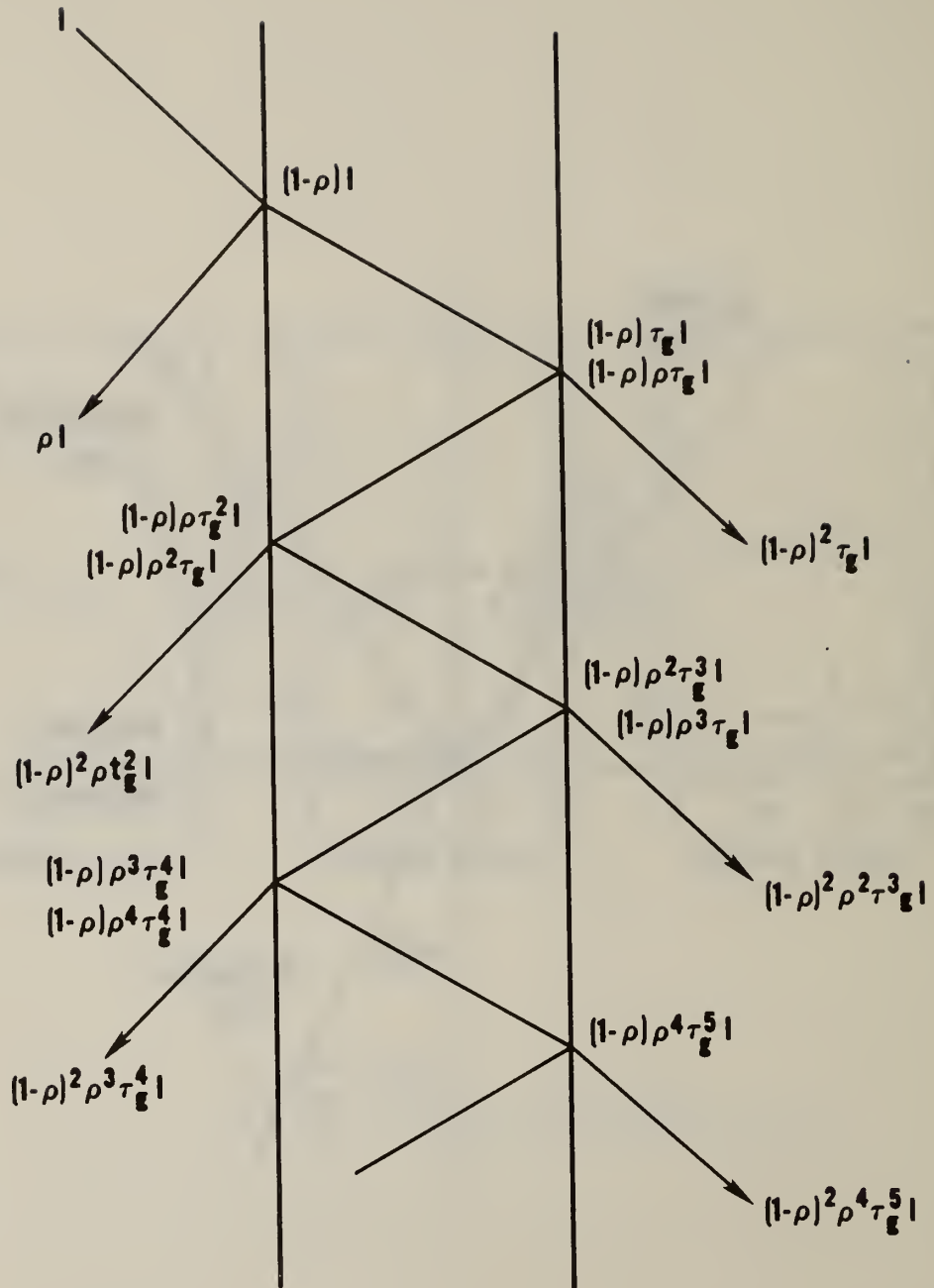
Figure III.D.3 Multiple reflections in a pane of glass

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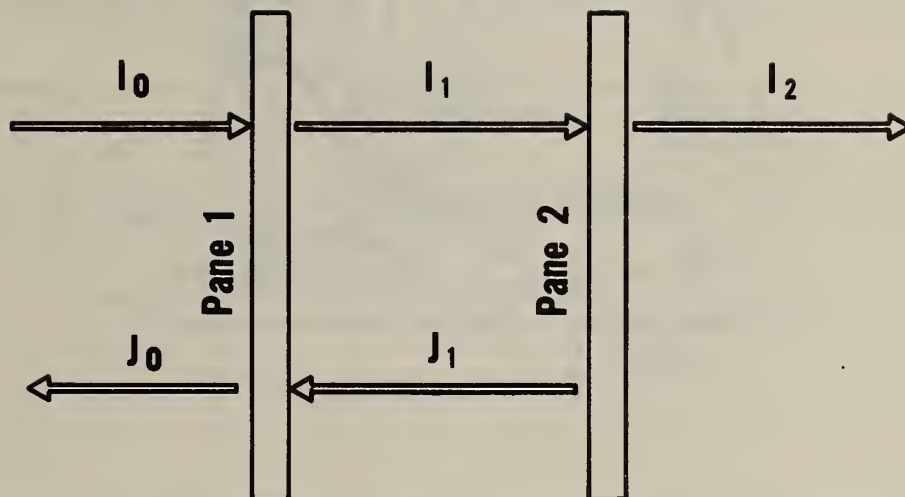
Figure III.D.4   Two-pane window system
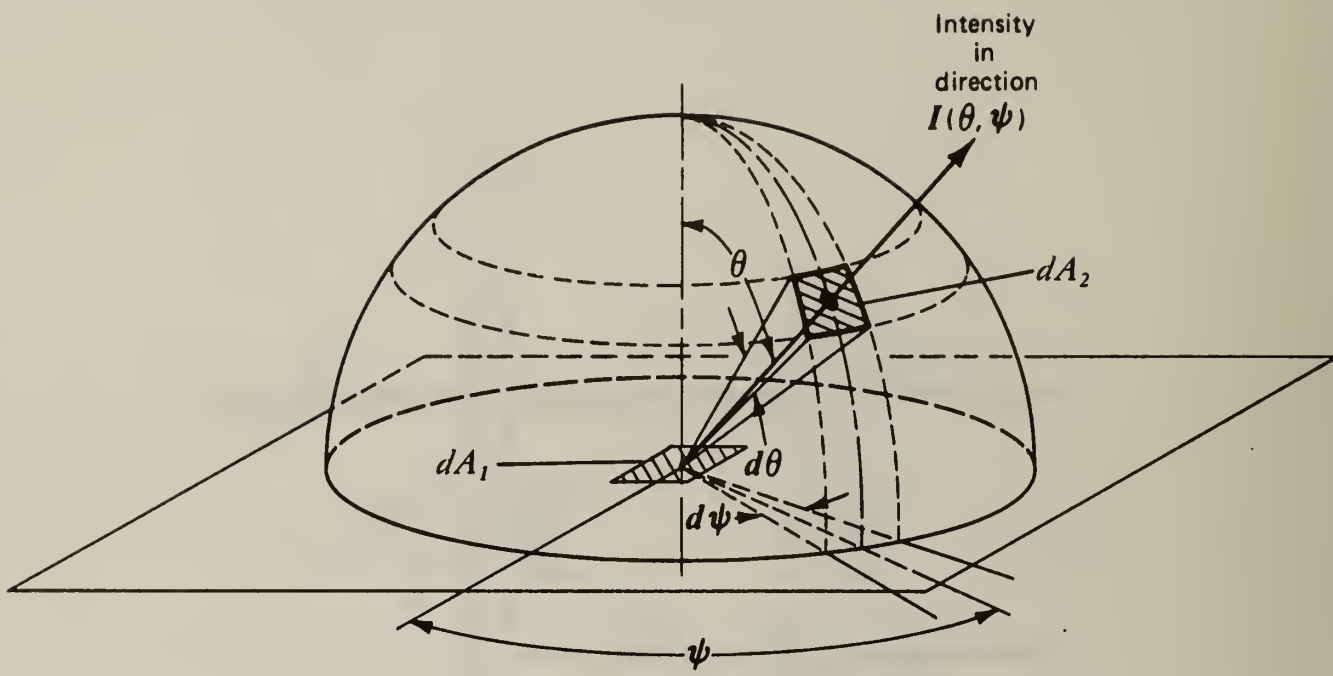
Figure III.D.5 Coordinate system for diffuse radiation
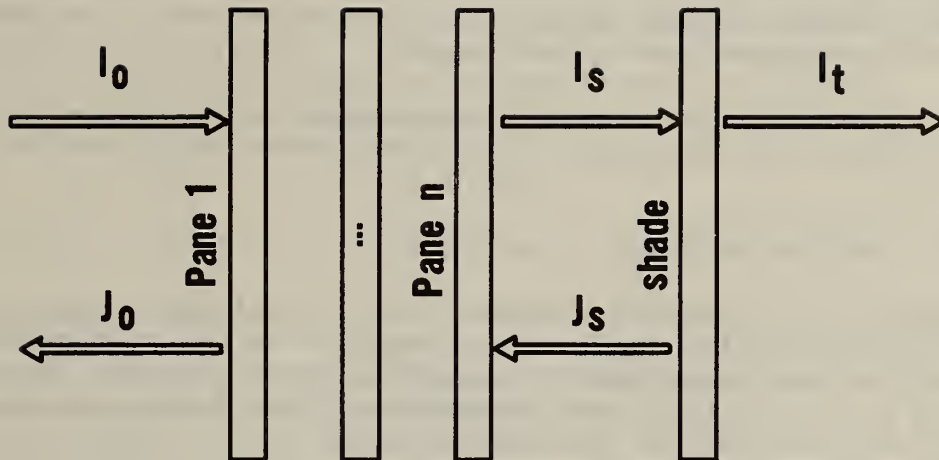
Figure III.D.6 Window system with interior shade

III.E   SOLAR GAINS AND SHADOWING

When assessing heat gains in buildings due to solar radiation, it is necessary to know how much of each part of the building is shaded and how much is in direct sunlight. As an example, figure E.1 shows a flat roofed, L-shaped structure with a window in each of the visible sides. The sun is to the right so that walls 1 and 3 and windows a and c are completely shaded, and wall 4 and window d are completely sunlit. Wall 2 and window b are partially shaded. The sunlit area of each surface changes as the position of the sun changes during the day. The purpose of the TARP shadow algorithm is to compute such sunlit areas.

The shadow algorithm is based on coordinate transformation methods similar to Groth and Lokmanhekim [1] and the shadow overlap method of Walton [2].

III.E.1   SURFACE GEOMETRY

Shadow calculations first require that the building surfaces be described geometrically. Surfaces are described by the coordinates of their vertices in a three dimensional Cartesian coordinate system. This "global" coordinate system has the X-axis pointing east, the Y-axis pointing north, and the Z-axis pointing up. The azimuth angle (ψ) of a surface is the angle from the north axis to the projection onto the X-Y plane of a normal to the surface (clockwise positive). The surface tilt angle (ϕ) is the angle between the Z-axis and the normal to the surface. The vertices are recorded in counter-clockwise sequence (as the surface is viewed from outside its zone).

TARP input allows the user to specify a rotation of ψ_b degrees of the "building" coordinate system from the global coordinate system. The global coordinates of zone origins are related to the building relative coordinates by

$$X_{zo} = X_{br} * \cos\psi_b - Y_{br} * \sin\psi_b \qquad (E.1.1a)$$

$$Y_{zo} = X_{br} * \sin\psi_b + Y_{br} * \cos\psi_b \qquad (E.1.1b)$$

$$Z_{zo} = Z_{br} \qquad (E.1.1c)$$

The user is also permitted to rotate a zone ψ_z degrees relative to the building coordinate system. Origins of zone surfaces are then given realtive to the zone coordinate system. The global coordinates of the surface origins are given by

$$X_{so} = X_{zo} + X_{zr} * \cos\psi_z - Y_{zr} * \sin\psi_z \qquad (E.1.2a)$$

$$Y_{so} = Y_{zo} + X_{zr} * \sin\psi z + Y_{zr} * \cos\psi_z \qquad (E.1.2b)$$

$$Z_{so} = Z_{zo} + Z_{zr} \qquad (E.1.2c)$$

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A surface azimuth angle relative to the zone coordinate system (ψ_s) is converted to a global azimuth by

$$\psi = \psi_s + \psi_z + \psi_b \qquad (E.1.3)$$

The surface tilt angle (ϕ) is not changed by these rotations about the Z-axis.

The coordinates of the surface vertices are given in a coordinate system in the plane of the surface relative to the second vertex as shown for four surfaces in figure E.2. The X-axis of the surface coordinate system is a horizontal line through the second vertex. The global coordinates of the surface vertices are given by

$$X = X_{so} - X_{sr} * \cos\psi - Y_{sr} * \sin\psi * \cos\phi \qquad (E.1.4a)$$

$$Y = Y_{so} + X_{sr} * \sin\psi - Y_{sr} * \cos\psi * \cos\phi \qquad (E.1.4b)$$

$$Z = Z_{so} + Y_{sr} * \sin\phi \qquad (E.1.4c)$$

Vertices in the global coordinate system can be transformed to the coordinate system relative to a given surface by

$$X' = X - X_{so} \qquad (E.1.5a)$$

$$Y' = Y - Y_{so} \qquad (E.1.5b)$$

$$Z' = Z - Z_{so} \qquad (E.1.5c)$$

$$X_{sr} = -X' * \cos\psi + Y' * \sin\psi \qquad (E.1.5d)$$

$$Y_{sr} = -X' * \sin\psi * \cos\phi - Y' * \cos\psi * \cos\phi + Z' * \sin\phi \qquad (E.1.5e)$$

$$Z_{sr} = X' * \sin\psi * \sin\phi + Y' * \cos\psi * \sin\phi + Z' * \cos\phi \qquad (E.1.6f)$$

III.E.2   SHADOW PROJECTION

All architectural forms are represented by plane polygons. This can give good accuracy even for curved surfaces: a sphere can be approximated by the 20 nodes of an icosohedron with only 3 percent error in the shadow area cast by the sphere. Consider how a solid object, which is composed of a set of enclosing plane polygons, casts a shadow. Figure E.3 shows a box shaped structure on a horizontal surface. The structure consists of a top (surface 1) and four vertical surfaces (2 and 3 visible to the observer and 4 and 5 not visible). The sun is positioned behind and to the right of the structure and a shadow is cast onto the horizontal surface (the ground). Surfaces 1, 4, and 5 are in sunlight; 2 and 3 are in shade. It is possible to think of the structure's shadow as the combination of shadows cast by surfaces 1, 2, 3, 4 and 5 or by 1, 4 and 5, or by surfaces 2 and 3. This last combination of shadow casting surfaces is the simplest. In the TARP shadow algorithm every surface is considered to be one of the surfaces which

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enclose a solid, and only those surfaces which are not sunlit at a given hour are considered shadowing surfaces.

The expressions in eq (E.1.6f) are the direction cosines of the surface:

$$CW_1 = \sin\psi * \sin\phi \tag{E.2.1a}$$

$$CW_2 = \cos\psi * \sin\phi \tag{E.2.1b}$$

$$CW_3 = \cos\phi \tag{E.2.1c}$$

The cosine of the angle of incidence of the sun's rays on the surface are given by the dot product of surface and sun (B.3.3) direction cosines.

$$\cos\theta = CS_1 * CW_1 + CS_2 * CW_2 + CS_3 * CW_3 \tag{E.2.2}$$

If $\cos\theta$ is less than zero, the sun is behind the surface.

A shadow is projected from the vertices of the shadowing surface (SS) along the direction of the sun's rays to the plane of the shadow receiving surface (RS). If any vertices of the SS are below the plane of the RS ($z < 0$), a false shadow is cast as in figure E.3. The "submerged" portion of the SS must be clipped off before projection. This is done by finding, through linear interpolation, the points on the perimeter of the SS which intersect the plane of the RS. These points become new vertices of the SS, which together with the other positive vertices define a clipped SS which casts only a real shadow.

A vertex located at (x, y, z) relative to the RS coordinate system casts a shadow to a point in the plane of the RS given by

$$x' = x - z * a / \cos\theta \tag{E.2.3a}$$

$$y' = y - z * b / \cos\theta \tag{E.2.3b}$$

where
$$a = \sin\psi * CS_1 - \cos\psi * CS_2$$
and
$$b = -\cos\psi * \cos\phi * CS_1 - \sin\psi * \cos\phi * CS_2 + \sin\phi * CS_3$$

III.E.3   HOMOGENEOUS COORDINATES

Two-dimensional homogeneous coordinate techniques are used to determine the vertices of shadow overlaps. In homogeneous coordinates, points and lines are represented by a single form which allows simple vector operations between those forms [3]. A point (X, Y) is represented by a three element vector (x, y, w) where $x = w*X$, $y = w*Y$, and w is any real number except zero. A line is also represented by a three element vector (a, b, c). The directed line (a, b, c) from point (x_1, y_1, w_1) to point (x_2, y_2, w_2) is given by

$$(a, b, c) = (x_1, y_1, w_1) \text{ cross } (x_2, y_2, w_2) \tag{E.3.1}$$

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The sequence in the cross product is a convention to determine sign. The condition that a point (x, y, w) lie on a line (a, b, c) is that

(a, b, c) dot (x, y, w) = 0   (E.3.2)

Normalize the representation of a point by dividing by w. Then if

(a, b, c) dot (x/w, y/w, 1) > 0   (E.3.3)

the point is to the left of the line, and if it is less than zero, the point is to the right of the line. The intercept (x, y, w) of line (a_1, b_1, c_1) and line (a_2, b_2, c_2) is given by

(x, y, w) = (a_1, b_1, c_1) cross (a_2, b_2, c_2) (E.3.4)

Note that the use of homogeneous coordinates as outlined above provides a consistant method and notation for defining points and lines, for determining intercepts, and for determining whether a point lies to the left, to the right, or on a line. Normalization provides the means for transforming to and from homogeneous notation and Cartesian coordinates. Thus, if (X, Y) is a Cartesian coordinate pair, its homogeneous coordinates are (X, Y, 1). Similarly, the homogeneous coordinates (x, y, w) can be transformed to the Cartesian point with coordinates (x/w, y/w).

III.E.4   OVERLAPPING SHADOWS

After transforming the shadows onto the plane of the receiving surface, the basic job of the shadow algorithm is to determine the area of the overlap between the polygons representing the shadows and the polygon representing the receiving surface.

There is considerable simplification if only convex (no interior angle > 180) polygons are considered. The overlap between two convex polygons is another convex polygon. Coordinate and projection transformations of a convex polygon produce another convex polygon. Any non-convex polygon can be constructed as a sum of convex ones.

The vertices which define the overlap between two convex polygons, A and B, consist of:

1)   the vertices of A enclosed by B,
2)   the vertices of B enclosed by A,
3)   and the intercepts of the sides of A with the sides of B.

In figure E.4a point a is the result of rule 1, point c is the result of rule 2, and points b and d result from rule 3. The overlap of A and B is the polygon a-b-c-d. Figure E.4b shows an overlap where all of the vertices of A are enclosed by B. Figure E.4c shows an overlap defined only by the intercepts of A and B. Figure E.4d shows a more complex overlap.

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Coordinate transformation retains the order of the vertices of a polygon, while a projection reverses the order. The sequence of vertices of the receiving polygons should be reversed so it and all shadow polygons will have the same sequence.

A point is enclosed by a clockwise, convex polygon if it lies to the right of all sides (or does not lie to the left of any side) of the polygon. The intercept of two sides may not lie beyond the ends of either side. These are "line segments" rather than "lines". It is possible to tell if line segments A and B intercept within their end points by noting that the ends of A must lie on both sides of B, and the ends of B must lie on both sides of A as shown in figure E.5. This should be done before the intercept is calculated.

Once the vertices are determined, they must be sorted into clockwise order for the area to be computed. Given a plane polygon of n sequential vertices (x_1, y_1), (x_2, y_2), ..., (x_n, y_n), its area is given by [4]

$$A = (x_1 y_2 + x_2 y_3 + \ldots + x_{n-1} y_n + x_n y_1 - y_1 x_2 - y_2 x_3 - \ldots - y_n x_1)/2$$

(E.4.1)

The area is positive if the vertices are counter-clockwise and negative if they are clockwise.

If two shadows overlap the receiving surface, they may also overlap each other as in figure E.6. The vertices of this overlap can be computed. The areas of all overlaps can be computed. The total sunlit area can be expressed as the sum of all polygon areas given a proper sign on each of the areas. The following convention was adopted:

receiving surface	positive (A)
overlap between shadow and receiving	negative (B & C)
overlap between two shadows	positive (D)

and so on through multiple overlaps where the sign of the overlap area is the product of the signs of the overlapping areas.

Partially transparent shadowing surfaces can also be modeled by giving a transparency (τ) to every shadowing polygon. Let τ of the receiving polygon be one. Then the τ of every overlap of polygons i and j is the product of τ_i and τ_j. The shaded area is then computed by summing $A_i * (1 - \tau_i)$ for all overlap polygons.

It is easy to determine the sunlit area of a window once all the shadow and overlap vertices on the wall have been computed. Consider wall 2 of figure E.1. First the wall is considered a simple rectangle and the window on it is ignored. The shadow overlapping is performed and the sunlit portion of the gross wall area is computed. Then the window rectangle is overlapped with the shadow to determine its sunlit area. The sunlit area of the window is subtracted from the gross wall sunlit area to determine the net wall sunlit

area. During this calculation it is not necessary to recompute the shadows, because they were precisely determined on the wall.

III.E.5   SOLAR GAINS

The total solar gain on any exterior surface is a combination of the absorption of direct and diffuse solar radiation given by

$$QSO = \alpha * (I_b * \cos\theta * S_s / S + I_s * F_{ss} + I_g * F_{sg}) \qquad (E.5.1)$$

where

α = solar absorptance of the surface
θ = angle of incidence of the sun's rays
S = area of the surface
S_s = sunlit area
I_b = intensity of beam (direct) radiation
I_s = intensity of sky diffuse radiation
I_g = intensity of ground reflected diffuse radiation
F_{ss} = angle factor between the surface and the sky
F_{sg} = angle factor between the surface and the ground

For the surface of a building located on a featureless plain

$$F_{ss} = (1 + \cos\phi) / 2 \qquad\qquad\qquad (E.5.2a)$$

and

$$F_{sg} = (1 - \cos\phi) / 2 \qquad\qquad\qquad (E.5.2b)$$

These values can be modified by the user.

For a window the absorptance, α, is divided into components α_b (for beam radiation) and α_d (for diffuse radiation) as described in section D. A similar expression describes the transmittance of solar radiation into the zone. In its default mode, TARP assumes that all transmitted beam radiation is incident on the floor. The floor absorbs a fraction of that radiation equal to the floor inside solar absorptance. The unabsorbed portion of the beam radiation is combined with the diffuse radiation and then evenly distributed over all surfaces as described in section F.2. In the detailed mode, TARP computes the beam radiation distribution on all surfaces.

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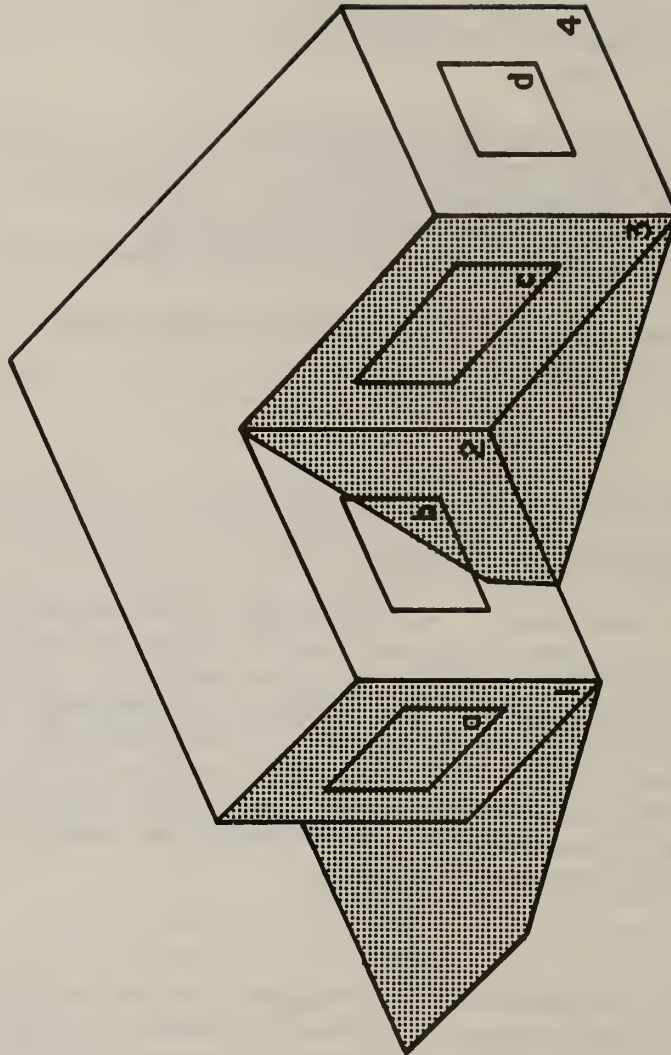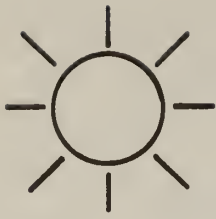
Figure III.E.1 Shadows on an L-shaped building

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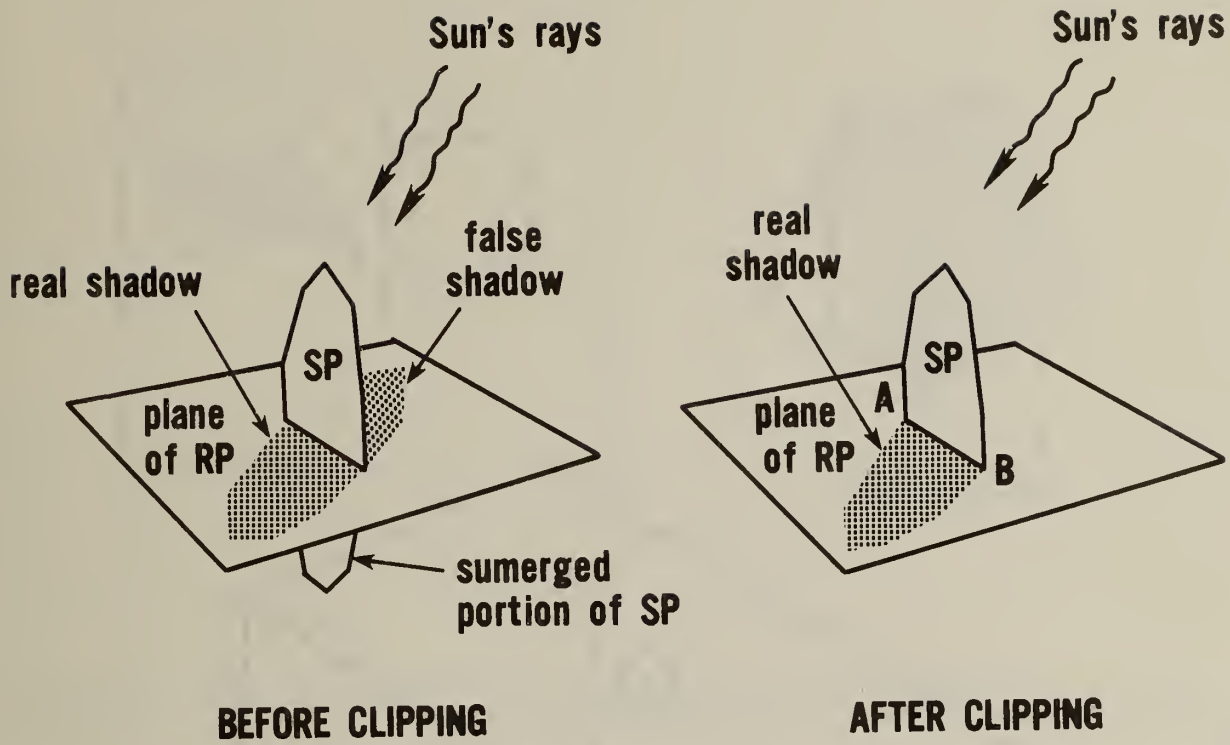
Figure III.E.2 Shadow polygon clipping
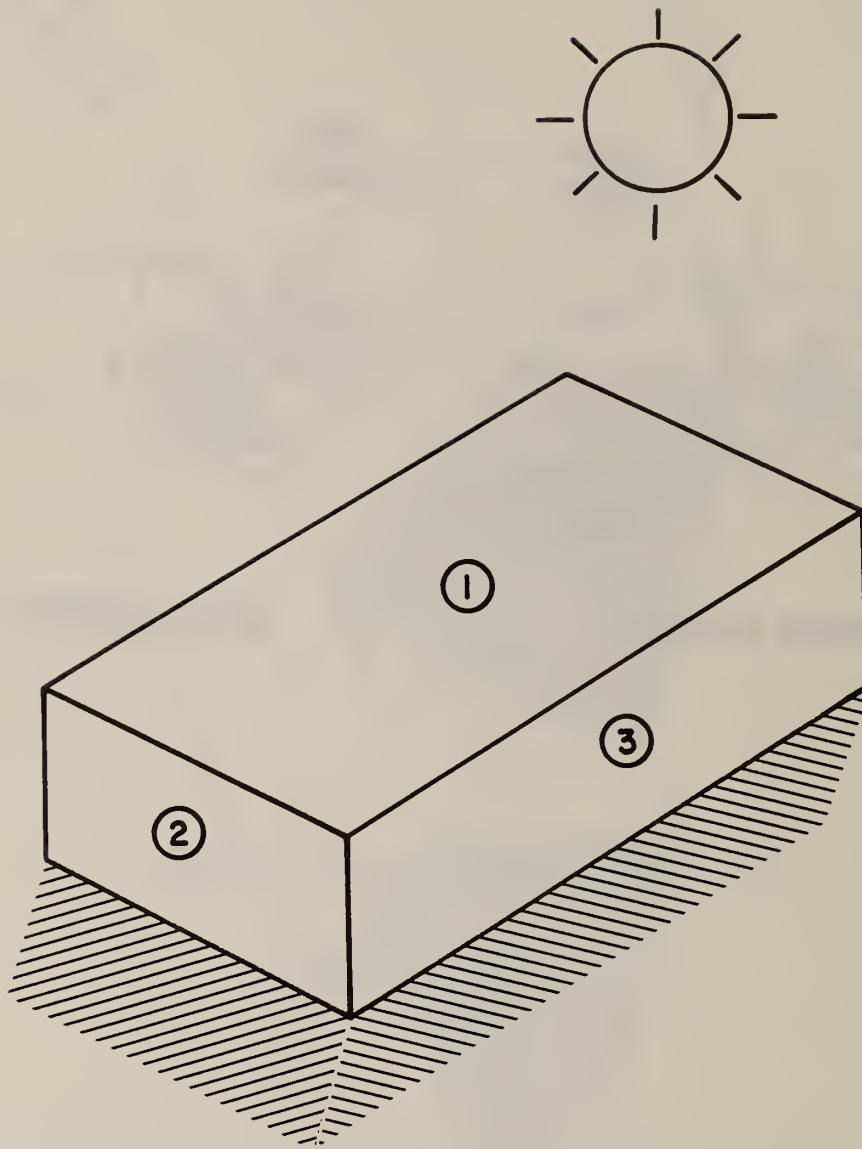
Figure III.E.3 Shadow casting surfaces
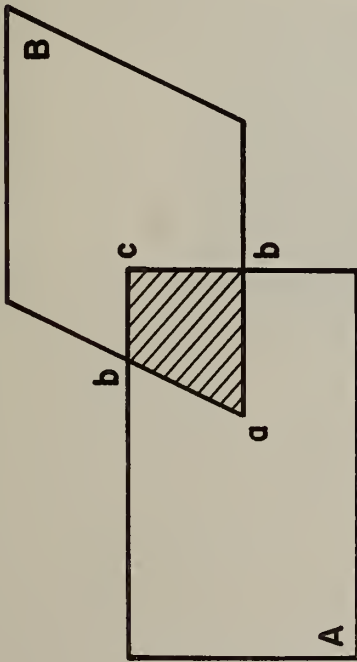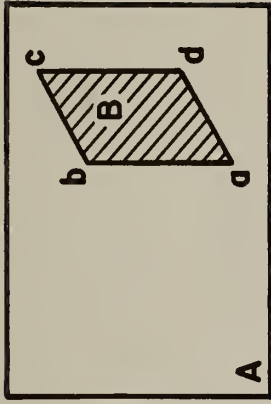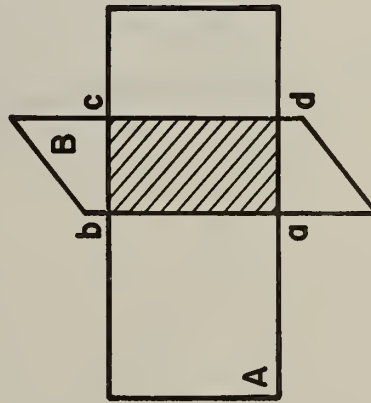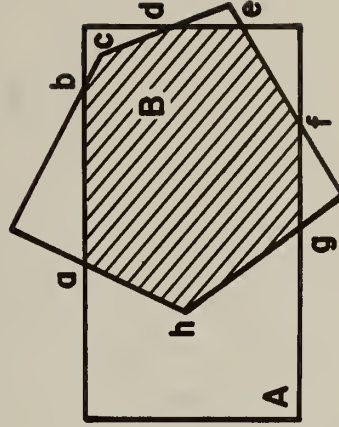
Figure III.E.4 Overlapping convex polygons

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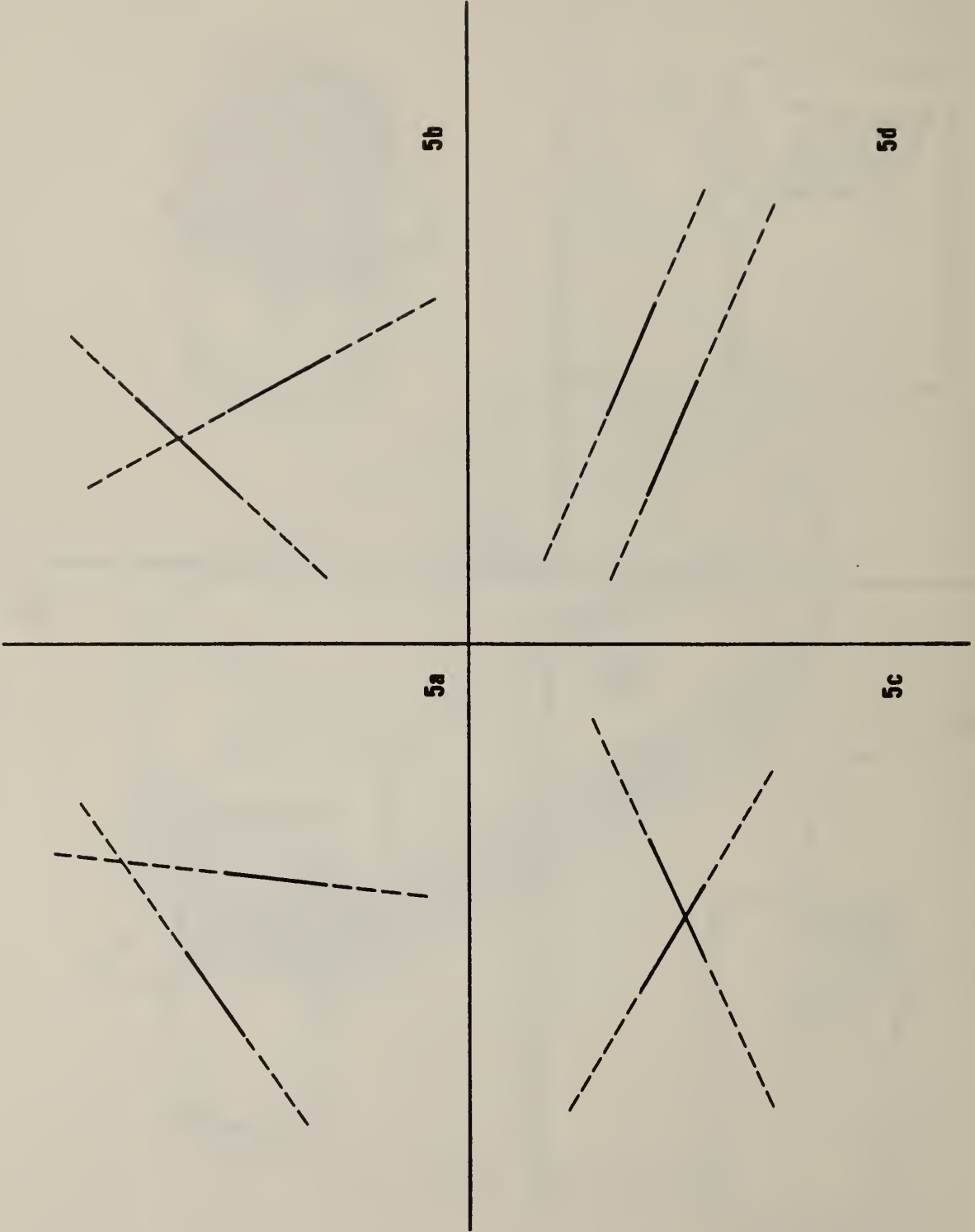
Figure III.E.5 Intercepts of line segments

56
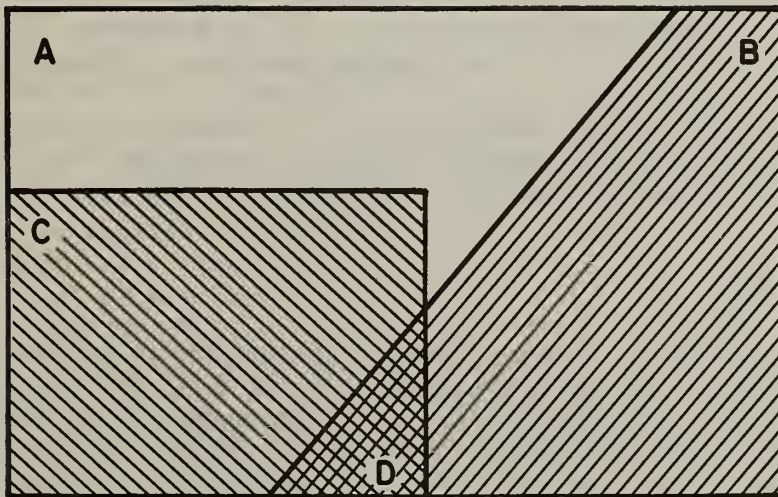
Figure III.E.6   Multiple shadow overlaps

III.F   INTERNAL HEAT GAINS

III.F.1   SOURCES AND TYPES OF GAINS

Internal heat gains from lights, people, and equipment of various types are usually significant elements in the zone thermal balance. TARP allows the user to specify heat gains from equipment of various types, lights, occupants, and baseboard heat controlled by outdoor temperature. The total heat gain is made up of convective, radiant, and latent gains in various proportions from each of these sources. Convective gains are instantaneous additions of heat to the zone air. Radiant gains are distributed on the surfaces of the zone, where they are first absorbed and then released back into the room (and some fraction conducted through the surface) according to the surface heat balances (section I). Latent gains must be handled by ventilation or air conditioning equipment. Recommended heat gains for many items of equipment are given by ASHRAE [1]. These recommendations include the sensible (convective plus radiative) and latent proportions. Sensible gains from equipment are predominately radiant. The user can specify the heat gains and proportions appropriate for any type of equipment. The gains from lights, people, and baseboard heat are slightly more complicated.

III.F.1.1   LIGHTS

Radiant gains from lights must be handled differently from other radiant gains for reasons described in F.2. It is necessary to divide the total radiant gains into visible and thermal portions. The total electric input to typical incandescent lights is converted into 10 percent visible radiation, 80 percent thermal radiation and 10 pecent convective gain. The electric input to typical flourescent lights is converted into 20 percent visible radiation, 20 percent thermal radiation, and 60 percent convective gain [2].

III.F.1.2   PEOPLE

Heat is generated in the human body by oxidation at a rate called the metabolic rate. This heat is dissipated from the body surface and respiratory tract by a combination of radiation, convection, and evaporation. The relative portions of sensible (radiation plus convection) and latent (evaporation) heat from people is a complex function of the metabolic rate and environmental conditions. TARP uses a polynomial function to divide the total metabolic heat gain into sensible and latent portions. That function is based upon a fit to data [3] at average adjusted metabolic rates of 350, 400, 450, 500, 750, 850, 1000, and 1450 Btu/h each at temperatures of 70, 75, 78, 80, and 82 F. Sensible gains of 0 at 96 F and sensible gains equal to the metabolic rate at 30 F were assumed in order to give reasonable values beyond the reported temperature range. The original data for the polynomial was in English units, but the following correlation is in metric units.

$$S = 6.461927 + .946892*M + .0000255737*M^2$$

$$+ 7.139322*T - .0627909*T*M + .0000589172*T*M^2$$

$$- .198550*T^2 + .000940018*T^2*M - .00000149532*T^2*M^2 \qquad (F.1.1)$$

where

M = metabolic rate (W)
T = air temperature (C)
S = sensible gain (W)
L = latent heat gain (W) [= M - S]

This function is compared to the original data points in figure F.1. The radiant fraction of the sensible gain is determined by the user.

III.F.1.3   BASEBOARD HEAT

Outdoor temperature controlled baseboard heat adds energy to the zone according a control profile as in figure F.2. At $T_a = T_2$, the baseboard heat gain is Q_2. For $T_a > T_2$, there is no heat gain. For $T_a < T_1$, a maximum amount of energy, Q_1, is added to the zone. There is proportional control between those temperatures:

$$Q = Q_2 - (Q_2 - Q_1)*(T_2 - T_a)/(T_2 - T_1) \qquad (F.1.2)$$

III.F.2   DISTRIBUTION OF RADIANT GAINS

It is useful to consider the distribution of short wavelength (including visible) radiant energy separate from long wavelength (thermal) radiant energy because many materials have different optical porperties at the different wavelenghts. An extreme example is glass which is opaque to the long wavelengths and transparent to the short. Properties of materials vary across the entire spectrum of wavelengths. In TARP, all radiant interactions are represented in terms of only two wavelengths: "short" and "long". Short wavelength refers to the distribution given by a ~6000K black body source such as the sun. Long wavelengths refer to radiation from ~300K sources such as walls or people. there is negligible overlap between these two distributions. Some sources, such as lights, must be considered as emitting both long and short wavelength radiation in proportions which approximate their actual effects on room surfaces.

Long wavelength radiation from all internal sources, such as people, lights, and equipment, is combined and then uniformly distributed over all surfaces according to (H.2.5).

Some fraction of the beam solar radiation transmitted into the zone is directly absorbed by the interior surfaces according to the solar distribution algorithm (3.1.5) selected by the user. The beam radiation not directly absorbed, plus the diffuse sky and ground-reflected radiation, plus the short wavelength radiation from lights are combined and distributed over the surfaces of the zone according to:

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$$QSI_i = QS_n * \alpha_i / \sum_{i=1}^{NS} S_i * (1 - \rho_i) \qquad (F.2.1)$$

If all surfaces of the room are opaque, the radiation is distributed in proportion to the area*absorptance product of each surface. For surfaces which are transparent, $\rho_i = 1 - \alpha_i - \tau_i$. That fraction of radiation represented by τ_i is lost from the zone.

The transmittance and absorptance of transparent surfaces (windows) are calculated as in section D based on optical properties of the window material layers. The total absorptance of the window is computed for the interior shading device, the inside surface, and the outside surface for diffuse solar radiation incident from outside the zone. Those absorptances are used for short wavelength radiation incident from inside the zone. In most cases, this should not cause significant error. When movable insulation covers the window, the radiation which would have been transmitted is absorbed at the outer surface of the window (thermally equal to the inside surface of the insulation).

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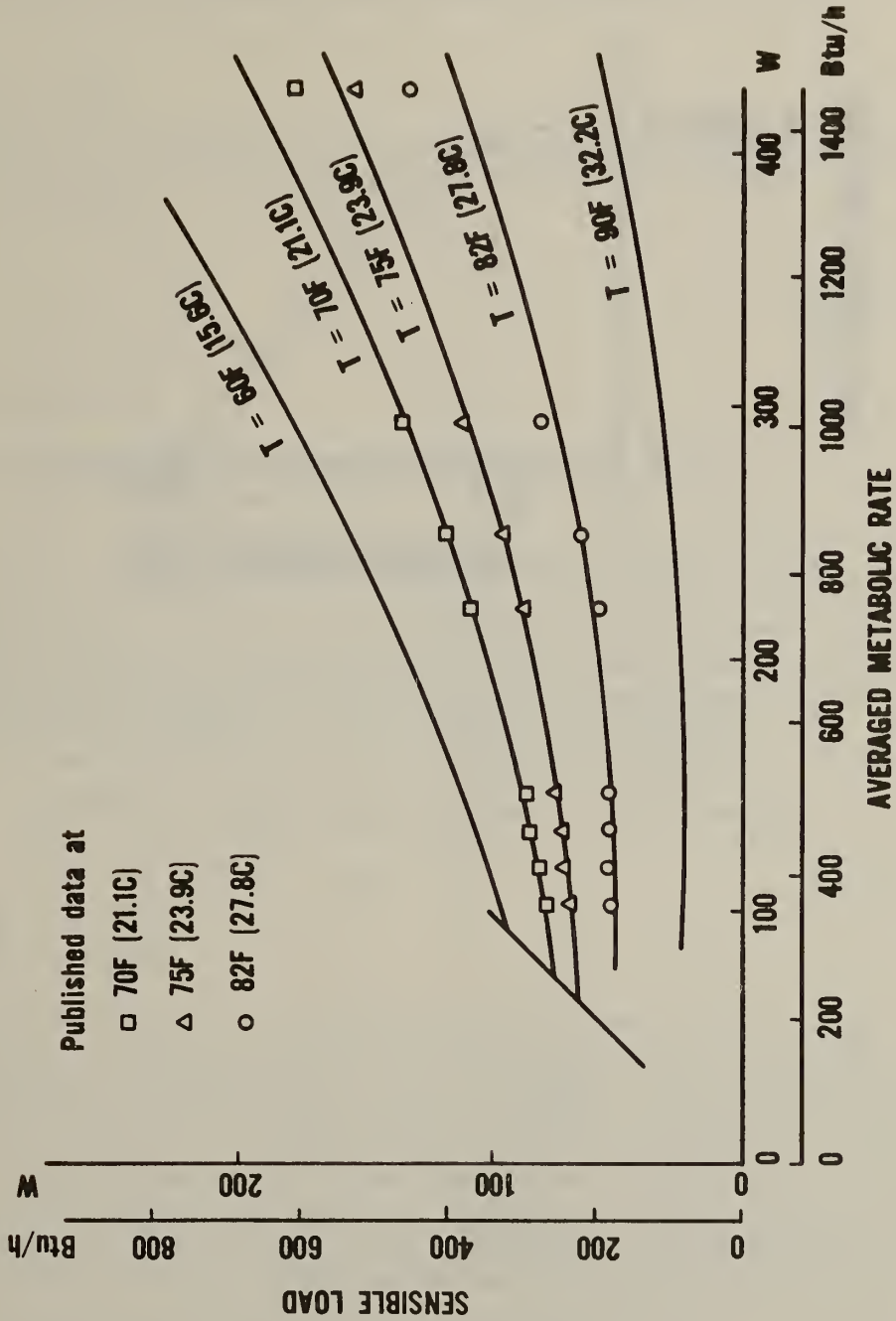
Figure III.F.1 Sensible heat gains from people

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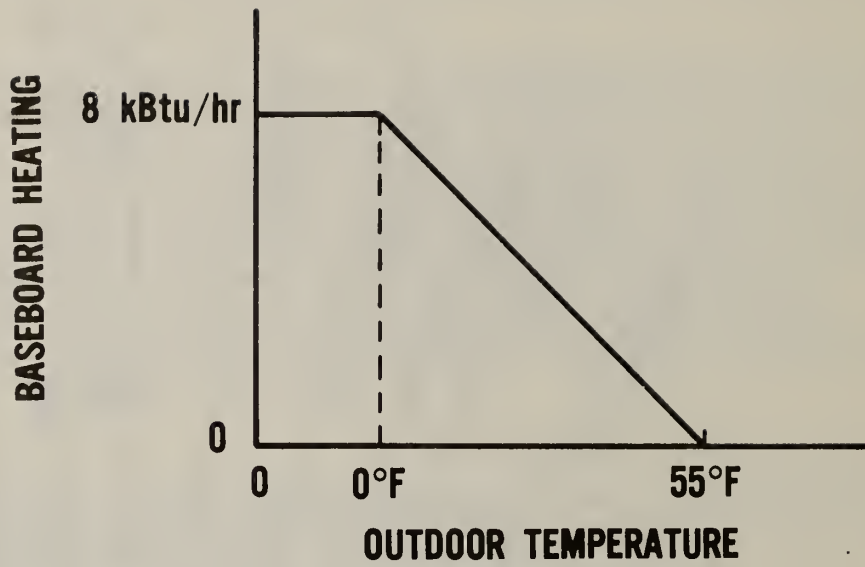
Figure III.F.2   Baseboard heat control profile

III.G   NATURAL AIR MOVEMENTS

Most building surfaces contain openings, either large or small, which permit the movement of air through them whenever there is a pressure difference across the surface. Pressure differences arise from naturally occurring wind and thermal forces. The following discussion of air movements emphasizes the relationships to basic principles of fluid mechanics.

III.G.1   WIND FORCES

Wind pressures on surfaces are proportional to the velocity head of the undisturbed air stream [1]. The wind pressure is thus calculated from Bernoulli's equation as

$$PW_i' = 0.5 * D_a * V^2 \qquad\qquad (G.1.1)$$

The density of air is given by

$$D_a = 0.0034838*PB/\underline{T}_a \qquad\qquad (G.1.2)$$

The wind speed is evaluated at the highest point of the surface using the wind speed to height correlation (B.3.1).

Wind direction effects are dependent on the building's configuration and its relationship to surrounding structures. No single correlation can truly model directional effects on all buildings or even the effects on a single building in different environments. The following correlation is a compromise derived by averaging several published correlations [2, 3]. It accounts for the trends observed in wind pressure measurements.
Let Y = angle of incidence of wind on the surface (0<=Y<=180.)

$$If(Y<=90.) \quad PW_i = (.75-1.05*Y/90.) * PW_i'$$

$$If(Y>=90.) \quad PW_i = (0.15*Y/90.-.45) * PW_i' \qquad\qquad (G.1.3)$$

III.G.2   THERMAL FORCES

Temperature differences cause air density differences which cause bouyancy (or "stack") effects. The magnitude of the force on a submerged surface (all surfaces are submerged in air) is equal to the area times the pressure at the centroid of the area. It is therefore necessary to know the pressure at the centroids and the locations of those centroids. The effect of air density on the pressure on any surface can be considered by a single simple formula. The pressure at height Z1 is equal to the pressure at height Z2 plus fluid density times the graviational constant (9.80 m/s^2)times (Z2 - Z1). Figure G.1 shows a surface separating two vertically adjacent zones.

The pressure difference (ΔP) across the surface is Pj - Pi. It is more useful to know this ΔP in terms of zone pressures Pm and Pn:

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$$P_j = P_m + D_m * g * (Z_m - Z_j) \qquad (G.2.1a)$$

$$P_i = P_n + D_n * g * (Z_n - Z_i) \qquad (G.2.1b)$$

The same formulae apply to a vertical surface as in figure G.2. They also apply to an envelope surface where P_j is the pressure of the outside air (figure G.3). Ambient air variables are substituted for the zone m variables:

$$P_j = P_a + D_a * g * (Z_a - Z_j) \qquad (G.2.2)$$

Z_a is the reference height for air pressure measurements. Its location is arbitrary. The zone reference heights, Z_n and Z_m, are also arbitrary. All are chosen for convenient or physically meaningful representation.

The pressure difference across surface i is

$$\Delta P = P_j - P_i$$

$$= P_m - P_n + D_m*g*(Z_m-Z_j) - D_n*g*(Z_n-Z_i)$$

$$= P_m - P_n + PS_i \qquad (G.2.3)$$

where
$$PS_i = D_m*g*(Z_m-Z_j) - D_n*g*(Z_n-Z_i)$$

is the "stack pressure" on surface i.

The height of the centroid of a triangle or rectangle is the average of the heights of the vertices. Since the stack effect also occurs within the thickness of a horizontal surface and since it is necessary to leave no building internal height unaccounted, Z_i and Z_j in figure G.1 should both be replaced by their average.

III.G.3   FLOW EQUATIONS

The flow through small openings in a surface is based on the orifice equation

$$F = C * A * D * \sqrt{2 * \Delta P / D} \qquad (G.3.1)$$

where A is the observed opening area and where the flow coefficient, C, is a function of the Reynolds number and the ratio of the opening size to the entire surface. When the opening is small, C equals 0.6 for a wide range of Reynolds numbers [4]. TARP assumes this value of C. The user may modify C by using an effective flow area (FA) which differs from the actual proportional opening area. Experimental results indicate that flow through real surfaces is a combination of orifice flow ($F \propto \sqrt{\Delta P}$) and capillary flow ($F \propto \Delta P$) with an exponent of about 0.65 [5]. In order to retain the concept of opening area and provide a simple grouping of all other terms in (G.3.1), C is multiplied by $\sqrt{2}$ and D divided by $\sqrt{D}$ to give:

$$F_i = 0.848 * FA_i * \sqrt{D} * (\Delta P)^{Xi} \qquad \text{(G.3.2)}$$

where FA_i is the effective flow area of the openings in the surface, D is the density of incoming air, and X_i is the flow exponent. The pressure difference for envelope surfaces is

$$\Delta P = PW_i + PS_i - P_n \qquad \text{(G.3.3a)}$$

and the ΔP for interzone surfaces is

$$\Delta P = PS_i + P_m - P_n \qquad \text{(G.3.3b)}$$

The surface flow equation becomes

$$F_i = 0.848 * FA_i * /D_m * (\Delta P)^{Xi} \qquad (\Delta P > 0) \qquad \text{(G.3.4a)}$$

or

$$F_i = -.848 * FA_i * /D_n * (-\Delta P)^{Xi} \qquad (\Delta P < 0) \qquad \text{(G.3.4b)}$$

For each zone there must be a mass balance

$$F_s + \Sigma F_i = 0 \qquad \text{(G.3.5)}$$

where F_s is the net mass flow into the zone from the air handling system and the F_i are the flows through openings in the zone envelope surfaces. These mass balances form a system of non-linear algebraic equations which can be solved for the zone pressures.

III.G.4   SOLUTION OF THE FLOW EQUATIONS

In some schemes for the evaluation of these simultaneous equations it is important to know the following partial derivatives:

$$\frac{\partial F_i}{\partial P_n} = -X_i * F_i / \Delta P \qquad \text{(G.4.1a)}$$

$$\frac{\partial F_i}{\partial P_m} = X_i * F_i / \Delta P \qquad \text{(interzone surface)} \qquad \text{(G.4.1b)}$$

or

$$\frac{\partial F_i}{\partial P_m} = 0 \qquad \text{(envelope surface)} \qquad \text{(G.4.1c)}$$

Note that it is not necessary to evaluate $(\Delta P)^{(Xi-1)}$ to compute these derivatives. Note also that as ΔP approaches zero these derivatives cannot be evaluated. This condition applies for large openings which cannot support a large pressure difference (except with very high flow rates). This is a potential source of trouble which must be considered.

These equations have been successfully solved by a modified Newton's method in all cases tested. A standard Newton's method was found to sometimes give very slow convergence because of overcorrections during the iteration. The modification reduces the Newton correction when this problem appears to occur.

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[4] ASHRAE Handbook - 1981 Fundamentals (ASHRAE, 1981), p 4.13, Fig 18.
[5] ASHRAE Handbook - 1981 Fundamentals (ASHRAE, 1981), p 22.8.

$$F_i = 0.848 * FA_i * \sqrt{D} * (\Delta P)^{Xi} \tag{G.3.2}$$

where FA_i is the effective flow area of the openings in the surface, D is the density of incoming air, and X_i is the flow exponent. The pressure difference for envelope surfaces is

$$\Delta P = PW_i + PS_i - P_n \tag{G.3.3a}$$

and the ΔP for interzone surfaces is

$$\Delta P = PS_i + P_m - P_n \tag{G.3.3b}$$

The surface flow equation becomes

$$F_i = 0.848 * FA_i * /D_m * (\Delta P)^{Xi} \qquad (\Delta P > 0) \tag{G.3.4a}$$

or

$$F_i = -.848 * FA_i * /D_n * (-\Delta P)^{Xi} \qquad (\Delta P < 0) \tag{G.3.4b}$$

For each zone there must be a mass balance

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or

$$\frac{\partial F_i}{\partial P_m} = 0 \qquad \text{(envelope surface)} \tag{G.4.1c}$$

Note that it is not necessary to evaluate $(\Delta P)^{(Xi-1)}$ to compute these derivatives. Note also that as ΔP approaches zero these derivatives cannot be evaluated. This condition applies for large openings which cannot support a large pressure difference (except with very high flow rates). This is a potential source of trouble which must be considered.

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[4] ASHRAE Handbook - 1981 Fundamentals (ASHRAE, 1981), p 4.13, Fig 18.
[5] ASHRAE Handbook - 1981 Fundamentals (ASHRAE, 1981), p 22.8.

Figure III.G.1 Pressure relationships for vertically adjacent zones
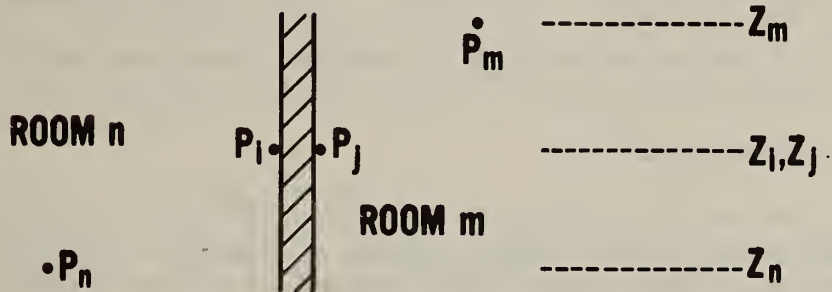
Figure III.G.2 Pressure relationships for horizontally adjacent zones
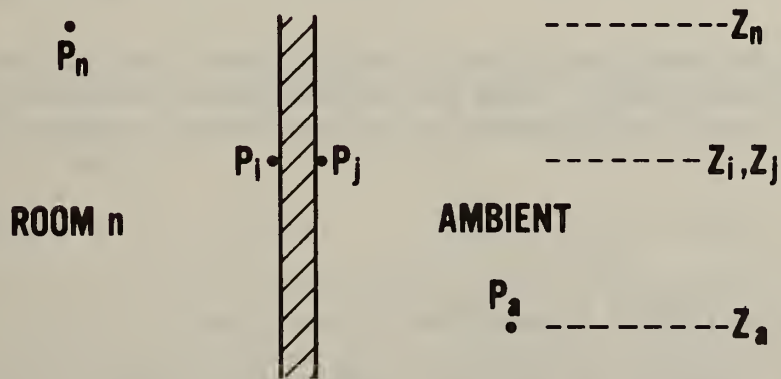
Figure III.G.3 Pressure relationships for envelope surfaces

III.H   ROOM RADIANT INTERCHANGE

III.H.1   DETAILED RADIANT INTERCHANGE

The surfaces of a room form an enclosure where they exchange energy
with the room air by convection and directly with each other by radiation.
The net radiant flux absorbed by surface i is given by

$$QI_i = \sum_j F_{ij} * (\underline{T}_j{}^4 - \underline{T}_i{}^4) + QLI_i + QSI_i \qquad (H.1.1)$$

This expression is not usually substituted into the surface heat balance
equations since the $\underline{T}^4$ terms would make the equations nonlinear and difficult
to solve. The radiation interchange factor, F_{ij} (which includes geometry and
radiocity factors) is difficult to calculate for rooms with arbitrary geometry.
Since each surface interacts with all other surfaces of the room (total of N
surfaces) there are N^2 interactions to be considered. This requires a time
consuming solution technique. Quicker solutions are possible by linearizing
and assuming constant radiative and convective coefficients for all surfaces
[1]. Alternate methods are available which use mean radiant temperature
instead of the detailed radiant interchange. These methods allow efficient
treatment of the problem without assuming constant coefficients. They so
significantly affect the solution time for problems with many surfaces that
they make simultaneous heat balances for many rooms feasible [2].

III.H.2   MRT NETWORK ALGORITHM

In the TARP radiant interchange between room surfaces is based on the
mean radiant temperature network (MRTN) method of Joseph A. Carroll [3].
Surfaces radiatively interact with an MRT instead of directly with each
other.

$$QI_i = HR_i * (TR_n - T_i) \qquad (H.2.1)$$

where HR_i is a radiative conductance. This gives N instead of N^2
interactions. The time required to solve the inside surface heat balances
is reduced from order N^2 to order N. The effects of QLI_i and QSI_i are
discussed below.

Since the MRT includes the effect of all surfaces, coupling the surface
to the MRT couples it to itself. The MRT network method includes a factor
F_i, the "MRT view factor", which compensates for the self weight of surface
i in the MRT.

$$F_i = 1 / [1 - S_i*F_i / (\sum_j S_j*F_j)] \qquad (H.2.2)$$

This expression can be solved iteratively.

The effects of surface emittance are modeled by a surface resistance in
the radiative conductance.

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$$HR_i = 4*\sigma*\underline{T}^3/[1/F_i + (1-\epsilon_i)/\epsilon_i] \qquad (H.2.3)$$

Near room temperature the radiative couplings between surfaces vary by about 1 percent per degree C variation in the mean radiant temperature. The TARP allows a quick mode of calculating the radiant interchange which uses a constant T (= 296K = 23C) for evaluating HR_i. A more accurate model uses the following algorithm to account for the non-linearity of the detailed equation.

1. Initialize all the HRi for a temperature of 27C:

$$HR_i = 6.13 / [1/F_i + (1-\epsilon_i)/\epsilon_i] \qquad (H.2.4a)$$

2. At each iteration first adjust all

$$HR_i = (0.865 + 0.005*T_i) * HR_i \qquad (H.2.4b)$$

3. Then evaluate

$$TRL_n = \Sigma \ HR_i*A_i*T_i / \Sigma \ HR_i*A_i \qquad (H.2.4c)$$

where the sum applies to all surfaces of room n

4. Then again adjust all

$$HR_i = (0.865 + 0.005*TRL_n) * HR_i \qquad (H.2.4d)$$

This method scales each HR_i by two factors nearly proportional to $T^{1.5}$, and estimates the radiant fluxes to within about 1 percent for surfaces between 0C and 50C.

In addition to the radiation from other surfaces, there is longwave radiation from various energy sources in the room. The effect of these radiant sources can be factored into the MRT and the radiant flux automatically distributed over the room surfaces.

$$TR_n = (\Sigma \ HR_i*S_i*T_i + QL_n) / \Sigma \ HR_i*S_i \qquad (H.2.5)$$

Shortwave radiation, such as from the sun and lights, should not be handled by this modification of the MRT because the room surfaces can have entirely different emissivites for short and long wavelength radiation. Therefore, H.2.1 should be written:

$$QI_i = HR_i *(TR_n - T_i) + QSI_i \qquad (H.2.6)$$

The MRTN method of Carroll is slightly more accurate than the "balanced mean radiant temperature" (MRTB) method of Walton. In addition it can easily handle multiple reflections and air emittance effects. However, when MRTN is used in the TARP iterative heat balance, it is slower than MRTB. A single MRTN iteration is slightly faster than MRTB, but more are required. This is because MRTN updates TR_n once per heat balance iteration of all

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surfaces while MRTB updates TR_n for each surface during the heat balance
iteration. The effect is the same as Jacobi versus Gauss-Seidel iteration [4].
The MRTN method was chosen over MRTB because of its accuracy and potential for
future expansion. It thus became important to find a method to reduce the
number of iterations to regain speed similar to MRTB. This method is described
in section L.

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III.I   SURFACE OUTSIDE HEAT BALANCES

III.I.1   SIMPLE SURFACE CONDUCTANCE

The convective plus radiative heat flux from a surface to the environment may be represented by:

$$. \quad CO + QO = HO * (TO - T_a) + QSO \qquad\qquad (I.1.1)$$

The surface coefficient, HO, accounts for both convection and longwave radiant interchange. QSO is the absorbed shortwave radiant flux. A simple correlation for HO uses a polynomial expression [1] based on an ASHRAE relationship [2] which relates the surface coefficient (W/m^2K) to wind speed (m/s) and surface roughness.

$$H_0 = A_0 + A_1 * V_a + A_2 * V_a^2 \qquad\qquad (I.1.2)$$

The values of the coefficients are determined by the surface roughness:

Roughness Index	A_0	A_1	A_2	Example Material
1	11.58	5.894	0.0	Stucco
2	12.49	4.065	0.028	Brick, rough plaster
3	10.79	4.192	0.0	Concrete
4	8.23	4.00	−0.057	Clear pine
5	10.22	3.10	0.0	Smooth plaster
6	8.23	3.33	−0.036	Glass, paint on pine

Va is the reported wind speed unmodified for surface height or orientation. This is reasonable for estimating design loads, but it needs improvement for detailed simulations.

Rain causes the surface temperature to rapidly approach the water temperature. TARP models this by setting HO to 1000. W/m^2K and replacing Ta in (I.1.1) by the wet bulb temperature.

III.I.2   DETAILED SURFACE CONDUCTANCE

A detailed description of the outside surface coefficient must include components of forced convection (H_f), natural convection (H_n), and radiant interchange (H_r). These are affected by surface size, shape, location, orientation, and many features in the surrounding environment. All of these effects are open to further study [3]. The following algorithms have been combined (perhaps not justifiably) to allow the user to study the effects of certain details in the outside conductance algorithm on relative zone conditions. They show the kind of details that can be considered in TARP. They will be progressively enhanced as better algorithms are developed.

III.I.2.1   FORCED CONVECTION

Wind velocity tends to increase at increasing heights above the ground. The relationship for this increase is described in B.3.

$$V_{az} = V_a * b * (Z/Z_o)^a \qquad (I.2.1)$$

Studies of the effect of surface shape on H_f give the following correlation [4].

$$St * Pr^{2/3} = 0.86 * Re^{-1/2} \qquad (I.2.2)$$

or

$$H_f = 0.86*D_a*C_p*P_r^{-2/3}*(.25*V_{az}*C*\nu/A)^{1/2} \qquad (I.2.3)$$

where

St = Stanton number ($H_f/D_a C_p V_z$)
Pr = Prandtl number ($C_p \nu /k$)
Re = Reynolds number ($4V_{az}A/C\nu$)
A = surface area
C = surface circumference
D_a = density of air
C_p = specific heat of air
V_{az} = free stream wind velocity (at height of surface)
ν = kinematic viscosity

For air $Pr^{-2/3}$ = 1.245, C_p = 1004 J/Kg K , and $D_a \sqrt{\nu}$ $\cong$ 0.00472 Kg/s $m^{5/2}$ which combine to give

$$H_f = 2.537 * \sqrt{C/A} * \sqrt{V_{az}} \qquad (I.2.4)$$

The local value of H_f was found to be greatest near the edges of the surface where the thermal boundary layer is thinnest. Therefore, to avoid computing too large a value for small subsurfaces (windows and doors), TARP uses the same C/A for the subsurfaces as for the wall they are on.

There is as yet no definitive study giving an algorithm for wind direction effects. Therefore, it was decided to follow the suggestion of Cole [5] and multiply H_f by a wind direction modifier, W_f, of one half for the leeward surfaces. W_f equals one for windward surfaces. In TARP leeward is defined as greater than 100 degrees from normal incidence.

A simple surace roughness multiplier, R_f, was developed from the ASHRAE graph of surface conductances [6]. At 0 mph all lines on this graph intercept at about 1.9 Btu/hrft^{2}F. The correlations for the six roughnesses are nearly linear. Therefore, a simple roughness multiplier was constructed by subtracting 1.9 from all values of H (at 25 mph) and dividing by the quantity [H (of roughness 6 at 25 mph) - 1.9] as summarized below.

Roughness	H (at 25 mph)	R_f
1	13.6	2.1
2	10.8	1.67
3	10.1	1.52
4	8.0	1.13
5	7.9	1.11
6	7.3	1.00

III.I.2.2   NATURAL CONVECTION

There must be a natural convection component in the overall surface coefficient to account for the convection which exists at zero wind velocity. The same expressions are used for outside natural convection as for inside convection (J.2).

$$\text{Heat flow up:} \qquad H_n = 9.482 * \sqrt[3]{|TO-Ta|}/(7.238 - |\cos\phi|) \qquad (I.2.5a)$$

$$\text{Heat flow down:} \quad H_n = 1.810 * \sqrt[3]{|TO-Ta|}/(1.381 + |\cos\phi|) \qquad (I.2.5b)$$

This component is assumed to be present at all wind speeds.

III.I.2.3   RADIANT INTERCHANGE

There is radiant interchange between the surface and the sky, and between the surface and the ground surface or adjacent structures. The effective temperature of the ground surface is assumed to be equal to T_a (pending further algorithm development). The effective temperature of any point in the sky depends on the optical path length through the atmosphere. Section B.3 describes the algorithm which computes the effective sky temperature which would be seen by a horizontal surface. For tilted surfaces the radiant interchange coefficient (H_r) must be divided into three parts: one (HS) to sky temperature, one (HG) to ground surface temperature, and one (Ha) to air temperature.

$$Ha = \sigma * \varepsilon * F_{ss} * (1 - \cos(\phi/2)) * (TO^4 - T_a^4)/|TO - T_a| \qquad (I.2.6a)$$

$$HS = \sigma * \varepsilon * F_{ss} * \cos(\phi/2) * (TO^4 - T_s^4)/|TO - T_s| \qquad (I.2.6b)$$

$$HG = \sigma * \varepsilon * F_{sg} * (TO^4 - T_g^4)/|TO - T_g| \qquad (I.2.6c)$$

Pending further research, TARP assumes the ground surface temperature, T_g, equals the air temperature, T_a. This three component split of H_r must still be validated or modified by experimental data. It produces proper results for horizontal surfaces. It causes a vertical surface to radiate to an effective temperature of $(.35 \, T_s + .65 \, T_a)$. TARP allows for radiant exchange to surfaces of buidings to be represented by the user-specified values of F_{ss} and F_{sg}. Other building surfaces can be expected to have about the same temperature as the surface in question. Therefore, there is no net radiant transfer to it, and the view factor to all other building surfaces is represented by $1 - F_{ss} - F_{sg}$.

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III.I.2.4 COMBINED FACTORS

Since the expressions for Hn and Hr are used to evaluate TO, the most recent value of TO is used in their calculation. The three factors combine to give the following expression for combined convective and radiative flux.

$$CO + QO = (H_f*W_f*R_f + H_n + HA)*(T_a-TO) + HS*(T_s-TO) + HG*(T_g-TO) + QSO$$
$$(I.2.7)$$

III.I.3 BASIC HEAT BALANCES

A heat balance must exist at the outside surface-air interface. The incoming conductive, convective, and radiative fluxes must sum to zero:

$$KO + CO + QO = 0 \qquad\qquad (I.3.1)$$

In contrast to the internal surface heat balance which treats all surfaces simultaneously, the external thermal balance for each surface is performed independent of all other surfaces. This implies that there is no direct interaction between the individual surfaces.

The TARP includes four possible representations for the basic outside surface heat balance. The first two depend on which of the optional surface conductance algorithms the user selects. The simple outside surface conductance (I.1) which includes both the convective and thermal interchange between the surface and the environment in a single coefficient, is represented by the thermal network in figure I.1. (I.3.1) can be expressed in terms of (C.1.6) and (I.1.1) as

$$KOP_t + Y_0*TI_t - X_0*TO_t + HO*(T_a - TO_t) + QSO = 0 \qquad (I.3.2)$$

This can be solved for the outside surface temperature.

$$TO_t = (KOP_t + QSO + Y_0*TI_t + HO*T_a) / (X_0 + HO) \qquad (I.3.3)$$

The detailed outside surface conductance model (I.2) considers convection and radiant interchange with the sky and with the ground as separate factors. Its use in the outside thermal balance is shown in figure I.2. In this case (I.3.1) can be expanded according to (C.1.6) and (I.2.7) to give

$$KOP_t + Y_0*TI_t - X_0*TO_t + HA*(T_a - TO_t)$$

$$+ HS*(T_s - TO_t) + HG*(T_g - TO_t) + QSO = 0 \qquad (I.3.4)$$

This can be solved for the outside surface temperature:

$$TO_t = (KOP_t + QSO + YO*TI_t + HA*T_a + HS*T_s + HG*T_g)$$

$$/ (X_0 + HA + HS + HG) \qquad (I.3.5)$$

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The third and fourth representations occur when the outside surface has been covered with a movable insulation. The insulation has a conductance of UM. This case is represented by the thermal network in figure I.3. The insulation must be massless because it is not generally possible to perform a correct thermal balance at the juncture of two surfaces each modeled by CTF.

The equation for the thermal balance betwen the surface and the insulation is

$$KOP_t + Y_0*TI_t - X_0*TO_t + UM*(TM-TO_t) + QSO = 0 \qquad (I.3.6)$$

which can be rewritten to solve for TO:

$$TO_t = (KOP_t + QSO + Y_0*TI_t + UM*TM) / (X_0 + UM) \qquad (I.3.7)$$

Depending on whether or not the detailed or simple algorithm for surface conductance is being used, there are two expresions for TM, the outside temperature of the insulation. For the simple conductance:

$$TM = (QSM + UM*TO_t + HO*T_a) / (UM + HO) \qquad (I.3.8)$$

For the detailed conductance:

$$TM = (QSM + UM*TO_t + HA*T_a + HS*T_s + HG*T_g)$$
$$/ (UM + HA + HS + HG) \qquad (I.3.9)$$

In this case the values of HA, HS, and HG must be found by using an estimated value of TM in place of TO in (I.2).

III.I.4   HEAT BALANCE CASES

TO_t and TI_t are related through the Y_0 CTF. However, TI_t is also unknown. While it is possible to combine the outside and inside surface heat balances to compute TO_t and TI_t simultaneously, the TARP uses a simpler procedure where TO_t is based on a previous value of TI. When Y_0 is small, as occurs in well insulated or very massive surfaces, TI_t can be replaced by TI_{t-1} (which is known from the previous hour's heat balance) without significantly effecting the value of TO_t. When Y_0 is large, TO and TI can be so strongly coupled that separate outside and inside heat balances do not work because the environment and zone temperatures have negligible influence on the heat balances. The TARP uses the inside surface heat balance to couple TO_t with TZ and TR. These two temperatures are less strongly influenced by TO and allow a reasonable heat balance. On the first heat balance iteration, TZ and TR are the values at time t-1. The user may optionally require that TO_t be recomputed with every iteration of TI_t. In this case TZ and TR have the values from the previous iteration, and a true simultaneous solution is achieved. In most conventional construction, recomputing TO_t does not significantly change the computed zone loads and temperatures. The inside surface heat balance is given by (J.3.3) which is repeated here.

$$TI_t = (KIP_t + QSI + HC*TZ + HR*TR + Y_0*TO)$$
$$/ (Z_0 + HC + HR) \qquad (I.4.1)$$

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The surface heat balances can be combined in eight ways according to conditions for calculation of the outside surface temperature. Compute

$$F_1 = Y_0 \,/\, (Z_0 + HI + HR) \qquad\qquad (I.4.2a)$$
$$F_2 = UM \,/\, (UM + HO) \qquad\qquad (I.4.2b)$$
$$F_3 = UM \,/\, (UM + HA + HS + HG) \qquad\qquad (I.4.2c)$$

as needed for the following cases.

CASE 1: Y_0 small, simple conductance, no movable insulation. From equation (I.3.3):

$$TO_t = (KOP_t + QSO + Y_0 * TI_{t-1} + HO * T_a) \,/\, (X_0 + HO) \qquad (I.4.3)$$

CASE 2: Y_0 not small, simple conductance, no movable insulation. From (I.3.3) and (I.4.1):

$$TO_t = [KOP_t + QSO + HO * T_a + F_1 * (KIP_t + QSI + HI * TZ + HR * TR)]$$
$$/\, (X_0 + HO - F_1 * Y_0) \qquad\qquad (I.4.4)$$

CASE 3: YO small, detailed conductance, no movable insulation. From (I.3.4):

$$TO_t = (KOP_t + QSO + Y_0 * TI_{t-1} + HA * T_a + HS * T_s + HG * T_g)$$
$$/\, (X_0 + HA + HS + HG) \qquad\qquad (I.4.5)$$

CASE 4: Y_0 not small, detailed conductance, no movable insulation. From (I.3.4) and (I.4.1):

$$TO_t = [KOP_t + QSO + HA * T_a + HS * T_s + HG * T_g$$
$$+ F_1 * (KIP_t + QSI + HI * TZ + HR * TR)]$$
$$/\, (X_0 + HA + HS + HG - F_1 * Y_0) \qquad\qquad (I.4.6)$$

CASE 5: Y_0 small, simple conductance, with movable insulation. From (I.3.7) and (I.3.8):

$$TO_t = [KOP_t + QSO + Y_0 * TI_{t-1} + F_2 * (QSM + HO * TM)]$$
$$/\, (X_0 + UM - F_2 * UM) \qquad\qquad (I.4.7)$$

CASE 6: Y_0 not small, simple conductance, with movable insulation. From (I.3.7), (I.3.8), and (I.4.1):

$$TO_t = [KOP_t + QSO + F_2 * (QSM + HO * T_a) + F_1 * (KIP_t + QSI + HI * TZ + HR * TR)]$$
$$/\, (X_0 + UM - F_2 * UM - F_1 * Y_0) \qquad\qquad (I.4.8)$$

CASE 7: Y_0 small, detailed conductance, with movable insulation. From (I.3.7) and (I.3.9):

$$TO_t = [KOP_t + QSO + Y_0*TI_{t-1} + F_3*(QSM + HA*T_a + HS*T_s + HG*T_g)]$$

$$/ (X_0 + UM - F_3*UM) \qquad\qquad (I.4.9)$$

CASE 8: Y_0 not small, detailed conductance, with movable insulation. From (I.3.7), (I.3.9), and (I.4.1):

$$TO_t = [KOP_t + QSO + F_1*(KIP_t + QSI + HI*TZ + HR*TR)$$

$$+ F_3*(QSM + HA*T_a + HS*T_s + HG*T_g)]$$

$$/ (X_0 + UM - F_3*UM - F_1*Y_0) \qquad\qquad (I.4.10)$$

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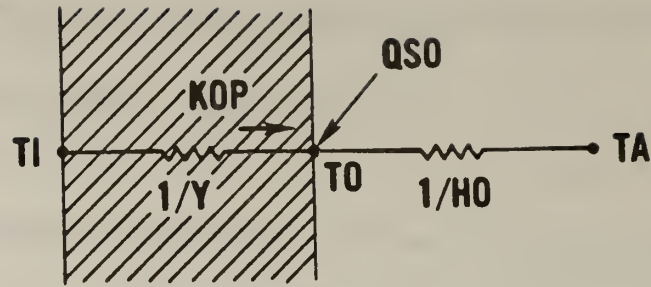
Figure III.I.1   Thermal network for simple outside surface coefficient
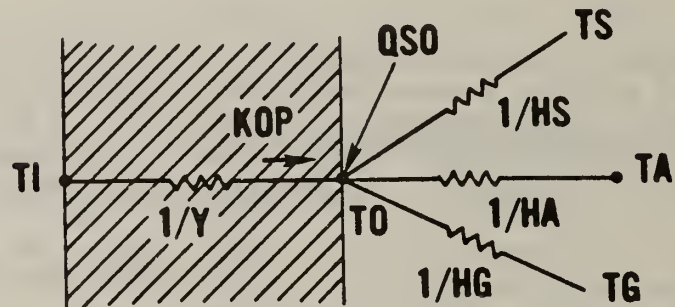
Figure III.I.2   Thermal network for detailed outside surface coefficient
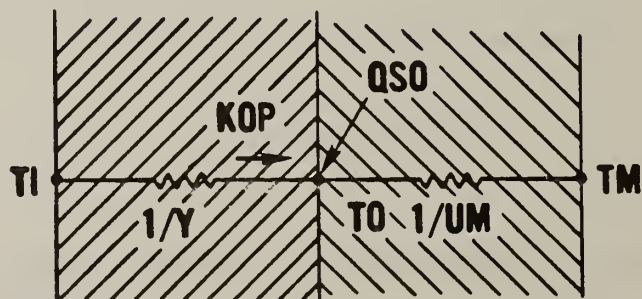
Figure III.I.3   Thermal network for outside movable insulation

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III.J   SURFACE INSIDE HEAT BALANCES

III.J.1   SIMPLE CONVECTION COEFFICIENT

The convective heat flux from the zone air to a surface is given by:

$$CI = HC * (TI - TZ) \qquad (J.1.1)$$

The coefficient for natural convection heat transfer is based on data from
ASHRAE [1]. The ASHRAE values are for combined convection and radiation, so
a radiative component of (1.02 times emissivity of 0.9) is subtracted from
the tabulated values which are then converted to metric. When warm air is
below a cool horizontal surface (or cool air above a warm surface), there is
more convective mixing than for air next to a veritcal surface. Conversely,
when cool air is below a warm surface (or warm air above a cool surface)
there is reduced convection.

HC (W/m²K)	Type of Heat Flow	Surface Tilt
4.043	enhanced	157.5 to 180 or 0 to 22.5 degrees
3.873	enhanced	112.5 to 157.5 or 22.5 to 67.5 degrees
3.078	normal	67.5 to 112.5 degrees (vertical surface)
2.283	reduced	22.5 to 67.5 or 112.5 to 157.5 degrees
0.920	reduced	0 to 22.5 or 157.5 to 180 degrees

When the air handling system is moving air through the zone, a single value
of 6.14 W/m²K (= 2.0 - 1.02 * 0.90 Btu/h*ft²*F) should be used for HI.

III.J.2   DETAILED NATURAL CONVECTION COEFFICIENT

ASHRAE has the following expressions for natural convection from large
surfaces [2].

HC (W/m²K)	Direction of Heat Flow	
$1.52* \sqrt[3]{|TZ-TI|}$	Upward	(J.2.1a)
$1.31* \sqrt[3]{|TZ-TI|}$	Horizontal	(J.2.1b)
$0.76* \sqrt[3]{|TZ-TI|}$	Downward	(J.2.1c)

It may be noted that these expressions are inconsistant with the values
given for the simple algorithm.

To account for all surface tilts, the following expressions are used.

Heat flow horizontal or upward:

$$HC = 9.482 * \sqrt[3]{|TZ-TI|} \, / \, (7.238-|\cos\phi|) \qquad (J.2.2a)$$

Heat flow horizontal or downward:

$$HC = 1.810 * \sqrt[3]{|TZ-TI|} / (1.382 + |\cos\phi|) \qquad (J.2.2b)$$

III.J.3 BASIC HEAT BALANCE

A heat balance must exist at the inside surface-air interface. The incoming convective, radiative, and conductive fluxes must sum to zero:

$$CI_i + QI_i + KI_i = 0.0 \qquad (J.3.1)$$

This equation can be expanded according to the descriptions of convection (J.1 and J.2), radiation (F.2.6), and conduction (C.1.4) and as shown in figure J.1 to give

$$HC_i*(TZ_n-TI_i) + HR_i*(TR_n-TI_i) + QSI_i + KIP_i + Y_{0,i}*TO_i - Z_{0,i}*TI_i = 0.0 \qquad (J.3.2)$$

Interior surface temperatures of envelope surfaces are computed by rearranging (J.3.2):

$$TI_i = (HC_i*TZ_n + HR_i*TR_n + QSI_i + KIP_i + Y_{0,i}*TO_i)$$

$$/ (HC_i + HR_i + Z_{0,i}) \qquad (J.3.3)$$

The value of TO_i must have been previously calculated by the methods in section I.4.

The following two partial derivatives are useful in improving the rate of convergence of the heat balance iterations.

$$\frac{\partial TI_i}{\partial TZ_n} = HC_i / (HC_i + HR_i + Z_{0,i}) \qquad (J.3.4a)$$

$$\frac{\partial TI_i}{\partial TR_n} = HR_i / (HC_i + HR_i + Z_{0,i}) \qquad (J.3.4b)$$

III.J.4 INTERNAL SURFACES

Internal masses and partitions separating identically conditioned zones can be treated as surfaces with equal inside and outside temperatures. In that case Equation (J.3.2) may be rearranged to give:

$$TI_i = (HC_i*TZ_n + HR_i*TR_n + QSI_i + KIP_i) \qquad (J.4.1)$$

$$/ (HC_i + HR_i + Z_{0,i} - Y_{0,i})$$

The partial derivatives are

$$\frac{\partial TI_i}{\partial TZ_n} = HC_i / (HC_i + HR_i + Z_{0,i} - Y_{0,i}) \qquad (J.4.2a)$$

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and

$$\frac{\partial TI_i}{\partial TR_n} = HR_i \ / \ (HC_i + HR_i + \ Z_{0,i} - \ Y_{0,i}) \qquad (J.4.2b)$$

III.J.5   INTERZONE SURFACES

In the TARP interzone surfaces are permitted to have movable insulation. This creates another set of basic heat balances at the air-insulation and the insulation-surface interfaces (figure J.2). The inside heat balances (with movable insulation) are

$$HC_i*(TZ_n-TM_i) + HR_i*(TR_n-TM_i) + UM_i*(TI_i-TM_i) + QSM_i = 0.0 \quad (J.5.1)$$

$$KIP_i + Y_{0,i}*TO_i - Z_{0,i}*TI_i + UM_i*(TM_i-TI_i) + QSI_i = 0.0 \qquad (J.5.2)$$

A similar set of equations exist for the far side of the surface (described as surface j adjacent to zone m). The far side heat balance (without movable insulation) is

$$HC_j*(TZ_m-TI_j) + HR_j*(TR_m-TI_j) + QSI_j + KIP_j + Y_{0,j}*TO_j - Z_{0,j}*TI_j = 0.0 \\ (J.5.3)$$

The far side heat balances (with movable insulation) are

$$HC_j*(TZ_m-TM_j) + HR_j*(TR_m-TM_j) + UM_j*(TI_j-TM_j) + QSM_j = 0.0 \quad (J.5.4)$$

$$KIP_j + Y_{0,j}*TO_j - Z_{0,j}*TI_j + UM_j*(TM_j-TI_j) + QSI_j = 0.0 \qquad (J.5.5)$$

The following relationships apply because i and j refer to opposite sides of the same surface:

$$TI_i = TO_j; \quad TO_i = TI_j; \quad KIP_i = KOP_j; \quad KOP_i = KIP_j;$$

$$Z_{0,j} = X_{0,i} \ (= X_0); \quad Y_{0,j} = Y_{0,i} \ (= Y_0).$$

The placement of insulation on either side leads to four basic cases. Compute

$$F_1 = Y_0 \ / \ (X_0 + HC_j + HR_j) \qquad\qquad (J.5.6a)$$
$$F_2 = UM_i \ / \ (UM_i + HC_i + HR_i) \qquad\qquad (J.5.6b)$$
$$F_3 = UM_j \ / \ (UM_j + HC_j + HR_j) \qquad\qquad (J.5.6c)$$
$$F_4 = Y_0 \ / \ (X_0 + UM_j - F_3*UM_j) \qquad\qquad (J.5.6d)$$

as needed for the cases below.

CASE 1: No movable insulation on either side. From equations (J.3.2) and (J.5.3):

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$$TI_i = [HC_i * TZ_n + HR_i * TR_n + QSI_i + KIP_i +$$

$$F_1 * (HC_j * TZ_m + HR_j * TR_m + QSI_j + KIP_j)]$$

$$/ (Z_0 + HC_i + HR_i - F_1 * Y_0) \qquad (J.5.7)$$

The partial derivatives are:

$$\frac{\partial TI_i}{\partial TZ_n} = HC_i / (HC_i + HR_i + Z_0 - F_1 * Y_0) \qquad (J.5.8a)$$

and

$$\frac{\partial TI_i}{\partial TR_n} = HR_i / (HC_i + HR_i + Z_0 - F_1 * Y_0) \qquad (J.5.8b)$$

CASE 2: Movable insulation on near side only. From equations (J.5.1), (J.5.2), and (J.5.3):

$$TI_i = [KIP_i + QSI_i + F_1 * (HC_j * TZ_m + HR_j * TR_m + QSI_j + KIP_j)$$

$$+ F_2 * (HC_i * TZ_n + HR_i * TR_n + QSM_i)]$$

$$/ (Z_0 + UM_i - F_1 * Y_0 - F_2 * UM_i) \qquad (J.5.9a)$$

$$TM_i = F_2 * [TI_i + (HC_i * TZ_n + HR_i * TR_n + QSM_i)/UM_i] \qquad (J.5.9b)$$

Since UM_i should be small, the partial derivatives are:

$$\frac{\partial TI_i}{\partial TZ_n} = HC_i / (HC_i + HR_i + UM_i) \qquad (J.5.10a)$$

and

$$\frac{\partial TI_i}{\partial TR_n} = HR_i / (HC_i + HR_i + UM_i) \qquad (J.5.10b)$$

CASE 3: Movable insulation on far side only. From equations (J.3.2), (J.5.4), and (J.5.5):

$$TI_i = \{HC_i * TZ_n + HR_i * TR_n + KIP_i + QSI_i$$

$$+ F_4 * [KIP_j + QSI_j + F_3 * (HC_j * TZ_m + HR_j * TR_m + QSM_j)]\}$$

$$/ (Z_0 + HC_i + HR_i - F_4 * Y_0) \qquad (J.5.11)$$

The partial derivatives are given by (J.5.8a) and (J.5.8b).

CASE 4: Movable insulation on both sides. QSI_i and QSI_j are both zero because the insulation is assumed opaque. From equations (J.5.1), (J.5.2), (J.5.4) and (J.5.5):

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$$TI_i = \{KIP_i + F_4*[KIP_j + F_3*(HC_j*TZ_m + HR_j*TR_m + QSM_j)]$$

$$+ F_2*(HC_i*TZ_n + HR_i*TR_n + QSM_i)\}$$

$$/ (Z_0 + UM_j - F_4*Y_0 - F_2*UM_i) \qquad (J.5.12a)$$

$$TM_i = F_2*[TI_i + (HC_i*TZ_n + HR_i*TR_n + QSM_i)/UM_i] \qquad (J.5.12b)$$

The partial derivatives are given by (J.5.10a) and (J.5.10b).

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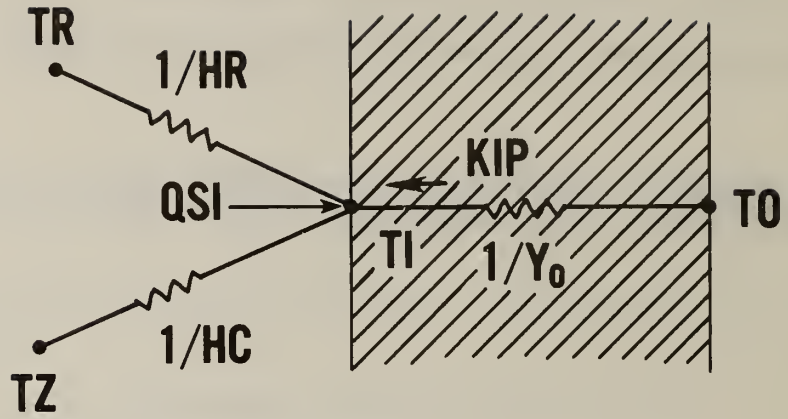
Figure III.J.1   Inside surface thermal network
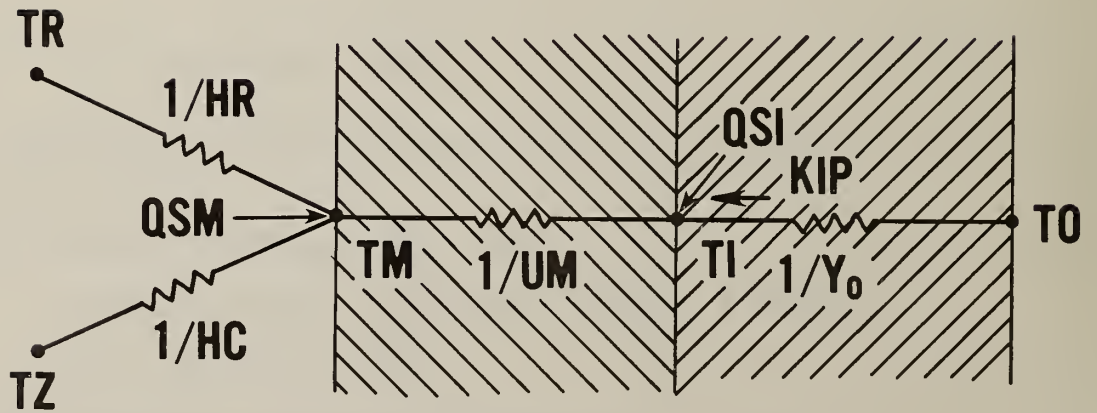
Figure III.J.2   Inside movable insulation thermal network

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III.K   ZONE AIR HEAT BALANCE

The calculation of the zone air temperature is based on a heat balance on the zone air. The convective gains from the room surfaces and internal sources plus the sensible gain from incoming air plus the energy added by the air handling system must equal zero.

$$CE + \Sigma\ HC_i*S_i*(T_i - TZ) + \Sigma\ F_j*C_p*(TS_j - TZ) + L = 0 \qquad (K.0.1)$$

The summations apply to all surfaces which are part of the zone.

The system performance model (III.K.1) may be used with the detailed natural air movement model (III.G) if the supply and exhaust air flows of every zone are equal (that is, Fs in equation (G.3.5) must be zero). The simple air movement models (III.K.2 through III.K.5) may not be used simulatneously with the detailed air movement model.

III.K.1   SYSTEM PERFORMANCE MODEL

The energy from the system is based on the user defined control profile which approximates the performance of the actual system. The control profile consists of a set of control points which define the heating or cooling capacity of the system as a function of the control temperature as in figure K.1. Control range p is between temperatures T_p and T_{p+1}. The control profile is linear between the control points. Simple proportionality gives

$$L = L_p + (T - T_p)*(L_{p+1} - L_p)/(T_{p+1} - T_p) \qquad (K.1.1)$$

This can be rearranged to

$$L = LT * T + LC \qquad (K.1.2a)$$

where

$$LT = (L_{p+1} - L_p)/(T_{p+1} - T_p) \text{ and } LC = L_p - LT*T_p \qquad (K.1.2b)$$

The control temperature consists of both the air and the mean radiant temperatures according to the formula

$$T = \beta * TR + (1 - \beta) * TZ \qquad (K.1.3)$$

where β is the user defined radiant fraction. When this expression is substituted into the zone air heat balance, it gives the following expression for computing the zone air temperature

$$TZ = [\ CE + SUM\ HC_i*S_i*T_i + SUM\ F_j*C_p*TS_j + \beta*LT*TR + LC]$$

$$/\ [\ SUM\ HC_i*S_i + SUM\ F_j*C_p - (1 - \beta)*LT\ ] \qquad (K.1.4)$$

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III.K.2   SIMPLE INFILTRATION MODEL

An equation for the mass flow of infiltration air can be developed from measured values in similar structures [1]. The TARP assumes a correlation of the form

$$FI = (A_0 + A_1 * |TZ - T_a| + A_2 * V + A_3 * V^2) * D_a \qquad (K.2.1)$$

This correlation accounts for stack effects in the temperature difference term and wind effects in the two velocity terms. Equation (K.1.4) simplifies to

$$TZ = [CE + \Sigma\ HC_i * S_i * T_i + FI * C_p * T_a + \beta * LT * TR + LC]$$

$$/ \Sigma\ HC_i * S_i + FI * C_p - (1 - \beta) * LT] \qquad (K.2.2)$$

III.K.3   ZONE VENTILATION MODEL

The heating effect of ventilation air is given by

$$LV = FV * C_p * (T_a - TZ) \qquad (K.3.1)$$

TARP ventilation operates by creation of a ventilation profile similar to the zone temperature control profile. A new ventilation profile is created every hour as the ambient temperature changes. No point on the ventilation profile is permitted to overlap the heating or cooling portions of the control profile. This assumes the same fan is used for ventilation and heating or at least that two separate fans are managed by the same controller.

Several types of ventilation profile are possible. Figure K.2 shows a profile when the ambient temperature (T_a) is higher than the desired temperature (TV). No cooling occurs until the zone air temperature exceeds TA.

When T_a is less than TV, there is a cooling capacity at TV. A small ramp between TV and TV+0.01 is created for stability of the heat balance iterations as in figure K.3.

When there is a heating control profile and the desired ventilation temperature is below the point which initiates heating, the TARP revises TV to above that point as in figure K.4.

When there is a cooling control profile, the ventilation profile is not permitted to extend upward into the cooling temperature range (figure K.5).

III.K.4   TWO ZONE MIXING MODEL

A simple model can be developed to describe the forced mixing of air between two zones with simple controls. A mass flow of up to FM will exist from zone m to zone n when $TZ_m - TZ_n > TD$. It is assumed that an equal return flow exists from zone n to m. Since the two zone air temperatures

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are intimately coupled, it is best to seek an exact simultaneous solution. The description of that solution is simplified by rearranging equation (K.2.2) to

$$B_n * TZ_n = A_n \qquad\qquad (K.4.1)$$

where

$$A_n = CE_n + \Sigma\ \ HC_i*TI_i + FI_n*Cp_n*T_a + \beta*LT_n*TR_n + LC_n$$

$$B_n = \Sigma\ \ HC_i + FI_n*C_{pn} - (1 - \beta)*LT_n$$

A similar equation exists for zone m. The effect of an interzone air flow is given by the two equations

$$(B_n + MM)*TZ_n = A_n + MM*TZ_m \qquad\qquad (K.4.2a)$$

$$(B_m + MM)*TZ_m = A_m + MM*TZ_n \qquad\qquad (K.4.2b)$$

where $MM = FM * C_p$.

There are three possible conditions for the interzone air flow. First is that $TZ_m - TZ_n < TD$ and therefore $MM = 0$. Second is that the maximum flow rate still leaves $TZ_m - TZ_n > TD$. Simultaneous solution of equations (K.4.2a) and (K.4.2b) gives

$$TZ_n = (A_n + F_1*A_m) / (B_n + MM - F_1*MM) \qquad\qquad (K.4.3a)$$

$$TZ_m = (A_m + MM*TZ_n) / (B_m + MM) \qquad\qquad (K.4.3b)$$

where $F_1 = MM / (B_m + MM)$

The third case occurs when no flow gives $TZ_m - TZ_n > TD$ and full flow would cause $TZ_m - TZ_n < TD$. It is then necessary to solve for the partial flow during the hour which will cause $TZ_m - TZ_n = TD$. This gives

$$MM = [A_m - B_m*(TD + A_n/B_n)] / [TD*B_m/B_n + TD] \qquad\qquad (K.4.4a)$$

$$TZ_n = (A_n + MM*TD) / B_n \qquad\qquad (K.4.4b)$$

$$TZ_m = TZ_n + TD \qquad\qquad (K.4.4c)$$

III.K.5   WHOLE HOUSE FAN MODEL

A model similar to the zone mixing model (III.K.4) can be developed which describes the effects of a fan moving air only from zone n to zone m with movement of air to and from ambient completing the mass balance. Such a case is the exhaust of house air into its attic. A simple control scheme allows a mass flow of up to FF whenever $TZ_n > TD > T_a$. The effect of the air flow on the zone energy balances is given by

$$(B_n + MF)*TZ_n = A_n + MF*TA \tag{K.5.1a}$$

and

$$(B_m + MF)*TZ_m = A_m + MF*TZ_n \tag{K.5.1b}$$

where

$$MF = FF * C_p$$

similar to equations (K.4.2).

There are three possible conditions for the interzone air flow. First is that $TD < T_a$ or $TZ_n < TD$ which gives $MF=0$. Second is that the maximum flow leaves $TZ_n > TD$. Direct solution of equations 1a and 1b gives

$$TZ_n = (A_n + MF*TA) / (B_n + MF) \tag{K.5.2a}$$

$$TZ_m = (A_m + MF*TZ_n) / (B_m + MF) \tag{K.5.2b}$$

The third case occurs when no flow gives $TZ_n > TD$ and full flow would cause $TZ_n < TD$. It is then necessary to solve for the partial flow during the hour which causes $TZ_n = TD$.

$$MF = (A_n - B_n*TD) / (TD-T_a) \tag{K.5.3a}$$

$$TZ_n = TD \tag{K.5.3b}$$

$$TZ_m = (A_m + MF*TZ_n) / (B_m + MF) \tag{K.5.3c}$$

REFERENCES

[1] Coblenz, C. W. and Achenbach, P. R., "Field Measurements of Ten Electrically-Heated Houses", ASHRAE Transactions (ASHRAE, 1963), pp 358-365.
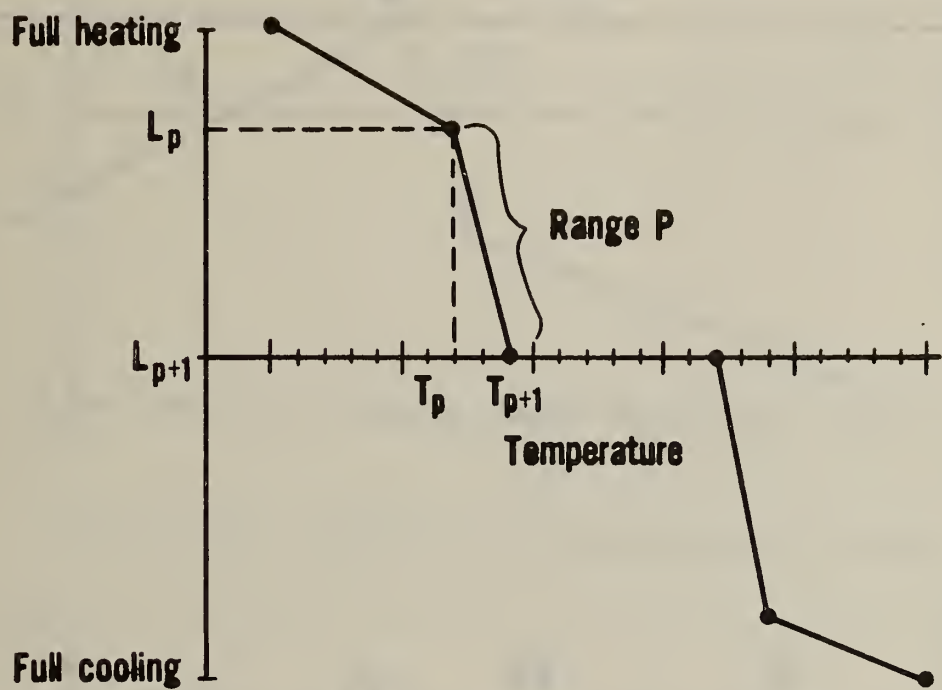
Figure III.K.1   Zone temperature control profile
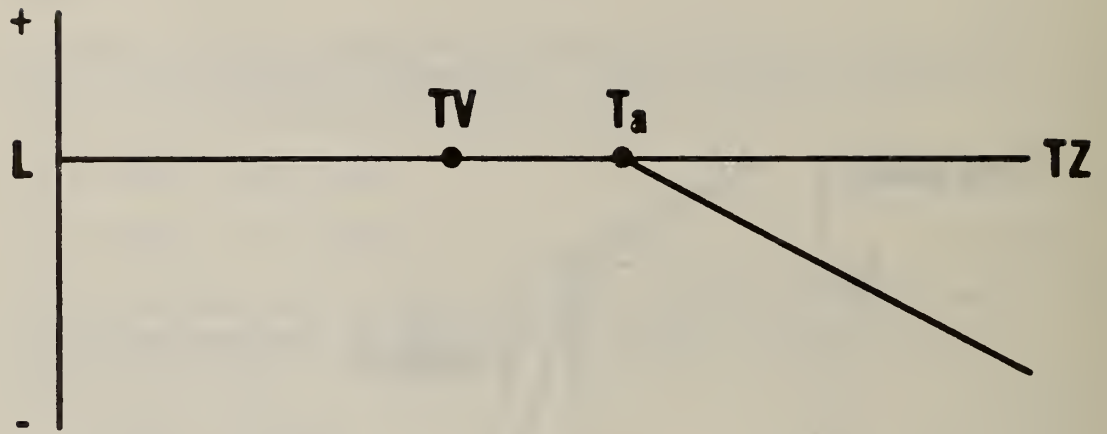
Figure III.K.2   Ventilation control profile: T_a higher than TV
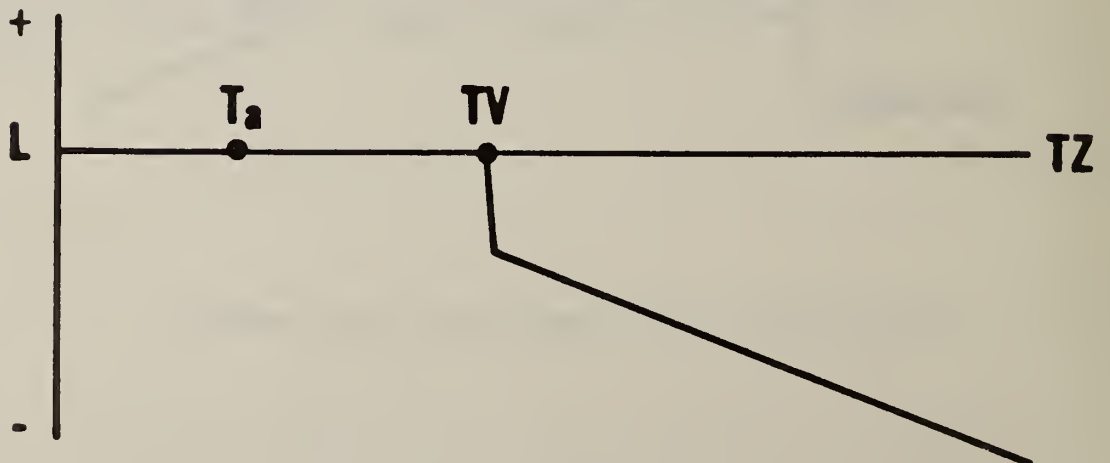
Figure III.K.3   Ventilation control profile: T_a higher than TV

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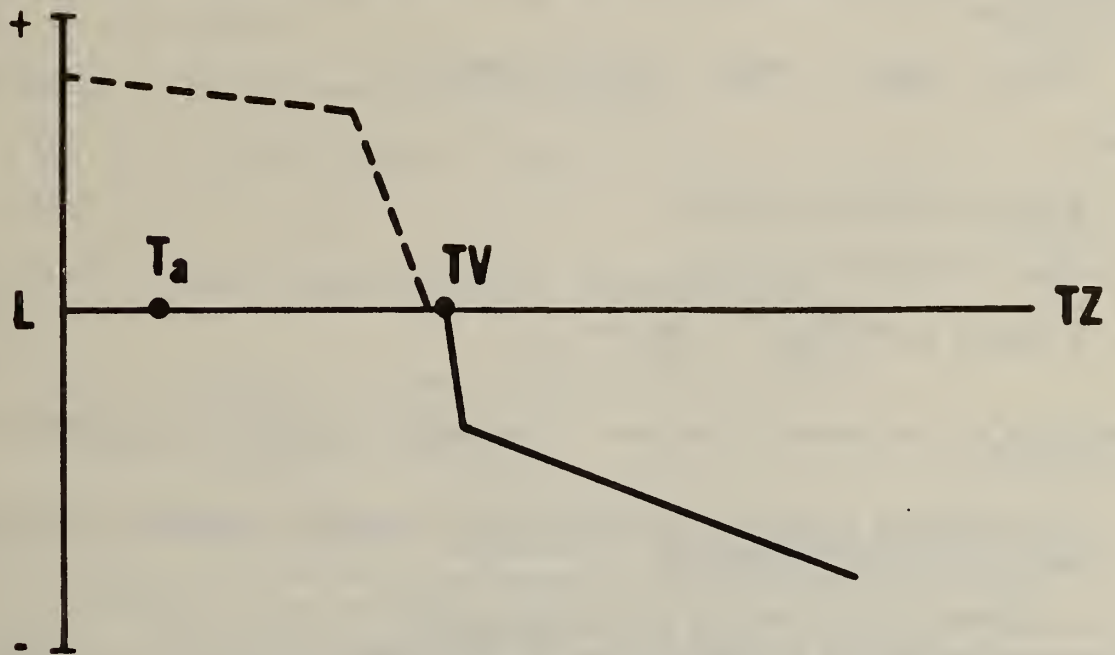
Figure III.K.4 Ventilation and heating control profiles
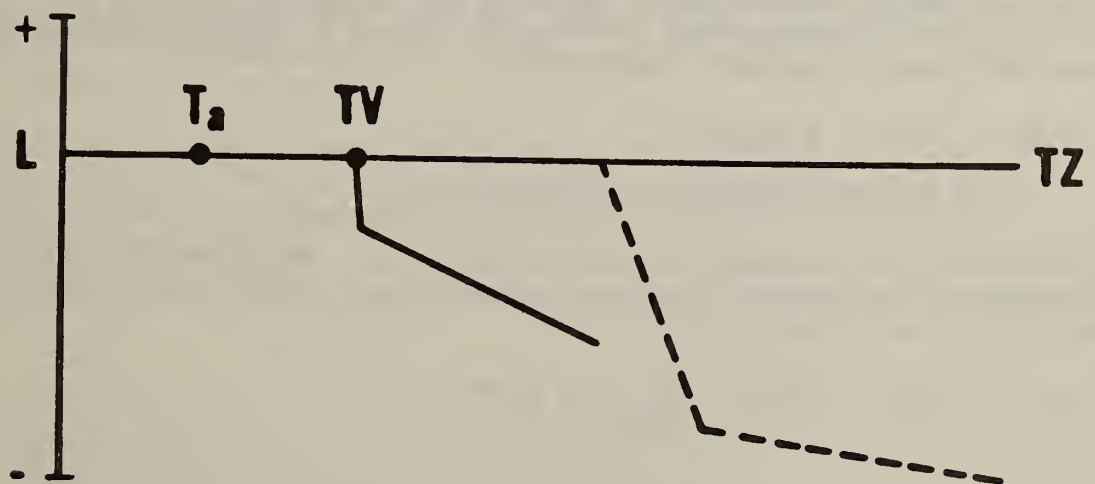
Figure III.K.5 Ventilation and cooling control profiles

III.L   HEAT BALANCE CONVERGENCE

In any zone the air temperature, mean radiant temperature, and the surface temperatures are intimately related. A change in any one will cause changes in all of the others. Those secondary changes should be predictable.

It was observed that, with the zone air temperature held nearly constant by a large heating capacity, there was a regular pattern in successive radiant temperature values during the heat balance iterations for a given hour.

$$(TR_{k+2} - TR_{k+1}) / (TR_{k+1} - TR_k) = \text{constant} \qquad (L.1.1)$$

where

k is the iteration number.

The value of that constant is

$$\Sigma \left(HR_i * S_i * \frac{\partial TI_i}{\partial TR_n} \right) / \Sigma \left(HR_i * S_i \right) \qquad (L.1.2)$$

with i for all surfaces of the zone. The partial derivatives are described in section J.

The following logic led to a method for improved convergence for fixed or floating zone air temperature.

(1) Do the first iteration in the normal manner.
(2) During the second iteration a new TR is computed (H.2.5). It is $\Delta TR0$ greater (negative value means less) than the first iteration TR.
(3) By itself, this would cause an increase of $\alpha * \Delta TR_0$ in the value of TR in the next iteration. α is the constant given by (L.1.2).
(4) It also causes an increase in the zone air temperature due to increased convective gain. Assuming that the average change in surface temperatures equals the change in radiant temperature

$$\Delta TZ_0 = \Delta TR_0 * \Sigma HC_i * S_i /$$

$$[\Sigma HC_i * S_i + \Sigma F_j * C_p - (1-\beta) * LT] \qquad (L.1.3)$$

(5) Increasing TZ will then increase the TI because of convective gain. Again assuming the change in surface temperatures is about equal to the change in radiant temperature

$$\Delta TR_1 = \Delta TZ_0 * \Sigma HC_i * S_i * \frac{\partial TI_i}{\partial TZ_n} / \Sigma HC_i * S^1$$

$$= \Delta TR_0 * \Sigma \ HC_i * S_i * \frac{\partial TI_i}{\partial TZ_n} \ /$$

$$[\Sigma \ HC_i * S_i + \Sigma \ F_j * C_p - (1-\beta)LT \ ]$$

$$= \gamma * \Delta \ TR_0 \qquad\qquad\qquad\qquad\qquad (L.1.4)$$

(6) Combine the changes in radiant temperature in (3) and (5) to give the total change in TR for one iteration.

$$\Delta TR_2 = (\alpha + \gamma) * \Delta TR_0 \qquad\qquad\qquad\qquad (L.1.5)$$

The total change in TR over several iterations is

$$\Delta TR = \Delta TR_0 * [\ 1 + (\alpha{+}\gamma) + (\alpha{+}\gamma)^2 + (\alpha{+}\gamma)^3 + \ldots \ ]$$

$$= \Delta TR_0 \ / \ (1 - \alpha - \gamma) \qquad\qquad\qquad (L.1.6)$$

(7) Similarly, the total change in zone air temperature is given by

$$\Delta TZ = [\Delta TR_0 * \Sigma \ HC_i * S_i \ ) * [\ (\alpha{+}\gamma) + (\alpha{+}\gamma)^2 + \ldots \ ] \ /$$

$$[\Sigma \ HC_i * S_i + \Sigma \ F_j * C_p - (1-\beta)*LT \ ] \qquad (L.1.7)$$

(8) The current estimates of TR and TZ are therefore increased by ΔTR and ΔTZ, respectively. Then the surface temperatures and resulting new zone air temperature are calculated in the normal manner. For the convergence test the new TZ is compared to the predicted value of TZ instead of the previous iteration value. If the two temperatures (or associated heating/cooling load) are sufficiently close, the solution has converged.

On the first iteration of a given hour, many parameters may have changed from the previous hour. These parameters include the delayed conductive gains and radiant and scheduled loads. These are additional factors which must be included in the convergence algorithm. So far that has only been partially successful.

Sample results of the convergence improvement algorithm for a single zone showed a reduction from an average of 7.6 to 2.3 iterations per hour in the floating temperature mode and from 5.4 to 2.1 iterations per hour in the fixed temperature mode.

IV.   INPUT

IV.A   OVERVIEW

It is intended that the TARP input deck be an on-line file which is
created and modified by a text editing system. It can also be a deck of
punched cards. There is a simple, consistant input structure. The input is
based on a keyword system (keyword = value) to produce a free-format,
self-descriptive input. In some ways it is similar to NAMELIST input which
is a feature of some versions of FORTRAN. The keywords have been kept short
(usually less than 5 letters) to reduce the amount of typing that must be
done. The keyword system is organized in a logical hierarchy which groups
related concepts and data. Defaulting is used extensively. This applies to
individual values and to groups of values representing entire elements of
building operation or description. Some groups of often used data can be
named and then used many times by referring to the name.

This input method was chosen from the following four basic
alternatives.

1. Columns or lines of numbers for simple fixed or free format FORTRAN
reading.
2. A free-format, self-descriptive language such as used by BLAST or DOE.
3. A prompting, fully interactive system.
4. A graphic, interactive system.

Method 4 could not be used because of its equipment and programming
time requirements. The complexity of describing building geometry may make
it the logical choice of input for a user-oriented loads program. Simple
FORTRAN reads (method 1) are easy to program and produce a small, fast
computer program. However, it is difficult to incorporate simple defaulting
and optional input. It is also difficult to understand and correct the
input without running it through the input processor. Self-descriptive
input (method 2) can be criticised as taking too long to prepare and
presenting more opportunites for error because of the additional words used
to describe the numbers. But defaulting is easy to incorporate, and the
user can understand the input deck directly after only a little practice.
Prompting, interactive input (method 3) can be of great help to the
beginning user. The large number of values involved in a complete building
description can make full prompting tedious. The prompting system must
allow for changing the input after it has been used for a loads calculation.
This method may be worth the programming time it would take to implement.

IV.B   INPUT LANGUAGE SYNTAX

Several goals were assisted by the development of a simple, consistant
input structure. That input structure may be considered a language and the
relationships of the components of a language are called "syntax". The
following pages describe the input syntax in two ways. First is the
Backus-Naur Form (BNF) which is traditional to computer science. Second is

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an English description of the same features for those who are unfamiliar with BNF.

IV.B.1   BNF DESCRIPTION

1.   <INPUT DECK> ::= <SECTION> {<SECTION>}

2.   <SECTION> ::= <SECTION NAME> [<KEY> {<KEY>}]

3.   <KEY> ::= <KEY NAME> (<SUBKEY> {<SUBKEY>})

4.   <SUBKEY> ::= <SUBKEY NAME> / |
                  <SUBKEY NAME> = <DATA> {, <DATA>} /

5.   <DATA> ::= <NAME> | <INTEGER> | <REAL> | <DATE> | <DESCRIPTION>

6.   <NAME> ::= <CHAR> {<CHAR> | <NULL>}

7.   <UNS INTEGER> ::= <DIGIT> {<DIGIT> | <NULL>}

8.   <INTEGER> ::= <UNS INTEGER> | - <UNS INTEGER>

9.   <REAL> ::= <INTEGER> | <INTEGER> . | . <UNS INTEGER> |
                  <INTEGER> . <UNS INTEGER> |
                  <INTEGER> . <UNS INTEGER> E <INTEGER>

10.   <DATE> ::= <MONTH> <UNS INTEGER> | <UNS INTEGER> <MONTH>

11.   <DESCRIPTION> ::= ' {<CHAR> | <SYMBOL> | <NULL>} '

12.   <CHAR> ::= <LETTER> | <DIGIT> | - | .

13.   <SYMBOL> ::= / | = | , | (|) | $ | * | [|]

14.   <NULL> ::= <BLANK> | +

15.   <LETTER> ::= A | B | ... | Y | Z

16.   <DIGIT> ::= 0 | 1 | ... | 8 | 9

17.   <MONTH> ::= JAN | FEB | ... | NOV | DEC

18.   <COMMENT> ::= $ |) |] {<CHAR> | <SYMBOL> | <NULL>} END-OF-LINE

IV.B.2   ENGLISH DESCRIPTION

1. The TARP input deck consists of several sections. There are presently four sections: PROJECT, LIBRARY, BUILDING, and ZONE.

2. Each section consists of a section name and one or more keys enclosed in brackets.

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3. A key is a key name and one or more subkeys enclosed in parentheses.

4. A subkey consists of a subkey name or a subkey name, an equals sign, one or more data values, and a terminating slash. When only a subkey name is called for, entry of that name enables some option. Most subkeys introduce one or more elements of data. Multiple data values are separated by commas.

5. There are five different data types. Only descriptions may be longer than 10 non-null characters.

6. A name consists of characters.

7. An unsigned integer consists of digits.

8. An integer is an unsigned integer for positive values or an unsigned integer preceeded by a minus sign for negative values.

9. There are five distinct representations for real numbers. Note that a decimal point is not necessary and that exponential notation is possible.

10. Dates consist of a month name and a day number.

11. A description is a string of characters and other symbols enclosed in apostrophes. It may be up to 100 characters long, including nulls and symbols. An apostrophe may not occur within the string.

12. "Characters" are letters, digits, hyphen (minus), and period.

13. There are several generally recognized symbols in FORTRAN 77. These symbols are used as punctuation in the input language. Most systems also provide other symbols which may be used in those language elements which use "symbols" such as ", %, @, etc.

14. The blank and plus sign are nulls. They are ignored by the input reader. Therefore, elements of the language may be separated by blanks to improve readability. The plus sign does not affect the value or character count of a number.

15. Letters are the 26 letters of the alphabet.

16. Digits are the 10 numerals.

17. Months are first three letter abbreviations of the 12 months.

18. Comments begin with a dollar sign or at the end of a key or end of a section and continue to the end of the line. They may be included on lines with input or on separate lines.

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Other features:

Successive identical subkey values "...,<DATA>,<DATA>,<DATA>,..." may be replaced by "...,<UNSIGNED INTEGER>*<DATA>,..." .

A line of input may be up to 80 characters long. Input features may be continued on succeeding lines. Punctuation determines the end of all input features except comments, which terminate at the end of the line.

The final subkey slash before ending a section may be dropped. That is, "/)" may be replaced by ")". The slash may be considered a separator rather than a terminator.

IV.B.3   ERROR PROCESSING

The TARP handles incorrect input by reporting the error and then skipping to the next readable input. It makes no attempt to correct the input error. It is more important for the user to correctly type punctuation than names or values. The approximate order of importance of punctuation is: ' $ [ ] ( ) / = , . Similarly, section names are more important than key names which are more important than subkey names which are more important than data. For example, an incorrect data value would cause the program to not process only that value, but an incorrect subkey name causes the program to skip all values following it (because the program cannot know to which subkey they apply) and go to the next subkey, which will be after the next "/". Similarly, an incorrect key name causes the program to skip the entire key including all its subkeys. The key name will have to be corrected and another run made to find any errors in the subkeys. The punctuation is critical because it determines where the input skipping stops. The program must then find a recognizable name or another skip will occur. Thus the brackets and parentheses are more important than slashes because an error in them causes more skipped input. The apostrophe and dollar sign are most critical because descriptions and comments can include punctuation symbols which could totally confuse the input reader. Although this process sounds complex, the consistancy of the syntax makes it very easy for the user to check punctuation before submitting the input to the computer. The input deck can be debugged in a small number of runs because the entire deck will be processed during every run instead of quitting at the first error.

IV.C   INPUT DETAILS

     The input must be made meaningful by defining the "vocabulary" of names
and data which fill in the syntax. Every section, key, and subkey is
discussed below. Each subkey description is headed by a line containing six
elements:

1. The section, key, and subkey numbers (e.g. 2.4.1). These serve in
cross-referencing to other input. Several related subkeys may be grouped
under one subkey number.

2. The subkey name, "=", data types. The data types mean: n = name, r =
real, i = integer, d = date, desc = description.

3. The default. Dimensional values are in metric units. Immediately below
is the value in English units.

4. The units. "-" means dimensionless. English units are given below the
metric units.

5. The status. "reqd" means a value must be given. "opt" means a value is
optional; otherwise the default will be used. "cond" means conditional.
One of several values must be chosen or a value must be chosen if some other
input has been set.

6. The permitted range of the data value.

IV.C.1   PROJECT SECTION

1.   PROJECT [Project Section.
     This section is required. It also must be first. It creates the data
     that relates to the entire project: weather data and various
     input/output controls.

1.1   RC (Run control parameters.
     This key is optional, but if it is used it must be first.

1.1.1   DESC = 'desc'   blank   -   opt   -
     This description will appear on the loads reports.

1.1.2   SYNTAX   no   -   opt   -
     This subkey causes the input processor to do only a "syntax check".
     Syntax and typing errors are listed. This avoids many of the calcu-
     lations that are normally done, so that the processor can run quicker
     and with less core, but it does not produce a simulation input file
     (SINPFL) for the loads program.

1.1.3   DEM   no   -   opt   -
     This subkey will enable the printing of more detailed error messages.
     It may be useful in the early debug phase or for the inexperienced
     user.

1.1.4   2SPC   no   -   opt   -
    This will cause double spacing. A blank line will be inserted between
    each user input line which is echoed in the input processor report.
    This enhances readability.

1.1.5   XREF   no   -   opt   -
    The input processor will report the sequence number of every major
    input element. This will aid in locating the input that may be causing
    errors in the loads calculation. See V.A.2.3 for further details.

1.1.6   OLDW   no   -   opt   -
    This subkey may be used if a environment file (ENVTFL) has been prepared
    and saved in a previous run. It causes keys 1.3, 1.4, 1.5, and 1.6 to
    be skipped, saving the time that would be spent preparing a new
    identical environment file.

1.1.7   ENGLISH   yes   -   opt   -
         METRIC
         UIN = n
         UOUT = n
    These subkeys provide different ways of specifying the units used for
    the input and output of numbers. See the Table of Units. ENGLISH
    means the input and output are in English units. METRIC means they are
    in metric units. Alternatively, the input units can can be either
    UIN=ENGLISH or UIN=METRIC and the outputs either UOUT=ENGLISH or
    UOUT=METRIC.

1.2   RPT (Set reports flags.

1.2.1   RNOS = 1,1,...   9   -   opt   -
         1 = dump PROJECT and LIBRARY data
         2 = dump DDY and WTAP data
         3 = dump CTF calculations
         4 = dump glass calculations
         5 = dump DSS data
         6 = dump ZONE data
         7 = dump cross reference values
         8 = dump SINPFL as read by loads program
         9 = report description of zone
        13 = report sunlit areas
        14 = report shadowing combinations
        15 = dump shadow calculation controls
        16 = dump shadow calculations
        20 = dumps 21-24 during warm-up period
        21 = dump primary zone data
        22 = dump constant load components
        23 = dump variables
        24 = dump temperature and flux histories
        25 = dumps 21-24 on WED nearest 21st of month

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```
1.3       LOC (                    Location.

1.3.1     DESC = 'desc'        blank     -              opt       -

1.3.2     LATD = r             40.       degrees   opt       -90.<=r<=90.
          The latitude of the site.  Degrees north is positive.

1.3.3     LONG = r             90.       degrees   opt       -180.<=r<=180.
          The longitude of the site.  Degrees west is positive.

1.3.4     TZ = r               6.        -          cond      0.<=r<=24.
          The time zone number of the site.  The United States eastern time zone
          is 5 and the Pacific time zone is 8.

1.3.5     ALT = r              0.        -          opt       -
          The altitude of the site.  Not used by the program.

1.3.6     TER = i              2         -          opt       1<=i<=3
          Type of terrain is used only with HO = 2 (3.1.6).
          Type numbers are as described in III.B.4.

1.4       GRND (                   Ground parameters.

1.4.1     GRT = r,r,...<12>    12*12.78  C          opt       -
                               12*55.    F


          Ground temperatures for the 12 months starting with January.  They are
          used only with other side coefficients (4.3).

1.4.2     MWT = r,r,...<12>    12*12.78  C          opt       -
                               12*55.    F
          Make-up water temperatures for the 12 months starting with January.
          Not yet used by the program.

1.5       WTAP (                   Weather tape parameters.

1.5.1     DESC = 'desc'        blank     -          opt       -

1.5.2     SKIP = i             0         -          opt       0<=i<=365
          Skip this number of days on the weather tape before starting to process
          days for the environment file (ENVTFL).

1.5.3     DAYS = i             365       -          opt       1<=i
          Process this number of days from the weather tape (WTHRTP) to the
          environment file (ENVTFL).

1.6       DDY (                    Design day description.

1.6.1     DESC = 'desc'        blank     -          opt       -
```

```
1.6.2    HIGH = r              35.0      C          opt          -
                               95.0      F

    High temperature for the design day.

1.6.3    LOW = r               22.78     C          opt          LOW<=HIGH
                               73.0      F
    Low temperature for the day.

1.6.4    WB = r                25.56     C          opt          -
                               78.0      F
    Wet bulb temperature at the time of the day's high temperature.  This
    temperature must be psychrometrically possible.

1.6.5    DATE = d              21JUL     -          opt          -
    The date determines the solar position and length of daylight.

1.6.6    PRES = r              100000.   Pa         opt          -
                               401.5     in H2O
    The absolute barometric pressure at the site is used in the
    psychrometric calculations.

1.6.7    WS = r                3.353     m/s        opt          -
                               660.      ft/min
    The default wind speed is 7.5 miles per hour.  (1 mph = 88 ft/min)

1.6.8    DIR = r               270.      degrees    opt          -360.<=r<=360.

    Wind direction:  north = 0 degrees, clockwise is positive.  The default
    wind is from the west.

1.6.9    CLR = r               1.0       -          opt          0.<=r
    The total solar radiation on a horizontal surface is the ASHRAE clear
    sky amount times this clearness number.  The proportion of beam and
    diffuse radiation changes according to a correlation function.

1.6.10   RAIN                  no        -          opt          -
    RAIN causes the outside temperatures of surfaces exposed to ambient to
    be set to the wet bulb temperature.  This models the cooling effect of
    rain on the building.

1.6.11   SNOW                  no        -          opt          -
    SNOW causes the ground reflectance to be increased from its default of
    0.2 to 0.7.  This gives a much higher diffuse solar gain to the zones.

1.6.12   SUN ...               MON       -          opt          -
    The day of the week determines which day-schedules (2.2) and control
    day-schedules (2.6) are used.  Allowable day names are:  SUN, MON, TUE,
    WED, THU, FRI, SAT, HOL, SP1, SP2, SP3, SP4.
```

2.   LIBRARY [Library Section.
          The library simplifies input by grouping relatively large amounts of
          data by name. That name can be referenced later in the input process
          instead of again specifying all the data. This produces economies when
          items are used several times. There are seven types of library data:
          day-schedules (DS), week-schedules(WS), materials (MATL), constructs
          (CONS), control profiles (CPFL), control day-schedules (CDS), and
          control week-schedules (CWS).

2.1   LIB (Library control parameters.

2.1.1   NAME = n   blank   -   opt   -
          Not yet used.

2.1.2   NDS = i   16   -   opt   -
          NWS = i   16   -   opt   -
          NMATL = i   16   -   opt   -
          NCONS = i   16   -   opt   -
          NCPFL = i   16   -   opt   -
          NCDS = i   16   -   opt   -
          NCWS = i   16   -   opt   -
          These subkeys control the number of library elements which can be
          defined. Library names are stored in an array which is 256 elements
          long. The total number of named library elements cannot exceed 256.
          The sum of these subkeys (including those left to default) cannot
          exceed 256.

2.1.3   ALL   no   -   opt   -
          DS   no   -   . opt   -
          WS   no   -   opt   -
          MATL   no   -   opt   -
          CONS   no   -   opt   -
          CPFL   no   -   opt   -
          CDS   no   -   opt   -
          CWS   no   -   opt   -
          These eight subkeys control the printing of library data. The eight
          individual names will each produce reports for that class of library
          data. ALL will cause all eight classes to be reported.

2.2   DS (Day-schedules.
          A day-schedule is a set of 24 numbers used to provide an hourly
          variation in some building parameter.

2.2.1   NAME = n   blank   -   reqd   -
          Each day-schedule name must be different from all other day-schedule
          names.

2.2.2   DESC = 'desc'   blank   -   opt   -
    A description will more fully describe the purpose of the schedule. It
    will appear in the day-schedule report.

2.2.3   FFC = r,r,...<24>   24*1.0   -   opt   0.<=R<=1.
    Fraction of full capacity. 24 values are required: one for each hour
    of the day. They may range from zero to one. A zero value can be
    replaced by OFF and ON can be used in place of one. This may be more
    intuitive for day-schedules which are controlling the on/off operation
    of something.

2.3   WS (Week-schedules.
    A week-schedule is a set of 12 day-schedules: one for each day of the
    week, one for holidays, and one for each of 4 special day types (SP1,
    SP2, SP3, and SP4). It is referenced by name in subsequent building
    input.

2.3.1   NAME = n   blank   -   reqd   -
    Each week-schedule must have a name different from all other
    week-schedule names.

2.3.2   DESC = 'desc'   blank   -   opt   -
    A description is useful in more fully describing the schedule, but its
    use is optional.

2.3.3   WD = n   blank   -   cond   -
    Set weekday (Monday through Friday) pointers to the named day-schedule.
    That day-schedule must have been previously defined (2.2). Other
    options are:
        WE = n   Set weekend (SAT & SUN) pointers.
        ALL = n   Set all 12 pointers.
        SUN = n   Set Sunday pointer only
        MON = n   Set Monday pointer only.
    and similarly for TUE = n, WED = n, THU = n, FRI = n, SAT = n, SP1 = n,
    SP2 = n, SP3 = n, and SP4 = n. At least one day must be defined (other
    pointers will be set by default rules).

2.4   MATL (Materials.
    These describe the materials used in the walls, windows, floors, etc.,
    of the building. Conductive, optical and surface properties can be
    described. The user must define the conductive properties (K, CP,
    and D) or R.

2.4.1   NAME = n   blank   -   reqd   -
    Each material must have a unique name.

2.4.2   DESC = 'desc'   blank   -   opt   -

2.4.3   K = r   0.   W/m*K   cond   0.<r
                              0.   Btu/hr*ft*F
    Conductivity.

```
2.4.4    CP = r                .8368    kJ/kg*K    cond      0.<r
                               0.2      Btu/lbm*F
         Specific heat.


2.4.5    D = r                 0.       kg/m^3     cond      0.<r
                               0.       lbm/ft^3
         Density.


2.4.6    R = r                 0.       m^2*K/W    cond      0.<r
                               0.       hr*ft^2*F/Btu
         Thermal resistance (R-value).


2.4.7    A = r                 .75      -          opt       0.<=r<=1.
         Absorptance (and emittance) for solar radiation.


2.4.8    E = r                 .90      -          opt       0.<r<1.
         Emittance (and absorptance) for thermal wavelength radiation.


2.4.9    TRNS = r              0.       -          opt       0.<r<1.
         Transmittance of GLASS (2.4.17) and SHADE (2.4.16) materials.


2.4.10   IR = r                1.52     -          opt       1.<r<2.
         Index of refraction of GLASS (2.4.17) materials.


2.4.11   FTRN = r              0.       -          opt       0.<r<1.
         This is the transmittance of a sheet of GLASS (2.4.17) with a
         thin metallic film on the inside surface.
         It must be used in conjunction with TRNS (2.4.9) which is the
         transmittance of the glass without the film.
         FTRN must be less than TRNS.
         The thickness of the film is computed from those values and IR
         (2.4.10) with optical properties of aluminum assumed for the film.


2.4.12   REF = r               0.       -          opt       0.<r<1.
         Reflectance of a SHADE (2.4.16)


2.4.13   SC = r                0.       -          opt       0.<r<1.14
         The ASHRAE defined shading coefficient of a window.  This must be used
         with GLASS (2.4.17).  All other optical properties are ignored.


2.4.14   RGH = i               2        -          opt       1<=i<=6
         The roughness index interacts with the wind speed to determine the
         outside convection coefficient.  Index values:
         1    very rough     - stucco, built-up roof with stone, wood shingles
         2    rough          - brick, plaster, concrete block
         3    medium rough   - concrete, asphalt, shingles
         4    medium smooth  - clear pine
         5    smooth         - smooth plaster or metal
         6    very smooth    - glass, smooth painted surfaces
```

2.4.15   AIR   -   -   cond   -
    This subkey must be used if the material is to used as an air layer in
    any transparent construct. The optical algorithms assume that the
    glass panes are separated by air layers. Those air layers
    automatically have TRNS=1 and IR=1.

2.4.16   SHADE   -   -   cond   -
    This indicates that the material is an interior shade in transparent
    constructs. It must have information on TRNS (2.4.9) and REF (2.4.12).
    Conductive properties need not be defined because they will not be
    used.

2.4.17   GLASS   -   -   cond   -
    This subkey indicates the glass panes in a transparent construct. A
    GLASS material must have conductive properties and optical properties
    chosen from: (TRNS, IR) or (TRNS, IR, FTRN) or (SC). The program
    assumes that multiple panes are separated by air layers for the optical
    calculations.

2.5   CONS   Constructs.
    Constructs are the wall and window sections, described in terms of
    their constituent layers, that make up the building.

2.5.1   NAME = n   blank   -   reqd   -
    Every construct must have a name different from all other constructs.

2.5.2   DESC = 'desc'   blank   -   opt   -
    A description will appear in the construct report to more fully
    describe the construct.

2.5.3   MATL = r,n,r,n,... 0,blank   m, -   reqd   -
                                         ft, -

    This subkey describes the material layers which form the construct.
    The values are pairs of (thickness, name of material) from the outside
    to the inside layer. Layers which are described by R-value (2.4.6)
    must be given a thickness to maintain the proper sequence of values.
    The value of that thickness is not used in the conductivity
    calculations, so even a zero is adequate.

2.5.4   OA = r   -   -   opt $0. <= r <= 1.$
    Outside absorptance (and emittance) for solar radiation. If no value
    is given, the default is the absorptance (2.4.7) of the outside (first)
    layer.

2.5.5   OE = r   -   -   opt $0. <= r <= 1.$
    Outside emittance (and absorptance) for thermal radiation. If no value
    is given, the default is the emittance (2.4.8) of the outside (first)
    layer.

2.5.6   ORGH = i   -   -   opt   1<=i<=6
     This describes the roughness of the outside surface. It has the values
     of subkey 2.4.14. If no value is given, the default is the roughness
     of the outer layer.

2.5.7   IA = r   -   -   opt   0.<=r<=1.
     Inside absorptance (and emittance) for solar radiation. If no value is
     given, the default is the absorptance (2.4.7) of the inside (last)
     layer.

2.5.8   IE = r   -   -   opt   0.<=r<=1.
     Inside emittance (and absorptance) for thermal radiation. If no value
     is given, the default is the emittance (2.4.8) of the inside (last)
     layer.

2.6   CPFL (Control profiles.
     Control profiles relate the capacity of the air handling system to the
     zone temperature.

2.6.1   NAME = n   blank   -   reqd   -
     Every control profile must have a unique name.

2.6.2   DESC = 'desc'   blank   -   opt   -
     The description more fully describes the control profile.

2.6.3   TMP = r,r,...   -   C   reqd   -
                                          F
     This subkey is a list of the control point temperatures which make up
     the control profile. See IV.E on control profiles.

2.6.4   CAP = r,r,...   -   -   reqd   -1.<=r<=1.
     This subkey is a list of the control point capacities which make
     up the control profile.
     Each capacity is matched to the control temperature (2.6.3).
     There may be no more than eight capacities in the profile.
     See IV.E on control profiles.

2.7   CDS (Control day-schedules.
     A control day-schedule is a set of 24 control profiles.

2.7.1   NAME = n   blank   -   reqd   -
     Each control day-schedule name must be different from all other control
     day-schedule names.

2.7.2   DESC = 'desc'   blank   -   opt   -
     A description will more fully describe the purpose of the control
     day-schedule. It will appear in the day-schedule report.

2.7.3   CPFL = n,n,...   blank   -   reqd   -
     24 profile names are required: one for each hour of the day. They
     must have been previously defined (2.6).

2.8   CWS (Control week-schedules.
     A control week-schedule is a set of 12 control day-schedules: one for
     each day of the week, one for holidays, and one for each of 4 special
     day types (SP1, SP2, SP3, and SP4). It is referenced by name in
     subsequent building input.

2.8.1   NAME = n   blank   -   reqd   -
     Each control week-schedule must have a name different from all other
     control week-schedule names.

2.8.2   DESC = 'desc'   blank   -   opt   -
     A description is useful in more fully describing the schedule, but its
     use is optional.

2.8.3   WD = n   blank   -   cond   -
     Set weekday (Monday through Friday) pointers to the named control
     day-schedule. That control day-schedule must have been previously
     defined (2.7). Other options are:
          WE = n   Set weekend (SAT & SUN) pointers.
          ALL = n   Set all 12 pointers.
          SUN = n   Set Sunday pointer only
          MON = n   Set Monday pointer only.
     and similarly for TUE = n, WED = n, THU = n, FRI = n, SAT = n, SP1 = n,
     SP2 = n, SP3 = n, and SP4 = n. At least one day must be defined (other
     pointers will be set by default rules).

3.   BUILDING [Building Section.
     This section describes features referring to all zones of the building.
     The entire section is optional. If used, it must occur before any zone
     (section 4.) descriptions.

3.1   SIM (Simulation control parameters.
     If this key is used, it must occur before any detached shadowing
     surfaces (3.2). It may not be used more than once.

3.1.1   N = r   0.0   degrees   opt   -360.<=r<=360.
     Degrees from true north to the north axis of building coordinate system
     (IV.F.5).
     Clockwise is positive.

3.1.2   SLDS = i   0   -   opt   0<=i<=3
     Solar distribution algorithm:
          0 = shading from 'SHD' surfaces only;
          1 = shading from 'SHD' and 'DSS' surfaces;
          2 = shading from all surfaces including other zones;
          3 = 2 + distribution of beam radiation on interior surfaces.
               The surfaces of each zone must form a simple convex envelope.

3.1.3   CNVG = r,r,r,i   .056,.01,.1,6   C,-,W,-   opt   -   .
                          .1,.01,.34,6   F,-,Btu/hr,-
     Heat balance iteration convergence limits:
     First variable = temperature convergence: when there is no heating or
     cooling load successive iterations of zone air temperature must be
     within r degrees.
     Second variable = loads convergence: when there is a load, successive
     iterations of loads must be (1 - load(n)/(load(n-1)) < r.
     Third number = minimum load: when load(n) < r, the next iteration
     would cause division by a small number. Therefore convergence is
     assumed. Convergence is also assumed if |load(n) - load(n-1)| < r.
     Fourth number = maximum number of iterations. Then record occurance of
     non-convergence and go to next time step.
     It is not necesary to give all 4 numbers, but to set the third number
     the first two must also be given.

3.1.4   FLOW = i   12   -   opt   0<i
     This subkey indicates that the loads processor will use the detailed
     air flow algorithm (III.G). It may be used without the value. The
     value specifies the maximum number of iterations: Run terminates if
     this number is exceeded because the heat balance is not valid if the
     flows are not balanced. Two other air flow convergence parameters
     are set as functions of the heat balance parameters (3.1.3).
     Relative flow convergence = realtive loads convergence.
     Absolute flow convergence = .00005 * minimum load.

3.1.5   HTB = i   0   -   opt   i = 0, 1, or 2
    Solve surface heat balances using only a single calculation of the
    outside surface temperature (0 or 1) or by iterating the outside
    temperatures simultaneously with the inside surface temperatures to
    convergence (2). The simpler mean radiant temperature (H.2.3) is used
    with HTB = 0 and the more detailed MRT (H.2.H) is used with 1 or 2.

3.1.6   HO = i   0   -   opt   i = 0 or 2
    Compute exterior convection coefficient using simple (0) or detailed
    (1) algoritmh (I.1 and I.2).

3.1.7   HI = i   0   -   opt   i = 0 or 1
    Compute interior convection coefficient using simple (0) or detailed
    (2) algorithm (J.1 and J.2).

3.2   DSS (Detached shadowing surfaces.
    Shadows from these surfaces are not used unless SLDS > 0 (3.1.2).

3.2.1   AZM = r   0   degrees   opt   -360.<=r<=360.
    Azimuth (facing) angle of surface relative to building coordinate
    system. For example, north = 0, east = 90, south = 180, west = 270 or
    -90.

3.2.2   TILT = r   90   degrees   opt   0.<=r<=180.
    Tilt of surface (0 = facing upward like flat roof; 90 = vertical; 180
    = facing downward like floor).

3.2.3   X = r   0.   m   opt   -
                           0.   ft
         Y = r   0.   m   opt   -
                           0.   ft
         Z = r   0.   m   opt   -
                           0.   ft
         ORG = r,r,r
    Coordinates of lower left corner of surface relative to building
    coordinate system. ORG provides a simpler way of describing all 3
    coordinates at once (ORG = X, Y, Z) . See IV.F on geometric data.

3.2.4   W = r   0.   m   reqd   -
                           0.   ft
         H = r   0.   m   reqd   -
                           0.   ft
         SIZE = r,r
          or
         VRTS = r,r,r,r   or r,r,r,r,r,r

    The first two forms specify the width and height of a rectangular
    surface (SIZE = W, H). The last form is for triangles or quadri-
    laterals. The first pair of numbers are the surface relative x-y
    coordinates of the first vertex counter-clockwise from the lower
    left vertex. The subsequent pairs of numbers are the coordinates

of the remaining vertices in counterclockwise sequence. See IV.F
on geometric data.

3.2.5   TRNS = r   0.   -   opt   0.<r<=1.

Transmittance of the shadowing surface.

3.2.6   FROM = d   1JAN   -   opt   -
        THRU = d   31DEC

The surface may apply for only part of the year. Any dates may be
used, but for greatest efficiency dates should be chosen from the
shadowing surface dates table.

4.   ZONE [Zone Section.
A zone is a space under the control of one thermostat (or uncontrolled)
where the air can be considered well mixed. The zone is composed of
surfaces which connect it to the environment or to other zones,
scheduled internal loads, and air temperature control strategy. There
may be multiple zone sections. They must appear after the PROJECT,
LIBRARY, and BUILDING sections.

4.1   GEOM (Zone geometry.
This key is required and must be the first key in the zone section. It
may not be used more than once.

4.1.1   NAME = n   blank   -   reqd   -
Each zone must have a unique name.

4.1.2   N = r   0.0   degrees   opt   -360.<=r<=360.
Degrees from building north axis to north axis of zone coordinate
system. Clockwise is positive.

4.1.3   X = r   0.   m   opt   -
                              0.   ft
           Y = r   0.   m   opt   -
                              0.   ft
           Z = r   0.   m   opt   -
                              0.   ft
           ORG = r,r,r
Coordinates of the lower left corner of the zone relative to the
building coordinate system. ORG provides a simpler way of describing
all 3 coordinates at once (ORG = X, Y, Z). See IV.F on geometric data.
Zone origin is necessary only for the more detailed shadowing
calculations (SLDS > 0; sec 3.1.2).

4.1.4   CLHT = r   3.0   m   opt   -
                              9.84   ft
Height of ceiling is used only in computing the zone height for
detailed air flow calculations (3.1.4 and G.2).

4.1.5   MIRX   no   -   opt   -
This key causes all surface x-vertices to be mirrored about the y-axis
(north-south axis).

4.1.6   MIRY   no   -   opt   -
This key causes all surface y-vertices to be mirrored about the x-axis
(east-west axis).

4.2   PEO (Occupant heat gains.
4.2.1   WS=n   -   -   reqd   -
The occupancy schedule is selected from the library of week-schedules
(2.3). The hours refer to clock time.

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4.2.2   CAP = r   0   -   cond   0.<r
          Enter the number of occupants.

4.2.3   ACT = r   0.1318   kW   opt   .102<=r<=.425
                               .450   kBtu/hr   .35<=r<=1.45
          Enter the activity level. The program will divide this number into
          latent and sensible portions based on room air temperature.

4.2.4   RAD = r   .5   -   opt   0.<=r<=1.
          This is the fraction of the sensible heat gain which is radiated to the
          room surfaces. The rest is convected to the room air.

4.2.5   FROM = d   1JAN   -   opt   -
          THRU = d   31DEC   -   opt   -
          The occupancy week-schedule may apply for only part of the year. The
          schedule used by another PEO key may not overlap.

4.3   LIT (Heat gains from lights.
          The total heat gain from lights is divided into several fractions and
          each is handled differently. The convective fraction is 1.-RA-RAD-VIS.
          It may not be less than zero.

4.3.1   WS = n   -   -   reqd   -
          The total lighting energy is modified by the week-schedule element
          (2.3) for the appropriate day and hour (clock time).

4.3.2   CAP = r   0.   kW   reqd   0.<r
                                  0.   kBtu/hr
          CAP is the peak power consumption (capacity) of the zone lights.

4.3.3   RA = r   0.   -   opt   0.<=r<=1.
          This is the fraction of the total lighting energy which goes directly
          into the return air instead of into the zone. This can occur with
          vented light fixtures.

4.3.4   RAD = r   .20   -   opt   0.<=r<=1.
          This is the fraction which can be considered long-wave radiant energy.
          It interacts with zone surfaces according to their inside emittance
          (2.5.8). The default fraction is typical of flourescent lights. A
          value of 0.80 is appropriate for incandescent lights.

4.3.5   VIS = r   .20   -   opt   0.<=r<=1.
          This is the fraction which can be considered short-wave (or visible)
          radiant energy. It interacts with the room surfaces according to their
          inside absorptance (2.5.7). It can leave the zone through transparent
          surfaces without creating a load. The default is typical of floures-
          cent lights. For incandescent lights 0.10 is an appropriate value.

4.3.6   REP = r   0.   -   opt   -
          This is the fraction of lighting energy which can be replaced by
          daylight (4.10).

4.3.7   FROM = d   1JAN   -   opt   -
          THRU = d   31DEC   -   opt   -
The lighting week-schedule may be applied to only part of the year.
The schedules used by other LIT keys may overlap. This allows a simple
way to combine lighting from different sources as might be necessary to
describe area and task lighting.

4.4   EQP (Heat gains from equipment.
EQP describes the heat gains from various types of equipment. The
convective fraction of that gain is 1.-LAT-RAD-LOST. It may not be
less than zero.

4.4.1   WS = n   -   -   reqd   -
The equipment is selected from the library of week-schedules (2.3).
The schedule refers to clock time.

4.4.2   CAP = r   0.   kW   reqd   0.<r
                               0.   kBTU/hr
CAP is the peak power consumption of the equipment. A negative
capacity is permitted. It can describe a process which cools the zone.
A zero capacity is meaningless.

4.4.3   LAT = r   0.   -   opt   0.<=r<=1.
This is the latent fraction, i.e., the fraction of energy used to add
water vapor to the zone air.

4.4.4   RAD = r   .3   -   opt   0.<=r<=1.
This is the radiant fraction which is treated as long-wave radiation.

4.4.5   LOST = r   0.   -   opt   0.<=r<=1.
The fraction lost allows the user to add energy to the total zone and
building consumption without effecting the zone loads. For example, it
might be used to account for outside lighting.

4.4.6   FROM = d   1JAN   -   opt   -
          THRU = d   31DEC   -   opt   -
Time periods for multiple EQP keys may overlap.

4.4.7   EL   -   -   cond   -
                               electricity
          GS   gas   cond
          ST   steam   cond
          HW   hot water   cond
          OTHR   other   cond
These simple subkeys identify the energy source of the equipment. They
allow summing of the building energy requirements by energy type. One
of them must be given. OTHR allows a load to occur in the zone without
adding to the energy requirements.

4.5   INF (Simple infiltration - Algorithm K.2.
INF allows scheduling of infiltration with simple temperature and wind

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speed dependencies. It may not be used with the detailed air flow
option (3.1.4).

4.5.1   WS = n   -   -   reqd   -
The infiltration schedule is selected from the library of
week-schedules (2.3). The schedule refers to clock time.

4.5.2   CAP = r   0. m^3/s reqd   0.<r
                           0. ft^3/min
Enter the peak infiltration volume flow rate. The user must convert
"air changes" to volume flow rate.

4.5.3   C = r   .606   -   opt   -
         T = r   .03636   1/C   opt   -
                           .0202   1/F
         V = r   .1177   s/m   opt   -
                           .000598   min/ft
         VV = r   0. $(s/m)^2$ opt   -
                           0. $(min/ft)^2$
The scheduled infiltration is modified by the factor:
     $(C + T*|TZ - TA| + V*SPD + VV*SPD^2)$
where TZ = zone air temperature
      TA = ambient air temperature
      SPD = wind speed
The default values are for a 7.5 mph wind and 0 temperature difference.
Users who wish to have a constant infiltration should set C to 1 and
the other coefficients to 0.

4.5.4   FROM = d   1JAN   -   opt   -
         THRU = d   31DEC   -   opt   -
Time periods from multiple INF keys may not overlap.

4.6   VENT (Ventilation - Algorithm K.3.
Ventilation describes the use of unconditioned outside air to cool the
zone. It may also be used to precool the zone during unoccupied hours.
It may not be used with the detailed air flow option (3.1.4).

4.6.1   WS = n   -   -   reqd   -
The ventilation schedule is chosen from the library of week-schedules
(2.3). The schedule refers to clock time.

4.6.2   CAP = r   0. m^3/s reqd   0.<r
                           0. ft^3/min
Enter the peak volumetric flow rate.

4.6.3   MIN = r   20.   C   opt   -
This causes ventilation to seek to bring the zone air temperature down
to the value given. If this subkey is used, do not use MAX (4.6.4).

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4.6.4   MAX = r   90.   C   opt   -
    This causes ventilation to occur whenever the zone air temperature is
    greater than this value. If this subkey is used, do not use MIN
    (4.6.3).

4.6.5   TD = r   2.   K   opt   0.<=r
                                 3.6   F
    This requires that the outside air be TD degrees cooler than the inside
    air before ventilation can occur.

4.6.6   FROM = d   1JAN   -   opt   -
          THRU = d   31DEC   -   opt   -
    Time periods of multiple VENT keys may not overlap.

4.7   MIX (Two zone mixing - Algorithm K.4.
    MIX simulates the controlled mixing of two zones such as occurs in
    attached sunspace designs. It may not be used with the detailed air
    flow option (3.1.4).

4.7.1   WS = n   -   -   reqd   -
    The mixing schedule is chosen from the library of week-schedules (2.3).
    The schedule refers to clock time.

4.7.2   CAP = r   0.   m^3/s   reqd   0.<r
                                 0.   ft^3/min
    Enter the peak volumetric flow rate. The mass flow will be based on
    standard (1.2kg/m3) air.

4.7.3   TD = r   0.   K   opt   0.<=r
                                 0.   F
    There is mixing with the adjacent zone whenever the zone air
    temperature is TD greater than the adjacent zone. When TD is zero,
    there is always mixing (as controlled by the schedule).

4.7.4   ZONE = n   -   -   reqd   -
    Give the name of the adjacent zone.

4.7.5   FROM = d   1JAN   -   opt   -
          THRU = d   31DEC   -   opt   -
    Time periods of multiple MIX subkeys may not overlap.

4.8   FAN (Whole house fan - Algorithm K.5.
    Fan simulates a whole house fan which exhausts house air into the
    attic. It may not be used with the detailed air flow option (3.1.4).

4.8.1   WS = n   -   -   reqd   -
    The fan schedule is chosen from the library of week-schedules (2.3).
    The schedule refers to clock time.

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4.8.2   CAP = r   0.   m³/s   reqd   0.<r
                                0.   ft³/min

Enter the peak volumetric flow rate. The mass flow will be based on
standard (1.2kg/m3) air.

4.8.3   T = r   0.   C   reqd   0.<=r
                                0.   F

The FAN will seek to cool the zone air temperature to T.

4.8.4   ZONE = n   -   -   reqd   -

Give the name of the adjacent (attic) zone.

4.8.5   FROM = d   1JAN   -   opt   -
         THRU = d   31DEC   -   opt   -

Time periods of multiple FAN subkeys may not overlap.

4.9   CTRL (Zone control - Algorithm K.1.

Details of zone temperature control are described in IV.E.

4.9.1   CWS = n   -   -   reqd   -

The control schedule is sectected from the library of control
week-schedules (2.8). The control profile is referenced by clock time.

4.9.2   HEAT = r   1.E6   kW   opt   0.<=r

Enter the peak heating capacity.

4.9.3   COOL = r   1.E6   kW   opt   0.<=r

Enter the peak cooling capacity.

4.9.4   RAD = r   0.   -   opt   0.<=r<1.

The control profile refers to a control temperature which is defined as
(1-RAD)*TZ + RAD*TR where TZ is the zone air temperature and TR is the
zone mean radiant temperature.

4.9.5   FROM = d   1 JAN   -   opt   -
         THRU = d   31DEC   -   opt   -

It is common to operate with different control profiles during
different seasons as heating or cooling capacities are shut off. The
time periods from multiple CTRL keys may not overlap.

4.10   DLT(Daylighting.

The program uses a very simple model to estimate the savings in
lighting energy by using daylighting. All DLT keys should appear in
the zone description before any LIT keys.

4.10.1   WS = n   -   -   reqd   -

The fraction of beam sunlight which is usable for lighting is modified
by the week-schedule (2.3) element for the hour (standard time).

4.10.2   BEAM = r   0.   -   opt   0.<=r<=1.

   This is the fraction of beam sunlight entering the zone which can be
   used to offset the visible energy from the lights.

4.10.3   DIFF = r   0.   -   opt   0.<=r<=1.
   This is the fraction of diffuse sunlight entering the zone which can be
   used to offset the visible energy from lights.

4.10.4   FROM = n   1 JAN   -   opt   -
          THRU = d   31DEC   -   opt   -
   Time periods from multiple DLT keys may not overlap.

4.11   BBH (Baseboard heat.
   This key describes a system which adds heat to the zone based on the
   outside air temperature.

4.11.1   WS = n   -   -   reqd   -
   The peak heating capacity avalable at any hour (clock time) is modified
   by the baseboard heating schedule selected from the week-schedule
   library (2.3).

4.11.2   CAP = r,r   0.,0.   kW   reqd   0.<=r
   The first value is the peak heating capacity. The second value is the
   minimum heating capacity at the shut-off temperature. Two values are
   required.

4.11.3   TMP = r,r   0.,0.   C   reqd   -
   The first value is the highest temperature at which the system gives
   full heating capacity. The second value is the maximum temperature for
   which the system produces any heat (the shut-off temperature). Both
   values are required.

4.11.4   RAD = r   .3   -   opt   0.<=r<=1.
   This is the radiant fraction which is treated as long-wave radiation.

4.11.5   FROM = d   1JAN   -   opt   -
          THRU = d   31DEC   -   opt   -
   Time periods from multiple BBH keys may not overlap.

4.11.6   ST   -   -   cond   -
          HW   -   -   cond   -

   These refer to the source of heating energy: steam or hot water. One
   or the other must be given.

4.12   MASS (Internal mass.
   Internal masses are modeled by the internal surface algorithms. The
   only difference from the treatment of a partition is that the internal
   mass is not given a location in the zone and, therefore, beam sunlight
   cannot fall directly on it.

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4.12.1   CONS = n   —   —   reqd   —
    Select the composition of the mass from the constructs library (2.5)
    (2.5).

4.12.2   AREA = r   0.   m^2 reqd   0.<r
                              0.   ft^2
    The mass must be given an area.

4.13   SRF (Heat transfer surfaces.
    All zone surfaces which conduct or store heat (except internal mass;
    4.12) are described by this key.

4.13.1   CONS = n   —   —   reqd   —
    Select the composition of the surface from the constructs library
    (2.5).

4.13.2   EX   —   —   cond   —
          IN   —   —   cond   —
          OP   —   —   cond   —
          TR   —   —   cond   —
          BS   —   —   cond   —
          SS   —   —   cond   —
    The user must specify the following three factors: Is this an EXterior
    or INterior surface? Is the surface OPaque or TRansparent? Are its
    coordinates defined as a Base Surface or a SubSurface? (The
    coordinates of a subsurface are defined relative to the most recently
    described base surface.) There are eight combinations of these
    factors. Three of those are not permitted because of various
    algorithmic restrictions in the program. The following table explains
    the three factors in terms of the common English names for such
    surfaces (at three basic tilt angles).

EX/IN	OP/TR	BS/SS	90 deg	0 deg	180 deg
EX	OP	BS	wall	roof	—
EX	OP	SS	door	—	—
EX	TR	BS	***	not permitted	***
EX	TR	SS	window	skylight	—
IN	OP	BS	partition	ceiling	floor
IN	OP	SS	***	not permitted	***
IN	TR	BS	—	—	—
IN	TR	SS	***	not permitted	***

4.13.3   AZM = r   180.   degrees   opt   -360.<=r<=360.
    Azimuth (facing) angle of the surface relative to the zone coordinate
    system. North = 0; clockwise positive. This is used fo base surfaces
    only. Subsurfaces face the same direction as their base surface.

4.13.4   TILT = r   90.   degrees   opt   0.<=r<=180.
    Tilt of surface (0 = facing upward like flat roof; 90 = vertical;
    180 = facing downward like floor). This is used for base surfaces
    only. Subsurfaces have the same tilt as their base surface.

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4.13.5   W = r   0.   m   reqd   0.<r
                                  0.   ft
         H = r   0.   m   reqd   0.<r
                                  0.   ft
      SIZE = r,r
      VRTS = r,r,r,r   or   VRTS = r,r,r,r,r,r
The first two forms specify the width and height of a rectangular
surface (SIZE = W, H). The last form is for triangles or
quadrilaterals. The first pair of numbers are the surface relative x-y
coordinates of the first vertex counter-clockwise from the lower left
vertex. The subsequent pairs of numbers are the coordinates of the
remaining vertices in counter-clockwise sequence. See IV.F on
geometric data.

4.13.6   X = r   0.   m   opt   -
                                  0.   ft
         Y = r   0.   m   opt   -
                                  0.   ft
         Z = r   0.   m   opt   -
                                  0.   ft
      ORG = r,r,r
For base surfaces (BS - 4.13.2) these are the coordinates of the lower
left corner of the surface relative to the zone coordinate system. The
base surface origin is not used in the simple shadow calculation mode
(3.1.2). For subsurfaces (SS - 4.13.2) these are the coordinates
relative to the lower left corner of the base surface. The Z
coordinate is the amount of the setback. ORG provides a simpler way of
describing all three coordinates at once (ORG = X, Y, Z) . See IV.F on
geometric data.

4.13.7   FSS = r   .5   -   opt   0.<=r<=1.
FSS is the angle factor between the surface and the sky. It is used in
determining the intensity of diffuse sky radiation incident on the
surface. If FSS is not specified, it is computed from the TILT
(4.13.4) angle: FSS = (1 + cos(tilt))/2.

4.13.8   FSG = r   .5   -   opt   0.<=r<=1.
FSG is the angle factor between the surface and the ground. It is used
in determining the intensity of diffuse ground reflected radiation on
the surface. If FSG is not specified, it is computed from the tilt
(4.13.4) angle: FSG = (1 - cos(tilt))/2.

4.13.9   ZONE = n   blank   -   opt   -
This is the name of the zone on the other side of the surface from the
current zone. The program will check for that zone to have a surface
which refers to this zone. That is, a single partition (or ceiling or
floor) which is between two zones, must must be described in each zone.
The program checks that these two surfaces have the same area and
U-value. It makes a partial check on the conduction transfer
functions. Remember that constructs are defined from the outer to the
inner layer and, therefore, asymmetric interzone partitions will have
to be defined twice to be referenced from the different zones.

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4.14   AFS (Air flow surface - Algorithm G

AFS describes the crack area and other openings in the base surface
which are used in the detailed air movement simulation. FLOW (3.1.4)
must have been specified. The base surface must be either an exterior
surface or an interzone surface (4.13.2 and 4.13.9). The AFS assumes
the azimuth of the base surface for computing wind direction effects.
When the AFS applies to an interzone surface, there must be an
identical AFS specified for the appropriate base surface in the
adjacent zone.

4.14.1   AREA = r   0. m^2 reqd   0.<r
                             0. ft^2

This is the effective area of the opening.

4.14.2   EXP = r   .65   -   opt   .5<=r<=1.

EXP is the flow expontent. It is typically .65 for exterior walls and
.50 for interzone openings.

4.14.3   ZS = r   -   m   opt   -
                             -          ft

This is the height of the centroid of the surface or opening relative
to the zone origin (G.2). The default value is the average of the
heights of the vertices of the base surface.

4.14.4   ZT = r   -   m   opt   -
                             -          ft

This is the height at which the wind speed is evaluated for the opening
(G.1). The default value is the highest vertex of the base surface.

4.15   SHD (Shadowing subsurfaces.

SHD describe simple shadowing surfaces which apply to the most recently
defined base surface (BS - 4.13.2) and all of its subsurfaces. The
base surface must be an exterior (EX) surface unmodified by OSC (4.16).

4.15.1   OHNG   -   -   cond   -
         LFIN   -   -   cond   -
         RFIN   -   -   cond   -
         PROJ   -   -   cond   -

There are four configurations for these features: overhang, left fin,
right fin, and projection. See IV.F for details.

4.15.2   W = r   0.   m   reqd   0.<=r
                             0.   ft
         H = r   0.   m   reqd   0.<=r
                             0.   ft
         SIZE = r,r

These subkeys specify the width and height of the rectangular shadowing
surface. SIZE is a shorter description (SIZE = W, H) . See IV.F on
geometric data.

```
4.15.3   X = r                0.          m          opt        -
                              0.          ft
         Y = r                0.          m          opt        -
                              0.          ft
         Z = r                0.          m          opt        0.<=r
                              0.          ft
```

ORG = r,r,r

The positioning of the shadowing subsurface is given relative to the base surface coordinate system. See IV.F on geometric data.

```
4.15.4   TRNS = r             0.          -          opt        0.<=r<1.
```
Transmittance of the shadowing surface.

```
4.15.5   FROM = d             1JAN        -          opt        -
         THRU = d             31DEC       -          opt        -
```
The surface may apply for only part of the year. Any dates may be used, but for greatest efficiency dates should be chosen from the shadowing surface dates table (IV.G.1).

```
4.16     OSC (               Other side coefficients.
```
OSC provides a means of approximating conditions on the outside of a surface where it is not desirable (or possible) to simulate those conditions. The OSC key applies to the most recently described surface. That surface should be EX / OP / BS (4.13.2). It should also have no shadowing or heat transfer subsurfaces. Other side coefficients establish an outside temperature which is a function of several factors. The temperature is computed from the formula:

$$T = (TZP*TZ + TAP*TA + CTP*CT + TGP*GRT + WSP*SPD*TA)$$
$$/ (TZP + TAP + TGP + WSP*SPD)$$

where TZ = most recent value of zone air temperature
      TA = ambient air temperature
      GRT = ground temperature (1.4.1)
      SPD = wind speed

and the other factors are user defined as described below. At least one of the factors in the divisor of the equation must be defined nonzero.

```
4.16.1   HO = r               0.          W/m²K      opt        0.<=r
                              0.          Btu/hr*ft²F
```
This is the value of the outside surface convection coefficient. If it is zero, the OSC temperature is the surface outside temperature. If it is not zero, The OSC temperature is an air temperature which is used with the convection coefficient to compute the outside surface temperature.

```
4.16.2   TZP = r              0.          -          opt        -
```
Zone temperature part.

```
4.16.3   TAP = r              0.          -          opt        -
```
Ambient air temperature part.

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4.16.4   CT = r   0.   C   opt   -
                                 0.   F
    Constant temperature.

4.16.5   CTP = r   0.   -   opt   -
    Constant temperature part.

4.16.6   TGP = r   0.   -   opt   -
    Ground temperature part.

4.16.7   WSP = r   0.   s/m   opt   -
                                 0.   min/ft
    Wind speed part.

4.17   EMI (Exterior movable insulation.
    Exterior movable insulation is applied to the most recently defined
    surface. That surface must have been defined as exterior (EX; 4.13.2)
    and not modified by subsequent OSC (4.16). EMI may apply to either
    massless or massive surfaces. EMI is opaque and can prevent solar
    gains through windows.

4.17.1   CONS = n   -   -   reqd   -
    The movable insulation is chosen from the constructs library. The
    movable insulation algorithm handles only massless insulation. It uses
    the U-value, outer solar and thermal absorptances and roughness of the
    construct.

4.17.2   DS = n   -   -   cond   -
         SNUP   -   -   cond   -
         SNDN   -   -   cond   -
    One of three methods must be chosen for control of the EMI. The first
    is reference to a day-schedule (2.2). A value of zero means no EMI for
    that hour (standard time) and a one means the EMI is in effect.
    Fractional values in the day-schedule modify the R-value. Any schedule
    value greater than zero causes sunlight to be absorbed on the EMI
    rather than on the surface. Second is SNUP which means the EMI is in
    effect whenever the sun is above the horizon. SNDN means the EMI is in
    effect when the sun is below the horizon.

4.17.3   FROM = d   1JAN   -   opt   -
         THRU = d   31DEC   -   opt   -
    The EMI may apply for only part of the year. It may be desirable to
    use different controls during different seasons. Any dates may be
    used, but since the EMI effects the solar gain calculations, dates
    should be chosen from the table of shadowing surface dates (IV.G.1) for
    greatest efficiency. Time periods from multiple EMI subkeys may not
    overlap.

4.18   IMI (Interior movable insulation.
    Interior movable insulation applies to interzone surfaces only. That
    is, the most recently defined surface should be interior (IN; 4.13.2)
    and have an other side zone name (4.13.9).

4.18.1   CONS = n   -   -   reqd   -
    The movable insulation is chosen from the constructs library. The
    movable insulation algorithm handles only massless insulation.

4.18.2   DS = n   -   -   cond   -
         GAIN   -   -   cond   -
         LOSS   -   -   cond   -
    One of three methods must be chosen for control of the IMI. First is
    reference to a day-schedule (2.2). A value of zero means no IMI for
    that hour (clock time) and a one means the IMI is in effect. Fraction
    values in the day-schedule modify the R-value. The second method is
    GAIN which causes the IMI to be in effect whenever the surface
    temperature is greater than the zone control temperature (4.9.4). LOSS
    is the inverse of the GAIN operation.

4.18.3   FROM = d   1JAN   -   opt   -
         THRU = d   31DEC   -   opt   -
    Since IMI does not effect the zone's solar gain, the dates need not
    refer to the shadowing surface dates. Time periods from multiple IMI
    subkeys may not overlap.

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IV.D   INPUT SUMMARY

This summary of the input language is intended to serve as a reminder of the
syntax and all the keywords. As the user becomes more familiar with the
input, he will use this summary more and the detailed input description
(IV.C) less. It may be desirable to copy these pages and place them near
the computer terminal.

Data types:
     n = name, r = real, i = integer, d = date, desc = description

1.   PROJECT [

1.1   RC (DESC = 'desc' / SYNTAX / DEM / 2SPC / XREF / OLDW /
               ENGLISH / METRIC / UIN = n / UOUT = n)

1.2   RPT (RNOS = i,...)

1.3   LOC (DESC = 'desc' / LATD = r / LONG = r / TZ = r / ALT = r /
               TER = i)

1.4   GRND (GRT = r,...<12> / MWT = r,...<12>)

1.5   WTAP (DESC = 'desc' / SKIP = i / DAYS = i)

1.6   DDY (DESC = 'desc' / HIGH = r / LOW = r / WB = r / DATE = d /
               PRES = r / WS = r / DIR = r / CLR = r / RAIN / SNOW /
               SUN / MON / TUE / WED / THU / FRI / SAT /
               HOL / SP1 / SP2 / SP3 / SP4)
      ]

2.   LIBRARY [

2.1   LIB (NAME = n / NDS = i / NWS = i / NMATL = i / NCONS = i /
               NCPFL = i / NCDS = i / NCWS = i / ALL / DS /
               WS / MATL / CONS / CPFL / CDS / CWS)

2.2   DS (NAME = n / DESC = 'desc' / FFC = r,...<24>)

2.3   WS (NAME = n / DESC = 'desc' / WD = n / WE = n / ALL = n /
               SUN = n / MON = n / TUE = n / WED = n / THU = n / FRI = n /
               SAT = n / HOL = n / SP1 = n / SP2 = n / SP3 = n / SP4 = n)

2.4   MATL (NAME = n / DESC = 'desc' / K = r / CP = r / D = r /
               R = r / A = r / E = r / TRNS = r / IR = r / FTRN = r /
               REF = r / SC = r / RGH = i / AIR / SHADE / GLASS)

2.5   CONS (NAME = n / DESC = 'desc' / MATL = r,n,r,n,...<10> /
               OA = r / OE = r / ORGH = i / IA = r / IE = r)

```
2.6     CPFL ( NAME = n / DESC = 'desc' / TMP = r,...<8> / CAP = r,...<8> )

2.7     CDS ( NAME = n / DESC = 'desc' / CPFL = n,...<24> )

2.8     CWS ( NAME = n / DESC = 'desc' / WD = n / WE = n / ALL = n /
              SUN = n / MON = n / TUE = n / WED = n / THU = n / FRI = n /
              SAT = n / HOL = n / SP1 = n / SP2 = n / SP3 = n / SP4 = n )
        ]

3.   BUILDING [

3.1     SIM ( N = r / SLDS = i / CNVG = r,r,r,i / FLOW = i /
              HTB = i / HO = i / HI = i )

3.2     DSS ( AZM = r / TILT = r / X = r / Y = r / Z = r / ORG = r,r,r /
              W = r / H = r / SIZE = r,r / VRTS = r,...<4 or 6> /
              TRNS = r / FROM = d / THRU = d )
        ]

4.   ZONE [

4.1     GEOM ( NAME = n / N = r / X = r / Y = r / Z = r / ORG = r,r,r /
               CLHT = r / MIRX / MIRY )

4.2     PEO ( WS = n / CAP = r / ACT = r / RAD = r / FROM = d / THRU = d )

4.3     LIT ( WS = n / CAP = r / RA = r / RAD = r / VIS = r / REP = r /
              FROM = d / THRU = d )

4.4     EQP ( WS = n / CAP = r / LAT = r / RAD = r / LOST = r /
              FROM = d / THRU = d / EL / GS / ST / HW / OTHR )

4.5     INF ( WS = n / CAP = r / C = r / T = r / V = r / VV = r /
              FROM = d / THRU = d )

4.6     VENT ( WS = n / CAP = r / MIN = r / MAX = r / TD = r /

               FROM = d / THRU = d )

4.7     MIX ( WS = n / CAP = r / TD = r / ZONE = n / FROM = d / THRU = d )

4.8     FAN ( WS = n / CAP = r / T = r / ZONE = n / FROM = d / THRU = d )

4.9     CTRL ( CWS = n / HEAT = r / COOL = r / RAD = r / FROM = d /
               THRU = d )

4.10    DLT ( WS = n / BEAM = r / DIFF = r / FROM = d / THRU = d )

4.11    BBH ( WS = n / CAP = r,r / TMP = r,r / RAD = r / FROM = d /
              THRU = d / ST / HW )
```

```
4.12    MASS ( CONS = n / AREA = r )

4.13    SRF ( CONS = n / EX / IN / OP / TR / BS / SS / AZM = r / TILT = r /
              W = r / H = r / SIZE = r,r / VRTS = r,...<4 or 6> / X = r /
              Y = r / Z = r / ORG = r,r,r / FS = r / FSG = r / ZONE = n )

4.14    AFS ( AREA = r / EXP = r / ZS = r / ZT = r )

4.15    SHD ( OHNG / LFIN / RFIN / PROJ / W = r / H = r /
              SIZE = r,r / X = r / Y = r / Z = r / ORG = r,r,r /
              TRNS = r / FROM = d / THRU = d )

4.16    OSC ( HO = r / TZP = r / TAP = r / CT = r / CTP = r / TGP = r /
              WSP = r )

4.17    EMI ( CONS = n / DS = n / SNUP / SNDN / FROM = d / THRU = d )

4.18    IMI ( CONS = n / DS = n / GAIN / LOSS / FROM = d / THRU = d )
        ]
```

IV.E   ZONE TEMPERATURE CONTROL

     The zone air temperature is determined by the interaction of the energy
flows in the zone and the operation of the air conditioning system. The
present version of the TARP does not include detailed system models. The
operation of the system is modeled by control profiles like those in the
loads section of the BLAST program [1] from which much of the following
discussion is taken. A control profile relates the zone air temperature to
the capability of the system to add or remove heat from the zone. The use
of the control profile in the zone air heat balance is described in III.K.1.
Figure E.1 shows a simple control profile which can either heat or cool the
zone.

     Point 1 might occur on a winter day. At that point, the room is at 68
F (20.0 C) and the heat loss from the room air exactly equals the room
heating capacity available at 68 F. In this example, the room heating load
(= heat delivered to the room air) is 40.0 kBtu/hr (11.7 kW).

     Point 2 might occur on a mild day in the spring or fall. At this point
(73 F [22.8 C]), no room heating or cooling is accomplished by the building
fan system (although heating or cooling energy may be consumed to condition
ventilation air). For the heat balance to occur at point 2, convective heat
gains caused by such factors as lights or occupancy must be balanced by
convective heat losses to room surfaces or by infiltration. The load at
point 2 is zero.

     Point 3 shows a cooling condition. Here heat gains to the room air are
balanced by cooling capacity available at the balance point temperature.

     The control profile can be described in terms of the temperatures and
heating/cooling capacities at control points A, B, C, and D. Simple linear
proportionality is assumed between the control points. At temperatures
below point A, the heating capacity is constant. The cooling capacity is
constant above point D. The control profile is described in two phases in
TARP. The full heating and cooling capacities are given for each zone
(4.9.2 and 4.9.3). The shape of the profile is described in the library
section by normalizing the control point capacities (divide heating
capacities by the full heating capacity; divide cooling capacities by the
full cooling capacity, the result being set negative). This allows the same
profile to be used in many zones which have identical control temperatures
but different full capacities. Full heating and cooling capacities can then
be adjusted independently of each other. The control profile in figure E.1
normalizes to that in figure E.2 which could be described by the input
language (2.6) as:

     CPFL (NAME=C1 / TMP=67,69,77,79 / CAP=1,0,0,-1)

The temperatures and capacities of the control points must be given in the
sequence shown. Very steep profiles are possible. The user may set two
successive control temperatures equal to each other to hold the room
temperature constant. TARP will make the second 0.01 C greater than the
first to permit the air heat balance calculations.

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System type can subtly affect room temperature control profiles. For example, assume that a package DX (direct expansion) condensing unit with electric heat has been selected to serve the zone whose control strategy is shown in figure E.1. Futher assume that the unit delivers 3850 cfm (1.82 m^3/s) to the space, that the cooling coil was selected to allow 55 F (12.8 C) air to be delivered at the design sensible load of 100 kBtu/hr (29.3 kW), and that the heating coil was selected to deliver 86.2 F (30.1 C) air at the design heating load of 80 kBtu/hr (23.4 kW). In this case, figure E.1 closely approximates the achieved room temperature control. The room thermostat will modulate the condensing unit from "off" to "full" capacity through as many capacity control steps as are available on the unit. This modulation will occur in a roughly linear fashion as the balance point room temperature varies from 77 to 79 F (25 to 26.1 C). The heating will be similarly modulated between 69 and 67 F (20.6 and 19.4 C), and both heating and cooling will be "off" between 69 and 77 F (20.6 and 25 C). Since the condensing unit's maximum heating and cooling capacity are approximately constant, the unit adds or removes fixed quantities of heat whenever the room temperature is below 67 F (19.4 C) or above 79 F (26.1 C).

If a single-zone drawthrough unit served by hot and chilled water is selected, the control strategy of figure E.1 may require a slight revision. When room temperature remains between 67 and 79 F (19.4 and 26.1 C), figure E.1 is correct. However, as long as the boiler and chiller serving the coils in the fan unit can deliver constant temperature hot and chilled water, the maximum capacity of the heating and cooling coils is not independent of room temperature. For example, as the room temperature rises toward 79 F (26.1 C), the room thermostat opens the cooling coil's chilled water valve until the valve is fully opened at 79 F (26.1 C). If room heat gains are sufficient, the room air temperature will continue to rise; but as it rises, the temperature of the air entering the coil also rises. Therefore, the cooling capacity of the coil gradually increases. The capacities below point A and above point D of figure E.1 are not constant, but are slowly increasing. Coil catalog data can be used to determine the change in coil capacity.

Figure E.3 shows the equivalent control profile that should be used if a three-deck multizone unit is selected to serve several zones with the same thermostat throttling ranges and deadband. The rationale for selecting this profile is:

1. Range C-D is the thermostat deadband in which air delivered to the zone passes through the bypass deck and is neither heated nor cooled.

2. In range B-C, air from the hot deck and the bypass deck of the fan system are mixed to meet zone heating requirements. This is the heating throttling range for the thermostat. At its lower end (67 F [19.4 C]), all air to the zone comes through the hot deck and is delivered to the zone at the hot deck tempeature (86.2 F [30.1 C], for example).

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3. If heat losses are severe, the room temperature may fall into range A-B. In this range, air entering the room comes from the hot deck only. As long as the fan system heating coil is not overloaded, the air is supplied to the zone at constant temperature. However, the amount of heat added to the room air continues to increase as the room air temperature falls. The amount of heat added per hour can be calculated from the following formula:

$$L = F * Cp * (Ts - TZ)$$

where

F = mass flow rate of air supplied by the fan system to the room
Cp = specific heat of air
Ts = supply air temperature to the room (the hot deck temperature)
TZ = air temperature in the room

For this system, F and Cp are constant and Ts is constant for range A-B. Therefore, as room temperature (TZ) falls, the heat added to the room increases linearly as shown in figure E.3.

4. Ranges D-E and E-F are analogous to ranges B-C and A-B, but are for cooling.

The TARP description of the profile in figure E.3 is:

CPFL (NAME=C2 / TMP=60,67,69,77,79,85 / CAP=1,.73,0,-0,-.8,-1)

When defining a control profile like the one shown in figure E.3, users should select arbitrary low and high room temperatures to establish the full heating and cooling (+1 and -1) points on the profile. In the example above, 60 and 85 F (15.6 and 29.4 C) were selected. When specifying corresponding heating and cooling capacities for each zone, the "design" capacity generally should not be used. Capacity should correspond with the selected low and high temperatures.

In the DX condensing unit, single-zone drawthrough, and three-deck multizone examples, load calculations will yield identical results when the control profiles shown in figures E.1 or E.3 are used, provided that the temperature in the space stays between 67 and 79 F (19.4 and 26.1 C) during the hours when the conrtol profile is in effect. Fortunately, most systems are designed with sufficient capacity to maintain comfort conditions, and users need be concerned about room temperature control characteristics which are outside the range of the thermostat only when the heating or cooling system has been indavertantly or deliberately undersized.

The same reasoning used for the three-deck multizone system can be used to construct control profiles for spaces served by conventional multi-zone, dual duct, or reheat systems (see figure E.4). Ranges A-B and C-D correspond to ranges A-B and E-F of figure E.3, respectively. Range B-C covers the temperature range where the mixing box, zone dampers, or reheat coils are modulated by the room thermostat. The TARP description of such a profile is:

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CPFL (NAME=C3 / TMP = 60,73,77,85 / CAP = 1,.58,-.74,-1)

No deadband is possible with these profiles so they cannot be approximated by profiles of the type shown in figures E.1 and E.3.

Figure E.5 shows a typical control profile for a VAV (variable air volume) system with reheat. It was constructed based on the assumption that 3850 cfm (1.82 m^3/s) of 55 F (12.8 C) delivery air is to be supplied to the zone with the VAV dampers fully open at 79 F (26.1 C). The dampers close to 20 percent of full flow at 77 F (25 C). Reheat is to operate between 69 and 67 F (20.6 to 19.4 C), and the reheat coil will deliver air at 140 F (60 C) when fully energized. The following temperatures and capacities define the control profile:

Temperature F (C)	Capacity kBtu/hr(kW)	Normalized Capacity
60.0 (15.6)	66 (19.3)	1.0
67.0 (19.4)	61 (17.9)	.91
69.0 (20.6)	-12 (-3.5)	-.09
77.0 (25.0)	-18 (-5.3)	-.15
79.0 (26.1)	-100(-29.3)	-.80
85.0 (29.4)	-125(-36.6)	-1.0

The TARP input for this profile is:

CPFL (NAME=C4 / TMP=60,67,69,77,79,85 / CAP=1,.91.-.09,-.15,-.8,-1)

REFERENCES

[1] Hittle, D. C., BLAST, Version 2.0: Users Manual, Vol 1, U. S. Army Construction Engineering Research Laboratory, Technical Report E-153 (Champaign IL, 1979), pp 41-46.
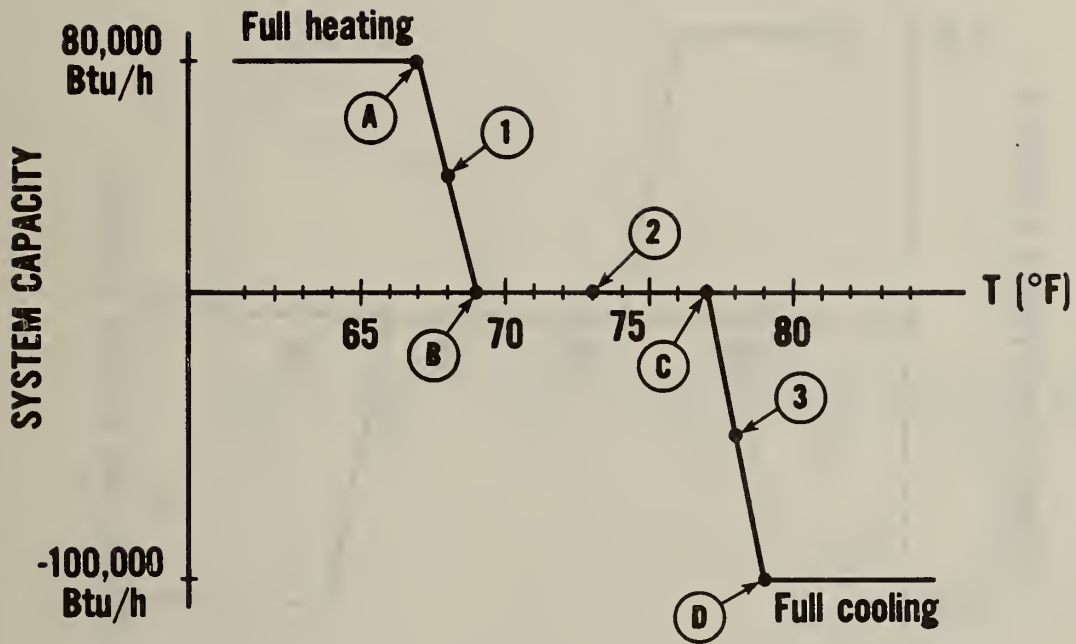
Figure IV.E.1   Simple control profile with deadband

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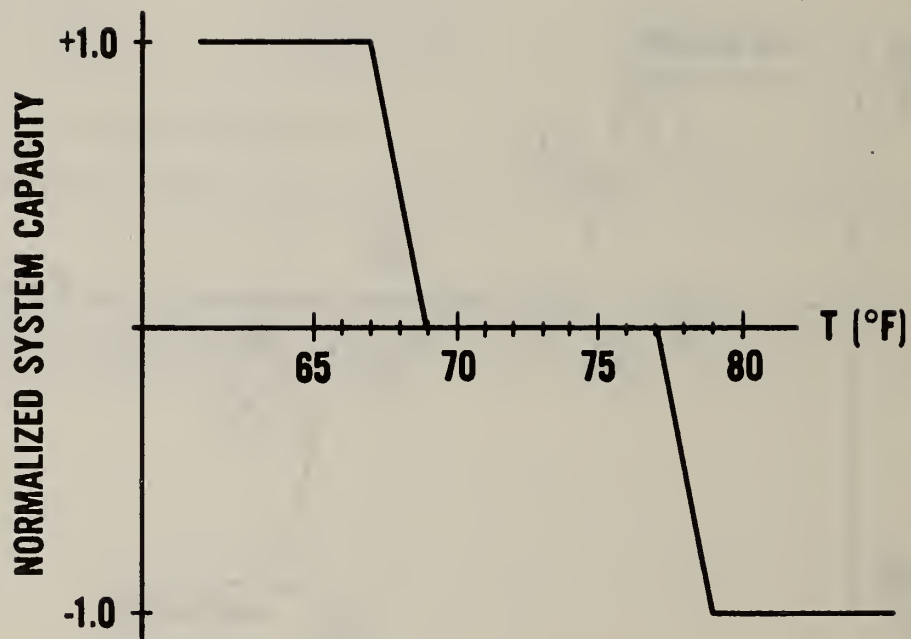
Figure IV.E.2   Normalized control profile

132
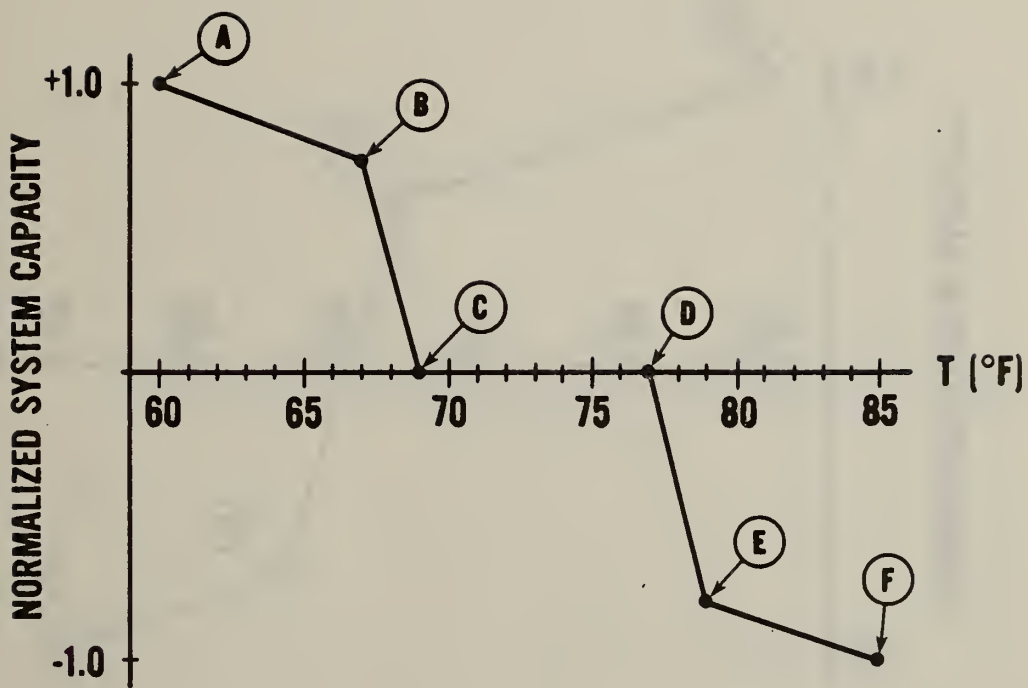
Figure IV.E.3 Control profile for three-deck multizone system

133
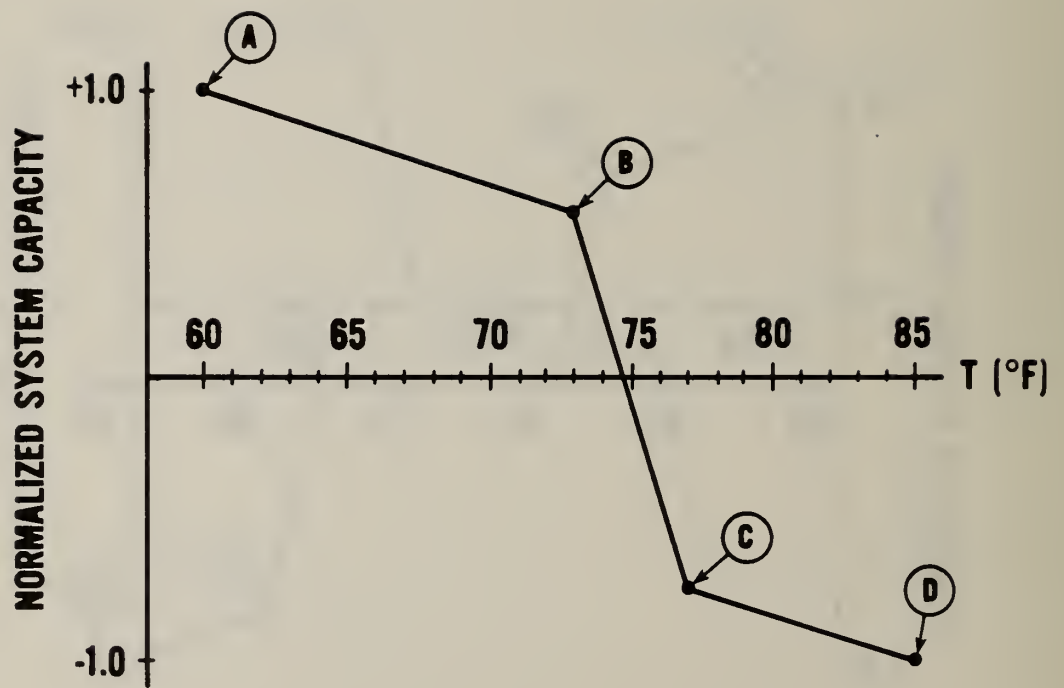
Figure IV.E.4 Control profile for multizone system
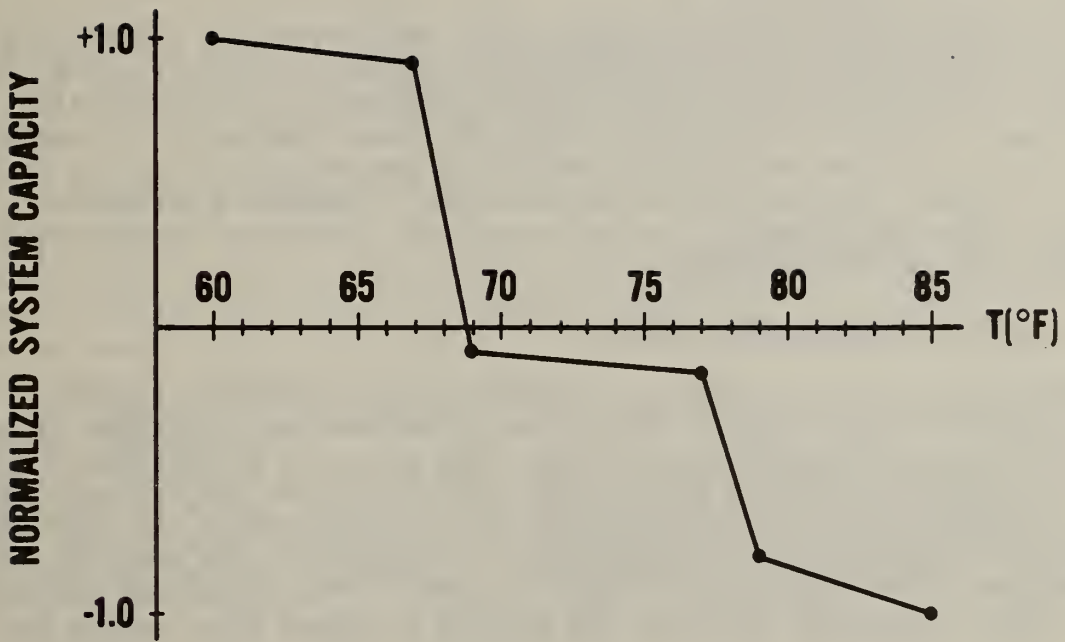
Figure IV.E.5   Control profile for VAV system

IV.F   GEOMETRIC DATA

     To accurately account for shading, solar gains, and the effects of wind
on exterior walls, windows, and roofs, a fairly detailed description of the
building's geometry is required. Every building surface is represented by
a plane polygon of three or four sides. Within the program, each polygon is
represented by the locations if its vertices in a simple Cartesian coordinate
system. In that system, the X axis points due east, the Y-axis points north,
and the Z-axis points upward. The orientation of each surface is maintained
by two conventions. First, the vertices are stored in counter-clockwise
sequence as the surface is viewed from outside the zone it encloses. (Looking
at the surface from the opposite side would give a clockwise sequence.)
Second, the orientation is described in terms of the "azimuth" and "tilt"
angles.

     The simplest level (0) of shadowing detail (3.1.2) requires that only
the azimuth and tilt angles be specified. Detailed air flow analysis (3.1.4)
and the detailed exterior surface coefficient algorithm (3.1.6) require
correct heights for every surface. The first and second levels of shadowing
detail require that all surfaces of the building envelope be correctly posi-
tioned in the building coordinate system. The third level of shadowing
detail requires that internal surfaces also be correctly positioned and that
the zone is completely enclosed.

     A heirarchy of coordinates systems exists to simplify the positioning of
surfaces. The building coordinate system is a simple rotation from the true
coordinate system which allows major building features to be aligned along
the X-Y axes. There is a coordinate system for every zone which is located
relative to the building system for simplifying the description of the zone
geometry. Finally, each surface of the zone has a coordinate system for
defining the size and shape of the surface and the location of subfeatures
which apply only to that surface.

IV.F.1   SURFACE COORDINATE SYSTEM

     Every wall, roof, or floor of a building is represented by a plane
surface of three or four sides. The origin of the surface coordinate system
is located at one of the surface vertices. The X-axis is a horizontal (rela-
tive to the global coordinate system) line in the plane of the surface. The
Y-axis is perpendicular to the X-axis and also in the plane of the surface.
The Z-axis is perpendicular to the surface. It is used in the descriptions
of subsurfaces. The coordinates of the vertices of the surface are described
in the surface coordinate system as the surface is viewed from outside its
zone.

     Input (4.13.5) allows a simple description of rectangular surfaces. For
example a rectangular wall 12 feet wide by 8 feet high (W=12 / H=8 or
equivalently SIZE=12,8) would be described by figure F.1. This representa-
tion of rectangles places the origin at the lower left corner so that all
vertices are positive numbers.

Non-rectangular surfaces can also be described by giving the coordinates of the vertices. For example, VRTS=10,0,5,30 describes the triangle in figure F.2. Negative coordinates like VRTS=12,-3,7,7,-5,10 are also possible (figure F.3). In the description of non-rectangular surfaces, a vertex at the origin (0,0) is assumed. The remaining vertices are given by their X-Y coordinates going counter-clockwise around the surface. Only convex surfaces (no interior angle greater than 180 degrees) with 3 or 4 vertices are permitted. Other surfaces should be divided into two or more convex surfaces. The reasons for this are discussed in III.E.4.

IV.F.2   WINDOW AND DOOR SUBSURFACES

The location and size of these features are described in the coordinate system of the base surface (wall, roof, etc.) on which they lie. The size of each window or door is given by its width and height (for example, W=4 / H=6 or equivalently SIZE=4,6). The subsurface is located on the base surface by giving the coordinates of its lower left corner relative to the origin of the base surface (for example X=4 / Y=1.5 or ORG=4,1.5,0). Coordinates are given relativve to the base surface coordinate system. Figure F.4 shows the window thus described placed on the wall from figure F.1. The subsurface must lie completely within the base surface. Non-rectangular subsurfaces must be described as equivalent rectangles.

It is common for windows and doors to be set back slightly behind the plane of the base surface. This causes shadowing of the subsurface, especially as the sun's rays become nearly parallel to the surface. The setback is described by the Z coordinate (Z=-.5) of the location of the subsurface. (A "set forward" is not permitted.)

IV.F.3   SHADOWING SUBSURFACES

TARP input (4.15) provides a simple way to describe rectangular shadowing features which are parallel to the major axes of the base surface coordinate system. There are four configurations:
1. An overhang (OHNG) lies parallel to the X-Z plane and can cast shadows downward onto the surface (figure F.5).
2. A left fin (LFIN) lies parallel to the Y-Z plane and is to the left of its shadow (figure F.6).
3. A right fin (RFIN) also lies parallel to the Y-Z plane but lies to to the right of its shadow (figure F.7). Section III.E.2 explains why TARP surfaces cast shadows to one side but not the other. It is necessary to use an LFIN and an RFIN to describe a feature which can shade both directions.
4. A projection (PROJ) lies parallel to the X-Y plane in front of the surface which it shadows (figure F.8).

Figures F.5 through F.8 show how the size and position of these shadowing features are described in terms of W, H (or SIZE) and X, Y, Z (or ORG).

A shadowing subsurface will shade the base surface and all its window or door subsurfaces. It will not shade any other base surface.

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IV.F.4   ZONE COORDINATE SYSTEM

The surfaces of a zone are located relative to each other in the zone coordinate system. It is a Cartesian coordinate system with a vertical Z-axis and the X and Y axes oriented parallel to major zone features to simplify placement of surfaces. A surface is located in the zone coordinate system by giving the coordinates of the surface origin relative to the zone origin (X=r / Y=r / Z=r or ORG=r,r,r [4.13.6]) and the azimuth (AZM = r [4.13.3]) and tilt (TILT=r [4.13.4]) angles of the surface.

The tilt angle is the angle from the Z-axis to the normal to the surface. A vertical surface has a tilt of 90 degrees. A horizontal roof has a tilt of 0. A floor has a tilt of 180 (the outward normal points down).

Azimuth is the clockwise angle between the Y-azis and the horizontal projection of the outward normal of the surface. For vertical surfaces this is simply the direction the wall faces. Figure F.9 shows the locations, azimuths and tilts of three vertical and three tilted surfaces. For horizontal surfaces the true azimuth angle is undefined, but one must be given to properly locate the surface vertices in the zone coordinate system. This is most easily done by imagining the horizontal surface rotated about an edge until it is vertical to allow identification of origin, width, and height as in figure F.10 for a flat roof and figure F.11 for a floor.

IV.F.5   BUILDING COORDINATE SYSTEM

The building coordinate system is chosen to simplify the placement of zones relative to each other. The X- and Y-axes are usually chosen to lie along the axes of most of the zones. Each zone is located in the building coordinate system by giving the coordinates of the zone origin relative to the building origin (X=r / Y=r / Z=r or ORG=r,r,r [4.1.3]) and the angle from the building Y-axis to the zone Y-axis (N=n [4.1.2]). Figure F.12 shows the location of three zones in a building coordinate system.

Because of the general orientation of the building, the Y-axis may not line up with true north. The angle from true north to the Y-axis of the building coordinate system (N=r [3.1.1]) must be given to allow TARP to compute the true coordinates of the surface vertices.

It is common for buildings to have two or more zones which are geometrically identical except for their location and orientation as shown by the four zone examples in figure F.13. TARP allows two ways to describe zones in terms of others already defined. First is rotation and translation. The description of zone 3 can be produced by duplicating the description of zone 2 and adding a rotation of 180 degrees about the zone origin and shifting the origin to ORG=24.5,55,0. This process is illustrated in figure F.14. Use the text editor to duplicate the geometric features of zone 2, and do the rotation and origin translation of the origin in the GEOM (4.1) key. This reduces the number of new lines that must be typed to describe a similar zone.

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Zone 4 in figure F.13 is very similar to zone 1, but its geometric description cannot be obtained by any combination of rotations and translations. It is a mirror image of zone 1. Its description must use one of the mirror image commands (MIRX [4.1.5] or MIRY [4.1.6]). Figure F.15 shows how zone 1 is first mirrored in the Y direction (Y coordinates in the zone system are replaced by their negatives) and then translated to a new origin to produce the description of zone 4. Figure F.16 shows that the same results could have been obtained by mirroring in the X direction, rotating 180 degrees, and translating the origin. Mirror imaging works for all surfaces and subsurfaces except those cases where a subsurface is on a non-rectangular base surface which was described with the first vertex not lying on the X-axis (such as the base surface in figure F.3).

IV.F.6   DETACHED SHADOWING SURFACES

The geomerty described thus far will allow calculation of shadowing from subsurfaces like fins and overhangs, and from other zone surfaces. In addition the user may wish to describe adjacent buildings or other significant shadow casting features which are not part of a particular zone and which can shade more than one zone or surface. This is done with the "detached shadowing surface" (DSS [3.2]). The description of such a surface invloves defining its size and shape (W=r / H=r or SIZE=r,r or VRTS=r,r,r,r,r,r [3.2.4]) as described above for a zone surface and then locating (X=r / Y=r / Z=r or ORG=r,r,r [3.2.3]) and orienting (AZM=r [3.2.1] and TILT=r [3.2.2]) the surface in the building coordinate system. The critical consideration in locating and orienting the surface is that it casts a shadow only into the hemisphere which it faces.
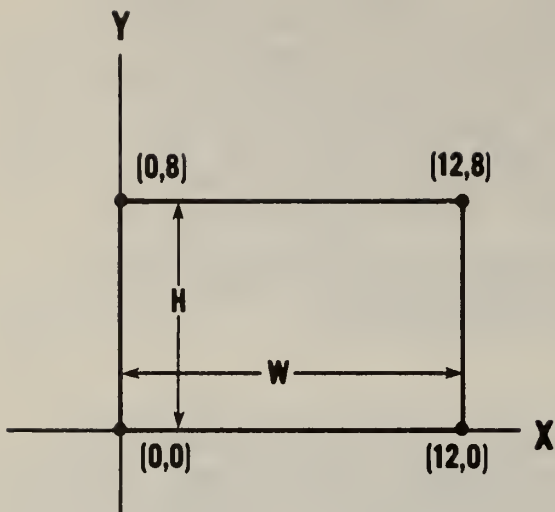
Figure IV.F.1 Rectangle
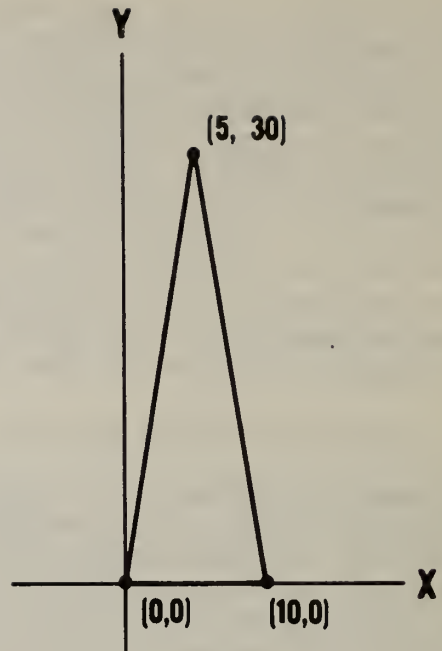
Figure IV.F.2 Triangle
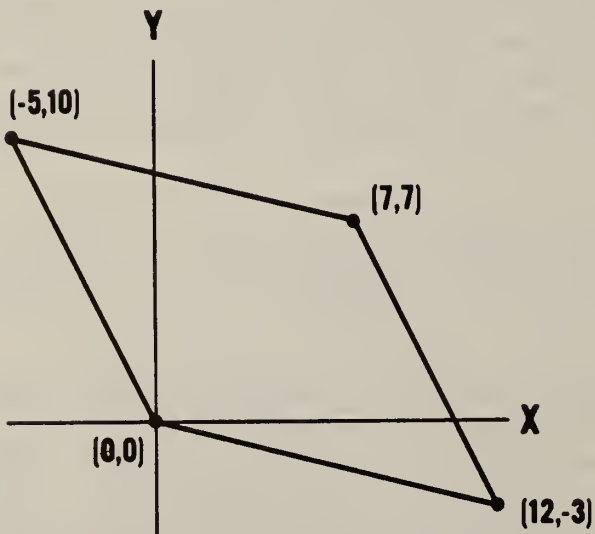
Figure IV.F.3 Quadrilateral
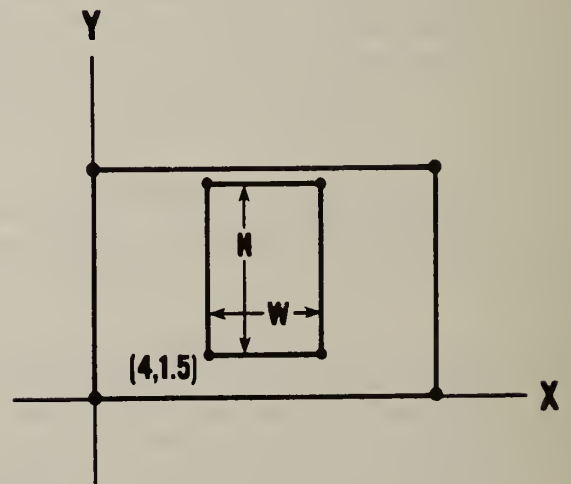
Figure IV.F.4 Window/door subsurface

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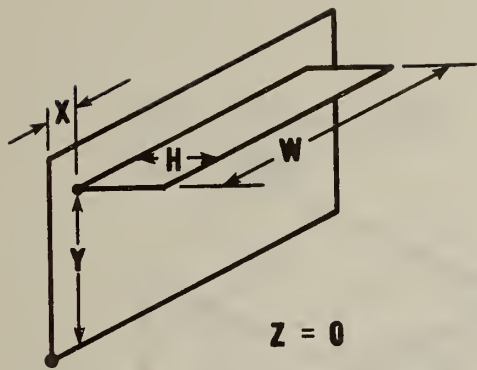
Figure IV.F.5 Overhang
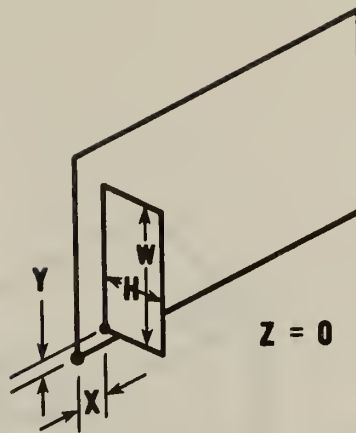
Figure IV.F.6 Left fin

- **Subsurface origin**
- **Base surface origin**
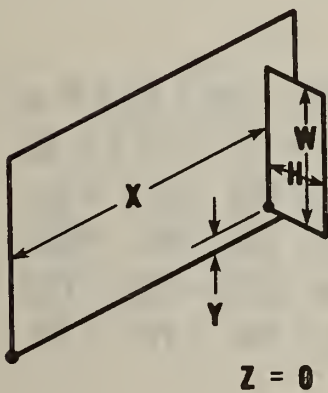
Figure IV.F.7 Right fin
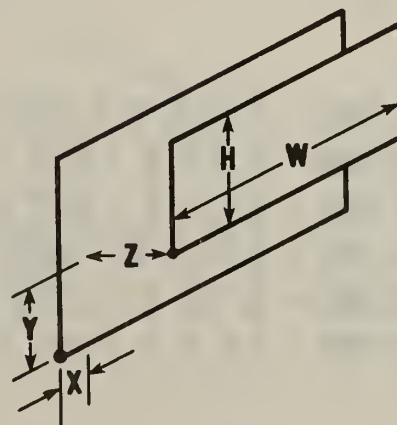
Figure IV.F.8 Projection
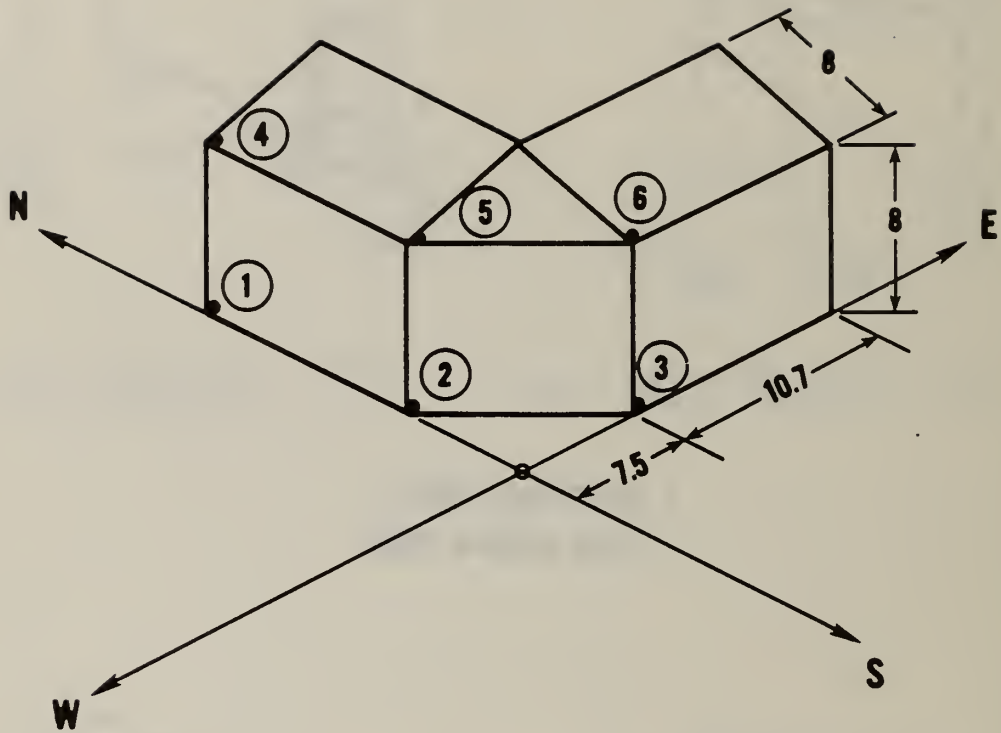
1: ORG = 0, 18.2, 0 / SIZE = 10.7, 8 / AZM = 270 / TILT = 90
2: ORG = 0, 7.5, 0 / SIZE = 10.7, 8 / AZM = 225 / TILT = 90
3: ORG = 7.5, 0, 0 / SIZE = 10.7, 8 / AZM = 180 / TILT = 90
4: ORG = 0, 18.2, 8 / SIZE = 10.7,8 / AZM = 270/ TILT = 20
5: ORG = 0, 7.5, 8 / VRTS = 10.7, 0, 5.3, 4/ AZM = 225/ TILT = 20
6: ORG = 7.5, 0, 8 / SIZE = 10.7, 8 / AZM = 180 / TILT = 20

Figure IV.F.9   Zone coordinate system: tilted surfaces

- **Base surface origin**
- **Zone origin**
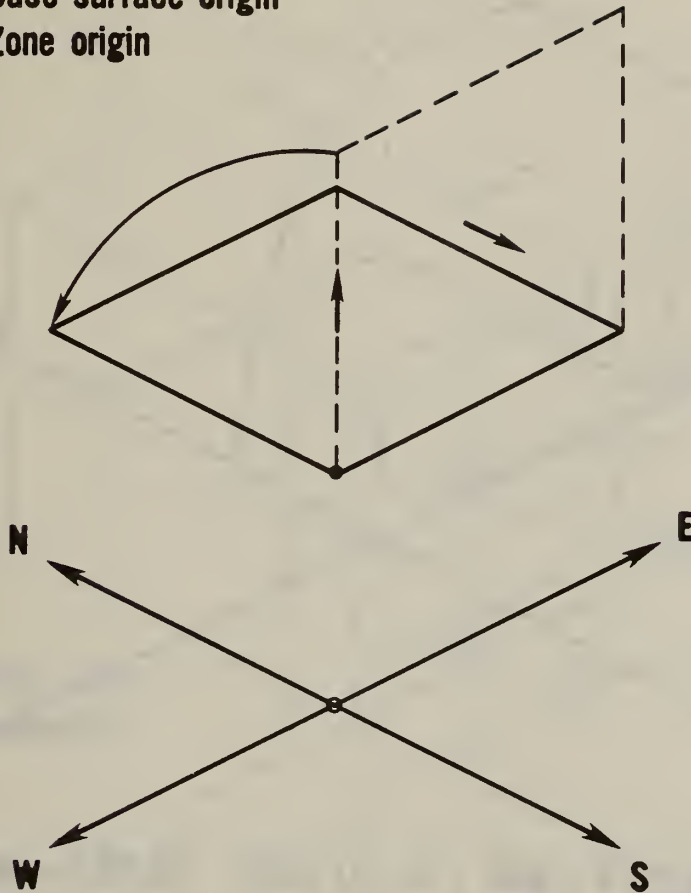
ORG = 0, 0, 8 / SIZE = 12, 12 / AZM = 180 / TILT = 0

Figure IV.F.10   Zone coordinate system: flat roof

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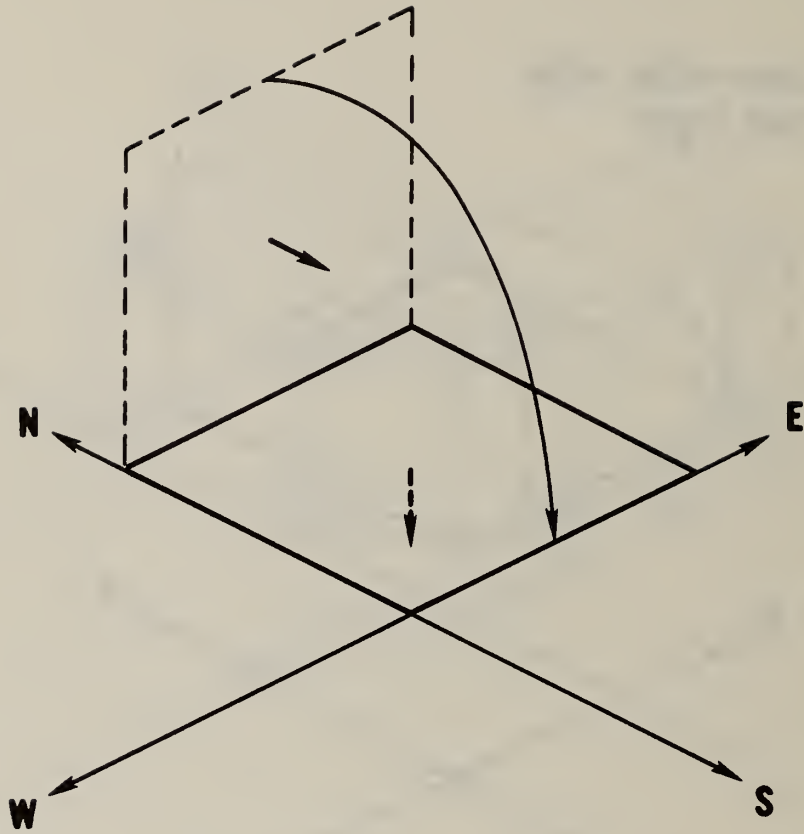
ORG = 0, 12, 0 / SIZE = 12, 12/ AZM = 180/TILT = 180

Figure IV.F.11   Zone coordinate system: floor

× Building origin
○ Zone origin

1: ORG = 0, 0, 0
2: ORG = 15, 0, 0
3: ORG = 0,0, 10
4: ORG = 15, 0, 10
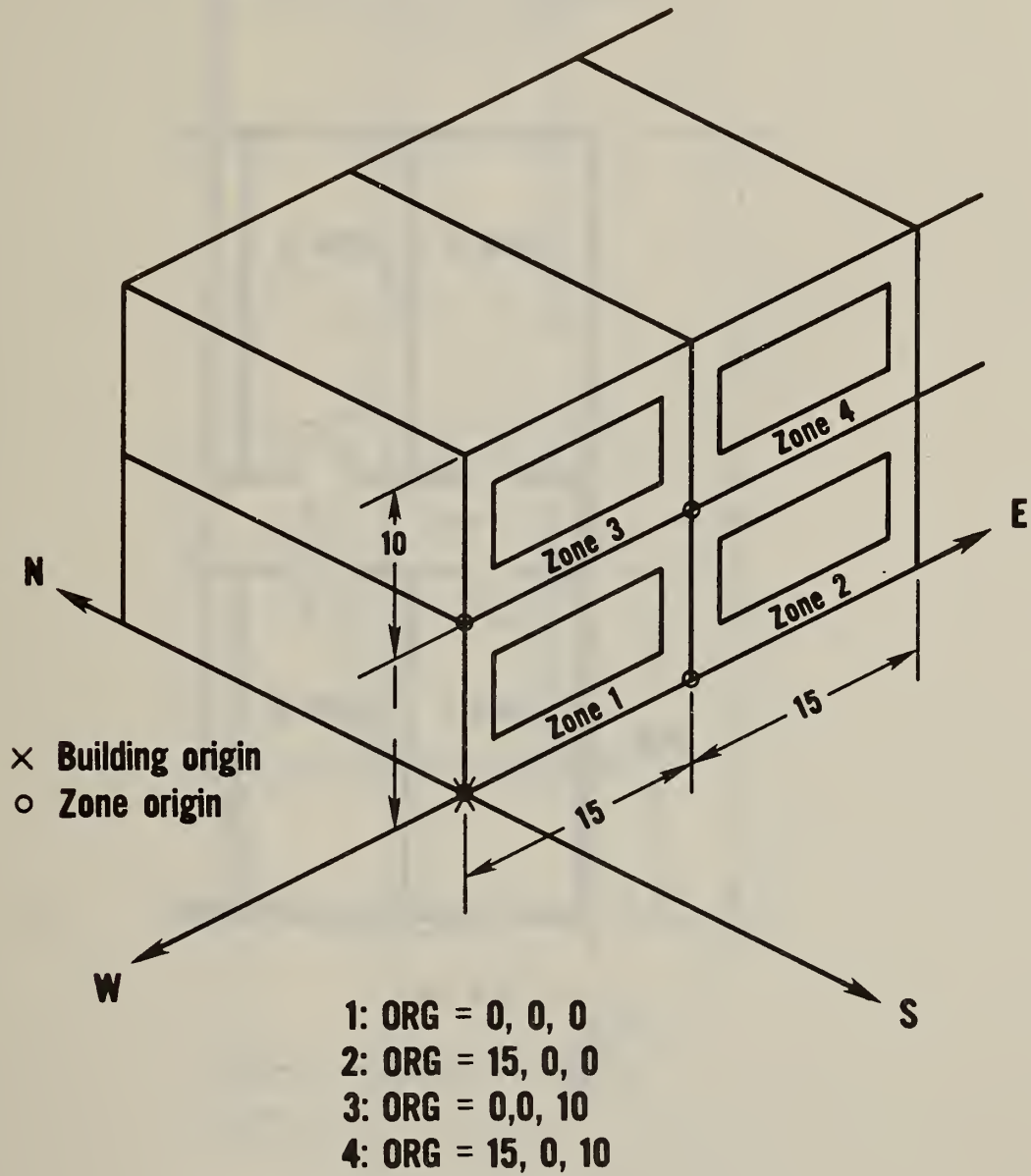
Figure IV.F.12   Building coordinate system: four zones

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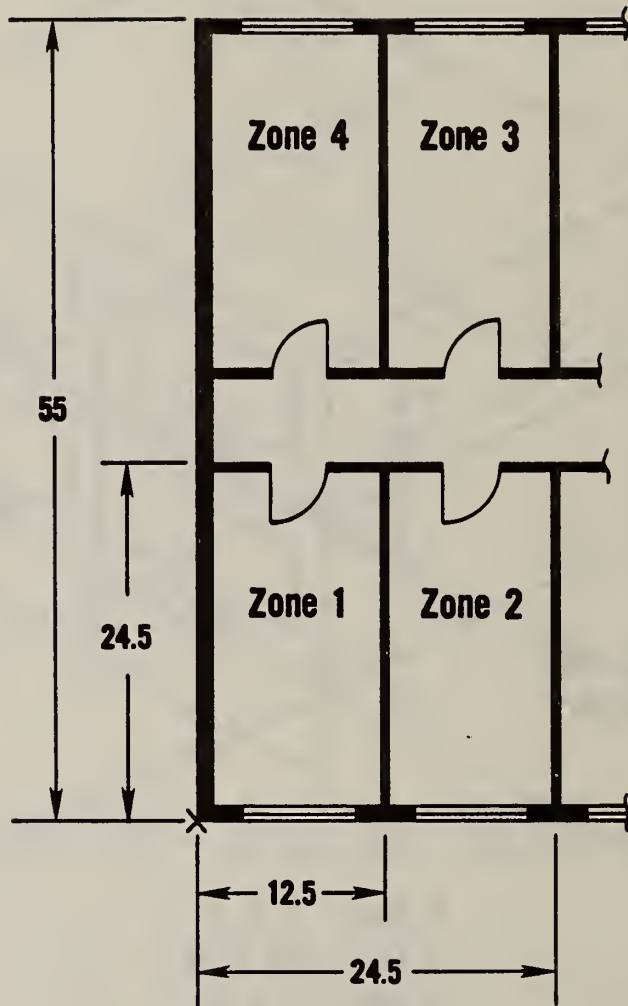
Figure IV.F.13 Portion of building with similar zones

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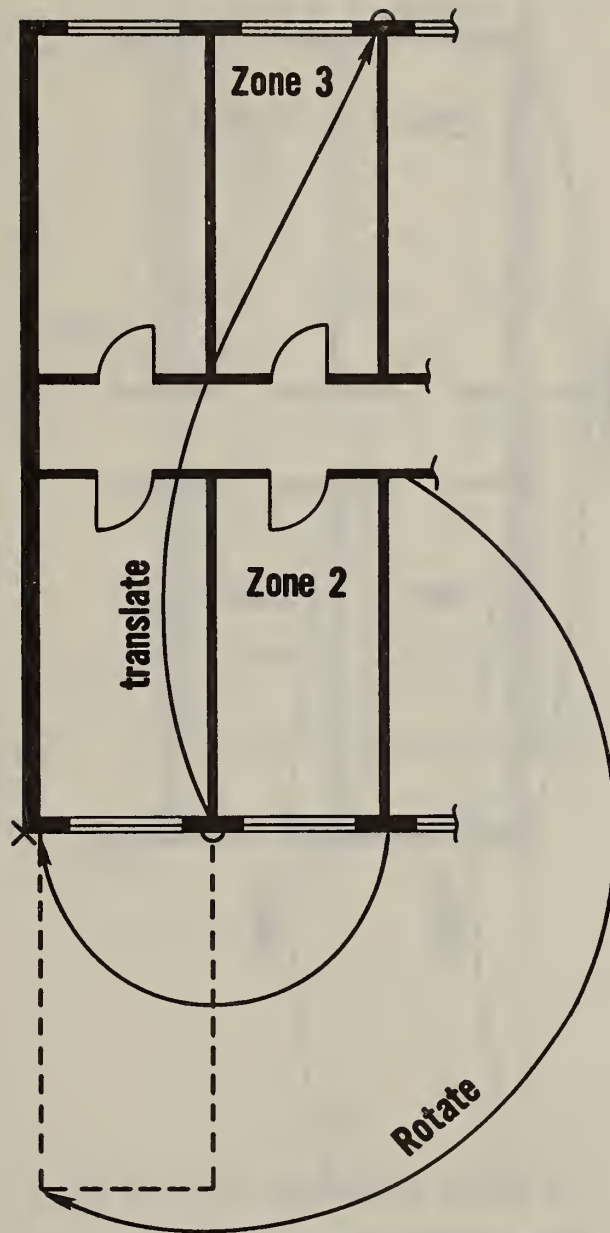
GEOM (N = 180/ ORG = 24.5, 55, 0 / ...

Figure IV.F.14   Zone 3 described by rotation and translation of zone 2

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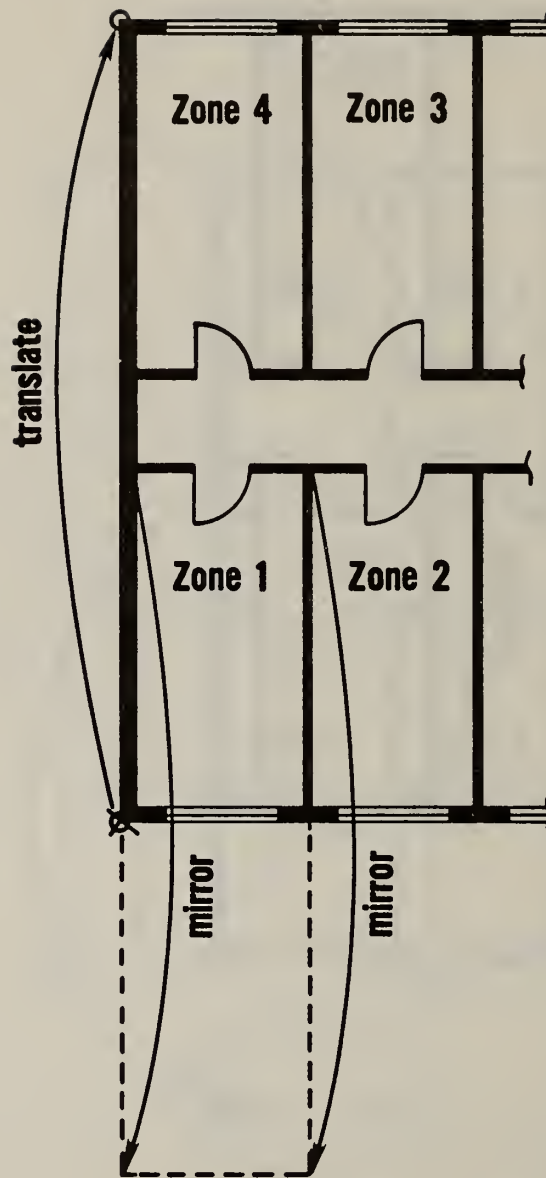
GEOM (MIRY/ORG = 0, 55, 0/ ...

Figure IV.F.15   Zone 4 described by mirror imaging and
translation of zone 1

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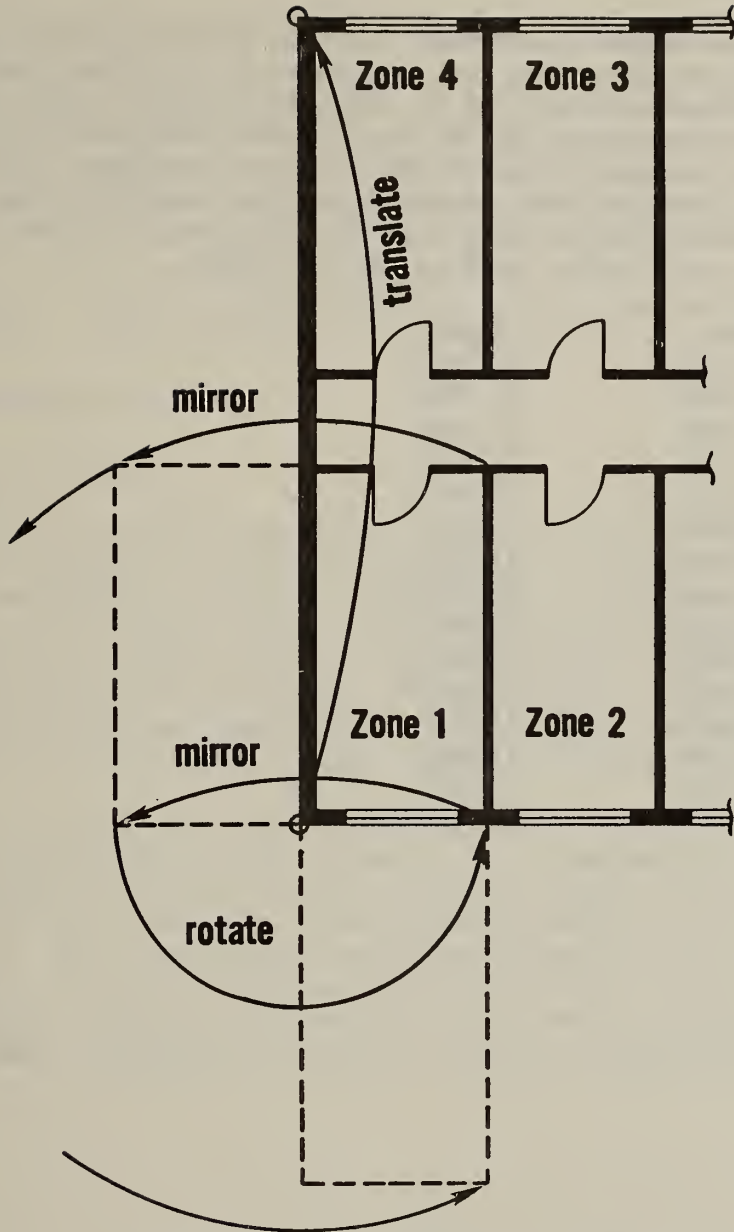
Figure IV.F.16 Zone 4 described by mirror imaging, rotation and translation of zone 1

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IV.G   TABLES

IV.G.1   SHADOWING DATES

Shadow patterns are normally computed for the 14 time periods listed
below. These periods were chosen so that the error in the solar position
would be less than 2 degrees on any day in the period. This causes the
periods to be shorter around March 21 and Sept 21 when the solar declination
angle changes rapidly. Shading features which do not use these dates will
increase the number of time periods and therefore the amount of time
necessary to calculate shadowing. Most shading features will occur over
several time periods, e.g. FROM = 16MAY / THRU = 30SEP.

PERIOD	FROM	THRU
1	1 JAN	31 JAN
2	1 FEB	20 FEB
3	21 FEB	12 MAR
4	13 MAR	31 MAR
5	1 APR	20 APR
6	21 APR	15 MAY
7	16 MAY	31 JUL
8	1 AUG	24 AUG
9	25 AUG	12 SEP
10	13 SEP	30 SEP
11	1 OCT	20 OCT
12	21 OCT	15 NOV
13	16 NOV	15 DEC
14	16 DEC	31 DEC

V. OUTPUT

The Thermal Analysis Research Program produces output in various levels of detail as directed by the user. Output reports generally consist of tables of numbers suitable for printing or display at a terminal. Development of more elegant graphic output has not been pursued because of the TARP emphasis on the fundamental heat transfer algorithms and computational methods. Almost every intermediate result that TARP calculates can be printed. Most of these intermediate results are available through "dumps" which have minimal descriptive information with the numbers and are in metric units -- the internal data representation. Several "reports" are also available. Reports present summary data and can be in either English or metric units. The following sections discuss the various output options.

V.A   INPUT REPORTS

V.A.1   Default Reports

The input processor produces an "echo" of the user input. This echo is organized by numbered lines on numbered pages as shown in the report for the sample problem from II.C shown in figure 1 on the following pages. Each page heading includes a page number, title, date, time of day, and central processor execution time. This last number is based on a non-ANSI function and may not be available on all computers. The input lines are numbered primarily to aid in editing the user input file. If user lines are not over about 72 characters long, the output will appear on most terminals without "wrap-around".

The last page of the input processor report tells the unused library elements and the required array dimensions (parameters) for the load calculator. The report of unused library names can help to identify typing errors which cause library elements to not be found when they are referenced later in the input. The report also identifies elements which can be removed from the input deck (possibly by commenting - $) to use less array space. The array dimensions report tells the minimum parameter sizes (see VI.C for a complete list of parameters) necessary to run the simulation.

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```
     1  PROJECT [
     2    RC(DEM/UIN=ENGLISH/UOUT=ENGLISH/
     3       DESC='THERMAL MASS TEST - SIMULTANEOUS ZONES, DIRECT SUN')
     4    RPT(RNOS = 9, 21)
     5    LOC(DESC='COLUMBIA, MO.'/LATD=38.9/LONG=92.3/TZ=6)
     6    GRND(GRT=40,42,48,55,62,67,70,69,63,55,48,42)
     7    DDY(DESC='MILD WINTER'/HIGH=50/LOW=30/WB=40/DATE=21FEB/
     8        CLR=1./MON/WS=1320/DIR=315)
     9    ]
    10  LIBRARY  [
    11    DS(NAME=NONE/DESC='ZERO ALL HOURS'/FFC=24*0)
    12    DS(NAME=FULL/DESC='ONE ALL HOURS'/FFC=24*1)
    13    DS(NAME=ON/DESC='NORTH OCCUPANCY'/
    14       FFC=6*1,.5,.16,8*0,4*.16,2*.33,.67,1)
    15    DS(NAME=OC/DESC='CENTER OCCUPANCY'/
    16       FFC=16*0,3*.17,.67,.5,.67,.17,0)
    17    DS(NAME=OS/DESC='SOUTH OCCUPANCY'/
    18       FFC=6*0,.5,.5,8*0,2*.33,.67,2*.16,3*0)
    19    WS(NAME=OCCN/DESC='NORTH OCCUPANCY'/WD=ON)
    20    WS(NAME=OCCC/DESC='CENTER OCCUPANCY'/WD=OC)
    21    WS(NAME=OCCS/DESC='SOUTH OCCUPANCY'/WD=OS)
    22    DS(NAME=LN/DESC='NORTH LIGHTING'/
    23       FFC=6*0,.7,.7,8*0,2*.33,4*.7,.4,0)
    24    DS(NAME=LC/DESC='CENTER LIGHTING'/
    25       FFC=16*0,.5,5*.7,.3,0)
    26    DS(NAME=LS/DESC='SOUTH LIGHTING'/
    27       FFC=6*0,.7,.7,8*0,5*.7,3*0)
    28    WS(NAME=LITN/DESC='NORTH LIGHTING'/WD=LN)
    29    WS(NAME=LITC/DESC='CENTER LIGHTING'/WD=LC)
    30    WS(NAME=LITS/DESC='SOUTH LIGHTING'/WD=LS)
    31    DS(NAME=EN/DESC='NORTH EQUIPMENT'/
    32       FFC=20*0,3*1,0)
    33    DS(NAME=EC/DESC='CENTER EQUIPMENT'/
    34       FFC=16*0,4*1,4*0)
    35    DS(NAME=ES/DESC='SOUTH EQUIPMENT'/
    36       FFC=6*.3,2*1,8*.3,2*1,3*.7,3*.3)
    37    WS(NAME=EQPN/DESC='NORTH EQUIPMENT'/WD=EN)
    38    WS(NAME=EQPC/DESC='CENTER EQUIPMENT'/WD=EC)
    39    WS(NAME=EQPS/DESC='SOUTH EQUIPMENT'/WD=ES)
    40    WS(NAME=CONST/DESC='CONSTANT 100%'/ALL=FULL)
    41    MATL(NAME=GYP/DESC='GYPSUM WALLBOARD'/K=.42/D=45./CP=.3)
    42    MATL(NAME=WD-S/DESC='SOFTWOOD'/K=.0675/D=32./CP=.33)
    43    MATL(NAME=SHTH/DESC='INTERMEDIATE DENSITY BUILDING BOARD SHEATHING'/
    44       K=.034/D=22./CP=.31)
    45    MATL(NAME=C-HW/DESC='HEAVY CONCRETE'/K=1.0/CP=.2/D=140.)
    46    MATL(NAME=R1/DESC='AIRSPACE RESISTANCE'/R=.91/AIR)
    47    MATL(NAME=R5/DESC='R5 POLYSTYRENE'/R=5.)
    48    MATL(NAME=R19/DESC='R19 INSULATION'/R=19.)
    49    MATL(NAME=R30/DESC='R30 INSULATION'/R=30.)
    50    MATL(NAME=SPDS/DESC='STANDARD GLASS'/GLASS/R=.0236/TRNS=.86)
    51    MATL(NAME=ASH/DESC='ASPHALT SHINGLES'/K=18.16/D=70/CP=.3)
    52    MATL(NAME=DIRT/K=.1/D=65./A=.70)
```

Figure V.1   Sample default output

```
53     MATL(NAME=AL/DESC='ALUMINUM SIDING'/K=128/D=171./CP=.2)
54     MATL(NAME=CPT/DESC='CARPET & PAD'/R=2.08)
55     CONS(NAME=WL-I/DESC='EXTERIOR WALL - INSULATION AREA'/
56         MATL=.0052,AL,  .0417,SHTH,  0,R19,  .0521,GYP)
57     CONS(NAME=WL-S/DESC='EXTERIOR WALL- STUD AREA'/
58         MATL=.0052,AL,  .0417,SHTH,  .292,WD-S,  .0521,GYP)
59     CONS(NAME=PTN-A/DESC='PARTITION - AIR SPACE AREA'/
60         MATL=.0521,GYP,  0,B1,  .0521,GYP)
61     CONS(NAME=PTN-S/DESC='PARTITION - STUD AREA'/
62         MATL=.0521,GYP,  .292,WD-S,  .0521,GYP)
63     CONS(NAME=WDW2/DESC='2 PANE WINDOW'/
64         MATL=0,SPDS,  0,B1,  0,SPDS)
65     CONS(NAME=FRAME/DESC='WINDOW FRAME'/MATL=0.1354,WD-S)
66     CONS(NAME=RF-T/DESC='CEILING/ROOF - TRUSS AREA'/
67         MATL=.0104,ASH,  .0417,WD-S,  .625,WD-S,  .0417,GYP)
68     CONS(NAME=RF-I/DESC='CEILING/ROOF - INSULATION AREA'/
69         MATL=.0104,ASH,  .0417,WD-S,  0,R30,  .0417,GYP)
70     CONS(NAME=PTN-M/DESC='MASSIVE PARTITION'/MATL=.667,C-HW)
71     CONS(NAME=SLAB-C/DESC='SLAB WITH CARPET'/
72         MATL=.5,DIRT,  0,R5,  .333,C-HW,  0,CPT)
73     CONS(NAME=SLAB-T/DESC='SLAB WITH TILE'/
74         MATL=.5,DIRT,  0,R5,  .333,C-HW)
75     CPFL(NAME=P1/DESC='HEATING SETBACK'/CAP=1,0/TMP=60,62)
76     CPFL(NAME=P2/DESC='STANDARD HEATING'/CAP=1,0/TMP=68,70)
77     CDS(NAME=HN/DESC='NORTH HEATING'/CPFL=6*P1,2*P2,8*P1,6*P2,2*P1)
78     CDS(NAME=HC/DESC='CENTER HEATING'/CPFL=16*P1,6*P2,2*P1)
79     CDS(NAME=HS/DESC='SOUTH HEATING'/CPFL=6*P1,2*P2,8*P1,5*P2,3*P1)
80     CWS(NAME=HEATN/DESC='NORTH HEATING'/WD=HN)
81     CWS(NAME=HEATC/DESC='CENTER HEATING'/WD=HC)
82     CWS(NAME=HEATS/DESC='SOUTH HEATING'/WD=HS)
83     ]
84   BUILDING [
85     SIM(SLDS=3/HTB=0/FLOW/CNVG=.1,.01,.34,12)
86     DSS(AZM=180./TILT=153.4/ORG=0,12,16/SIZE=44,2)
87     DSS(AZM=180./TILT=206.6/ORG=0,0,8/SIZE=44,2)
88     DSS(AZM=0./TILT=116.6/ORG=0,36,8/SIZE=44,2)
89     ]
90   ZONE [
91     GEOM(NAME=NORTH)
92     CTRL(CWS=HEATN/HEAT=12)
93     PEO(WS=OCCN/CAP=3)
94     LIT(WS=LITN/CAP=1.4)
95     EQP(WS=EQPN/CAP=1.0)
96     MASS(CONS=PTN-A/AREA=480)
97     SRF(EX/OP/BS/CONS=WL-I/AZM=0/ORG=44,36,0/SIZE=41,8)
98       SRF(EX/TR/SS/CONS=WDW2/ORG=12,5,-.25/SIZE=20,2)
99       AFS(AREA=0.2/EXP=.65)
100    SRF(EX/OP/BS/CONS=WL-S/AZM=0/ORG=3,36,0/SIZE=3,8)
101    SRF(EX/OP/BS/CONS=RF-T/AZM=0/ORG=44,36,8/SIZE=41,8.95/TILT=26.6)
102      AFS(AREA=0.1/EXP=.65)
103    SRF(EX/OP/BS/CONS=RF-I/AZM=0/ORG=3,36,8/SIZE=3,8.95/TILT=26.6)
104    SRF(IN/OP/BS/CONS=PTN-M/AZM=180/ORG=0,24,0/SIZE=44,12/ZONE=CENTER)
```

Figure V.1 (continued)

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```
105        AFS(AREA=0.5/EXP=.50)
106      SRF(IN/OP/BS/CONS=PTN-M/AZM=270/ORG=0,36,0/VRTS=12,0,  12,12,  0,8)
107      SRF(IN/OP/BS/CONS=PTN-M/AZM=90/ORG=44,24,0/VRTS=12,0,  12,8,  0,12)
108      SRF(EX/OP/BS/CONS=SLAB-C/AZM=180/ORG=0,36,0/SIZE=44,12/TILT=180)
109        OSC(TGP=1)
110      ]
111    ZONE [
112      GEOM(NAME=CENTER)
113      CTRL(CWS=HEATC/HEAT=12)
114      PEO(WS=OCCC/CAP=3)
115      LIT(WS=LITC/CAP=1.4)
116      EQP(WS=EQPC/CAP=1.0)
117      MASS(CONS=PTN-A/AREA=480)
118      SRF(EX/OP/BS/CONS=FRAME/AZM=180/ORG=0,12,12/SIZE=44,3)
119        SRF(EX/TR/SS/CONS=WDW2/ORG=2,0,-.25/SIZE=40,3)
120        AFS(AREA=0.25/EXP=.65)
121      SRF(EX/OP/BS/CONS=RF-T/AZM=0/ORG=44,24,12/SIZE=41,8.95/TILT=26.6)
122        AFS(AREA=0.1/EXP=.65)
123      SRF(EX/OP/BS/CONS=RF-I/AZM=0/ORG=3,24,12/SIZE=3,8.95/TILT=26.6)
124      SRF(IN/OP/BS/CONS=PTN-A/AZM=180/ORG=3,12,0/SIZE=41,12/ZONE=SOUTH)
125        AFS(AREA=0.5/EXP=.50)
126      SRF(IN/OP/BS/CONS=PTN-S/AZM=180/ORG=0,12,0/SIZE=3,12/ZONE=SOUTH)
127      SRF(IN/OP/BS/CONS=PTN-M/AZM=0/ORG=44,24,0/SIZE=44,12/ZONE=NORTH)
128        AFS(AREA=0.5/EXP=.50)
129      SRF(IN/OP/BS/CONS=PTN-M/AZM=270/ORG=0,24,0/VRTS=12,0,  12,16,  0,12)
130      SRF(IN/OP/BS/CONS=PTN-M/AZM=90/ORG=44,12,0/VRTS=12,0,  12,12,  0,16)
131      SRF(EX/OP/BS/CONS=SLAB-C/AZM=180/ORG=0,24,0/SIZE=44,12/TILT=180)
132        OSC(TGP=1)                                           .
133      ]
134    ZONE [
135      GEOM(NAME=SOUTH)
136      CTRL(CWS=HEATS/HEAT=12)
137      PEO(WS=OCCS/CAP=3)
138      LIT(WS=LITS/CAP=1.4)
139      EQP(WS=EQPS/CAP=9.4/LOST=.4)
140      MASS(CONS=PTN-A/AREA=480)
141      SRF(EX/OP/BS/CONS=WL-I/AZM=180/ORG=0,0,0/SIZE=41,8)
142        SRF(EX/TR/SS/CONS=WDW2/ORG=12,3,-.25/SIZE=20,4)
143        AFS(AREA=0.2/EXP=.65)
144      SRF(EX/OP/BS/CONS=WL-S/AZM=180/ORG=41,0,0/SIZE=3,8)
145      SRF(EX/OP/BS/CONS=RF-T/AZM=180/ORG=0,0,8/SIZE=41,8.95/TILT=26.6)
146        AFS(AREA=0.1/EXP=.65)
147      SRF(EX/OP/BS/CONS=RF-I/AZM=180/ORG=41,0,8/SIZE=3,8.95/TILT=26.6)
148      SRF(IN/OP/BS/CONS=PTN-A/AZM=0/ORG=44,12,0/SIZE=41,12/ZONE=CENTER)
149        AFS(AREA=0.5/EXP=.50)
150      SRF(IN/OP/BS/CONS=PTN-S/AZM=0/ORG=3,12,0/SIZE=3,12/ZONE=CENTER)
151      SRF(IN/OP/BS/CONS=PTN-M/AZM=270/ORG=0,12,0/VRTS=12,0,  12,8,  0,12)
152      SRF(IN/OP/BS/CONS=PTN-M/AZM=90/ORG=44,0,0/VRTS=12,0,  12,12,  0,8)
153      SRF(EX/OP/BS/CONS=SLAB-T/AZM=180/ORG=0,12,0/SIZE=44,12/TILT=180)
154        OSC(TGP=1)
155      ]
```

Figure V.1   (continued)

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UNUSED LIBRARY NAMES (IF ANY):
  DAY-SCHEDULE: NONE
  WEEK-SCHEDULE: CONST

MRLP MINIMUM ARRAY DIMENSIONS:

  ZON: 3
  SRF: 32
  HTS: 32
  AFS: 10
  CGS: 12
  GTF: 1
  TFH: 283
  CTF: 140
  SSC: 3
  DSH: 11
  WSH: 10
  CON: 11
  PFL: 2
  CDS: 3
  CWS: 3

Figure V.1 (concluded)

V.A.2   RUN CONTROL MODIFICATIONS

    The run control statement (1.1) includes four optional modifications
of the output.

V.A.2.1   DEM and error messages.

    TARP does extensive input checking. Incorrect or questionable input is
reported to the user by error messages which begin with two stars and a
severity descriptor. Figure 2 shows how error messages appear in the
output. NAME has been misspelled as NAEM in line 15 of the input. This is
immediately reported. Since DEM (1.1.3) was specified in the run control
statement, a list of valid key words is also printed. Errors that might
occur due to bad punctuation, causing the input processor to believe it is
in a different input section, can be quickly spotted from the SECTION: and
KEY: entries. At the end of the day-schedule description (line 16) it is
noted that the user did not give this schedule a name (since the required
NAME subkey was never recognized). The error in line 15 propagates through
the program causing some other errors to be noted. At line 20, the
week-schedule is not created because the day schedule named OC could not be
found. The final error message at the end of the output indicates that a
loads input file (the SINPFL) was not created. All input which produces
SEVERE errors must be corrected before the SINPFL is created.


```
1DEM AND ERROR MESSAGES


    15    DS(NAEM=OC/DESC='CENTER OCCUPANCY'/
** SEVERE   INVALID SUBKEY: NAEM
          SECTION: LIBRARY      KEY: DS            VALID SUBKEYS ARE:
              NAME        DESC        FFC
    16    FFC=16*0,3*.17,.67,.5,.67,.17,0)
** SEVERE   LIBRARY ELEMENT MUST HAVE NAME
    17    DS(NAME=OS/DESC='SOUTH OCCUPANCY'/
    18      FFC=6*0,.5,.5,8*0,2*.33,.67,2*.16,3*0)
    19    WS(NAME=OCCN/DESC='NORTH OCCUPANCY'/WD=ON)
    20    WS(NAME=OCCC/DESC='CENTER OCCUPANCY'/WD=OC)
** SEVERE   OC       NOT IN LIBRARY
** SEVERE   WEEKDAY-SCHEDULE NOT DEFINED
        .
        .
        .
** FATAL   INPUT FILE NOT CREATED BECAUSE OF 'SEVERE' ERRORS
```


Figure V.2   Sample error messages

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V.A.2.2   Double spacing

The 2SPC command (1.1.4) causes a blank line to be printed before every input line echo as shown in figure 3. Note that double spacing does not begin until the command has been recognized, so there is no skip between lines 1 and 2.

```
PAGE  1  NBS THERMAL ANALYSIS RESEARCH PROGRAM   82/05/07,  07.07.18,     .707

  1   PROJECT [
  2     RC(DEM/2SPC/UIN=ENGLISH/UOUT=ENGLISH/

  3       DESC='THERMAL MASS TEST - SIMULTANEOUS ZONES, DIRECT SUN')

  4     RPT(RNOS = 9).

  5     LOC(DESC='COLUMBIA, MO.'/LATD=38.9/LONG=92.3/TZ=6)

  6     GRND(GRT=40,42,48,55,62,67,70,69,63,55,48,42)

  7     DDY(DESC='MILD WINTER'/HIGH=50/LOW=30/WB=40/DATE=21FEB/

  8       CLR=1./MON/WS=1320/DIR=315)

  9     ]

 10   LIBRARY  [

 11     DS(NAME=NONE/DESC='ZERO ALL HOURS'/FFC=24*0)

 12     DS(NAME=FULL/DESC='ONE ALL HOURS'/FFC=24*1)
```

Figure V.3   Double spacing

V.A.2.3   Cross referencing

The XREF command (1.1.5) allows the user to match the data in the reports and, especially, the dumps to his input. In general, the input is read and organized into various arrays. The XREF reports the array locations. In figure 4, line 87 describes a detached shadowing surface (3.2). Information about this surface will be stored as element 2 in arrays having a MAXSRF parameter dimension. The next DSS (line 88) is stored as element 3 in those arrays. Zone controls and scheduled loads (lines 92-95) are stored in arrays with MAXCGS dimensions. The MASS is the first heat transfer surface, so its data goes into the MAXHTS dimensioned arrays at location 1. The surface description (line 97) has two cross references because both geometric data (in MAXSRF dimensioned arrays) and heat transfer data (in MAXHTS arrays) must be stored. The zone number appears after the zone description is completed (line 110).

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```
          .
          .
          .
87      DSS(AZM=180./TILT=206.6/ORG=0,0,8/SIZE=44,2)
          SRF =   2
88      DSS(AZM=0./TILT=116.6/ORG=0,36,8/SIZE=44,2)
          SRF =   3
89      ]
90   ZONE [
91      GEOM(NAME=NORTH)
92      CTRL(CWS=HEATN/HEAT=12)
          CGS =   1
93      PEO(WS=OCCN/CAP=3)
          CGS =   2
94      LIT(WS=LITN/CAP=1.4)
          CGS =   3
95      EQP(WS=EQPN/CAP=1.0)
          CGS =   4
96      MASS(CONS=PTN-A/AREA=480)
          HTS =   1
97      SRF(EX/OP/BS/CONS=WL-I/AZM=0/ORG=44,36,0/SIZE=41,8)
          SRF =   4
          HTS =   2
98        SRF(EX/TR/SS/CONS=WDW2/ORG=12,5,-.25/SIZE=20,2)
          SRF =   5
          HTS =   3
99        AFS(AREA=0.2/EXP=.65)
          AFS =   1
          .
          .
          .
107     SRF(IN/OP/BS/CONS=PTN-M/AZM=90/ORG=44,24,0/VRTS=12,0, 12,8, 0,12)
          SRF =  11
          HTS =   9
108     SRF(EX/OP/BS/CONS=SLAB-C/AZM=180/ORG=0,36,0/SIZE=44,12/TILT=180)
          SRF =  12
          HTS =  10
109       OSC(TGP=1)
          SSC =   1
110     ]
          ZON =   1
111  ZONE [
112     GEOM(NAME=CENTER)
113     CTRL(CWS=HEATC/HEAT=12)
          CGS =   5
114     PEO(WS=OCCC/CAP=3)
          CGS =   6
```

Figure V.4   Cross references

V.A.2.4   Metric units

TARP processes input and writes reports in English units by default.
The user can request that the input or output or both be in metric units
(1.1.7). Two samples of metric reports are shown in figure 5. The first is
the final loads summary described in V.B.1. Second is a wall and conduction
transfer function report described in V.A.4.4.

BUILDING LOADS FOR

THERMAL MASS TEST - SIMULTANEOUS ZONES, DIRECT SUN

COLUMBIA, MO.

MILD WINTER

ZONE	TOTAL HEATING (KWH)	TOTAL COOLING (KWH)	PEAK HEATING (KW)	PEAK COOLING (KW)	MAX TEMP (C)	MIN TEMP (C)	HX	HT	V	CL	CX
NORTH	14.94	0.00	2.977	0.000	20.71	16.61	0	10	0	0	0
CENTER	.33	0.00	.330	0.000	22.84	17.83	0	2	0	0	0
SOUTH	.09	0.00	.090	0.000	25.48	19.98	0	1	0	0	0
TOTAL:	1.536E+01	0.	3.067	0.000	25.48	16.61					

MAX HEATING OCCURS AT HOUR 7 ON 21FEB
MAX TEMP OCCURS AT HOUR 18 ON 21FEB
MIN TEMP OCCURS AT HOUR 6 ON 21FEB

PTN-S   : PARTITION - STUD AREA
 4:

DESCRIPTION OF CONSTRUCTION

LAYER	THICKNESS METERS	CONDUCTIVITY W/(M*K)	DENSITY KG/M**3	SPECIFIC HEAT KJ/(KG*K)	RESISTANCE M**2*K/W
GYP	.0159	.726	720.831	1.255	0.000
WD-S	.0890	.117	512.591	1.381	0.000
GYP	.0159	.726	720.831	1.255	0.000

  5 CONDUCTION TRANSFER FUNCTIONS OF ORDER 2

TIME	INTERNAL	CROSS	EXTERNAL	FLUX
1	8.68390584	.01854220	8.68390584	.58886750
2	-11.49423688	.30212722	-11.49423688	-.03735637
3	3.53278776	.22263065	3.53278776	
4	-.16599941	.01302198	-.16599941	
5	-.00006837	.00006688	-.00006837	

THERMAL CONDUCTANCE =   1.241 W/(M**2*K)
OUTER THERMAL ABSORPTANCE = .90
INNER THERMAL ABSORPTANCE = .90
OUTER SOLAR ABSORPTANCE = .75
INNER SOLAR ABSORPTANCE = .75
OUTER SURFACE ROUGHNESS =ROUGH

Figure V.5 Two reports using metric units

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V.A.3   NUMBERED REPORTS

Seven data dumps can be requested by specifying report numbers (1.2.1).

V.A.3.1   RNOS = 1; dump PROJECT and LIBRARY data

This provides summaries at the end of the PROJECT and LIBRARY sections. The DUMP OF PROJECT CONTROL DATA shown below lists the values associated with different variables which can be set in the PROJECT section. Refer to VI.C for a description of the individual variables.

```
DUMP OF PROJECT CONTROL DATA

COMMON /TITLES/:
 PTITLE = THERMAL MASS TEST - SIMULTANEOUS ZONES, DIRECT SUN
 LTITLE = COLUMBIA, MO.
 ETITLE = MILD WINTER

COMMON /RUNCTL/:
 EMUI   =          2
 SYNTAX =          F
 CALCS  =          T
 DEM    =          T
 OLDW   =          F

COMMON /EFLHDR/:
 LATD   =     38.900
 LONG   =     92.300
 TZNR   =      6.000
 ALTD   =      0.000
 TRRAIN =          3
 SINL   =       .628
 COSL   =       .778
 MERID  =      2.300
 TGRND  =    4.4    5.6   8.9 12.8 16.7 19.4 21.1 20.6 17.2 12.8   8.9   5.6
 TMKUP  =   12.8 12.8 12.8 12.8 12.8 12.8 12.8 12.8 12.8 12.8 12.8 12.8
 NRENVS =          1
 NRDAYS            1
 WSTATN =          0

COMMON /REPORT/:
 EMUO   =          2
 RFLAGS =       T    T    T    T    T    T    T    F    F    F
                F    F    F    F    F    F    F    F    F    F
                F    F    F    F    F    F    F    F    F    F
```

Figure V.6   Dump of project control data

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The DUMP OF LIBRARY CONTROL DATA shown below gives the number and names of all library entries. First, summary data is given for each of the seven libraries. This data is taken from common block LIBCTL. It begins with the day-schedule (DS) by giving the 0 location (DSO), the number of schedules defined (NDS), and the maximum number of schedules permitted (MXDS). This last number can be set by the user (2.1.2). Similar data is presented for the other six libraries. Next comes a list of all library element names (LNAMES) presented in eight names per row in sequence. The list of numbers can be used to determine to which library the names belong. For example, the first 16 names are day-schedules. DS names occupy the first two rows including the five undefined (blank) names in the second row. Week-schedules (WS) names occupy the net two rows with ten names defined and six left undefined, etc.

```
DUMP OF LIBRARY CONTROL DATA

LIBRARY NAME =

      DS =      0    11    16
      WS =     16    10    16
    MATL =     32    13    16
    CONS =     48    11    16
    CPFL =     64     2    16
     CDS =     80     3    16
     CWS =     96     3    16

ELEMENT NAMES:
NONE       FULL       ON        OC        OS        LN        LC        LS
EN         EC         ES
OCCN       OCCC       OCCS      LITN      LITC      LITS      EQPN      EQPC
EQPS       CONST
GYP        WD-S       SHTH      C-HW      B1        R5        R19       R30
SPDS       ASH        DIRT      AL        CPT
WL-I       WL-S       PTN-A     PTN-S     WDW2      FRAME     RF-T      RF-I
PTN-M      SLAB-C     SLAB-T
P1         P2

HN         HC         HS

HEATN      HEATC      HEATS
```

Figure V.7   Dump of library control data

V.A.3.2   RNOS = 2; dump of DDY and WTAP data

This is a dump of all weather data for every day described in the DDY (1.6) and WTAP (1.5) keys. It is a dump of data in the EVDAT common block. The data names are summarized as follows:

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NAME	VARIABLE	DESCRIPTION
YEAR	YEAR	year
MO	MONTH	month number
DY	DYOFM	day of month
DW	DAYOFW	day of week number
HOL	HOLIND	holiday and special days indicator
DST	DSTIND	daylight saving time indicator
SSDECL	SSDECL	sine of the solar declination angle
CSDESL	CSDECL	cosine of the solar declination angle
EQTIME	EQTIME	equation of time (h)
TD	ODB	dry bulb temperature (C)
TW	OWB	wet bulb temperature (C)
BP	OBP	barometric pressure (Pa)
H	OHR	humidity ratio
WS	SPD	wind speed (m/s)
WD	DIR	wind direction (deg)
TS	SKY	sky radiative temperature (C)
QB	SRADBM	direct normal (beam) solar flux (W/m**2)
QD	SRADDF	sky brightness (W/m**2)
QR	SRADGR	ground brightness (W/m**2)
RN	RAIN	rain indicator
SN	SNOW	snow indicator

```
    7    DDY(DESC='MILD WINTER'/HIGH=50/LOW=30/WB=40/DATE=21FEB/
    8         CLR=1./MON/WS=1320/DIR=315)

YEAR MO DY DW HOL DST SSDECL CSDECL EQTIME
1958  2 21  2   0   0  -.184   .983  -.229
```

TD	TW	BP	H	WS	WD	TS	QB	QD	QR	RN	SN
.33	-.87	100000.	.0031	6.7	315.	-16.16	0.0	0.0	0.0	0	0
-.22	-1.19	100000.	.0031	6.7	315.	-16.69	0.0	0.0	0.0	0	0
-.67	-1.45	100000.	.0031	6.7	315.	-17.10	0.0	0.0	0.0	0	0
-1.00	-1.64	100000.	.0031	6.7	315.	-17.42	0.0	0.0	0.0	0	0
-1.11	-1.71	100000.	.0031	6.7	315.	-17.52	0.0	0.0	0.0	0	0
-.89	-1.58	100000.	.0031	6.7	315.	-17.31	0.0	0.0	0.0	0	0
-.33	-1.25	100000.	.0031	6.7	315.	-16.79	0.0	0.0	0.0	0	0
.67	-.67	100000.	.0031	6.7	315.	-15.85	307.4	18.6	10.2	0	0
2.11	.09	100000.	.0031	6.7	315.	-14.49	734.5	44.5	51.1	0	0
3.78	1.05	100000.	.0031	6.7	315.	-12.93	875.8	53.1	88.0	0	0
5.67	2.12	100000.	.0031	6.7	315.	-11.15	937.7	56.8	116.1	0	0
7.44	3.09	100000.	.0031	6.7	315.	-9.48	965.4	58.5	133.2	0	0
8.78	3.80	100000.	.0031	6.7	315.	-8.23	972.2	58.9	138.0	0	0
9.67	4.27	100000.	.0031	6.7	315.	-7.39	961.0	58.2	130.2	0	0
10.00	4.44	100000.	.0031	6.7	315.	-7.08	927.0	56.2	110.4	0	0
9.67	4.27	100000.	.0031	6.7	315.	-7.39	852.7	51.7	80.0	0	0
8.89	3.86	100000.	.0031	6.7	315.	-8.12	675.5	40.9	41.5	0	0
7.67	3.21	100000.	.0031	6.7	315.	-9.27	107.0	6.5	2.6	0	0
6.22	2.43	100000.	.0031	6.7	315.	-10.63	0.0	0.0	0.0	0	0
4.78	1.62	100000.	.0031	6.7	315.	-11.99	0.0	0.0	0.0	0	0
3.56	.93	100000.	.0031	6.7	315.	-13.14	0.0	0.0	0.0	0	0
2.44	.28	100000.	.0031	6.7	315.	-14.18	0.0	0.0	0.0	0	0
1.56	-.17	100000.	.0031	6.7	315.	-15.02	0.0	0.0	0.0	0	0
.89	-.55	100000.	.0031	6.7	315.	-15.64	0.0	0.0	0.0	0	0

Figure V.8 Dump of weather data

V.A.3.3   RNOS = 3; dump of conduction transfer function calculations

Details of the CTF calculations are presented beginning with a list
of the layers and their thermal properties (L = thickness, K = conductivity,
CP = specific heat, D = density, R = thermal resistance value). SUMB,
CND, RR, and CC are variable names (see VI.C). The RR value is calculated
only for single layer constructions. The number of roots (NRT) found and
the search increment (SINC) are reported as well as the values of the
ROOTs and the variable RATIO. From the ROOTs and RATIOs the CTF are com-
puted for orders zero (0 0) through (0 5) until the convergence criteria
have been met. The X, Y, Z, and J CTF are reported for all orders. This
report is simplified for massless constructs since no CTF (only the U
value) are calculated.

```
DUMP OF CONDUCTION CALCULATIONS FOR:
   PARTITION - STUD AREA

   LAYER            L          K         CP         D          R
   GYP             .016       .726      1.255     720.831     0.000
   WD-S            .089       .117      1.381     512.591     0.000
   GYP             .016       .726      1.255     720.831     0.000

   SUMB = 254.58173  CND =    1.24059  RR =           -I  CC =    14368.09

   NUMBER OF ROOTS =   9;  SEARCH INCREMENT = .007856

      N          ROOT            RATIO
      1       .013546079      .516548286
      2       .027011651      .072319215
      3       .040288196      .002899261
      4       .053198718      .000037605
      5       .065446912      .000000201
      6       .076662966      .000000001
      7       .086835154      .000000000
      8       .096795305      .000000000
      9       .107590765      .000000000

   NUMBER OF RESPONSE FACTORS =   5;   ORDER =   2

      N        0 0          0 1          0 2          0 3          0 4          0 5

      1      8.683909     8.683909     8.683906     8.683909     8.683909     8.683909
      2     -6.380569   -10.866227   -11.494237   -11.519418   -11.519744   -11.519746
      3      -.548920     2.746952     3.532788     3.566114     3.566547     3.566549
      4      -.250886      .032658     -.165999     -.176242     -.176376     -.176377
      5      -.127301      .002293     -.000068     0.000000     0.000000     0.000000

      1       .018542      .018542      .018542      .018542      .018542      .018542
      2       .313046      .303468      .302127      .302073      .302073      .302073
      3       .406281      .244577      .222631      .221755      .221743      .221743
      4       .240573      .030710      .013022      .012377      .012368      .012368
      5       .126555      .002288      .000067     0.000000     0.000000     0.000000

      1      8.683909     8.683909     8.683906     8.683909     8.683909     8.683909
      2     -6.380569   -10.866227   -11.494237   -11.519418   -11.519744   -11.519746
      3      -.548920     2.746952     3.532788     3.566114     3.566547     3.566549
      4      -.250886      .032658     -.165999     -.176242     -.176376     -.176377
      5      -.127301      .002293     -.000068     0.000000     0.000000     0.000000

      2       .588868     -.037356     0.000000     0.000000     0.000000
```

Figure V.9 Dump of CTF calculations for massive construct

V.A.3.4   RNOS = 4; dump of glass calculations

Details of the optical calculations are presented beginning with the
DESCription of the construction and a list of the normal transmittance,
index of refraction, film transmittance, and reflectance of the GLASS or
SHADE layers (AIR layers are assumed between each optical layer). The
optical properties for the individual panes are:
EXTC = k*L from (D.3.5)
GN = index of refraction
FN = film index or refraction (D.4.1)
FK = film extinction coefficient (D.4.1)
FD = film thickness.

Then the computed reflectances and transmittances of the panes are
reported at various angles of incidence:
T1 = transmittance for TE light
R11 = reflectance for TE light incident from outside
R12 = reflectance for TE light incident from inside
T2 = transmittance for TM light
R21 = reflectance for TM light incident from outside
R22 = reflectance for TM light incident from inside

The polynomial coefficients are the least squares fit values for
(D.1.7b) and (D.1.7a). T refers to transmittance, A to absorptance, O to
outside, I to inside, and S to shade.


```
DUMP OF OPTICAL CALCULATIONS FOR:   2 PANE WINDOW

   LAYER          TRNS       IR        FTRN        REF
   SFDS           .860     1.520      0.000      0.000
   B1            0.000     1.520      0.000      0.000
   SFDS           .860     1.520      0.000      0.000

OPTICAL PROPERTIES AT WAVELENGTH =   .725
PANE= 1  EXTC= .065  GN=1.520  FN=0.000  FK=0.000  FD=0.000
PANE= 2  EXTC= .065  GN=1.520  FN=0.000  FK=0.000  FD=0.000

OPTICAL VALUES AT COS(THETA)= .991
PANE= 1  T1= .858  R11= .079  R12= .079  T2= .861  R21= .075  R22= .075
PANE= 2  T1= .858  R11= .079  R12= .079  T2= .861  R21= .075  R22= .075
          .
          .
          .
OPTICAL VALUES AT COS(THETA)= .875
PANE= 1  T1= .828  R11= .106  R12= .106  T2= .882  R21= .051  R22= .051
PANE= 2  T1= .828  R11= .106  R12= .106  T2= .882  R21= .051  R22= .051

OPTICAL VALUES AT COS(THETA)= .938
PANE= 1  T1= .845  R11= .090  R12= .090  T2= .871  R21= .064  R22= .064
PANE= 2  T1= .845  R11= .090  R12= .090  T2= .871  R21= .064  R22= .064

OPTICAL VALUES AT COS(THETA)=1.000
PANE= 1  T1= .860  R11= .077  R12= .077  T2= .860  R21= .077  R22= .077
PANE= 2  T1= .860  R11= .077  R12= .077  T2= .860  R21= .077  R22= .077
```

Figure V.10 Dump of optical calculations

```
POLYNOMIAL COEFFICIENTS:
    I        T2              A02              AI2              AS2
    1    3.8544537E-01    2.4276461E+00    5.7576912E-01          -I
    2    1.0308017E+01   -2.2363210E+01   -3.6428286E+00          -I
    3   -3.3949733E+01    1.0021852E+02    1.4986929E+01          -I
    4    5.0154231E+01   -2.3554957E+02   -3.4400820E+01          -I
    5   -3.9590559E+01    2.7725274E+02    3.9841064E+01          -I
    6    1.4092558E+01   -1.2867078E+02   -1.8204343E+01          -I

    I        T1              A01              AI1              AS1
    1   -3.8380648E-01    1.2150528E-01    1.2238673E-02          -I
    2    4.4021943E+00   -1.3248196E-01    2.4052260E-01          -I
    3   -6.7817725E+00    1.6526246E-01   -4.1181869E-01          -I
    4    4.8351028E+00   -1.2219971E-01    2.9334734E-01          -I
    5   -1.3277812E+00    3.5232619E-02   -7.9688593E-02          -I
```

Figure V.10 (continued)

V.A.3.5   RNOS = 5; dump of DSS data

    This dump begins with the surface number (same as SRF number in
V.A.2.3).   Then the coordinates of the vertices of the surface are presented
as X, Y, and Z values (in meters) arranged in the same order as the surface
is viewed.   For example, (-.000 3.113 5.150) are the X, Y, and Z coordinates
respectively of the upper left vertex.   (13.411 3.658 4.877) refers to
the lower corner.   Several individual values are then presented:
CA = cosine of the azimuth (global coordinate system) angle
SA = sine of the azimuth angle
CT = cosine of the tilt angle
ST = sine of the tilt angle
TRNS = surface transmittance
ON = start date in cyclic date (B.1.4) form
OFF = end date
S1,S2 = variables SHDSRF(I,1) and SHDSRF(I,2).   See VI.C.

```
    85   BUILDING C
    86     SIM(SLDS=3/HTB=0/FLOW/CNVG=.1,.01,.34,12)
    87     DSS(AZM=180./TILT=153.4/ORG=0,12,16/SIZE=44,2)

  SURFACE:      1
  VERTICES:
            -.000        3.113        5.150              13.411      3.113      5.150
            0.000        3.658        4.877              13.411      3.658      4.877

     CA      SA      CT      ST     TRNS    ON   OFF   S1   S2
   -1.000   -.000   -.894    .448   0.000   33   415    0    0

    88     DSS(AZM=180./TILT=206.6/ORG=0,0,8/SIZE=44,2)

  SURFACE:      2
  VERTICES:
            -.000       -.545        2.165              13.411     -.545      2.165
            0.000       0.000        2.438              13.411     -.000      2.438

     CA      SA      CT      ST     TRNS    ON   OFF   S1   S2
   -1.000   -.000   -.894   -.448   0.000   33   415    0    0
              .
              .
              .
```

Figure V.11 Dump of shadowing surface data

V.A.3.6   RNOS = 6; dump of ZONE data

The zone data dump produces output as shown in figure 12. There are different data formats corresponding to the many different elements of zone data. Controls and scheduled loads produce similar output as shown for lines 92 through 95. First the schedule number (corresponding to CGS in V.A.2.3) is given. Then the contents of CGSZON (zone number), type of load), GGSON (on date), CGSOFF (stop date), CGSDX (week-schedule pointer), and elements 1 to 5 of RCGS (see VI.c) are given order.

Lines 96 and 101 produce dumps of heat transfer surface data. They begin with the heat transfer surface number (corresponding to HTS in V.A.2.3). On the next two lines the following values are given:

NAME	VARIABLE	DESCRIPTION
AREA	AREA	Area of surface (m2)
INV	ISENV	Zone number
ONV	OSENV	Outside environment / far side zone number
FSS	FSS	View factor to sky
FSG	FSG	View factor to ground
K	KPTR	Pointer to construct data
AZM	SFAZIM	Azimuth angle (degrees)
CTILT	CTILT	Cosine of tilt angle
HOC	HOC	Factor for detailed outside convection
THE	TMPHPR	Pointer to external temperature histories
THI	TMPHPI	Pointer to internal temprature histories
QHE	FLXHPE	Pointer to external flux histories
QHI	FLXHPI	Pointer to internal flux histories

The surface described in line 101 is part of the envelope of the zone. Therefore, it also has shadowing surface data identical to that described in V.A.3.5.

The air flow opening at line 102 produces another dump beginning with the XREF number (corresponding to AFS). Then following variables are dumped in order:

NAME	VARIABLE	DESCRIPTION
AREA	FAREA	Effective flow area
EXP	FEXP	Flow exponent
ZS	ZS	Height of opening
ZT	ZT	Height of top of base surface
COS1	FCOS1	Direction cosine
COS2	FCOS2	Direction cosine
PTR	AFSPTR	Number of adjacent zone (0 = ambient)
ZONE	ZNMOUT	Name of adjacent zone

Other side coefficients (line 109) also produce a data dump beginning with the XREFF number (corresponding to OSC). Then the following variables are dumped in order:

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```
 90   ZONE C
 91      GEOM(NAME=NORTH)
 92      CTRL(CWS=HEATN/HEAT=12)

SCHEDULE:    1
ZON TYP  ON OFF   DX        R1            R2          R3          R4          R5
  1  12  33 415    1    3514.501**********      0.000       0.000       0.000

 93      PEO(WS=OCCN/CAP=3)

SCHEDULE:    2
ZON TYP  ON OFF   DX        R1            R2          R3          R4          R5
  1   1  33 415    1       3.000      131.800       .500       0.000       0.000

 94      LIT(WS=LITN/CAP=1.4)

SCHEDULE:    3
ZON TYP  ON OFF   DX        R1            R2          R3          R4          R5
  1   2  33 415    4     410.025        0.000       .200        .200       0.000

 95      EQP(WS=EQPN/CAP=1.0)

SCHEDULE:    4
ZON TYP  ON OFF   DX        R1            R2          R3          R4          R5
  1   3  33 415    7     292.875        0.000       .300       0.000        .700

 96      MASS(CONS=PTN-A/AREA=480)

HEAT TRANSFER SURFACE:     1
  AREA     INV   ONV    FSS    FSG     K
 44.59      1     -1  0.000  0.000     3
 AZM   CTILT     HOC      THE     THI     QHE     QHI
  0.   0.000    0.000      0       0       1       1
        .
        .
        .
101      SRF(EX/OP/BS/CONS=RF-T/AZM=0/ORG=44,36,8/SIZE=41,8.95/TILT=26.6)

HEAT TRANSFER SURFACE:     5
  AREA     INV   ONV    FSS    FSG     K
 34.09      1     -3   .947   .053     7
 AZM   CTILT     HOC      THE     THI     QHE     QHI
  0.    .894    3.339     20      26      32      37

SURFACE:     7
VERTICES:
         13.411      8.534      3.660               .914      8.534      3.660
         13.411     10.973      2.438               .914     10.973      2.438

   CA     SA     CT     ST    TRNS    ON   OFF    S1    S2
 1.000  0.000   .894   .448  0.000    33   415     5     5

102      AFS(AREA=0.1/EXP=.65)

AIR FLOW SURFACE:     2
    AREA        EXP        ZS         ZT        COS1        COS2       PTR       ZONE
    .009       .650      3.049       .695        .448       0.000       0
        .
        .
        .
109      OSC(TGP=1)

OTHER SIDE COEFFICIENTS:     1
   HO    TZF   TAP    CT    CTP    TGP    WSP    HTS
 0.000 0.000 0.000  0.00  0.000  1.000  0.000    10

110      ]
```

Figure V.12   Dump of zone data

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NAME	VARIABLE	DESCRIPTION
HO	RSSC(2,I)	Convection coefficient
TZP	RSSC(3,I)	Zone air temperature part
TAP	RSSC(4,I)	Ambient air temperature part
HO	RSSC(5,I)	Constant temperature
TZP	RSSC(6,I)	Constant temperature part
TAP	RSSC(7,I)	Ground temperature part
WSP	RSSC(8 I)	Wind speed factor
HTS	ISSC(9,I)	HTS number of the base surface

Movable insulation also produces a data dump from the RSSC/ISSC arrays:

NAME	VARIABLE	DESCRIPTION
R	RSSC(1,I)	Thermal resistance of insulation
A	RSSC(3,I)	Outside solar absorptance
E	RSSC(4,I)	Outside thermal emittance
RGH	ISSC(5,I)	Outside roughned number
ON	ISSC(6,I)	Start date for movable insulation
OFF	ISSC(7,I)	Stop date
CTL	ISSC(8 I)	Control type or pointer to day-schedule
HTS	ISSC(9,I)	HTS number of the base surface

V.A.3.7   RNOS = 7; dump of cross reference values

The matching of interzone partitions and openings can become difficult, so the following dump has been provided (figure V.13). As the input processor encounters interzone partitions (IZP) and openings (AFO) it checks data in two match-up lists. If the IZP/AFO does not match one of the entries in the list, it is added to the list. Otherwise, if it does match, the matched element in the list is removed. This dump monitors that process.

The first interzone partition is defined at line 104. No match for this IZP is found, so the number of unmatched IZP's is now 1. The far side and near side zone names are CENTER and NORTH, respectively. The surface area is 449.053 m^2; the U-value is 8.5074 W/m^2K; the number of temperature CTF terms is 3; and the number of flux CTF terms is 2. These numbers and names will be used to find the matching description of the IZP from the adjacent zone.

The air flow opening at line 105 also created an entry in the AFO table. The count and zone names are similar to those used for the IZP. The number are the opening area, flow exponent, and opening height, respectively.

The input processor continues to not find matches (lines 124, 125, 126, 148, and 149) or to match IZP and AFO (lines 127, 128, and 150). When a match is found, the reduced number of items IZP or AFO tables is reported as well as the HTS or AFS of the match. In this particular example, there is a typing error in the name of the adjacent zone at line 148. This error prevents a match of both IZP and AFO. At the conclusion of input processing

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this failure to match is reported as SEVERE errors. The data accompanying the error messages (produced by default) should be sufficient to determine the incorrect or missing surfaces and openings.

```
        .
        .
        .
104   SRF(IN/OF/BS/CONS=PTN-M/AZM=180/ORG=0,24,0/SIZE=44,12/ZONE=CENTER)
        IZP - NO MATCH:   1 CENTER        NORTH         49.053    8.5074   3  2
105     AFS(AREA=0.5/EXP=.50)
        IZF - NO MATCH:   1 CENTER        NORTH          .04645     .500     1.829
        .
        .
        .
124   SRF(IN/OP/BS/CONS=PTN-A/AZM=180/ORG=3,12,0/SIZE=41,12/ZONE=SOUTH)
        IZP - NO MATCH:   2 SOUTH         CENTER        45.708    4.8998   1  1
125     AFS(AREA=0.5/EXP=.50)
        IZF - NO MATCH:   2 SOUTH         CENTER         .04645     .500     1.829
126   SRF(IN/OP/BS/CONS=PTN-S/AZM=180/ORG=0,12,0/SIZE=3,12/ZONE=SOUTH)
        IZP - NO MATCH:   3 SOUTH         CENTER         3.345    1.2406   4  2
127   SRF(IN/OP/BS/CONS=PTN-M/AZM=0/ORG=44,24,0/SIZE=44,12/ZONE=NORTH)
        IZP - MATCH:  NIZP =  2;    HTS =  7
128     AFS(AREA=0.5/EXP=.50)
        IZF - MATCH;  NUAFS =  1;    AFS =  3
        .
        .
        .
148   SRF(IN/OF/BS/CONS=PTN-A/AZM=0/ORG=44,12,0/SIZE=41,12/ZONE=CETNER)
        IZP - NO MATCH:   3 CETNER        SOUTH         45.708    4.8998   1  1
149     AFS(AREA=0.5/EXP=.50)
        IZF - NO MATCH:   2 CETNER        SOUTH          .04645     .500     1.829
150   SRF(IN/OF/BS/CONS=PTN-S/AZM=0/ORG=3,12,0/SIZE=3,12/ZONE=CENTER)
        IZP - MATCH:  NIZP =  2;    HTS = 17
        .
        .
        .
```

PAGE 4   NBS THERMAL ANALYSIS RESEARCH PROGRAM   82/05/14.   06.33.00.   1.733

** SEVERE   UNMATCHED INTER-ZONE SURFACES:

ZONE	FAR SIDE	HTS	AREA	CONSTRUCT
CENTER	SOUTH	16	45.708	PTN-A
SOUTH	CETNER	28	45.708	PTN-A

** SEVERE   UNMATCHED INTER-ZONE OPENINGS:

ZONE	FAR SIDE	AFS	AREA	EXP	ZS
CENTER	SOUTH	6	.04645	.500	1.829
SOUTH	CETNER	10	.04645	.500	1.829

UNUSED LIBRARY NAMES (IF ANY):
  DAY-SCHEDULE: NONE
  DAY-SCHEDULE:
  WEEK-SCHEDULE: CONST
** FATAL   INPUT FILE NOT CREATED BECAUSE OF 'SEVERE' ERRORS

Figure V.13   Dump of cross reference values

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V.A.4   LIBRARY REPORTS

The library data can be reported by library commands (2.1.3).

V.A.4.1   Day-schedules (DS)

Figure 14 shows typical reports for two day-schedules. A simple graph is
provided with the data. The first line of the DS report is the user defined
name (ON) and description (NORTH OCCUPANCY). The next line gives the schedule
number / array index (3). Then comes a list of hour numbers. Below these the
hourly fractions of full capacity are presented by a simple bar graph. Each
hour is three X's wide. The final line of a DS report is the hourly fractions
as a percent of full capacity.

```
ON           : NORTH OCCUPANCY
 3:
             1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

 1.0 +XXXXXXXXXXXXXXXXXX                                                  XXX+
     +XXXXXXXXXXXXXXXXXX                                                  XXX+
  .8 +XXXXXXXXXXXXXXXXXX                                                  XXX+
     +XXXXXXXXXXXXXXXXXX                                                XXXXX+
  .6 +XXXXXXXXXXXXXXXXXX                                                XXXXX+
     +XXXXXXXXXXXXXXXXXXXXX                                            XXXXX+
  .4 +XXXXXXXXXXXXXXXXXXXXX                                           XXXXX+
     +XXXXXXXXXXXXXXXXXXXXX                                     XXXXXXXXXXX+
  .2 +XXXXXXXXXXXXXXXXXXXXXXXX                        XXXXXXXXXXXXXXXXXXXXXX+
     +XXXXXXXXXXXXXXXXXXXXXXXX                        XXXXXXXXXXXXXXXXXXXXXX+
   0 +XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX+

     100100100100100100 50 16  0  0  0  0  0  0  0  0 16 16 16 16 33 33 67100

OC           : CENTER OCCUPANCY
 4:
             1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

 1.0 +                                                                     +
     +                                                                     +
  .8 +                                                                     +
     +                                                    XXX    XXX       +
  .6 +                                                    XXX    XXX       +
     +                                                    XXXXXXXXX        +
  .4 +                                                    XXXXXXXXX        +
     +                                                    XXXXXXXXX        +
  .2 +                                            XXXXXXXXXXXXXXXXXXX       +
     +                                            XXXXXXXXXXXXXXXXXX        +
   0 +XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX+

       0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 17 17 17 67 50 67 17  0
```

Figure V.14   Day-schedule reports

V.A.4.2   Week-schedules (WS)

The first two lines of the week-schedule report give the user defined
name, description, and the schedule number. These are followed by a list of
12 days: SUN through FRI on one line and SAT through SP4 lines below. Below
each day name is the name of the day-schedule in effect on that day. Below
that is the day-schedule number. Figure 15 shows three week-schedules.

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```
OCCN        : NORTH OCCUPANCY
  1:
     SUN           MON           TUE           WED           THU           FRI
     ON            ON            ON            ON            ON            ON
      3             3             3             3             3             3

     SAT           HOL           SP1           SP2           SP3           SP4
     ON            ON            ON            ON            ON            ON
      3             3             3             3             3             3

OCCC        : CENTER OCCUPANCY
  2:
     SUN           MON           TUE           WED           THU           FRI
     OC            OC            OC            OC            OC            OC
      4             4             4             4             4             4

     SAT           HOL           SP1           SP2           SP3           SP4
     OC            OC            OC            OC            OC            OC
      4             4             4             4             4             4

OCCS        : SOUTH OCCUPANCY
  3:
     SUN           MON           TUE           WED           THU           FRI
     OS            OS            OS            OS            OS            OS
      5             5             5             5             5             5

     SAT           HOL           SP1           SP2           SP3           SP4
     OS            OS            OS            OS            OS            OS
      5             5             5             5             5             5
```

Figure V.15   Week-schedule reports

V.A.4.3   Materials (MATL)

The first two lines of the materials report give the user defined name, description, and the schedule number. The thermal properties of the material are given below the names (using the input subkey names) of those properties. Optical properties are also reported when they apply.

```
MATERIALS:

GYP         : GYPSUM WALLBOARD
  1:                            OTHER

      K           CP            D             R             A             E             RGH
     .420         .300        45.000        0.000          .75           .90            2




WD-S        : SOFTWOOD
  2:                            OTHER

      K           CP            D             R             A             E             RGH
     .068         .330        32.000        0.000          .75           .90            2
```

Figure V.16   Materials report

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V.A.4.4   Constructs (CONS)

The first two lines of the construct report give the user defined name, description, and the schedule number. The name and thermal properties of each layer are given. The number and values of the conduction transfer functions are reported. "Internal" refers to the Z functions, "cross" to the Y functions, "external" to the X functions, and "flux" to the J functions. The thermal conductance and surface properties are reported as shown below in figure 17.

Considerably more data is reported for transparent constructs. Figure V.18 shows a sample report for a double pane window. It begins with a report of the conductive properties. There is only one CTF because the layers have no thermal mass. Then the optical properties are reported. The transmittance, reflectance, and absorptances of the window are reported for 16 evenly spaced values of the cosine of the angle of incidence and for diffuse radiation. The program computes polynomial coefficients to approximate the angular dependence of these properties. These fitted values are reported for the window transmittance and absorptances at the outer and inner surfaces of the window.

```
PTN-S       : PARTITION - STUD AREA
  4:

DESCRIPTION OF CONSTRUCTION

    LAYER       THICKNESS  CONDUCTIVITY  DENSITY   SPECIFIC HEAT  RESISTANCE
                FEET       BTU/(HR*FT*F) LB/FT**3  BTU/(LB*F)     HR*FT**2*F/BTU


    GYP           .0521       .420       45.000      .300        0.000
    WD-S          .2920       .068       32.000      .330        0.000
    GYP           .0521       .420       45.000      .300        0.000

    5 CONDUCTION TRANSFER FUNCTIONS OF ORDER 2

    TIME      INTERNAL        CROSS        EXTERNAL        FLUX

      1      1.53034770      .00326766    1.53034770      .58886750
      2     -2.02560683      .05324329   -2.02560683     -.03735637
      3       .62257626      .03923376     .62257626
      4      -.02925375      .00229484    -.02925375
      5      -.00001205      .00001179    -.00001205

    THERMAL CONDUCTANCE =     .219 BTU/(HR*FT**2*F)
    OUTER THERMAL ABSORPTANCE = .90
    INNER THERMAL ABSORPTANCE = .90
    OUTER SOLAR ABSORPTANCE = .75
    INNER SOLAR ABSORPTANCE = .75
    OUTER SURFACE ROUGHNESS =ROUGH
```

Figure V.17 Constructs report

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WDW2   : 2 PANE WINDOW
  5:

DESCRIPTION OF CONSTRUCTION

LAYER	THICKNESS FEET	CONDUCTIVITY BTU/(HR*FT*F)	DENSITY LB/FT**3	SPECIFIC HEAT BTU/(LB*F)	RESISTANCE HR*FT**2*F/BTU
SPDS	0.0000	0.000	0.000	.200	.024
B1	0.0000	0.000	0.000	.200	.910
SPDS	0.0000	0.000	0.000	.200	.024

    1 CONDUCTION TRANSFER FUNCTIONS OF ORDER 0

TIME	INTERNAL	CROSS	EXTERNAL	FLUX
1	1.04471375	1.04471375	1.04471375	

THERMAL CONDUCTANCE =   1.045 BTU/(HR*FT**2*F)
OUTER THERMAL ABSORPTANCE = .90
INNER THERMAL ABSORPTANCE = .90
OUTER SOLAR ABSORPTANCE = .75
INNER SOLAR ABSORPTANCE = .75
OUTER SURFACE ROUGHNESS =ROUGH

OPTICAL VALUES

LAYER	TRNS	IR	FTRN	TRNS	REF
SPDS	.860	1.520	0.000		
SPDS	.860	1.520	0.000		

ANGULAR DEPENDENCE OF VALUES:

COS(THETA):   .0625 .1250 .1875 .2500 .3125 .3750 .4375 .5000

TRANSMITTANCE: .0563 .1548 .2639 .3705 .4647 .5415 .6003 .6434
REFLECTANCE: .8314 .7109 .5932 .4830 .3875 .3109 .2532 .2119
ABSORPTANCE: .0872 .0975 .0982 .0959 .0926 .0893 .0862 .0835
ABSORPTANCE: .0251 .0368 .0447 .0507 .0552 .0584 .0603 .0612

FITTED VALUES FOR LOADS CALCULATIONS:

TRANSMITTANCE: .0568 .1540 .2643 .3708 .4645 .5412 .6004 .6436
OUTER ABSORPTANCE: .0855 .1002 .0971 .0944 .0932 .0906 .0859 .0822
INNER ABSORPTANCE: .0249 .0371 .0446 .0505 .0553 .0585 .0603 .0611

ANGULAR DEPENDENCE OF VALUES:

COS(THETA):   .5625 .6250 .6875 .7500 .8125 .8750 .9375 1.00 DIFFUSE

TRANSMITTANCE: .6743 .6962 .7117 .7228 .7308 .7366 .7409 .7440 .6554
REFLECTANCE: .1832 .1639 .1511 .1429 .1380 .1352 .1341 .1341 .2089
ABSORPTANCE: .0811 .0788 .0767 .0747 .0728 .0709 .0691 .0673 .0782
ABSORPTANCE: .0615 .0611 .0605 .0595 .0584 .0572 .0559 .0546 .0575

FITTED VALUES FOR LOADS CALCULATIONS:

TRANSMITTANCE: .6742 .6963 .7118 .7228 .7307 .7366 .7410 .7439 .6554
OUTER ABSORPTANCE: .0811 .0788 .0767 .0747 .0728 .0709 .0691 .0673 .0782
INNER ABSORPTANCE: .0615 .0612 .0605 .0595 .0584 .0572 .0559 .0546 .0575

Figure V.18 Construct report for a window

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V.A.4.5   Control profiles (CPFL)

The first two lines of the control profile report give the user defined
name, description, and the schedule number. The next line is a list of the
user defined control temperatures followed by a line of matching fractions
of full capacity. The number of control points is determined by the user
subject to array dimension constraints. Figure 19 shows this report for two
control profiles.

```
CONTROL PROFILES:

P1              : HEATING SETBACK
  1:
      TMP:   60.000   62.000
      CAP:    1.000    0.000

P2              : STANDARD HEATING
  2:
      TMP:   68.000   70.000
      CAP:    1.000    0.000
```

Figure V.19   Control profiles reports

V.A.4.6   Control day-schedules (CDS)

After the two line of standard heading information the CDS report gives a
list of 24 hours (on four lines) with the profile name and index reported below
each hour. Figure 20 shows a CDS report for two control day-schedules.

V.A.4.7   Control week-schedules (CWS)

The first lines of the control week-schedule report give the user defined
name, description, and the schedule number. These are followed by a list of
12 days: SUN through FRI on one line and SAT through SP4 four lines below.
Below each day name is the name of the control day-schedule in effect on that
day. Below that is the control day schedule number. Figure 21 shows two
control week-schedules.

CONTROL DAY-SCHEDULES:

HN   : NORTH HEATING
  1:
      1   2   3   4   5   6
      P1   P1   P1   P1   P1   P1
      1   1   1   1   1   1

      7   8   9   10   11   12
      P2   P2   P1   P1   P1   P1
      2   2   1   1   1   1

     13   14   15   16   17   18
      P1   P1   P1   P1   P2   P2
      1   1   1   1   2   2

     19   20   21   22   23   24
      P2   P2   P2   P2   P1   P1
      2   2   2   2   1   1

HC   : CENTER HEATING
  2:
      1   2   3   4   5   6
      P1   P1   P1   P1   P1   P1
      1   1   1   1   1   1

      7   8   9   10   11   12
      P1   P1   P1   P1   P1   P1
      1   1   1   1   1   1

     13   14   15   16   17   18
      P1   P1   P1   P1   P2   P2
      1   1   1   1   2   . 2

     19   20   21   22   23   24
      P2   P2   P2   P2   P1   P1
      2   2   2   2   1   1

Figure V.20   Control day-schedule reports

CONTROL WEEK-SCHEDULES:

HEATN   : NORTH HEATING
  1:
     SUN   MON   TUE   WED   THU   FRI
     HN   HN   HN   HN   HN   HN
      1   1   1   1   1   1

     SAT   HOL   SP1   SP2   SP3   SP4
     HN   HN   HN   HN   HN   HN
      1   1   1   1   1   1

HEATC   : CENTER HEATING
  2:
     SUN   MON   TUE   WED   THU   FRI
     HC   HC   HC   HC   HC   HC
      2   2   2   2   2   2

     SAT   HOL   SP1   SP2   SP3   SP4
     HC   HC   HC   HC   HC   HC
      2   2   2   2   2   2

Figure 21.   Control week-schedule reports

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V.B   LOADS REPORTS

V.B.1   DEFAULT REPORTS

Sample default output of the loads calculator program is shown in figure 22. The loads calculator is designed to be recompiled to match the specific problem being simulated. The user may decide to store different compilations on tape. Therefore, the first action of the loads calculator program is not to print the maximum available array space so the user can determine the capabilities of the program by executing it, even without a simulation input file (SINPFL). The names for the array sizes match those reported by the input processor as described in V.A.1 and VI.C. If the user has attached a SINPFL, the program prints the array space required to solve the current simulation. If insufficient space is available, a warning is given, and execution is terminated. Otherwise, simulation begins. If the available array space is much too large, it may be desirable to compile so that just sufficient space is available and charges for program size during execution are minimized. During the calculation of the solar gain multipliers, two other array requirements are reported: the shadowing combinations (CMB) and homogeneous coordinate space (HCS). These sizes depend on the number of surfaces, the shadowing algorithm (3.1.2), and the specific arrangement of surfaces and so they cannot be known before program execution.

The next default report is shown as page 2 in figure 22. It describes the calculational effort used to determine the building loads. First, the temperature and flux history initialization period is reported. The execution time for initialization can be determined by comparing the completion time with the start time (which was given with the page 2 header). Initialization proceeds until load and temperature extreme values for two successive days are within the convergence limits. In this example that required seven days. There were 635 surface and air heat balances, or about 3.78 iterations per hour. This number can be reduced by widening the convergence limits. That will also result in fewer days for initialization. Wider convergence limits tend to change peak values more than they change the total loads. There were 2181 Newton's method iterations to compute air flows. That is about 3.43 iterations per heat balance iteration. There were no heat balance iterations which failed to converge. Failure to converge may be due to an inadequate iteration limit (3.1.3) or to cycling between points on two different segments of a control profile. The loads for that hour may or may not be reasonable. Check the peak loads (below) for impossible values. Similar information on time, days, and iterations is given for the simulation period.

The final summary of building loads is presented as page 3 of the example. The report is headed by three descriptions: project (1.1.1), location (1.3.1), and weather (1.5.1 or 1.6.1). Then the following values are presented for each zone: Total heating and cooling requirements, peak heat and cooling loads, maximum and minimum zone air temperatures, hours at peak heating capacity (HX), other heating hours (HT), ventilating hours (V), cooling (below peak capacity) hours (CL), and hours at peak cooling capacity (CX). Building-wide values are summarized by the line labeled "TOTAL:" These values include the total heating and cooling requirements for all zones, the peak coincident heating and cooling

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loads, and the maximum and minimum of all zone temperatures. The hour and day
are reported for the occurrence of the peak loads and temperatures. In the
example, there is no time reported for peak cooling since there was no cooling
load.

```
PAGE  1  NBS THERMAL ANALYSIS RESEARCH PROGRAM   82/05/17.  05.38.06.    3.004

MRLP MAXIMUM ARRAY DIMENSIONS:

     ZON:    4
     SRF:   36
     HTS:   36
     AFS:   24
     CGS:   16
     GTF:    4
     TFH:  512
     CTF:  192
     SSC:   16
     DSH:   16
     WSH:   16
     CON:   16
     PFL:    8
     CDS:    8
     CWS:    8

MRLP ARRAY SPACE USED:

     ZON:    3
     SRF:   32
     HTS:   32
     AFS:   10
     CGS:   12
     GTF:    1
     TFH:  283
     CTF:  140
     SSC:    3
     DSH:   11
     WSH:   10
     CON:   11
     PFL:    2
     CDS:    3
     CWS:    3



    REQUIRED CMB =    82

    REQUIRED HCS =    10
```

Figure V.22   Default loads calculation output

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BEGIN TEMPERATURE AND FLUX HISTORIES INITIALIZATION

INITIALIZATION COMPLETE AT TIME   5.576
        7 DAYS SIMULATED
      635 HEAT BALANCE ITERATIONS
     2181 AIR FLOW ITERATIONS
        0 ITERATIONS DID NOT CONVERGE

SIMULATION COMPLETE AT TIME   7.867
        1 DAYS SIMULATED
      100 HEAT BALANCE ITERATIONS
      335 AIR FLOW ITERATIONS
        0 ITERATIONS DID NOT CONVERGE

BUILDING LOADS FOR

 THERMAL MASS TEST - SIMULTANEOUS ZONES, DIRECT SUN

 COLUMBIA, MO.

 MILD WINTER

ZONE	TOTAL HEATING (KBTU)	TOTAL COOLING (KBTU)	PEAK HEATING (KBTUH)	PEAK COOLING (KBTUH)	MAX TEMP (F)	MIN TEMP (F)	HX	HT	V	CL	CX
NORTH	52.29	0.00	10.300	0.000	69.26	61.89	0	11	0	0	0
CENTER	1.45	0.00	1.292	0.000	73.00	64.01	0	2	0	0	0
SOUTH	.56	0.00	.563	0.000	77.64	67.78	0	1	0	0	0
TOTAL:	5.430E+01	0.	10.863	0.000	77.64	61.89					

MAX HEATING OCCURS AT HOUR 7 ON 21FEB
MAX TEMP OCCURS AT HOUR 18 ON 21FEB
MIN TEMP OCCURS AT HOUR 6 ON 21FEB

Figure V.22 (continued)

V.B.2   NUMBERED REPORTS

    Several reports and data dumps can be requested by specifying report
numbers (1.2.1).

V.B.2.1   RNOS = 8; Dump of SINPFL as read by loads program

    This is a dump of every value transferred from the input processor to the
loads calculator by the simulation input file (SINPFL). It includes all project
data except the weather and can, therefore, be rather long. Figure 23 for a
SINPFL dump of the sample problem data is four pages long.

    The SINPFL dump begins with a dump of variables which can be described as
run control data. Refer to VI.C for a description of the individual variables.
Next comes a dump of library data beginning with the day-schedules. The data
for each day-schedule consists of the array index, the schedule name, and 24
hours of capacity fractions expressed as percents. The week-schedules are
dumped in a similar manner. Each line describes one schedule and consists of
an array index, the schedule name, and 12 pointers to day-schedule array
indices.

    There is no data for materials. All materials have been used in constructs.
The headings for the constructs data are:

NAME	VARIABLE	DESCRIPTION
NT	NTRTFC	Number of temperature CTF terms
PE	TRTFPE	Pointer to external (X) CTF terms
PC	TRTFPC	Pointer to cross (Y) CTF terms
PI	TRTFPI	Pointer to internal (Z) CTF terms
NF	NFRTFC	Number of flux CTF terms
PF	FLRTFP	Pointer to flux CTF terms
XO	CTFXO	X CTF for time=0
YO	CTFYO	Y CTF for time=0
ZO	CTFZO	Z CTF for time=0
AO	OSABS	Outside solar absorptance
EO	OTABS	Outside thermal emittance
AI	ISABS	Inside solar absorptance
EI	ITABS	Inside thermal absorptance
VF	IVABSF	Multiplier for diffuse solar absorptance
U	UVAL	Thermal conductance of construct
R	OROUGH	Outside roughness number
W	WTYPE	Pointerr to window array index

    The conduction transfer functions are listed directly from the CTF array
at ten numbers per line. The construct pointer values (PE, PC, and PI) point
to the location immediately before CTF location. For example, the X(1) value
of WL-S is -6.3074297 (PE = 7; therefore CTF index = 8). The X(0), Y(0), and
Z(0) values are stored separately. The window pointer, WTYPE, points to the
array index of the window coefficients. In this example, there is only one
window type, but each type has four line of data: one each for transmittance

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and outside, inside, and shade absorptance. Each line of data consists of the window type index, data abbreviation, value for diffuse radiation, and polynomial coefficients for angular properties.

Control profile data consists of the array index, profile name, number of control points, and control temperatures and capacity fractions. In the example, the capacities for P1 are 1.0 at T=15.56 and 0.0 at T=16.67. The control day-schedule data consists of the array index, schedule name, and 24 pointers to control profile array indices. The control week-schedule data consists of the array index, schedule name, and 12 pointers to control day-schedule array indices.

Inputs (4.2) through (4.11) create scheduled loads and activities. Each line of the scheduled loads dump consists of the array index, zone number (CGSZON), type (CGSTYP), start and stop dates (CGSON and CGSOFF), schedule pointer (CGSDF), all 5 values of RCGS, and zone names (CGSZON). See VI.C for descriptions of these variables.

Next the surfaces involved in shadowing and solar gains (SRF) are described. This consists first of the array index, number of vertices, and X, Y, and Z coordinates of the vertices for each surface. Then comes the subsurface data previously described in V.A.3.5.

The heading for the columns of data for the heat transfer surfaces (HTS) are:

NAME	VARIABLE	DESCRIPTION
AREA	AREA	Area of surface
Z	ISENV	Zone number
ONV	OSENV	Outside environment / far side zone number
FSS	FSS	View factor to sky
FSG	FSG	View factor to ground
SSC	SSCPTR	Pointer to special coefficients
K	KPTR	Pointer to construct data
THE	TMPHPE	Pointer to external temperature histories
THI	TMPHPI	Pointer to internal temperature histories
FHE	FLXHPE	Pointer to external flux histories
FHI	FLXHPI	Pointer to internal flux histories
AZM	SFAZIM	Azimuth angle (degrees)
CTILT	CTILT	Cosine of tilt angle
HOC	HOC	Factor for detailed outside convection

The special coefficient data consists of the array index and nine values from ISSC or RSSC (see VI.C) depending on the type of data being described (see also V.A.3.6). Special surface coefficients are stored at the bottom of the array and movable insulation data are stored at the top.

RUN CONTROL:
EMUO = 2

RFLAGS   F F F F F F T T T F F F
         F F F F F F T T F F F
         T T T T F F F F F F F F

SOLDIS = 3
TCNVG   = .0556
LCNVG1 = .0100
LCNVG2 = .0996
MAXIT   = 12
HTBAL   = 0
DHALG   = 0
IHALG   = 0
AFLOW   = 1
ACNVG1 = .0100
ACNVG2 = .0000
ACNVG3 = .0000
AMAXIT = 12

LIBRARY:

DAY-SCHEDULES:
1 NONE
2 FULL   100 100 100 100 100 100 100 100   0   0   0   0
3 ON   100 100 100 100 100 100 100 100   0   0   0   0
4 OC   0 50   0 16 16 17 33 50 67 67 100 100
5 OS   0 50 50 67 67 17 33 50 16 16 33 67
6 LN   0 70 70   0   0 70 70 70 16 16   0 17
7 LC   0 70 70   0   0 70 70 70 70 70 40 70
8 LS   0   0   0   0   0   0   0   0   0   0 30   0
9 EN   0 100 100 100 100   0   0   0 100 100 100 100
10 EC   0 100 100 100 100 100 100 100 70 100   0 100
11 ES   30 30 30 30 30 30 30 30 30 30 30 30

WEEK-SCHEDULES:
1 OCCN   3 3 3 3 3 3 3 3
2 OCCC   4 4 4 4 4 4 4 4
3 OCCS   5 5 5 5 5 5 5 5
4 LITN   6 6 6 6 6 6 6 6
5 LITC   7 7 7 7 7 7 7 7
6 LITS   8 8 8 8 8 8 8 8
7 EQPN   9 9 9 9 9 9 9 9
8 EQPC   10 10 10 10 10 10 10 10
9 EQPS   11 11 11 11 11 11 11 11
10 CONST 2 2 2 2 2 2 2 2

CONSTRUCTS:

		NT	FE	PC	PI	NF	PF	XO	YO	ZO	AO	ED	AI	EI	UF	U	R	J
1	WL-I	2	0	2	4	1	6	2.806	.220	4.248	.750	.900	.750	.900	.750	.279	2	0
2	WL-S	4	7	11	15	1	19	4.593	.005	8.684	.750	.900	.750	.900	.750	1.000	2	0
3	FTN-A	1	21	22	23	2	24	8.494	4.503	8.494	.750	.900	.750	.900	.750	4.900	2	0
4	FTN-S	4	25	29	33	2	37	8.684	.019	8.684	.750	.900	.750	.900	.750	1.241	2	0
5	WDW2	0	39	39	39	0	39	5.928	5.928	5.928	.750	.900	.750	.900	.136	5.928	2	1
6	FRAME	2	39	41	43	1	45	5.481	1.529	5.481	.750	.900	.750	.900	.750	2.829	2	0
7	RF-T	6	46	52	58	5	64	6.643	.000	8.065	.750	.900	.750	.900	.750	.569	2	0
8	RF-I	2	69	71	73	1	75	3.873	.155	3.369	.750	.900	.750	.900	.750	.185	2	0
9	PTN-M	8	76	79	82	2	85	33.881	.345	33.881	.750	.900	.750	.900	.750	8.507	2	0
10	SLAB-C	8	87	95	103	2	111	7.300	.000	2.552	.700	.900	.750	.900	.750	.457	2	0
11	SLAB-T	7	115	122	129	4	136	7.300	.000	33.543	.700	.900	.750	.900	.750	.549	2	0

Figure V.23   Dump of SINPFL

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TRANSFER FUNCTIONS:
```
  1   -2.5278906    .0007745    .0585821    .0000064    .0023383    .0005898   -6.3074297    2.1913321    -.1701522
 11    -.0001604    .1303580   .1530421    .0182837  -13.2198161   5.2871352    -.4435605    -.0006664     .7875525
 21    -.0944633  -3.5941588   .3969768  -3.5941588  -11.4942369   3.5327878    -.1659994    -.0000684     .3021272
 31     .2226306   .0130220   .0000669  -11.4942369   3.5327878   -.0000684     .5888675    -.0373564   -2.7764006
 41    -.0339609  1.1996385   .0093482  -2.7764006    .0339609  -16.8168694  15.3861333    -6.2155929   1.0945002
 51    -.0726984   .0012641   .0009941    .0029472    .0093951    .0060339    .0000372  -20.8567580   19.5905340
 61   -8.1700639  1.4917542  -.1027480    .0018451   1.8687430    .2754416    -.0229241     .0004788   -3.6880357
 71     .0001720   .0299762   .0000004  -3.1848037    .0003207    .0001007   7.3391719    -.1604196    2.8850762
 81    1.2008836   .0286105 -36.6001481  7.3391719   -.1604196    .4948389 -36.6001481  -22.0509244   24.4059857  -11.8667380
 91    2.3390075  -.1257694  -.0005882   -.0000003   -.0000066    .0001889     .0006341    .0004705     .0001002
101     .0000084   .0000004   .0000000  -6.3591088  -1.7329572   .1629810    -.0009349    -.0000293    -.0000011
111    -.0000000  2.4347023 -2.0132431   .6308696   -.0554117  16.8112578 -18.4101751   -6.7871467   1.1601606    -.0580476
121    -.0002645  -.0000056   .0001719    .0034217    .0080983    .0039974    .0004949     .0000005   -87.6863367
131   80.8926204 -31.3375508  4.8604217   -.2553859   -.0000927   -.0000001  1.9360081    -1.2650689    .3252876    -.0257356
                      -I          -I          -I          -I          -I          -I          -I          -I
```

WINDOW COEFFICIENTS:
```
1  T    .65542   -.38381    4.40219   -6.78177    4.83510   -1.32778     .38545    10.30802  -33.94973    50.15423  -39.59056   14.09256
1  A0   .07823    .12151    -.13248     .16526    -.12220     .03523    2.42765   -22.36321  100.21852  -235.54957  277.25274 -128.67078
1  AI   .05746    .01224     .24052    -.41182     .29335    -.07969     .57577    -3.64283   14.98693   -34.40082   39.84106  -18.20434
1  AS  0.00000      -I         -I         -I         -I         -I         -I         -I         -I         -I          -I         -I
```

CONTROL PROFILES:
```
1 P1    2   15.56   1.00   16.67   0.00   0.00   0.00   0.00   0.00   0.00
2 P2    2   20.00   1.00   21.11   0.00   0.00   0.00   0.00   0.00   0.00
                                    -I
```

CONTROL DAY-SCHEDULES:
```
1 HN    1    1    1    1    1    1    1    1    1
2 HC    1    1    1    2    2    2    2    2    2
3 HS    1    1    1    1    1    1    1    1    1
```

CONTROL WEEK-SCHEDULES:
```
1 HEATN   1    1    1    1    1    2    2    1    1
2 HEATC   2    2    2    1    1    2    2    1    1
3 HEATS   3    3    3    3    3    2    2    1    1
```

SCHEDULED LOADS:
```
 Z  TYP  ON  OFF   WS
 1   1   12  33   415   1   3514.501**********   3514.501**********   0.000 NORTH
 2   1   1   33   415   1      3.000                131.800           0.000 NORTH
 3   1   2   33   415   4    410.025                  0.000            .200 NORTH
 4   1   3   33   415   7    292.875                  0.000            .700 NORTH
 5   2  12   33   415   2   3514.501**********   3514.501**********   0.000 CENTER
 6   2   1   33   415   2      3.000                131.800           0.000 CENTER
 7   2   2   33   415   5    410.025                  0.000            .200 CENTER
 8   2   3   33   415   8    292.875                  0.000            .700 CENTER
 9   3  12   33   415   3   3514.501**********   3514.501**********   0.000 SOUTH
10   3   1   33   415   3      3.000                131.800           0.000 SOUTH
11   3   2   33   415   6    410.025                  0.000            .200 SOUTH
12   3   3   33   415   9   2753.026                  0.000            .300 SOUTH
```

Figure V.23 (continued)

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SURFACES:

	CA	SA	CT	ST	S1	S2	ON	OFF	TRANS
1	-1.000	-.000	.894	.448	0	0	33	415	0.000
2	-1.000	-.000	.894	.448	0	0	33	415	0.000
3	-1.000	0.000	-.448	-.894	0	0	33	415	0.000
4	1.000	0.000	.000	1.000	2	2	0	0	0.000
5	1.000	0.000	.000	1.000	3	-2	0	0	0.000
6	1.000	0.000	-.000	1.000	4	4	0	0	0.000
7	1.000	0.000	.894	.448	5	5	0	0	0.000
8	1.000	0.000	.894	.448	6	6	0	0	0.000
9	-1.000	0.000	.000	1.000	7	7	0	0	0.000
10	-1.000	-1.000	.000	1.000	8	8	0	0	0.000
11	-1.000	1.000	.000	1.000	9	9	0	0	0.000
12	-1.000	-.000	-1.000	.000	10	10	0	0	0.000
13	-1.000	.000	.000	1.000	12	12	0	0	0.000
14	1.000	0.000	.894	.448	13	-12	0	0	0.000
15	1.000	0.000	.894	.448	14	14	0	0	0.000
16	-1.000	0.000	.000	1.000	15	15	0	0	0.000
17	-1.000	0.000	.000	1.000	16	16	0	0	0.000
18	-1.000	.000	-1.000	-.000	17	17	0	0	0.000
19	1.000	0.000	.000	1.000	18	18	0	0	0.000
20	1.000	-1.000	-1.000	.000	19	19	0	0	0.000
21	1.000	.000	.000	1.000	20	20	0	0	0.000
22	-1.000	0.000	-1.000	.000	21	21	0	0	0.000
23	-1.000	-1.000	-1.000	.000	23	23	0	0	0.000
24	-1.000	.000	-1.000	-.000	24	-23	0	0	0.000
25	-1.000	0.000	.000	1.000	25	25	0	0	0.000
26	-1.000	.000	.894	.448	26	26	0	0	0.000
27	1.000	.000	.894	.448	27	27	0	0	0.000
28	-1.000	0.000	.000	1.000	28	28	0	0	0.000
29	1.000	0.000	-1.000	1.000	29	29	0	0	0.000
30	.000	-1.000	-1.000	1.000	30	30	0	0	0.000
31	-1.000	1.000	-1.000	1.000	31	31	0	0	0.000
32	-1.000	-1.000	-1.000	-.000	32	32	0	0	0.000

Figure V.23   (continued)

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HEAT TRANSFER SURFACES:

	AREA	Z	ONV	FSS	FSG	SSC	K	THE	THI	FHE	FHI	AZM	CTLT	HOC
1	44.59	1	-1	0.00	0.00	0	3	0	0	1	1	0.	0.00	0.00
2	30.47	1	-3	.50	.50	0	1	2	4	6	7	0.	-.00	3.36
3	3.72	1	-3	.50	.50	0	5	8	8	8	8	0.	-.00	3.36
4	2.23	1	-3	.50	.50	0	2	8	12	16	18	0.	-.00	5.88
5	34.09	1	-3	.95	.05	0	7	20	26	32	37	0.	.89	3.34
6	2.49	1	-3	.95	.05	0	8	42	44	46	47	0.	.89	6.04
7	49.05	1	-2	18	T	0	9	131	48	134	51	180.	-.00	6.00
8	11.15	1	-2	.50	.50	0	9	53	53	56	56	270.	-.00	0.00
9	49.05	1	-2	.50	1.00	16	9	58	58	61	61	90.	-.00	0.00
10	11.15	1	-4	.00	0.00	0	10	63	71	79	83	180.	-1.00	1.30
11	44.59	2	-1	.00	0.00	0	3	87	87	88	88	0.	0.00	0.00
12	12.26	2	-3	.50	.50	0	6	89	91	93	94	180.	-.00	5.52
13	11.15	2	-3	.50	.50	0	5	95	95	95	95	180.	-.00	5.52
14	34.09	2	-3	.95	.05	0	7	95	101	107	112	0.	.89	3.44
15	2.49	2	-3	.95	.05	0	8	117	119	121	122	0.	.89	6.21
16	45.71	2	3	28	T	0	3	218	123	219	124	180.	-.00	0.00
17	3.34	2	3	29	T	0	4	220	125	224	129	180.	-.00	0.00
18	49.05	2	-1	7	.50	0	9	48	131	51	134	270.	-.00	0.00
19	15.61	2	-2	.50	.50	0	9	136	136	139	139	90.	-.00	1.30
20	15.61	2	-2	.50	.50	15	10	141	141	144	144	180.	-1.00	0.00
21	49.05	2	-4	.00	1.00	0	1	146	154	162	166	180.	-0.00	3.36
22	44.59	3	-1	.00	0.00	0	3	170	170	171	171	0.	-.00	3.36
23	30.47	3	-3	.50	.50	0	5	172	174	176	177	180.	-.00	5.88
24	7.43	3	-3	.50	.50	0	2	178	178	178	178	180.	-.00	3.34
25	2.23	3	-3	.95	.05	0	7	178	182	186	188	180.	.89	6.04
26	34.09	3	-3	.95	.05	0	8	190	196	202	207	180.	-.00	0.00
27	2.49	3	-3	.95	T	0	8	212	214	216	217	0.	.89	0.00
28	45.71	3	2	16	T	0	3	123	218	124	219	0.	-.00	0.00
29	3.34	3	2	17	T	0	4	125	220	129	224	0.	-.00	0.00
30	11.15	3	-2	.50	.50	0	9	226	226	229	229	270.	-.00	0.00
31	11.15	3	-2	.50	.50	0	9	231	231	234	234	90.	-.00	0.00
32	49.05	3	-4	0.00	1.00	14	11	236	243	250	254	180.	-1.00	1.30

SPECIAL COEFFICIENTS:

16	3	3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	10
15	3	3	0.000	0.000	0.000	0.000	1.000	1.000	0.000	0.000	1.000	0.000	21
14	3	3	0.000	0.000	0.000	0.000	1.000	1.000	0.000	0.000	1.000	0.000	32

AIR FLOW SURFACES:

	FAREA	FEXP	ZS	ZV	FCOS1	FCOS2	PTR	NAME
1	.0186	.650	1.22	.64	1.000	0.000	0	
2	.0093	.650	3.05	.70	.448	0.000	0	
3	.0465	.500	1.83	.70	0.000	0.000	2	CENTER
4	.0232	.650	4.11	.73	-1.000	-.000	0	
5	.0093	.650	4.27	.74	-.448	0.000	0	
6	.0465	.500	1.83	.70	0.000	0.000	3	SOUTH
7	.0465	.500	1.83	.64	0.000	0.000	1	NORTH
8	.0186	.650	1.22	.70	-1.000	-.000	0	
9	.0093	.650	3.05	.70	-.448	-.000	0	
10	.0465	.500	1.83	.70	0.000	0.000	2	CENTER

ZONE RELATED VALUES:

	NAME	FSRF	LSRF	FHTS	LHTS	FAFS	LAFS	ZZ	VMULT	VCONV
1	NORTH	4	12	1	10	1	3	1.500	.0056	0.0000
2	CENTER	13	22	11	21	4	7	1.500	.0047	0.0000
3	SOUTH	23	32	22	32	8	10	1.500	.0055	0.0000

Figure V.23   (continued)

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The headings for the air flow opening data are:

NAME	VARIABLE	DESCRIPTION
FAREA	FAREA	Effective flow area
FEXP	FEXP	Flow exponent
ZS	ZS	Height of opening
ZV	ZVMOD	Factor for wind pressure calculation
FCOS1	FCOS2	Direction cosine
FCOS2	FCOS2	Direction cosine
PTR	AFSPTR	Number of adjacent zone (0=ambient)
NAME	AFSNAM	Name of adjacent zone

The zone related values consist of the array index, the zone name, the indices of the first and last surfaces which are part of the zone, the first and last heat transfer surface numbers, the first and last air flow surface numbers, the height of the zone for pressure calculations, and multipliers for visible and convective gains.

V.B.2.2   RNOS = 9; Zone description report

This report gives a description of each zone (one zone per page). It begins with the zone name, for example, NORTH in figure V.24. Next is a listing of the scheduled loads and controls. The data is presented using the input variable names. The surfaces of the zone are described next. The first zone includes a description of the detached shadowing surfaces. The reported U-values do not include surface coefficients. Finally, the air flow openings are described. ZONE is the name of the zone on the other side of the opening.

DESCRIPTION OF ZONE NORTH

SCHEDULED LOADS AND CONTROLS

TYPE	SCHEDULE	FROM	THRU	DATA			
CTRL	HEATN	1JAN	31DEC	HEAT= 1.20E+04	COOL= 3.41E+09	RAD=0.00	
PEO	OCCN	1JAN	31DEC	CAP= 3.00E+00	ACT= 4.50E+02	RAD= .50	
LIT	LITN	1JAN	31DEC	CAP= 1.40E+03	RA=0.00	RAD= .20	VIS= .20
				REP=0.00			
EQP/EL	EQPN	1JAN	31DEC	CAP= 1.00E+03	LAT=0.00	RAD= .30	LOST=0.00

SURFACES

TYPE	AZM	TILT	AREA	U	CONSTRUCT	ZONE	FROM	THRU	TRNS
DET. SHADE	180.	153.					1JAN	31DEC	.000
DET. SHADE	180.	153.					1JAN	31DEC	.000
DET. SHADE	0.	117.					1JAN	31DEC	.000
ENVELOPE	0.	90.	328.00	.049	WL-I				
WINDOW	0.	90.	40.00	1.045	WDW2				
ENVELOPE	0.	90.	24.00	.176	WL-S				
ENVELOPE	0.	27.	366.95	.100	RF-T				
ENVELOPE	0.	27.	26.85	.033	RF-I				
INTERZONE	180.	90.	528.00	1.499	PTN-M	CENTER			
PARTITION	270.	90.	120.00	1.499	PTN-M				
PARTITION	90.	90.	120.00	1.499	PTN-M				
USER DEFND	180.	180.	528.00	.081	SLAB-C				

AIR FLOW OPENINGS

AREA	EXP	ZS	ZONE
.0186	.65	1.22	AMBIENT
.0093	.65	3.05	AMBIENT
.0465	.50	1.83	CENTER

Figure V.24   Zone description report

V.B.2.3   RNOS = 13; Report of sunlit fractions

This report gives the fraction sunlit area for all heat transfer surfaces. It begins with the date and solar declination and equation of time values used in computing the solar position. The values of the cosine of the angle of incidence on each surface and the sunlit fraction are presented for 24 hours on the half hour. Nine values from ISSC or RSSC (see VI.C) depending on the They are in the HTS number sequence. The sunlit fractions apply only to the outside of envelope surfaces, so partitions and such cannot have sunlit fractions but are reported to maintain the sequence of surfaces.

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RESULTS OF SHADOWING CALCULATIONS

DATE = 21FEB   SIN(DECL) =-.1875   COS(DECL) = .9823   EQN OF TIME =-.2299

FORM OF DATA: / COSINE OF INCIDENCE, SUNLIT FRACTION /

STANDARD TIME = 0:30
```
/   -I,    -I   /  -I,0.000   /  -I,0.000   /  -I,0.000   /  -I,0.000   /  -I,0.000  /
/  -I,0.000  /   -I,    -I    /  -I,0.000   /  -I,0.000   /  -I,0.000   /  -I,0.000  /
/  -I,0.000  /  -I,0.000   /  -I,0.000   /  -I,0.000   /  -I,0.000   /  -I,0.000  /
/  -I,0.000  /  -I,0.000   /  -I,0.000   /  -I,0.000   /  -I,0.000   /  -I,0.000  /
```
.
.

STANDARD TIME = 10:30
```
/   -I,    -I   / -.689,0.000  / -.689,0.000  / .188,1.000  / .188,1.000  / .465,0.000 /
/ .465,0.000  /  -.556,0.000  /   -I,    -I   / .689, .929  / .188,1.000  / .689,1.000 /
/ .689,0.000  /  -.689,0.000  / .465,0.000  / -.556,0.000  /  -I,    -I   / .689, .545 /
/ .689, .766  /  .805,1.000   / -.689,0.000  / -.689,0.000  / -.465,0.000  / .465,0.000 /
```

STANDARD TIME = 11:30
```
/   -I,    -I   / -.746,0.000  / -.746,0.000  / .226,1.000  / .226,1.000  / .225,0.000 /
/ .225,0.000  /  -.626,0.000  /   -I,    -I   / .746, .928  / .226,1.000  / .746,1.000 /
/ .746,0.000  /  -.746,0.000  / .746, .091  / -.626,0.000  /   -I,    -I   / .746, .542 /
/ .746, .727  /  .894,1.000   / -.746,0.000  / -.746,0.000  / -.225,0.000  / .225,0.000 /
```
.
.

REQUIRED HCS =   10
```

Figure V.25   Results of shadowing calculations

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V.B.2.4    RNOS = 14; Report of shadowing combinations

    Some surfaces of the building can never be shaded by others because of
various geometric constraints.  TARP does a one-time determination of which
surfaces can possibly be shaded by others and stores the results to save
time in long term or multiple environment runs.  The shadowing combinations
report for the example problem is shown in figure 26.  Information is
presented for each General shadow Receiving Surface (GRS), that is, each
EXterior, Base Surface (4.13.2) of the building.  Surfaces are referred to by
their SRF numbers.  The first such surface is GRSNR = 4.  For this surface
there is one possible shadowing surface (NGSS = 1), seven interior surfaces
which may receive direct sun through the window (NBKS = 7), and one subsurface
(NSBS = 1) (4.13.2).  A general shadowing surface (GSS) is either a GRS or a
detached shadowing surface (3.2).  The one GRS which might shade GRS #4 is SRF
#3.  The detailed solar distribution within the zone must refer to the EXterior
of INterior (4.13.2) surfaces which are called back surfaces (BKS) during
shadowing calculations.  The seven back surfaces which might receive beam
sunlight through the window are SRFs #6, 7, 8, 9, 10, 11, and 12.  The only
subsurface of the GRS is SRF #5.  Note that GRS #6 has no (transparent) SBS
and therefore no BKS need be computed.

```
PAGE   4  NBS THERMAL ANALYSIS RESEARCH PROGRAM   82/05/11.  14.04.45.    3.182

SHADOWING COMBINATIONS

GRSNR =    4      NGSS =  1      NBKS =  7      NSBS =  1
     GSSNR =     3
     BKSNR =     6     7     8     9    10    11    12
     SBSNR =     5

GRSNR =    6      NGSS =  1      NBKS =  0      NSBS =  0
     GSSNR =     3

GRSNR =    7      NGSS =  0      NBKS =  0      NSBS =  0

GRSNR =    8      NGSS =  0      NBKS =  0      NSBS =  0

GRSNR =   13      NGSS =  3      NBKS =  8      NSBS =  1
     GSSNR =     1    26    27
     BKSNR =    15    16    17    18    19    20    21    22
     SBSNR =    14

GRSNR =   15      NGSS =  0      NBKS =  0      NSBS =  0

GRSNR =   16      NGSS =  0      NBKS =  0      NSBS =  0

GRSNR =   23      NGSS =  1      NBKS =  8      NSBS =  1
     GSSNR =     2
     BKSNR =    25    26    27    28    29    30    31    32
     SBSNR =    24

GRSNR =   25      NGSS =  1      NBKS =  0      NSBS =  0
     GSSNR =     2

GRSNR =   26      NGSS =  2      NBKS =  0      NSBS =  0
     GSSNR =     1    13

GRSNR =   27      NGSS =  2      NBKS =  0      NSBS =  0
     GSSNR =     1    13

   REQUIRED CMB =    82
```

Figure V.26   Shadowing combinations report

V.B.2.5   RNOS = 15, 16; Dump of shadowing calculations

The shadowing calculation dumps are intended for checking the shadow calculation process. They produce a large amount of output. Figure V.27 shows part of the output for only one hour. Report 15 provides summary results such as a record of which subroutines where called and the net results of the calculations. Report 16 gives the details of the homogeneous coordinate calculations. The output from 16 is printed as the calculations occur, and so it is intermingled with report 15. The output consists of subroutine names (see VI.B) and variable names (see VI.C) with values. To use this report, follow the calculations through the program listing and simultaneously through the report.

```
STANDARD TIME = 10:30
/    -I,    -I /  -.689,0.000 /  -.689,0.000 /  -.689,0.000 /   .188,1.000 /   .188,1.000 /   .689,0.000 /  -.465,0.000 /
/   .465,0.000 /  -.689,0.000 /     -I,    -I /    .689,  .091 /   .689,  .929 /   .188,1.000 /   .188,1.000 /   .689,0.000 /
/   .689,0.000 /  -.556,0.000 /  -.465,0.000 /  -.465,0.000 /  -.556,0.000 /     -I,    -I /   .689,  .545 /   .689,  .610 /
/   .689,  .766 /   .805,1.000 /   .805,1.000 /  -.689,0.000 /  -.689,0.000 /  -.689,0.000 /   .465,0.000 /  -.556,0.000 /
```

DUMP OF SHADOWING CONTROL DATA

```
EQTM=-.230  SIND=-.188  COSD= .982  SUNCOS(I)=   .225  -.746   .626

BEGIN SHDGRS: GRSNR= 4 HTS= 2  CTHETA(GRSNR)=-.746  NGSS= 1  NBKS= 7  NSBS= 1  LOCSCH= 1
SHDSRS:  SRSNR= 5  HTSS= 3
  END SHDINT: DB(NZ)=    0.000  DS(NZ)=   1.218  DG(NZ)=   1.218
  END SBS:  SAREA(HTSS)=    0.000  NSBSHC= 0  NRVLHC= 0  TRH=0.00  ABO= .75  ARI=0.00  CBI=0.00
  END SHDGRS:  GRSNR= 4 HTS= 2  SAREA(HTS)=      0.000

BEGIN SHDGRS:  GRSNR= 6 HTS= 4  CTHETA(GRSNR)=-.746  NGSS= 1  NBKS= 0  NSBS= 0  LOCSCH= 14
  END SHDGRS:  GRSNR= 6 HTS= 4  SAREA(HTS)=      0.000

BEGIN SHDGRS:  GRSNR= 7 HTS= 5  CTHETA(GRSNR)= .226  NGSS= 0  NBKS= 0  NSBS= 0  LOCSCH= 19
  END SHDGRS:  GRSNR= 7 HTS= 5  SAREA(HTS)=     34.091

BEGIN SHDGRS:  GRSNR= 8 HTS= 6  CTHETA(GRSNR)= .226  NGSS= 0  NBKS= 0  NSBS= 0  LOCSCH= 23
  END SHDGRS:  GRSNR= 8 HTS= 6  SAREA(HTS)=      2.494

BEGIN SHDGRS:  GRSNR= 13 HTS=12  CTHETA(GRSNR)= .746  NGSS= 3  NBKS= 8  NSBS= 1  LOCSCH= 27
  HCGRS:  NS= 1 NV=4  AREA=     12.258  C=   .302  S=   .839
  HC:    13411     914/       13411       914/       0/       0      914/
SHDGSS:  GSSNR= 1  CTHETA(GSSNR)=-.226
HCGSS:   NS= 2 NV=4  AREA=    -2.468  T=0.00
  HC:    13411    1219/       13247     1035/      -164  AREA=   1035/       0  T=0.00
  OVRLAP:  NS1= 1  NS2= 2  NS3= 2  NIN1=0  NIN2=0  NIN3=0  MISS=1  AREA=     -2.468  T=0.00
SHDGSS:  GSSNR= 26  CTHETA(GSSNR)= .894
SHDGSS:  GSSNR= 27  CTHETA(GSSNR)= .894
END SHDGSS:  SAREA(HTS)=    12.258   NGSSHC= 0
SHDBKS:  BKSNR= 15  CTHETA(BKSNR)= .226  FBKSHC= 2   NBKSHC= 0
SHDBKS:  BKSNR= 16  CTHETA(BKSNR)= .226  FBKSHC= 2   NRKSHC= 0
SHDBKS:  BKSNR= 17  CTHETA(BKSNR)= .746  FBKSHC= 2   NBKSHC= 0
SHDBKS:  BKSNR= 18  CTHETA(BKSNR)= .746  FBKSHC= 2   NBKSHC= 0
SHDBKS:  BKSNR= 19  CTHETA(BKSNR)=-.746  FBKSHC= 2   NBKSHC= 0
HCBKS:   NS= 2 NV=4  AREA=    -49.044  T=0.00
  HC:    14514    3069/       14514      -588/     1103     1103      3069/
  OVRLAP:  NS1= 1  NS2= 2  NS3= 2  NIN1=2  NIN2=0  NV3=4  MISS=4  AREA=    -11.250  T=1.00
  HC:    1103      0/       1103       914/     13411   13411      0/
SHDBKS:  BKSNR= 20  CTHETA(BKSNR)=-.225  FBKSHC= 2.  NBKSHC= 1
HCBKS:   NS= 3 NV=4  AREA=    -4.707  T=0.00
  HC:    1103    3069/       1103      -3658/        0        0     1219/
  OVRLAP:  NS1= 1  NS2= 3  NS3= 3  NIN1=2  NIN2=0  NV3=4  MISS=4  AREA=     -1.008  T=1.00
  HC:       0      0/          0       914/      1103     1103      0/
SHDBKS:  BKSNR= 21  CTHETA(BKSNR)= .225  FBKSHC= 2   NBKSHC= 2
SHDBKS:  BKSNR= 22  CTHETA(BKSNR)=-.626  FBKSHC= 2   NRKSHC= 2
HCBKS:   NS= 4 NV=4  AREA=    -41.172  T=0.00
  HC:       0  -3658/       1103       -588/     14514   13411     -3658/
  OVRLAP:  NS1= 1  NS2= 4  NS3= 4  NIN1=0  NIN2=0  NV3=0  MISS=1  AREA=    -41.172  T=1.00
HCBKS:   NBKSHC= 2
END SHDBKS:
```

Figure V.27 Dump of shadowing calculations

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SHDSBS; SBSNR= 14 HTSS=13
HCSBS: NS= 4 NV=4 AREA= 11.143
  HC: 12802   914/   0/   610   0/   914/
SHDRVL: NSBSHC= 1
HCRVL: NS= 5 NV=4 AREA= 10.344
  HC: 12802   914/   64/   633   64/   914/
END SHDRVL; NRVLHC= 1 SAREA(HTSS)= 10.344
SHDINT; FINSHC= 5 FBKSHC= 2 NBKSHC= 2 FSBSHC= 4 NSBSHC= 1 DB(NZ)= 0.000
MULTOL; LOCHCA= 4
OVRLAP: NS1= 4 NS2= 2 NS3= 5 NIN1=2 NIN2=1 NV3=4 MISS=4 AREA= 9.944 T=1.00
  HC: 1103   914/   12802   12802   64/   1103
END MULTOL; LOCHCA= 5
MULTOL; LOCHCA= 4
OVRLAP: NS1= 4 NS2= 3 NS3= 5 NIN1=2 NIN2=1 NV3=4 MISS=4 AREA= .400 T=1.00
  HC: 633   64/   633   1103   914/   1103
END MULTOL; LOCHCA= 5
END SHDINT; DB(NZ)= 1.394 DS(NZ)= 3.653 DG(NZ)= 3.653 ABI= .06 CBI=0.00
END SBS; SAREA(HTSS)= 10.344 NSBSHC= 1 NRVLHC= 1 TBM= .72 ABO= .07
END SHDGRS; GRSNR= 13 HTS= 12 SAREA(HTS)= 1.114

. . .

AO   0.000   0.000   0.000   .169   0.000   0.000
          0.000   .051   .169   .169   0.000   0.000
          0.000   .052   .033   .407   .671   .670
          0.000   .303   .000   0.000   0.000   0.000

AI   0.000   0.000   0.000   0.000   0.000   0.000
          0.000   .041   0.000   .082   .010   0.000
          0.000   .000   .027   0.000   0.000   0.000
          0.000   .027

CR   0.000   0.000   0.000
DB   0.000   .597   1.394
DS   1.218   3.653   3.653
DG   1.218   2.436   3.653
                  2.436

STANDARD TIME = 11:30
  / -I, -I / -.746,0.000 / -.746,0.000 / .226,1.000 / .746,0.000 / -.225,0.000 /
  / .225,0.000 / -.626,0.000 /   -I, -I / .746, .091 / .746, .928 / .226,1.000 / .746,0.000 /
  / .746,0.000 / -.746,0.000 / -.225,0.000 / .225,0.000 / -.626,0.000 /   -I, -I / .746, .542 / .746, .596 /
  / .746, .727 / .894,1.000 / .894,1.000 / -.746,0.000 / -.746,0.000 / -.225,0.000 / -.626,0.000 /

Figure V.27 (continued)

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V.B.2.6   RNOS = 21; Hourly dump of primary zone loads data

   This report provides hourly loads data. It consists of a line of time data, a line of weather data, and a line of loads data for each zone (see figure V.28). All data are in metric units. The time data consists of:

STDTIM   standard time; ts in (III.B.1.1)
CLKTIM   clock time.; td in (III.B.1.1)
DAYOFS   number of days simulated (including current day)
DAYOFY   day of year; DY in (B.1.2)
MONTH   month number
DAYOFM   day of month
DAYOFW   day of week; DW in (B.1.7)
DAYTYP   day type; pointer to schedules
CDATE   cyclic date; CD in (B.1.4)

   The weather data consists of:

DB   dry-bulb temperature
WB   wet-bulb temperature
BP   barometric pressure
SPD   wind speed
DIR   wind direction
TS   sky temperature
HB   direct normal solar flux
HD   sky brightness
HR   ground brightness
TG   ground temperature

   The zone loads data consists of:

TZ   zone air temperature
TR   zone radiant temperature
SN   sensible load (+ = heating, - = cooling
LA   latent gain from internal sources
EE   energy for lights and electric equipment
GE   energy for steam equipment
ST   energy for gas equipment
HW   energy for hot water equipment
OT   energy for other equipment
RA   energy direct to return air
BB   baseboard load
OAMFL   mass flow rate of outside air into zone

TIME: STDTIM=16; CLKTIM=16; DAYOFS= 1; DAYOFY= 52; MONTH= 2; DAYOFM=21; DAYOFW=2; DAYTYP= 2; CDATE= 85
WEATHER: DB= 9.67; WB= 4.27; BP=100000.; SPD= 6.7; DIR=315.; TS= -7.39; HB=852.7; HD= 51.7; HR= 80.0; TG= 5.56

LOADS:	TZ	TR	SN	LA	EE	GE	ST	HW	OT	RA	BB	OAMFL
1	17.62	18.15	0.	0.	0.	0.	0.	0.	0.	0.		4.450E-02
2	22.37	22.55	0.	0.	0.	0.	0.	0.	0.	0.		0.
3	23.79	23.82	0.	8.259E+02	0.	0.	0.	0.	0.	0.		6.789E-03

TIME: STDTIM=17; CLKTIM=17; DAYOFS= 1; DAYOFY= 52; MONTH= 2; DAYOFM=21; DAYOFW=2; DAYTYP= 2; CDATE= 85
WEATHER: DB= 8.89; WB= 3.86; BP=100000.; SPD= 6.7; DIR=315.; TS= -8.12; HB=675.5; HD= 40.9; HR= 41.5; TG= 5.56

LOADS:	TZ	TR	SN	LA	EE	GE	ST	HW	OT	RA	BB	OAMFL
1	20.47	19.44	2.040E+03	1.600E+01	1.353E+02	0.	0.	0.	0.	0.		4.559E-02
2	22.78	22.47	0.	2.701E+02	4.979E+02	0.	0.	0.	0.	0.		8.418E-03
3	25.20	24.77	0.	5.915E+01	3.040E+03	0.	0.	0.	0.	0.		

TIME: STDTIM=18; CLKTIM=18; DAYOFS= 1; DAYOFY= 52; MONTH= 2; DAYOFM=21; DAYOFW=2; DAYTYP= 2; CDATE= 85
WEATHER: DB= 7.67; WB= 3.21; BP=100000.; SPD= 6.7; DIR=315.; TS= -9.27; HB=107.0; HD= 6.5; HR= 2.6; TG= 5.56

LOADS:	TZ	TR	SN	LA	EE	GE	ST	HW	OT	RA	BB	OAMFL
1	20.57	19.79	1.722E+03	2.139E+01	1.353E+02	0.	0.	0.	0.	0.		4.622E-02
2	22.24	21.83	0.	2.798E+01	5.799E+02	0.	0.	0.	0.	0.		0.
3	25.36	24.72	0.	6.616E+01	3.040E+03	0.	0.	0.	0.	0.		9.520E-03

Figure V.28   Hourly dump of zone loads

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V.B.2.7   RNOS = 21, 22, 23, 24; Dump of zone loads calculations

Reports 22, 23, and 24 give details of the loads calculation process. All are in metric units. These dumps can be quite lengthly. Figure 29 shows part of the output generated for one hour. Report 21 should be specified to report times for the other reports.

Report 22 describes the control profiles and solar gains for the hour. The report of control values describes the control profile (IV.E) for each zone. It consists first of the zone number, the number of control temperature ranges (NRCTR), and the temperature range which will be used for the first air heat balance (EFSTR). The second line is a list of control point temperatures. It is followed by the QFSTDC and QFSTIF variables for the control ranges between the indicated temperatures. The solar gains data consists first of the total short wavelength (including from lights) flux (W/m^2) absorbed by each heat transfer surface on the outside (QSO), the inside (QSI), and on any movable insulation (QSM). Then the radiant gains converted directly to convection (QC), the total diffuse solar gain (QD), the total diffuse shortwave radiant gain (QS), the total beam sunlight into the zone (QBV), and the total diffuse sunlight into the zone (QDV).

The following dumps (23) describe the heat balance calculations. They begin with the airflow calculations. The following data is presented for each airflow opening (I).

N	(inside) zone number
M	(far side) zone number (0 = ambient)
PS	stack pressure (G.2.3)
PW	wind pressure (G.1.3)
PZ	zone pressure
DP	pressure difference across opening
FLOW	mass flow rate through opening (+ = in, − = out)

Then the partial outside (KOP) and partial inside (KIP) conductive fluxes (C.1.7 and C.1.5) are presented for each heat transfer surface. These values are constant for the hour. The convection coefficients (HC) are also presented for each surface followed by the outside surface temperatures (TO) and then the inside surface temperatures (TI). The results of the zone air heat balances are summarized under ZON:

TZ	zone air temperature
TR	zone mean radiant temperature
ET	effective temperature
CT	control temperature range
VT	ventilation control range
SL	sensible load (+ = heat, − = cool)
LL	latent load
SUMC	sum of direct convective loads
QL	total longwave radiant gains
PZ	zone air pressure

The FLOW, TI and ZON values are dumped for each heat balance iteration. HC and TO may also be dumped if new values are computed.

Report 24 is a dump of the contents of the temperature and flux histories array. It occurs after heat balances have converged. The hourly shift of the histories is accomplished by the TSHIFT variable until it equals zero and the histories are moved. NTFH is the number of temperature and flux histories. The histories are matched to their respective heat transfer surfaces by the TMPHPE, TMPHPI, FLXHPE, and FLXHPI pointers which can be obtained by reports 6 or 8. Report 21 then summarizes the zone loads for the hour.

```
TIME:  STDTIM=17;  CLKTIM=17;  DAYOFS=  1;  DAYOFY= 52;  MONTH= 2;  DAYOFM=21;  DAYOFW=2;  DAYTYP= 2;  CI
WEATHER:  DB=  8.89;  WB=  3.86;  BP=100000.;  SPD= 6.7;  DIR=315.;  TS= -8.12;  HB=675.5;  HD= 40.9;  I
CONTROL:  ZONE= 1;  NRCTR=3;  EFSTR=1
   CONTEM:          -98.000      20.000      21.111      98.000
   QFSTDC:                0.        -3.163E+03   0.
   QFSTIF:            3.515E+03   6.678E+04   0.
CONTROL:  ZONE= 2;  NRCTR=3;  EFSTR=3
   CONTEM:          -98.000      20.000      21.111      98.000
   QFSTDC:                0.        -3.163E+03   0.
   QFSTIF:            3.515E+03   6.678E+04   0.
CONTROL:  ZONE= 3;  NRCTR=3;  EFSTR=3
   CONTEM:          -98.000      20.000      21.111      98.000
   QFSTDC:                0.        -3.163E+03   0.
   QFSTIF:            3.515E+03   6.678E+04   0.
QSO:       0.000     30.890      3.278     30.890     41.927     41.927      0.000      0.000
           0.000      0.000      0.000     51.047     27.444     41.927     41.927      0.000
           0.000      0.000      0.000      0.000      0.000      0.000    160.489     21.825
         200.228    240.603    240.514      0.000      0.000      0.000      0.000      0.000

QSI:        .535       .535      2.463       .535       .535       .535       .535       .535
            .535       .535      2.851      2.851     19.673      2.851      2.851      2.851
          2.851     16.057      2.851     51.005      2.851      2.053      2.053     15.643
          2.053      2.053      2.053      2.053      2.053      2.053     15.217     13.679

QSM:       0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
           0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
           0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
           0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000

          QC          QD          QS          QBV         QDV
   1  0.          1.274E+02   7.130E-01   0.          1.003E+02
   2  0.          8.084E+02   3.801E+00   2.053E+03   3.009E+02
   3  0.          4.971E+02   2.737E+00   1.052E+03   2.006E+02
FLOW:   I    N    M       PS          PW          PZ          DP          FLOW
        1    1    0    -18.06        2.57      -19.75      4.25820      161.67
        2    1    0    -18.72       -1.14      -19.75      -.11059       -7.42
        3    1    2       .06        0.00      -19.75      -.98394     -153.97
        4    2    0    -19.60       -3.30      -20.79     -2.10995     -125.08
        5    2    0    -19.69       -1.27      -20.79      -.16838       -9.67
        6    2    3       .02        0.00      -20.79      -.01496      -18.83
        7    2    1      -.06        0.00      -20.79       .98394      153.97
        8    3    0    -17.99       -2.57      -20.83       .27151       27.01
        9    3    0    -19.10       -3.61      -20.83     -1.88684      -46.41
       10    3    2      -.02        0.00      -20.83       .01496       18.83
KOP:      91.796     28.722       .000     54.964     81.925     46.633    771.327    771.327
         771.327     46.261     91.796     59.301       .000     82.829     46.871     91.796
         199.303    771.327    771.327    771.327     46.923     91.796     41.915       .000
          85.136    133.525     76.771     91.796    199.303    771.327    771.327     49.593
KIF:      71.786     71.192      -.000    138.661    131.319     57.395    698.483    603.115
         603.115     39.761     91.968     70.383      -.000    162.679     73.416     93.171
         197.591    760.825    747.766    765.739     44.098     96.059     95.667      -.000
         192.235    174.818     77.400     94.865    202.337    765.428    761.470    794.945
```

Figure V.29   Dump of zone loads calculations

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TEMPERATURE AND FLUX HISTORIES: TSHIFT= 68;   NTFH=259

Figure V.29 (continued)

VI.   COMPUTER PROGRAM

The general structure of the Thermal Analysis Research Program was described in chapter II.B and figure II.1. This chapter expands upon that introduction by describing the program subroutines, variables, and files.

VI.A   INPUT PROCESSOR

The input processor (IP) is the first of the two TARP subprograms. It checks and interprets the user input, creates the input files for the loads calculator (LC), and writes various reports. This processing involves all of chapter IV and primarily sections B, C, and D of chapter III. Data about the location and weather goes to the LC in the ENVTFL (environment file). The description of the building, including library data, goes in the SINPFL (simulation input file).

The IP is divided into four major sections corresponding to the input language sections. These sections may be used to reduce core requirements by overlay (or segmentation). A small input processor will help to give fast job turn-around necessary to quickly debug the user input deck. Each section is headed by a subroutine that is called when a section name and "[" is encountered in the input. The name of that routine is similar to the section name. The section processor subroutines all have similar structures, especially for how they handle incorrect input.

Each section contains several subroutines which process the input language keys. The names of these routines are the same as the key names. Most of the key processing routines also have similar structures consisting of: initialization, decoding the subkeys, error checking, calculation of derived data, output to SINPFL, reports and dumps. The output to SINPFL consists of an identifier record containing two integers and one or (sometimes) more data records. The data records usually have values for a single surface, schedule, etc., which is read by the LC into arrays for all surfaces, schedules, etc.

Some key processing subroutines call other groups of subroutines for complex calculations. The largest of these groups are those that compute the conduction transfer functions and the window optical coefficients.

A short description of each of the 130 input processor subroutines is given below. After the descriptions is a diagram (figure VI.A.1) showing the general relationship of the IP routines and the segment structure.

AFS   subroutine

Evaluate the subkeys of AFS (4.14). The AFSDAT common block contains data to match interzone openings. Data is output in the AFSIL common block.

BBH   subroutine

   Evaluate the subkeys of BBH (4.11). Data is output in the SSCISL
   common block.

BDLIB   block data

   Set initial values for library processing.

BDPROJ   block data

   Set initial values for project processing.

BDSLR   block data

   Set initial values for processing user input.

BEAM   subroutine

   Evaluate window optical properties for beam sunlight at 16 angles of
   incidence.

BLANK(ARRAY,LEN)   subroutine

   Blank (set to ' ') an ARRAY of character strings of length LEN.

BUILDG   subroutine

   Evaluate the keys of BUILDING (section 3). This is the root subroutine
   of the building segment.

CDS   subroutine

   Evaluate the subkeys of CDS (2.7). Convert control profile names to
   pointers.

CHKCP   subroutine

   Check description of control profile: number, range, and order of
   temperatures and normalized capacities.

COMPMS   subroutine

   Compute the optical properties for the pane-shade system for both
   polarizations of light incident from the outside. Compute overall
   transmittance and reflectance and individual absorptances.

CONS   subroutine

Evaluate the subkeys of CONS (2.5). Evaluate the thickness of each
layer, and convert its material name to a pointer to retrieve materail
data from unit 4. Compute conduction transfer functions. Compute
optical coefficients for constructs having no opaque layers. Data is
written to the constucts file (unit 5) for reference by zone surfaces.
Data is output to the SINPFL in common blocks CONDAT, GLAS, and GLASO.

CPFL   subroutine

Evaluate the subkeys of CPFL (2.6). Call CHKCP to check the control
profile. Data is output in the CNTPFL common block.

CREPT(SCRFL)   subroutine

Transfer constructs reports (2.1.3) from unit SCRFL to the output file.

CTRL   subroutine

Evaluate the subkeys of CTRL (4.9). Data is output in the CGSIL common
block.

CTF(I,CONVG)   subroutine

Calculate the higher order conduction transfer functions from the
response factors (order 0 CTF) and the RATIO's. Check convergence by
(C.2.1).

CWS   subroutine

Evaluate the subkeys of CWS (2.8). Convert control day-schedule names
to pointers.

DCHXYZ   subroutine

Compute conduction transfer functions of a single layered slab
using the algorithm of D. C. Hittle.

DDY   subroutine

Evaluate the subkeys of DDY (1.6). Data is output as a single day in
the ENVTFL.

DER   subroutine

Calculate the total construct and total derivative matrices for a
single value of the Laplace parameter.

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DIFFUS   subroutine

   This subroutine operates in one of two modes. It may compute the
   optical properties of a combination of glass panes for both polarizations
   of diffuse light of a given wavelength incident from both sides (D.6.2).
   Or it may compute the optical properties af a pane-shade system for both
   polarizations of diffuse of a given wavelength incident from the outside
   only. A Simpson's rule integration is used.

DIFSHD   subroutine

   Compute the reflectance of an interior shading device for both
   polarizations of diffuse light.

DLT   subroutine

   Evaluate the subkeys of DLT (4.10). Data is output in the CGSIL common
   block.

DMPAFS   subroutine

   Dump air flow opening data in the AFSIL common block. Dump initiated by
   RNOS=6 (1.2.1).

DMPCGS   subroutine

   Dump zone control and general schedule data in the CGSIL common block.
   Dump initiated by RNOS=6 (1.2.1).

DMPHTS   subroutine

   Dump heat transfer surface data in the HTSIL, HTSIS, and HTSISL common
   blocks. Dump initiated by RNOS=6 (1.2.1).

DMPSRF   subroutine

   Dump surface geometry data in the SRFIS common block. Dump initiated by
   RNOS=6 (1.2.1).

DMPSSC   subroutine

   Dump special surface data in the SSCISL common block. Dump initiated by
   RNOS=6 (1.2.1).

DS   subroutine

   Evaluate the subkeys of DS (2.2). Check number and range of profile
   values.

DSS   subroutine

   Evaluate the subkeys of DSS (3.2). Coordinates are converted from the
   building to the global coordinate system by (E.1.1) and (E.1.4). Data
   is output in the SRFIS common block.

DUMPGL(MODE)   subroutine

   Dump optical calculations according to MODE.
   MODE=1: describe optical layers.
   MODE=2: report optical properties.
   MODE=3: report optical values (T, R, A) for each layer.
   MODE=4: print polynomial coefficients.
   Initiated by RNOS=4 (1.2.1).

DUMPLB   subroutine

   Dump library control data initiated by RNOS=1 (1.2.1).

DUMPNV   subroutine

   Dump one day of weather data. Initiated by RNOS=2 (1.2.1).

DUMPPJ   subroutine

   Dump project data: common blocks TITLES, RUNCTL, EFLHDR, and REPORT.
   Initiated by RNOS=1 (1.2.1).

DUMPRF(MODE)   subroutine

   Dump conduction transfer calculations according to MODE.
   MODE=1: describe conductive layers.
   MODE=2: print roots and ratios.
   MODE=3: Print all orders of conduction transfer functions.
   Initiated by RNOS=3 (1.2.1).

DUPLIB(LO,LEN)   subroutine

   Check for duplicate name in library.

DYS(JFLAG,DY,MO,DM,LY)   subroutine

   If JFLAG = 1, compute day-of-year (DY) from month number (MO),
   day-of-month (DM), and leap year indicator (LY) (B.1.1). Otherwise,
   compute MO and DM from DY and LY.

EMI   subroutine

   Evaluate the subkeys of EMI (4.17). Data is output in the SSCISL
   common block.

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EQP   subroutine

    Evaluate the subkeys of EQP (4.4). Data is output in the CGSIL common
block.

ERROR(MSG,ETYPE)   subroutine

    Print error message (character string MSG). Process according to error
type (ETYPE).
ETYPE=0: informative message.
ETYPE=1: 'warning' -- unusual, but not fatal, input.
ETYPE=2: 'severe' -- input error which will prevent running LC.
          COUNT of type 2 errors may not exceed 30.
ETYPE=3: 'fatal' -- immediate run termination.
ETYPE<0: set ETYPE to the highest ETYPE number with which ERROR
          was ever called.

EXTCF(TO,N)   real function

    Compute k*L (extinction coefficient times thickness) of glass pane N
with normal incidence transmittance TO (D.3.11).

FAN   subroutine

    Evaluate the subkeys of FAN (4.8). Data is output in the CGSIL common
block.

FILM(J,N,LAMBDA,CTHETA,STHETA,CPHI)   subroutine

    Compute the optical properties of a thin reflective film on side J
(1=outside, 2=inside) of glass pane N.

FINDFD(N,TPLAIN,TFILM)   subroutine

    Determine the thickness of a thin reflective film on pane N by its
normal transmittance with (TFILM) and without (TPLAIN) the film.

FINISH   subroutine

    Finish input processing. Check for and report unmatched interzone
surfaces and openings. Check for and report unused library names.
Terminate run if there were any 'severe' errors. Report minimum LC
array sizes (PARAMETERS). Write the last SINPFL record - common block
RUNCTL.

GEOM   subroutine

    Evaluate the subkeys of GEOM (4.1). Values are set for the subsequent
geometric processing of zone surfaces.

GETB3W(NSKIP,NDAYS)   subroutine

Skip NSKIP days of weather data from the BLAST 3.0 weather file
(WTHRTP, unit 3). Transfer the following NDAYS of data to the ENVTFL.

GETLIN   subroutine

Get the next line on user input from the INPUT file. Echo the line in
the output file. Print error message if data is being skipped.

GLASSX   subroutine

Compute the total transmittance and reflectance of a system of up to
four panes of glass and the absorptance of each pane for both
polarizations of light and both directions of incidence (at a given
wavelength and angle of incidence).

GRND   subroutine

Evaluate the subkeys of GRND (1.4). Data goes into ENVTFL header
record.

ICTF   subroutine

Initialize arrays for conduction transfer function calculations.

IDSTF(MO,DM,DW)   integer function

IDSTF = 1 when daylight savings time is in effect, and it equals 0
otherwise. IDSTF is based on the month number (MO), the day-of-month
(DM), and the day-of-week (DW). Daylight savings time begins on the
last Sunday in April, and it continues until standard time resumes on
the last Sunday of October.

ILLINI(A,B,TOL,RT,REPEAT)   subroutine

Use modified false position method to compute root (RT) in the interval
bounded by A and B. Convergent solution is found the upper bound –
lower bound < TOL. If solution is not found, set REPEAT to true.

IMI   subroutine

Evaluate the subkeys of IMI (4.18). Data is output in the SSCISL
common block.

INF   subroutine

Evaluate the subkeys of INF (4.5). Data is output in the CGSIL common
block.

INITCF   subroutine

   Compute the units conversion factors. Most factors are derived from
   CFL(2)=.3048, CFM(2)=.45359237, and CFC(2)=4.184 to give a consistant
   set of conversion factors.

INITGL   subroutine

   Direct the calculation of window optical coefficients. Set up
   properties of optical layers (no air layers). Set coefficients of
   shading coefficients window directly. Otherwise, evalaute optical
   properties (SPCTRM) and compute polynomial coefficients (WDWPOL).
   Print dumps and reports as required. This is the root subroutine of
   the optical calculations segment.

INITRF   subroutine

   Direct calculation of conduction transfer functions. Compute
   properties of conductive layers (no interior shades). Evaluate CTF for
   multi-layer (RESPNS) or single layer (DCHXYZ) constructs and report
   results. This is the root subroutine of the conduction calculations
   segment.

INTCON(ANUM,EFLAG)   integer function

   Evaluate character string ANUM as an integer (syntax rule [IV.B.1] 8).
   If ANUM is a proper integer, return EFLAG set to 0. Otherwise, set
   INTCON to 0, set EFLAG to 1, and print error message.

ISHADE   subroutine

   Add the effect of an interior shade to optical properties of the glass
   panes in the window (D.7).

IZERO(ARRAY,LEN)   subroutine

   Set ARRAY (length LEN) of integers to 0.

JDS(JFLAG,JD,YR,MO,DM)   subroutine

   If JFLAG = 1, compute the Julian date (JD) from the year (YR), month
   (MO), and day-of-month (DM) (B.1.2). Otherwise, compute YR, MO, and DM
   from YR (B.1.3).

LIB   subroutine

   Evaluate the subkeys of LIB (2.1). Data is used to control the
   processing of library input. Open the library report scratch files.

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LIBRRY   subroutine

    Evaluate keys of LIBRARY (section 2.). Insure sequence of key input.
    This is the root subroutine of the library segment.

LIT   subroutine

    Evaluate the subkeys of LIT (4.3). Data is output in the CGSIL common
    block.

LOC   subroutine

    Evaluate the subkeys of LOC (1.3). Data is stored in the weather file
    header (common block EFLHDR).

LOCLIB(ITEM,LO,LEN,LOC)   subroutine

    Determine location (LOC) of ITEM in the library relative to LO. The
    library consists of seven groups of named elements. All names in the
    seven groups are stored in the LNAMES array beginning at various
    locations. LO is the array location before the first entry in the
    group of interest. LEN is the number of elements of that group. LOC
    records the sequence in which the library entries were defined and in
    which they exist on scratch files or will exist in the loads calculator
    arrays. If ITEM is not found, set LOC to zero.

LOCORD(LIST,LEN,ITEM)   integer function

    Determine the location of ITEM in a LEN long array (LIST) of
    alphabetically ordered words. If ITEM is not found, return the value
    zero. A bisection search is used.

LOCRAN(LIST,LEN,ITEM)   integer function

    Determine the location of ITEM in a LEN long array (LIST) or unordered
    words. If ITEM is not found, return the value zero. A linear search
    is used.

LREPT(SCRFL,NLINES,TITLE)   subroutine

    Transfer library reports (2.1.3) from unit SCRFL to the output file.
    Each report element is NLINES long and is given a TITLE. Close the
    SCRFL when finished.

LSQFIT(ITYPE,N,N1,N2)   subroutine

    Compute the polynomial coefficients of the optical properties equations
    (D.1.7a and b). A standard least squares fit is used.
    ITYPE = 1 does the polynomial which is evaluated by POLY1F.
    ITYPE = 2 does the polynomial which is evaluated by POLY2F.
    N is the order of the polynomial.
    N1 is the location in X and Q of the first data value.
    N2 is the location in X and Q of the last data value.

LYF(YR)   integer function

    Compute the leap year indicator from the four digit year number (YR).
If YR is a leap year, set LYF to 1. Otherwise set LYF to 0.

MASS   subroutine

    Evaluate the subkeys of MASS (4.12). Thermal properties are read from
UNIT 5. Data are output in common blocks HTSIL and HTSISL.

MATL   subroutine

    Evaluate the subkeys of MATL (2.4). The input data are checked against
appropriate ranges. The material properties are written to UNIT 4 for
reference by the CONS subroutine. The materials report (MATL - 2.1.3)
is written to UNIT 23.

MATRIX(W)   subroutine

    Evaluate the conduction matrix for a multi-layered slab.

MIX   subroutine

    Evaluate the subkeys of MIX (4.7). Data is output in the CGSIL common
block.

MODY(DATE,EFLAG)   integer function

    Evaluate character string DATE as a date (syntax rule [IV.b.1] 10).
Compute MODY in the cyclic date form (B.1.4). If DATE is a valid date,
return EFLAG set to 0. Otherwise, set MODY to 0, set EFLAG to 1, and
print error message. Note that day-of-month numbers from 1 through 31
are considered valid for all months.

OSC   subroutine

    Evaluate the subkeys of OSC (4.16). Data is output in the SSCISL
common block. Error checking includes (1) OSC not permitted with
interior surface, (2) OSC not permitted with EMI on same surface, and
(3) multiple definitions of OSC for the same surface not permitted.

PAGE(IACT,NEED)   subroutine

    Write output report page headings. This routine can be used to count
the number of lines being printed on issue page eject commands at
appropriate intervals according to the use of IACT and NEED.
IACT=0: Initialize page routine. Set page length to NEED.
IACT=1: NEED lines are to be printed. If there is insufficient space
        remaining on the page, eject page and print heading.
IACT=2: Return page number in NEED.
IACT=3: Return number of lines left on page in NEED.
IACT=4: Eject page and print heading if NEED lines not left on page.
        Do not increment line count.
The page heading includes a report of cumulative program execution time
determined from the non-ANSI function SECOND. This function can be
removed without otherwise affecting the program.

PANE(N)   subroutine

    Compute the transmittance, reflectance and absorptance of pane number
N (counted from the outside). This routine uses the optical algorithms
of III.D.3.

PEO   subroutine

    Evaluate the subkeys of PEO (4.2). Data is output in the CGSIL common
block.

POLY1F(X,A,N)   real function

    Evaluate simple polynomial expression (D.1.7a):

$$P = A(1) + A(2)*X + A(3)*X^2 + \ldots + A(N)*X^{N-1}$$

POLY2F(X,A,N)   real function

    Evaluate simple polynomial expression (D.1.7b):

$$P = A(1)*X + A(2)*X^2 + \ldots + A(N)*X^N$$

PROJCT   subroutine

    Open the simulation input (SINPFL) and environment (ENVTFL) files.
Evaluate the keys of PROJECT (section 1.). Write the weather file
header record and close the weather file. Write the first records on
the simulation input file. Initiate dump of "project" data (RNOS=1 -
1.2.1). This is the root subroutine of the project segment.

PSYCH   subroutine

    This routine may be used to test the psychrometric package. It is not
called by TARP.

PSYDPW(W,PB)   real function

    Compute the dew point temperature (TD) from the humidity ratio (W) and
    the barometric pressure (PB) (B.2.6).

PSYHTW(TA,W)   real function

    Compute the enthalpy (H) from the dry bulb temperature (TA) and
    humidity ratio (W) (B.2.9).

PSYRHT(TA,TD)   real function

    Compute the relative humidity (RH) from the dry bulb (TA) and dew point
    (TD) temperatures (B.2.7). Check for 0 < RH < 1.

PSYTWD(TA,W,PB)   real function

    Compute the wet bulb temperature (TW) from the dry bulb temperature
    (TA), humidity ratio (W), and the barometric pressure (PB). TW is
    computed by iteration of function PSYWTP to a convergent solution. The
    first set is to check for saturated air which means TW = TA. Failing
    that, an initial guess for TW is made at TA-1. This initial guess is
    increased if it produces an impossibly low humidity ratio. The initial
    guess is used in a secant iteration. If the secant iteration should
    fail, a slower but more reliable bisection iteration is available.

PSYVTW(TA,W,PB)   real function

    Compute the specific volume (V) of moist air from the dry bulb
    temperature (TA), humidity ratio (W), and barometric pressure (PB)
    (B.2.8). Check for reasonable range: 0.58 < V < 3.

PSYWDP(TD,PB)   real function

    Compute humidity ratio (W) from dew point temperature (TD) and
    barometric pressure (PB) (B.2.2). Check for W > 1.61E-6 (W for TD =
    -70C).

PSYWTH(TA,H)   real function

    Compute humidity ratio (W) from dry bulb temperature (TA) and enthalpy
    (H) (B.2.5). Check for W > 1.61E-6 (W for TD = -70C).

PSYWTP(TA,TW,PB)   real function

    Compute humidity ratio (W) from dry bulb (TA) and wet bulb (TW)
    temperatures and barometric pressure (PB) (B.2.3). Check for W >
    1.61E-6 (W for TD = -70C).

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PSYWTR(TA,RH,PB)   real function

   Compute humidity ratio (W) from dry bulb temperature (TA), relative
   humidity (RH), and barometric pressure (PB) (B.2.4). Check for W >
   1.61E-6 (W for TD = -70C).

QTF   subroutine

   Compute flux conduction transfer coefficients from RATIO values.

RC   subroutine

   Evaluate the subkeys of RC (1.1). Data are stored in the RUNCTL common
   block and used in subsequent processing of user input.

READER   subroutine

   Decode the user input (in UINREC) according to input syntax rules
   (IV.B.1). Output is current status (UISTAT) and individual words in
   the AWORD array. The longest element of input processed in one call to
   this routine is a subkey with data.

RELCON(ANUM,EFLAG)   real function

   Evaluate character string ANUM as a real number (syntax rule [IV.B.1]
   9). If ANUM is a valid number, return EFLAG set to 0. Otherwise, set
   RELCON to 0.0, set EFLAG to 1, and print error message.

REPTGL(LSC)   subroutine

   Report on the calculation of window optical coefficients. This report
   is initiated by CONS (2.1.3). The report is in two formats: one for
   detailed optical calculations and the other if a shading coefficient
   was used (LSC true).

REPTRF   subroutine

   Report on the calculation of conduction transfer functions. This
   report is initiated by CONS (2.1.3). Also report surface properties.

RESPNS   subroutine

   Direct the calculation of conduction transfer functions for
   multi-layered slabs.

RFCOMP   subroutine

   Compute conduction transfer functions for multi-layered slab from the
   roots and residues.

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RPT   subroutine

Evaluate the subkeys of RPT (1.2). Data is stored in the RFLAGS array.

RSBF(I,COSINC,WL)   real function

Compute reflectance of an interior shading device. This returns the
value of RSO which was computed from user input REF (2.4.12). This
routine is a program stub to allow computation of reflectance from
polarization (I), angle (COSINC), and wavelength (WL) when data for
such a calculation exists.

SATPTX(T)   real function

Compute the saturation pressure of water at temperature (T) by the
detailed ASHRAE correlation (B.2). This subroutine is not called by
TARP. It is used with PSYCH to test the psychrometric package.

SATUPT(T)   real function

Compute the saturation pressure of water at temperature (T) (B.2.1).
Check for -70 < T < 100.

SATUTP(P)   real function

Compute the saturation temperature of water at pressure (P) (B.2.1).
Check for P in the range corresponding to -70 < T < 100.

SEARCH   subroutine

Determine upper and lower bounds within which a root must exist. Call
ILLINI to converge to root. Trigonometric identities are used (with
APPROX) to evaluate AS and BS as PT is incremented. The search for
roots of BS is helped by the fact that roots of BS must lie between
roots of AS.

SETUPV   subroutine

Compute vertices of polygon. Vertices of rectangular and
non-rectangular base surfaces are evaluated in the global coordinate
system by equations (E.1.4). Rectangular subsurfaces have vertices
computed in the base surface coordinate system. Subsurface azimuth and
tilt angles are computed from the base surface angles.

SHD   subroutine

Evaluate the subkeys of SHD (4.15). Data is output in the SRFIS common
block.

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SIM   subroutine

   Evaluate the subkeys of SIM (3.1). Data is stored in the RUNCTL common
   block and output as one of the last steps of input processor operation.

SLR   program

   SLR stands for "simplified language reader". This is the root program
   of the input processor. It initializes program variables and opens
   files, directs the processing of input sections, prints final reports
   and closes files. The variable SEQ is used to insure that sections are
   not used out of sequence.

SKYTF(TA,TD,N)   real function

   Compute sky temperature from dry bulb (TA) and dew point (TD)
   temperatures and tenths cloud cover (N - integer) (B.3.1 through B.3.4)

SPCTRM   subroutine

   Use the detailed optical algorithms to compute the window optical
   properties. This routine includes a loop to integrate the optical
   properties over wavelength. The loop is executed for only one average
   wavelength. This was found to give sitisfactory results for typical
   window materials.

SRF   subroutine

   Evaluate the subkeys of SRF (4.13). Data is output in the SRFIS,
   HTSIL, and HTSISL common blocks. The subkey names (in KEYS) are
   sequenced according to frequency of occurrance to speed the INDEX
   operation in SUBKEY. The large number of options in the SRF
   description make this the most complex input subroutine. There are
   several error messages relating to syntax requirements. Then the sky
   and ground view factors are computed by (E.5.2a) and (E.5.2b), unless
   the user chose to provide his own values by (4.13.7) and (4.13.8). The
   surface area (gross area for base surfaces) is computed from (E.4.1).
   The conductive and radiative properties of the surfaces are read from
   unit 5. If the surface is an interzone partition (IZP), and attempt is
   made to match it to previously defined IZP's. An IZP must be described
   in two zones. RNOS=7 (1.2.1) reports on this matching process. The
   surface geometric data (primarily coordinates of vertices) is computed.
   Values are stored in the BASES common block for the geometric
   description of subsurfaces.

SUBKEY(KEYS,LKEYS,NKEYS,LOC)   subroutine

> This subroutine evaluates the subkey name (syntax element [IV>B>1] 4).
> The subkey name is always the first word in ALIST. KEYS is a single
> string of all subkey names, each no more than LKEYS characters long.
> The number of names in KEYS is NKEYS. LOC is the word number location
> of the subkey name in KEYS. The INDEX function is used in determining
> LOC. If the name is not found, an error message is printed. All valid
> subkey names are optionally (DEM - 1.1.3) printed.

SUDDEN   subroutine

> This routine fills a single day of weather data in common block ENVDAT
> from the user's dedign day description (DDY - 1.6). Calendar values
> are computed. A dew point temperature (TD) for the day is computed.
> It is used in computing the hourly wet bulb temperatures, humidity
> ratios, and sky temperatures. Solar intensities are computed.

SUN2(DAYYR,A,B,C,AVSC)   subroutine

> Compute the ASHRAE A, B, and C values from the day-of-year (DAYYR).
> These are computed from truncated Fourier series computed from data in
> ASHRAE 1981 Fundamentals, page 27.2.

SUN5(HOUR)   subroutine

> Compute the solar direction cosines at standard time HOUR.

SURFIN(ZAVG,ZTOP)   subroutine

> Compute coordinates of surface vertices. Determine avarage and maximum
> height of surface from ground.

TSBF(I,COSINC,WL)   real function

> Compute transmittance of an interior shading device. This returns the
> value of TSO which was computed from user input TRNS (2.4.9) and REF
> (2.4.12). This routine is a program stub to allow computation of
> transmittance from polarization (I), angle (COSINC), and wavelength
> (WL) when data for such a calculation exists.

VALID(KEYS,LKEYS,NKEYS,LEVEL)   subroutine

> List valid input names. LEVEL (equals 1, 2, or 3) determines whether
> section, key, or subkey names are being listed. The names are all in
> the single string KEYS. The number of names is NKEYS. Each is LKEYS
> characters long.

VENT   subroutine

> Evaluate the subkeys of VENT (4.6). Data is output in the CGSIL common
> block.

WDWPOL   subroutine

This routine directs the calculation of the polynomial coefficients
(D.1.7a and b) describing the optical properties of the window.

WS   subroutine

Evaluate the subkeys of WS (2.3). Data is output in the local array
PTR and the optional report is on unit 22. The day schedule pointers
can be filled from a single weekday pointer.

WTAP   subroutine

Evaluate the subkeys of WTAP (1.5). Get weather from the BLAST weather
file unless SYNTAX (1.1.2) or OLDW (1.1.6) are in effect.

WXREF(A,I)   subroutine

Write cross reference data consisting of the array name (A) and the
location (I) in that array. WXREF is initiated by XREF (1.1.5). It
relates the input keys to the arrays reported by DUMPIN in the loads
calculator. DUMPIN is caused by RNOS=8 (1.2.1).

ZERO(ARRAY,LEN)   subroutine

Set ARRAY (length LEN) of real numbers to 0.

ZERORE   subroutine

ZERORE calculates the residues related to the double pole at zero.

ZONE   subroutine

Evaluate keys of ZONE (section 4.). Insure sequence of KEY input.
Data is output in the ZONISL common block. Key names (in KEYS) are
approximately in the order of frequency of occurrence to speed
execution of the INDEX function. This is the root subroutine of the
zone segment.

This diagram (continued over several pages) shows the general relationship of the input processor subroutines to each other. A subroutine calls other subroutines which are to the right and below it on the diagram. Multiple calls to the same subroutine are not shown, only the first. Circled letters are continuation points for often used groups of subroutines and for large groups of subroutines. Not all subroutines and functions are included. The intrinsic FORTRAN 77 routines have been left out. Several simple utility routines which are called from many places are not always shown. These include: ERROR, INTCON, IZERO, LOCLIB, MODY, PAGE, RELCON, WXREF, and ZERO.

Figure VI.A.1   Tree structure of input processor program

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```
┌─LIBRRY─┐
│        ├─READER───(A)
│        ├─VALID
│        ├─LIB ─────┐
│        │          └─SUBKEY─────(B)
│        ├─DS ──────┐
│        │          ├─SUBKEY─────(B)
│        │          └─DUPLIB
│        ├─WS ──────┐
│        │          ├─SUBKEY─────(B)
│        │          └─DUPLIB
│        ├─MATL ────┐
│        │          ├─SUBKEY─────(B)
│        │          └─DUPLIB
│        ├─CONS ────┐
│        │          ├─SUBKEY ────(B)
│        │          ├─DUPLIB
│        │          ├─INITRF────(D)
│        │          └─INITGL────(E)
│        ├─CPFL ────┐
│        │          ├─SUBKEY ────(B)
│        │          ├─DUPLIB
│        │          └─CHKCP
│        ├─CDS ─────┐
│        │          ├─SUBKEY────(B)
│        │          └─DUPLIB
│        ├─CWS ─────┐
│        │          ├─SUBKEY────(B)
│        │          └─DUPLIB
│        └─DUMPLB
│
├─BUILDG─┐
│        ├─READER────(A)
│        ├─VALID
│        ├─SIM ─────┐
│        │          └─SUBKEY────(B)
│        └─DSS ─────┐
│                   ├─SUBKEY ───(B)
│                   └─DMPSRF
│
└─ZONE ──┐
         ├─READER────(A)
         ├─VALID
         ├─AFS──────┐
         │          ├─SUBKEY────(B)
         │          └─DMPAFS
         ├─BBH ─────┐
         │          ├─SUBKEY────(B)
         │          └─DMPCGS
         └─CTRL─────┐
                    ├─SUBKEY ───(B)
                    └─DMPCGS
```

Figure VI.A.1 (continued)

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Figure VI.A.1 (continued)

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Figure VI.A.1 (continued)

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Figure VI.A.1 (concluded)

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VI.B   LOADS CALCULATOR

The loads calculator (LC) subprogram of TARP computes the zone loads based on the algorithms in chapter III, primarily sections E through L. It is divided into three sections. The first reads the SINPFL created by the IP and fills the LC arrays. It checks for sufficient array space and performs some checks and calculations which require that the entire building description be present in the arrays. The second section section uses the geometric and optical descriptions of the building surfaces to compute solar gain factors for various periods of the year. The third section computes the zone loads by simultaneous, hour-by-hour heat balances.

The three segment structure of the LC is used to name many of the common blocks. For example, common block HTSISL is composed of variables dimensioned MAXHTS and is used in the Input, Shadowing, and Loads segments. Common block ZONL has variables dimensioned MAXZON and is used in only the Loads segment.

A short description of each of the 90 loads calculator subroutines is given below. After the descriptions is a diagram (figure VI.B.1) showing the general relationship of the LC routines and the segment structure.

AIRMV0   subroutine

Compute air movements for the simple algorithms: infiltration (INF - 4.5 - K.2), two zone mixing (MIX - 4.7 - K.3), and whole house fan (FAN - 4.8 - K.4). The mixing and fan models may not be used when other ventilation (VENT - 4.6) is possible.

AIRMV1   subroutine

Compute infiltration and interzone air flows using the detailed air movement algorithms in III.G.

BDMRL   block data

Set initial values for loads calculator program.

BDSIM   block data

Set initial values for loads simulation.

BTWEEN(N1,N0,N2)   logical function

Determine if cyclic date N1 lies between dates N0 and N2 (B.1.6).

CALOAD   subroutine

Calculate values for the building loads report including system status hours, zone loads, zone peaks, building loads, and building peak values.

CHACS   subroutine

   Set up the control points and coeficients of the system performance
   (K.1) and ventilation models (K.3).

CHKBKS(NRS,NBS)   subroutine

   Check that a convex zone has been defined. No vertex of surface number
   NBS may lie in front of surface number NRS.

CHKGSS(NRS,NSS,ZMIN,NOSHAD)   subroutine

   Determine if surface number NSS can possibly shade surface NRS. If it
   can, set NOSHAD false. NSS cannot shade NRS if any of the following
   conditions are true:
   (1) No point of NSS is above the lowest point (height ZMIN) of NRS.
   (2) NSS is horizontal and faces up.
   (3) NSS is entirely behind NRS.
   (4) NRS is entirely behind NSS.

CHKSBS   subroutine

   Check that a subsurface is completely enclosed by its base surface.
   This routine uses the shadow overlap technique.

CISAF   subroutine

   Compute the fraction absorbed by each surface of the total beam solar
   energy transmitted into the zone. This is for the simple solar
   distribution which assumes all beam solar gains are incident on the
   floors of the zone. The fraction absorbed is proportional to the solar
   absorptance of each floor.

CIVAF   subroutine

   Compute the distribution of diffuse short wavelength radiation on all
   surfaces. Each surface absorbs a fraction of the total diffuse energy
   in the zone in proportion to its area and solar absorptance with an
   allowance for loss through transparent surfaces (F.2.1).

CLIP   subroutine

   'Clip' the shadowing surface polygon so that none of it lies below the
   plane of the shadow receiving surface (E.2). This prevents the casting
   of false shadows.

CROSS(A,B,C)   subroutine

   Compute C as the cross product of A and B. All are three element
   vectors.

CTRANS(NS,NR)   subroutine

Transform the coordinates of the vertices of surface NS from the global coordinate system to the surface coordinate system relative to surface NR (E.1.5).

DAILY   subroutine

Perform all operations which can be done once per day. Read the weather data and set date values. Set the solar gains file group number. Check external movable insulation and set pointers if the date is in effect. Set the schedule and control pointers according to the date. Set the monthly report flags.

DOT(A,B)   real function

Compute the dot product of A and B which are each vectors of 3 elements.

DUMPAF   subroutine

Dump air flow values (RNOS=23 - 1.2.1).

DUMPEH   subroutine

Dump values in the environment file header (RNOS=8 - 1.2.1).

DUMPHW   subroutine

Dump weather values for the hour (RNOS=21 - 1.2.1).

DUMPIN   subroutine

Dump all values read from the simulation input file (RNOS=8 - 1.2.1).

DUMPQB   subroutine

Dump results of the zone loads calculations (RNOS=23 - 1.2.1).

DUMPSC   subroutine

Report shadowing combinations (RNOS=14 - 1.2.1).

DUMPSG   subroutine

Dump solar gain values (RNOS=22 - 1.2.1).

DUMPST   subroutine

Dump Surface temperatures and other surface related values (RNOS=23 - 1.2.1).

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DUMPS1(I)   subroutine

Print the solar incidence angles and sunlit fractions for all heat
transfer surfaces for hour number I (RNOS=13 - 1.2.1).

DUMPS2(MODE)   subroutine

Dump the numbers which are controlling the shadowing calculations
(RNOS=15 - 1.2.1). MODE is set by the calling to routine to tell which
values to print.

DUMPS3(MODE)   subroutine

Dump details of the shadowing calculations (RNOS=16 - 1.2.1). These
are primarily the coordinates of the shadow and overlap figures. MODE
determines which values to print.

DUMPTC(NZ)   subroutine

Dump temperature profile control points for zone NZ (RNOS=22 - 1.2.1).

DUMPTH   subroutine

Dump all temperature and flux history values (RNOS=24 - 1.2.1).

DUMPTM   subroutine

Dump time and date values (RNOS=21 - 1.2.1).

DUMPVC(NZ)   subroutine

Dump ventilation profile control points for zone NZ (RNOS=22 - 1.2.1).

DUMPZL   subroutine

Dump zone load values for all zones (RNOS=21 - 1.2.1).

ERROR(MSG,ETYPE)   subroutine

Print error message (character string MSG). Process according to error
type (ETYPE).
ETYPE=0: informative message.
ETYPE=1: 'warning' -- unusual, but not fatal, value or action.
ETYPE=2: 'severe' -- unusual value or action usually leading to
          incorrect answers or ETYPE=3 error.
ETYPE=3: 'fatal' -- immediate run termination usually caused by
          exceeding iteration limit, exceeding valid control range,
          or invalid arithmetic operation (division by 0, etc.).

GAUSSY(A,B,X,N,MAX)   subroutine

   Solve a system of simultaneous linear algebraic equations (A * X = B)
   by Gauss elimination. There are no safety check or pivoting in this
   routine: it will not fail gracefully for an invalid set of equations.
   It is used in the Newton iteration for pressure where the A matrix
   is diagonally dominant and known to produce valid equations.

HBAIR(CNVG)   subroutine

   Compute the zone air temperatures for normal control (K.1.4) or
   ventilation control (K.3). Check heat balance convergence and set CNVG
   false if it has not been achieved.

HBOUT   subroutine

   Compute surface outside temperatures for building envelope surfaces.
   Use the algorithms in I.4.

HBSRF   subroutine

   Compute surface inside temperatures according to algorithms in J.3,
   J.4, and J.5.

HTRANS(I,NS,NV)   subroutine

   Convert Cartesian coordinates to homogeneous coordinates (E.3) and
   compute the area (E.4.1) of the figure.

IBLRPT   subroutine

   Initialize the building loads report varaibles.

IMRTNW   subroutine

   Initialize the mean radiant temperature network algorithm. Compute the
   MRT view factors (H.2.2) and the constant part of the radiative
   conductance (H.2.3).

IMVINS(I,N)   subroutine

   Determine presence of inside movable insulation for heat transfer
   surface I in zone N. If present, set UM(I) to the insulation U-values.
   Otherwise, set UM(I) to zero.

INCLOS(N1,NV1,N2,NV2,NV3,NIN)   subroutine

   Determine which vertices of HC figure N1 lie within figure N2. N1 has
   NV1 vertices, and N2 has NV2 vertices. NIN is the number of enclosed
   vertices. NV3 is a running count of the number of vertices in the
   overlap of N1 and N2. The algorithm is described in E.4. The
   coordinates of the inclosed vertices are stored in XTEMP and YTEMP.

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INITBL   subroutine

   Direct the set-up of the simulation data. This is the root routine in
   the initailization segment. The segmentation is helped by temporary
   storage of data on units 4 and 5. The report of array limits is the
   first action. It will occur even if there is no SINPFL or ENVTFL
   attached. Next, those files are opened and the environment header is
   read. Then the SINPFL is read [READER] and the required array space
   reported. Some calculations are made that require data simultaneously
   for all zones and surfaces [SETIZP, CISAF, and CIVAF]. Dumps [DUMPEH,
   DUMPIN] (RNOS=8, 1.2.1) and reports [REPTZD] (RNOS=9, 1.2.1) are
   written. Inter-segment scratch files 4 and 5 are written.

INITSG   subroutine

   Direct the calculation of the solar gains multipliers. This is the
   root routine of the solar gains segment. The segmentation is helped by
   the temporary storage of data on unit 5. Determine shadowing
   combinations [SGCOMB]. Read the environment file to determine solar
   position and days to be simulated.

INITTH   subroutine

   Initailize temperatures and temperature/flux histories.

INITZP   subroutine

   Initialze values for computing zone pressures. In particular, set the
   $ZZ(0)$ and $PZ(0)$ values (for ambient air) to zero. Set system flows to
   zero. Set wind pressures to zero (needed to allow inclusion of PW term
   in the equation for internal surfaces).

INTCPT   subroutine

   Determine all intercepts between the sides of figure NS2 and the sides
   of figure NS1 (E.3.4 and E.4).

IZERO(ARRAY,LEN)   subroutine

   Set ARRAY (length LEN) of integers to 0.

JDS(JFLAG,JD,YR,MO,DM)   subroutine

   If JFLAG = 1, compute the Julian date (JD) from the year (YR), month
   (MO), and day-of-month (DM) (B.1.2). Otherwise, compute YR, MO, and DM
   from YR (B.1.3).

LOCRAN(LIST,LEN,ITEM)   integer function

   Determine the location of ITEM in a LEN long array (LIST) of unordered
   words. A linear search is used. An unsuccessful search returns the
   value zero.

MRL(OUTPUT,SINPFL,ENVTFL)   program

    Multi-room loads program. This is the main (or root) program of the
    loads calculator. It calls the three segments of the loads
    calculation.

MRTNET   subroutine

    Compute the zone mean radiant temperatures for the second and
    subsequent heat balance iterations. Use the simple (H.2.3) or the
    detailed (H.2.4) algorithm. This routine includes equations to improve
    heat balance convergence.

MRTNT1   subroutine

    Compute the zone mean radiant temperatures for the first heat balance
    iteration of the hour. Use the simple (H.2.3) or the detailed (H.2.4)
    algorithm. This routines includes equations to improve convergence of
    the MRT on the first iteration. Development of those equations is not
    complete.

MULTOL(NNN,LOCO,NRFIGS)   subroutine

    Determine the overlaps of figure NNN with previous figures stored in
    locations LOCO+1 through LOCO+NRFIGS of the HC arrays.

OCNVCO(I,HM,OABS,TO,HO,HS,HG)   subroutine

    Evaluate the heat exchange coefficients HA (=HO), HS, and HG for heat
    transfer surface number I. Input also includes the U-value of movalbe
    insulation, if present, the solar absorptance of the surface/movable
    insulation, and the most recently computes surface outside temperature
    TO. Use the algorithms in (I.2). The surface temperature of movable
    insulation is estimated from (I.3.8) with HO as input computed from the
    simple algorithm.

OMVINS(I,OABS)   subroutine

    Evaluate external movable insulation for heat transfer surface number I.
    If it is present, return its solar absorptance in OABS and set UM(I).
    Otherwise, set UM(I) to zero.

ORDER(NS3,NV3)   subroutine

    Sort the unordered vertices found by enclosure [INCLOS] and intercept
    [INTCPT] into clockwise sequence for use by subsequent overlap
    calculations. Results are placed in location NS3 in the HC arrays.

OVRLAP   subroutine

    Use homogeneous coordinate techniques (E.4) to compute the overlap
    between two convex polygons.

PAGE(IACT,NEED)   subroutine

Write output report page heading. See PAGE description in the list of
IP subroutines.

POLY1F(X,A,N)   real function

Evaluate simple polynomial expression (D.1.7a):

$$P = A(1) + A(2)*X + A(3)*X^2 + ... + A(N)*X^{N-1}$$

POLY2F(X,A,N)   real function

Evaluate simple polynomial expression (D.1.7b):

$$P = A(1)*X + A(2)*X^2 + ... + A(N)*X^N$$

QINSRC   subroutine

Compute (or set up parameters and pointers) for scheduled internal
loads. First initialize the loads arrays. Then process every element
in the CGS arrays (that is not off for the day) according to type
(CGSTYP).

QSDIST   subroutine

Distribute short wavelength radiant gains (solar and lights) on the
inside surfaces of the zones. This includes a single pass of light
through transparent interzone partitions and calculation of the light
converted to instantaneous convective gain on internal shades.
Determine if the radiant gain should be placed on movable insulation
instead of the surface. Include the transmission of light through
windows ut of the zone and to the environment.

QSUN   subroutine

Determine solar gains. Use the solar gains multipliers and the solar
radiation intensities to determine the diffuse solar gains in the zones,
the solar gains on outside surfaces, and the beam soalr gains on inside
surfaces. Also evaluate placement of movable insulation for the hour
[IMVINS and OMVINS].

READIN   subroutine

Read the simulation input file (SINPFL) and determine the array space
used. Data which was prepared in single element arrays in the IP is
read into multiple element arrays. The reading is directed by
two-element records that tell which arrays will be filled when the next
record is read. The unformatted read statements must match the IP write
statements. Note that each data read is protected to prevent array
overflow. Also note that a simulation control information (created in
FINISH) must be the last record read. Otherwise, an end-of-file is
encountered which terminates the run.

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REPTBL   subroutine

    Report building loads (a default action).

REPTSM(KEY)   subroutine

    Report simulation values like numbers of iterations and execution time.
    Time is determined by the non-ANSI function SECOND. This function can
    be removed without otherwise effecting the program.

REPTZD   subroutine

    Report a description of the zone (RNOS=9 - 1.2.1).

RPTASU(NR,MAX,NAME,LIMIT)   subroutine

    Report array space utilization. For PARAMETERized arrays, print a
    message giving the number (NR) of elements utilized and the short
    parameter name (NAME). If NR is greater than the size (MAX) of the
    arrays, print a string of stars to highlight the message and set LIMIT
    true.

SETIZP   subroutine

    Set interzone pointers for interzone partitions, MIX and FAN
    operations, and interzone air flow openings. Unmatched items cause run
    termination.

SGACTN   subroutine

    Determine which groups of days are used for shadowing calculations.
    This is based on the shadowing group dates (Table IV.G.1) and the dates
    of any shadowing surface or movable insulation actions which change the
    building shadowing configuration. The angles (declination and equation
    of time) from which solar position is calculated are determined by
    averaging the values for all days in the period.

SGBEAM   subroutine

    Direct the calculation of solar gains multipliers for a day. For each
    hour, compute the angle of incidence of the sun's rays on every surface
    (E.2.2); compute the solar multipliers [SHADOW]; store the results on
    unit 3 for later heat balance calculations.

SGCOMB   subroutine

    Determine which surfaces can shade each other. This is constant for
    the entire simulation and can, therefore, be used to avoid recomputing
    such data at every hour. Data is stored in the SHDCMB array and is
    used to direct the calculation sequence of the SHADOW subroutine.
    Shadowing combinations are computed for heat transfer, exterior, base
    surfaces. All surfaces which can shade the base surface are determined
    [CHKGSS]. All heat transfer subsurfaces are determined [CHKSBS]. For

the detailed solar distribution algorithm, all inside surfaces which might receive beam sunlight are determined [CHKBKS]. Complex building configurations which cause SHDCMB to overflow are handled by reducing the level of shadowing detail, if possible.

SHADOW(IHOUR)   subroutine

Compute the sunlit areas and solar gains multipliers for all building envelope surfaces at time IHOUR. From the shadow combinations array, determine the number of shadowing surfaces (NGSS), inside (back) surfaces (NBKS), and heat transfer subsurfaces (NSBS). If the surface faces away from the sun, its sunlit area (and all subsurfaces) must be zero. If it faces the sun and there are no shadowing surfaces, it must be totally sunlit. Otherwise, compute the shadow patterns on the surface [SHDGSS]. For window subsurfaces and the detailed solar distribution call SHDBKS. Then process the subsurfaces [SHDSBS] to compute their sunlit areas and solar gains multipliers and to determine how they modify the gross sunlit area of the base surface. Finally, compute the solar gain multiplier of the base surface.

SHDBKS(NGRS)   subroutine

Project the zone inside surfaces along the sun's rays to the plane of the current general shadow receiving surface. This is done for the detailed internal solar distribution (3.1.2) if there are windows on the base surface and if the sun might shine through the window onto the inside surface. This is not possible if the inside surface faces the sun. The projected figure of the inside surface is reduced to fit within the base surface by the overlap algorithm (E.4) [OVRLAP].

SHDGSS(NGRS)   subroutine

Compute the shadow figures on surface (base surface – 4.13.2) number NGRS. If there are no shadowing surfaces, the surface must be fully sunlit. Otherwise, determine the shadows from all shadowing surfaces. If the shadowing surface is sunlit, it cannot be casting a show (E.2) so skip it. Also skip if indicated by shadowing surface dates. Transform and clip the coordinates of the shadowing surface to the receiving surface coordinate system (E.2). Determine the overlap of the shadow on the surface (E.4). Also determine how it overlaps any previous shadows. Add (signed) shaded areas to compute the gross sunlit area of the base surface. The effects of subsurfaces is not yet computed.

SHDINT(L)   subroutine

Determine the distribution of solar gains from a single window of optical type L (index to optical coefficients). Compute multipliers for zone diffuse gains. Compute multipliers for beam gains using detailed or simple internal solar distributions. The detailed distribution involves overlapping the window sunlit pattern with the

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projections of the internal surfaces along the sun's rays to the plane of the base surface and computing the sunlit area of each internal surface. If the internal surface is transparent, its diffuse transmittance is used to pass sunlight into the adjacent zone. The simple distribution puts the sunlight on the floor(s) of the zone according to ISABSF [CISAF]. In either case, that portion of the sunlight which is not directly absorbed by the internal surface becomes a diffuse gain for the entire zone.

SHDRVL   subroutine

Evaluate the shadowing effect of a subsurface setback (4.13.6). The shadow from the setback reduces the potential sunlit area of the subsurface. This potential area is still rectangular. It is overlapped with the shadow figures already known to lie within the subsurface opening [SHDSBS] to compute the actual sunlit area.

SHDSBS(IHOUR)   subroutine

Evaluate the sunlit areas of the subsurfaces (windows, doors). The shadow patterns have already been accurately determined on the base surface and stored in the homogeneous coordinate arrays [SHDGSS]. The subsurfaces are evaluated one at a time. Each subsurface figure is overlapped with the shadow figures. This determines a sunlit area which must be removed from the gross sunlit area of the base surface. Check for movable insulation [SMVINS] and if it applies skip most of the following calculations. Evaluate the shadowing effect of a setback [REVEAL]. If the surface is transparent, compute its optical properties and determine the windows contribution to the distribution of sunlight in the zone [SHDINT]. Finally, compute the solar multipliers for the subsurface.

SIMBLD   subroutine

Simulate the building thermal performance. This is the root routine of the loads segment. The segmentation is helped by temporary storage of data on unit 4. There are several initializations [IMRTNW, REPTSM(1), and IBLRPT]. The largest initialization requires several days simulation [SIMDAY] to remove the transients in the temperature histories. This initialization is terminated in accordance with the hourly heat balance convergence criteria. Then the actual simulation [SIMDAY] is done for the number of days required. A summary report is printed [REPTBL].

SIMDAY   subroutine

Do the simultaneous multizone heat balance calculations for one day. This involves an initialization of values which are constant for the day [DAILY] followed by a loop of heat balance calculations for 24 (standard time) hours. The loop involves setting up the constant values for the hour (weather data, solar gains [QSUN], scheduled loads

[QINSRC], control profiles [CHACS], distribution of short wavelength radiation [QSDIST]), doing the first iteration of the multizone heat balance (compute variable coefficients [VARTMP], air movements [AIRMV0 or AIRMV1], surface outside heat balances [HBOUT], mean radiant temperatures [MRTNT1], surface inside heat balances [HBSRF], the zone air heat balances [HBAIR]), do subsequent iterations to convergence, summarize the hour's loads data [CALOAD], and prepare for the next hour [UTHRMH]. Various data dumps are available as the calculations proceed.

SMVINS(K,IHOUR,OABS)   subroutine

Evalaute exterior movable insulation (EMI). K is the pointer stored in SSCPTR(heat transfer surface number). It points to data about the EMI in the ISSC/RSSC arrays. Time (IHOUR), environmental conditions, and the type of control will determine if the EMI is applied or if it is not. If it is not, OABS is set to zero. If it is applied, OABS is set to the solar absorptance of the EMI.

SOLVZP   subroutine

Solve the detailed air flow equations for the zone pressures. On the first iteration of the hour approximate the zone pressures (PZ) by solving a linear set of equations (flow exponents set to one). This gives a reasonable set of starting values for PZ. Then use a modified Newton's method to solve the simultaneous non-linear algebraic equations (G.3.5, G.4.1a to c). This method always produces a diagonally dominant matrix which can be solved by GAUSSY, a simplified Gauss elimination routine.

STATUS(UNIT)   subroutine

Print the status of unit number UNIT as determined by the FORTRAN INQUIRE function. This routine is used for program debugging purposes only.

SUN3(DAYYR,SINDEC,EQTIM)   subroutine

Compute the sine of the solar declination angle (SINDEC) and the equation of time value (EQTIM) for a given day-of-year (DAYYR).

SUN4(HOUR)   subroutine

Compute the solar direction cosines for a given HOUR.

UTHRMH   subroutine

Update the surface temperature and flux history values. All histories are stored contiguously in the TFH array. New values of temperature and flux are added to the array by overwriting old values (that will not be needed next hour) of other surfaces. This causes the histories

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to "crawl" slowly through the TFH array. Compute the inside (C.1.4) and outside (C.1.6) conductive fluxes and store in the TFH array. Compute KIP (C.1.5) and KOP (C.1.7) for the next hour. Shift the history values back one hour by incrementing TSHIFT. If the histories have reached the bottom of the TFH array, shift all values back to the top of the array and reset TSHIFT.

VARTMP   subroutine

Evaluate variables that are directly influenced by zone air temperature. These variables are the occupant sensible/latent gains (F.1.1), and the interior convection coefficients (J.1 and J.2).

ZERO(ARRAY,LEN)   subroutine

Set ARRAY (length LEN) of real numbers to 0.

This diagram (continued over several pages) shows the general relationship
of the loads calculator subroutines to ech other. A subroutine calls other
subroutines which are to the right and below it on the diagram. Multiple calls
to the same routine are not shown, only the first. Circled letters are contin-
uation points for often used groups of subroutines. Not all subroutines and
functions are included. The intrinsic FORTRAN 77 have been left out. The
simple utility routines ERROR and PAGE which are called from many places are
not always shown.

Figure VI.B.1 Tree structure of the loads calculator program

Figure VI.B.1 (continued)

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Figure VI.B.1 (concluded)

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VI.C   VARIABLES

PARAMETERS are extensively used to set array dimensions. This allows
the same common block to describe only a single surface, schedule, etc., in
the IP program and hold all surfaces, schedules, etc. in the LC. The IP
computes the required dimensions necessary for the LC to simultaneously hold
all descriptions. The following list describes the TARP parameters. "Short
names" are those used to describe parameters in IP and LC reports.

parameter	short name	description
ALEN	–	maximum number of words decoded at one time
DESLEN	–	maximum number of characters in a description
MAXAFS	AFS	maximum number of air flow openings
MAXCDS	CDS	maximum number of control day-schedules
MAXCGS	CGS	maximum number of control/general schedule descriptions
MAXCON	CON	maximum number of constructs
MAXCMB	–	maximum number of shadowing combinations
MAXCTF	CTF	maximum number of conduction transfer functions (CTF)
MAXCWS	CWS	maximum number of conrol week-schedules
MAXDSH	DSH	maximum number of day-scheduled
MAXENV	–	maximum number of environments
MAXGTP	GTP	maximum number of optical constructs
MAXHCS	–	maximum number of homogeneous coordinate figures
MAXHCV	–	maximum number of vertices in an HC figure
MAXHTS	HTS	maximum number of heat transfer surfaces
MAXLNM	–	maximum number of library names (entries)
MAXNL	–	maximum number of layers in a construct
MAXNRF	–	maximum number of response factors
MAXNRT	–	maximum number of roots for CTF calculation
MAXNWL	–	maximum number of wavelengths
MAXPFL	PFL	maximum number of control profiles
MAXPNT	–	maximum number of user defined points in control profile
MAXRNG	–	maximum number of control ranges (=MAXPNT+1)
MAXSSC	SSC	maximum number of special surface coefficients
MAXSRF	SRF	maximum number of surfaces (ex MASS, inc shadowing)
MAXTFH	TFH	maximum number of temperature and flux histories
MAXTMP	–	maximum number of control points (=MAXPNT+2)
MAXWSH	WSH	maximum number of week-schedules
MAXZON	ZON	maximum number of zones
RFGLEN	–	number of report flags
UINLEN	–	number of characters in one user input record
WRDLEN	–	maximum number of characters in a word

Nearly all significant variables in the TARP are in common blocks. The
list below describes all such variables by giving the name, common block,
subprogram using the variable (IP, LC, or BOTH), type, dimensions (including
parameters), and units on one line followed by a verbal description.

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```
A          /GLAS3/    IP        real        (2,4,2)             -
     Absorptances of single panesof glass
           (polarization, pane number, side of incidence).

A          /ZONL/     LC        real        (MAXZON)            C/W
     Temperature independent part of the zone heat balance equation.
     For example (K.1.4) and (K.4.1).

AA         /GLAS3/    IP        real        (2,5,2)             -
     Absorptances of layers in a window system
           (polarization, surface number, side of incidence).

AAB        /GLAS6/    IP        real        (16,2,5)            -
     Absorptances of a window system for beam light
           (angle number, polarization, surface number).

AABW       /GLAS8/    IP        real        (16,5)              -
     Beam absorptances integrated over wavelength and polarization
           (angle number, surface number).

AAD        /GLAS5/    IP        real        (2,5,2)             -
     Absorptances of a window system for diffuse light
           (polarization, surface number, side of incidence).

AADW       /GLAS7/    IP        real        (5)                 -
     Diffuse absorptances integrated over wavelength and polarization
           (surface number).

ABI        /SHDCTL/   LC        real        -                   -
     Fraction of beam solar radiation absorbed at the inside surface of
     a window.

ABO        /SHDCTL/   LC        real        -                   -
     Fraction of beam solar radiation absorbed at the outside surface of
     a window.

ACHAR      /UINDAT/   IP        integer     -                   -
     Pointer to current character in AWORD.

ACNVG1     /RUNCTL/   IP        real        -                   -
           /SIMCTL/   LC
     Relative air flow convergence (3.1.4).

ACNVG2     /RUNCTL/   IP        real        -                   m3/s
           /SIMCTL/   LC
     Absolute air flow convergence (3.1.4).

ACNVG3     /RUNCTL/   IP        real        m3/s                Pa
           /SIMCTL/   LC
     Minimum pressure across any opening (3.1.4).
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AD   /RF4/   IP   real   -   -
     Upper left element of the layer derivative matrix.

AFAREA   /AFSDAT/ IP   real   - m^2
     Air flow opening area for matching interzone openings.

AFEXP   /AFSDAT/ IP   real   -   -
     Air flow opening exponent for matching interzone openings.

AFLOW   /RUNCTL/ IP   integer   -   -
          /SIMCTL/ LC
     Flag for detailed (1) or simple (0) air flow modeling (3.1.4).

AFSNAM   /AFSNAM/ LC   chr*WRD (MAXAFS)   -
     Name of zone on opposite side of interzone opening.

AFSPTR   /AFSIL/   LC   integer (MAXAFS)   -
     Number of the zone on the opposite side of the opening (0 means ambient).

AI   /SOLFAC/ LC   real   (MAXHTS)   -
     Beam solar radiation factor for the inside of a surface.

AID   /GLASO/   BOTH   real   (MAXGTP)   -
     Fraction of diffuse solar radiation absorbed at the inside surface
     of a window.

AIRDEN   /AIR/   LC   real   - kg/m^3
     Density of ambient air.

AI1   /GLAS/   BOTH   real   (5,MAXGTP)   -
     Polynomial coefficients for window inside beam solar absorptance
     (c_i in D.1.7a).

AI2   /GLAS/   BOTH   real   (6,MAXGTP)   -
     Polynomial coefficients for window inside beam solar absorptance
     (c_i in D.1.7b).

AL   /RF4/   IP   real   -   -
     Upper left element of the layer matrix.

ALIST   /ALIST/   IP   char*WRD (ALEN)   -
     List of words decoded from user input: a section name, key name,
     or subkey name and data.

ALTD   /EFLHDR/ BOTH   real   -   m
     Altitiude of site (not yet used).

AMAXIT   /RUNCTL/ IP   integer   -   -
     Maximum number of air flow iterations for convergence (3.1.4).

AN   /GLAS9/ IP   real   -   -
      Index of refraction of air (=1.0).

AO   /SOLFAC/ LC   real   (MAXHTS)   -
      Beam solar radiation absorption factor for the outside of a surface.

AOD   /GLASO/ BOTH   real   (MAXGTP)   -
      Fraction of diffuse solar radiation absorbed at the outside surface of
      a window.

AO1   /GLAS/   BOTH   real   (5,MAXGTP)   -
      Polynomial coefficients for window outside beam solar absorptance
      (c_i in D.1.7a).

AO2   /GLAS/   BOTH   real   (6,MAXGTP)   -
      Polynomial coefficients for window outside beam solar absorptance
      (c_i in D.1.7b).

AP   /IZPDAT/ IP   real   - m^2
      Area of interzone partition.

AREA   /HTSISL/ BOTH   real   (MAXHTS) m^2
      Area of heat transfer surface.

AS   /RF4/   IP   real   -   -
      Upper left element of the total construct matrix.

ASD   /GLASO/ BOTH   real   (MAXGTP)   -
      Absorptance for diffuse radiation of the interior shading device.

AS1   /GLAS/   BOTH   real   (5,MAXGTP)   -
      Polynomial coefficients for beam absorptance of the interior shading
      device (c_i in D.1.7a).

AS2   /GLAS/   BOTH   real   (6,MAXGTP)   -
      Polynomial coefficients for beam absorptance of the interior shading
      device (c_i in D.1.7b).

AT   /RF4/   IP   real   -   -
      Upper left element of the total derivative matrix.

AWORD   /UINDAT/ IP   integer   -   -
      Pointer to current word in ALIST.

AZS   /AFSDAT/ IP   real   -   m
      Height of air flow opening for matching interzone openings.

B   /ZONL/   LC   real   (MAXZON)   W
      Temperature dependent part of the zone air heat balance equation.
      For example (K.1.4) and (K.4.1).

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BAREA   /BASES/   IP   real   -   m^2
      Net area of base surface (= gross area minus subsurface areas).

BASE   /BASES/   IP   real   -   m
      Distance from surface origin to first vertex (for imaging).

BAZM   /BASES/   IP   real   -   degrees
      Azimuth angle of base surface (4.13.3).

BBLOAD   /ZONL/   LC   real   (MAXZON)   Wh
      Baseboard heating load.

BCA   /BASES/   IP   real   -   -
      Cosine of azimuth angle of base surface (4.13.3).

BCLD   /BLDRPT/   LC   real   -   Wh
      Total sensible cooling load for the building.

BCT   /BASES/   IP   real   -   -
      Cosine of tilt angle of base surface (4.13.4).

BD   /RF4/   IP   real   -   -
      Upper right element of the layer derivative matrix.

BDRELN   /RUNCTL/   IP   real   -   degrees
      Angle from true north to Y-axis of building coordinate system
      (3.1.1 and E.1.1).

BETA   /RF2/   IP   real   (MAXNL)   -
      Layer thickness divided by the square root of the thermal diffusivity.

BHOC   /BASES/   IP   real   -   -
      Value of HOC for the base surface.

BHLD   /BLDRPT/   LC   real   -   Wh
      Total sensible heating load for the building.

BHTS   /BASES/   IP   integer   -   -
      Heat transfer surface number of the base surface.

BKSNR   /SHDCTL/   LC   integer   -   -
      Back (inside) surface number.

BL   /RF4/   IP   real   -   -
      Upper right element of the layer matrix.

BMNT   /BLDRPT/   LC   real   -   C
      Minimum temperature of any zone in the building.

BMXC   /BLDRPT/   LC   real   -   W
      Peak cooling load for the building.

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BMXH   /BLDRPT/ LC   real   -   W
     Peak heating load for the building.

BMXT   /BLDRPT/ LC   real   -   C
     Maximum temperature of any zone in the building.

BS   /RF4/   IP   real   -   -
     Upper right element of the total construct matrix.

BSA   /BASES/   IP   real   -   -
     Sine of azimuth angle of base surface (4.13.3).

BST   /BASES/   IP   real   -   -
     Sine of tilt angle of base surface (4.13.4).

BT   /RF4/   IP   real   -   -
     Upper right element of the total derivative matrix.

BTILT   /BASES/   IP   real   -   degress
     Tilt angle of base surface (4.13.4).

BTYP   /BASES/   IP   integer   -   -
     Type number of the base surface: 1=envelope, 2=interior.

BZS   /BASES/   IP   real   -   m
     Average Z coordinate of base surface.

BZT   /BASES/   IP   real   -   m
     Maximum Z coordinate of base surface.

C   /GLAS12/ IP   real   (6)   -
     Coefficients of the window properties curve fit.

C   /SHDCTL/ LC   real   -   -
     X displacement of a shadow in the surface coordinate system (E.2.3a).

CA   /SRFIS/   BOTH   real   (MAXSRF)   -
     Cosine of surface azimuth angle (3.2.1 and 4.13.3).

CALCS   /RUNCTL/ IP   logical   -   -
     Opposite of SYNTAX.

CAP   /TCDESC/ LC   real   (MAXPNT+1)   W
     Heating/cooling capacities at the control point temperatures
     (Lp in K.1.1).

CB   /SOLFAC/ LC   real   (MAXZON)   -
     Beam solar radiation convection factor for the zone.

CBI   /SHDCTL/ LC   real   -   -
     Fraction of beam solar radiation convected at an interior shade.

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```
CC          /RF/      IP          real        -                    W/m²K
     Layer thickness * density * specific heat (= thermal capacitance).

CD          /RF4/     IP          real        -                    -
     Lower left element of the layer derivative matrix.

CDATE       /SIMCTL/  LC          integer     -                    -
     Cyclic date (B.1.4).

CDSH        /CNTPTR/  LC          integer     (24,MAXCDS)          -
     Control day-schedules (pointers to control profiles).

CDSNAM      /LIBNMS/  LC          char*WRD    (MAXCDS)             -
     Names of control day-schedules (2.7.1).

CDSO        /LIBCTL/  IP          integer     -                    -
     Pointer to control day-schedules  in LNAMES (location 0).

CFA         /REPORT/  BOTH        real        -                    *
     Area conversion factor:  ft² * CFA(2) = m²

CFC         /REPORT/  BOTH        real        -                    *
     Specific heat conversion factor:  Btu/lbF * CFC(2) = kJ/kgK

CFD         /REPORT/  BOTH        real        -                    *
     Density conversion factor:  lb/ft³ * CFD(2) = kg/m³

CFE         /REPORT/  BOTH        real        -                    *
     Energy conversion factor:  Btu * CFE(2) = Wh

CFH         /REPORT/  BOTH        real        -                    *
     Enthalpy converstion factor:  Btu/lb * CFH(2) = kJ/kg

CFK         /REPORT/  BOTH        real        -                    *
     Conductivity conversion factor:  Btu/hrftF * CFK(2) = W/mK

CFL         /REPORT/  BOTH        real        -                    *
     Length conversion factor:  ft * CFL(2) = m

CFM         /REPORT/  BOTH        real        -                    *
     Mass conversion factor:  lb * CFM(2) = kg

CFMF        /REPORT/  BOTH        real        -                    *
     Mass flow conversion factor:  lb/hr * CFMF(2) = kg/s

CFP         /REPORT/  BOTH        real        -                    *
     Pressure conversion factor:  in(H2O) * CFP(2) = N/m²    (= Pa)

CFQ         /REPORT/  BOTH        real        -                    *
     Power conversion factor:  Btu/hr * CFQ(2) = W
```

```
CFS        /REPORT/   BOTH        real        -                        *
      Speed conversion factor:  ft/min * CFS(2) = m/s

CFT        /REPORT/   BOTH        real        -                        *
      Temperature conversion factor:  R * CFT(2) = K

CFU        /REPORT/   BOTH        real        -                        *
      U-value conversion factor:  Btu/hrft$^2$F * CFU(2) = W/m$^2$K

CFV        /REPORT/   BOTH        real        -                        *
      Volume conversion factor:  ft$^3$ * CFV(2) = m$^3$

CFVF       /REPORT/   BOTH        real        -                        *
      Volumetric flow conversion factor:  ft$^3$/min * CFVF(2) = m$^3$/s

CGSDX      /CGSIL/    BOTH        integer    (MAXCGS)              -
      Pointer to week-schedule (or control week-schedule)

CGSHX      /CGSIL/    BOTH        integer    (MAXCGS)              -
      Pointer to day-schedule (or control day-schedule)

CGSNAM     /CGSNAM/   LC          chr*WRD    (MAXCGS)              -
      Name of zone to which the scheduled load applies.  This identifies
      the adjacent zone for which MIX and FAN operations apply.

CGSOFF     /CGSIL/    BOTH        integer    (MAXCGS)              -
      Date (cycilc date form - eq B.1.4) week-schedule ends.

CGSON      /CGSIL/    BOTH        integer    (MAXCGS)              -
      Date (cyclic date form - eq B.1.4) week-schedule begins.

CGSTYP     /CGSIL/    BOTH        integer    (MAXCGS)              -

Type of action:
      1 = people
      2 = lights
      3 = electric equipment
      4 = gas equipment
      5 = steam equipment
      6 = hot water equipment
      7 = other equipment
      8 = infiltration
      9 = ventilation
     10 = controls
     11 = daylighting
     12 = steam baseboard heat
     13 = hot water baseboard heat

CGSZON     /CGSIL/    BOTH        integer    (MAXCGS)              -
      Number of the zone for which the action applies.
```

CL   /RF4/   IP   real   –   –
    Lower left element of the layer matrix.

CLKTIM   /SIMCTL/ LC   integer   –   hr
    "Clock time" ($=t_d$ in B.1.1) for selecting scheduled activities.

CNAME   /ZNAMES/ IP   char*WRD –   –
    Construct name (4.13.1).

CND   /RF/   IP   real   – $W/m^2 K$
    Conductivity of the construct.

CNTCAP   /CNTPFL/ BOTH   real   (MAXPNT,MAXPFL)   W
    Heating/cooling capacity at the control point.

CNTTMP   /CNTPFL/ BOTH   real   (MAXPNT,MAXPFL)   C
    Effective zone temperature of the control point.

CNVMRT   /ZONL/   LC   real   (MAXZON)   –
    Parameter user to predict the mean radiant temperature (TR) and
    speed zone heat balance convergence.

COND   /MATDAT/ IP   real   (MAXNL)   W/mK
    Conductivity of each layer of construct (from outside).

CONNAM   /LIBNMS/ LC   char*WRD (MAXCON)   –
    Construct names (2.5.1).

CONSO   /LIBCTL/ IP   integer   –   –
    Pointer to constructs in LNAMES (location 0).

CONTEM   /TCDESC/ LC   real   (MAXTMP,MAXZON)   C
    Control point temperatures.

COSBR   /RUNCTL/ IP   real   –   –
    Cosine of the building rotation angle.

COSD   /SLPSSH/ BOTH   real   –   –
    Cosine of the solar declination angle.

COSINC   /GLAS1/   IP   real   –   –
    Cosine of the angle of incidence.

COSL   /EFLHDR/ BOTH   real   –   –
    Cosine of the latitude angle.

COSZR   /BASES/   IP   real   –   –
    Cosine of the zone rotation angle.

CP   /TCDESC/ LC   integer   (MAXZON)   –
    Pointer to control profile.

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CPAIR   /AIR/   LC   real   –   Ws/kgK
     Specific heat of air.

CPFL0   /LIBCTL/ IP   integer   –   –
     Pointer to control profile in LNAMES (location 0).

CPOLD   /ZONL/   LC   integer   (MAZON)   –
     Prior hour's pointer to control profile.
     If CP = CPOLD, it is not necessary to recompute the control profile.

CR   /TCDESC/ LC   real   (MAXZON)   –
     Zone temperature control radiant fraction (b in eq K.1.3).

CS   /RF4/   IP   real   –   –
     Lower left element of the total construct matrix.

CSDECL   /ENVDAT/ BOTH   real   –   –
     Cosine of the solar declination angle.

CT   /SRFIS/ BOTH   real   (MAXSRF)   –
     Cosine of surface tile angle (3.2.2 and 4.13.4).

CT   /RF4/   IP   real   –   –
     Lower left element of the total derivative matrix.

CTF   /BLDCTF/ LC   real   (MAXCTF)   –
     Array of conduction transfer fucntions for all constructs.

CTFX0   /CONDAT/ BOTH   real   (MAXCON)   W/m^{2}K
     X conduction transfer function for each construct for time = 0.

CTFY0   /CONDAT/ BOTH   real   (MAXCON)   W/m^{2}K
     Y conduction transfer function for each construct for time = 0.

CTFZ0   /CONDAT/ BOTH   real   (MAXCON)   W/m^{2}K
     Z conduction transfer function for each construct for time = 0.

CTHETA   /SRFIS/ BOTH   real   (MAXSRF)   –
     Cosine of the angle of incidence of the sun's rays on the surface.

CTILT   /HTSISL/ BOTH   real   (MAXHTS)   –
     Cosine of the heat transfer surface tilt anlge.

CTQ   /RF1/   IP   real   (5)   –
     Flux conduction transfer functions (orders 0 through 5).

CTX   /RF1/   IP   real   (0:5,0:MAXNRF)   W/m^{2}K
     X (external) conduction transfer functions (orders 0 through 5).

CTY   /RF1/   IP   real   (0:5,0:MAXNRF)   W/m^{2}K
     Y (cross) conduction transfer functions (orders 0 through 5).

CTZ   /RF1/   IP   real   (0:5,0:MAXNRF)   W/m^{2}K
      Z (internal) conduction transfer functions (orders 0 through 5).

CWSH   /CNTPTR/ LC   integer   (12,MAXCWS)   -
      Control week schedules (2.8): pointers to control day schedules.

CWSNAM   /LIBNMS/ LC   char*WRD   (MAXCWS)   -
      Names of control week shcedules (2.8.1).

CWS0   /LIBCTL/ IP   integer   -   -
      Pointer to control week-schedules in LNAMES (location 0).

D   /RF1/   IP   real   (5)   -
      1.0 - RATIO

DAYOFM   /ENVDAT/ BOTH   integer   -   -
      Day of the month number (DM in B.1.2)

DAYOFS   /SIMCTL/ LC   integer   -   -
      Number of days simulated.

DAYOFW   /ENVDAT/ BOTH   integer   -   -
      Day of the week number (DW in B.1.2).

DAYOFY   /ENVDAT/ BOTH   integer   -   -
      Day of the year number (DY in B.1.2).

DAYTYP   /SIMCTL/ LC   integer   -   -
      Day type number (used to select schedules).

DB   /SOLFAC/ LC   real   (MAXZON)   -
      Beam radiation factor for zone (beam converted to diffuse by shade).

DD   /RF4/   IP   real   -   -
      Lower right element of the layer derivative matrix.

DDBP   /DDENVT/ IP   real   -   Pa
      Design day barometric prpessure (1.6.6).

DDCLR   /DDENVT/ IP   real   -   -
      Design day clearness number (1.6.9).

DDDOFM   /DDENVT/ IP   integer   -   -
      Design day day-of-month number (1.6.5).

DDDTYP   /DDENVT/ IP   integer   -   -
      Design day type number (1.6.12).

DDMDBT   /DDENVT/ IP   real   -   C
      Design day maximum dry bulb temperature (1.6.2).

DDMON   /DDENVT/ IP   integer   -   -
     Design day month number (1.6.5).

DDRN   /DDENVT/ IP   integer   -   -
     Design day rain indicator (1=rain) (1.6.10).

DDSNW   /DDENVT/ IP   integer   -   -
     Design day snow indicator (1=snow) (1.6.11).

DDTRNG   /DDENVT/ IP   real   -   C
     Design day temperature range (from 1.6.2 and 1.6.3).

DDWBT   /DDENVT/ IP   real   -   C
     Design day wet bulb temperature (1.6.4).

DDWDIR   /DDENVT/ IP   real   -   degrees
     Design day wind direction (1.6.8).

DDWSPD   /DDENVT/ IP   real   -   m/s
     Design day wind speed (1.6.7).

DELT   /REPORT/ BOTH   real   -   *
     Temperature conversion factor: (F+DELT(2)) * CFT(2) = C

DEM   /RUNCTL/ IP   logical   -   -
     Detailed error messages (1.1.3).

DENS   /MATDAT/ IP   real   (MAXNL)   kg/m^3
     Material density (2.4.5).

DG   /SOLFAC/ LC   real   (MAXZON)   -
     Ground reflected diffuse radiation factor for the zone.

DIR   /ENVDAT/ BOTH   real   (24)   degress
     Wind direction (G.1.3).

DL   /RF4/   IP   real   -   -
     Lower right element of the layer matrix.

DS   /RF4/   IP   real   -   -
     Lower right element of the total construct matrix.

DS   /SOLFAC/ LC   real   (MAXZON)   -
     Diffuse sky radiationn factor for the zone.

DSH   /SCHDLS/ LC   real   (24,MAXDSH) -
     Day schedules (2.2).

DSHNAM   /LIBNMS/ LC   char*WRD   (MAXDSH)   -
     Day schedule names (2.2.1).

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DSTIND   /ENVDAT/ BOTH   integer   -   -
    Daylight savings time indicator.

DS0   /LIBCTL/ IP   integer   -   -
    Pointer to day schedules in LNAMES (location 0).

DT   /RF4/   IP   real   -   -
    Lower right element of total derivative matrix.

DTR   /REPORT/ BOTH   real   -   *
    Conversion factor: degrees * DTR = radians.

DYS   /CALNDR/ BOTH   char*3   (12)   -
    Names of day types (2.3.3).

EELOAD   /ZONL/   LC   real   (MAXZON)   Wh
    Zone electric load (lights plus electric equipment).

EFILL   /ENVDAT/ BOTH   integer   (3)   -
    Array filler.

EFSTR   /TCDESC/ LC   integer   (MAXZON)   -
    Pointer to temperature control range (p in K.1.1).

EMIT   /MATDAT/ IP   real   (MAXNL)   -
    Emittance o material for thermal wavelength radiation (2.4.8).

EMUI   /RUNCTL/ IP   integer   -   -
    Input in English (2) or metric (1) units (1.1.7).

EMUO   /REPORT/ BOTH   integer   -   -
    Output in English (2) or metric (1) units (1.1.7).

ENDATE   /SIMCTL/ LC   integer   -   -
    Cyclic date on which current shadowing data ends.

ENVDAT   /ENVDAT/ BOTH   integer   (256)   -
    Environment data - all equivalenced to this array.

ENVREC   /SIMCTL/ LC   integer   -   -
    Environment record number (index to ENVTFL direct access file).

ENVTNR   /SIMCTL/ LC   integer   -   -
    Environment number.

EQTIME   /ENVDAT/ BOTH   real   -   hr
    Equation of time.

EQTM   /SLPSSH/ BOTH   real   -   hr
    Equation of time.

ETITLE   /TITLES/ BOTH   char*DESC (13)   -
        Environment titles (1.5.1 and 1.6.1).

EVDATE   /ENVDAT/ BOTH   integer   -   -
        Julian date (JD in B.1.2).

EXTC   /GLAS9/   IP   real   (4)   -
        Product of pane extinction coefficient times thickness.

EXTCW   /GLAS10/ IP   real   (4,MAXNWL)   -
        Product of pane extinction coefficient times thickness for each
        wavelength.

EVTR.   /TCDESC/ LC   integer   (MAXZON)   -
        Pointer to ventilation control temperature range.

FACTOR   /ZONL/   LC   real   (MAXZON)   C
        Intermediate result for computing mean radiant temperature
        (TRL_n if H.2.4c).

FAFS   /ZONISL/ BOTH   integer   (MAXZON)   -
        Number of the first air flow opening in the zone description.

FAHS   /ZONL/   LC   real   (MAXZON) m^3/s
        Net air flow from the air handling system into the zone (set to 0).

FAREA   /AFSIL/   BOTH   real   (MAXAFS) m^2
        Air flow opining area (4.14.1).

FBKSHC   /SHDCTL/ LC   integer   -   -
        Pointer to HC location for inside (back) surface calculations.

FCOS1   /AFSIL/   BOTH   real   (MAXAFS)   -
        Direction cosine of opening for computing relative wind direction.

FCOS2   /AFSIL/   BOTH   real   (MAXAFS)   -
        Direction cosinf of opening for computing relative wind direction.

FCOUNT   /SIMCTL/ LC   integer   -   -
        Number of air flow iterations from start of simulation.

FEXP   /AFSIL/   BOTH   real   (MAXAFS)   -
        Air flow opening exponent (4.14.2).

FD   /GLAS9/   IP   real   (2,4)   -
        Thickness of reflective films (D in D.4.4a).
            (side, pane number)

FGSSHC   /SHDCTL/ LC   integer   -   -
        Pointer to HC location for general shadowing surface calculations.

```
FHTS      /ZONISL/  BOTH       integer    (MAXZON)           -
     Number of the first heat transfer surface in the zone description.

FINSHC    /SHDCTL/  LC         integer    -                  -
     Pointer to HC location for inside solar distribution calculation.

FK        /GLAS9/   IP         real       (2,4)              -
     Reflective film extinction coefficient ($k_2$ in D.4.1).
          (side, pane number)

FKW       /GLAS10/  IP         real       (4,MAXNWL)         -
     Reflective film extinction coefficient ($k_2$ in D.4.1).
          (pane number, wavelength)

FLRTFP    /CONDAT/  BOTH       integer    (MAXCON)           -
     Pointers to flux components of conduction transfer functions.

FLXHPE    /HTSIL/   BOTH       integer    (MAXHTS)           -
     Pointers to external flux histories.

FLXHPI    /HTSIL/   BOTH       integer    (MAXHTS)           -
     Pointers to internal flux histories.

FN        /GLAS9/   IP         real       (2,4)              -
     Reflective film index of refraction ($n_2$ in D.4.1).
          (side, pane number)

FNW       /GLAS10/  IP         real       (4,MAXNWL)         -
     Reflective film index of refraction ($n_2$ in D.4.1).
          (pane number, wavelength)

FP        /ZONL/    LC         integer    (MAXZON)           -
     Pointer to scheduled fan action (RCGS).

FRVLHC    /SHDCTL/  LC         integer    -                  -
     Pointer to HC location for setback (reveal) calculations.

FSBSHC    /SHDCTL/  LC         integer    -                  -
     Pointer to HC location for subsurface calculations.

FSG       /HTSISL/  BOTH       real       (MAXHTS)           -
     Angle factor between the surface and the ground (4.13.8 and E.5.1 and
     I.2.6c).

FSRF      /ZONISL/  BOTH       integer    (MAXZON)           -
     Number of first surface in zone description.

FSS       /HTSISL/  BOTH       real       (MAXHTS)           -
     Angle factor between the surface and the sky (4.13.7 and E.5.1 and
     I.2.6a,b).
```

FTRANS   /MATDAT/ IP   real   (MAXNL)   –
     Transmittance of pane of glass with reflective film (2.4.11).

G   /HTSL/   LC   real   (MAXHTS)   W/m^{2}K
     Constant part of HR (H.2.4a).

GELOAD   /ZONL/   LC   real   (MAXZON)   Wh
     Gas equipment load.

GN   /GLAS9/   IP   real   (4)   –
     Index of refraction of pane.

GNW   /GLAS10/ IP   real   (4,MAXNWL)   –
     Wavelength dependent indices of refraction.

GRSNR   /SHDCTL/ LC   integer   –   –
     Surface number of the general (base) shadow receiving surface.

GSSNR   /SHDCTL/ LC   integer   –   –
     Surface number of the general shadowing surface.

GTND   /SIMCTL/ LC   logical   –   –
     "Go to next day." (False during temperature history initialization.)

HC   /HTSL/   LC   real   (MAXHTS)   W/m^{2}K
     Inside convection coefficient.

HCA   /HCFS/   LC   integer   (MAXHCV,MAXHCS) –
     'A' homogeneous coordinates of side of figure.

HCAREA   /HCFS/   LC   real   (MAXHCS)   m^2
     Area of homogeneous coordiante figure.

HCB   /HCFS/   LC   integer   (MAXHCV,MAXHCS) –
     'B' homogeneoues coordinates of sides of figure.

HCC   /HCFS/   LC   integer   (MAXHCV,MAXHCS) –
     'C' homogeneous coordinates of sides of figure.

HCMULT   /SHDCTL/ LC   real   –   –
     Homogeneous coordinate multiplier: convert dimensions in meters to
     integer values in millimeters.

HCNS   /HCFS/   LC   integer   (MAXHCS)   –
     Surface numbers of back surface homogeneous coordinate figures.

HCNV   /HCFS/   LC   integer   (MAXHCS)   –
     Number of vertices of homogeneous coordinate figures.

HCOUNT   /SIMCTL/ LC   integer   –   –
     Number of heat balance iterations in current hour.

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HCT       /HCFS/    LC        real      (MAXHCS)              -
     Transmittances of homogeneous coordinate figures.

HCX       /HCFS/    LC        integer   (MAXHCV,MAXHCS)       -
     'X' homogeneous coordinates of vertices of figure.

HCY       /HCFS/    LC        integer   (MAXHCV,MAXHCS)       -
     'Y' homogeneous coordinates of vertices of figure.

HOC       /HTSIL/   BOTH      real      (MAXHTS)              -
     Constant part of detailed outside convection coefficient.

HOLIND    /ENVDAT/  BOTH      integer   -                     -
     Holiday indicator (1 = holiday; 0 = not holiday;
          2 = special 1; 3 = special 2, ...)

HR        /HTSL/    LC        real      (MAXHTS)         W/m²K
     Surface radiative conductance (H.2.3 and H.2.4d).

HRS       /CALNDR/  BOTH      char*2    (24)                  -
     Hours (for reports).

HTBAL     /RUNCTL/  IP        integer   -                     -
          /SIMCTL/  LC
     Heat balance method (3.1.5).

HTS       /SHDCTL/  LC        integer   -                     -
     Heat transfer surface number.

HTSS      /SHDCTL/  LC        integer   -                     -
     Heat transfer subsurface number.

HWLOAD    /ZONL/    LC        real      (MAXZON)            Wh
     Hot water load.

ICOUNT    /SIMCTL/  LC        integer   -                     -
     Number of non-convergent heat balance iterations.

IHALG     /RUNCTL/  IP        integer   -                     -
          /SIMCTL/  LC
     Inside convection algorithm (3.1.7).

INF       /ZONL/    LC        real      (MAXZON)           W/C
     Simple infiltration capacity rate.

INTSHD    /GLAS1/   IP        integer   -                     -
     0 = no interior shade; 1 = interoir shade  present.

IP        /ZONL/    LC        integer   (MAXZON)              -
     Pointer to scheduled infiltration (RCGS).
```

ISABS   /CONDAT/   BOTH   real   (MAXCON)   -
          Inside surface short wavelength absorptance (2.4.7 and 2.5.7).

ISABSF   /HTSIS/   BOTH   real   (MAXHTS)   -
          Fraction of beam solar gain absorbed directly by surface.
          The remainder becomes a diffuse gain to the zone.

ISENV   /HTSISL/   BOTH   integer   (MAXHTS)   -
          Surface inside environment number (= zone number).

ISHC   /GLAS11/   IP   integer   -   -
          1 indicates properties of interior shade are independent of theta.
          0 not yet used.

ISSC   /SSCISL/   BOTH   integer   (9,MAXSSC)   -
          Equivalenced to RSSC.

ITABS   /CONDAT/   BOTH   real   (MAXCON)   -
          Inside surface thermal absorptance/emittance (2.4.8 and 2.5.8).

IVABSF   /CONDAT/   BOTH   real   (MAXCON)   -
          Fraction of visible diffuse light absorbed by each surface.

IZPHTS   /HTSISL/   BOTH   integer   (MAXHTS)   -
          Heat transfer surface number of opposite side of interzone surface.
          Equivalenced to FSS to save storage space.

JDATE   /SHDCTL/   LC   integer   -   -
          Julian date.

JDATE0   /SHDCTL/   LC   integer   -   -
          Julian date at start of shadow group-of-days.

JJ   /GLAS4/   IP   integer   -   -
          Inner or outer surface indicator.

KELVIN   /REPORT/   BOTH   real   -   C
          Conversion factor: C + KELVIN = K

KEY1   /ALIST/   IP   char*WRD   -   -
          Name of current input section.

KEY2   /ALIST/   IP   char*WRD   -   -
          Name of current input key.

KK   /RF2/   IP   real   (3,MAXNRT)   -
          Combination of residue elements.

KIP   /HTSL/   LC   real   (MAXHTS) W/m^2
          Constant part of inside conductive flux (C.1.5).

KOP   /HTSL/   LC   real   (MAXHTS)   W/m^2
     Constant part of outside conductive flux (C.1.7).

KPTR   /HTSISL/ BOTH   integer   (MAXHTS)   -
     Pointer to construct data.

LAFS   /ZONISL/ BOTH   integer   -   -
     Number of the last air flow opening in the zone description.

LALOAD   /ZONL/   LC   real   (MAXZON)   Wh
     Latent heat gain.

LAMBDA   /GLAS1/   IP   real   -   nm
     Wave length of light for optical calculations.

LATD   /EFLHDR/ BOTH   real   -   degrees
     Location latitude (1.3.2).

LCNVG1   /RUNCTL/ IP   real   -   -
           /SIMCTL/ LC
     Loads convergence.

LCNVG2   /RUNCTL/ IP   real   -   W
           /SIMCTL/ LC
     Minimum load.

LDESC   /LIBNMS/ IP   char*DESC -   -
     Location description (1.3.1).

LENGTH   /MATDAT/ IP   real   (MAXNL)   m
     Thickness of layer (2.5.3).

LFLAGS   /LIBCTL/ LIBCTL   logical   (7)   -
     Library report flags (2.1.3).

LFLAGS   /SIMCTL/ LC   logocal   (4)   -
     Temporary report flags corresponding to RFLAGS 21-24.

LHTS   /ZONISL/ BOTH   integer   (MAXZON)   -
     Number of the last heat transfer surface of the zone.

LIBNAM   /LIBNMS/ IP   char*WRD -   -
     Library name (2.1.1).

LNAMES   /LIBNMS/ IP   char*WRD (256)   -
     Names of library entries - used as index to library data.

LOCHCA   /SHDCTL/ LC   integer   -   -
     Current location in the homogeneous coordinate arrays.

```
LOCSCM    /SHDCTL/  LC          integer    -                    -
      Current location in the shadowing combinations (SHDCMB) array.

LONG      /EFLHDR/  BOTH        real       -                    degrees
      Location longitude (1.3.3).

LR        /RF2/     IP          real       (MAXNL)              m²K/W
      Thermal resistance of layer.

LRAIN     /SIMCTL/  LC          logical    -                    -
      Rain indicator for the hour.

LSRF      /ZONISL/  BOTH        integer    (MAXZON)             -
      Surface number of the last surface of the zone.

LTITLE    /TITLES/  BOTH        char*DESC  -                    -
      Location title (1.3.1).

LUSED     /LIBCTL/  IP          logical    (MAXLNM)             -
      Set to TRUE when a library name is referenced.

MATL0     /LIBCTL/  IP          integer    -                    -
      Pointer to matrials (location 0).

MAXIT     /RUNCTL/  IP          integer    -                    -
          /SIMCTL/  LC
      Maximum number of heat balance iteration in an hour (3.1.3).

MAXPAN    /GLAS9/   IP          integer    -                    -
      Maximum number of glass pane in a window.

MCPI      /ZONL/    LC          real       (MAXZON)             W/K
      Mass flor rate time specific heat for infiltration.

MCPM      /MIXING/  LC          real       (MAXZON)             W/K
      Mass flow rate times specific heat for mixing.

MCPTM     /MIXING/  LC          real       (MAXZON)             W
      MCPM times air temperature for mixing.

MCPV      /ZONL/    LC          real       (MAXZON)             W/K
      Mass flor rate times specific heat for ventilation.

MDHMNT    /BLDRPT/  LC          integer    -                    -
      Month/day/hour at which minimum temperture (BMNT) occurs.

MDHMXC    /BLDRPT/  LC          integer    -                    -
      Month/day/hour at which maximum cooling load (BMXC) occurs.

MDHMXH    /BLDRPT/  LC          integer    -                    -
      Month/day/hour at which maximum heating load (BMXC) occurs.
```

```
MDHMXT    /BLDRPT/  LC        integer    -              -
     Month/day/hour at which maximum temperture (BMXT) occurs.

MERID     /EFLHDR/  LC        real       -              degrees
     Degrees east of time zone central meridian.

MIRRX     /BASES/   IP        logical    -              -
     Mirror X coordinates (4.1.5).

MIRRY     /BASES/   IP        logical    -              -
     Mirror Y coordinates (4.1.6).

MISS      /SHDCTL/  LC        integer    -              -
     Results of polygon overlap calculation:
             1 = no overlap
             2 = NS1 completely within NS2
             3 = NS2 completely within NS1
             4 = partial overlap

MNAMES    /MATNMS/  IP        char*WRD   (MAXNL)        -
     Names of materials (2.4.1).

MNS       /CALNDR/  BOTH      char*3     (12)           -
     Month names.

MONTH     /ENVDAT/  BOTH      integer    -              -
     Month number.

MP        /ZONL/    LC        integer    (MAXZON))      -
     Pointer to scheduled mixing (RCGS).

MTYPE     /MATDAT/  IP        integer    (MAXNL)        -
     Material type (2.4.15, 2.4.16, 2.4.17):
             0 = opaque, 1 = glass, 2 = shade, 3 = air.

MXCDS     /LIBCTL/  IP        integer    -              -
     Maximum number of control day=schedules (2.1.3).

MXCONS    /LIBCTL/  IP        integer    -              -
     Maximum number of constructs (2.1.3).

MXCPFL    /LIBCTL/  IP        integer    -              -
     Maximum number of control profiles (2.1.3).

MXCWS     /LIBCTL/  IP        integer    -              -
     Maximum number of control week-schedules (2.1.3).

MXDS      /LIBCTL/  IP        integer    -              -
     Maximum number of day-schedules (2.1.3).
```

```
MXMATL    /LIBCTL/  IP         integer    -                    -
     Maximum number of materials (2.1.3).

MXWS      /LIBCTL/  IP         integer    -                    -
     Maximum number of week-schedules (2.1.3).

NAFS      /SIMCTL/  LC         integer    -                    -
     Total number of air flow opening descriptions.

NBKS      /SHDCTL/  LC         integer    -                    -
     Number of back surfaces.

NBKSHC    /SHDCTL/  LC         integer    -                    -
     Number of back figures in HC arrays.

NC        /IZPDAT/  IP         integer    -                    -
     Number of temperature CTF to determine interzone surface match.

NCDS      /LIBCTL/  IP         integer    -                    -
          /SIMCTL/  LC
     Number of control day-schedules.

NCGS      /RUNCTL/  IP         integer    -                    -
          /SIMCTL/  LC
     Number of zone control and general schedules (RCGS).

NCMB      /SHDCMB/  LC         integer    -                    -
     Number of shadowing combinations.

NCL       /RF/      IP         integer    -                    -
     Number of conductive layers in construct.

NCON      /SIMCTL/  LC         integer    -                    -
     Number of constructs.

NCONS     /LIBCTL/  IP         integer    -                    -
     Number of constructs.

NCPFL     /LIBCTL/  IP         integer    -                    -
     Number of control profiles.

NCTF      /RUNCTL/  IP         integer    -                    -
          /SIMCTL/  LC
     Number of conduction transfer functions coefficients.

NCWS      /LIBCTL/  IP         integer    -                    -
          /SIMCTL/  LC
     Number of control week-schedules.

NDS       /LIBCTL/  IP         integer    -                    -
     Number of day-schedules.
```

NDSH   /SIMCTL/   LC   integer   -   -
     Number of day-schedules.

NEVTRC   /EFLHDR/   BOTH   integer   -   -
     Number of ventilation temperature ranges.

NFRTFC   /CONDAT/   BOTH   integer   (MAXCON)   -
     Number of flux referring CTF coefficients.

NGSS   /SHDCTL/   LC   integer   -   -
     Number of general shadowing surfaces.

NGSSHC   /SHDCTL/   LC   integer   -   -
     Number of general shadowing figures in homogeneous coordinate arrays.

NGTP   /RUNCTL/   IP   integer   -   -
          /SIMCTL/   LC
     Number of constructs with optical coefficients.

NHCS   /SHDCTL/   LC   integer   -   -
     Maximum number of homogeneous coordinate figures used.

NHTS   /RUNCTL/   IP   integer   -   -
          /SIMCTL/   LC
     Number of heat transfer surfaces.

NINSHC   /SHDCTL/   LC   integer   -   -
     Number of inside surfaces (shadow overlaps on back surfaces) in HC
     arrays.

NIN1   /SHDCTL/   LC   integer   -   -
     Number of vertices of HC figure NS1 within HC figure NS2.

NIN2   /SHDCTL/   LC   integer   -   -
     Number of vertices of HC figure NS2 within HC figure NS1.

NIZP   /IZPDAT/   IP   integer   -   -
     Number of unmatched interzone surfaces.

NL   /RF/   IP   integer   -   -
     Number of layers in construct.

NMATL   /LIBCTL/   IP   integer   -   -
     Number of materials in library.

NOFOCC   /ZONL/   LC   integer   (MAXZON)   -
     Number of occupants (4.2.2).

NOIMI   /HTSISL/   BOTH   integer   (MAXHTS)   -
     True if there is never inside movable insulation (4.18) on the surface.
     Equivalenced to FSG to save space.

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NOSC   /SIMCTL/ LC   integer   -   -
     Number of "other side coefficient" (4.16) descriptions.

NPANES   /GLAS1/   IP   integer   -   -
     Number of glass panes in window construct.

NPFL   /SIMCTL/ LC   integer   -   -
     Number of contol profiles.

NQ   /IZPDAT/ IP   integer   -   -
     Number of flux CTF coefficients for matching interzone surfaces.

NRATIO   /RF2/   IP   integer   -   -
     Number of RATIO.

NRCTR   /TCDESC/ LC   (MAXZON) -   -
     Number of control temperature ranges in control profile.

NRDAYS   /EFLHDR/ BOTH   integer   (13)   -
     Number of days in the simulation environment.

NRENVS   /EFLHDR/ BOTH   integer   -   -
     Number of environments on the environemnt file.

NRF   /RF/   IP   integer   -   -
     Number of temperature CTF calculated.

NRSTAT   /CNTPFL/ BOTH   integer   (MAXPFL)   -
     Number of control points in control profile.

NRT   /RF/   IP   integer   -   -
     Number of roots computed.

NRVLHC   /SHDCTL/ LC   integer   -   -
     Number of reveal figures in HC arrays.

NRVTR   /TCDESC/ LC   integer   (MAXZON)   -
     Number of ventilation temperature ranges.

NSBS   /SHDCTL/ LC   integer   -   -
     Number of door/window subsurfaces.

NSBSHC   /SHDCTL/ LC   integer   -   -
     Number of subsurface figures in the homogeneous coordinate arrays.

NSRF   /RUNCTL/ IP   integer   -   -
              /SIMCTL/ LC
     Number of surfaces (all except internal mass).

NSSC   /RUNCTL/ IP   integer   -   -
     Number of special surface coefficients (RSSC).
              /SIMCTL/ LC

NSURFS   /GLAS1/   IP   integer   -   -
     Number of optical surfaces in window construct (glass + shade).

NS1   /SHDCTL/   LC   integer   -   -
     Number of the HC figure being overlapped.

NS2   /SHDCTL/   LC   integer   -   -
     Number of the HC figure doing the overlapping.

NS3   /SHDCTL/   LC   integer   -   -
     HC location to place results of overlap.

NTFH   /RUNCTL/   IP   integer   -   -
          /SIMCTL/   LC
     Number of temperature/flux history terms (with space for time shift).

NTIMES   /PSYCOM/   IP   integer   -   -
     Number of times specific psychrometric errors have occurred.

NTRTFC   /CONDAT/   BOTH   integer   (MAXCON)   -
     Number of temperature CTF coefficients.

NUAFS   /AFSDAT/   IP   integer   -   -
     Number of unmatched interzone air flow openings.

NV   /SRFIS/   BOTH   integer   (MAXSRF)   -
     Number of vertices of surface.

NVERTS   /VERTS/   IP   integer   -   -
     Number of vertices of surface.

NVS   /SHDVRT/   LC   integer   -   -
     Number of vertices of the shadow.

NVT   /SHDVRT/   LC   integer   -   -
     Number of vertices of the transformed/clipped surface.

NV1   /SHDCTL/   LC   integer   -   -
     Number of vertices of figure NS1.

NV2   /SHDCTL/   LC   integer   -   -
     Number of vertices of figure NS2.

NV3   /SHDCTL/   LC   integer   -   -
     Number of vertices of figure NS3.

NWL   /GLAS10/   IP   integer   -   -
     Number of wavelengths used to evaluate optical properties.

NWS   /LIBCTL/   IP   integer   -   -
     Number of week-schedules.

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```
NWSH      /SIMCTL/  LC          integer    -              -
     Number of week-schedules.

NXMI      /SIMCTL/  LC          integer    -              -
     Number of exterior movable insulation (4.17) descriptions.

NZON      /RUNCTL/  IP          integer    -              -
          /SIMCTL/  LC
     Number of zones.

OAMFL     /ZONL/    LC          real       (MAXZON)       kg/s
     Infiltration mass flow rate.

OBP       /ENVDAT/  BOTH        real       (24)           Pa
     Barometric pressure (absolute).

ODB       /ENVDAT/  BOTH        real       (24)           C
     Ambient dry bulb temperature.

OFFDAT    /SRFIS/   BOTH        integer    (MAXSRF)       -
     Stop date (cyclic) for shadowing surfaces.

OHALG     /RUNCTL/  IP          integer    -              -
          /SIMCTL/  LC
     Outside surface coefficient algorithm (3.1.6).

OHR       /ENVDAT/  BOTH        real       (24)           -
     Humidity ratio of ambient air.

OLDW      /RUNCTL/  IP          logical    -              -
     Use old WTHRFL (1.1.6).

ONDAT     /SRFIS/   BOTH        integer    (MAXSRF)       -
     Start date (cyclic) for shadowing surfaces.

ORDER     /RF/      IP          integer    -              -
     Order (number of flux coefficients) of conduction transfer functions.

OROUGH    /CONDAT/  BOTH        integer    (MAXCON)       -
     Surface outside roughness number (2.4.14 and 2.5.6).

OSABS     /CONDAT/  BOTH        real       (MAXCON)       -
     Surface outside solar absorptance (2.4.7 and 2.5.4).

OSENV     /HTSISL/  BOTH        integer    (MAXHTS)       -
     Surface outside environment number:
          >0 = adjacent zone number
          -1 = internal mass
          -2 = partition
          -3 = envelope surface
          -4 = surface with OSC (4.16)
```

```
OTABS      /CONDAT/  BOTH      real      (MAXCON)              -
      Surface outside thermal absorptance/emittance (2.4.8 and 2.5.8).

OTLOAD     /ZONL/    LC        real      (MAXZON)              Wh
      Load from "other" sources (4.4.7).

OWB        /ENVDAT/  BOTH      /real     (24)                  C
      Ambient wet bulb temperature.

PFC        /RF2/     IP        real      (MAXNRT)              -
      Components of pulse functions.

PFLNAM     /LIBNMS/  LC        char*WRD  (MAXPFL)              -
      Names of control profiles.

PI         /REPORT/  BOTH      real      -                     -
      π = 3.14159...

PP         /ZONL/    LC        integer   (MAXZON)              -
      Pointer to people gains (in RCGS).

PRAIR      /AIR/     LC        real      -                     -
      Prandtl number of air.

PS         /AFSIL/   BOTH      real      (MAXAFS)              Pa
      Stack pressure (G.2.3).

PTITLE     /TITLES/  BOTH      char*DESC -                     -
      Project title (1.1.1).

PW         /AFSIL/   BOTH      real      (MAXAFS)              Pa
      Wind pressure (G.1.3).

PZ         /ZONL/    LC        real      (MAXZON)              Pa
      Zone pressure (G.1.3).

Q          /GLAS12/  IP        real      (16)                  -
      Dependent varaible in optical properties curve fits.

QBV        /ZONL/    LC        real      (MAXZON)              W
      Total beam sunlight entering zone (for daylight calculations).

QC         /ZONL/    LC        real      (MAXZON)              W
      Solar gain convected from shading devices.

QD         /ZONL/    LC        real      (MAXZON)              W
      Total diffuse solar gain in zone (includes beam radiation diffused
      after first surface absorption in zone).

QDV        /ZONL/    LC        real      (MAXZON)              W
      Total diffuse sunlight entering zone (for daylight calculations).
```

```
QFSTDC    /TCDESC/  LC        real      (MAXRNG,MAXZON)    W/K
      LT in (K.1.2a).

QFSTIF    /TCDESC/  LC        real      (MAXRNG,MAXZON)    W
      LC in (K.1.2a).

QFVTDC    /TCDESC/  LC        real      (4,MAXZON)         W/K
      Ventilation coefficient (similar to QFSTDC).

QFVTIF    /TCDESC/  LC        real      (4,MAXZON)         W
      Ventilation coefficient (similar to QFSTIF).

QL        /ZONL/    LC        real      (MAXZON)           W
      Total long wave radiant gains in zone (QLn in H.2.5).

QOCCON    /ZONL/    LC        real      (MAXZON)           W
      Convective gains from occupants.

QOCLAT    /ZONL/    LC        real      (MAXZON)           W
      Latent gains from occupants.

QOCRAD    /ZONL/    LC        real      (MAXZON)           W
      Radiant gains from occupants.

QS        /ZONL/    LC        real      (MAXZON)           W
      Total diffuse, short wavelength gains in zone.

QSA       /ZONL/    LC        real      (MAXZON)           W
      Solar radiation available for daylighting.

QSI       /HTSL/    LC        real      (MAXHTS)           W/m$^2$
      Short wave radiant flux absorbed by inside surfaces.

QSM       /HTSL/    LC        real      (MAXHTS)           W/m$^2$
      Short wave radaint flux absorbed by movable insulation.

QSO       /HTSL/    LC        real      (MAXHTS)           W/m$^2$
      Short wave radaint flux absorbed by outside surface.

R         /GLAS2/   IP        real      (2,4,2)            -
      Reflectances of single pane of glass
            (polarization, pane number, side of incidence).

RAIN      /ENVDAT/  BOTH      integer   -                  -
      Rain indicator (24 hours, compressed).

RALOAD    /ZONL/    LC        real      (MAXZON)           Wh
      Return air load (part of sensible gain from lights 4.3.3).

RATIO     /RF/      IP        real      (MAXNRT)           -
      Ratios defining higher order conduction transfer functions.
```

```
RCGS       /CGSIL/    BOTH      real       (5,MAXCGS)             -
      Data for scheduled loads; varies according to CGSTYP.
      Type = 1 (people - 4.2)
            1 = number of occupants
            2 = activity level                                    W
            3 = fraction radiant
      Type = 2 (lights - 4.3)
            1 = design lighting load                              W
            2 = fraction of load to return air
            3 = fraction radiant (long wavelengths)
            4 = fraction visible (short wavelengths)
            5 = fraction of load replaceable ·by daylight
      Types = 3, 4, 5, 6, and 7 (equipment - 4.4)
            1 = design load                                       W
            2 = fraction latent
            3 = fraction radiant
            4 = fraction lost
            5 = fraction convected
      Type = 8 (infiltration - 4.5)
            1 = design volumetric flow                            m³/s
            2 = constant part of Achenbach-Coblenz equation
            3 = temperature part
            4 = velocity part                                     s/m
            5 = velocity squared part                             s²/m²
      Type = 9 (ventilation - 4.6)
            1 = design volumetric flow                            m³/s
            2 = minimum temperature                               C
            3 = maximum temperature                               C
            4 = temperature difference                            C
      Type = 10 (two-zone mixing - 4.7)
            1 = design volumetric flow                            m³/s
            4 = temperature difference                            C
      Type = 11 (whole house fan - 4.8)
            1 = design volumetric flow                            m³/s
            4 = desired temperature                               C
      Type = 12 (controls - 4.9)
            1 = maximum heating capacity                          W
            2 = maximum cooling capacity                          W
            3 = fraction of control based on mean radiant temperature
      Type = 13 (daylight - 4.10)
            1 = fraction beam usable
            2 = fraction diffuse usable
      Types = 14 and 15 (baseboard heat - 4.11)
            1 = temperature at lower control point               C
            2 = temperature at upper control point               C
            3 = capacity at upper control point                  W
            4 = slope of curve                                   W/C
            5 = fraction radiant

RCOUNT    /SIMCTL/   LC              integer     -               -
      Number of heat balance iterations.
```

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REFRAC   /MATDAT/   IP   real   (MAXNL)   –
          Index of refraction (2.4.10).

REPEAT   /RF/   IP   logical   –   –
          If true, repeat root search with smaller SINC.

RFLAGS   /REPORT/   BOTH   logical   (RFGLEN)   –
          Reports flags:
          1 = dump PROJECT and LIBRARY data
          2 = dump DDY and WTAP data
          3 = dump CTF calculations
          4 = dump glass calculations
          5 = dump DSS data
          6 = dump ZONE data
          7 = dump cross reference values
          8 = dump SIMBLD as read by LC
          9 = report description of zone
          13 = report sunlit areas
          14 = report shadowing combinations
          15 = dump shadow calculation controls
          16 = dump shadow calculations
          20 = dumps 21-24 during warm-up period
          21 = dump primary zone data
          22 = dump constant load components
          23 = dump variables
          24 = dump temperature and flux histories
          25 = dumps 21-24 on WED nearest 21st of month

RHO   /GLAS4/   IP   real   (2,4)   –
          Energy reflectances of the air-glass interfeces
                (polarization, interface and direction)

ROOT   /RF2/   IP   real   (MAXNRT)   –
          Roots for computing response factors.

ROUGH   /MATDAT/   IP   integer   (MAXNL)   –
          Material roughness number (2.4.14).

RR   /GLAS3/   IP   real   (2,2)   –
          Reflectance of a window system (polarization, side of incidence).

RR   /RF/   IP   real   –   m^{2}K/W
          Thermal resistance of single layer slab.

RRB   /GLAS6/   IP   real   (2,16)   –
          Reflectance of a window system for beam light
                (angle number, polarization).

RRBW   /GLAS8/   IP   real   (16)   –
          Outside beam reflectances integrated over wavelength and polarization
                (angle number).

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RRD   /GLAS5/   IP   real   (2,2)   -
    Reflectances of a window system for diffuse light
        (polarization, side of incidence).

RRDW   /GLAS7/   IP   real   -   -
    Outside diffuse reflectance integrated over wavelength and
    polarization.

RSD   /GLAS11/ IP   real   (2)   -
    Reflectance of shade for diffuse light.

RSSC   /SSCISL/ BOTH   real   (9,MAXSSC)   -
    Array of special surface coefficients created by OSC (4.16), EMI (4.17)
    and IMI (4.18). Equivalenced to ISSC for integer values.
    For OSC, RSSC(N,SSC) =
        N=1:   3 (integer)
        N=2:   convection coefficient (4.16.1)
        N=3:   zone air temperature part (4.16.2)
        N=4:   ambient air temperature part (4.16.3)
        N=5:   constant temperature (4.16.4)
        N=6:   constant temperature part (4.16.5)
        N=7:   ground temperature part (4.16.6)
        N=8:   wind speed factor (4.16.7)
        N=9:   heat transfer surface number of base surface (integer)
    For EMI, RSSC(N,SSC) =
        N=1:   1 (integer)
        N=2:   U-value of construct
        N=3:   outside solar absorptance
        N=4:   outside thermal absorptance
        N=5:   surface roughness number (integer)
        N=6:   start date (cyclic) (4.17.3) (integer)
        N=7:   stop date (cyclic) (4.17.3) (integer)
        N=8:   positive value = pointer to day-schedule (4.17.2),
               -1 = sun up control, -2 = sun down control (integer)
        N=9:   heat transfer surface number of the base surface (integer)
    For IMI, RSSC(N,SSC) =
        N=1 through N=7 and N=9: same as EMI
        N=8:   positive value = pointer to day-schedule (4.18.2),
               -1 = maximum heat gain, -2 = maximum heat loss (integer)

RSO   /GLAS11/ IP   real   -   -
    Reflectance of shade at normal incidence (2.4.12).

RTD   /REPORT/ BOTH   real   -   *
    Conversion factor: radians * RTD = degrees

RVAL   /MATDAT/ IP   real   (MAXNL) m^2K/W
    R-value of material (2.4.6).

S   /SHDCTL/ LC   real   -   -
    Y displacement of a shadow in the surface coordinate system (E.2.3b).

SA   /SRFIS/   BOTH   real   (MAXSRF)   –
        Sine of surface azimuth angle (4.13.3).

SABS   /MATDAT/ IP   real   (MAXNL)   –
        Solar absorptance of the material (2.4.7).

SAREA   /HTSIS/   BOTH   real   (MAXHTS) m^2
        Sunlit area of the surface.

SBSNR   /SHDCTL/ LC   integer   –   –
        Subsurface number; pointer to SRFIS arrays.

SFAZIM   /HTSIL/   BOTH   real   (MAXHTS)   degrees
        Surface azimuth angle (3.2.1 and 4.13.3).

SHAPE   /VERTS/   IP   integer   –   –
        Surface shape number: 1=triangle, 2=quadrilateral, 3=rectangle,
        4=door/window, 5=overhang, 6=projection, 7=left fin, 8=right fin.

SHDCF   /MATDAT/ IP   real   (MAXNL)   –
        Shading coefficient of material (2.4.13).

SHDCMB   /SHDCMB/ LC   integer   (MAXCMB)   –
        Shadowing combinations array. For each base, envelope surface:
        surface number, number of shadowing surfaces, number of back surfaces,
        number of subsurfaces, list of shadowing surfaces, list of back
        surfaces, list of subsurfaces.

SHDGRP   /SIMCTL/ LC   integer   –   –
        Shadow group (of days) number.

SHDREC   /SIMCTL/ LC   integer   –   –
        Shadow file record number.

SHDSRF   /SRFIS/   BOTH   integer   (2,MAXSRF)   –
        Surface data array (for shadowing).
        SHRSRF(1,NS) =
        +1 to +MAXHTS: Heat transfer surface number (HTS or I) of surface NS.
        0   : Detached shadowing surface.
        –1   : Shadowing subsurface.
        SHRSRF(2,NS) =
        +1 to +MAXHTS: Coordinates are relative to global origin.
        –1 to –MAXHTS: Coordinates are relative to surface –HTS.

SINBR   /RUNCTL/ IP   real   –   –
        Sine of the building rotation angle (3.1.1).

SINC   /RF/   IP   real   –   –
        Root search increment.

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SIND      /SLPSSH/  BOTH       real       -                    -
     Sine of the solar declination angle.

SINL      /EFLHDR/  BOTH       real       -                    -
     Sine of the location latitude (1.3.2).

SINZR     /BASES/   IP         real       -                    -
     Sine of the zone rotation angle (4.1.2).

SKY       /ENVDAT/  BOTH       real       (24)                 C
     Sky temperatures (B.3.4).

SNAME     /ZNAMES/  IP         chr*WRD    -                    -
     Schedule name.

SNLOAD    /ZONL/    LC         real       (MAXZON)             Wh
     Sensible heating (+) or cooling (-) load in the zone.

SNOW      /ENVDAT/  BOTH       integer    -                    -
     Snow indicator (compressed 24 hours).

SOLDIS    /RUNCTL/  BOTH       integer    -                    -
     Solar distribution algorithm (3.1.2).

SPC2      /RUNCTL/  IP         logical    -                    -
     If true, double space the echo of user input (1.1.4).

SPD       /ENVDAT/  BOTH       real       (24)                 m/s
     Wind speed.

SPHT      /MATDAT/  IP         real       (MAXNL)              kJ/kgK
     Specific heat of material (2.4.4).

SQTRDZ    /ZONL/    LC         real       (MAXZON)             √(kg/m³)
     Square root of zone air density.

SQRTV     /AIR/     LC         real       -                    √(m/s)
     Square root of wind velocity.

SRADBM    /ENVDAT/  BOTH       real       (24)                 W/m²
     Intensity of beam solar radiation.

SRADDF    /ENVDAT/  BOTH       real       (24)                 W/m²
     Intensity of diffuse solar radiation (sky brightness).

SRADGR    /ENVDAT/  BOTH       real       (24)                 W/m²
     Intensity of ground reflected solar radiation.

SREF      /MATDAT/  IP         real       (MAXNL)              -
     Reflectance of shade (2.4.12).
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SSCPTR   /HTSISL/ BOTH   integer   (MAXHTS)   —
     Pointer to special surface coefficients.

SSDECL   /ENVDAT/ BOTH   real   —   —
     Sine of the solar declination angle.

ST   /SRFIS/ BOTH   real   (MAXSRF)   —
     Sine of the surface tilt angle (3.2.2 and 4.13.4).

STATM   /BLDRPT/ LC   integer   (6,MAXZON)   —
     System status hours: Total for run in 6 categories.
     1 = heating capacity exceeded.
     2 = in heaing mode.
     3 = in ventilation mode.
     4 = in cooling mode.
     5 = cooling capacity exceeded.
     6 = no heating, cooling, or ventilating.

STDTIM   /SIMCTL/ LC   integer   —   —
     Standard time (t_s in sec B.1.1).

STLOAD   /ZONL/   LC   real   (MAXZON)   Wh
     Steam load in zone (steam equipment plus steam baseboard heat).

SUMB   /RF/   IP   real   —   —
     Sum of BETA values for all layers.

SUMC   /ZONL/   LC   real   (MAXZON)   W
     Sum of scheduled convective gains.

SUMDTI   /ZONL   /LC   real   (MAXZON)   —
     Sum of outside temperature derivatives.

SUMHA   /ZONL/   LC   real   (MAXZON)   W/K
     Sum of (HI*AREA) for zone surfaces (HCi*Si in K.2.2).

SUMHAD   /ZONL/   LC   real   (MAXZON)   —
     Sum of air temperature derivatives (J.3.4a, J.4.2a, J.5.8a, J.5.10a).

SUMHAT   /ZONL/   LC   real   (MAXZON)   W
     Sum of (HI*AREA*T) for zone surfaces ($HC_i*S_i*T_i$ in K.2.2).

SUMUA   /ZONL/   LC   real   (MAXZON)   W/K
     Sum of (HR*AREA) for zone surfaces (H.2.5).

SUMUAD   /ZONL/   LC   real   (MAXZON)   —
     Sum of radiant temperature derivatives (J.3.4b, J.4.2b, J.5.8b,
     and J.5.10b).

SUMUAT   /ZONL/   LC   real   (MAXZON)   W
     Sum of (HR*AREA*T) for zone surfaces (H.2.5).

SUMX   /RF1/   IP   real   (5)   -
     Sum of X CTF to test convergence (C.2.1).

SUMY   /RF1/   IP   real   (5)   -
     Sum of Y CTF to test convergence (C.2.1).

SUMZ   /RF1/   IP   real   (5)   -
     Sum of Z CTF to test convergence (C.2.1).

SUNCOS   /SLPSSH/   BOTH   real   (3)   -
     Solar direction cosines.

SYNTAX   /RUNCTL/   IP   logical   -   -
     Process input to only check syntax (1.1.2).

T   /GLAS2/   IP   real   (2,4)   -
     Transmittances of single panes of glass (polarization, pane number).

T   /HTSL/   LC   real   (MAXHTS)   C
     Temperature of inside of surface (or inside movable insulation) for
     computing mean radiant temperature and convective gain to zone.

TAU   /GLAS4/   IP   real   (2,4)   -
     Energy transmittances of the air-glass interfaces
             (polarization, interface in direction).

TBM   /SHDCTL/   LC   real   -   -
     Transmittance of window for beam radiation.

TCNVG   /RUNCTL/   IP   real   -   C
         /SIMCTL/   LC
     Temperature convergence (3.1.3).

TD   /GLAS0/   BOTH   real   (MAXGTP)   -
     Fraction of diffuse solar radiation transmitted through window.

TE   /ZONL/   LC   real   (MAXZON)   C
     Zone effective temperature for control purposes (K.1.3).

TFH   /BLDTFH/   LC   real   (MAXTFH)   C & W/m^2
     Array of surface temperature and flux histories for CTF calculations.

TGRND   /EFLHDR/   BOTH   real   (12)   C
     Ground temperatures (monthly values; 1.4.1).

TI   /HTSL/   LC   real   (MAXHTS)   C
     Temperature of inside of surface.

TINC   /RF/   IP   real   -   s
     Time increment for CTF calculations.

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TMKUP   /EFLHDR/ BOTH   real   (12)   C
    Make-up water temperatures (not used).

TMPHPE   /HTSIL/   BOTH   integer   (MAXHTS)   –
    Pointers to external temperature histories.

TMPHPI   /HTSIL/   BOTH   integer   (MAXHTS)   –
    Pointers to internal temperature histories.

TO   /HTSL/   LC   real   (MAXHTS)   C
    Temperature of outside (side away from zone) of surface.

TR   /ZONL/   LC   real   (MAXZON)   C
    Mean radiant temperature of zone (H.2.5).

TRANS   /MATDAT/ IP   real   (MAXNL)   –
    Transmittance of material (2.4.9).

TRANS   /SRFIS/   BOTH   real   (MAXSRF)   –
    Transmittance of shadowing surface (3.2.5 and 4.15.4).

TRRAIN   /EFLHDR/ BOTH   integer   –   –
    Terrain classification (1.3.6 and sec B.4).

TRTFPC   /CONDAT/ BOTH   real   (MAXCON) W/m^2K
    Cross (Y) temperature conduction transfer functions.

TRTFPE   /CONDAT/ BOTH   real   (MAXCON) W/m^2K
    External (X) temperature conduction transfer functions.

TRTFPI   /CONDAT/ BOTH   real   (MAXCON) W/m^2K
    Internal (Z) temperature conduction transfer functions.

TSD   /GLAS11/ IP   real   (2)   –
    Transmittance of shading device (polarization).

TSHIFT   /BLDTFH/ LC   integer   –   –
    Time shift for temperature and flux histories in TFH array.

TSO   /GLAS11/ IP   real   –   –
    Transmittance of shade at normal incidence.

TT   /GLAS3/   IP   real   (2)   –
    Transmittances of layers in a window system (polarization)

TTB   /GLAS6/   IP   real   (16,2)   –
    Transmittances of a window system for beam light
        (angle number, polarization).

TTBW   /GLAS8/   IP   real   (16)   –
    Beam transmittances integrated over wavelength and polarization
        (angle number).

TTD   /GLAS5/   IP   real   (2)   -
     Transmittances of a window system for diffuse light (polarization).

TTDW   /GLAS7/   IP   real   -   -
     Diffuse transmittances integrated over wavelength and polarization.

TVENT   /TCDESC/ LC   real   (5,maxzon)   C
     Ventilation control point temperatures.

TZ   /ZONL/   LC   real   (MAXZON)   C
     Zone air temperature.

TZNR   /EFLHDR/ BOTH   real   -   -
     Time zone number (1.3.4).

T1   /GLAS/   BOTH   (5,MAXGTP)-
     Polynomial coefficients for beam solar transmittance (c_i in D.1.7a)

T2   /GLAS/   BOTH   (6,MAXGTP)-
     Polynomial coefficients for beam solar transmittance (c_i in D.1.7b)

UCHAR   /UINDAT/ IP   integer   -   -
     Current character in line (record) of user input.

UIERR   /UINDAT/ IP   integer   -   -
     User input error:
          0   no error
          1   invalid subkey value:
                    continue processing
          2   invalid subkey name:
                    skip input to next / or) or]
          3   error in key name processing:
                    skip input to next) or]
          4   error in section name processing:
                    skip input to next]
          5   at end of information:
                    set UISTAT=6

UILINE   /UINDAT/ IP   integer   -   -
     User input line number.

UINREC   /UINREC/ IP   char*80   -   -
     User input record (line of 80 characters).

UISTAT   /UINDAT/ IP   integer   -   -
     User input status:
          0   initial setting in subroutine READER
          1   at /   at end of subkey
          2   at)   at end of key, end subkey also
          3   at (at end of key name
          4   at]   at end of section
          5   at [at end of section name
          6   at end-of-information

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UM   /HTSL/   LC   real   (MAXHTS)   W/m^{2}K
    U-value of movable insulation. 0 means no movable insulation.

UV   /IZPDAT/ IP   real   –   W/m^{2}K
    U-value of surface for matching interzone surfaces.

UVAL   /CONDAT/ BOTH   real   (MAXCON)   W/m^{2}K
    Construct U-value.

VCONV   /ZONL/   LC   real   (MAXZON)   –
    Visible to convective factor.

VMULT   /ZONL/   LC   real   (MAXZON)   –
    Visible multiplier.

VP   /ZONL/   LC   integer   (MAXZON)   –
    Pointer to Ventilation control.

VVF   /ZONL/   LC   real   (MAXZON)   m^3/s
    Ventilation design volumetric flow.

WA   /VERTS/   IP   real   –   degrees
    Surface azimuth angle (3.2.1 and 4.13.3).

WFDAYS   /WFLHDR/ IP   integer   –   –
    Number of days on BLAST weather file.

WFEDAT   /WFLHDR/ IP   integer   –   –
    Julian date of last day on BLAST weather file.

WFEFCD   /WFLHDR/ IP   real   –   –
    Cosine of solar declination on first day of BLAST weather file.

WFEFET   /WFLHDR/ IP   real   –   hr
    Equation of time on first day of BLAST weather file.

WFEFSD   /WFLHDR/ IP   real   –   –
    Sine of solar declination on first day of BLAST weather file.

WFFDAY   /WFLHDR/ IP   integer   –   –

WFFILL   /WFLHDR/ IP   integer   (46)   –
    Array filler.

WFLATD   /WFLHDR/ IP   real   –   degrees
    Location latitude of BLAST weather file.

WFLONG   /WFLHDR/ IP   real   –   degrees
    Location longitude of BLAST weather file.

WFSDAT   /WFLHDR/ IP   integer   –   –
    Julian date of first day on BLAST weather file.

WFSDAY   /WFLHDR/ IP   integer   -   -
     Day-of-month of first day of BLAST weather file.

WFSMON   /WFLHDR/ IP   integer   -   -
     Month of first day of BLAST weather file.

WFSTTN   /WFLHDR/ IP   integer   -   -
     Weather station number of BLSAT weather file.

WFSYR   /WFLHDR/ IP   integer   -   -
     Year of first day of BLAST weather file.

WFTMZN   /WFLHDR/ IP   real   -   -
     Time zone of BLAST weather file.

WL   /GLAS10/ IP   real   (1)   nm
     Wavelength at which optical properties are computed.

WREC   /WFLHDR/ IP   integer   (64)   -
     BLAST weather file header array (all values equivalenced to this array.

WS   /VERTS/   IP   real   -   degrees
     Surface slope (tilt) angle (3.2.2 and 4.13.4).

WSH   /SCHDLS/ LC   integer   (12,MAXWSH)   -
     Week-schedules (pointers to day-schedules).

WSHNAM   /LIBNMS/ LC   char*WRD   (MAXWSH)   -
     Names of week-schedules.

WSTATN   /EFLHDR/ BOTH   integer   -   -
     Weather station number.

WSO   /LIBCTL/ IP   integer   -   -
     Pointer to week-schedules (location 0).

WTITLE   /WFLHDR/ IP   integer   (4)   -
     BLAST weather file title.

WTYPE   /CONDAT/ BOTH   integer   -   -
     Window type (=1 if window; =0 if opaque).

X   /GLAS12/ IP   real   (16)   -
     Independent variable (cosθ) for curve fit.

X   /VERTS/   IP   real   (4)   m
     X-coordinate (surface relative or global) of surface vertices.

XLLC   /VERTS/   IP   real   -   m
     X-coordinate (global) of surface origin (X_{so} in E.1.2a).

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XLOAD   /ZONL/   LC   real   (MAXZON)   Wh
     Previous value of zone sensible load.

XREF   /RUNCTL/ IP   logical   -   -
     If true, print cross reference data (1.1.5).

XTEMP   /HCFS/   LC   integer   (MAXHCS)   -
     X homogeneous coordinates of overlap before sequencing.

XTR   /ZONL/   LC   real   (MAXZON)   C
     Previous value of the zone mean radiant temperature.

XTZ   /ZONL/   LC   real   (MAXZON)   C
     Previous value of zone air temperature.

XV   /SRFIS/   BOTH   real   (4,MAXSRF)   m
     X-coordinates (global) of surface vertices.

XVC   /SHDVRT/ LC   real   (5)   m
     X-coordinates (surface relative) of clipped shadowing surface.

XVS   /SHDVRT/ LC   real   (5)   m
     X-coordinates (surface relative) of shadow.

XVT   /SHDVRT/ LC   real   (5)   m
     X-coordinates (surface relative) of shadowing surface.

XX   /VERTS/   IP   real   (4)   m
     X-coordinates (surface relative) of surface vertices.

Y   /VERTS/   IP   real   (4)   m
     Y-coordinates (surface relative or global) of surface.

YEAR   /ENVDAT/ BOTH   integer   -   -
     Year (4 digits).

YLLC   /VERTS/   IP   real   -   m
     Y-coordinate of surface origin (Y_{so} in E.1.2b).

YTEMP   /HCFS/   LC   integer   (MAXHCV)   -
     Y homogeneous coordinates of overlap before sequencing.

YV   /SRFIS/   BOTH   real   (4,MAXSRF)   m
     Y-coordinates (global) of surface vertices.

YVC   /SHDVRT/ LC   real   (5)   m
     Y-coordinates (surface relative) of slipped shadowing surface.

YVS   /SHDVRT/ LC   real   (5)   m
     Y-coordinates (surface relative) of the shadow.

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YVT      /SHDVRT/ LC       real      (5)                    m
     Y-coordinates (surface relative) of the shadowing surface.

YY       /VERTS/  IP       real      (4)                    m
     Y-coordinates (surface relative) of the surface.

Z        /VERTS/  IP       real      (4)                    m
     Z-coordinates (surface relative or global) of surface vertices.

ZCLD     /BLDRPT/ LC       real      (MAXZON)               Wh
     Total sensible cooling load for zone

ZHLD     /BLDRPT/ LC       real      (MAXZON)               Wh
     Total sensible heating load for zone.

ZLLC     /VERTS/  IP       real      -                      m
     Z-coordinate of surface origin ($Z_{so}$ in E.1.2c).

ZMNT     /BLDRPT/ LC       real      (MAXZON)               C
     Minimum zone air temperature.

ZMXC     /BLDRPT/ LC       real      (MAXZON)               W
     Peak sensible cooling requirement.

ZMXH     /BLDRPT/ LC       real      (MAXZON)               W
     Peak sensible heating requirement.

ZMXT     /BLDRPT/ LC       real      (MAXZON)               C
     Maximum zone air temperature.

ZNAMES   /ZNAMES/ LC       char*WRD  (MAXZON)               -
     Names of zones.

ZNAMIN   /ZNAMES/ IP       char*WRD  -                      -
     Name of current zone.

ZNMOUT   /ZNAMES/ IP       char*WRD  -                      -
     Name of far side zone.

ZNRELN   /BASES/  IP       real      -                      degrees
     Angle from the building Y-axis (north) to the zone Y-axis
     (4.1.2 and E.1.2).

ZNXORG   /BASES/  IP       real      -                      m
     X-coordinate of zone origin ($X_{zo}$ in E.1.1a).

ZNYORG   /BASES/  IP       real      -                      m
     Y-coordinate of zone origin ($Y_{zo}$ in E.1.1b).

ZNZORG   /BASES/  IP       real      -                      m
     Z-coordinate of zone origin ($Z_{zo}$ in E.1.1c).
```

ZRRES   /RFO/   IP   real   (3)   –
       Residues at the double pole at 0.

ZS   /AFSIL/   BOTH   real   (MAXAFS)   m
       Height of the air flow opening.

ZT   /AFSIL/   IP   real   (MAXAFS)   m
       Height of top of surface (for evalauting PW).

ZV   /SRFIS/   BOTH   real   (4,MAXSRF)   –
       Z-coordinates (global) of surface vertices.

ZVC   /SHDVRT/ LC   real   (5)   m
       Z-coordinates (surface relative) of clipped shadowing surface.

ZVMOD   /AFSIL/   BOTH   real   (MAXAFS)   –
       Height modifier for computing wind pressure.

ZVS   /SHDVRT/ LC   real   (5)   m
       Z-coordinates (surface relative) of the shadow (= 0).

ZVT   /SHDVRT/ LC   real   (5)   m
       Z-coordinates (surface relative) of shadowing surface.

ZZ   /ZONISL/ BOTH   real   (MAXZON)   m
       Height of zone for computing zone pressure.

VI.D   FILES

INPUT PROCESSOR FILES:

UNIT	FILE	ACCESS	DESCRIPTION
11	SINPFL	seq	Simulation input file
12	ENVTFL	dir	Environment file
13	WTHRTP	seq	Weather tape from BLAST program
14	-	dir	Materials data
15	-	dir	Constructs data
16	-	dir	Interzone surface data
17	-	dir	Interzone opening data
21	-	seq	Day-schedules library report
22	-	seq	Week-schedules library report
23	-	seq	Materials library report
24	-	seq	Constructs library report
25	-	seq	Control profiles library report
26	-	seq	Control day-schedules library report
27	-	seq	Control week-schedules library report

LOADS CALCULATOR FILES:

11	SINPFL	seq	Simulation input file
12	ENVTFL	dir	Environment file
13	-	dir	Solar gains multipliers
14	-	seq	Input segment to loads segment data
15	-	seq	Input segment to shadowing segment data

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10. SUPPLEMENTARY NOTES

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

11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

The Thermal Analysis Research Program (TARP) has been developed as a research tool for the thermal analysis of buildings. It especially aims to study the interactions of many complex heat transfer phenomena. TARP uses the detailed heat balance method for the simultaneous calculation of the energy requirements of multiple rooms. Interroom conductive and convective processes are simulated in detail. This program reference manual describes the algorithms, input, output, and program structure of TARP. The program is written to be portable and modifiable. It is written in FORTRAN 77 and has run on CDC and UNIVAC computers. Future expansions of the program are anticipated, particularly for the simultaneous simulation of equipment performance and building thermal response.

12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)

Building energy analysis; load calculation; computer modeling; building heat transfer.

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